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# Babine Lake sockeye salmon: Stock status and forecasts for 1998 

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#### Abstract

The Babine-Nilkitkwa lake system is the largest natural lake in British Columbia ( $500 \mathrm{~km}^{2}$ ). It also supports the largest sockeye salmon population in Canada, a total adult stock that has averaged over 4 million annually since 1990 . This working paper provides a comprehensive assessment of sockeye production from the Babine-Nilkitkwa system in that it brings together, for the first time in many years, recently compiled information on trends in spawning escapements by run timing group, fry recruitment, smolt production, adult returns, harvest rate, and surplus production from Babine Lake Development Project (BLDP) facilities. Exploitation rate on Skeena River sockeye has increased over the last decade, averaging $68 \%$ since 1990, and exceeding $70 \%$ in 1996 and 1997. Recent escapements to enhanced sites in Babine Lake have exceeded spawning requirements such that over a third of the Babine fence count has been surplus produced by the BLDP. Enhanced fry now account for about $90 \%$ of fry recruitment to the main basin. As expected, increased fry and smolt production has increased adult returns although the relationship between adult returns and smolt abundance is non-linear. Available data indicate that further increases in adult returns could be expected by increasing smolt production, and that fry recruitment is still below levels required to yield maximum smolt biomass. However, prespawning mortality at the BLDP sites in 1994 and 1995 caused by parasitic infections has significantly reduced fry recruitment and smolt production. Near record low smolt production and jack returns from the 1993 brood, together with near record low smolt production and age 4 returns from the 1994 brood, provide clear signals that adult returns in 1998 and 1999 will be much lower than in recent years. The smolt forecast model indicates a $75 \%$ chance that adult returns to the Skeena River in 1998 will exceed 820,000 sockeye, and a $50 \%$ chance that returns will exceed $1,420,000$ sockeye.


## Résumé

Le bassin Babine-Nilkitkwa est le plus grand lac naturel de la Colombie-Britannique ( $500 \mathrm{~km}^{2}$ ). Il abrite la plus importante population de saumon rouge du Canada avec un stock d'adultes dont l'effectif annuel moyen est supérieur à 4 millions de poissons depuis 1990. Le présent document de travail constitue une évaluation détaillée de la production de saumon rouge du réseau Babine-Nilkitkwa et regroupe, pour la première fois depuis plusieurs années, des renseignements récemment compilés sur les tendances des échappées de géniteurs en fonction du moment des remontées, du recrutement d'alevins, de la production de saumoneaux, des remontées d'adultes, du taux de récolte et de la production excédentaire des installations du projet de mise en valeur du lac Babine. Le taux d'exploitation du saumon rouge de la rivière Skeena a augmenté au cours de la dernière décennie pour atteindre en moyenne $68 \%$ depuis 1990 et dépasser $70 \%$ en 1996 et 1997. Les échappées récentes vers les sites mis en valeur du lac Babine ont été supérieures aux besoins du frai de sorte que plus du tiers des poissons dénombrés à la barrière de comptage du lac étaient des excédents produits par les installations du projet. Des alevins des travaux de mise en valeur représentent maintenant $90 \%$ environ du recrutement en alevins du bassin principal. Comme prévu, l'augmentation de la production d'alevins et de saumoneaux a donné lieu à une augmentation des remontées d'adultes mais la relation entre les remontées d'adultes et l'abondance des saumoneaux n'est pas linéaire. Les données montrent que l'on peut escompter d'autres augmentations des remontées d'adultes d'une augmentation de la production de saumoneaux et que le recrutement d'alevins est encore inférieur au niveau donnant lieu à l'atteinte de la biomasse de saumoneaux maximale. Mais une mortalité d'avant le frai aux sites du projet en 1994 et 1995, due au parasitisme, a réduit de façon appréciable le recrutement en alevins et la production de saumoneaux. Les valeurs faibles presque records de la production de saumoneaux et du retour de saumons mâles des géniteurs de 1993 de même que de la production de saumoneaux et des retours de poissons d'âge 4 (géniteurs de 1994) sont des indices clairs que les remontées d'adultes de 1998 et 1999 seront de beaucoup inférieures à celles des années antérieures. Le modèle de prévision des saumoneaux fait état, pour 1998, d'une probabilité de $75 \%$ d'une remontée de saumons rouges supérieure à 820000 poissons et d'une probabilité de $50 \%$ d'une remontée supérieure à 1420000 saumons dans la Skeena.

## TABLE OF CONTENTS

1.0 INTRODUCTION ..... 3
2.0 METHODS ..... 4
2.1 DATA SOURCES ..... 4
2.1.1 Spawning Escapements .....  .4
2.1.2 Escapements By Run Timing Group .....  4
2.1.3 Fry Recruitment ..... 5
2.1.4 Smolt Production ..... 5
2.1.5 Adult Returns ..... 6
22 Forecasting models ..... 7
3.0 RESULTS AND DISCUSSION ..... 9
3.1 TRENDS IN ABUNDANCE ..... 9
3.1.1 Spawning Escapements ..... 9
3.1.2 Fry and Smolt Production ..... 9
3.1.3 Adult Returns ..... 10
3.2 PRODUCTIVITY ..... 11
3.2.1 Factors Limiting Fry Recruitment ..... 11
3.2.2 Factors Limiting Smolt Production ..... 12
3.2.3 Factors Affecting Smolt-to-Adult Survival ..... 13
3.3 Harvest Rate ..... 14
3.3.1 Trends in Harvest Rate Relative to Target ..... 14
3.3.2 Impact on Wild Skeena Sockeye salmon ..... 15
3.4 FORECASTS ..... 16
3.4.1 Forecast for 1998 ..... 16
3.4.2 Considerations for 1999 To 2001 ..... 16
4.0 CONCLUSIONS ..... 16
5.0 ACKNOWLEDGEMENTS ..... 18
6.0 REFERENCES ..... 18
7.0 FIGURES, TABLES AND APPENDICES ..... 21

### 1.0 INTRODUCTION

The Babine-Nilkitkwa lake system is the largest natural lake in British Columbia with a surface area of $500 \mathrm{~km}^{2}$ (Figure 1). It also supports the largest sockeye salmon population in Canada. The total stock is estimated to have averaged over 4 million adults annually since 1990.

The Fisheries Research Board of Canada began investigations of sockeye salmon in the Babine system in the 1940s and extensive data have been gathered to date (e.g., McDonald and Hume 1984 and references therein). Three distinct runs (early-, mid-, and late-timing) have been identified by tagging studies (Smith and Jordan 1973). We consider these runs to be subpopulations, rather than distinct populations, because they are connected by relatively high levels of gene flow as estimated from surveys of genetic variation in allozymes (Varnavskaya et al. 1994), mitochondrial DNA and microsatellite DNA (C.C. Wood, J.W. Bickham, and J.C. Patton, unpubl. data). Early investigations also revealed that sockeye salmon production from Babine Lake was limited by the availability of suitable spawning habitat (Johnson 1958). These conclusions led directly to the Babine Lake Development Project in the 1960s, an ambitious enhancement project involving the construction of flow control structures and large spawning channels in Pinkut Creek and Fulton River (West and Mason 1987).

Sockeye salmon production from Babine Lake increased significantly as a result of the Babine Lake Development Project (BLDP). At least $90 \%$ of Skeena sockeye salmon now originate from the Babine-Nilkitkwa system (West and Mason 1987; McKinnell and Rutherford 1994) compared with less than $80 \%$ prior to 1970 (Brett 1952). Unfortunately, the resulting mixture of enhanced and wild stocks in commercial fishing areas has created conflict among user groups and an awkward situation for managers who must choose between maximizing the catch of enhanced Babine sockeye salmon with concomitant loss of production from other wild, less productive stocks, or ensuring the conservation and continued production from non-enhanced sockeye salmon stocks and other salmonid species by foregoing harvest opportunities on enhanced sockeye salmon in the mixed-stock fishing areas. Sprout and Kadowaki (1987) provide an historical account of the management of Skeena River sockeye salmon fisheries.

Stock assessment of Babine sockeye salmon has been complicated by several factors: First, Babine sockeye salmon are harvested in numerous mixed-stock fisheries in Southeast Alaska and northern British Columbia, so that the total catch cannot be known with certainty. However, recently revised, best estimates of total Skeena River sockeye salmon returns based on a sophisticated run reconstruction analysis by Gazey and English (1996) are now available. 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 surplus production returning to the enhanced sites. In the past, puzzling discrepancies between the overall fence count and summed estimates of escapement to individual spawning sites were attributed to an uncensused "lake spawning" population. However, Wood et al. (1995) demonstrated that opportunities for lake spawning are extremely limited within Babine Lake; they also suggested a parsimonious approach for estimating the uncensused (surplus) production returning to the enhancement facilities after correcting visual escapement estimates for the early-, mid-, and late-timing runs for obvious bias.

Finally, annual smolt production from Babine Lake has been estimated since the 1950s, but interpretation of these data has been complicated by the existence of both early- and late-migrant smolts and by enhancement. Macdonald et al. (1987) analyzed smolt productior data for brood years 1959-1983, and Wood et al. (1995) compiled additional data for brood years 1984-1993.

This working paper provides a comprehensive assessment of sockeye salmon production from the Babine-Nilkitkwa lake system in that it brings together, for the first time: in raany years, recently compiled information on trends in spawning escapements, fry recruitrient, smolt production, adult returns, harvest rate, and surplus production from BLDP facilitiss. We use these data to assess whether the total production of smolts and adults from Babine Lake is close to the maximum level that can be expected, and whether current management targets and policy have had any undesirable impacts on wild sockeye salmon production within Babine Lake. We also derive forecasts expressed as cumulative probability distributions for adult sockeye salmon returns to the Skeena River in 1998. Prespawning mortality at the BLDP sites in 1994 and 1995 caused by parasitic infections, and abnormally low fry-to-smolt survival, have significantly reduced fry recruitment and smolt production for brood years 1993-1995. Consequently, we are advising that adult returns may decline dramatically until the year 2001.

### 2.0 METHODS

### 2.1 DATA SOURCES

### 2.1.1 Spawning Escapements

Since 1949, all sockeye salmon returning to Babine Lake have been counted at the Babine River fence situated 1 km below the outlet of Nilkitkwa Lake. Escapement data in Appendix 1 are from the Area 4 spreadsheet tables maintained by DFO staff in Prince Rupert (file: 4esc.xls). Entries are generally consistent with data in the regional Salmon Escapement Database System but they allow for finer spatial resolution of spawning sites. Visual estimates of sockeye salmon 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 Pi:kut 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.

### 2.1.2 Escapements By Run Timing Group

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" (Appendix 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 fac:, recent studies
indicate that lake spawning accounts for a negligible proportion of the uncounted escapement (see Wood et al. 1995).
'The visual estimates of "surplus" enhanced fish shut below fences in the Fulton and Pinkut systems 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. Wood et al. (1995) used a simple but parsimonious algorithm to correct estimates of escapement to unenhanced streams, grouped according to their run timing as early-, mid-, or late-timing streams, and considered that any remaining uncounted fish were surplus enhanced fish. We followed this approach to update the adjusted escapement data series in Wood et al. (1995).

## 2:1.3 Fry Recruitment

Following McDonald and Hume (1984) and Wood et al. (1995), we assumed that an average of 233 fry were produced by each sockeye salmon 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, Habitat and Enhancement Branch staff have enumerated sockeye salmon fry originating from spawning sites above the adult counting fences in Fulton River and Pinkut Creek 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 by dividing the estimate of fry production by an estimate of potential egg deposition based on adult counts, sex ratio, fecundity and egg retention data (D. Bailey unpubl. data).

Fry production from spawning sites below the adult counting fences was estimated very approximately from visual estimates of the number of spawners below the fence (Appendix 2) and sex ratio, fecundity and egg retention data, and egg-to-fry survival rates observed for fish spawning upstream of the fences. However, spawning habitat below the fences was considered sufficient for successful spawning by a maximum of only 50,000 spawners in Fulton River and 5,000 spawners in Pinkut Creek; additional spawners were assumed to produce no additional fry because of overcrowding and superimposition of redds, and thus were considered surplus (as in Wood et al. 1995).

### 2.1.4 Smolt Production

Smolt migrations out of Babine Lake have been sampled and enumerated by markrecapture near the outlet of Nilkitkwa Lake annually since 1951 except for 1989 when the program was not funded. We recomputed mark-recapture estimates of abundance data (with estimates of variance) using a new (1996) implementation of the parsimonious model of Macdonald and Smith (1980) provided by P.D.M. Macdonald (Department of Mathematics and Statistics, McMaster

University, Hamilton, Ont., L8S 4K1). The smolt estimate for the 1984 brood year was excluded from our analyses because the parsimonious model did not fit the mark-recapture data adequately, suggesting that assumptions of the analysis were inappropriate; smolt estimaties based on the conventional "constant sampling fraction" model which makes different (but also questionable) assumptions are presented in Table 2, but not used. In addition, the smolt estimate for the 1995 brood year should be regarded as a minimum estimate because flooding conditions in 1597 required that the mark-recapture program be aborted before the normal termination date, although after the normal date of peak migration.

Smolt size data for brood years 1959 to 1983 were taken from Macdonald e: al. (1987). Smolt data for brood years 1949-1959 are from the unpublished records of H.D. Smith (available from 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 baseci on "he constant sampling fraction model (see Macdonald and Smith 1980).

Tagging studies have confirmed that fry originating from the Upper and Lcwer Babine rivers and a few small tributaries to Nilkitkwa Lake and the North Arm of Fabine Lake rear primarily within Nilkitkwa Lake and the North Arm; these juveniles emigrate a; "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. The parsimonious model estimates a transition day that best separates the early and late smolt migrations based on observed differences in the time lag; between release and recapture. In years when distinct modes in abundance are evident for th.e early and late migrants, the transition day can also be obtained by inspection (see Figure 2). Howevar, estimates from the parsimonious model almost invariably concur with those based or trends in daily abundance, and are considered to be more objective and precise. Estimates of transition day only affect conclusions about the relative magnitude of the early- and late-migran: sutpopulations. Estimates of the early-migrant subpopulation are considered to be less reliable than for the latemigrant subpopulation because in some years it was obvious that an unknow., bet significant proportion of the early migrants had migrated before the mark-recapture program begarı.

Following Wood et al. (1995), we assumed that early-migrant smolts originated only from late-timing adults spawning in the Upper and Lower Babine rivers, thus ignoring the minor contributions of smolts from early-timing adults spawning in tributaries to Nilkit.cwa $\because$ ake and the North Arm. Similarly, we assumed that late-migrant smolts originated only from the early-timing and mid-timing adults whose fry rear in the main basin of Babine Lake (including Monison Arm).

### 2.1.5 Adult Returns

Skeena River sockeye salmon are caught in a complex array of mixed-stock fisheries in southern Southeast Alaska and throughout northern British Columbia. Catch data by major stock have recently been revised for 1970-1996 based on run reconstructions by Gazey and English (1996) for 1982-1992 and stock composition estimates for 1982-1983 from a :oint Canada-U.S. tagging study. Despite the many assumptions involved, the revised estimates of total :eturns to the

Skeena River are probably satisfactory for most assessment purposes, given that Skeena sockeye salmon are predominant in the mixed-stock catches. In this report, we have used the revised total stock (by calendar year) and total return (by brood year) data reported by Wood et al. (1997) for years 1970-1996. We extended the time series of returns by brood year back to 1950 by including estimates of returns from brood years 1950-1969 reported by Macdonald et al. (1987). The estimates prior to 1970 do not include Alaskan catches, but these were relatively small.

To estimate adult returns to Babine Lake, we have assumed that $90 \%$ of all age 1.2 and 1.3 Skeena sockeye salmon originated from Babine Lake. This approximation is based on data in McKinnell and Rutherford (1994) and probably overestimates Babine returns prior to 1970; it may also underestimate Babine returns in some years after 1970. Age 1.1 or "jack" sockeye salmon are not caught to any significant extent in fisheries until after they are enumerated at the Babine fence. Thus, we used the Babine fence count of jack sockeye salmon as the best estimate of age 1.1 returns to Babine Lake (see Appendices 3 and 4). Elsewhere the Babine fence count of jacks is reported as the (minimum) estimate of age 1.1 returns to the entire Skeena system (e.g., Wood et al. 1997).

### 2.2 Forecasting models

Three models were used to forecast Skeena sockeye salmon returns in 1998:
(1) the 5 -yr mean model used in previous years (Wood et al. 1997)

$$
\ln \left(\mathrm{N}_{1998}\right)=\mathrm{a}=\sum \ln \left(\mathrm{N}_{\mathrm{i}}\right) / 5 \quad \text { for } \mathrm{i}=1993 \text { to } 1997
$$

where $N_{i}$ is the total stock size in year $i$;
(2) a non-linear stock-recruitment relationship based on observed smolt production

$$
\ln \left(\mathrm{R}_{\mathrm{J}}\right)=\mathrm{a}+\mathrm{bln}\left(\mathrm{~J}_{\mathrm{V}}\right)+\varepsilon
$$

where $R_{t}$ is the adult return and $J_{t}$ is the smolt abundance for brood year $t$. Parameter estimates based on the entire data series are $a=5.615$ and $b=0.502$ for $R_{t}$ and $J_{t}$ in millions of fish..
(3) and a non-linear sibling age-class model (Bocking and Peterman 1988) based on observed returns of a younger age class from the same brood year

$$
\ln \left(R_{t, k+1}\right)=a+b \ln \left(R_{t, k}\right)+\varepsilon
$$

where $R_{\mathrm{L}, \mathrm{k}}$ is the adult return at age k in brood year t . Parameter estimates based on the entire data series are $a=5.617$ and $b=0.691$ for predicting $R_{1994,4}$ and $a=5.785$ and $b=0.599$ for predicting $\mathrm{R}_{1993,5}$ (in millions of fish).

Probability distributions for the forecasts were computed by assuming tha: residuals in the log-transformed domain are normally distributed. Forecasted run sizes corresponding to risk averse probability reference points of $75 \%$ and $50 \%$ were then transformed back to the arithnetic scale. The modal (most likely) run size in the log-transformed domain corresponds to the median (50\%) value in the original (arithmetic) scale. Cumulative probability distribution plots were generated from the student's $t$ distribution function (tcf) in SYSTAT using estimated méns and standard deviations in the log-transformed domain. For the 5 -yr mean model, the standard deviation was computed from the series used to compute the forecasts (i.e., the most recent five years). For the regression models, means and standard deviations for the forecasted log-transformed stock sizes were computed as:

$$
\begin{equation*}
\mathrm{E}\left[\ln \left(\mathrm{R}_{\mathrm{v}}\right)\right]=\mathrm{a}+\mathrm{b} \mathrm{X}_{1998} \tag{4}
\end{equation*}
$$

$$
\begin{equation*}
\mathrm{SD}\left[\ln \left(\mathrm{R}_{\mathrm{t}}\right)\right]=\mathrm{s}_{\mathrm{y} . \mathrm{x}}\left\{1+1 / \mathrm{n}+\left(\mathrm{X}_{1997}-\mathrm{X}_{\text {mean }}\right)^{2} / \sum\left(\mathrm{X}_{\mathrm{i}}-\mathrm{X}_{\text {mean },}^{r^{\prime}}\right\}^{2}\right\}^{0.5} \tag{5}
\end{equation*}
$$

where $a$ and $b$ are the regression parameters, $\mathrm{s}_{\mathrm{y} . \mathrm{x}}$ is the standard error of the estimate, $\mathrm{X}_{1998}$ is the independent variable (number of smolts or returns for a sibling age class for the b:ood returning in 1998), $X_{\text {mean }}$ is the average value of the independent variable, and $n$ is the number of data points in the regression (Draper and Smith, 1966).

For models (2) and (3), we computed total stock size for 1998 by combiaing forecasts of returns from the 1993 and 1994 brood years. For the smolt model, we assumed the long-term average proportion of returns at age $4\left(\mathrm{q}_{4}=0.45\right)$ within each forecasted brood year, so that $\mathrm{N}_{1998}=$ $\mathrm{q}_{4} \mathrm{R}_{1994}+\left(1-\mathrm{q}_{4}\right) \mathrm{R}_{1993}$. As a simple but conservative approximation, igncring bias from transformation, we assumed

$$
\begin{align*}
& \mathrm{E}\left[\ln \left(\mathrm{~N}_{1998}\right)\right] \approx \ln \left\{\mathrm{q}_{4} \exp \left(\mathrm{E}\left[\mathrm{R}_{1994}\right]\right)+\left(1-\mathrm{q}_{4}\right) \exp \left(\mathrm{E}\left[\mathrm{R}_{1993}\right]\right)\right\}  \tag{4}\\
& \mathrm{SD}\left[\ln \left(\mathrm{~N}_{1998}\right)\right] \approx \max \left\{\mathrm{SD}\left[\ln \left(\mathrm{R}_{1994}\right), \mathrm{SD}\left[\ln \left(\mathrm{R}_{1993}\right)\right]\right\}\right. \tag{5}
\end{align*}
$$

The latter assumption seems reasonable because the forecasted contributions from each brood year are very similar.

For the sibling model, $\mathrm{N}_{1998}=\mathrm{R}_{1994,4}+\mathrm{R}_{1993,5}$ and we assumed

$$
\begin{align*}
& \mathrm{E}\left[\ln \left(\mathrm{~N}_{1998}\right)\right] \approx \ln \left\{\exp \left(\mathrm{E}\left[\mathrm{R}_{1994,4}\right]\right)+\exp \left(\mathrm{E}\left[\mathrm{R}_{1993,5}\right]\right)\right\}  \tag{6}\\
& \mathrm{SD}\left[\ln \left(\mathrm{~N}_{1998}\right)\right] \approx \mathrm{SD}\left[\ln \left(\mathrm{R}_{1993}\right)\right] \tag{7}
\end{align*}
$$

because the forecasted contributions from the 1993 brood year accounted for over $90 \%$ of $\mathrm{N}_{1998}$.

### 3.0 RESULTS AND DISCUSSION

### 3.1 Trends in Abundance

### 3.1.1 Spaẅning Escapements

Spawning escapements to Fulton River and Pinkut Creek increased dramatically following the first significant return of enhanced sockeye salmon in 1970 (Figure 3). Escapements exceeded requirements for the first time in 1975 in Fulton River and in 1981 in Pinkut Creek (Appendix 1). These fish are considered surplus under the assumption that they cannot contribute to fry production given the overcrowded conditions in the streams below the fences and the limited occurrence and poor reproductive success of surplus fish spawning in Babine Lake or neighbouring streams (see Wood et al. 1995). Since 1981, surpluses have returned to Pinkut Creek in every year except 1983, and to Fulton River in 10 of 16 years. Best estimates of total enhanced surplus over the same period have averaged $46 \%$ (range $31-63 \%$ ) of the total enhanced run counted through the Babine fence or $36 \%$ (range $24-55 \%$ ) of the total fence count (Table 1).

Total escapements to unenhanced spawning sites declined between 1970 and 1985 but have since rebuilt to their former abundance. However, trends differ among run timing groups (Figure 3). The early-timing run appears to have declined since exploitation of BLDP returns began in 1970; although average escapements are not statistically different before and after enhancement ( $p>0.36$, Wilcoxin-Mann-Whitney test). In contrast, the unenhanced component of the mid-timing run decreased significantly after 1970 ( $p<0.003$ ) and has not recovered since 1985 ( $p>0.77$ ). The relatively large late-timing run drives the total pattern and appears to have declined between 1970 and 1985, and to have increased slightly thereafter (Figure 3); however, average escapements in these three periods (pre-1970, 1970-1985, and 1986-1987) were not statistically different ( $\mathrm{p}=0.39$ ) because of high variability in escapements during the first and last period.

### 3.1.2 Fry and Smolt Production

Main Basin: Average fry recruitment to the main basin has increased over threefold following enhancement, from an average of 55.1 million ( $1260 \mathrm{fry} / \mathrm{ha}$ ) to an average of 172.3 million fish ( 3940 fry/ha) (Table 2, Figure 4). Smolts from the main basin showed a corresponding increase in average abundance from 19.6 million ( 449 smolts/ha) to 72.4 million ( 1660 smolts/ha) annually (Figure 5). Smolt production from the main basin in 1994 (1992 brood year) set a new record at 188.7 million ( $\mathrm{SE}=8.8$ million, 4320 smolts/ha). Wood et al. (1995) suspected that this estimate was biased high because it implied "an improbable emergent fry-to-smolt survival rate of $83 \%$, 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, pers. comm.)". However, this brood year has subsequently produced record numbers of adults within each age class. In retrospect, it appears that the estimates of fry abundance for the 1992 brood were likely too low.

The BLDP has accounted for the vast majority of fry recruitment to the main basin of Babine Lake (mean $=89 \%$, range $=63-98 \%$ ) and most from the entire Babine-Nilkitkwa system ( mean $=67 \%$, range $=33-85 \%$ ). Infection by the "ich" parasite (white spot disease) caused high
prespawning mortality at both enhancement sites in 1994 and 1995 (Traxler et al. in press). As a result, BLDP fry production from the 1994 and 1995 broods was $<60 \%$ of the 1984-93 average. Observations in 1994 also confirmed the presence of the parasite in other locations within the watershed (Morrison River, Pierre Creek and Babine River). Consistent with these observations, total smolt production from the 1994 and 1995 brood years has fallen to the lowest level observed since production from the BLDP began ( $<20$ million). The parasite was present during spawning in 1996, but at low levels, and fry recruitment from the BLDP returned to above average levels. However, moderate levels of parasite-induced prespawning mortality w'ere again reported at both enhancement sites in 1997, so that fry production is expected to te 20-30\% below target levels (M. Higgins and M. Kent, DFO, Pacific Biological Station, urpubl. report).

It is important to recognize, however, that prespawning mortality cannot have been solely responsible for the recent decline in smolt production. Smolt production was unusually low for the 1993 brood year before any prespawning mortality due to ich infection had been observed. Moreover, fry-to-smolt survival, estimated after prespawning mortality, has been below average and declining since the 1993 brood year (Table 2). These facts suggest that some othet agent of mortality may also be responsible. IHN disease has been detected at low titres in sockeye salmon fry from the BLDP facilities in some years, including the recent years of poor survival (G. Traxler DFO, Pacific Biological Station, unpubl. data). However, it is not known whether the IHN virus poses a threat to wild juvenile sockeye salmon when present at such low titres.

Nilkitkwa Lake: Prior to brood year 1966, over $35 \%$ of sockeye salmon smolt prciduction from the Babine system were early-migrant smolts, attributed to Nilkitkwa Lake and the no:th arm of Babine Lake (Table 3). Early-migrant smolt production has declined dramatically from an average of 11.9 million smolts from brood years prior to 1970, the year enhanced returns were first exploited, to an average of only 2.7 million during the most recent decade (brood years 1985-1994) (p<0.001, Figure 6). This trend generally follows the trend of decreasing escapements to the Upper and Lower Babine River over the same period, except that the unusually large spawning escapements recorded in brood years 1985, 1992 and 1793 apparently failed to produce commensurate numbers of smolts (see Figure 7 and discussion in the next section).

### 3.1.3 Adult Returns

Adult returns to Babine Lake averaged 1.0 million sockeye salmon per brood year before 1966 (the first enhanced brood), and 2.7 million thereafter. In fact, adult returns have increased more or less steadily such that adult returns from the last five complete brood years (1988-1992) have averaged 4.3 million of which $86 \%$ is attributable to the BLDP (Figure 8). Adult returns for the most recent complete brood (1992) set a new record at 6.08 million (Table 3).

### 3.2 Productivity

### 3.2.1 Factors Limiting Fry Recruitment

Egg-to-fry survival and overall incubation capacity at the enhanced sites are the main factors affecting fry recruitment from the BLDP sites and the entire Babine system. BLDP fry have accounted for as much as $98 \%$ of the estimated fry recruitment to the main basin, and $85 \%$ of the estimated fry recruitment to the entire Babine-Nilkitkwa system. Egg-to-fry survival at the two major BLDP spawning channels has averaged about $50 \%$ in normal (disease-free) years, although it has varied by an order of magnitude from $7-76 \%$ in the large Fulton spawning channel, and $9-83 \%$ in the Pinkut channel. At present, parasitic infections causing prespawning mortality, and the unidentified factor causing abnormally low fry-to-smolt survival, have emerged as potentially serious limitations to future fry production from BLDP. Further research is recommended to determine how these sources of mortality may be ameliorated as soon as possible.

Recent surveys were undertaken (with Skeena Green Plan funding) to assess the feasibility of enhancing Morrison River sockeye salmon, both to increase fry recruitment to Morrison Arm, and to increase the productivity of the run to ensure its conservation while permitting increased harvest rates on Pinkut-Fulton sockeye salmon with the same run-timing. The surveys confirmed that fry densities are typically lower in Morrison Arm than in the main basin of Babine Lake (K. Shortreed and J. Hume, Cultus Lake Laboratory, Science Branch, unpubl. data), despite unused and apparently suitable spawning habitat in the Morrison River and its tributaries (D. Lofthouse, DFO, Vancouver, pers. comm.). This suggests that wild spawning escapements to the Morrison River system currently limit, and given selective fisheries on midtiming sockeye salmon, will likely continue to limit fry recruitment to Morrison Arm. No decision regarding enhancement has been made for the Morrison system, and current activities focus on improving opportunities for wild spawning through beaver dam control.

Spawning escapements to the Upper and Lower Babine rivers appear to be limiting fry recruitment to Nilkitkwa Lake. Late-timing escapements and early-migrant smolt abundances remain below average levels recorded before 1970. This implies that current escapements are not adequate to fully seed Nilkitkwa Lake, assuming that the quality of incubation or rearing habitat has not changed. However, the poor levels of early-migrant smolt production resulting from apparently very large late-timing escapements in brood years 1985, 1992, and 1993 is puzzling because it appears inconsistent with previous levels of smolt production from moderate to high escapements (Figure 7). The early-migrant smolt migration was seriously underestimated for the 1991 brood because of unusually early migration in 1993, so this estimate was omitted from Figure 7. However, nothing abnormal was reported for the smolt enumeration of brood years 1985, 1992, and 1993. We are uncertain whether to attribute the discrepancy to errors in fitting transition dates to separate the early- and late-migrant smolts, unreliable escapement estimates, prespawning mortality at high density, or unusually poor egg-to-smolt survival. This uncertainty can only be resolved by research to assess potential egg deposition and subsequent fry-to-smolt survival.

### 3.2.2 Factors Limiting Smolt Production

Increased fry recruitment from the BLDP has not caused a detectable red action in fry-tosmolt survival in the main basin of Babine Lake. Calculated emergent fry-to-smolt survival has been highly variable but without trend, and it is uncorrelated with fry density (Fig are 9). The high variation in calculated survival is at least partly due to imprecision in the estimates of fry and smolt abundance as evidenced by several years of unbelievably high survival (e.g., $>100 \%$ for brood year 1962, and $>80 \%$ for brood years 1979 and 1992). Even after excluding these imorobable values, fry-to-smolt survival in the main basin appears to have increased following enharcement 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 (aere and in previous reports, McDonald and Hume 1984; Macdonald et al. 1987). Record high adult returns from the 1992 brood also suggest that the smolt abundance estimate for that year was more reliable than the fry recruitment estimate.

Smolts emigrating from Babine Lake are predominantly ( $>98 \%$ ) yearlings (Mc.Donald and Hume 1984). Until recently the trend of increasing juvenile density in the main basin was associated with a steady decrease in average smolt size (Figure 10) because smolt size is: negatively correlated both with fry (Figure 11) and smolt (Figure 12) abundance for the corresponiding 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 , This is still large in comparison to other productive, interior sockeye salmon lakes such as Shuswap Lake where smolts average $<3.5 \mathrm{~g}$ on the dominant year cycle (Hume et al. 1995).

Smolt weights achieved in the last four years exceed, or are among the highest of those observed at comparable fry recruitments (or smolt densities) in any previous years. These observations are compelling given that recent smolt densities span the entire range of historical values and they suggest that Babine Lake has become more productive. T.is inference is corroborated by direct measurements of primary productivity (PR) which was estimated at 111.5 $\mathrm{mg} \mathrm{C} \mathrm{m}^{-2} \mathrm{~d}^{-1}$ in 1973 compared with $132.8 \mathrm{mg} \mathrm{C} \mathrm{m}^{-2} \mathrm{~d}^{-1}$ in 1994 and $144 \mathrm{mg} \mathrm{C} \mathrm{m}^{-2} \mathrm{~d}^{-1}$ in $1995(\mathrm{~K}$. Shortreed and J. Hume, DFO, Cultus Lake Laboratory, unpubl. data). Increased nutrient loading from the large surplus escapements in recent years may be responsible for this increase in primary productivity (see Schmidt et al. in press).

In any case, it is obvious that maximum smolt biomass has not yet been achievel within the range of fry recruitments achieved to date (Figures 11 and 12). The predicted maximum smolt biomass for the main basin of Babine Lake based on PR values for 1994-95 ar.d a PR-sockeye salmon production model calibrated to empirical data for Alaskan sockeye salmen lakes was just under $600,000 \mathrm{~kg}$ or about $120,000,000$ smolts. This is close to actual production levels that have been sustained over the last two decades. The comparison provides further evidence that the PR model as calibrated to Alaskan sockeye salmon lakes underestimates the production potential of interior Canadian lakes (see Shortreed et al. 1997).

### 3.2.3 Factors Affecting Smolt-to-Adult Survival

Smolt-to-adult survival has averaged $3.8 \%$ since smolt enumeration began in brood year 1959 but has varied considerably from year to year (range $0.8-8.1 \%$ ), especially when smolt abundance was high (Figure 13). Returns from the 1992 brood were 4.2 times greater than those from the 1979 brood year, even though similar (record high) numbers of smolts were counted past the Babine fence. The 1979 brood set the record for poor survival at $0.8 \%$ whereas the 1992 brood survived just slightly below the long-term average at $3.1 \%$. Overall, the relationship between adult returns to Babine Lake $\left(\mathrm{R}_{\downarrow}\right)$ and total Babine smolt abundance $\left(\mathrm{J}_{\mathrm{t}}\right)$ is non-linear:

$$
\begin{equation*}
\ln \left(\mathrm{R}_{\mathrm{V}}\right)=5.87+0.481 \ln \left(\mathrm{~J}_{\mathrm{t}}\right) \tag{8}
\end{equation*}
$$

$$
\mathrm{r}^{2}=0.28, \mathrm{p}<0.002
$$

It seems possible that the density-dependence in equation (8) is associated with competition in freshwater that affects smolt size. Smolts from the 1992 brood were 20\% heavier than those from the 1979 brood. However, in general, smolt size is very poorly correlated with smolt-to-adult survival ( $p>0.08$, Figure 14). Similarly, the proportion of smolts returning as jacks (age 1.1 ) is only weakly positively correlated with smolt weight ( $p<0.03$, Figure 14).

In previous analyses, Peterman (1982) and McDonald and Hume (1984) pointed out that smolts survived better, on average, in odd years than in even years. Peterman (1982) and Ricker (1982) explored several possible explanations involving negative interactions with pink salmon which were then typically more abundant in even years in northern B.C. This relationship is no longer evident in time series of residuals from the common relationship fitted to all years (Figure 15). Brood years 1979 and 1992 are extreme examples where the even-odd year pattern of previous years no longer holds. However, it should be noted that since 1979, odd-year pink salmon have become more abundant than even-year pink salmon in the Skeena River. In fact, pink salmon abundance ( PS$)_{\nu}$ ) is a statistically-significant variable in the following regression:

$$
\text { (9) } \ln \left(\mathrm{R}_{\mathrm{t}}\right)=1.457+0.478 \ln \left(\mathrm{~J}_{\mathrm{t}}\right)+0.321 \ln \left(\mathrm{PS}_{\mathrm{t}}\right)
$$

Note that the coefficient for the pink salmon term is positive, and thus at odds with Peterman's original (1982) hypothesis. More likely, common environmental conditions have favoured the survival of both sockeye salmon and pink salmon in the Skeena River. Sockeye salmon smolt size was excluded from equation (9) by a step-wise fitting procedure because it had no statistically significant effect ( $p>0.15$ ).

To look for evidence that sockeye salmon smolt-to-adult survival has changed systematically over time, we used "regime" as a categorical variable. Following the hypothesis of Welch et al. (1997), we defined regime $=1$ for sea entry years 1952-1976 (brood years 1950-1974), 2 for sea-entry years 1977-1989 (brood years 1975-1987), and 3 for sea-entry years 1990-1994 (brood years 1988-1992). Smolt-to-adult survival (i.e., $\mathrm{R}_{\mathrm{t}} / \mathrm{J}_{\mathrm{t}}$ ) was not statistically different between regimes ( $p>0.75$, Wilcoxin-Mann-Whitney test). However, regime was statistically significant ( $\mathrm{p}<0.02$ ) as a categorical variable in the regression of $\ln \left(\mathrm{R}_{\mathrm{V}}\right)$ on $\ln \left(\mathrm{J}_{4}\right)$, primarily because of the strong positive residuals during the last three brood years. Pink salmon abundance was no longer significant as an independent variable if regime was included in the analysis, supporting our speculation that the correlation between sockeye salmon and pink salmon arises indirectly through
another shared effect here labelled regime. A deficiency of this analysis is that smolt abundance has generally increased over time, and is thus somewhat confounded with regime. However, smolt abundance declined to near record low levels in brood years 1993-96. Adult retums over the next few years will provide important data for testing our assumptions about the relative magnitude of density-dependent versus climatic effects on smolt-to-adult survival.

In conclusion, we attribute the record returns from the 1992 brood year rimarily to the record level of freshwater production. In addition, smolts from the 1992 brood, and cther recent brood years, experienced higher smolt-to-adult survival than would typically be expec:ed at such high smolt densities. This is the same as stating that competition between smolts has been relaxed in recent years. The regression of $\ln \left(\mathrm{R}_{\nu}\right)$ on $\ln \left(\mathrm{J}_{\mathrm{J}}\right)$ using data for all years (see Figr re $\left.1: 3\right)$ indicates that, on average, and particularly under recent conditions, increased adult returns san te expected from increased smolt production. Thus, efforts to maximize smolt production in Eabine Lake and other Skeena lakes are warranted if the goal is to increase adult returns. However, the climinishing returns associated with density-dependent survival will affect the cost-effectiveness of such efforts.

### 3.3 Harvest Rate

### 3.3.1 Trends in Harvest Rate Relative to Target

Prior to 1983, Skeena sockeye salmon were managed to a fixed escapemer.t target of $1,003,976$ sockeye salmon for Babine sub-area and $1,163,111$ sockeye salmon for the entire Skeena system. Between 1983 and 1993, additional restrictions were placed on the timing of fishing effort in response to concerns about the status of steelhead trout and coho salmon. Actial eicapements and exploitation rates are plotted in comparison to the Skeena target in Figure 16. In practice, the management appears to have been a compromise between a fixed escapement policy and a fixed harvest rate policy. Since 1994, the official management policy has been based on en inseason model of abundance that implies a variable exploitation rate policy (D. Peacock, DFO, Prince Rupert, pers. comm.).

Both total catch and exploitation rate on Skeena River sockeye salmon have increased over the last decade (Figure 17). Total exploitation rate for the entire Skeena sockeye salmon run (including Alaskan catches) has averaged $68 \%$ since 1990 and exceeded $70 \%$ in 1996 and 1997 (preliminary). No reliable data are available to compute exploitation rates for the l3abirie and nonBabine runs separately. However, managers use an in-season management model based on differences in run-timing to direct commercial fishing effort towards the mostly enhenced, midtiming Babine run. The percentage of the total catch (excluding jacks) taken in terruinal fisheries at or above the Babine fence has also increased from $1.6 \%$ before 1990 , to $5.4 \%$ in the last three years. Thus, harvest rates on unenhanced Skeena sockeye salmon may have been considerably lower than the total exploitation rate.

The escapement target for Babine Lake cannot be based on conventional considerations of stock productivity because adult returns to Babine Lake originate from both wild and enhanced sites with very different productivities. The total escapement required to maximize prod'uction from the BLDP is less than 500,000 spawners, and yet in normal (disease-free) years the BLD)P accounts
for about $90 \%$ of the fry recruitment to the main basin. In contrast, an escapement of about 300,000 late-timing spawners to the Upper and Lower Babine rivers appears necessary to fully seed Nilkitkwa Lake (Figure 7). Any escapement target chosen for the aggregate of early-, mid-, and late-timing subpopulations reflects a deliberate trade-off between maximizing harvestable surplus and maintaining adequate levels of production from the diversity of unenhanced sites.

### 3.3.2 Impact on Wild Skeena Sockeye salmon

Escapements to non-Babine sockeye salmon populations have been increasing, despite the sustained high harvest rates on the Skeena run as a whole (Figure 18). Presumably this is a direct result of continuing efforts to harvest the mid-timing Babine sockeye salmon as selectively as possible. Even so, recent analyses of limnological and spawning ground survey data for other (nonBabine) Skeena lakes indicate that in most cases, these escapements are much too low if the objective is to fully utilize lake rearing habitat, and maximize smolt production (Shortreed et al. 1997).

Within Babine Lake, escapements to the unenhanced streams began to decline shortly after the first enhanced sockeye salmon returned which suggests that increased exploitation rates on enhanced returns caused the decline (Wood et al. 1995). 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, have not. Since 1985, the wild mid-timing escapements have averaged less than half of pre-enhancement levels. Similarly, since 1985, smolt production from the late-timing runs (Nilkitkwa Lake) has averaged less than a quarter of levels observed before exploitation of enhanced returns began in 1970.

Analyses in this and a companion working paper (Shortreed et al. 1997) provide compelling evidence that the Skeena River system has the lake rearing capacity to produce significantly larger adult returns than realized to date. The enhancement techniques required to harness this potential are already well developed -- some were pioneered in the Skeena system. However, from the perspective of biological production and conservation, the present pattern of utilization, with most fish being harvested in mixed-stock fisheries in Alaska and northern British Columbia is a poor compromise between the dual objectives of maximizing catch from a single productive stock (enhanced Babine sockeye salmon) and conserving the diversity of less productive salmon populations. The result is that over the last ten years, an average of over half a million enhanced sockeye salmon surplus to escapement goals has gone unharvested annually, whereas unenhanced Skeena sockeye salmon populations have been maintained at the lowest levels deemed acceptable. Managers appear to have done a commendable job in achieving these goals considering the complex and irrational nature of this policy.

### 3.4 FORECASTS

### 3.4.1 Forecast for 1998

Forecasts of Skeena River sockeye salmon returns in 1998 are summarized n Figures 19-21 based on three alternative models. As expected, the 5 -yr mean forecast used ir. previous years predicts continued above average adult returns. The $5-\mathrm{yr}$ mean model has performed as well or better than other models under typical situations because variation in the independent variables used by other models has been small, and their effects have been obscured by other factors. In the present case, the independent variables in the alternative models are at or near the extrene low end of their historical ranges. Therefore, we recommend that the 5 -yr mean model be rejected in favour of the smolt and sibling age-class models that utilize our knowledge of the alarmingly poor smolt production, and returns at age 3 and age 4 from the 1993 and 1994 brood years. Moreover, because forecasts from the smolt and sibling models are lower than from the $5-\mathrm{yr}$ mean model, their use is more consistent with the precautionary principle.

The smolt and sibling models produce almost identical forecasts for 1998 with a $75 \%$ chance that adult returns to the Skeena River will exceed 820 thousand sockeye sa mon, and a $50 \%$ chance that returns will exceed either 1.22 million sockeye salmon (sibling model) or 1.42 million sockeye salmon (smolt model). The congruence of these models provides a clear signal that adult returns in 1998 will be much lower than in recent years.

### 3.4.2 Considerations for 1999 To 2001

Because smolt production has continued to decline to 1997, forecasts for 1999 and 2000 based on the smolt model will be even lower than for 1998. Forecasts from the sibling; age class models cannot be generated more than one year in advance. It is imperative that the smolt migration be enumerated in 1998 because continued low smolt abundance in 1998 would indicate that prespawning mortality is not the principal factor causing reduced smolt production from Babine Lake.

Fry recruitment to Babine Lake returned to normal levels last spring, and it is hoped that smolt production will return to normal in 1998 (the 1996 brood year). Unfortunately, both Pinkut Creek and Fulton River facilities experienced a moderate level of parasite-induced prespawning mortality in 1997, and fry production is expected to be $20-30 \%$ below target levels. Until the sporadic problems arising from parasite infection can be addressed, the prognosis for future fry recruitment remains uncertain.

### 4.0 CONCLUSIONS

1. Escapements within Babine Lake: Escapements to enhanced sites in Babine Lake continue to exceed spawning requirements such that on average, over a third of the Babine fence count is surplus produced by the Babine Lake Development Project. In contrast, escapements to the unenhanced Morrison River continue to be low relative to pre-enhancement levels, and stated
escapement objectives. Recent escapements to the unenhanced early-timing and late-timing subpopulations are not statistically different from pre-enhancement levels.
2. Smolt production from Babine Lake (main basin): Smolt production from the main basin of Babine Lake has increased dramatically as a result of enhancement. BLDP fry now account for about $90 \%$ of fry recruitment to the main basin. Even so, all the available data suggest that fry recruitment is still below levels required to yield maximum smolt biomass and maximum adult returns.
3. Smolt production from Nilkitkwa Lake and the North Arm of Babine Lake: Smolt production from Nilkitkwa Lake, as inferred from enumeration of early-migrant smolts, has declined to less than a quarter of the level observed before exploitation of enhanced returns began in 1970. Data for Nilkitkwa Lake are less reliable than for Babine Lake, and further investigation seems warranted.
4. Adult returns: Increased smolt production from the Babine-Nilkitkwa lake system has led to dramatic increases in adult returns. However, the relationship between adult returns and smolt abundance is non-linear. presumably reflecting competition among smolts. Recent returns have been higher than expected based on the density-dependent model, suggesting that favourable conditions have led to relaxed density-dependence after emigration. The disparity between smolt-to-adult survival in even and odd years noted previously by Peterman (1982) is no longer evident. Despite density-dependence, increased adult production could be expected from increased smolt production, especially if current conditions continue.
5. Harvest Management: Exploitation rate on Skeena River sockeye salmon has increased over the last decade, averaging $68 \%$ since 1990 , and exceeding $70 \%$ since 1996. Despite the increased exploitation, spawning escapements to non-Babine sockeye salmon populations have been increasing, presumably because of continuing efforts to harvest the mid-timing Babine sockeye. salmon as selectively as possible. Even so, recent analyses of limnological and spawning ground survey data for other (non-Babine) Skeena lakes indicate that in most cases, these escapements are much too low if the objective is to fully utilize lake rearing habitat and maximize smolt production (Shortreed et al. 1997). Thus, from the perspective of biological production and conservation, the present pattern of utilization, with most fish being harvested in mixed-stock fisheries in Alaska and northern British Columbia is a poor compromise between the dual objectives of maximizing catch from a single productive stock (enhanced Babine sockeye salmon) and maintaining production from the diversity of less productive salmon populations.
6. Outlook for 1998-2000: The smolt and sibling forecasting models produced almost identical forecasts for 1998 with a $75 \%$ chance that adult returns to the Skeena River will exceed 820 thousand sockeye salmon, and a $50 \%$ chance that returns will exceed either 1.22 million sockeye salmon (sibling model) or 1.42 million sockeye salmon (smolt model). The congruence of these models provides a clear signal that adult returns in 1998 will be much lower than in recent years. Because smolt production has continued to decline to 1997, forecasts for 1999 and 2000 based on the smolt model will be even lower than for 1998. Fry recruitment to Babine Lake returned to normal levels last spring, but is expected to be $20-30 \%$ below
target levels next spring. It is imperative that the smolt migration be enumerated in 1998 because continued low smolt abundance in 1998 would indicate that prespawning mortality is not the principal factor causing reduced smolt production from Babine Lake. Until the cause of abnormally low fry-to-smolt survival is understood, the prognosis :or future smolt production remains uncertain.

### 5.0 ACKNOWLEDGEMENTS

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### 7.0 FIGURES, TABLES AND APPENDICES

Table 1. Reconstructed Babine Lake escapements by run-timing group.

| Year | Fence Count | Catch ${ }^{\text {a }}$ | $\begin{gathered} \text { BLDP as } \\ \% \text { of fence } \\ \hline \end{gathered}$ | Early Total | Pinkut-Fultor' | Middle |  | Total | Late Total | TotalEscapement |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  | Surplus | Morrison |  |  |  |
| 1950 | 364356 | 27449 | 0.0 | 35844 | 44962 | 0 | 8812 | 53774 | ? 472851 | 336907 |
| 1951 | 141415 | 19007 | 0.0 | 35149 | 35342 | 0 | 6276 | 41618 | 45641 | 122408 |
| 1952 | 349011 | 34404 | 0.0 | 10486 | 62820 | 0 | 1848 | 64667 | :3945 | 314607 |
| 1953 | 686586 | 26913 | 0.0 | 61547 | 208708 | 0 | 33088 | 241796 | :356330) | 659673 |
| 1954 | 493677 | 21847 | 0.0 | 48107 | 143365 | 0 | 25487 | 168852 | :54871 | 471830 |
| 1955 | 71352 | 10423 | 0.0 | 8338 | 20721 | 0 | 1776 | 22497 | 3009 | 60929 |
| 1956 | 355345 | 30582 | 0.0 | 34283 | 117093 | 0 | 32651 | 149743 | 14073Ei | 324763 |
| 1957 | 433149 | 20434 | 0.0 | 50518 | 142785 | 0 | 29033 | 171817 | 190379 | 412715 |
| 1958 | 812050 | 38580 | 0.0 | 196599 | 183674 | 0 | 25850 | 209524 | :36734i' | 773470 |
| 1959 | 782868 | 16727 | 0.0 | 104474 | 248747 | 0 | 46018 | 294765 | 36690:! | 766141 |
| 1960 | 262719 | 16754 | 0.0 | 42485 | 78262 | 0 | 12298 | 90560 | 112920 | 245965 |
| 1961 | 941711 | 30856 | 0.0 | 133007 | 276734 | 0 | 33657 | 310391 | .16745i' | 910855 |
| 1962 | 547995 | 18122 | 0.0 | 21587 | 136862 | 0 | 16828 | 153690 | '354597' | 529873 |
| 1963 | 588000 | 20021 | 0.0 | 76661 | 241228 | 0 | 56319 | 297548 | 19377() | 567979 |
| 1964 | 827437 | 19855 | 0.0 | 67738 | 306602 | 0 | 35992 | 342595 | :397251 | 807582 |
| 1965 | 580000 | 18540 | 0.0 | 27278 | 207236 | 0 | 11094 | 218330 | 31585\%: | 561460 |
| 1966 | 389000 | 18652 | 0.0 | 31918 | 80044 | 0 | 15199 | 95243 | ? 23187 | 370348 |
| 1967 | 602807 | 18992 | 0.0 | 95242 | 167718 | 0 | 24201 | 191919 | :296655; | 583815 |
| 1968 | 552000 | 19146 | 0.0 | 62457 | 147571 | 0 | 55410 | 202981 | : 26741 \% | 532854 |
| 1969 | 634000 | 17293 | 0.0 | 89318 | 148885 | 0 | 32626 | 181511 | :345878 | 616707 |
| 1970 | 662000 | 20048 | 36.8 | 81749 | 224536 | 0 | 7432 | 231968 | :328235; | 641952 |
| 1971 | 816000 | 23450 | 41.2 | 34049 | 313244 | 0 | 8381 | 321625 | +136876 | 792550 |
| 1972 | 680145 | 24283 | 45.1 | 52692 | 283389 | 0 | 10277 | 293666 | :30950¢. | 655862 |
| 1973 | 797461 | 17015 | 46.3 | 140253 | 337492 | 34382 | 32179 | 404053 | :36140 | 780446 |
| 1974 | 726990 | 22318 | 36.5 | 109851 | 235408 | 29780 | 38189 | 303377 | :91444. | 704672 |
| 1975 | 820795 | 13896 | 69.6 | 60353 | 464933 | 134442 | 28686 | 628061 | 118485; | 806899 |
| 1976 | 580597 | 18157 | 65.8 | 13336 | 338263 | 39683 | 8022 | 385967 | $16313{ }^{\prime}$ | 562440 |
| 1977 | 937992 | 10777 | 69.2 | 52713 | 591788 | 67384 | 15577 | 674748 | 19975. | 927215 |
| 1978 | 401318 | 10920 | 66.0 | 32024 | 171267 | 125774 | 3931 | 300972 | 57402: | 390398 |
| 1979 | 1160966 | 21500 | 57.6 | 42455 | 552632 | 165164 | 21765 | 739562 | :35744¢ | 1139466 |
| 1980 | 526259 | 22635 | 45.5 | 30437 | 178863 | 86093 | 11168 | 276123 | 19706\%. | 503624 |
| 1981 | 1432734 | 30300 | 78.7 | 46093 | 586207 | 649611 | 7178 | 1242997 | 113342. | 1402434 |
| 1982 | 1136835 | 42000 | 67.9 | 93630 | 505550 | 331233 | 4827 | 841610 | 159595; | 1094835 |
| 1983 | 886393 | 20000 | 78.0 | 26965 | 472789 | 254708 | 8904 | 736401 | '10302i' | 866393 |
| 1984 | 1052385 | 20500 | 67.9 | 26503 | 486395 | 306475 | 8065 | 800935 | : 204447 | 1031885 |
| 1985 | 2148044 | 17500 | 42.7 | 75649 | 517259 | 896769 | 17229 | 1431257 | 1 $22363{ }^{\circ}$ | 2130544 |
| 1986 | 701507 | 23500 | 61.8 | 26865 | 298412 | 181419 | 3874 | 483705 | $16743{ }^{\circ}$ | 678007 |
| 1987 | 1307852 | 20296 | 61.8 | 37960 | 452629 | 543775 | 15786 | 1012190 | : 237406 ; | 1287556 |
| 1988 | 1408879 | 25000 | 62.7 | 42373 | 495753 | 580318 | 23459 | 1099530 | :241976 | 1383879 |
| 1989 | 1132316 | 22000 | 74.1 | 18412 | 434467 | 517173 | 7701 | 959341 | 132563 | 1110316 |
| 1990 | 978646 | 22000 | 67.8 | 21328 | 457633 | 271425 | - 7395 | 736454 | 198864. | 956646 |
| 1991 | 1176318 | 20800 | 40.2 | 58719 | 328999 | 310238 | 24980 | 664217 | 432582: | 1155518 |
| 1992 | $1915149^{\text {c }}$ | 73879 | 47.7 | 47075 | 515297 | 681364 | 8515 | 1205176 | !89902() | 1841270 |
| 1993 | 1737426 | 177590 | 51.5 | 16646 | 511120 | 414730 | 21962 | 947812 | ! $99537{ }^{\circ}$ | 1559836 |
| 1994 | 1052905 | 48465 | 78.7 | 24636 | 563623 | 276301 | 7561 | 847485 | - 32318 \% | 1004440 |
| 1995 | 1737009 | 98592 | 82.4 | 78739 | 636049 | 846928 | 6556 | 1489533 | 7014 | 1638417 |
| 1996 | 2056205 | 352234 | 81.1 | 59502 | 581946 | 910598 | 7976 | 1500520 | 143948; | 1703971 |
| 1997 | 1086610 | 156000 |  |  |  |  |  |  |  |  |

${ }^{\text {a }}$ harvest after enumeration at Babine fence
${ }^{b}$ includes Pinkut-Fulton (after 1969), surplus, and prorated catch
${ }^{\text {c }}$ Babine fence count - catch - surplus
${ }^{d}$ reconstructed fence count, actual count not credible, see PSARC s95-06

Table 2. Babine Lake freshwater production, main basin only.

| Brood Year | Estimated Abundance |  |  | Smolt Weight |  | Smolt <br> Biomass (kg) | Fry-to-smolt Survival (\%) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\mathrm{Fry}^{*} 10^{6}$ | Smolts | SE | Mean | (SD) |  |  |
| 1950 | 20.9 | 0 | 0 | 4.9 |  |  |  |
| 1951 | 17.9 | 0 | 0 | 6.2 |  |  |  |
| 1952 | 17.5 | 0 | 0 | 6.3 |  |  |  |
| 1953 | 70.7 | 0 | 0 | 5.4 |  |  |  |
| 1954 | 50.6 | 0 | 0 | 5.1 |  |  |  |
| 1955 | 7.2 | 0 | 0 | 5.9 |  |  |  |
| 1956 | 42.9 | 0 | 0 | 6.1 |  |  |  |
| 1957 | 51.8 | 0 | 0 | 5.5 |  |  |  |
| 1958 | 94.6 | 0 | 0 | 6.2 |  |  |  |
| 1959 | 93.0 | 13216226 | 547152 | 5.2 |  | 68724 | 14.2 |
| 1960 | 31.0 | 17140050 | 1087906 | 5.6 |  | 95984 | 55.3 |
| 1961 | 103.3 | 6645905 | 285134 | 5.3 |  | 35223 | 6.4 |
| 1962 | 40.8 | 41741112 | 5433752 | 5.3 |  | 221228 | 102.2 |
| 1963 | 87.2 | 28334963 | 1399898 | 5.1 |  | 144508 | 32.5 |
| 1964 | 95.6 | 22768048 | 730334 | 4.7 |  | 107010 | 23.8 |
| 1965 | 57.2 | 7415431 | 382854 | 5.3 |  | 39302 | 13.0 |
| 1966 | 64.2 | 23677175 | 778924 | 4.5 |  | 106547 | 36.9 |
| 1967 | 75.3 | 28093879 | 1649028 | 5.4 |  | 151707 | 37.3 |
| 1968 | 103.2 | 38431464 | 916012 | 5.1 |  | 196000 | 37.3 |
| 1969 | 87.9 | 38753163 | 1106440 | 5.8 |  | 224768 | 44.1 |
| 1970 | 135.7 | 37325167 | 1340116 | 5.3 |  | 197823 | 27.5 |
| 1971 | 162.0 | 88690671 | 4257584 | 5.3 |  | 470061 | 54.8 |
| 1972 | 173.2 | 77854348 | 2615787 | 4.8 | 1.3 | 373701 | 45.0 |
| 1973 | 190.9 | 33248302 | 1135680 | 5.4 | 1.3 | 179541 | 17.4 |
| 1974 | 141.6 | 38590631 | 947016 | 5.1 | 1.0 | 196812 | 27.3 |
| 1975 | 175.3 | 54481971 | 1974869 | 4.9 | 1.3 | 266962 | 31.1 |
| 1976 | 233.8 | 80398367 | 4269472 | 4.5 | 1.3 | 361793 | 34.4 |
| 1977 | 207.4 | 110424296 | 4785295 | 5.0 | 0.7 | 552121 | 53.2 |
| 1978 | 131.7 | 55128796 | 2483147 | 4.3 | 0.9 | 237054 | 41.9 |
| 1979 | 212.0 | 179427612 | 16855600 | 4.5 | 1.2 | 807424 | 84.7 |
| 1980 | 171.4 | 122067466 | 5993841 | 4.6 | 1.2 | 561510 | 71.2 |
| 1981 | 229.8 | 142594834 | 16709866 | 4.4 | 1.2 | 627417 | 62.0 |
| 1982 | 217.8 | 93464694 | 10791980 | 3.9 | 1.2 | 364512 | 42.9 |
| 1983 | 124.4 | 42796531 | 2181594 | 4.2 | 0.3 | 179745 | 34.4 |
| $1984{ }^{\text {a }}$ | 228.2 | 49387722 |  | 5.3 | 1.7 | 261755 | 21.6 |
| 1985 | 212.9 | 122873389 | 6321951 | 5.0 | 1.3 | 614367 | 57.7 |
| 1986 | 226.4 | 80536904 | 3266217 | 4.5 | 1.1 | 362416 | 35.6 |
| 1987 | 117.0 | no smolt pro | gram |  |  |  |  |
| 1988 | 212.2 | 61049322 | 2034479 | 5.0 | 1.2 | 305247 | 28.8 |
| 1989 | 164.7 | 51809312 | 1430708 | 4.8 | 1.3 | 248685 | 31.5 |
| 1990 | 247.0 | 97523387 | 3561698 | 4.8 | 1.1 | 468112 | 39.5 |
| 1991 | 192.1 | 83095829 | 16576996 | 4.3 |  | 357312 | 43.3 |
| 1992 | 228.1 | 188667005 | 8762382 | 5.4 | 1.2 | 1020688 | 82.7 |
| 1993 | 181.7 | 30887461 | 4066305 | 5.6 | 1.3 | 165248 | 17.0 |
| 1994 | 131.9 | 17310854 | 405299 | 5.6 |  | 96941 | 13.1 |
| $1995{ }^{\text {b }}$ | 114.2 | 7747408 | 506990 | 5.3 |  | 41371 | 6.8 |
| 1996 | 248.0 |  |  |  |  |  | 0.0 |

${ }^{\text {a }}$ Smolt abundance estimates are questionable and were excluded from analyses in this report. Values reported here are from the constant sampling fractioon model because the parsimonious model fitted poorly, presumably because of a failure in the assumptions of the mark/recapture model

[^0]Table 3. Summary of total sockeye production from the Babine-Nilkitkwa lake system.


Table 4. Skeena sockeye run size forecasts for 1998

|  |  |  |
| :--- | ---: | ---: |
|  | Probability Reference Points ${ }^{2}$ |  |
| Model | 0.5 | 0.75 |
| 5 -yr Mean | 4550000 | 3550000 |
| Smolt $(\mathrm{Y}=\mathrm{aXb})$ | 1420000 | 820000 |
| Sibling $(\mathrm{Y}=\mathrm{aXb})$ | 1220000 | 820000 |
| Recommended | 1220000 | 820000 |

[^1]
## FIGURE CAPTIONS

1. Map of the Babine-Nilkitkwa lake system 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. Rearing areas and typical timing of early- and late-migrant smolts from the Babine-Nilkitkwa lake system (from Macdonald et al. 1987).
3. Trends in reconstructed escapements by run timing group. Lines fitted by LOWESS $(\mathrm{F}=0.5)$.
4. Trends in estimated fry recruitment to the main basin of Babine Lake (upper) and to the entire Babine-Nilkitkwa system (lower). Lightly hatched portions represent contritutions from the BLDP.
5. Trends in smolt abundance from the main basin of Babine Lake (late-migrant smolts) and from the entire Babine-Nilkitkwa system (lower). Error bars represent one standard error.
6. Trends in smolt abundance from Nilkitkwa Lake (early-migrant smolts). Error ba:s represent one standard error.
7. Stock-recruitment relationship for Nilkitkwa Lake as inferred from late-t:ming spawning escapements and subsequent early-migrant smolt abundance. Solid circles and upper curve, brood years prior to 1985; open circles and lower curve, brood years since 1985. Curves are fitted as a power function $\left(Y=a X^{b}\right)$.
8. Trends in adult returns to Babine Lake by brood year. Line is fitted by LOWESS ( $\mathrm{F}==0.5$ ).
9. Relationship between fry-to-smolt survival (upper panel), late-migrant smolt abundance (lower panel) and estimated fry recruitment to the main basin of Babine Lake. Curves fitted by LOWESS ( $\mathrm{F}=0.5$ ) and as a power function, respectively.
10. Trends in mean smolt weight for late-migrant smolts rearing in the main basin of Babine Lake. Line is fitted by LOWESS ( $\mathrm{F}=0.5$ ).
11. Relationships between smolt weight (upper) and smolt biomass (lower) and fy recruitment to the main basin of Babine Lake. Lines fitted as power functions.
12. Relationships between smolt weight (upper) and smolt biomass (lower) and late-migrant smolt abundance from main basin of Babine Lake. Lines fitted as power functions.
13. Relationship between smolt-to-adult survival (upper panel), subsequent adult returns to Babine Lake (lower panel) and the total number of smolts leaving Babine Lake. Curves fitted as power functions.
14. Linear regressions (with $95 \%$ confidence bounds) of smolt-to-adult survival (upper) and proportion of smolts returning as jacks (at age 3) on the mean weight of late-migrant smolts leaving Babine Lake.
15. Trends in residuals from the adult returns-smolt abundance relationship in Figure 13, distinguished by even (open circles, dashed line) and odd (solid circles, solid line) years. Lines fitted by LOWESS ( $\mathrm{F}=0.5$ ).
16. Total exploitation rates (excluding jacks) and resulting escapements of Skeena sockeye salmon for 1970-1996 compared with target (solid line). The dashed line is the average exploitation rate since 1990.
17. Trends in total exploitation rate (upper) and total catch (lower) of Skeena sockeye salmon. Age . 3 (jack) sockeye salmon have been excluded. Curved line fitted by LOWESS ( $\mathrm{F}=0.5$ ).
18. Trends in Skeena sockeye salmon escapement to non-Babine subareas (upper) and the Babine subarea (lower). Note logarithmic scale on y -axis; curves fitted by LOWESS ( $\mathrm{F}=0.5$ ).
19. The $5-\mathrm{yr}$ mean-based forecast for total Skeena sockeye salmon stock size in 1998. The cumulative probability distribution is shown in relation to the distribution of historical stock sizes. This forecast is not recommended for 1998.
20. The smolt-based forecast for total Skeena sockeye salmon stock size in 1998. The cumulative probability distribution is shown in relation to the distribution of historical stock sizes.
21. The recommended forecast for total Skeena sockeye salmon stock size in 1998 based on the observed return of sibling age classes (jacks in 1996 and age 4 sockeye salmon in 1997). The cumulative probability distribution is shown in relation to the distribution of historical stock sizes.


Figure 1


Figure 2.


Figure 3.


Figure 4.


Figure 5. Note that values of brood year 1995 are minimum estimates due to flcoding.


Figure 6.


Figure 7.


Figure 8.


Figure 9.


Figure 10.


Figure 11.



Figure 12.


Figure 13.


Figure 14.


Figure 15.


Figure 16.


Figure 17.



Figure 18.
A. Historical distribution of stock sizes

B. Forecast of stock size
(5-yr mean)


Figure 19.

## A. Historical distribution of stock sizes



Figure 20.
A. Historical distribution of stock sizes

B. Forecast of stock size
(Sibling $Y=a X b$ )


TOTAL STOCK SIZE

Figure 21.

Appendix 1. Babine Lake sockeye escapements (unadjusted) 1950-1996 with averages by decade (source: B. Spilsted DFO, Prince Rupert)

| Stream | Timing | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | Average |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Bablne Fence Count |  | 364,356 | 141,415 | 349,011 | 686,586 | 493,677 | 71,352 | 355,345 | 433,149 | 812,050 | 782,868 | 448,981 |
| Unenhanced Spawning Sites |  |  |  |  |  |  |  |  |  |  |  |  |
| Babine R. (Sec 1-3) | late | 130,000 | 20,000 | 62,000 | 150,000 | 140,000 | 15,500 | 70,000 | 130,000 | 160,000 | 165,000 | 104,250 |
| Babine R. (Sec 4) | late | 145,000 | 12,000 | 100,000 | 130,000 | 100,000 | 15,000 | 55,000 | 70,000 | 110,000 | 130,000 | 86,700 |
| Babine R. (Sec 5) | early |  |  |  |  |  |  |  |  |  |  |  |
| Babine Lake | early |  |  |  |  |  |  |  |  |  |  |  |
| Boucher Creek | early |  |  | 400 | 4,000 | 400 |  |  |  |  |  | 1,600 |
| Donalds Creek | early |  |  |  | 300 | 300 |  |  | 200 |  | 800 | 400 |
| Five-Mile Creek | early |  | 111 |  | 300 | 2,000 | 100 |  | 200 |  | 600 | 552 |
| Fork Creek | earty |  |  |  |  |  |  |  |  |  | 600 | 600 |
| Four-Mile Creek | early | 4,664 | 927 | 192 | 2,000 | 2,200 | 400 | 400 | 2,500 | 7,000 | 5,400 | 2,568 |
| Hazelwood Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Kew Creek | early |  |  |  | 100 | 300 |  |  |  |  | 400 | 267 |
| Morrison Creek | mid | 9,800 | 2,200 | 400 | 16,000 | 12,000 | 600 | 18,000 | 20,000 | 9,000 | 22,000 | 11,000 |
| Nichyeskwa R | early |  |  |  |  |  |  |  |  |  |  |  |
| Nilkwitka R. | early |  |  |  |  |  |  |  |  |  |  |  |
| Nine-Mile Creek | early | 978 | 407 | 75 | 2,500 | 1,000 | 50 |  | 4,000 |  | 2,400 | 1,426 |
| Pendelton Creek | early | 1,341 |  |  | 1,500 | 1,100 |  |  | 300 |  | 2,500 | 1,348 |
| Pierre Creek | early | 17,920 | 12,460 | 3,500 | 20,000 | 17,000 | 4,000 | 20,000 | 23,000 | 80,000 | 34,000 | 23,188 |
| Shass Creek | early | 2,697 | 2,333 | 2,500 | 6,000 | 3,100 | 500 | 5,000 | 7,000 | 30,000 | 14,000 | 7,313 |
| Six-Mile Creek | early | 1,225 |  |  | 2,663 | 1,800 | 100 | 50 | 600 | 2,500 | 3,500 | 1,555 |
| Sockeye Creek | early | 900 | 786 |  | 600 | 900 | 500 |  | 2,500 | 2,000 | 4,000 | 1,523 |
| Sutherland Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Tachek Creek | early | 2,055 | 2,600 |  | 2,500 | 1,900 | 300 |  | 6.771 | 3,000 | 6,000 | 3,141 |
| Tahlo Creek | mid |  | 1.000 | 450 | 10,000 | 12,000 | 1,200 | 11,000 | 9,000 | 10,000 | 12,500 | 7.461 |
| Tahlo Creek (upper) | mid |  | 1,200 | 400 |  |  |  |  | 1,500 |  | 2,500 | 1,400 |
| Telzato Creek | early |  |  |  |  |  |  |  |  |  | 900 | 900 |
| Tsezakwa Creek | early |  |  |  |  |  |  |  |  |  | 400 | 400 |
| Twain Creek | early | 8,081 | 5,020 | 827 | 10,000 | 14,000 | 2,500 | 5,000 | 6,000 | 20,000 | 9,000 | 8,043 |
| Wright Creek | early |  |  |  |  |  |  |  |  |  | 800 | 800 |
| Total WIld |  | 324,661 | 61,044 | 170,744 | 358,463 | 310,000 | 40,750 | 184,450 | 283,571 | 433,500 | 417,300 | 258,448 |
| Enhanced Spawning Sites |  |  |  |  |  |  |  |  |  |  |  |  |
| Fulton Channel \#1 | mid |  |  |  |  |  |  |  |  |  |  |  |
| Fulton Channel \#2 | mid |  |  |  |  |  |  |  |  |  |  |  |
| Fulton Above Weir | mid | 50,000 | 19,000 | 35,000 | 140,000 | 110,000 | 17,000 | 80,000 | 120,000 | 90,000 | 120,000 | 78,100 |
| Fulton Below Weir | mid |  |  |  |  |  |  |  |  |  |  |  |
| Pinkut Channel | mid |  |  |  |  |  |  |  |  |  |  |  |
| Pinkut Above Weir | mid |  | 5,779 | 7.500 | 24,000 | 25,000 | 4,000 | 24,000 | 30,000 | 45,000 | 80,000 | 27,253 |
| Pinkut Airlift | mid |  |  |  |  |  |  |  |  |  |  |  |
| Pinkut Below Weir | mid |  |  |  |  |  |  |  |  |  |  |  |
| Total Enhanced |  | 50,000 | 24,779 | 42,500 | 164,000 | 135,000 | 21,000 | 104,000 | 150,000 | 135,000 | 200,000 | 102,628 |
| Harvest at or Above Weir |  | 27,449 | 19,007 | 34,404 | 26,913 | 21,847 | 10,423 | 30,582 | 20,434 | 38,580 | 16,727 | 24,637 |
| Uncounted |  |  | 36,585 | 101,363 | 137,210 | 26,830 |  | 36,313 |  | 204,970 | 148,841 | 98,873 |

Appendix 1. (cont'd)

| Stream | Timing | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | Average |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Babine Fence Count |  | 262,719 | 941,711 | 547,995 | 588,000 | 827,437 | 580,000 | 389,000 | 602,807 | 552,000 | 634,000 | 592,567 |
| Unenhanced Spawning Sites |  |  |  |  |  |  |  |  |  |  |  |  |
| Babine R. (Sec 1-3) | late | 41,000 | 200,000 | 210,000 | 141,450 | 250,000 | 120,000 | 70.000 | 135,000 | 185,000 | 178,000 | 153,045 |
| Babine R. (Sec 4) | late | 60,000 | 175,000 | 75,000 | 55,350 | 48,000 | 120,000 | 114,000 | 55,000 | 37,000 | 60,000 | 79,935 |
| Babine R. (Sec 5) | early |  |  |  |  |  | 2,000 |  |  |  |  | 2,000 |
| Babine Lake | early |  |  |  |  |  |  |  |  |  |  |  |
| 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 | 2,000 | 2,000 | 3,000 | 3,690 | 2,064 | 1,400 | 1,500 | 4,000 | 4,000 | 4,500 | 2,815 |
| Hazelwood Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Kew Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Morrison Creek | mid | 6,000 | 18,000 | 9,000 | 32,500 | 16,000 | 5,000 | 9,000 | 14,000 | 35,000 | 12,250 | 15,675 |
| Nichyeskwa R | early |  |  |  |  |  |  |  |  |  |  |  |
| Nilkwitka R. | early |  |  |  | 400 | 200 |  | 50 |  |  | 400 | 263 |
| Nine-Mile Creek | early | 2,000 | 4,000 | 500 | 1,230 | 1,500 | 500 | 1,000 | 1,000 | 600 | 1,110 | 1,344 |
| Pendelton Creek | early |  |  | 200 |  | 1,400 |  |  |  |  |  | 800 |
| Pierre Creek | early | 11,000 | 55,000 | 4.500 | 36,900 | 22,000 | 10,000 | 11,000 | 40,000 | 25,000 | 25,000 | 24,040 |
| Shass Creek | early | 12,000 | 30,000 | 5,000 | 14,760 | 8,000 | 5,000 | 6,000 | 3,000 | 7.500 | 9,000 | 10,026 |
| Six-Mile Creek | early | 1,000 |  | 1.000 | 1,845 | 1,500 | 100 | 300 | 1,200 | 1,000 | 300 | 916 |
| Sockeye Creek | early | 2,000 |  | 1,100 | 3,075 | 1,500 | 50 | 1,400 | 700 | 1,200 | 2,140 | 1,463 |
| Sutherland Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Tachek Creek | early | 2,000 |  | 600 | 1,600 | 3,000 | 700 | 300 | 1,000 | 500 | 2,350 | 1,339 |
| Tahio Creek | mid | 5,000 | 7,000 | 4,500 | 24,600 | 10,000 | 3,500 | 2,500 | 1,500 | 11,000 | 10,200 | 7,980 |
| Tahlo Creek (upper) | mid |  | 2,000 | 25 | 100 | 1,000 |  |  |  |  |  | 781 |
| Telzato Creek | early |  |  |  |  | 350 |  |  |  |  | 100 | 225 |
| Tsezakwa Creek | early |  | 200 |  |  |  |  |  |  |  |  | 200 |
| Twain Creek | early | 6,000 | 15,000 | 1.400 | 14,760 | 9,000 | 3,000 | 2,500 | 10,000 | 12,000 | 16,660 | 9,032 |
| Wright Creek | eady |  |  |  |  |  |  |  |  |  |  |  |
| Total Wild |  | 150,000 | 508,700 | 315,875 | 332,260 | 376,364 | 271,400 | 219,700 | 266,500 | 319,850 | 322,410 | 308,306 |
| Enhanced Spawning Sites |  |  |  |  |  |  |  |  |  |  |  |  |
| Fulton Channel \#1 | mid |  |  |  |  |  |  | 18,186 | 21,752 | 26,043 | 21,034 | 21,754 |
| Fulton Channel \#2 | mid |  |  |  |  |  |  |  |  |  | 23,770 | 23,770 |
| Fulton Above Weir | mid | 40,000 | 175,000 | 80,000 | 180,000 | 140,000 | 135,000 | 40,395 | 110,224 | 99,244 | 60,555 | 106,042 |
| Fulton Below Weir | mid |  |  |  |  |  |  |  | 4,000 |  |  | 4,000 |
| Pinkut Channel | mid |  |  |  |  |  |  |  |  | 13.479 | 33.745 | 23.612 |
| Pinkut Above Weir | mid | 30,000 | 47,000 | 30,000 | 65,000 | 90,000 | 23,780 | 21,463 | 31,742 | 6,633 | 7,331 | 35,295 |
| Pinkut Airlift | mid |  |  |  |  |  |  |  |  |  |  |  |
| Pankut Patou Me:- | mid |  |  |  |  |  |  |  |  | 2, 172 | 2,450 | 2,5ii |
| Total Enhanced |  | 70,000 | 222,000 | 110,000 | 245,000 | 230,000 | 158,780 | 80,044 | 167,718 | 147,571 | 148,885 | 158,000 |
| Harvest at or Above Weir |  | 16,754 | 30,856 | 18,122 | 20,021 | 19,855 | 18,540 | 18,652 | 18,992 | 19,146 | 17.293 | 19,823 |
| Uncounted |  | 25,965 | 180,155 | 103,998 |  | 201,418 | 133,280 | 70,654 | 149,597 | 65,433 | 145,812 | 119,590 |


| Stream | Timing | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | Average |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Babine Fence Count |  | 662,000 | 816,000 | 680,145 | 797,461 | 726,990 | 820,795 | 580,597 | 937,992 | 401,318 | 1,160,966 | 758,426 |
| Unenhanced Spawning Sites |  |  |  |  |  |  |  |  |  |  |  |  |
| Babine R. (Sec 1-3) | late | 234,000 | 321,000 | 189,000 | 153,000 | 203,529 | 92,000 | 127,159 | 121,232 | 32,915 | 272,555 | 174,639 |
| Babine R. (Sec 4) | late | 84,000 | 96,000 | 70,000 | 40,000 | 35,000 | 3,000 | 3,000 | 40,351 | 10,895 | 19,770 | 40,202 |
| Babine R. (Sec 5) | early |  |  |  |  |  |  |  |  |  |  |  |
| Babine Lake | early |  |  |  |  |  |  |  |  |  |  |  |
| 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 | 2,500 | 6,000 | 7,370 | 11,000 | 7,256 | 1,750 | 800 | 8,800 | 6,000 | 6,800 | 5,828 |
| Hazelwood Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Kew Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Morrison Creek | mid | 7,200 | 6,000 | 8,000 | 17,200 | 13,755 | 16,000 | 3,600 | 9,000 | 1,500 | 11,200 | 9,346 |
| Nichyeskwa R | early |  |  |  |  |  |  |  | 1,600 |  |  | 1,600 |
| Nilkwitka R. | early | 400 |  |  |  |  |  |  |  |  |  | 400 |
| Nine-Mile Creek | early | 1,200 | 1,200 | 802 | 1,100 | 950 | 140 | 900 | 900 | 215 | 900 | 831 |
| Pendelton Creek | early |  |  |  |  | 100 |  | 1,000 | 600 | 300 |  | 500 |
| Pierre Creek | early | 44,000 | 14,200 | 25,075 | 60,890 | 42,920 | 20,100 | 2,430 | 10,000 | 4,000 | 11,500 | 23,512 |
| Shass Creek | early | 5,400 | 2,400 | 750 | 13,900 | 12,000 | 4,500 | 1,400 | 6,000 | 1,200 | 3.100 | 5,065 |
| Six-Mile Creek | early | 600 | 350 | 1,400 | 4,800 | 880 | 100 | 450 | 1,500 | 300 | 1,400 | 1,178 |
| Sockeye Creek | early | 4,800 | 650 | 650 | 600 | 3,500 | 2,600 | 1,300 | 1,700 | 1,500 | 800 | 1,810 |
| Sutherland Creek | early |  |  |  | 400 | 400 |  |  |  | 400 |  | 400 |
| Tachek Creek | early | 2,400 | 500 | 1,200 | 850 | 2,900 | 1,150 | 500 | 3.500 | 1,500 | 1,200 | 1,570 |
| Tahlo Creek | mid |  | 2,000 | 600 | 9,000 | 17,200 | 7.000 | 1,400 | 3,600 | 1,500 | 6,600 | 5,433 |
| Tahlo Creek (upper) | mid |  |  |  | 100 | 300 |  | 1,400 |  |  |  | 600 |
| Telzato Creek | early | 100 |  |  |  |  |  |  |  |  |  | 100 |
| Tsezakwa Creek | early |  |  |  |  |  |  |  | 200 | 10 | 20 | 77 |
| Twain Creek | early | 18,000 | 7,000 | 6,800 | 21,000 | 18,500 | 17,800 | 1,800 | 9,000 | 9,000 | 9,000 | 11,790 |
| Wright Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Total Wild |  | 404,900 | 457,500 | 311,694 | 333,930 | 359,690 | 166,390 | 147,199 | 218,423 | 71,257 | 344,845 | 281,583 |
| Enhanced Spawning Sites |  |  |  |  |  |  |  |  |  |  |  |  |
| Fulton Channel \#1 | mid | 25,483 | 24.746 | 21,600 | 25,272 | 12,530 | 14,874 | 16,834 | 19,080 | 10,613 | 21,284 | 19,232 |
| Fulton Channel \#2 | mid | 58,786 | 115,481 | 106,491 | 112,062 | 62,397 | 108,199 | 110,676 | 127,548 | 88,648 | 126,035 | 101,632 |
| Fuiton Above Weir | mid | 99,789 | 125,869 | 81,387 | 99,975 | 46,709 | 192,670 | 140,561 | 345,403 | 39,042 | 244,568 | 141,597 |
| Fulton Below Weir | mid | 11,500 | 16,705 |  |  | 17,575 | 81,756 | 20,000 | 10,000 | 5,000 | 25,000 | 23,442 |
| Pinkut Channel | mid | 19,763 | 21,665 | 57,083 | 63,260 | 51,655 | 48,083 |  | 64,556 | 23,716 | 68,411 | 46,466 |
| Pinkut Above Weir | mid | 8,257 | 7,878 | 15,828 | 17,969 | 17,000 | 12,000 | 20,227 | 20,201 | 4,248 | 26,000 | 14,961 |
| Pinkut Airlift | mid |  |  |  | 16,654 | 25,542 | 40,107 | 28,965 |  |  | 36,334 | 29,520 |
| Pinkut Below Weir | mid | 958 | 900 | 1,000 | 2,300 | 2,000 | 5,000 | 1,000 | 5,000 |  | 5,000 | 2,573 |
| Total Enhanced |  | 224,536 | 313,244 | 283,389 | 337,492 | 235,408 | 502,689 | 338,263 | 591,788 | 171,267 | 552,632 | 355,071 |
| Harvest at or Above Weir |  | 20,048 | 23,450 | 24,283 | 17,015 | 22,318 | 13,896 | 18,157 | 10,777 | 10,920 | 21,500 | 18,236 |
| Uncounted |  | 12,916 | 21,806 | 60,779 | 109,024 | 109,574 | 137,820 | 76,978 | 118,604 | 147,874 | 241,989 | 103,736 |


| Stream | Timing | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | Average |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Babine Fence Count Unenhanced Spawning Sites |  | 526,259 | 1,432,734 | 1,136,835 | 886,393 | 1.052,385 | 2,148,044 | 701.507 | 1,307,852 | 1,408,879 | 1,132,316 | 1,173,320 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| Babine R. (Sec 1-3) | late | 150,640 | 70,000 | 94,647 | 74,000 | 158,986 | 500,000 | 120,000 | 175,000 | 185,000 | 100,000 | 162,827 |
| Babine R. (Sec 4) | late | 8,175 | 20,000 | 34,300 | 7.000 | 5,787 | 14,000 | 14,000 | 17,500 | 11,500 | 5,000 | 13,726 |
| Babine R. (Sec 5) | early |  |  |  |  |  |  |  |  |  |  |  |
| Babine Lake | early |  |  |  |  |  |  |  |  |  |  |  |
| Boucher Creek | early |  |  |  |  |  |  |  | N/I | $\mathrm{N} / \mathrm{l}$ | N/I |  |
| Donalds Creek | early |  |  |  | 100 |  |  | 0 | 50 | 50 | N/O | 50 |
| Five-Mile Creek | early | 4 |  | 150 | 100 | 20 | 150 | 0 | 30 | 0 | N/I | 57 |
| Fork Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Four-Mile Creek | early | 3,600 | 6,500 | 15,000 | 4,200 | 2,300 | 5,000 | 3,000 | 2,000 | 1,200 | 500 | 4,330 |
| Hazelwood Creek | early | 50 |  |  |  |  |  | N/I | N/I | N/I | N/I | 50 |
| Kew Creek | early |  |  |  |  |  |  |  |  |  |  |  |
| Morrison Creek | mid | 4,000 | 5,000 | 3,500 | 4,500 | 2,500 | 7,000 | 2,500 | 9,000 | 12,000 | 3,000 | 5,300 |
| Nichyeskwa R | early | 1,000 | 300 |  |  |  |  | $\mathrm{N} / 1$ | N/I | N/I | N/I | 650 |
| Nilkwitka R. | early | 6 |  |  |  |  |  | $\mathrm{N} / 1$ | 200 | 50 | N/O | 85 |
| Nine-Mile Creek | early | 750 | 500 | 1,000 | 400 | 1,000 | 1,850 | 500 | 1,500 | 200 | 300 | 800 |
| Pendelton Creek | early | 25 | 600 | 5,500 | 150 | 100 | 850 | 550 | 700 | 600 | 80 | 916 |
| Pierre Creek | early | 3,750 | 10,000 | 20,000 | 7,500 | 12,650 | 23,000 | 7.700 | 11,500 | 12,500 | 6,750 | 11.535 |
| Shass Creek | early | 3,000 | 6,000 | 4,500 | 1,500 | 950 | 12,000 | 2,000 | 5,150 | 12,000 | 2,600 | 4,970 |
| Six-Mile Creek | early | 1,300 | 800 | 6,000 | 950 | 200 | 700 | 1,500 | 300 | 250 | 10 | 1,201 |
| Sockeye Creek | early | 3,100 | 1,500 | 2.500 | 500 | 40 | 2,000 | 50 | 600 | 600 | 30 | 1,092 |
| Sutherland Creek | early | 500 |  |  |  |  |  | N/I | 350 |  | N/I | 425 |
| Tachek Creek | early | 950 | 700 | 4,000 | 400 | 100 | 800 | 600 | 1,100 | 500 | 14 | 916 |
| Tahlo Creek | mid | 5,000 | 700 | 400 | 2,500 | 4,000 | 7,200 | 600 | 3,800 | 7,000 | 3,100 | 3,430 |
| Tahlo Creek (upper) | mid |  |  |  |  |  | N/O | $\mathrm{N} / \mathrm{l}$ | N/O | 50 | N/O | 50 |
| Telzato Creek | early |  |  |  |  |  |  | $\mathrm{N} / \mathrm{l}$ |  |  |  |  |
| Tsezakwa Creek | early | UNK | N/I | N/I | N/I | N/I | N/1 |  |  |  |  |  |
| Twain Creek | early | 7,500 | 10,000 | 17,000 | 5,400 | 4,000 | 16,000 | 5,600 | 7,500 | 6,500 | 4,300 | 8,380 |
| Wright Creek | early |  |  |  |  |  |  |  |  | 10 |  | 10 |
| Total Wild |  | 193,350 | 132,600 | 208,497 | 109,200 | 192,633 | 590,550 | 158,600 | 236,280 | 250,010 | 125,684 | 219,740 |
| Enhanced Spawning Sites |  |  |  |  |  |  |  |  |  |  |  |  |
| Fulton Channel \#1 | mid | 8,550 | 20,795 | 16,845 | 21.712 | 16,655 | 17.208 | 13,640 | 16,438 | 13,685 | 16,032 | 16,156 |
| Fulton Channel \#2 | mid | 64,100 | 144,969 | 115,507 | 164,810 | 109,803 | 104,340 | 85,696 | 102,471 | 104,301 | 115,315 | 111,131 |
| Fulton Above Weir | mid | 42,558 | 175,302 | 221,714 | 156,552 | 210,022 | 200,312 | 86,100 | 136,239 | 200,000 | 150,000 | 157,880 |
| Fulton Below Weir | mid | 6,000 | 100,000 | 45,000 | 5,000 | 10,000 | 300,000 | 5,000 | 10,000 | 200,000 | 100,000 | 78,100 |
| Pinkut Channel | mid | 41,655 | 79,847 | 55,085 | 94,520 | 69,500 | 76,377 | 51,800 | 74,076 | 58,382 | 66,800 | 66,804 |
| rinkut ADove weir | mid | 13,000 | 25,541 | 25,000 | 25,195 | 19,566 | 19.235 | 20,378 | 20,266 | 24,429 | 24,501 | 21,911 |
| Pinkut Airlift | mid |  | 90,753 | 22,399 |  | 45,849 | 50,787 | 30,798 | 88,139 | 45,958 | 12,819 | 48,438 |
| Pinkıt Ralnw Weir | mid | 1 non | 60.10 m | 5n, กn | 5, 0 n | 150 n 1 n | 70n | 5n, non | 3501200 | 150,000 | 2n,0nก | 113,500 |
| Total Enhanced |  | 178,863 | 697,207 | 551,550 | 472,789 | 631,395 | 1,068,259 | 343,412 | 797,629 | 796,753 | 505,467 | 604,332 |
| Harvest at or Above Weir |  | 22,635 | 30,300 | 42,000 | 20,000 | 20,500 | 17,500 | 23,500 | 20,296 | 25,000 | 22,000 | 24,373 |
| Uncounted |  | 132,417 | 572,927 | 334,788 | 284,404 | 207,857 | 471,735 | 175,995 | 253,847 | 337,166 | 479,165 | 325,030 |



Appendix 2. Enhanced sockeye fry production (millions) from Fulton River and Pinkut Creek Projects by brood year.

|  | Fulton River Project |  |  |  |  |  | Pinkut Creek Project |  |  |  |  |  | BLDP Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Brood Year | Above Fence | Below ${ }^{\text {a }}$ <br> Fence | River Total | Channel One | Channel Two | Total | Above Fence | Below ${ }^{\text {b }}$ <br> Fence | River <br> Total | Channel | Airlift | Total |  |
| 1966 | 24.0 |  | 24.0 | 25.5 |  | 49.5 |  |  | 3.7 |  |  | 3.7 | 53.2 |
| 1967 | 27.8 | 1.0 | 28.8 | 16.0 |  | 44.8 |  |  | 2.7 |  |  | 2.7 | 47.5 |
| 1968 | 38.7 | 0.0 | 38.7 | 24.7 |  | 63.4 | 1.4 | 0.5 | 1.9 | 10.4 |  | 12.3 | 75.7 |
| 1969 | 11.2 | 0.0 | 11.2 | 5.9 | 25.4 | 42.5 | 1.3 | 0.5 | 1.8 | 15.2 |  | 17.0 | 59.5 |
| 1970 | 34.9 | 4.0 | 38.9 | 13.4 | 37.3 | 89.6 | 3.0 | 0.3 | 3.3 | 22.0 |  | 25.3 | 114.9 |
| 1971 | 27.4 | 3.6 | 31.0 | 20.0 | 82.2 | 133.2 | 2.0 | 0.2 | 2.2 | 16.7 |  | 18.9 | 152.1 |
| 1972 | 33.4 | 0.0 | 33.4 | 23.2 | 69.9 | 126.5 | 2.8 | 0.2 | 3.0 | 29.0 |  | 32.0 | 158.5 |
| 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 | 150.7 |
| 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 | 107.1 |
| 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 | 154.6 |
| 1976 | 43.9 | 6.1 | 50.1 | 17.9 | 141.8 | 209.8 | 7.7 | 0.4 | 8.1 |  | 10.9 | 19.0 | 228.8 |
| 1977 | 32.1 | 0.9 | 33.0 | 14.3 | 84.0 | 131.3 | 5.3 | 1.3 | 6.6 | 53.6 |  | 60.2 | 191.5 |
| 1978 | 29.8 | 3.8 | 33.6 | 8.3 | 62.8 | 104.7 | 3.5 | 0.0 | 3.5 | 15.1 |  | 18.6 | 123.3 |
| 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 | 197.0 |
| 1980 | 28.4 | 3.9 | 32.3 | 8.0 | 68.4 | 108.7 | 10.0 | 0.8 | 10.8 | 42.2 |  | 53.0 | 161.7 |
| 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 | 217.4 |
| 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 | 194.9 |
| 1983 | 37.4 | 1.2 | 38.6 | 5.9 | 14.0 | 58.5 | 6.3 | 1.3 | 7.6 | 49.9 |  | 57.5 | 116.0 |
| 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 | 220.1 |
| 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 | 191.3 |
| 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 | 219.2 |
| 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 | 104.5 |
| 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 | 196.9 |
| 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 | 158.6 |
| 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 | 240.3 |
| 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 | 172.6 |
| 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 | 215.1 |
| 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 | 172.7 |
| 1994 | 12.8 | 12.5 | 25.3 | 15.1 | 36.6 | 77.0 | 5.6 | 08 | 64 | 290 | 56 | 47.4 | 124.4 |
| 1995 | 21.9 | 12.5 | 34.4 | 4.7 | 22.1 | 61.2 | 3.7 | 0.8 | 4.5 | 17.6 | 6.5 | 33.1 | 94.3 |
| 1996 | 33.6 | 12.5 | 46.1 | 12.0 | 117.7 | 175.8 | 2.1 | 0.8 | 2.9 | 46.8 | 4.0 | 56.5 | 2323 |

a maximum 12.5 million fry based on 25,000 females at 3080 eggs per female and $16.2 \%$ egg-to-fry survival (data from above fence in 1984-1993)
${ }^{\text {b }}$ maximum 0.8 million fry based on 2,500 females at 3080 eggs per female and $10.4 \%$ egg-to-fry survival (data from above fence in 1984-1993)

Appendix 3. Escapements, total stock sizes and exploitation rate by calendar year

|  | Skeena | Skeena Sockeye Stock Size |  |  |  |  | Exploitation | Babine |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Year | Escapement | Age 3 | Age 4 | Age 5 | Other | Total | Rate | Stock Size |
| 1970 | 678652 | 166000 | 925392 | 453946 | 106905 | 1652243 | 0.54 | 1503619 |
| 1971 | 821850 | 54600 | 1129289 | 758599 | 95334 | 2037822 | 0.59 | 1839500 |
| 1972 | 697237 | 258700 | 420678 | 1231737 | 83201 | 1994317 | 0.60 | 1820755 |
| 1973 | 820196 | 208350 | 1153052 | 1057572 | 237767 | 2656740 | 0.67 | 2411901 |
| 1974 | 723898 | 256772 | 831757 | 1628184 | 92115 | 2808829 | 0.72 | 2553623 |
| 1975 | 822633 | 137396 | 1127097 | 364197 | 27455 | 1656145 | 0.46 | 1504270 |
| 1976 | 575590 | 255458 | 548679 | 924801 | 31281 | 1760219 | 0.62 | 1609743 |
| 1977 | 951805 | 47697 | 1131537 | 1293885 | 71222 | 2544341 | 0.62 | 2294677 |
| 1978 | 424075 | 296274 | 263777 | 864870 | 55652 | 1480573 | 0.64 | 1362143 |
| 1979 | 1166236 | 90509 | 2498508 | 313432 | 112656 | 3015104 | 0.60 | 2722645 |
| 1980 | 542164 | 233886 | 288034 | 1092804 | 92271 | 1706995 | 0.63 | 1559684 |
| 1981 | 1424509 | 155395 | 3177365 | 411161 | 91119 | 3835040 | 0.61 | 3467076 |
| 1982 | 1140737 | 60223 | 621563 | 3039052 | 124433 | 3845271 | 0.70 | 3466766 |
| 1983 | 893724 | 353135 | 755494 | 1310373 | 83927 | 2502929 | 0.58 | 2287950 |
| 1984 | 1055215 | 120752 | 1451716 | 788985 | 151587 | 2513040 | 0.56 | 2273811 |
| 1985 | 2174806 | 66714 | 1733185 | 3323273 | 76072 | 5199244 | 0.58 | 4685991 |
| 1986 | 716312 | 88125 | 611270 | 116550 | 57854 | 1873799 | 0.60 | 1695232 |
| 1987 | 1324128 | 638641 | 977637 | 1276820 | 74940 | 2968038 | 0.43 | 2735098 |
| 1988 | 1417543 | 77631 | 2627321 | 1070368 | 157997 | 3933317 | 0.63 | 3547748 |
| 1989 | 1137994 | 122711 | 871807 | 1630157 | 107649 | 2732324 | 0.56 | 2471363 |
| 1990 | 989566 | 89631 | 817553 | 1627596 | 183654 | 2718434 | 0.62 | 2455554 |
| 1991 | 1232568 | 416049 | 887664 | 2480221 | 300839 | 4084773 | 0.66 | 3717901 |
| 1992 | 1550109 | 258240 | 1671873 | 2020415 | 731657 | 4682185 | 0.65 | 4239791 |
| 1993 | 1629426 | 90580 | 1598624 | 2895397 | 400844 | 4985445 | 0.67 | 4495959 |
| 1994 | 1026816 | 320804 | 646101 | 1873677 | 199919 | 3040500 | 0.62 | 2768530 |
| 1995 | 1720292 | 542895 | 2286244 | 2099914 | 377430 | 5306482 | 0.64 | 4830123 |
| 1996 | 1782357 | 43000 | 3701513 | 2740730 | 449405 | 6934647 | 0.74 | 6245482 |

Appendix 4. Babine sockeye fence counts and adult returns by brood year.

| Brood | Fence | Adult Returns |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Year | Count | Age 3 | Age 4 | Age 5 | Total |
| 1950 | 364356 | 28000 | 469257 | 148222 | 645479 |
| 1951 | 141415 | 10000 | 46463 | 67201 | 123665 |
| 1952 | 349011 | 31000 | 434217 | 200633 | 665850 |
| 1953 | 686586 | 18000 | 506219 | 799712 | 1323932 |
| 1954 | 493677 | 50000 | 603269 | 695721 | 1348990 |
| 1955 | 71352 | 31000 | 214794 | 126156 | 371950 |
| 1956 | 355345 | 32000 | 309078 | 318483 | 659561 |
| 1957 | 433149 | 49000 | 1410864 | 566607 | 2026471 |
| 1958 | 812050 | 28000 | 463162 | 148568 | 639729 |
| 1959 | 782868 | 46000 | 547639 | 1064682 | 1658321 |
| 1960 | 262719 | 173000 | 416160 | 281810 | 870970 |
| 1961 | 941711 | 60000 | 584313 | 437073 | 1081387 |
| 1962 | 547995 | 64000 | 490567 | 846472 | 1401038 |
| 1963 | 588000 | 182000 | 877467 | 1143762 | 2203229 |
| 1964 | 827437 | 29300 | 179053 | 459616 | 667969 |
| 1965 | 580000 | 53400 | 671660 | 362169 | 1087229 |
| 1966 | 389000 | 154000 | 740532 | 633713 | 1528244 |
| 1967 | 602807 | 166000 | 936606 | 960300 | 2062906 |
| 1968 | 552000 | 54600 | 332547 | 848039 | 1235187 |
| 1969 | 634000 | 258700 | 1034572 | 1354501 | 2647773 |
| 1970 | 662000 | 208350 | 748582 | 327777 | 1284709 |
| 1971 | 816000 | 256772 | 1014387 | 832321 | 2103481 |
| 1972 | 680145 | 137396 | 493811 | 1164496 | 1795703 |
| 1973 | 797461 | 255458 | 1018383 | 778383 | 2052224 |
| 1974 | 726990 | 47697 | 237400 | 282088 | 567185 |
| 1975 | 820795 | 296274 | 2248657 | 983524 | 3528455 |
| 1976 | 580597 | 90509 | 259230 | 370045 | 719784 |
| 1977 | . 937992 | 233886 | 2859629 | 2735147 | 5828662 |
| 1978 | 401318 | 155395 | 559406 | 1179336 | 1894137 |
| 1979 | 1160966 | 60223 | 679944 | 710087 | 1450254 |
| 1980 | 526259 | 353135 | 1306544 | 2990945 | 4650624 |
| 1981 | 1432734 | 120752 | 1559867 | 1004895. | 2685514 |
| 1982 | 1136835 | 66714 | 550143 | 1149138 | 1765995 |
| 1983 | 886393 | 88125 | 879873 | 963331 | 1931329 |
| 1984 | 1052385 | 638641 | 2364589 | 1467142 | 4470372 |
| 1985 | 2148044 | 77631 | 784626 | 1464836 | 2327093 |
| 1986 | 701507 | 122711 | 735798 | 2232199 | 3090707 |
| 1987 | 1307852 | 89631 | 798898 | 1818373 | 2706902 |
| 1988 | 1408879 | 416049 | 1504686 | 2605857 | 4526592 |
| 1989 | 1132316 | 258240 | 1438761 | 1686309 | 3383310 |
| 1990 | 978646 | 90580 | 581490 | 1889922 | 2561993 |
| 1991 | 1176318 | 320804 | 2057619 | 2466657 | 4845080 |
| 1992 | 1233785 | 542895 | 3331361 |  |  |
| 1993 | 1737426 | 43000 |  |  |  |
| 1994 | 1052905 |  |  |  |  |
| 1995 | 1737009 |  |  |  |  |
| 1996 | 2056205 |  |  |  |  |
| 1997 | 1086610 |  |  |  |  |


[^0]:    ${ }^{\mathrm{b}}$ Minimum estimate. Flooding conditions resulted in early termination of the program, but after normal peak of migration.

[^1]:    ${ }^{a}$ see Figures $19-21$ for full cumulative probability

