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# ASSESSMENT OF FRESHWATER PRODUCTION OF SOCKEYE SALMON IN BABINE LAKE

by


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## 1.0 INTRODUCTION

This working paper is intended as the first step towards a comprehensive assessment of the status of Babine Lake sockeye salmon. The Babine-Nilkitkwa lake system is the largest natural lake in British Columbia (500 $km^2$) and supports the largest sockeye salmon runs in the Skeena River (Fig. 1). Some investigators (e.g., West and Mason 1987) consider that 95% of Skeena sockeye now originate from the Babine system although this has been disputed (McKinnell and Rutherford 1994). The Fisheries Research Board of Canada began investigations of sockeye populations in the Babine system in the 1940s and extensive data have been gathered to date (e.g., McDonald and Hume 1984 and references therein). For an historical account of management of Skeena River sockeye fisheries, see Sprout and Kadowaki (1987).

Stock assessment of Babine sockeye is complicated by several factors: First, Babine sockeye are harvested in numerous mixed-stock fisheries in Southeast Alaska and northern British Columbia, so that the total catch is not known with any certainty. Henderson and Diewert (1989) performed simple run reconstructions and stock recruitment analyses that provide gross indications of stock status. A more sophisticated run reconstruction analysis is now being completed and is scheduled to be reviewed by PSARC later this year; those results are expected to provide reconstructed catch data along with estimates of their reliability.

Second, overall escapements to Babine Lake are known accurately from fence counts in the Lower Babine River since the 1940s, but these data require careful interpretation because of enhancement activities and puzzling discrepancies between the overall fence count and summed estimates of escapement to individual spawning sites. In the past these discrepancies were attributed to an uncensused "lake spawning" population. However, the parallel increasing trends in the magnitude of discrepancies and returns to enhancement facilities, together with empirical data from surveys of lake spawning habitat have made this explanation seem unlikely.

Third, annual smolt production from Babine Lake has been estimated since the 1950s, but again interpretation of these data has been complicated by the existence of both early- and late-migrant smolts and by enhancement. Smolt production data for the 1959-1983 brood years were previously analyzed by Macdonald et al. (1987) but data for more recent years have not been examined elsewhere.

Our primary objective in this working paper is to assess the status of freshwater production of sockeye salmon in Babine Lake and to provide corrected escapement data and updated smolt data that can be used to assess marine survival and overall stock-recruitment relationships once separate run reconstruction analyses have been reviewed by PSARC. Much of our present assessment involves examining potential explanations for discrepancies in escapement data and devising an appropriate framework for correcting escapement data. We also examine the effect of juvenile density on fry-to-smolt survival and smolt size to assess limitations to rearing capacity in the main basin of Babine Lake. These results will complement other information expected from extensive limnological and juvenile surveys now being completed under the Skeena River

Sustainable Fisheries Plan.

## 2.0 METHODS AND DATA SOURCES

### 2.1 Sources of Escapement Data

Escapement data in Appendix 1 were taken from spreadsheet tables provided by by L. Jantz (DFO, Prince Rupert). These data have been maintained independently of the regional Salmon Escapement Database System to allow for finer spatial resolution of spawning sites. Where direct comparisons were possible, escapement data were generally identical in both databases; where discrepancies exist, L. Jantz's data were assumed to be correct.

Since 1949, all sockeye returning to Babine Lake have been counted at the Babine River fence situated 1 km below the outlet of Nilkitkwa Lake. Three distinct run timing groups have been identified by tagging studies (Smith and Jordan 1973) and total escapements for the early-, mid-, and late-timing runs are summarized in Table 1. Visual estimates of sockeye abundance have been documented for most early-timing and mid-timing lake tributary spawning sites since 1950. Since 1966, spawning escapements to Fulton River and Pinkut Creek and associated spawning channels have been counted through fences maintained as part of the Babine Lake Development Project. Once target escapements for these rivers and spawning channels have been met, the fences are closed and escapements below the fences are estimated by systematic visual surveys (Appendix 1) but an unknown proportion also remains uncounted in Babine Lake. Late-timing runs to the Upper and Lower Babine rivers were enumerated by mark-recapture techniques from 1976 to 1992 and by visual surveys in other years.

### 2.2 Revisions to Escapement Data

In most years, the sum of escapements to individual spawning sites is significantly less than the Babine fence count, and fish unaccounted for are referred to here as "uncounted" (Table 1). Previously, uncounted fish were recorded as "lake spawners" although there was no evidence that spawning occurred to any significant extent within Babine Lake itself. In fact, recent studies indicate that lake spawning accounts for a negligible proportion of the uncounted escapement (see Results and Discussion).

The visual estimates of "surplus" enhanced fish shut below fences in the Fulton and Pinkut systems ($\hat{P}^{FP}$ in Table 1) account for most but not all of the uncounted fish in recent years. However uncounted fish also existed prior to the earliest measurable return of enhanced fish in 1970, which suggests that spawning escapements to the various tributaries were generally underestimated by visual survey and/or mark-recapture techniques. We regressed known Babine fence counts (less catches taken at or above the fence) for the pre-enhancement period 1950-1969 on the summed estimates of escapements to individual tributaries (see Appendix 2). The resulting regression equation was applied in subsequent years to correct estimates of escapement obtained with these procedures. The remaining uncounted fish were considered to be surplus enhanced fish.

In 1992, the Babine fence was deemed unsafe and was operated only for the peak migration period (29 July-29 September); thus, for the first time on record, summed estimates of spawning escapement and surplus enhanced fish greatly exceeded the Babine fence count. For this year, the fence count was "reconstructed" by estimating the enhanced surplus from the visual estimate of enhanced surplus using a regression equation fitted to all years excluding 1992 (see Appendix 2 for details). The fence was rebuilt and operated satisfactorily in subsequent years.

### 2.3 Recent Investigations of Lake Spawning in Babine Lake

Prompted by an increasing trend in number of uncounted sockeye, studies were conducted from 1990 to 1993 by C. C. Wood, D.T. Rutherford, and Archipelago Marine Research Ltd. (under contract to DFO) to determine the potential importance of lake spawning in Babine Lake. These researchers attempted to document the quantity and quality of suitable lake spawning sites, and to determine if any sockeye, particularly those surplus to spawning channel capacity, spawned successfully along the margins of Babine Lake.

Extensive reconnaissance of possible shoreline spawning was carried out from fixed-wing aircraft, and more reliable surveys were conducted from boats along 45 km of shoreline and groundtruthed in selected areas by divers (Fig. 2). To maximize the opportunity to observe lake spawning by surplus enhanced fish, surveys were conducted during the latter part of the spawning season (late August to late October). Substrate composition and dissolved oxygen concentration within substrates were assessed along underwater transects at selected shoreline sites throughout the main basin of Babine Lake. Reference samples of substrates were collected, dried, seived and weighed to determine composition by particle size. Substrates were also classified by underwater inspection as one of three types: A - good incubation habitat with several layers of gravel or cobble above a sand or silt substrate such that very little silt occurred within the interstitial spaces of the gravel; B - poor incubation habitat with silt or sand filling the interstitial spaces of gravel or cobble; and C - very poor incubation habitat comprising mainly silt or a mixture of sand and silt. In each substrate type, dissolved oxygen concentration was measured by drawing samples of interstitial water with a syringe-like device and potential egg-to-alevin survival was measured by planting eyed eggs in Vibert incubation baskets modified with liners to retain alevins. Details of methods and results for underwater surveys and incubation experiments are documented in unpublished reports by Archipelago Marine Research Ltd. available from C.C. Wood.

### 2.4 Sockeye Fry Enumeration

Following McDonald and Hume (1984), we assumed that an average of 233 fry were produced by each sockeye spawning in natural streams. In this context, natural streams include all spawning sites except those in Fulton River and Pinkut Creek after the initiation of the Babine Lake Development Project in 1966.

From 1966 to 1993, sockeye fry originating from spawning sites in Fulton River and Pinkut Creek above the adult counting fences have been enumerated by Salmonid Enhancement Program staff using fixed-position, converging throat traps or fan traps (West and Mason 1987). The total migration is estimated by weighting catches in index traps by time and cross-sectional area fished (details in Ginetz 1977). Egg-to-fry survival was calculated from these estimates of fry production and estimates of actual egg deposition based on adult counts, fecundity, and sex ratio data. Fry production from spawning sites below the adult counting fences were calculated by multipling egg-to-fry survival rates observed upstream of the fences by potential egg deposition from spawners enumerated visually below the fence (Appendix 3). Spawning habitat below the fences was considered to permit successful spawning by a maximum of 45,000 and 5,000 spawners in Fulton River and Pinkut Creek, respectively. We assumed that additional fish observed below the fence were surplus in that they did not produce additional fry because of overcrowding.

### 2.5 Smolt enumeration

Smolt migrations out of Babine Lake have been sampled and enumerated by mark-recapture near the outlet of Nilkitkwa Lake annually since 1951 except for 1989 when the program was not funded. Smolt size data and estimates of abundance from the parsimonious model of Macdonald and Smith (1980) for brood years 1959 to 1983 were taken from Macdonald et al. (1987). Comparable abundance data for recent years were computed by P.D.M. Macdonald (Department of Mathematics and Statistics, McMaster University, Hamilton, Ont., L8S 4K1 personal communication). Smolt data for brood years 1949-1959 are from the unpublished records of H.D. Smith (available from C.C. Wood); abundance estimates for these years are considered less reliable than in later years because tagging procedures were still being developed and estimates were based on the constant sampling fraction model (see Macdonald and Smith 1980).

Tagging studies have confirmed that fry originating from the Upper and Lower Babine rivers and a few small tributaries to Nilkitkwa Lake and the North Arm of Babine Lake rear primarily within Nilkitkwa Lake and the North Arm; these juveniles emigrate as "early migrant" smolts (Macdonald and Smith, unpublished MS, Department of Mathematics and Statistics, McMaster University, Hamilton, Ont., L8S 4K1). In contrast, fry emerging from other tributaries to the main basin of Babine Lake rear primarily within the main basin and emigrate one to two weeks later as "late migrant" smolts (e.g., Fig. 3).

For simplicity given the approximate nature of our calculations, we ignored the minor contributions of smolts from early-timing subpopulations spawning in tributaries to Nilkitkwa Lake and the North Arm by assuming that early migrant smolts originated only from the late-timing (Upper and Lower Babine River) subpopulations. Similarly, we assumed that late migrant smolts originated only from the early-timing and mid-timing subpopulations from fry that reared in the main basin of Babine Lake including Morrison Arm.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Accounting for Discrepancies in Escapement Estimates

There are three plausible explanations for the discrepancy between the Babine fence count and summed estimates of escapement to individual spawning sites (Table 1):

1) spawning in unsurveyed areas (e.g., lake spawning in Babine Lake)

2) visual estimates of spawning escapements generally underestimate actual abundance.

3) surplus returns to enhancement facilities at Fulton River and Pinkut Creek cannot be enumerated reliably because they are denied access to upstream spawning sites. Visual estimates of abundance indicate that many attempt to spawn in gravel below the main counting fences but an unknown proportion remain in the lake.

## 3.2 Lake Spawning

### 3.2.1 Potential Habitat for Lake Spawning

Substrates in the main basin of Babine Lake are predominately sand and silt (type C). Silty gravel and cobble (type B) was most common in the shallow nearshore zone to maximum depths of 5 m; below 5 m the substrate was usually plumose silt or hard clay (type C). Type A substrate occurred in very shallow water (<1 m) exposed to wave action and very rarely in small patches to a maximum depth of 5 m. Lake char eggs were recovered from one such patch.

Interstitial dissolved oxygen concentration was closely associated with the percentage of silt in substrate samples, and hence with substrate type (Fig. 4). As expected, survival of eyed eggs planted in various substrates was highly correlated both with substrate type and dissolved oxygen concentration (Fig. 5). These results imply that the underwater surveys of habitat type coupled with dissolved oxygen sampling provide a reliable indication that substrates below 1 m in the main basin of Babine Lake are generally unsuitable for incubating sockeye eggs with rare exceptions. No upwelling or groundwater percolation was observed at any site. Dissolved oxygen concentrations were very low in substrates near the outlets of tributary streams so that spawning is unlikely to be successful on outwash fans -- a common habitat for lake spawning in other lakes.

### 3.2.2 Occurrence and Success of Lake Spawning

Shoreline spawning was observed in 1992 but not in 1990 or 1991. Most spawning activity in 1992 was observed in two sections of shoreline within 5 km of Pinkut Creek; an estimated 900 sockeye were seen spawning along 1.2 km of shoreline just west of Pinkut Creek, and an estimated 650 fish were seen spawning along 1.9 km of shoreline just west of Boling Point. In total, about 2000 spawners were observed in the vicinity of Pinkut Creek, and an estimated 400 spawners were observed in six other minor spawning areas in the remainder of the main basin, 300 of these near Fulton River. Similarly, unpublished surveys conducted by H.D. Smith (personal communication) in the 1960's identified a few minor shoreline spawning sites but failed to reveal any major spawning sites or favourable spawning habitat.

In all cases, spawning occurred in substrates where dissolved oxygen concentrations exceeded 6 ppm (almost always in type A substrate). Moreover, 74% of redds at 40 locations examined by divers occurred at depths of <1 m. Only 12% occurred below 2 m and the maximum depth observed was 6.1 m.

The failure to detect significant numbers of shoreline spawners by boat and aerial survey despite repeated attempts over many years strongly suggests that lake spawning accounts for only a negligible proportion of the uncounted fish. In the 1992 study, observers from a boat or aircraft could readily detect spawning activity to 2 m when the surface was calm.

The fact that most spawning activity was observed near Pinkut Creek and to a lesser extent near Fulton River in 1992 -- a year when many surplus enhanced fish were reported (Appendix 1) -- suggests that surplus fish do attempt to spawn in Babine Lake when they are not permitted to enter their streams. This may be especially true at Pinkut Creek where the fence is located only 40 m above the lake. In 1992, the 200,000 surplus fish reported at the mouth of Pinkut Creek had mostly diasppeared at the time diving surveys reported 2000 shoreline spawners in the same general vicinity. In contrast, the fence on Fulton River is located 1.1 km upstream from the lake and in 1992, as in other years, large numbers of surplus fish remained in the river below the fence; very few were observed spawning along the shoreline in the vicinity of Fulton River. However, a surprising number (about 1300) of unspawned sockeye were observed in neighbouring Tachek Creek on 5 October 1992. We concluded that these were stray, surplus sockeye from Fulton River because the small early-timing run in this creek had completed spawning by late August. Of 45 female carcasses examined, 41 (91%) had died without spawning.

Ten shoreline redds identified near Pinkut Creek in October 1992 were marked and revisited in March 1993 by divers working under the ice. This site was considered to offer some of the best substrate for incubation. Because of the seasonal drop in lake level and the thickness of ice, redds originally at a depth of $\leq$0.6 m were frozen in ice. Live, recently hatched alevins were recovered from eight of the deeper redds where apparent survival to the alevin stage averaged 18.5%. Actual survival would have been somewhat lower because divers could not collect decomposed dead eggs or eggs that had been eaten. Eggs and alevins were concentrated in the marked redds; very few eggs or alevins were recovered from substrate between marked redds indicating that alevins from shallower redds were unlikely to have escaped freezing by moving into deeper substrate after hatching. These results indicate that shoreline spawning can be successful in some parts of Babine Lake but egg-to-fry survival will generally be poor at depths of <1 m where most spawning and suitable incubation habitat was observed.

In summary, all the evidence to date suggests that lake spawning occurs in Babine Lake, but that it accounts for a negligible proportion of the uncounted fish, and contributes little to fry recruitment. Suitable lake spawning habitat is rare and most occurs in very shallow water such that any significant concentration of spawning activity would have been observed from the surface. The distribution of lake spawning activity strongly suggests that lake spawning sockeye are mostly if not entirely surplus escapements to Pinkut Creek and to a lesser extent Fulton River. Survival of eggs in most shoreline redds is expected to be poor because of generally poor dissolved oxygen concentrations at depths >1 m and damage from dewatering, freezing, and ice scouring at depths <1 m.

### 3.3 Underestimation by Visual Counts

Prior to 1970, all sockeye returning to Babine Lake resulted from natural reproduction, primarily in the Upper and Lower Babine rivers, Fulton River, Pinkut Creek, and Morrison Creek (Ginetz 1977). During this period, uncounted fish could not have been surplus enhanced fish, and we have rejected the lake spawning explanation. Furthermore, it seems implausible that important tributary spawning sites could have gone unnoticed given the extent of survey effort over the years. Thus, we conclude that prior to 1970, uncounted fish reflect enumeration errors. By regressing the Babine fence count (less the small aboriginal harvest at or above the fence and fence counts to Fulton and Pinkut after 1965) on the summed estimates of escapement to individual spawning sites (excluding fence counts), we estimate that true escapements were about 20% higher than recorded during this period (Fig. 6). This regression equation was then used to predict the true escapement to unenhanced spawning sites after 1970 (see Appendix 2, Table 2). Because enumeration effort in unenhanced streams has generally declined since the pre-enhancement period, the corrected escapements to these streams may still underestimate true levels in recent years.

### 3.4 Surplus Enhanced Production

Following the first significant return of enhanced sockeye in 1970, spawning escapements to Fulton River and Pinkut Creek have increased dramatically (Appendix 1). Visual estimates of escapements below the counting fences exceeded desired levels for the first time in 1975 in Fulton River and in 1981 in Pinkut Creek. We refer to these fish as surplus because we assume that they cannot contribute to fry production given the overcrowded conditions in the streams below the fences and given our previous conclusions about the limited occurrence and poor reproductive success of surplus fish spawning in Babine Lake or neighbouring streams. Since 1981, surpluses have returned to Pinkut Creek in every year except 1983, and to Fulton River in 7 of 13 years.

Although the visual estimates of surplus are considered uncertain, they account for up to 79% of the uncounted fish after ruling out lake spawning and correcting estimates of escapement to unenhanced spawning sites. Thus, we reasoned that total surplus (Fulton and Pinkut combined) could be calculated by subtracting catches and corrected escapements to all spawning sites from the Babine fence count (except in 1992, see Appendix 2). These best estimates of surplus were then regressed on the visual estimates of surplus for comparison (Fig. 7). As expected, visual estimates of enhanced surplus were highly correlated with, but always underestimated the values calculated by subtraction ($r=0.85$, $b=1.568$). No subtracted estimate of surplus was available in 1992 because of the unreliable Babine fence count; accordingly, we used the regression equation to generate a best estimate of surplus from the visual estimate of surplus (Fig. 7).

Best estimates of total enhanced surplus have increased dramatically since enhancement began

(Table 2, Fig. 8) and have averaged 30% (range 19-63%) of the total enhanced run counted through the Babine fence. As an independent check on our conclusions that this many fish do not spawn successfully, we also calculated the average proportion of the overall adult returns that would spawn sucessfully under this scenario. If on average exploitation rate by all fisheries $\leq$60% (Henderson and Diewert 1989), then (1-0.6)(1-0.3)*100% $\geq$ 28% of the enhanced run survives to reproduce. It is not surprising these enhanced runs would sustain harvest rates of over 70% given egg-to-fry survival rates reported by West and Mason (1987).

### 3.5 Interactions Between Enhanced and Wild Runs

Overall escapements to unenhanced spawning sites declined between 1970 and 1985 but have since rebuilt to their former abundance (Fig. 8). However, trends differ among run timing groups (Fig. 9). The early-timing run appears to have declined steadily since 1970, but average escapements are not statistically different before and after enhancement ($p>0.30$, Wilcoxin-Mann-Whitney test). In contrast, the unenhanced component of the mid-timing run decreased signficantly after enhancement ($p<0.02$) and has not recovered since 1985 ($p>0.95$, t test). The relatively large late-timing run drives the overall pattern showing a non-significant decline after enhancement until 1985 ($p>0.20$, Wilcoxin-Mann-Whitney test) and a marginally significant increase after 1985 ($p=0.09$).

The fact that wild escapements begin to decline immediately after the first enhanced sockeye return suggests that increased exploitation rates on enhanced returns caused the decline. This conclusion is supported by the fact that early-timing escapements were least affected whereas wild mid-timing escapements were most affected. Furthermore, late-timing escapements increased following the implementation of more conservative management policies (Henderson and Diewert 1989) whereas mid-timing runs that overlap the enhanced runs completely, did not. Since 1985, the wild mid-timing run has averaged less than 60% of pre-enhancement levels.

### 3.6 Fry and Smolt Production

Average fry recruitment to the main basin has increased over threefold following enhancement, from an average of 60.7 million (1391 fry/ha) to an average of 188.2 million fish (4312 fry/ha) (Table 3, Fig. 10). Smolts from the main basin showed a corresponding increase in average abundance from 22.9 million (325 smolts/ha) to 90.8 million (2081 smolts/ha) annually. Smolt production from the main basin in 1994 (1992 brood year) set a new record at 190.3 million (4361 smolts/ha) but this estimate is likely biased high since it implies an improbable emergent fry-to-smolt survival rate of 83% (see below) and was over three times larger than the hydroacoustic estimate of fry abundance (56 million) from surveys the previous fall (K. Shortreed and J. Hume, DFO, personal communication).

Smolts emigrating from Babine Lake are predominantly (98%) yearlings (McDonald and Hume 1984). The trend of increasing juvenile density in Babine Lake is associated with a steady decrease in average size (Fig. 11) because smolt size is negatively correlated both with fry (Fig.

12) and smolt (Fig. 13) abundance for the corresponding brood year. Even so, the average weight of yearling smolts resulting from brood years of maximum fry recruitment or smolt abundance remains between 4 and 5 g.

Emergent fry-to-smolt survival appears to have been highly variable (Fig. 14) but this is at least partly due imprecision in the estimates of fry and smolt abundance as evidenced by three years of unbelievably high survival (e.g., >100% for brood year 1962 and >80% for brood years 1979 and 1992). Even after excluding these improbable values, fry-to-smolt survival appears to have increased following enhancement from an average of 28% (range 6-55%) to 42% (range 17-71%) ($p<0.03$, *t* test). However, this may simply indicate that fry production from unenhanced sites was less than has been assumed here and in previous reports (McDonald and Hume 1984; Macdonald et al. 1987).

Although smolt size declines with juvenile density, fry-to-smolt survival does not (Fig. 15) indicating that additional fry recruitment to the main basin would probably increase smolt abundance. Furthermore, average smolt size is still large in comparison to other productive, interior sockeye lakes such as Shuswap Lake where smolts average <3.5 g on the dominant year cycle (Hume et al. 1995). Thus, further density-dependent reduction in smolt size, and perhaps marine survival, may be acceptable given the increased numbers of smolts produced. An analysis of adult returns is required to determine the optimal tradeoff between smolt size and smolt abundance.

Smolt production from Babine Lake has been sustained at a high level (mean 2138 smolts/ha, range 761-4361 smolts/ha) since enhancement without any obvious decline in sockeye productivity. This has important implications for strategies to rebuild Fraser River sockeye populations in which smolt production varies widely over a 4-yr cycle. For example, fall fry densities in Shuswap Lake range from <200 fall fry/ha on off-year cycles to 5000 fall fry/ha on dominant year cycles (Hume et al. 1995). Fears have been expressed that rebuilding all years of a 4-yr cycle would cause a qualitative change in the forage base such that overall production might collapse or be reduced below present levels. Experience in Alaska, particularly from sockeye populations in the Kenai River that went unharvested because of the *Exxon Valdez* oil spill suggested that excessive spawning escapements in consecutive years caused a collapse in smolt production. However, in the Kenai system, investigators were misled by problems with smolt enumeration and their conclusions about collapse turned out to unfounded (D. Schmidt, unpublished reports, Alaska Department of Fish and Game, 34828 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-8367). Even so, concerns about the risk of overstocking sockeye rearing lakes remain. Babine Lake may provide the best opportunity in Canada to evaluate the impact of heavy grazing by juvenile sockeye over many consecutive years. Intensive limnological investigations and juvenile assessments are now being conducted under the Skeena River Sustainable Fisheries ("Green") Plan (K. Shortreed, DFO, West Vancouver Laboratory, personal communication).

## 4.0 CONCLUSIONS

1) Opportunities for lake spawning by sockeye in surveyed areas of Babine Lake are severely limited by substrate quality. Thus, we conclude that lake spawning produces a negligible proportion of total fry recruitment to the main basin of Babine Lake.

2) Escapements to spawning sites not enumerated by fences were generally 20% larger than estimated prior to 1970. Underestimation is assumed to be at least as serious in more recent years because surveys have been less frequent. Thus, on average, at least 12% of the discrepancy between the Babine fence count and summed estimates of escapement to individual spawning sites (including visual estimates of enhanced surplus) can be attributed to enumeration error.

3) We attribute the remaining discrepancy to underestimation of surplus enhanced fish that are shut below fences in Fulton River and Pinkut Creek.

4) We recommend using the corrected estimates of total escapements by early-, mid-, and late-timing runs to Babine Lake in Table 2 (based on the algorithm in Appendix 2) to compute wild fry production and as input to future run reconstruction analyses.

5) Total escapements to unenhanced spawning sites declined between 1970 and 1985 but have since rebuilt to their former abundance. However, the recent recovery is evident in the relatively large late-timing run that spawns primarily in the Upper Babine River but not in the unenhanced component of the mid-timing run.

6) Smolt size and survival data suggest that there is still unutilized rearing capacity in Babine Lake. However this conclusion should be reconsidered when results from an intensive, continuing limnological study become available.

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Table 1. Babine fence count, unadjusted sockeye escapement data summarized by run timing group, terminal catch and uncounted escapements for 1950-1993. Notation defined in Appendix 2. Note reconstructed estimate for 1992 ( [a] incomplete count was 1,233,785)

| YEAR | $R_T$ | $S_E$ | $S_M^W$ | $S_L$ | $S_T^W$ | $S_M^{FP}$ | C | $\hat{}P^{FP}$ | UNCOUNTED |
|---|---|---|---|---|---|---|---|---|---|
| 1950 | 364356 | 39861 | 9800 | 275000 | 324661 | 50000 | 27449 | 0 | -37754 |
| 1951 | 141415 | 24644 | 4400 | 32000 | 61044 | 24779 | 19007 | 0 | 36585 |
| 1952 | 349011 | 7494 | 1250 | 162000 | 170744 | 42500 | 34404 | 0 | 101363 |
| 1953 | 686586 | 52463 | 26000 | 280000 | 358463 | 164000 | 26913 | 0 | 137210 |
| 1954 | 493677 | 46000 | 24000 | 240000 | 310000 | 135000 | 21847 | 0 | 26830 |
| 1955 | 71352 | 8450 | 1800 | 30500 | 40750 | 21000 | 10423 | 0 | -821 |
| 1956 | 355345 | 30450 | 29000 | 125000 | 184450 | 104000 | 30582 | 0 | 36313 |
| 1957 | 433149 | 53071 | 30500 | 200000 | 283571 | 150000 | 20434 | 0 | -20856 |
| 1958 | 812043 | 144500 | 19000 | 270000 | 433500 | 135000 | 38580 | 0 | 204963 |
| 1959 | 782868 | 85300 | 37000 | 295000 | 417300 | 200000 | 16727 | 0 | 148841 |
| 1960 | 262719 | 38000 | 11000 | 101000 | 150000 | 70000 | 16754 | 0 | 25965 |
| 1961 | 941711 | 106700 | 27000 | 375000 | 508700 | 222000 | 30856 | 0 | 180155 |
| 1962 | 548000 | 17350 | 13525 | 285000 | 315875 | 110000 | 18122 | 0 | 104003 |
| 1963 | 588000 | 78700 | 57200 | 196800 | 332700 | 245000 | 20021 | 0 | -9721 |
| 1964 | 827437 | 51164 | 27000 | 298000 | 376164 | 230000 | 19855 | 0 | 201418 |
| 1965 | 580000 | 20900 | 8500 | 240000 | 269400 | 158780 | 18540 | 0 | 133280 |
| 1966 | 389000 | 24150 | 11500 | 184000 | 219650 | 80044 | 18652 | 0 | 70654 |
| 1967 | 603000 | 61000 | 15500 | 190000 | 266500 | 168197 | 18992 | 0 | 149311 |
| 1968 | 552000 | 51850 | 46000 | 222000 | 319850 | 147571 | 19146 | 0 | 65433 |
| 1969 | 634000 | 61560 | 22450 | 238000 | 322010 | 148885 | 17293 | 0 | 145812 |
| 1970 | 662000 | 79300 | 7200 | 318000 | 404500 | 224536 | 20048 | 0 | 12916 |
| 1971 | 816000 | 32500 | 8000 | 417000 | 457500 | 313244 | 23450 | 0 | 21806 |
| 1972 | 680145 | 44094 | 8600 | 259000 | 311694 | 283389 | 24283 | 0 | 60779 |
| 1973 | 797461 | 114630 | 26300 | 193000 | 333930 | 337492 | 17015 | 0 | 109024 |
| 1974 | 726990 | 89906 | 31255 | 238529 | 359690 | 235408 | 22318 | 0 | 109574 |
| 1975 | 820795 | 48390 | 23000 | 95000 | 166390 | 465933 | 13896 | 36756 | 137820 |
| 1976 | 587659 | 10640 | 6400 | 130159 | 147199 | 338263 | 18157 | 0 | 84040 |
| 1977 | 937992 | 42640 | 12600 | 161583 | 216823 | 591788 | 10777 | 0 | 118604 |
| 1978 | 401318 | 24447 | 3000 | 43810 | 71257 | 171267 | 10920 | 0 | 147874 |
| 1979 | 1160966 | 34720 | 17800 | 292325 | 344845 | 552632 | 21500 | 0 | 241989 |
| 1980 | 526059 | 24529 | 9000 | 158815 | 192344 | 178863 | 22635 | 0 | 132217 |
| 1981 | 1432734 | 36600 | 5700 | 90000 | 132300 | 697207 | 30300 | 0 | 572927 |
| 1982 | 1136344 | 75650 | 3900 | 128947 | 208497 | 441473 | 42000 | 110000 | 334374 |
| 1983 | 886393 | 21200 | 7000 | 81000 | 109200 | 427789 | 20000 | 45000 | 284404 |
| 1984 | 1052385 | 21360 | 6500 | 164773 | 192633 | 486395 | 20500 | 145000 | 207857 |
| 1985 | 2148044 | 62400 | 14200 | 514000 | 590600 | 518259 | 17500 | 550000 | 471685 |
| 1986 | 701507 | 21600 | 3100 | 134000 | 158700 | 298412 | 23500 | 45000 | 175895 |
| 1987 | 1307852 | 30830 | 12800 | 192500 | 236130 | 452629 | 20296 | 345000 | 253797 |
| 1988 | 1408929 | 34410 | 19050 | 196500 | 249960 | 496753 | 25000 | 300000 | 337216 |
| 1989 | 1132316 | 14584 | 6100 | 105000 | 125684 | 435371 | 22000 | 70000 | 479261 |
| 1990 | 978562 | 17160 | 5950 | 160000 | 183110 | 458633 | 22000 | 160000 | 154819 |
| 1991 | 1176318 | 48188 | 20500 | 355000 | 423688 | 328999 | 20800 | 245000 | 157831 |
| 1992 | 1942588[a] | 40360 | 7300 | 505000 | 552660 | 516297 | 73879 | 400000 | -309051 |
| 1993 | 1737426 | 13700 | 18075 | 490000 | 521775 | 512122 | 177590 | 250000 | 275939 |

Table 2. Corrected escapement and terminal run size estimates by run timing group based on algorithm in Appendix 2. Notation defined in Appendix 2.

| YEAR | $C_M^W$ | $C_M^{FP}$ | $S_V$ | $\sim S_T^W$ | $\sim S_E$ | $\sim S_M^W$ | $\sim S_L^W$ | $\sim S_M^{FP}$ | $P^{FP}$ | $R_E$ | $R_M^W$ | $R_M^{FP}$ | $R_M$ | $R_L$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1950 | 4498 | 22951 | 374661 | 336907 | 35844 | 8812 | 247289 | 44962 | 0 | 35844 | 13311 | 67912 | 81223 | 247289 |
| 1951 | 2866 | 16141 | 85823 | 122408 | 35149 | 6276 | 45641 | 35342 | 0 | 35149 | 9142 | 51483 | 60625 | 45641 |
| 1952 | 983 | 33421 | 213244 | 314607 | 11056 | 1844 | 239005 | 62702 | 0 | 11056 | 2827 | 96123 | 98950 | 239005 |
| 1953 | 3683 | 23230 | 522463 | 659673 | 66241 | 32828 | 353534 | 207070 | 0 | 66241 | 36511 | 230300 | 266811 | 353534 |
| 1954 | 3298 | 18549 | 445000 | 471830 | 48773 | 25447 | 254470 | 143139 | 0 | 48773 | 28745 | 161689 | 190433 | 254470 |
| 1955 | 823 | 9600 | 61750 | 60929 | 8338 | 1776 | 30094 | 20721 | 0 | 8338 | 2599 | 30321 | 32920 | 30094 |
| 1956 | 6668 | 23914 | 288450 | 324763 | 34283 | 32651 | 140736 | 117093 | 0 | 34283 | 39319 | 141006 | 180325 | 140736 |
| 1957 | 3453 | 16981 | 433571 | 412715 | 50518 | 29033 | 190379 | 142785 | 0 | 50518 | 32486 | 159766 | 192251 | 190379 |
| 1958 | 4760 | 33820 | 568500 | 773463 | 196597 | 25850 | 367344 | 183672 | 0 | 196597 | 30610 | 217492 | 248102 | 367344 |
| 1959 | 2611 | 14116 | 617300 | 766141 | 105867 | 45921 | 366129 | 248223 | 0 | 105867 | 48533 | 262339 | 310872 | 366129 |
| 1960 | 2275 | 14479 | 220000 | 245965 | 42485 | 12298 | 112920 | 78262 | 0 | 42485 | 14573 | 92740 | 107314 | 112920 |
| 1961 | 3346 | 27510 | 730700 | 910855 | 133007 | 33657 | 467457 | 276734 | 0 | 133007 | 37003 | 304245 | 341247 | 467457 |
| 1962 | 1984 | 16138 | 425875 | 529878 | 21587 | 16828 | 354600 | 136863 | 0 | 21587 | 18812 | 153001 | 171813 | 354600 |
| 1963 | 3790 | 16231 | 577700 | 567979 | 77376 | 56237 | 193488 | 240877 | 0 | 77376 | 60027 | 257109 | 317136 | 193488 |
| 1964 | 2086 | 17769 | 606164 | 807582 | 68165 | 35972 | 397020 | 306425 | 0 | 68165 | 38058 | 324194 | 362252 | 397020 |
| 1965 | 942 | 17598 | 428180 | 561460 | 27406 | 11146 | 314705 | 208204 | 0 | 27406 | 12088 | 225802 | 237889 | 314705 |
| 1966 | 2343 | 16309 | 219650 | 290304 | 31918 | 15199 | 243187 | 80044 | 0 | 31918 | 17542 | 96353 | 113895 | 243187 |
| 1967 | 1603 | 17389 | 266500 | 415811 | 95176 | 24184 | 296451 | 168197 | 0 | 95176 | 25787 | 185586 | 211373 | 296451 |
| 1968 | 4550 | 14596 | 319850 | 385283 | 62457 | 55410 | 267415 | 147571 | 0 | 62457 | 59960 | 162167 | 222127 | 267415 |
| 1969 | 2266 | 15027 | 322010 | 467822 | 89435 | 32616 | 345771 | 148885 | 0 | 89435 | 34882 | 163912 | 198794 | 345771 |
| 1970 | 623 | 19425 | 404500 | 417416 | 81832 | 7430 | 328154 | 224536 | 0 | 81832 | 8053 | 243961 | 252014 | 328154 |
| 1971 | 584 | 22866 | 457500 | 479306 | 34049 | 8381 | 436876 | 313244 | 0 | 34049 | 8965 | 336110 | 345075 | 436876 |
| 1972 | 715 | 23568 | 311694 | 372473 | 52692 | 10277 | 309504 | 283389 | 0 | 52692 | 10992 | 306957 | 317949 | 309504 |
| 1973 | 1230 | 15785 | 333930 | 408572 | 140253 | 32179 | 236140 | 337492 | 34382 | 140253 | 33409 | 387659 | 421068 | 236140 |
| 1974 | 2616 | 19702 | 359690 | 439484 | 109851 | 38189 | 291444 | 235408 | 29780 | 109851 | 40804 | 284891 | 325695 | 291444 |
| 1975 | 654 | 13242 | 166390 | 207524 | 60353 | 28686 | 118485 | 465933 | 133442 | 60353 | 29340 | 612618 | 641957 | 118485 |
| 1976 | 337 | 17820 | 147199 | 184494 | 13336 | 8022 | 163137 | 338263 | 46745 | 13336 | 8359 | 402827 | 411186 | 163137 |
| 1977 | 225 | 10552 | 216823 | 268043 | 52713 | 15577 | 199754 | 591788 | 67384 | 52713 | 15801 | 669724 | 685525 | 199754 |
| 1978 | 188 | 10732 | 71257 | 93364 | 32032 | 3931 | 57402 | 171267 | 125767 | 32032 | 4119 | 307766 | 311885 | 57402 |
| 1979 | 671 | 20829 | 344845 | 421670 | 42455 | 21765 | 357449 | 552632 | 165164 | 42455 | 22436 | 738625 | 761062 | 357449 |
| 1980 | 1084 | 21551 | 192344 | 238668 | 30437 | 11168 | 197064 | 178863 | 85893 | 30437 | 12252 | 286306 | 298558 | 197064 |
| 1981 | 246 | 30054 | 132300 | 166616 | 46093 | 7178 | 113344 | 697207 | 538611 | 46093 | 7424 | 1265873 | 1273297 | 113344 |
| 1982 | 368 | 41632 | 208497 | 258052 | 93630 | 4827 | 159595 | 441473 | 394819 | 93630 | 5195 | 877924 | 883119 | 159595 |
| 1983 | 322 | 19678 | 109200 | 138896 | 26965 | 8904 | 103027 | 427789 | 299708 | 26965 | 9226 | 747175 | 756401 | 103027 |
| 1984 | 270 | 20230 | 192633 | 239015 | 26503 | 8065 | 204447 | 486395 | 306475 | 26503 | 8335 | 813099 | 821435 | 204447 |
| 1985 | 467 | 17033 | 590600 | 716576 | 75710 | 17229 | 623637 | 518259 | 895709 | 75710 | 17696 | 1431002 | 1448697 | 623637 |
| 1986 | 242 | 23258 | 158700 | 198296 | 26989 | 3873 | 167433 | 298412 | 181299 | 26989 | 4115 | 502970 | 507085 | 167433 |
| 1987 | 558 | 19738 | 236130 | 291212 | 38022 | 15786 | 237404 | 452629 | 543715 | 38022 | 16344 | 1016082 | 1032426 | 237404 |
| 1988 | 923 | 24077 | 249960 | 307808 | 42373 | 23459 | 241976 | 496753 | 579368 | 42373 | 24382 | 1100198 | 1124580 | 241976 |
| 1989 | 304 | 21696 | 125684 | 158676 | 18412 | 7701 | 132563 | 435371 | 516269 | 18412 | 8005 | 973336 | 981341 | 132563 |
| 1990 | 282 | 21718 | 183110 | 227588 | 21328 | 7395 | 198864 | 458633 | 270341 | 21328 | 7677 | 750693 | 758370 | 198864 |
| 1991 | 1220 | 19580 | 423688 | 516281 | 58719 | 24980 | 432582 | 328999 | 310238 | 58719 | 26200 | 658817 | 685017 | 432582 |
| 1992 | 745 | 73134 | 552660 | 671048 | 49006 | 8864 | 613178 | 516297 | 681364 | 49006 | 9609 | 1270795 | 1280404 | 613178 |
| 1993 | 6054 | 171536 | 521775 | 633986 | 16646 | 21962 | 595377 | 512122 | 413728 | 16646 | 28016 | 1097386 | 1125402 | 595377 |

Table 3. Juvenile sockeye abundance, size and survival data for the main basin of Babine Lake.

| BROOD YEAR | NUMBER (millions) EMERGENT FRY | SMOLTS | MEAN SMOLT WEIGHT(G) | FRY-TO-SMOLT SURVIVAL(%) |
|---|---|---|---|---|
| 1950 | 20.9 | | 4.9 | |
| 1951 | 17.9 | | 6.2 | |
| 1952 | 17.6 | | 6.3 | |
| 1953 | 71.3 | | 5.4 | |
| 1954 | 50.6 | | 5.1 | |
| 1955 | 7.2 | | 5.9 | |
| 1956 | 42.9 | | 6.1 | |
| 1957 | 51.8 | | 5.5 | |
| 1958 | 94.6 | | 6.2 | |
| 1959 | 93.2 | 13.2 | 5.2 | 14 |
| 1960 | 31.0 | 17.0 | 5.6 | 55 |
| 1961 | 103.3 | 6.4 | 5.3 | 6 |
| 1962 | 40.8 | 41.5 | 5.3 | 102 |
| 1963 | 87.3 | 28.2 | 5.1 | 32 |
| 1964 | 95.7 | 13.1 | 4.7 | 14 |
| 1965 | 57.5 | 7.5 | 5.3 | 13 |
| 1966 | 64.2 | 19.5 | 4.5 | 30 |
| 1967 | 75.3 | 28.2 | 5.4 | 37 |
| 1968 | 103.2 | 38.5 | 5.1 | 37 |
| 1969 | 87.9 | 38.7 | 5.8 | 44 |
| 1970 | 135.7 | 37.4 | 5.3 | 28 |
| 1971 | 162.0 | 89.0 | 5.3 | 55 |
| 1972 | 173.2 | 78.5 | 4.8 | 45 |
| 1973 | 190.9 | 33.2 | 5.4 | 17 |
| 1974 | 141.6 | 38.4 | 5.1 | 27 |
| 1975 | 175.3 | 54.7 | 4.9 | 31 |
| 1976 | 233.8 | 80.9 | 4.5 | 35 |
| 1977 | 207.4 | 112.4 | 5.0 | 54 |
| 1978 | 131.7 | 55.4 | 4.3 | 42 |
| 1979 | 212.0 | 178.8 | 4.5 | 84 |
| 1980 | 171.4 | 122.3 | 4.6 | 71 |
| 1981 | 229.8 | 142.6 | 4.4 | 62 |
| 1982 | 217.8 | 90.9 | 3.9 | 42 |
| 1983 | 124.4 | 42.4 | 4.2 | 34 |
| 1984 | 228.2 | 157.1 | 5.3 | 69 |
| 1985 | 213.0 | 125.8 | 5.0 | 59 |
| 1986 | 226.4 | 80.2 | 4.5 | 35 |
| 1987 | 117.0 | | | |
| 1988 | 212.2 | 61.7 | 5.0 | 29 |
| 1989 | 164.7 | 45.2 | 4.8 | 27 |
| 1990 | 247.0 | 96.7 | 4.8 | 39 |
| 1991 | 192.2 | 82.7 | 4.3 | 43 |
| 1992 | 228.7 | 190.3 | | 83 |
| 1993 | 181.7 | | | |

# FIGURE CAPTIONS

1) Map of Babine-Nilkitkwa Lake showing principal tributaries, location of the Babine counting fence and the Babine Lake Development Project sites at Fulton River and Pinkut Creek (from Ginetz 1977)

2) Extent of surveys for lake spawning sockeye in Babine Lake, 1990-1992.

3) Rearing areas and typical timing of early- and late-migrant smolts from Babine-Nilkitkwa Lake (from Macdonald et al. 1987).

4) Interstitial dissolved oxygen concentrations by substrate type along 25 transects in the south end of Babine Lake, October 1992.

5) Percentage survival of eyed eggs planted in Vibert boxes in substrates with different interstitial dissolved oxygen concentrations (measured at the time of planting, October 1991).

6) Relationship between true escapement (fence count minus terminal catch) and summed visual estimates of escapement to individual spawning sites for the pre-enhancement period 1950-1969. Dashed line represents expected relationship without error; solid line and 95% confidence intervals fitted by linear regression (see Appendix 2).

7) Relationship between surplus enhanced escapement calculated by subtraction (see Appendix 2, 1992 excluded) and the visual estimate of surplus. Line and 95% confidence intervals fitted by linear regression (see Appendix 2); solid circle indicates value predicted for 1992 when surplus could not be calculated by subtraction.

8) Trends in corrected total wild and enhanced escapements and surplus enhanced escapements. Lines fitted by LOWESS (F=0.5).

9) Trends in corrected escapements by run timing group. Circles represent unenhanced spawning sites, squares enhanced sites. Lines fitted by LOWESS (F=0.5).

10) Trends in emergent fry and smolt abundance rearing in the main basin of Babine Lake by brood year.

11) Trends in mean smolt weight by brood year for smolts rearing in the main basin of Babine Lake. Line and 95% confidence limits fitted by linear regression.

12) Relationship between mean smolt weight and emergent fry abundance for fish rearing in the main basin of Babine Lake. Line fitted by LOWESS (F=0.5).

13) Relationship between mean smolt weight and smolt abundance for fish rearing in the main basin of Babine Lake. Line fitted by LOWESS (F=0.5).

14) Trends in emergent fry-to-smolt survival for smolts rearing in the main basin of Babine Lake. Line and 95% confidence limits fitted by linear regression. Solid circles denote improbable values exceeding 80% fry-to-smolt survival.

15) Relationship between $\log_e$ (emergent fry-to-smolt abundance) and emergent fry abundance. Line and 95% confidence intervals fitted by regression: ln(smolts/fry) = -1.457 + 0.003 (fry), r=0.32, p=0.07 (as plotted, all data); ln(smolts/fry) = -1.635 + 0.004 (fry), r=0.40, p=0.03 (3 data points denoted by solid circles excluded where fry-to-smolt survival >80%); abundance in millions.

Figure 1

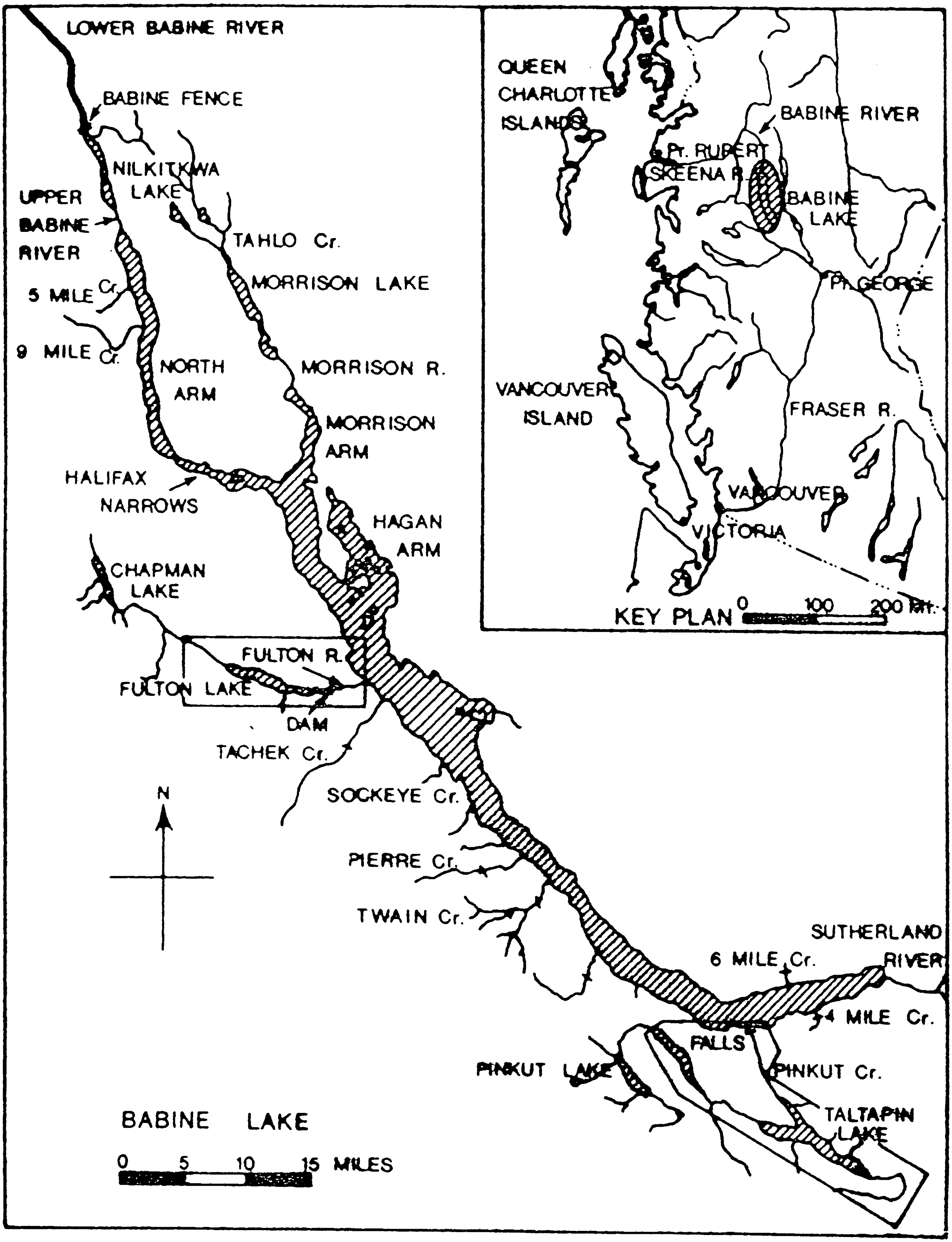
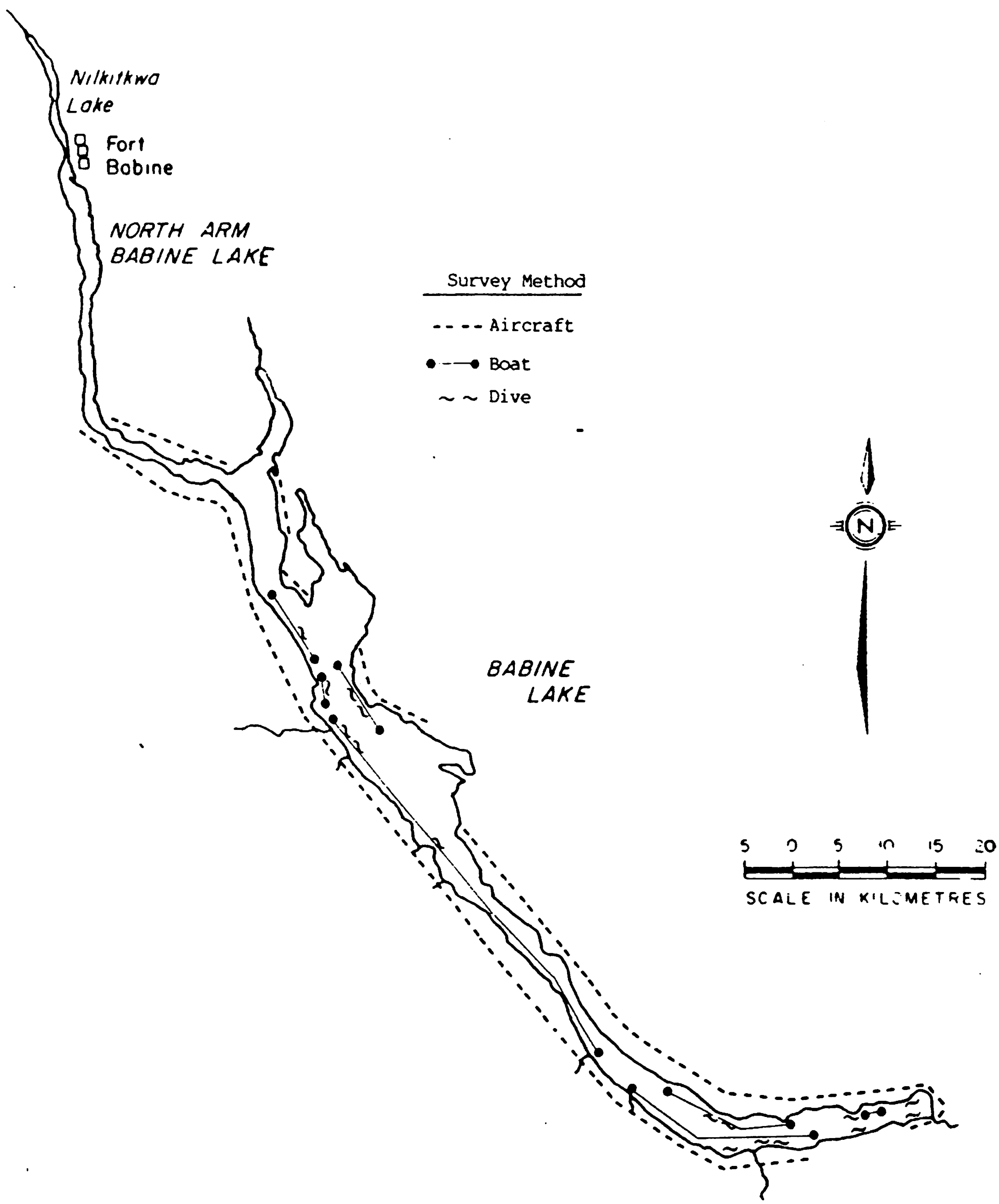

LOWER BABINE RIVER
BABINE FENCE
NILKITKWA LAKE
UPPER BABINE RIVER
TAHLO Cr.
MORRISON LAKE
5 MILE Cr.
9 MILE Cr.
NORTH ARM
MORRISON R.
MORRISON ARM
HALIFAX NARROWS
HAGAN ARM
CHAPMAN LAKE
FULTON R.
FULTON LAKE
DAM
TACHEK Cr.
SOCKEYE Cr.
PIERRE Cr.
TWAIN Cr.
N
SUTHERLAND RIVER
6 MILE Cr.
4 MILE Cr.
FALLS
PINKUT LAKE
PINKUT Cr.
TALTAPIN LAKE
BABINE LAKE
0 5 10 15 MILES
QUEEN CHARLOTTE ISLANDS
BABINE RIVER
Pr. RUPERT
SKEENA R.
BABINE LAKE
Pr. GEORGE
VANCOUVER ISLAND
FRASER R.
VANCOUVER
VICTORIA
KEY PLAN
0 100 200

Figure 2


Nilkitkwa Lake
Fort Babine
NORTH ARM BABINE LAKE
Survey Method
Aircraft
Boat
Dive
BABINE LAKE
N
5 0 5 10 15 20
SCALE IN KILOMETRES

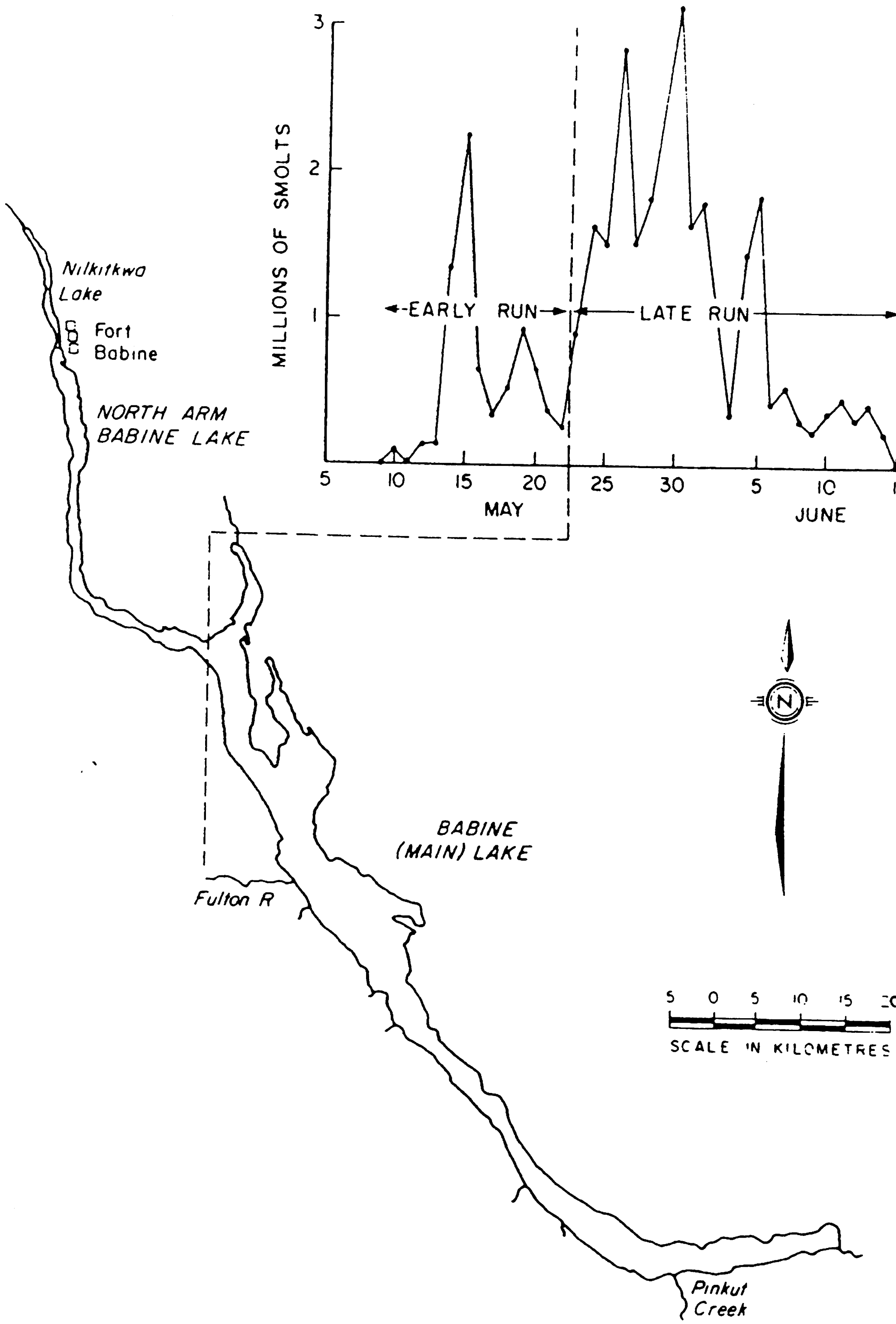

MILLIONS OF SMOLTS
3
2
1
EARLY RUN
LATE RUN
5
10
15
20
25
30
5
10
15
MAY
JUNE
Nilkitkwa
Lake
Fort
Babine
NORTH ARM
BABINE LAKE
BABINE
(MAIN) LAKE
Fulton R
Pinkut
Creek
N
SCALE IN KILOMETRES

Figure 4

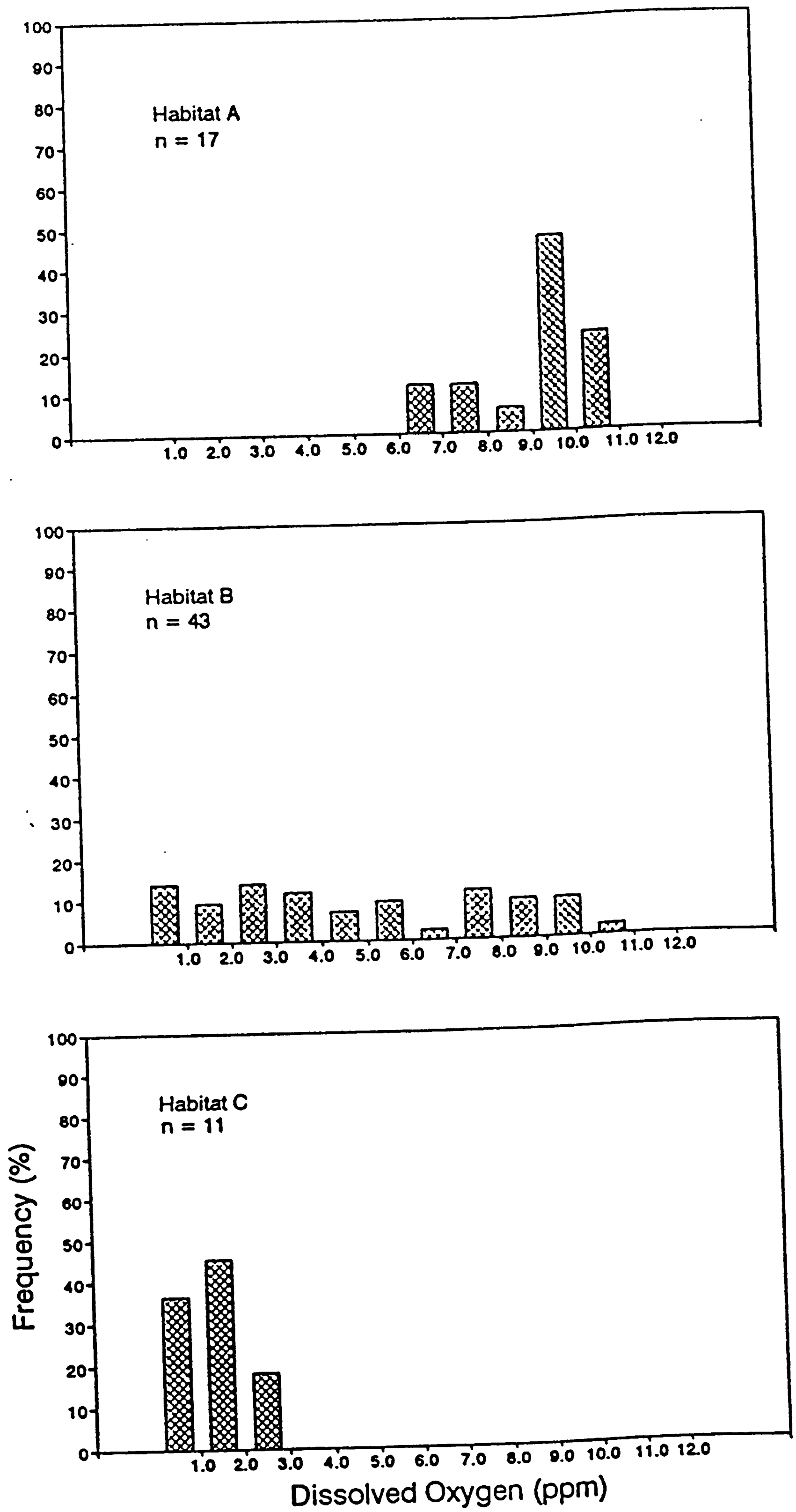
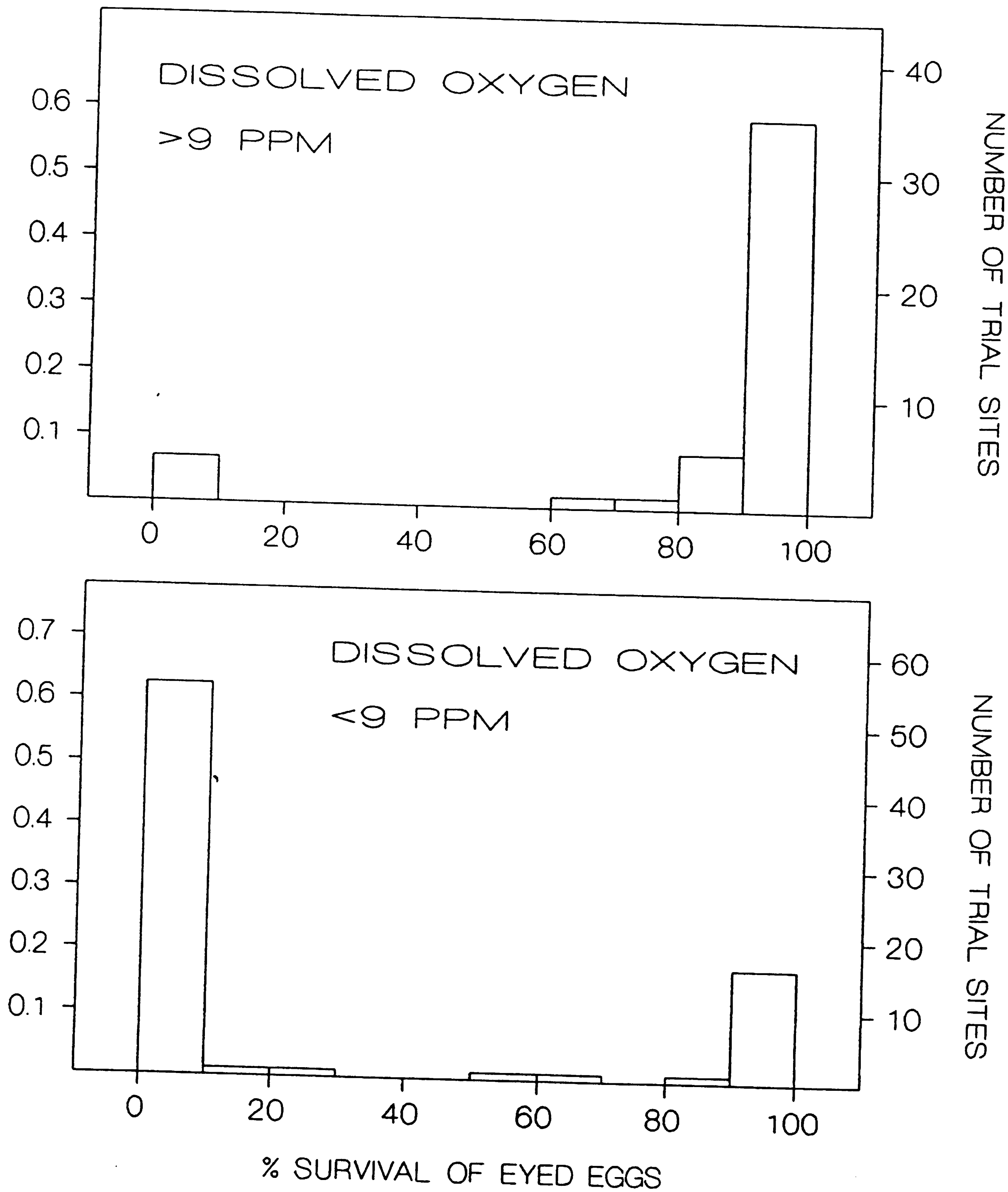
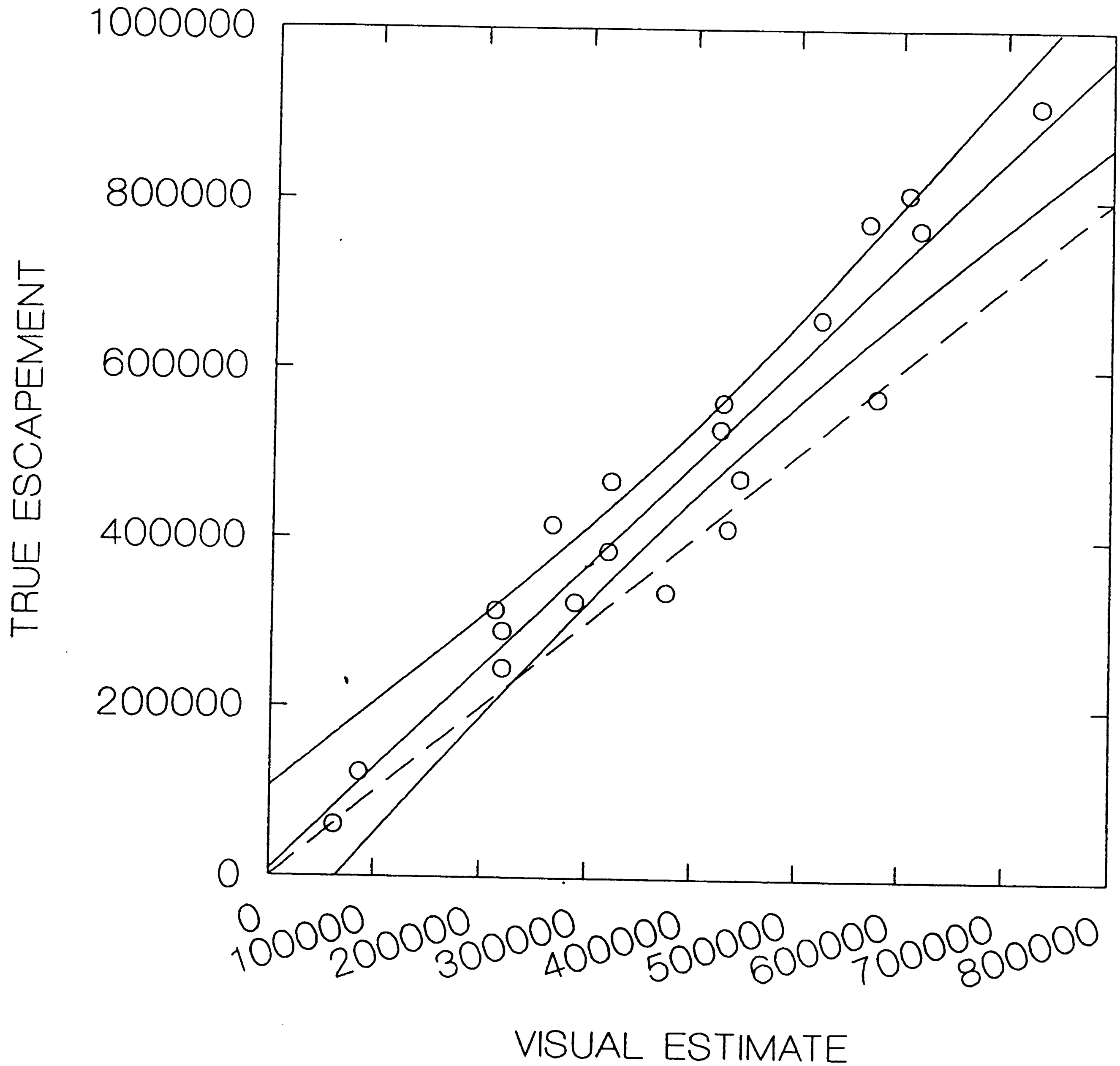
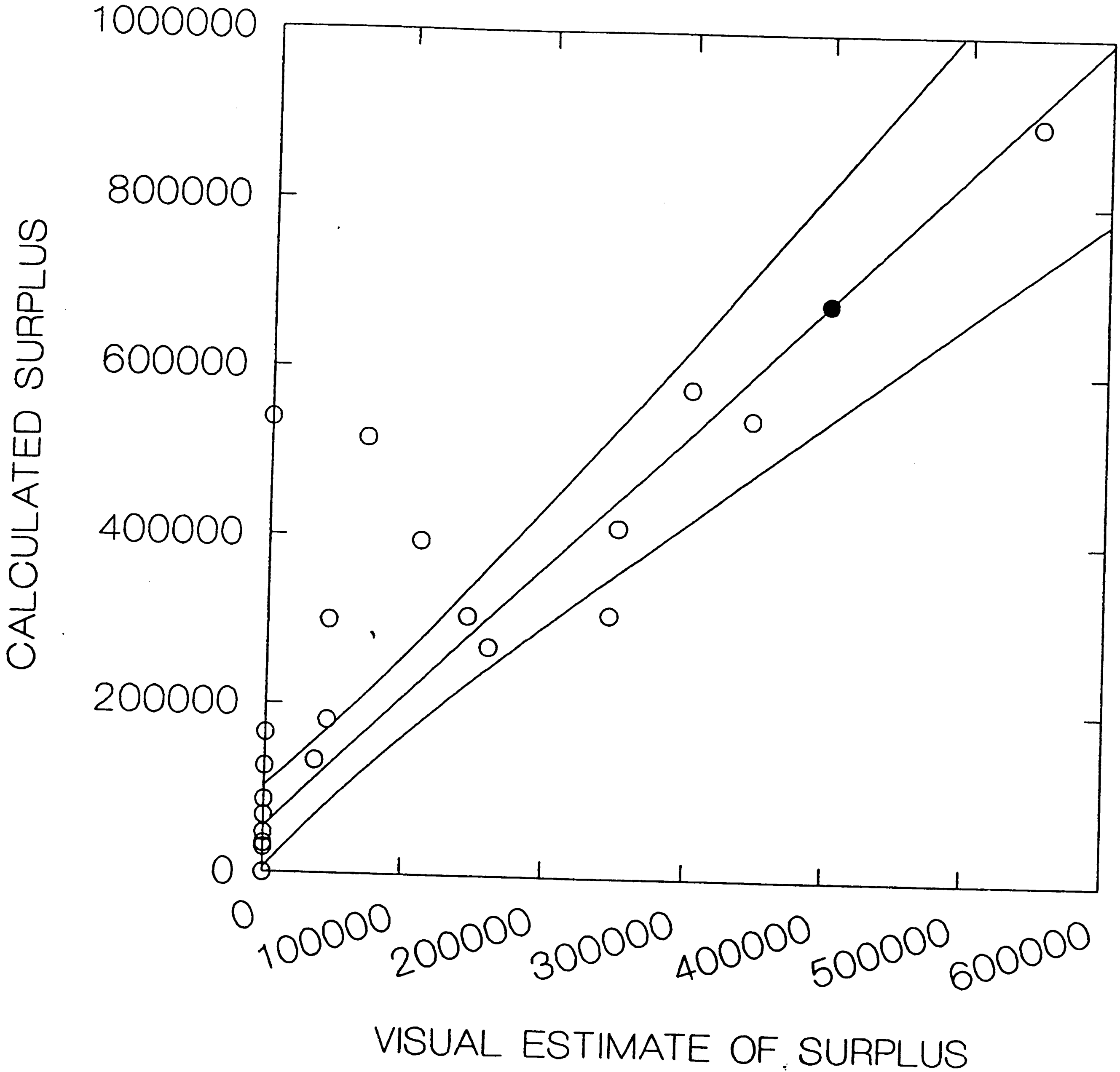
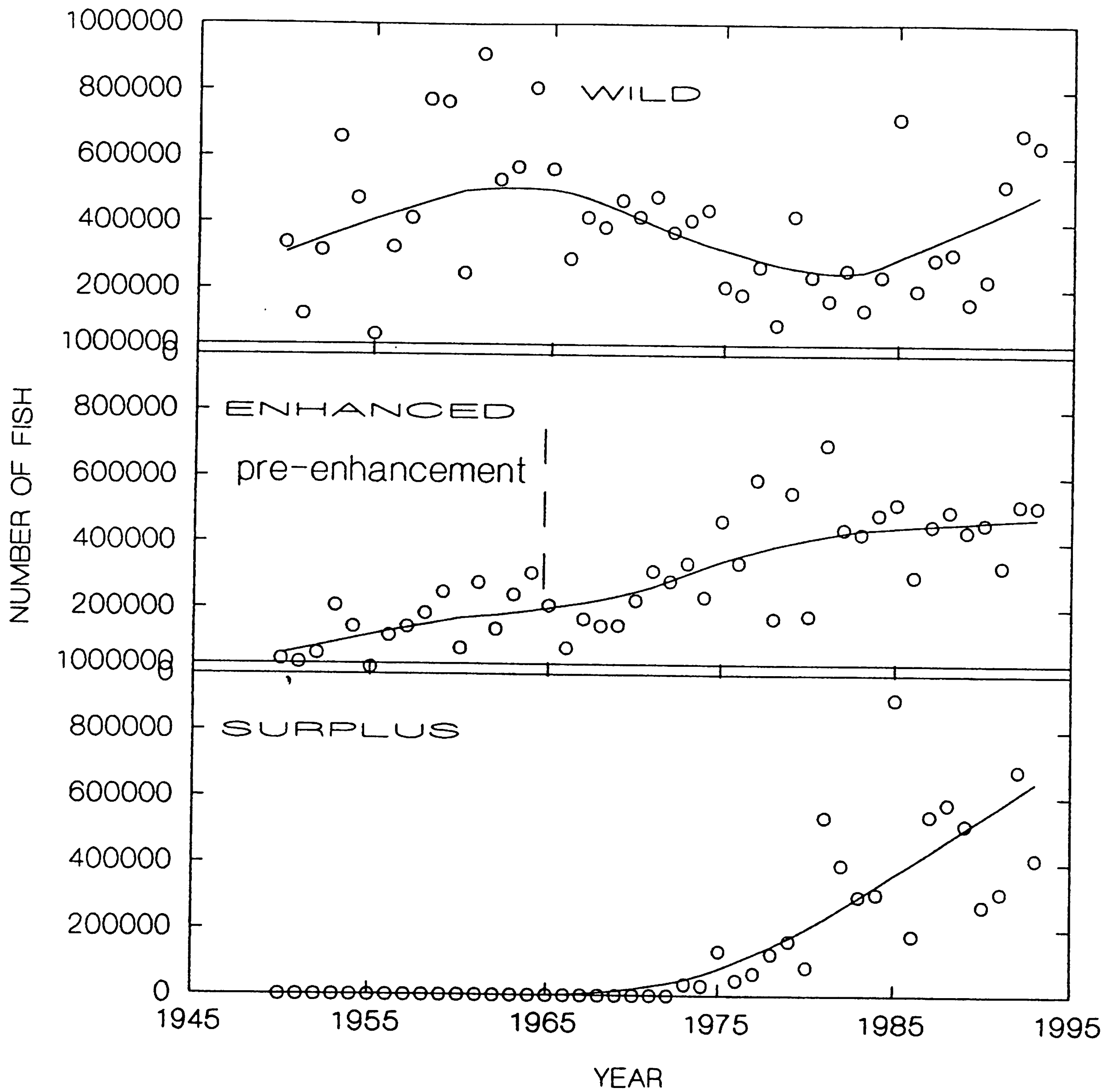

Habitat A
n = 17
Habitat B
n = 43
Habitat C
n = 11
100
90
80
70
60
50
40
30
20
10
0
1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0
Frequency (%)
Dissolved Oxygen (ppm)

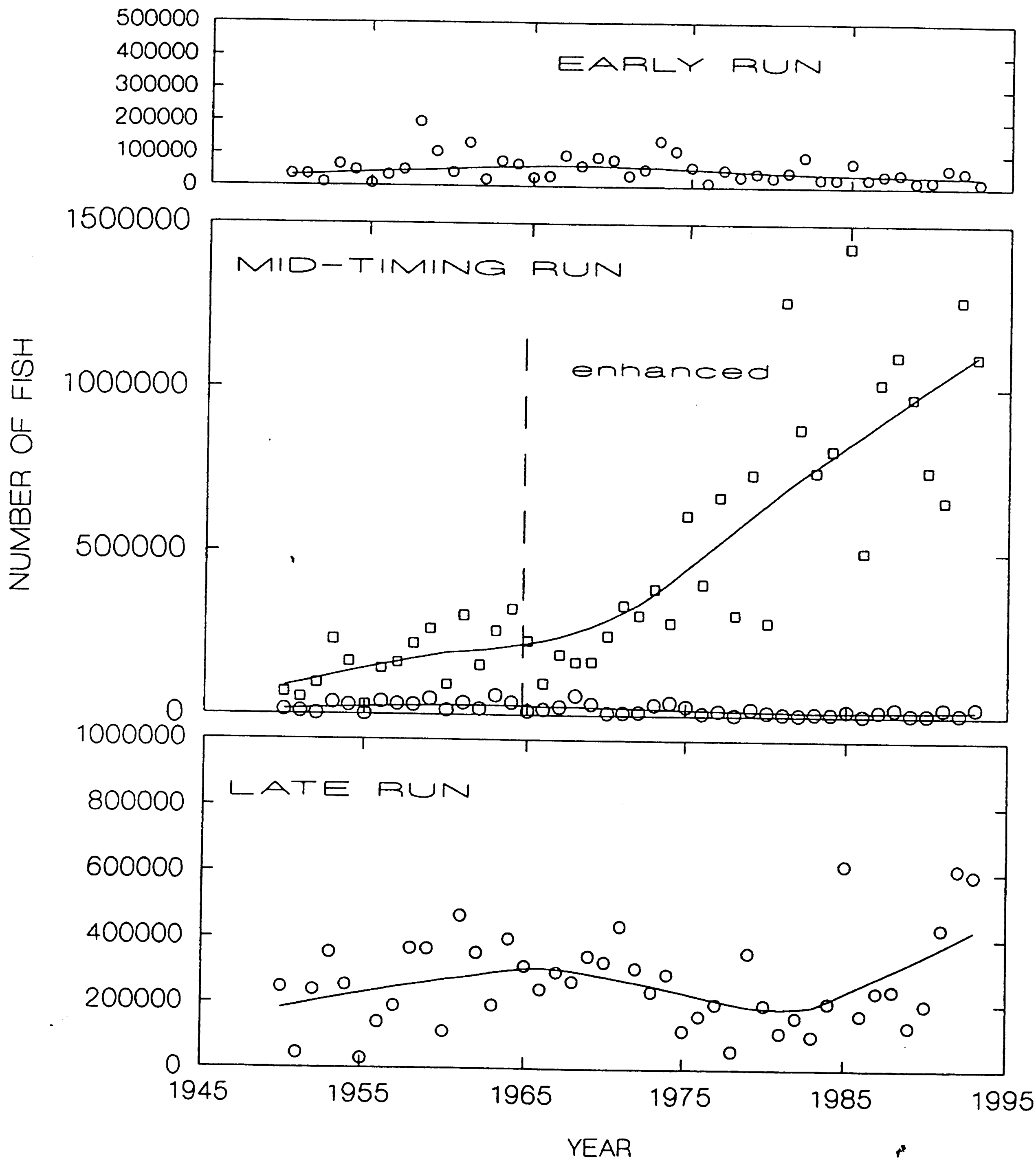
Figure 5


DISSOLVED OXYGEN
>9 PPM
0.6
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
40
30
20
10
NUMBER OF TRIAL SITES
DISSOLVED OXYGEN
<9 PPM
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
60
50
40
30
20
10
NUMBER OF TRIAL SITES
% SURVIVAL OF EYED EGGS


1000000
800000
600000
400000
200000
0
TRUE ESCAPEMENT
0
100000
200000
300000
400000
500000
600000
700000
800000
VISUAL ESTIMATE


1000000
800000
600000
400000
200000
0
CALCULATED SURPLUS
0
100000
200000
300000
400000
500000
600000
VISUAL ESTIMATE OF SURPLUS


WILD
ENHANCED
pre-enhancement
SURPLUS
NUMBER OF FISH
YEAR
1000000
800000
600000
400000
200000
0
1945
1955
1965
1975
1985
1995


500000
400000
300000
200000
100000
0
EARLY RUN
1500000
1000000
500000
0
MID-TIMING RUN
enhanced
1000000
800000
600000
400000
200000
0
LATE RUN
NUMBER OF FISH
1945
1955
1965
1975
1985
1995
YEAR

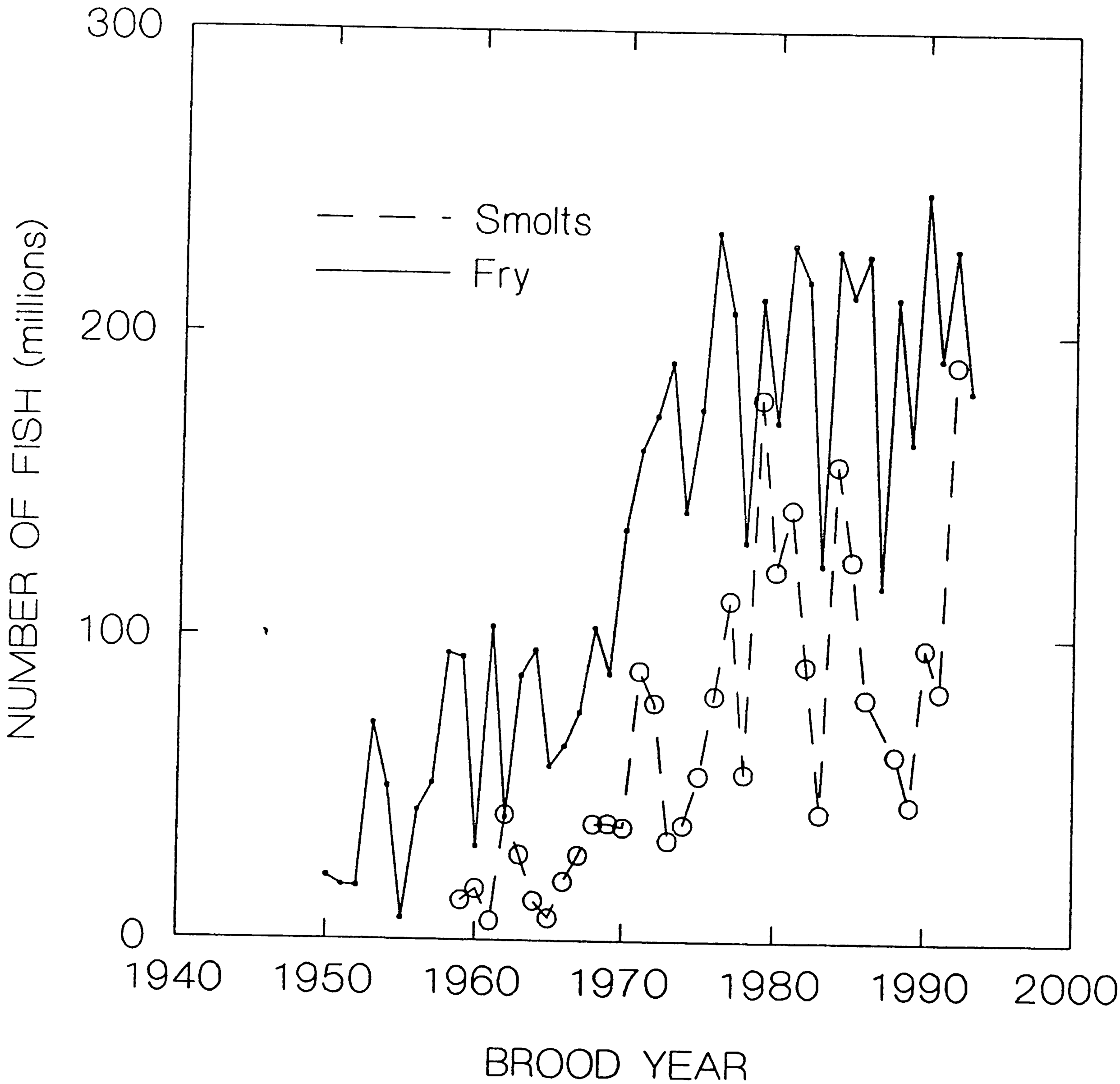
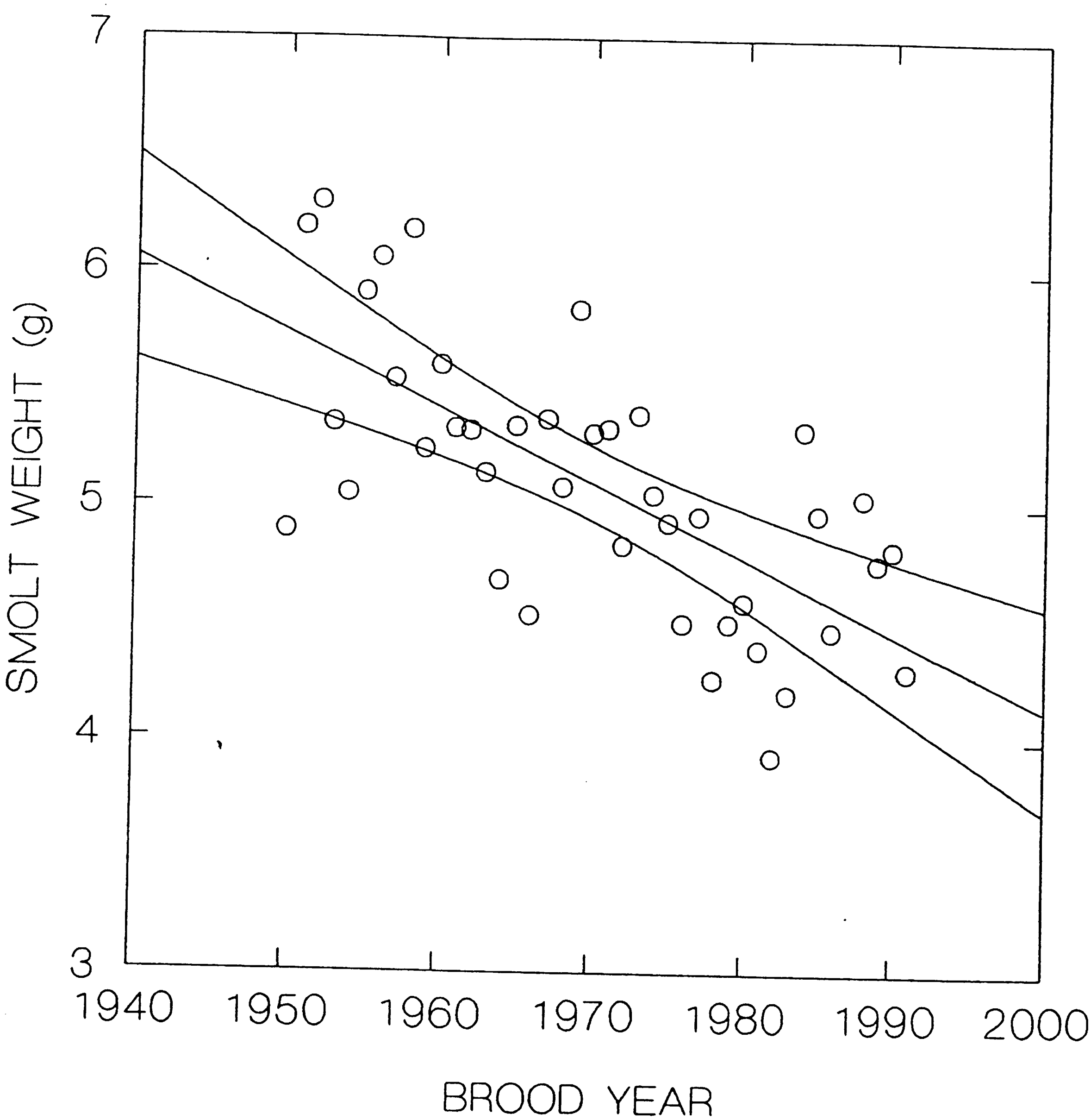
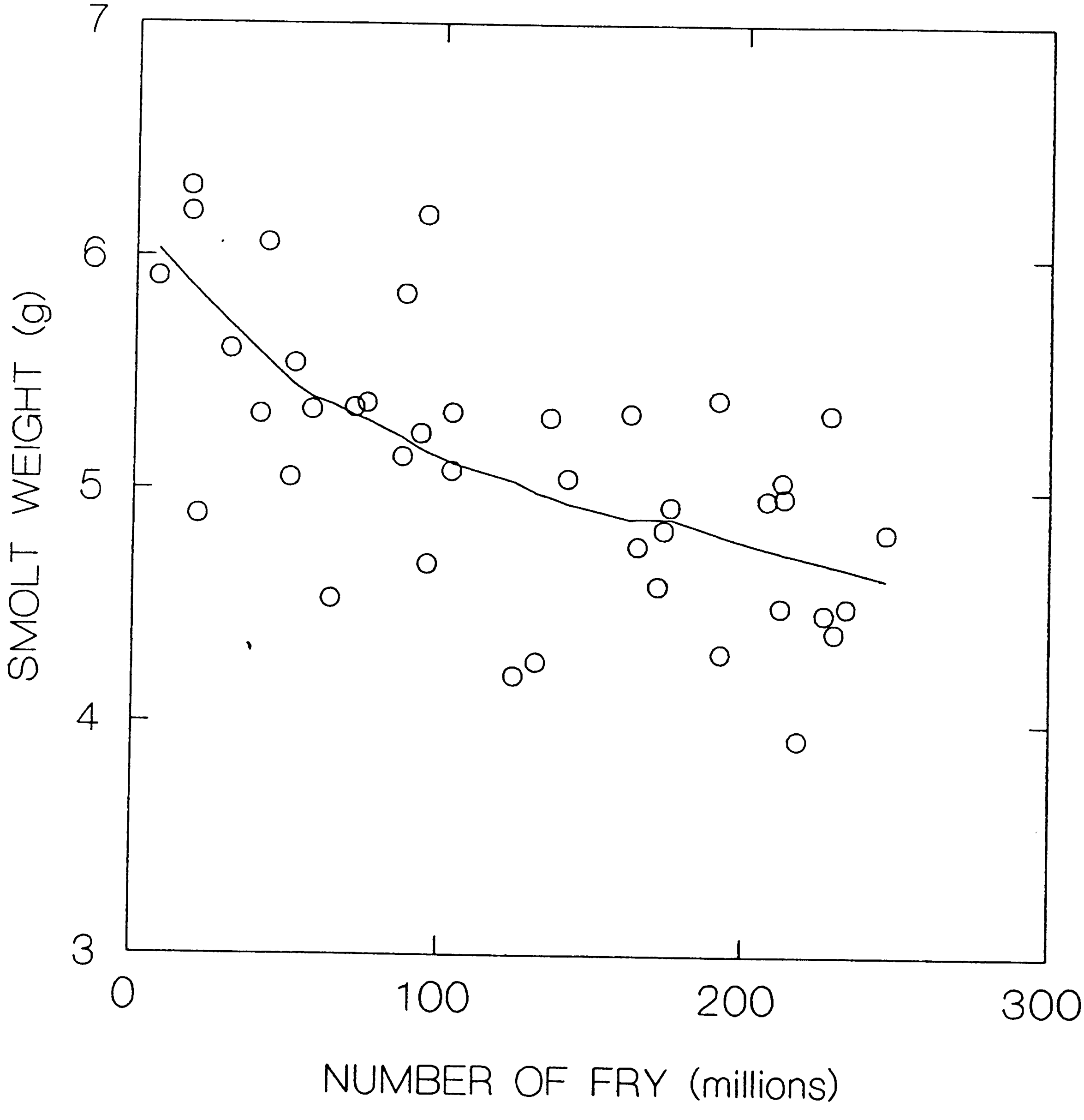
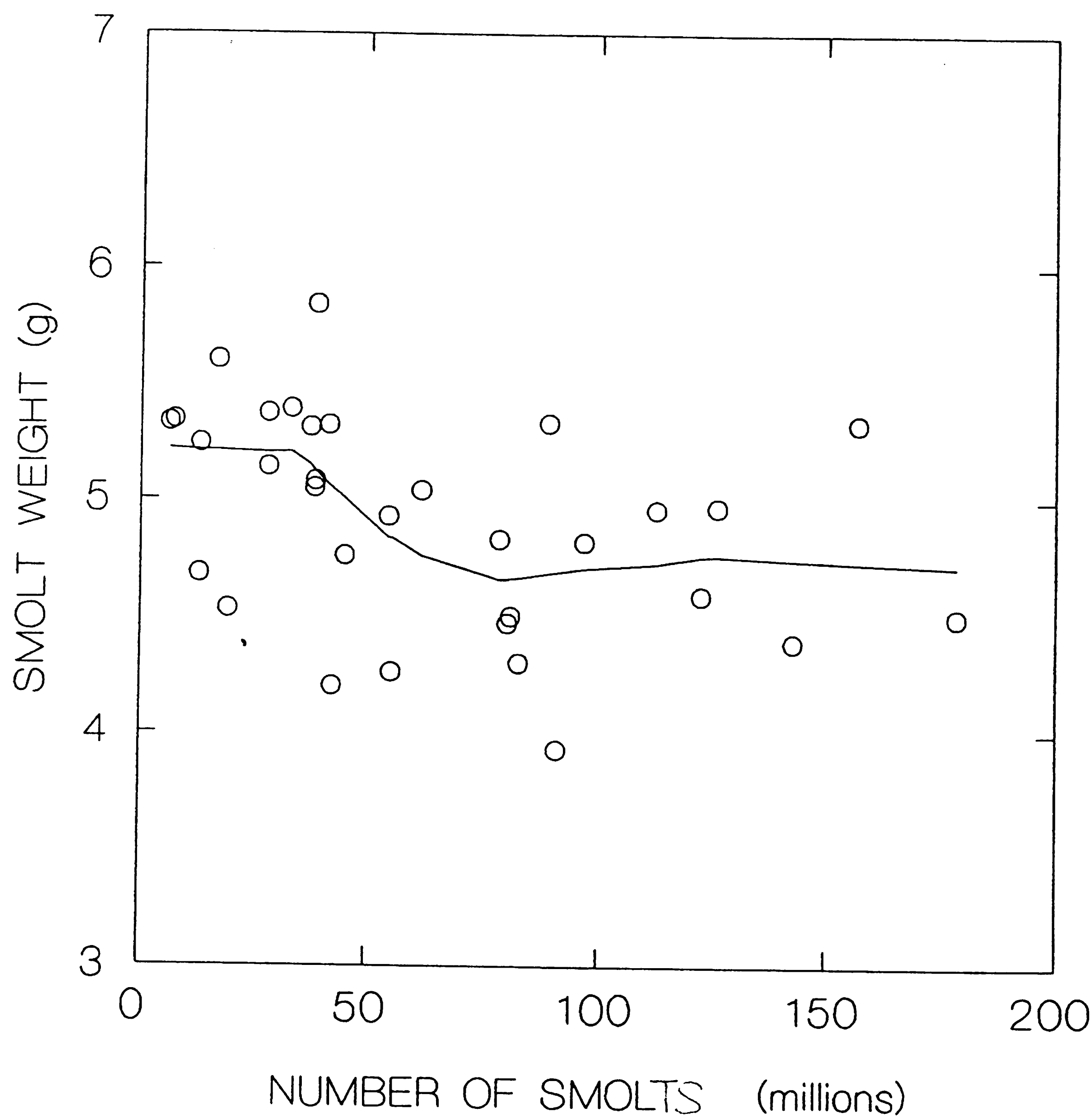

300
200
100
0
NUMBER OF FISH (millions)
Smolts
Fry
1940
1950
1960
1970
1980
1990
2000
BROOD YEAR

Figure 11


7
6
5
4
3
SMOLT WEIGHT (g)
1940
1950
1960
1970
1980
1990
2000
BROOD YEAR


SMOLT WEIGHT (g)
7
6
5
4
3
0
100
200
300
NUMBER OF FRY (millions)


7
6
5
4
3
0
50
100
150
200
SMOLT WEIGHT (g)
NUMBER OF SMOLTS (millions)

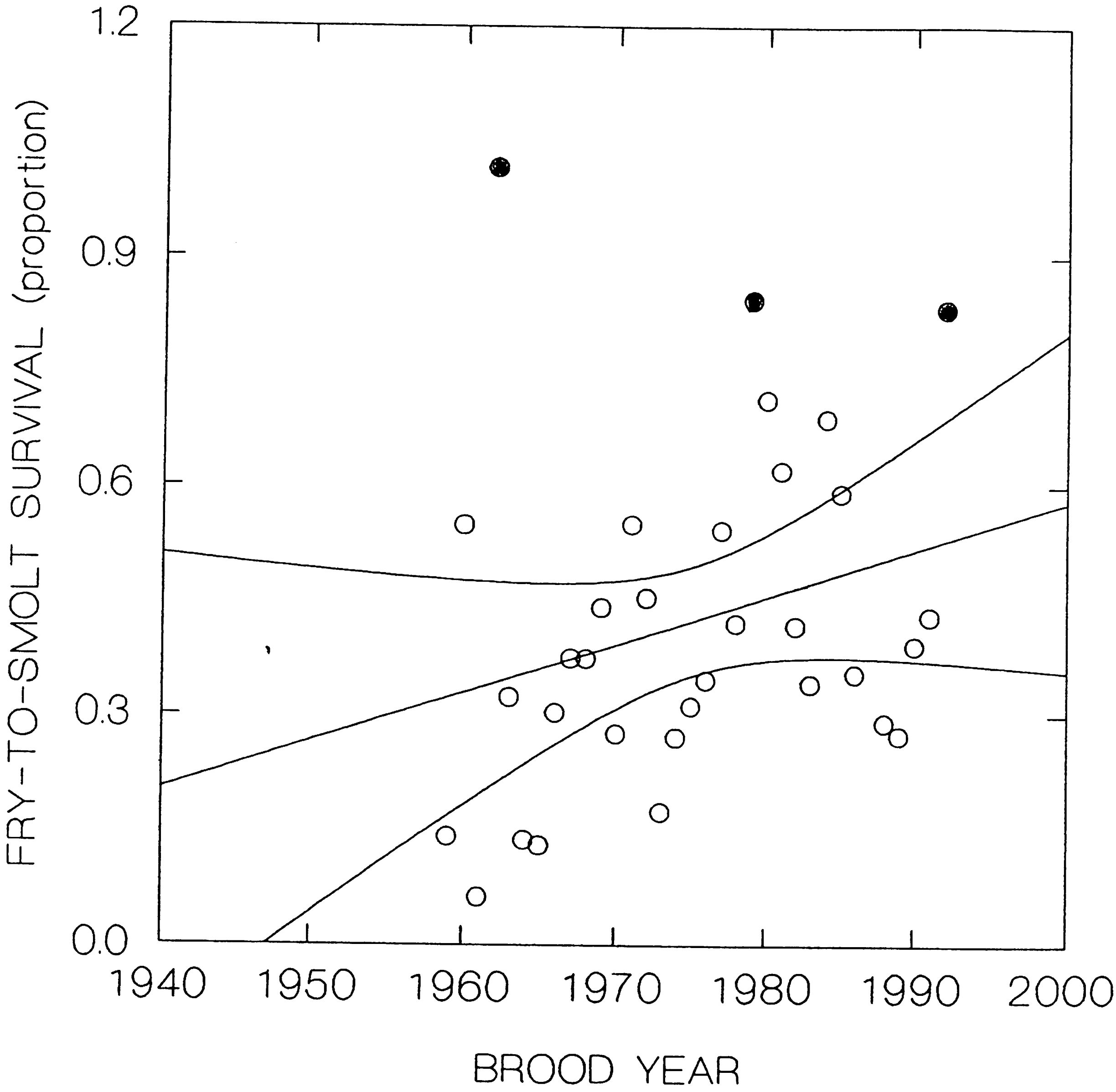
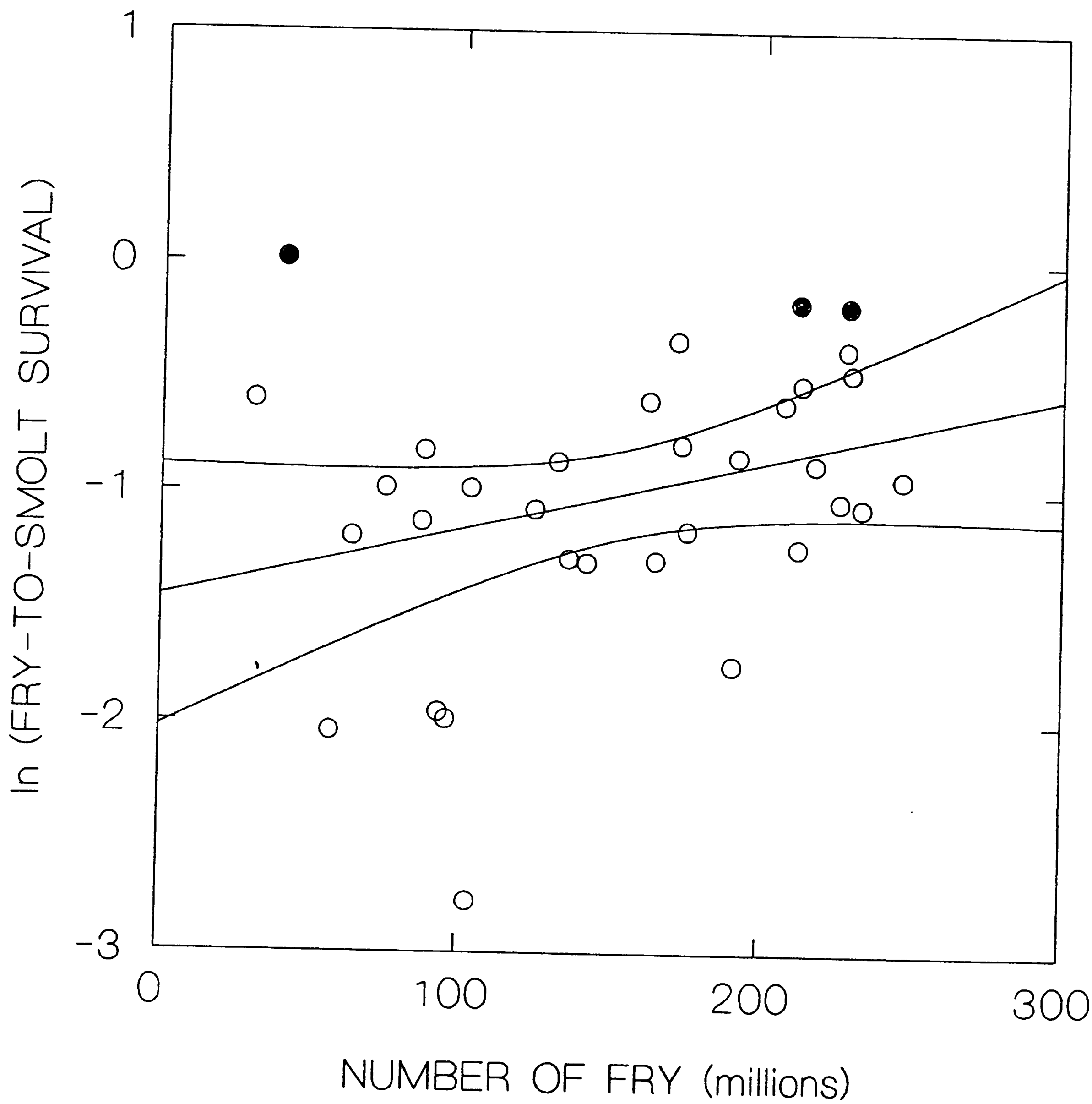

1.2
0.9
0.6
0.3
0.0
FRY-TO-SMOLT SURVIVAL (proportion)
1940
1950
1960
1970
1980
1990
2000
BROOD YEAR

Figure 15


ln (FRY-TO-SMOLT SURVIVAL)
1
0
-1
-2
-3
0
100
200
300
NUMBER OF FRY (millions)

Appendix 1. Babine Lake sockeye escapements 1950-1993 with averages by decade (source: L. Jantz, DFO, Prince Rupert).

| | TIMING | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | AVERAGE 1950-59 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Babine Fence Count** | | 364356 | 141415 | 349011 | 686586 | 493677 | 71352 | 355345 | 433149 | 812043 | 782868 | 448980 |
| **Unenhanced Spawning Sites** | | | | | | | | | | | | |
| Babine R(Sec 1-3) | late | 130000 | 20000 | 62000 | 150000 | 140000 | 15500 | 70000 | 130000 | 160000 | 165000 | 104250 |
| Babine R(Sec 4) | late | 145000 | 12000 | 100000 | 130000 | 100000 | 15000 | 55000 | 70000 | 110000 | 130000 | 86700 |
| Boucher Creek | early | | | 400 | 4000 | 400 | | | | | | 1600 |
| Donalds Creek | early | | | | 300 | 300 | | | 200 | | 800 | 400 |
| Five-Mile Creek | early | | 111 | | 300 | 2000 | 100 | | 200 | | 600 | 552 |
| Fork Creek | early | | | | | | | | | | 600 | 600 |
| Four-Mile Creek | early | 4664 | 927 | 192 | 2000 | 2200 | 400 | 400 | 2500 | 7000 | 5400 | 2568 |
| Hazelwood Creek | early | | | | | | | | | | | |
| Kew Creek | early | | | | 100 | 300 | | | | | 400 | 267 |
| Morrison Creek | mid | 9800 | 2200 | 400 | 16000 | 12000 | 600 | 18000 | 20000 | 9000 | 22000 | 11000 |
| Nine-Mile Creek | early | 978 | 407 | 75 | 2500 | 1000 | 50 | | 4000 | | 2400 | 1426 |
| Pendelton Creek | early | 1341 | | | 1500 | 1100 | | | 300 | | 2500 | 1348 |
| Pierre Creek | early | 17920 | 12460 | 3500 | 20000 | 17000 | 4000 | 20000 | 23000 | 80000 | 34000 | 23188 |
| Shass Creek | early | 2697 | 2333 | 2500 | 6000 | 3100 | 500 | 5000 | 7000 | 30000 | 14000 | 7313 |
| Six-Mile Creek | early | 1225 | | | 2663 | 1800 | 100 | 50 | 600 | 2500 | 3500 | 1555 |
| Sockeye Creek | early | 900 | 786 | | 600 | 900 | 500 | | 2500 | 2000 | 4000 | 1523 |
| Sutherland River | early | | | | | | | | | | | |
| Tachek Creek | early | 2055 | 2600 | | 2500 | 1900 | 300 | | 6771 | 3000 | 6000 | 3141 |
| Tahlo Creek | mid | | 1000 | 450 | 10000 | 12000 | 1200 | 11000 | 9000 | 10000 | 12500 | 7461 |
| Tahlo Cr(Upper) | mid | | 1200 | 400 | | | | | 1500 | | 2500 | 1400 |
| Telzato Creek | early | | | | | | | | | | 900 | 900 |
| Tsezakwa Creek | early | | | | | | | | | | 400 | 400 |
| Twain Creek | early | 8081 | 5020 | 827 | 10000 | 14000 | 2500 | 5000 | 6000 | 20000 | 9000 | 8043 |
| Wright Creek | early | | | | | | | | | | 800 | 800 |
| Total Unenhanced | | 324661 | 61044 | 170744 | 358463 | 310000 | 40750 | 184450 | 283571 | 433500 | 417300 | 266435 |
| **Enhanced Spawning Sites** | | | | | | | | | | | | |
| Fulton Channel #1 | mid | | | | | | | | | | | |
| Fulton Channel #2 | mid | | | | | | | | | | | |
| Fulton Above Weir | mid | 50000 | 19000 | 35000 | 140000 | 110000 | 17000 | 80000 | 120000 | 90000 | 120000 | 78100 |
| Fulton Below Weir | mid | | | | | | | | | | | |
| Pinkut Channel #1 | mid | | | | | | | | | | | |
| Pinkut Above Weir | mid | | 5779 | 7500 | 24000 | 25000 | 4000 | 24000 | 30000 | 45000 | 80000 | 27253 |
| Pinkut Airlift | mid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pinkut Below Weir | mid | | | | | | | | | | | |
| Total Enhanced | | 50000 | 24779 | 42500 | 164000 | 135000 | 21000 | 104000 | 150000 | 135000 | 200000 | 102628 |
| **Harvest at or Above Fence** | | 27449 | 19007 | 34404 | 26913 | 21847 | 10423 | 30582 | 20434 | 38580 | 16727 | 24637 |
| **"Missing"** | | -37754 | 36585 | 101363 | 137210 | 26830 | -821 | 36313 | -20856 | 204963 | 148841 | 63267 |
| **Accounted for** | | 336907 | 122408 | 314607 | 659673 | 471830 | 60929 | 324763 | 412715 | 773463 | 766141 | 424344 |

Appendix 1 (cont'd).

| | TIMING | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | AVERAGE 1960-69 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Babine Fence Count** | | 262719 | 941711 | 548000 | 588000 | 827437 | 580000 | 389000 | 603000 | 552000 | 634000 | 592587 |
| **Unenhanced Spawning Sites** | | | | | | | | | | | | |
| Babine R(Sec 1-3) | late | 41000 | 200000 | 210000 | 141450 | 250000 | 120000 | 70000 | 135000 | 185000 | 178000 | 153045 |
| Babine R(Sec 4) | late | 60000 | 175000 | 75000 | 55350 | 48000 | 120000 | 114000 | 55000 | 37000 | 60000 | 79935 |
| Boucher Creek | early | | | | | | | | | | | |
| Donalds Creek | early | | | | | 800 | | | | | | 800 |
| Five-Mile Creek | early | | 500 | 50 | | 50 | 150 | 150 | 100 | 50 | 400 | 181 |
| Fork Creek | early | | | | | | | | | | | |
| Four-Mile Creek | early | 2000 | 2000 | 3000 | 3690 | 2064 | 1400 | 1500 | 4000 | 4000 | 4500 | 2815 |
| Hazelwood Creek | early | | | | | | | | | | | |
| Kew Creek | early | | | | | | | | | | | |
| Morrison Creek | mid | 6000 | 18000 | 9000 | 32500 | 16000 | 5000 | 9000 | 14000 | 35000 | 12250 | 15675 |
| Nine-Mile Creek | early | 2000 | 4000 | 500 | 1230 | 1500 | 500 | 1000 | 1000 | 600 | 1110 | 1344 |
| Pendelton Creek | early | | | 200 | | 1400 | | | | | | 800 |
| Pierre Creek | early | 11000 | 55000 | 4500 | 36900 | 22000 | 10000 | 11000 | 40000 | 25000 | 25000 | 24040 |
| Shass Creek | early | 12000 | 30000 | 5000 | 15600 | 8000 | 5000 | 6000 | 3000 | 7500 | 9000 | 10110 |
| Six-Mile Creek | early | 1000 | | 1000 | 1845 | 1500 | 100 | 300 | 1200 | 1000 | 300 | 916 |
| Sockeye Creek | early | 2000 | | 1100 | 3075 | 1500 | 50 | 1400 | 700 | 1200 | 2140 | 1463 |
| Sutherland River | early | | | | | | | | | | | |
| Tachek Creek | early | 2000 | | 600 | 1600 | 3000 | 700 | 300 | 1000 | 500 | 2350 | 1339 |
| Tahlo Creek | mid | 5000 | 7000 | 4500 | 24600 | 10000 | 3500 | 2500 | 1500 | 11000 | 10200 | 7980 |
| Tahlo Cr(Upper) | mid | | 2000 | 25 | 100 | 1000 | | | | | | 781 |
| Telzato Creek | early | | | | | 350 | | | | | 100 | 225 |
| Tsezakwa Creek | early | | 200 | | | | | | | | | 200 |
| Twain Creek | early | 6000 | 15000 | 1400 | 14760 | 9000 | 3000 | 2500 | 10000 | 12000 | 16660 | 9032 |
| Wright Creek | early | | | | | | | | | | | |
| Total Unenhanced | | 150000 | 508700 | 315875 | 332700 | 376164 | 269400 | 219650 | 266500 | 319850 | 322010 | 310682 |
| **Enhanced Spawning Sites** | | | | | | | | | | | | |
| Fulton Channel #1 | mid | | | | | | | 18186 | 21754 | 26043 | 21034 | 21754 |
| Fulton Channel #2 | mid | | | | | | | | | | 23770 | 23770 |
| Fulton Above Weir | mid | 40000 | 175000 | 80000 | 180000 | 140000 | 135000 | 40395 | 110701 | 99244 | 60555 | 106090 |
| Fulton Below Weir | mid | | | | | | | | 4000 | | | 4000 |
| Pinkut Channel #1 | mid | | | | | | | | | 13479 | 33745 | 23612 |
| Pinkut Above Weir | mid | 30000 | 47000 | 30000 | 65000 | 90000 | 23780 | 21463 | 31742 | 6633 | 7331 | 35295 |
| Pinkut Airlift | mid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pinkut Below Weir | mid | | | | | | | | | 2172 | 2450 | 2311 |
| Total Enhanced | | 70000 | 222000 | 110000 | 245000 | 230000 | 158780 | 80044 | 168197 | 147571 | 148885 | 158048 |
| **Harvest at or Above Fence** | | 16754 | 30856 | 18122 | 20021 | 19855 | 18540 | 18652 | 18992 | 19146 | 17293 | 19823 |
| **"Missing"** | | 25965 | 180155 | 104003 | -9721 | 201418 | 133280 | 70654 | 149311 | 65433 | 145812 | 106631 |
| **Accounted for** | | 245965 | 910855 | 529878 | 567979 | 807582 | 561460 | 370348 | 584008 | 532854 | 616707 | 572764 |

Appendix 1 (cont'd).

| | TIMING | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | AVERAGE 1970-79 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Babine Fence Count** | | 662000 | 816000 | 680145 | 797461 | 726990 | 820795 | 587659 | 937992 | 401318 | 1160966 | 759133 |
| **Unenhanced Spawning Sites** | | | | | | | | | | | | |
| Babine R(Sec 1-3) | late | 234000 | 321000 | 189000 | 153000 | 203529 | 92000 | 127159 | 121232 | 32915 | 272555 | 174639 |
| Babine R(Sec 4) | late | 84000 | 96000 | 70000 | 40000 | 35000 | 3000 | 3000 | 40351 | 10895 | 19770 | 40202 |
| Boucher Creek | early | | | | | | | | | 6 | | 6 |
| Donalds Creek | early | | | | | | | | 400 | | | 400 |
| Five-Mile Creek | early | 300 | 200 | 47 | 90 | 500 | 250 | 60 | 40 | 16 | | 167 |
| Fork Creek | early | | | | | | | | | | | |
| Four-Mile Creek | early | 2500 | 6000 | 7370 | 11000 | 7256 | 1750 | 800 | 8800 | 6000 | 6800 | 5828 |
| Hazelwood Creek | early | | | | | | | | | | | |
| Kew Creek | early | | | | | | | | | | | |
| Morrison Creek | mid | 7200 | 6000 | 8000 | 17200 | 13755 | 16000 | 3600 | 9000 | 1500 | 11200 | 9346 |
| Nine-Mile Creek | early | 1200 | 1200 | 802 | 1100 | 950 | 140 | 900 | 900 | 215 | 900 | 831 |
| Pendelton Creek | early | | | | | 100 | | 1000 | 600 | 300 | | 500 |
| Pierre Creek | early | 44000 | 14200 | 25075 | 60890 | 42920 | 20100 | 2430 | 10000 | 4000 | 11500 | 23512 |
| Shass Creek | early | 5400 | 2400 | 750 | 13900 | 12000 | 4500 | 1400 | 6000 | 1200 | 3100 | 5065 |
| Six-Mile Creek | early | 600 | 350 | 1400 | 4800 | 880 | 100 | 450 | 1500 | 300 | 1400 | 1178 |
| Sockeye Creek | early | 4800 | 650 | 650 | 600 | 3500 | 2600 | 1300 | 1700 | 1500 | 800 | 1810 |
| Sutherland River | early | | | | 400 | 400 | | | | 400 | | 400 |
| Tachek Creek | early | 2400 | 500 | 1200 | 850 | 2900 | 1150 | 500 | 3500 | 1500 | 1200 | 1570 |
| Tahlo Creek | mid | | 2000 | 600 | 9000 | 17200 | 7000 | 1400 | 3600 | 1500 | 6600 | 5433 |
| Tahlo Cr(Upper) | mid | | | | 100 | 300 | | 1400 | | | | 600 |
| Telzato Creek | early | 100 | | | | | | | | | | 100 |
| Tsezakwa Creek | early | | | | | | | | 200 | 10 | 20 | 77 |
| Twain Creek | early | 18000 | 7000 | 6800 | 21000 | 18500 | 17800 | 1800 | 9000 | 9000 | 9000 | 11790 |
| Wright Creek | early | | | | | | | | | | | |
| Total Unenhanced | | 404500 | 457500 | 311694 | 333930 | 359690 | 166390 | 147199 | 216823 | 71257 | 344845 | 283452 |
| **Enhanced Spawning Sites** | | | | | | | | | | | | |
| Fulton Channel #1 | mid | 25483 | 24746 | 21600 | 25272 | 12530 | 14874 | 16834 | 19080 | 10613 | 21284 | 19232 |
| Fulton Channel #2 | mid | 58786 | 115481 | 106491 | 112062 | 62397 | 108199 | 110676 | 127548 | 88648 | 126035 | 101632 |
| Fulton Above Weir | mid | 99789 | 125869 | 81387 | 99975 | 46709 | 192670 | 140561 | 345403 | 39042 | 244568 | 141597 |
| Fulton Below Weir | mid | 11500 | 16705 | 0 | 0 | 17575 | 81756 | 20000 | 10000 | 5000 | 25000 | 18754 |
| Pinkut Channel #1 | mid | 19763 | 21665 | 57083 | 63260 | 51655 | 48083 | 0 | 64556 | 23716 | 68411 | 41819 |
| Pinkut Above Weir | mid | 8257 | 7878 | 15828 | 17969 | 17000 | 12000 | 20227 | 20201 | 4248 | 26000 | 14961 |
| Pinkut Airlift | mid | 0 | 0 | 0 | 16654 | 25542 | 40107 | 28965 | 0 | 0 | 36334 | 14760 |
| Pinkut Below Weir | mid | 958 | 900 | 1000 | 2300 | 2000 | 5000 | 1000 | 5000 | 0 | 5000 | 2316 |
| Total Enhanced | | 224536 | 313244 | 283389 | 337492 | 235408 | 502689 | 338263 | 591788 | 171267 | 552632 | 355071 |
| **Harvest at or Above Fence** | | 20048 | 23450 | 24283 | 17015 | 22318 | 13896 | 18157 | 10777 | 10920 | 21500 | 18236 |
| **"Missing"** | | 12916 | 21806 | 60779 | 109024 | 109574 | 137820 | 84040 | 118604 | 147874 | 241989 | 104443 |
| **Accounted for** | | 641952 | 792550 | 655862 | 780446 | 704672 | 806899 | 569502 | 927215 | 390398 | 1139466 | 740896 |

Appendix 1 (cont'd).

| | TIMING | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | AVERAGE 1980-89 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Babine Fence Count** | | 526059 | 1432734 | 1136344 | 886393 | 1052385 | 2148044 | 701507 | 1307852 | 1408929 | 1132316 | 1173256 |
| **Unenhanced Spawning Sites** | | | | | | | | | | | | |
| Babine R(Sec 1-3) | late | 150640 | 70000 | 94647 | 74000 | 158986 | 500000 | 120000 | 175000 | 185000 | 100000 | 162827 |
| Babine R(Sec 4) | late | 8175 | 20000 | 34300 | 7000 | 5787 | 14000 | 14000 | 17500 | 11500 | 5000 | 13726 |
| Boucher Creek | early | | | | | | | | N/I | N/I | N/I | |
| Donalds Creek | early | | | | 100 | | | 0 | 50 | 50 | N/O | 50 |
| Five-Mile Creek | early | 4 | | 150 | 100 | 20 | 200 | 100 | 30 | 0 | N/I | 76 |
| Fork Creek | early | | | | | | | | | | | |
| Four-Mile Creek | early | 3600 | 6500 | 15000 | 4200 | 2300 | 5000 | 3000 | 2000 | 1200 | 500 | 4330 |
| Hazelwood Creek | early | 50 | | | | | | N/I | N/I | N/I | N/I | 50 |
| Kew Creek | early | | | | | | | | | | | |
| Morrison Creek | mid | 4000 | 5000 | 3500 | 4500 | 2500 | 7000 | 2500 | 9000 | 12000 | 3000 | 5300 |
| Nine-Mile Creek | early | 750 | 500 | 1000 | 400 | 1000 | 1850 | 500 | 1500 | 200 | 300 | 800 |
| Pendelton Creek | early | 25 | 600 | 5500 | 150 | 100 | 850 | 550 | 700 | 600 | 80 | 916 |
| Pierre Creek | early | 3750 | 10000 | 20000 | 7500 | 12650 | 23000 | 7700 | 11500 | 12500 | 6750 | 11535 |
| Shass Creek | early | 3000 | 6000 | 4500 | 1500 | 950 | 12000 | 2000 | 5200 | 12000 | 2600 | 4975 |
| Six-Mile Creek | early | 1300 | 800 | 6000 | 950 | 200 | 700 | 1500 | 300 | 250 | 10 | 1201 |
| Sockeye Creek | early | 3100 | 1500 | 2500 | 500 | 40 | 2000 | 50 | 600 | 600 | 30 | 1092 |
| Sutherland River | early | 500 | | | | | | N/I | 350 | | N/I | 425 |
| Tachek Creek | early | 950 | 700 | 4000 | 400 | 100 | 800 | 600 | 1100 | 500 | 14 | 916 |
| Tahlo Creek | mid | 5000 | 700 | 400 | 2500 | 4000 | 7200 | 600 | 3800 | 7000 | 3100 | 3430 |
| Tahlo Cr(Upper) | mid | | | | | | N/O | N/I | N/O | 50 | N/O | 50 |
| Telzato Creek | early | | | | | | | N/I | | | | |
| Tsezakwa Creek | early | UNK | N/I | N/I | N/I | N/I | N/I | | | | | |
| Twain Creek | early | 7500 | 10000 | 17000 | 5400 | 4000 | 16000 | 5600 | 7500 | 6500 | 4300 | 8380 |
| Wright Creek | early | | | | | | | | | 10 | | 10 |
| Total Unenhanced | | 192344 | 132300 | 208497 | 109200 | 192633 | 590600 | 158700 | 236130 | 249960 | 125684 | 220089 |
| **Enhanced Spawning Sites** | | | | | | | | | | | | |
| Fulton Channel #1 | mid | 8550 | 20795 | 16845 | 21712 | 16655 | 17208 | 13640 | 16438 | 13685 | 16032 | 16156 |
| Fulton Channel #2 | mid | 64100 | 144969 | 115507 | 164810 | 109803 | 104340 | 85696 | 102471 | 104301 | 115315 | 111131 |
| Fulton Above Weir | mid | 42558 | 175302 | 221714 | 156552 | 210022 | 200312 | 86100 | 136239 | 200000 | 150000 | 157880 |
| Fulton Below Weir | mid | 6000 | 100000 | 45000 | 5000 | 10000 | 300000 | 5000 | 10000 | 200000 | 100000 | 78100 |
| Pinkut Channel #1 | mid | 41655 | 79847 | 55008 | 94520 | 69500 | 76377 | 51800 | 74076 | 58382 | 66704 | 66787 |
| Pinkut Above Weir | mid | 15000 | 25541 | 25000 | 25195 | 19566 | 19235 | 20378 | 20266 | 24429 | 24501 | 21911 |
| Pinkut Airlift | mid | 0 | 90753 | 22399 | 0 | 45849 | 50787 | 30798 | 88139 | 45956 | 12819 | 38750 |
| Pinkut Below Weir | mid | 1000 | 60000 | 50000 | 5000 | 150000 | 300000 | 50000 | 350000 | 150000 | 20000 | 113600 |
| Total Enhanced | | 178863 | 697207 | 551473 | 472789 | 631395 | 1068259 | 343412 | 797629 | 796753 | 505371 | 604315 |
| **Harvest at or Above Fence** | | 22635 | 30300 | 42000 | 20000 | 20500 | 17500 | 23500 | 20296 | 25000 | 22000 | 24373 |
| **"Missing"** | | 132217 | 572927 | 334374 | 284404 | 207857 | 471685 | 175895 | 253797 | 337216 | 479261 | 324963 |
| **Accounted for** | | 503424 | 1402434 | 1094344 | 866393 | 1031885 | 2130544 | 678007 | 1287556 | 1383929 | 1110316 | 1148883 |

Appendix 1 (cont'd).

| | TIMING | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | AVERAGE 1990-93 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Babine Fence Count** | | 978562 | 1176318 | 1233785 | 1737426 | | | | | | | 1281523 |
| **Unenhanced Spawning Sites** | | | | | | | | | | | | |
| Babine R(Sec 1-3) | late | 150000 | 350000 | 500000 | 475000 | | | | | | | 368750 |
| Babine R(Sec 4) | late | 10000 | 5000 | 5000 | 15000 | | | | | | | 8750 |
| Boucher Creek | early | N/I | N/I | 100 | UNK | | | | | | | 100 |
| Donalds Creek | early | N/O | 12 | N/O | N/I | | | | | | | 6 |
| Five-Mile Creek | early | N/I | N/I | 60 | N/O | | | | | | | 60 |
| Fork Creek | early | | | | | | | | | | | |
| Four-Mile Creek | early | 1800 | 3500 | 2500 | UNK | | | | | | | 2600 |
| Hazelwood Creek | early | N/I | N/I | N/I | N/I | | | | | | | |
| Kew Creek | early | | | | | | | | | | | |
| Morrison Creek | mid | 4500 | 13000 | 4800 | 6000 | | | | | | | 7075 |
| Nine-Mile Creek | early | N/I | N/I | 4400 | 200 | | | | | | | 2300 |
| Pendelton Creek | early | 200 | 400 | 1100 | UNK | | | | | | | 567 |
| Pierre Creek | early | 4300 | 25000 | 18000 | UNK | | | | | | | 15767 |
| Shass Creek | early | 2500 | 8100 | 2000 | 3000 | | | | | | | 3900 |
| Six-Mile Creek | early | 230 | 300 | N/O | UNK | | | | | | | 265 |
| Sockeye Creek | early | N/O | 320 | 2700 | 3500 | | | | | | | 2173 |
| Sutherland River | early | N/I | 900 | N/I | | | | | | | | 900 |
| Tachek Creek | early | 130 | 156 | 2500 | 7000 | | | | | | | 2447 |
| Tahlo Creek | mid | 1450 | 7500 | 2500 | 12000 | | | | | | | 5863 |
| Tahlo Cr(Upper) | mid | N/O | N/O | N/O | 75 | | | | | | | |
| Telzato Creek | early | | | | | | | | | | | |
| Tsezakwa Creek | early | | | | | | | | | | | |
| Twain Creek | early | 8000 | 9500 | 7000 | UNK | | | | | | | 8167 |
| Wright Creek | early | | | | | | | | | | | |
| Total Unenhanced | | 183110 | 423688 | 552660 | 521775 | | | | | | | 429688 |
| **Enhanced Spawning Sites** | | | | | | | | | | | | |
| Fulton Channel #1 | mid | 16181 | 12409 | 14577 | 21129 | | | | | | | 16074 |
| Fulton Channel #2 | mid | 108108 | 97010 | 122021 | 102125 | | | | | | | 107316 |
| Fulton Above Weir | mid | 172904 | 52068 | 178144 | 164173 | | | | | | | 141822 |
| Fulton Below Weir | mid | 150000 | 20000 | 250000 | 100000 | | | | | | | |
| Pinkut Channel #1 | mid | 69715 | 84339 | 79009 | 85245 | | | | | | | 79577 |
| Pinkut Above Weir | mid | 25047 | 25924 | 35221 | 34773 | | | | | | | 30241 |
| Pinkut Airlift | mid | 16678 | 32249 | 37325 | 54677 | | | | | | | |
| Pinkut Below Weir | mid | 60000 | 250000 | 200000 | 200000 | | | | | | | |
| Total Enhanced | | 618633 | 573999 | 916297 | 762122 | | | | | | | 717763 |
| **Harvest at or Above Fence** | | 22000 | 20800 | 73879 | 177590 | | | | | | | 73567 |
| **"Missing"** | | 154819 | 157831 | -309051 | 275939 | | | | | | | 69885 |
| **Accounted for** | | 956562 | 1155518 | 1159906 | 1559836 | | | | | | | 1207956 |

Appendix 2. Notation and calculations of adjusted spawning escapements and surplus enhanced production.

Assumptions/comments:

1) Runs to spawning areas downstream of the counting fence are excluded
2) Babine fence count was unreliable in 1992 (not operated by DFO)
3) All catches at or above the Babine fence exploit mid-timing runs
4) The first measurable returns from enhancement (spawning channels in Fulton River and later Pinkut Creek) occurred in 1970.
5) Estimates of escapement below fences in Fulton River and Pinkut Creek are reliable up to but not necessarily above target levels (45,000 and 5000 respectively).
6) Target escapements below fences in Fulton River and Pinkut Creek represent maximum number of successful spawners there; additional fish do not contribute to fry production and are considered surplus.
7) Spawning in Babine Lake itself is not successful.

Notation and definitions:

A run is defined as the number of adults returning to Babine Lake through the Babine fence such that:

$R_T$ = total run = Babine fence count except in 1992

$R_E$ = early-timing run comprising numerous small, wild sub-populations (e.g. Pierre Creek)

$R_M^W$ = mid-timing run to Morrison River subpopulations that have not been enhanced (W for wild)

$R_M^{FP}$ = mid-timing run to Fulton River and Pinkut Creek subpopulations; includes enhanced returns after 1969.

$R_M = R_M^W + R_M^{FP}$

$R_L$ = late-timing run to the Babine River (wild)

$C = C_M = C_M^W + C_M^{FP}$ = all sockeye from the wild and Fulton-Pinkut components of the mid-timing run harvested at or above the Babine fence

$S_T = S_E + S_M + S_L$ = observed number of sockeye spawning in the early-, mid-, and late-timing runs

$S_T^W = S_E + S_M^W + S_L$ = observed number spawning in <u>wild</u> subpopulations

$S_M^{FP}$ = observed number spawning in the Fulton-Pinkut subpopulations
= visual estimate for years 1950-1965
= weir count + min{target, visual estimate} below fence for years 1966-1993

$S_V$ = total visual counts (excluding fence counts) of spawning escapements
= $S_T^W + S_M^{FP}$ before 1966
= $S_T^W$ from 1966 to present

Calculations to adjust escapement and run size estimates:

1) From 1950-1969:

$$\sim S_T^W = R_T - C \quad \text{(before 1966)}$$

$$= R_T - C - S_M^{FP} \quad \text{(from 1966-1969)}$$

$$= a + bS_V$$

and by least squares regression ($r=0.957$, $p<0.001$)
$a = 7855.645$, $b = 1.200$

2) For 1970-1993, excluding 1992:

$$\sim S_T^W = \min \left\{ \begin{array}{c} a + bS_V \\ R_T\text{-}C\text{-}S_M^{FP} \end{array} \right\}$$

3) $\sim S_E = \sim S_T^W \; (S_E/S_V)$

$\sim S_M^W = \sim S_T^W \; (S_M^W/S_V)$

$\sim S_L = \sim S_T^W \; (S_L/S_V)$

$\sim S_M^{FP} = \sim S_T^W \; (S_M^{FP}/S_V)$ (for years 1950-1965)

$= S_M^{FP}$ (for years 1966-1993)

4) For all years excluding 1992:

$P^{FP}$ = potential surplus

$= R_T - \tilde{S}_T - C_T$

$= c + d(\hat{P}^{FP})$

where $\hat{P}^{FP}$ is a rough visual estimate of surplus below fences in Fulton River and Pinkut Creek and
$c = 54164$ and $d = 1.568$ by least squares regression ($r=0.853$, $p<0.001$)

5) Then for 1992 where $R_T$ must be estimated:

$R_T = C + \tilde{S}_T^W + \tilde{S}_M^{FP} + \tilde{P}^{FP}$

where $S_T^W = a + bS_V$

$\tilde{S}_M^{FP} = S_M^{FP}$

$\tilde{P}^{FP} = c + d(\hat{P}^{FP})$

Appendix 3. Enhanced sockeye fry production (millions) from Fulton River and Pinkut Creek by brood year.

| | FULTON | | | | | | PINKUT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BROOD YEAR | ABOVE FENCE | BELOW FENCE | RIVER TOTAL | CHANNEL ONE | CHANNEL TWO | FULTON TOTAL | ABOVE FENCE | BELOW FENCE | RIVER TOTAL | CHANNEL | AIRLIFT | PINKUT TOTAL |
| 1966 | 24.0 | | 24.0 | 25.5 | | 49.5 | | | 3.7 | | | 3.7 |
| 1967 | 27.8 | 1.0 | 28.8 | 16.0 | | 44.8 | | | 2.7 | | | 2.7 |
| 1968 | 38.7 | 0.0 | 38.7 | 24.7 | | 63.4 | 1.4 | 0.5 | 1.9 | 10.4 | | 12.3 |
| 1969 | 11.2 | 0.0 | 11.2 | 5.9 | 25.4 | 42.5 | 1.3 | 0.5 | 1.8 | 15.2 | | 17.0 |
| 1970 | 34.9 | 4.0 | 38.9 | 13.4 | 37.3 | 89.6 | 3.0 | 0.3 | 3.3 | 22.0 | | 25.3 |
| 1971 | 27.4 | 3.6 | 31.0 | 20.0 | 82.2 | 133.2 | 2.0 | 0.2 | 2.2 | 16.7 | | 18.9 |
| 1972 | 33.4 | 0.0 | 33.4 | 23.2 | 69.9 | 126.5 | 2.8 | 0.2 | 3.0 | 29.0 | | 32.0 |
| 1973 | 27.5 | 0.0 | 27.5 | 15.0 | 75.0 | 117.5 | 2.7 | 0.4 | 3.1 | 24.1 | 6.0 | 33.2 |
| 1974 | 20.1 | 7.6 | 27.7 | 15.0 | 48.5 | 91.2 | 2.7 | 0.3 | 3.0 | 8.3 | 4.6 | 15.9 |
| 1975 | 31.9 | 9.9 | 41.8 | 12.7 | 68.6 | 123.1 | 1.8 | 0.8 | 2.6 | 22.3 | 6.6 | 31.5 |
| 1976 | 43.9 | 6.1 | 50.1 | 17.9 | 141.8 | 209.8 | 7.7 | 0.4 | 8.1 | | 10.9 | 19.0 |
| 1977 | 32.1 | 0.9 | 33.0 | 14.3 | 84.0 | 131.3 | 5.3 | 1.3 | 6.6 | 53.6 | | 60.2 |
| 1978 | 29.8 | 3.8 | 33.6 | 8.3 | 62.8 | 104.7 | 3.5 | 0.0 | 3.5 | 15.1 | | 18.6 |
| 1979 | 27.9 | 2.9 | 30.8 | 9.0 | 91.5 | 131.3 | 7.3 | 1.4 | 8.7 | 47.5 | 9.5 | 65.7 |
| 1980 | 28.4 | 3.9 | 32.3 | 8.0 | 68.4 | 108.7 | 10.0 | 0.8 | 10.8 | 42.2 | | 53.0 |
| 1981 | 46.0 | 18.5 | 64.5 | 12.3 | 53.3 | 130.1 | 6.1 | 1.9 | 8.0 | 57.7 | 21.6 | 87.3 |
| 1982 | 35.8 | 7.3 | 43.1 | 9.6 | 54.0 | 106.7 | 9.5 | 1.9 | 11.4 | 68.0 | 8.8 | 88.2 |
| 1983 | 37.4 | 1.2 | 38.6 | 5.9 | 14.0 | 58.5 | 6.3 | 1.3 | 7.6 | 49.9 | | 57.5 |
| 1984 | 39.4 | 1.9 | 41.3 | 9.3 | 99.9 | 150.5 | 12.8 | 1.5 | 14.3 | 46.6 | 8.7 | 69.6 |
| 1985 | 43.5 | 10.1 | 53.6 | 5.2 | 83.4 | 142.2 | 4.5 | 0.0 | 4.5 | 35.9 | 8.7 | 49.1 |
| 1986 | 38.1 | 2.2 | 40.3 | 7.6 | 96.9 | 144.8 | 11.9 | 2.5 | 14.4 | 44.7 | 15.4 | 74.4 |
| 1987 | 11.6 | 0.8 | 12.4 | 2.8 | 44.3 | 59.5 | 10.7 | 0.5 | 11.2 | 19.1 | 14.8 | 45.0 |
| 1988 | 19.5 | 7.4 | 26.9 | 4.4 | 121.6 | 152.9 | 5.3 | 0.7 | 6.0 | 25.5 | 12.5 | 44.0 |
| 1989 | 23.3 | 10.1 | 33.4 | 12.0 | 87.1 | 132.5 | 5.2 | 0.5 | 5.7 | 11.2 | 9.2 | 26.1 |
| 1990 | 34.0 | 9.8 | 43.8 | 15.8 | 118.7 | 178.3 | 13.9 | 0.5 | 14.4 | 45.1 | 2.6 | 62.0 |
| 1991 | 15.1 | 5.8 | 20.9 | 13.4 | 82.8 | 117.1 | 3.3 | 1.3 | 4.6 | 40.3 | 10.7 | 55.6 |
| 1992 | 26.8 | 7.5 | 34.3 | 4.6 | 91.5 | 130.4 | 4.7 | 1.3 | 6.0 | 62.5 | 16.2 | 84.8 |
| 1993 | 33.7 | 15.8 | 49.5 | 3.7 | 76.9 | 130.1 | 4.2 | 1.0 | 5.2 | 25.1 | 12.3 | 42.6 |