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Stock Status of Fraser River Sockeye

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ABSTRACT

Cass, A. J. 1989. Stock Status of Fraser sockeye. Can. Tech. Rep. Fish. Aquat. Sci. 1674: 106 p.

This report presents the first formal resource assessment of Fraser River sockeye salmon since the signing of the Canada-U.S. fishing treaty in 1985. The Ricker stock-recruitment model was used to evaluate the productivity of 22 stocks. For many stocks there was considerable uncertainty in the spawner-return relationship and thus the estimates of optimal escapement. This is related to two phenomena. First is variability in stock-recruitment data caused by variable environmental effects on survival and measurement errors in the data. Second, and most serious concern, is the potential influence of year-class interaction and its effect on cyclic variation in abundance. Except for lower Fraser River stocks, where recent declines in returns have occurred, all stocks (where data exists) have remained stable or have shown increases since 1952. However, increases have mainly occurred on the dominant cycles. If a single spawner-recruit curve is appropriate then the stocks have been overfished and the opportunity for rebuilding is tremendous. Rebuilding on off-cycle lines is recommended in concert with an experimental design to identify factors influencing productivity.

RÉSUMÉ

Cass, A. J. 1989. Stock Status of Fraser sockeye. Can. Tech. Rep. Fish. Aquat. Sci. 1674: 106 p.

Le présent rapport porte sur la première évaluation formelle des ressources en saumon nerka du fleuve Fraser depuis la signature du traité canado-américain sur la pêche en 1985. Le modèle de recrutement des stocks de Ricker a été utilisé pour évaluer la productivité de 22 stocks. Pour de nombreux stocks, on a constaté une incertitude considérable dans la relation reproducteurs-retours et, par conséquent, dans l'estimation des échappés optimales. Cette situation est liée à deux phénomènes : 1° des erreurs de mesure dans les données et la variabilité dans les données sur le recrutement des stocks causée par des effets environnementaux variables sur la survie et 2°, ce qui est une source de préoccupation plus importante, l'influence possible de l'interaction des classes d'âge et ses effets sur la variation cyclique de l'abondance. Sauf pour ce qui est des stocks du cours inférieur de fleuve Fraser, où un déclin dans le nombre de saumons de retour est survenu récemment, tous les stocks (pour lesquels on dispose de données) sont demeurés stables ou ont connu une augmentation depuis 1952. Cependant, les augmentations sont survenues principalement au cours des cycles dominants. Si une seule courbe reproducteurs-recrues est appropriée, alors les stocks ont été surexploités et la possibilité de reconstitution des stocks est formidable. Il est recommandé de reconstituer les stocks à partir des lignées hors cycle (années de faible abondance) en ayant recours à une conception expérimentale permettant d'identifier les facteurs qui influent sur la productivité.

INTRODUCTION

FRASER RIVER Sockeye

This report presents the first formal resource assessment of Fraser River sockeye by the Department of Fisheries and Oceans (DFO) since the signing of the Canada-U.S. fishing treaty in 1985. A draft of the report was presented to the Pacific Stock Assessment Review Committee (PSARC Working Paper S88-1) in February 1988. The assessment comes at a time when rebuilding strategies of Fraser sockeye stocks are being developed by the DFO. Rebuilding policies of Fraser sockeye are one of the most important issues concerning west coast fisheries.

Sockeye salmon production from the Fraser River support the most valuable commercial fishery in British Columbia and during 1975-86 accounted for 62% of the sockeye catch. The landed value of the Canadian commercial catch from the Fraser River during that period averaged \$37 million/yr. The Canadian commercial catch averaged 4.2 million fish/yr. The combined Canada-U.S. catch averaged 5.9 million fish/yr. Fraser River sockeye are also an important Indian food fishery. The average catch in the Indian food fishery during 1975-86 was 340,000 fish/yr.

This report follows nearly 50 yrs of management and data collection by the International Pacific Salmon Fishery Commission (IPSFC). Throughout that period the data used for resource assessment remained somewhat of an enigma to the DFO. The first part of this report summarizes the methods used by the IPSFC to collect data for resource assessment. The second part of this report gives an historical perspective of the fishery and issues affecting management of Fraser River sockeye. The third part presents an assessment of the productivity for 22 river-lake systems in the Fraser River watershed based on the relationship between spawning escapement and subsequent returns for the spawning years 1948-52. The report concludes with a summary of information and research needs along with recommendations for management of the Fraser River sockeye resource.

It is important to note that the transfer of management responsibilities to DFO was a recent event and a review of the data is currently in progress. Results presented here must be viewed as preliminary pending the completion of the review.

DATA SOURCES

Intensive commercial exploitation of Fraser River sockeye began with the development of canning facilities in the 1860s (Rounsefell and Kelez, 1938). There is considerable uncertainty in the estimates of the catches and particularly the escapements during the early years of the fishery. The spawning escapements for most stocks were estimated annually by the IPSFC since 1938. The catch by stock and age class were estimated since 1952. In this report, the relationship between spawning escapement and total returns (catch plus escapement) were used to assess the productivity of 22 Fraser sockeye stocks. The trend in catch, returns and escapement of Fraser River sockeye during 1915-86 are shown in Fig. 1. Annual 1948-85 escapements, returns and returns per spawner for each stock are listed in Appendix A.

ESTIMATES OF SPAWNING ESCAPEMENT

Escapement data for Fraser River sockeye are the most extensive of any system on the Pacific coast. Each year spawning escapements are estimated in about 100 streams. An historical perspective on the methods used to enumerate spawning escapement is presented in Howard and Chapman (1948) and Schaefer (1951). The following description of procedures used to estimate escapement summarizes a recent review by Andrew and Webb (1987).

Procedures used by the IPSFC included Petersen mark-recapture experiments, live and dead counts, fence counts and aerial surveys. The choice of enumeration methods used each year for a given stock is based on several criteria (Table 1). The quality of escapement data is largely dependent on the method of enumeration. Although the level of uncertainty in the data has not been evaluated, large scale Petersen mark-recapture experiments are likely more accurate than live and dead counts.

The Petersen method (Ricker 1975) is generally used if the number of spawners are predicted to be greater than 25,000 fish. Petersen estimates are performed by tagging about 1% of the number of spawners expected along with a recovery of 10-40% of the carcasses.

Adjustments to the escapement estimate are often made to account for straying of tagged fish to other streams and to estimate the numbers of precocious, age-3 males (jacks) when small numbers are present. The number of tagged strays is estimated by the equation

$$(1) \quad S_a = R_b / M_b \times N_b ;$$

where, S_a = stray tags from stream a

R_b = tagged recoveries at stream b

M_b = total dead recoveries at stream b

N_b = escapement estimate at stream b

The number of strays is then subtracted from the tags applied at stream a.

Jack abundance has often been used as a predictor of adult returns in the following year. In streams where there are a low number of jacks there are often a small number of tags applied to jacks and little or no recovery of tagged jacks. In this situation the jack population are frequently estimated by the equation

$$(2) \quad J = M \times F \times P ;$$

where, J = jack escapement

M = total dead recoveries of jacks

F = availability factor determined by comparing

escapements using Petersen estimates and calculations based on the male recovery ratio

P = male tag recoveries / males tagged

An availability factor (F) of 1.26 was determined in the 1970s from tagging programs on the Chilko, Birkenhead, Weaver and Adams systems. These systems have large populations of jacks.

Most streams are enumerated using live and dead counts. As fish move into the spawning areas live counts are made at periodic intervals. When carcasses start to occur they are pitched and counted. The period of peak live count plus the cumulative sum of the carcasses to that date are used

along with a calibration factor determined from tag recovery experiments to estimate escapement. The calibration factor is calculated by the equation

$$(3) \quad F = N / L + D ;$$

where, F - calibration factor

N - Petersen estimate

L - peak live count

D - cumulative dead count

The calibration has been made on a number of systems on various occasions. Factors of 1.8 and 1.9 have been used on the Stuart system. Factors of 1.8 have been used on other systems.

The dead pitch, among other things, provides data on the sex ratio and estimates of the proportion of females that have spawned (effective females). In this analysis estimates of the spawning escapement of effective females was used as a measure of parental stock. Recruitment was calculated as the catch plus total escapement of the returning progeny summed over all age groups.

ESTIMATES OF CATCH

Fraser River sockeye are caught in mixed-stock fisheries in coastal British Columbia as maturing fish migrate to their stream of origin. The stock composition of the catch was historically estimated by the IPSFC using scale traits established during freshwater life coupled with estimates of run timing and run size. The sampling methods used for scale collections are given in Clutter and Whitesel (1956). The analytical procedures used to separate the stocks using scale traits are presented in Henry (1961).

In-season management of Fraser River sockeye fisheries is the responsibility of the Pacific Salmon Commission. Samples from commercial catches and test fisheries provide the basic data to allocate the catch to the various stocks and estimate the age composition. Samples of 120 to 240 sockeye are collected weekly from as many as 12 commercial fisheries and daily from 3 test fisheries (Woodey 1987).

Circuli counts from the freshwater growth zones on scales were the principal traits used to identify stocks. The frequency distribution of circuli counts collected from the fisheries were compared to the frequency distribution of circuli from scales collected from discrete stocks on the spawning grounds. Scales from age-3 jacks collected each year from the spawning grounds were used to identify age-4 adults of the same cohort in the following year's fishery. The pre-season forecast of stock abundance, the estimated run timing and migration patterns of the stocks were used to graphically identify the modes in the frequency distributions.

At the completion of the fishery the data are re-analyzed using scales from adults of the same age collected from the spawning grounds. Woodey (1987) reports that the pre-season estimates of stock composition generally agrees with the post-season results. The final estimates of recruitment are based on the post-season analysis. To estimate the returns by brood year, the catches are summed across each age group in a cohort to estimate the total returns by brood year.

Other methods of stock identification that use newly developed technologies are currently being investigated by the Pacific Salmon Commission (Cook and Guthrie 1987) and the DFO. A comparison of stock composition estimates using maximum likelihood procedures (Fournier et al. 1984) with the

estimates derived using historical methods is currently underway. The procedure may be useful to quantify and correct for possible biases in the historical catch records.

HISTORY OF THE FISHERY AND MANAGEMENT

Prior to the devastation of salmon stocks in 1913 with the obstruction at Hell's gate, the dominant runs (1901 cycle) were reported by Ricker (1987) to be 100 million sockeye with catches in the range of 35-50 million sockeye. Ricker estimated the dominant runs to be 20 times larger than the three other cycle years. The IPSFC (1973) reported catches in 1913 of about 30 million sockeye. As a result of habitat destruction, the most notable being the effect of the Hell's Gate slide in 1913, and overfishing in the years that followed, catches declined (Ricker 1987; Thompson 1945). Catches during 1915-30 averaged 1.9 million fish/yr for all cycles. During 1930-50 catches increased to an average of 2.6 million (Killick and Clemens 1963).

All stocks upriver from Hell's Gate remained at low levels until 1926, when a relatively large escapement was reported on the Lower Adams River (Larkin and Ricker 1964). Subsequently, escapement levels were variable but continued to increase. The largest escapement to the Fraser River in recent history was 4.0 million in 1958 of which 2.5 million was for the Lower Adams. Escapement to the Lower Shuswap River increased from 9,000 - 30,000 spawners on the dominant cycle in the 1950s and 1960s to 514,000 spawners in 1982 (IPSFC 1983). Escapements to the Chilko River began to increase in the 1930s as did other stocks. However, sustained increases in upriver stocks were affected by the mortalities incurred from obstacles at Hell's Gate. Following construction of the fishways in the Fraser canyon along with a 5-year fishing closure on early and mid-season runs during 1946-50 there was a marked increase in all runs.

The dynamics of Fraser River sockeye are characterized by a 4-yr cycle in abundance in many Fraser tributaries. The persistence of the classic dominant-subdominant-off-off cycle is most notable in the Lower Adams River run but is also prominent in the Lower Shuswap, Stuart and Horsefly systems. Strong variation in year-class strengths have occurred in other river-lake systems, but not in the same cyclic pattern observed for the Adams, Stuart and Horsefly systems.

The DFO is presently developing strategies to rebuild year classes on off cycle years. The significance of interactions among adjacent year classes that rear in the same lake, otherwise known as "cyclic dominance", is the most important issue concerning the development of rebuilding plans. Ward and Larkin (1964) hypothesize that depensatory predation in the fry to smolt stage is responsible for cyclic dominance. Walters and Staley (1987) hypothesize that cyclic dominance could be caused by depensatory fishing mortality. Extensive research by the IPSFC (IPSFC 1976) has failed to resolve the issue. Collie and Walters (1987), in a simulation study, concluded that with the existing time series of escapement and return data, neither the depensatory predation nor the depensatory fishing hypotheses can be rejected as causes of cyclic dominance in Adams River sockeye. They evaluated various management strategies for Adams River sockeye by comparing simulation results using the Ricker model and Larkin's (1971) version of the Ricker model that includes lag terms for measuring interactions among year classes. Their results indicated that a high and constant harvest rate is sufficient to maintain cyclic

dominance. Although, they found evidence for both depensatory fishing and predation, depensation was not a prerequisite for the persistence of cyclic dominance in Adams River sockeye.

PRODUCTIVITY EVALUATIONS

RETURNS PER SPAWNER MODELS

Several models describing the relationship between escapement (stock) and subsequent returns (recruitment) are proposed for fish populations (see Ricker 1954; Beverton and Holt 1957; Ward and Larkin 1964; Larkin 1971; Paulik, 1973; Ware 1980; Shepherd 1982). The most common models fit to these data are the "Ricker model" (Ricker 1954) and the "Beverton-Holt model" (Beverton and Holt 1957). In the Ricker model, recruitment declines as stock size increases forming a "dome-shaped" relationship. In its linear form the Ricker model is

$$(4) \quad \ln(R_t/S_t) = a - bS_t + \sigma\epsilon ;$$

where, R_t = returns in year t ,

S_t = spawning stock that produced R_t ,

a = density independent parameter,

e^a = returns/spawner at low stock size,

b = density dependent parameter equal to

the slope of the regression,

σ = standard deviation of the residuals,

ϵ = independent normally distributed random variable

with mean 0.0 and variance 1.

Larkin (1971) proposed a Ricker model with additional terms to account for possible interactions among year classes. Larkin's model can be written as

$$(5) \quad \ln(R_t/S_t) = a - b_0 S_t - b_1 S_{t-1} - b_2 S_{t-2} - b_3 S_{t-3} + \sigma\epsilon ;$$

where, b_t , b_{t-1} , etc. are coefficients of interactions among year classes such as predation or competition.

The Beverton-Holt model assumes that the rate of increase in returns per spawner declines asymptotically as escapement increases. The curve defined by the Beverton-Holt model forms a hyperbola. The best estimation equation that preserves the multiplicative error assumption is

$$(6) \quad \ln(R_t) = \ln((aS_t)/b+S_t) + \sigma\epsilon ;$$

where, a = parameter equal to the maximum

recruitment as S goes to infinity,

b = parameter is value of S at which

$a/2$ recruits are produced.

Theoretically, the Ricker and Beverton-Holt models characterize two diverse forms of density dependency. The weakness of the Ricker and Beverton-Holt is the failure to account for potential interactions among year classes. Larkin's form of the Ricker model, while presupposing the same form of density dependency as the original Ricker model, measures first order interactions among year classes. The extra b parameters are surrogates for the effects of predators. A weakness of the Larkin model is that the predators themselves are not represented. Only the potential effects of predators on prey are represented. Another practical limitation is the inability to compute precise estimates of optimal escapement or maximum catch. Collie and Walters (1987) describe a "brute-force" method for calculating maximum catch in Adams River sockeye.

Despite years of research by the IPSFC, there are no data to determine which recruitment model best describes the form of density dependency or depensation controlling the dynamics of Fraser River sockeye. Measurement errors in stock-recruitment data generally mask the true form of density dependency (Walters 1986).

Monte Carlo simulations were performed to compare the fit of the Ricker and Beverton-Holt models to simulated data with comparable variance and harvest rates observed in Fraser sockeye escapement and return data. Simulations of 100 data sets were performed using the Beverton-Holt relationship. For each data set, 34 stock-recruitment data pairs were simulated corresponding to the observed time series of data available for Fraser River sockeye. Each data set was simulated by assuming a random, log-normal error and with $\sigma = 0.5$ and a 70% harvest rate. Recruitment parameters were selected to correspond to observed ranges for sockeye. Each simulation was started with a stock size of $S = 1.0$. For each simulated data set, 40 data pairs were generated and then the next 34 data pairs were accumulated for use in the regression to allow the dynamics of the simulations to stabilize at the desired level. The Beverton-Holt and the Ricker model were then fit to each data set. The performance of the two models were evaluated by comparing the mean of the sum of squares of the residuals for 100 data sets.

The simulation results indicate that the level of variance inherent in Fraser River escapement and return data is not adequate to distinguish the correct form of density dependency. The difference between the sums of squares was negligible and independent of the "a" and "b" parameters used in the simulations. Although more complex models may provide better fits to particular data sets, they will not identify the form of density dependency inherent in Fraser River sockeye stocks because of the large variance in the data.

The use of the Beverton-Holt model was abandoned in favour of the Ricker model under the assumption that recruitment declines at high levels of spawning escapement. There is crude evidence for low recruitment following high escapements in some Fraser River stocks (i.e. Adams River, Chilko River, Stellako River). We also abandoned the Larkin model because of the computational short-comings. Collie and Walters (1987) have demonstrated that it is not possible to determine whether the Ricker model or the Larkin model correctly encapsulates the dynamics of Fraser River sockeye. Nevertheless, because the Ricker model does not account for possible interactions among year classes, estimates of maximum catches derived from the Ricker model are more optimistic than suggested by the Larkin model.

ESTIMATING BIASES IN STOCK-RECRUITMENT PARAMETERS

Three sources of bias identified in fitting stock-recruitment curves to data are (1) measurement errors in estimates of spawning escapement (2) correlations among residuals and subsequent levels of spawning escapement and (3) autocorrelations among residuals (Walters and Ludwig 1981; Ludwig and Walters 1981, Walters 1985). All the causes of bias lead to an overestimate of the density dependent parameter, b .

Unfortunately, little can be done to correct for bias caused from measurement errors in the historical data. Using procedures similar to Walters and Staley (1987) we investigated the significance of bias caused from correlations among residuals and subsequent escapement.

Monte Carlo simulations were performed to estimate the bias over a range of a and b parameters. Simulated data sets were generated using the two equations

$$(7) \quad S_t = S_{t-1} e^{a - b S_{t-1} + \sigma \epsilon}; \quad \text{where } \epsilon \sim N(0, 1)$$

$$(8) \quad R_t = S_t * (1 - h_t); \quad \text{where } h_t \sim U(0, 1)$$

where; h_t = harvest rate in year t .

Parameters a and b were re-estimated using standard linear techniques as described above. For a and b values typical of Pacific salmonids ($a=1.0$ to 3.5 , $b=0.05$ to 1.0) 100 data sets were generated using two levels of exploitation. Simulations were performed at the optimal h and at $h=10\%$ greater than optimal rate for each parameter combination. Nine and 34 stock-recruitment data pairs were generated at each level of exploitation for a total of four possible scenarios. These sample sizes are equal to the number of data pairs available on each 4-yr cycle and for all years combined, respectively. Simulations were started with $S=1.0$ and $\sigma=0.7$. Simulations of 40 data pairs were generated before accumulating the data pairs used to re-estimate the recruitment parameters. At each of the four scenarios 100 data sets were generated. The average of the re-estimated a and b parameters was then used as a measure of bias. The results of each simulation are presented in Appendix B.

There were no parameter combinations for which the mean of the biased parameters were statistically different ($p>0.05$) from the true parameters in either of the 4 scenarios. As reported by Walters (1985), the bias resulted in overestimates of a and particularly b and thus underestimates of optimal escapement. Simulations performed by holding spawning escapements at the optimal level and simulating 34 data pairs resulted in relatively small biases at Ricker a values typical for Fraser River sockeye ($a = 2.0 - 3.0$). In this scenario the Ricker b parameter was overestimated by an average of 3-6%. At sample sizes of 9 data pairs the bias increased by an average of 17-25%. Under the scenario of overexploitation the bias in b with 34 data pairs averaged 15-390%. For simulations using 9 data pairs, the bias in b was much greater and averaged 80-560% in the range of 2.0 - 3.0. These results suggest the bias is profoundly affected by sample size and the level of stock size compared to the equilibrium stock size. In overexploited stocks the stock-recruitment curve would create the false impression that stocks would not recover appreciably following reduced fishing pressure.

Simulations were also performed to estimate and correct the bias. For simulations using all-years data, the observed estimates of effective female escapement for the first four years in the time series were used to generate a

time series of stock-recruitment data pairs equal to the number of observed data pairs for each stock. For simulations of the cycle year runs, the first year in the time series was used to generate stock-recruitment data pairs for each of the cycle years. The observed estimates of σ , the annual estimates of h and the annual proportion of effective females were used to simulate each data set. The a and b parameters were then estimated as the mean of 1000 simulations. The observed bias was generally consistent with results presented above (Table 2). The bias was largest in the density dependent parameter b . The range of bias in b for all years of data combined was from <1% for the early Chilko, Harrison, Gates and Upper Pitt River stocks to 36% for the Late Stuart stock and 38% for the Lower Adams River stock. The largest bias was for cycle years data and ranged from <1% to over 500% for the Late Stuart.

A procedure used by Walters and Staley (1987) was used to investigate bias in recruitment curves when fit to stocks with abundance estimates below the unfished equilibrium. Recruitment curves were simulated for each of the cycles for stocks that have dominant and "off-cycle" runs. The a and b parameters and σ were estimated from the time series of all-years data using standard regression techniques. The escapement in the first year in the historical time series was used as the initial stock size and the observed time series of exploitation and the proportion of effective females was used to generate 9 fake stock-recruitment data pairs for each stock. The a and b parameters were fit to data for all years and to each of the four cycle years. Simulation were repeated 1000 times to estimate the average bias in the a and b parameters.

There were no significant differences ($p>0.05$) in the a or b parameters. However, there were extremely large positive biases in b that caused the recruitment curves to bend at fractions of the true curve in every stock (Table 3). The influence of bias is illustrated for the Chilko River and Lower Adams stocks in Fig. 2. As concluded by Walters and Staley (1987), the bias appears to depends on stock size in relation to the unfished equilibrium.

To address the third source of bias mention above, the autocorrelation of the residuals was calculated by fitting the Ricker model to stock-recruitment data for all years combined in each stock. Significant deviations particularly at a lag of 4 years would imply a cyclic pattern in abundance and suggest separate stock-recruitment relationships among cycles. For each time-lag the autocorrelation was calculated using the equation

$$(9) \quad r_k = \frac{1}{N-k} \sum_{t=1}^{N-k} v_t v_{t+k} / v_t^2$$

where, r_k = autocorrelation at lag k years.

v_t = residual at year t .

N = no of years in time series.

(source: Box and Jenkins 1976)

There were no significant differences in the autocorrelations for any of the stocks. With the exception of the Horsefly River, there was no evidence for the existence of cycles (Table 4).

ESTIMATING OPTIMAL ESCAPEMENT

Estimates of spawning escapement were calculated for each stock for all years combined and for each cycle. By definition, the optimal spawning escapement is equal to the escapement where the slope of the recruitment curve is equal to 1. By setting the first derivative of the recruitment equation equal to 1, the optimal escapement, S^* , is calculated by the equation

$$(10) \quad S^* = 1 - (1 - aS^*/b)\exp(1-S^*/b + (\sigma^2/2)) .$$

The estimates of optimal escapement corrected for time series bias were most often higher than the uncorrected estimates (Table 5). There were no significant biases in any of the stocks ($p > 0.05$) and except for the late Stuart and Lower Adams stocks, the bias was negligible for most stocks when using data for all years. The bias corrected estimate was 57% higher for the late Stuart stock and 52% for the Lower Adams stock. The bias in the cycle year estimates were also negligible for most stocks but there were also some extremely large biases. For example, the Raft, Late Stuart and Bowron stocks had biases in excess of 100%. The bias for the 1985 cycle of the late Stuart stock was 530%.

STOCK STATUS

In the following section the trend in returns and escapements for each stock are discussed in relation to the preceding stock-recruitment analysis. The mean historical escapements and catches for each stock (1948-85) are compared to the optimal escapements and corresponding maximum catches in Table 6. For all stocks the estimated optimal escapements were larger than the historical mean escapements (adult males plus females). The sum of the mean escapements for all stocks of 1.3 million adults was 18% of the corresponding estimates of the optimal escapement. The sum of the mean catches for all stocks of 5.1 million adults was 30% of the theoretical maximum catch of 16.7 million adults.

Stuart, Trembleur and Takla Lakes

Two runs to the Stuart, Trembleur and Takla lake systems are identified from run timing and spawning distribution. An early run (early Stuart) utilizes more than thirty small streams primarily on Takla Lake. The largest single spawning area in the early Stuart system is on the Driftwood River, the most northerly spawning habitat in the Fraser River watershed. The late run (late Stuart) utilizes a smaller number of streams on Stuart and Trembleur Lakes.

Although individuals spawning areas have dominant and off-cycle runs that are not necessarily in-phase, both the early and late Stuart runs were, collectively characterized by a dominant 1985 cycle. All other cycles, particularly in the late Stuart system, have been minor producers. Returns to the early Stuart (Fig. 3a) and late Stuart systems (Fig. 4a) have been highly variable with no trend in abundance since 1952.

Adult returns to the early Stuart system on the 1985 cycle ranged from 256,000 in 1965 to 1.4 million in 1973. The average 1952-85 return was

809,000/yr. Spawning escapements on the 1985 cycle averaged 208,000/yr and ranged from 23,000 in 1965 to 582,000 in 1949.

The fit of the Ricker model to data for the Early Stuart run was relatively good ($\sigma=0.7$) (Fig. 3b). However, because the early Stuart population spawn in approximately 30 different streams, the optimal escapement of 420,000 adults for all streams combined may not be representative. Several small streams on the early Stuart run were over-utilized in some years while the large spawning area on the Driftwood River was under-utilized. Low resolution of individual streams in the early Stuart fishery inhibits the ability to control escapements to these streams. Increasing production by redistributing escapements amongst the early Stuart streams is therefore unlikely.

Despite an inability to control escapements to individual streams on the early Stuart system, the early Stuart run presents some unique opportunities for stock rebuilding. Collectively, the early Stuart run is the only Fraser River stock that does not co-migrate in significant numbers with other stocks. Since 1983 there has been a 50% reduction in the exploitation rates through fisheries management to increase escapement to the early Stuart system.

Adult returns to the late Stuart streams ranged from 606,000 in 1977 to 1.9 million in 1985. The average 1953-85 return was 1.3 million/yr. Escapements averaged 273,000 adults/yr. There is an extremely high level of uncertainty in the optimal escapement (662,000 adults) for the late Stuart run ($\sigma=1.3$) (Fig. 4b). There is a potential for increasing production to the late Stuart system, particularly on the off-cycles. However, there is much less ability to control escapements from the late Stuart run because the run-timing overlaps with other major stocks.

The Fraser-Francois (Nechako) system

Two spawning areas enumerated in the Nechako system are on the Nadina and Stellako rivers. The Nadina River historically supported an early and late run. The early run is now of minor importance and escapement estimates are included with estimates for the late run. The loss of the early run is believed to be the result of habitat degradation from logging (Williams pers. com.). A spawning channel designed for 14,000 females was constructed in on the Nadina River 1973 to increase utilization of the rearing area in Francois Lake (Cooper 1977). Most sockeye production since 1973 has been from the spawning channel. Returns to the Nadina River averaged 56,000/yr during 1952-85. The 1985 and 1987 cycles produced the largest returns, however, returns on the 1986 and 1988 cycles have increased since the early 1960s (Fig. 5a). Our estimate of the optimal escapement of 22,000 adults (Fig. 5b) is near the average for the 1985 and 1987 cycles.

The trend in production from the Stellako was relatively constant and averaged 419,000 returns/yr since 1952. The 1986 and 1987 cycles produced the major runs (Fig. 6a). Average returns on these cycles were 526,000/yr and 718,000/yr, respectively. Returns on the 1985 and 1988 cycles averaged 274,000/yr and 192,000/yr. Escapements to the Stellako averaged 75,000/yr. The estimate of optimal escapement for the Stellako of 295,000 adults was equal to the largest observed escapement. However, the largest escapement is an outlier on the recruitment curve (Fig. 6b). The true optimal escapement for the Stellako River may be larger.

Bowron River ~~Native to salmonid streams throughout most of the basin~~
~~Native to salmonid streams throughout most of the basin~~

The average 1952-85 returns from the Bowron River were 54,000 sockeye/yr. Four cycles of the 1987 run were a dominant feature on the Bowron River beginning in 1967. Interestingly, this occurred at the same as a decline in the abundance of the minor cycles (Fig. 7a). This is similar to a situation on the Raft River system (see North Thompson) where the 1988 cycle emerged as a dominant cycle, seemingly at the expense of the other cycles. The estimated optimal escapement of 30,000 adults may be an underestimate of the true level given the variability in the observed returns/spawner for the 1987 cycle (Fig. 7b).

Quesnel Lake

The main spawning areas are the Horsefly River and, to a lesser extent, the Mitchell River. The 1985 cycle has been the main contributor to the Quesnel Lake system. Returns to the Horsefly River on 1985 cycle increased exponentially from 476,000 in 1953 to 8.1 million returns in 1985. Returns to the 1986 cycle also increased with returns in 1986 of 514,000 sockeye (Fig. 8a). The large returns in 1985 resulted in a convex recruitment curve (exponential population growth) (Fig. 8b). As a result it was not possible to estimate the optimal estimate from the Ricker model. However, the increase in the returns/spawner suggests the Horsefly may support escapements in excess of 500,000 adults/yr. The adult escapement to the Horsefly River was 1.1 million in 1985. The largest production of sockeye in the Quesnel Lake system utilize spawning grounds on the Upper Horsefly River. There is also a large under-utilized spawning area on the Lower Horsefly River that has considerable potential for sockeye production.

The Mitchell River is the only other spawning area where escapements and returns were routinely measured. The trend in production from the Mitchell River is similar to the Upper Horsefly and the 1985 cycle is the only major run (Fig. 9a). Returns to the Mitchell have increased steadily from 7,000 returns in 1957 to 1.4 million returns in 1985. Because of the exponential population growth in the 1985 cycle, optimal escapement could not be estimated (Fig. 9b). However, the optimal is likely beyond the range of observed escapements and may exceed 200,000 adults.

Chilko Lake

Relatively large returns to the Chilko River occurred on the 1987 and 1988 cycles. Escapements on these cycles have been preserved at nearly equal strengths at averages of 473,000 and 309,000 adults/yr, respectively. Returns and exploitation rates on all four cycle years have remain relatively constant since 1952 (Fig. 10a). The 1988 cycle is the most important contributor to the Fraser River fishery on that cycle.

The fit of the Ricker model to the Chilko River data is comparatively good ($\sigma=0.6$) (Fig. 10b). The estimate of optimal escapement of 798,000 adults is beyond the 1948-85 range of observed adult escapement. The largest observed escapement occurred in 1948 and was 671,000 adults.

In the early 1960s a relatively small population of lake spawning sockeye was discovered at the south end of Chilko Lake. Estimates of escapement have been made annually since 1971. The estimates during most years were from mark-recapture experiments on dead (floating) carcasses and

are likely subject to large measurement errors. Estimates of adult escapement in 1984 were the largest since enumeration began at 128,000 adults. The estimate of optimal escapement for this stock (31,000 adults) is unreliable due to the short-time series and suspected measurement errors in the data.

South Thompson (Early runs)

Of the 13 early spawning runs to the South Thompson and Shuswap Lake systems, the runs to the Seymour River and Scotch Creek were routinely enumerated.

Returns on each of the four cycles to the Seymour River have shown little trend (Fig. 11a). Returns on the 1986 and 1987 cycles were consistently larger than the other two runs and averaged 222,000/yr and 169,000/yr, respectively. Returns on the 1988 and 1985 cycle averaged 26,000 and 33,000 adults/yr. The estimate of optimal escapement of 69,000 adults is larger than observed escapements on the Seymour River. However, escapements on the 1986 cycle were 63,000 adults on the last two returns of that cycle. Average escapements to the Seymour were 43,000 adults/yr on the 1986 cycle and 34,000/yr on the 1987 cycle. Escapements to the 1988 and 1985 cycles averaged 6,000 and 7,000 sockeye/yr. There has been a steady increase in escapements on the 1988 cycle from 4,000/yr in the 1950s to 11,000 since 1976. There were some extreme deviations from the recruitment curve (Fig. 11b) but the fit of the model was relatively good ($\sigma=0.8$). Habitat degradation cause by logging in the Seymour watershed has been reported but the effect on recruitment is not known (Williams, pers com)

Returns and escapements to Scotch Creek were small compared to other Shuswap systems that are routinely enumerated (Fig. 12a). Returns on the 1985 and 1986 cycles averaged 26,000 and 14,000 sockeye/yr, respectively. Corresponding escapements averaged 5,000 and 1,000 adults/yr. Returns to the other two cycles have been negligible. There is large uncertainty in the estimated optimal escapement of 11,000 adults as reflected in the wide 95% confidence limits for the recruitment curve ($\sigma=1.6$) (Fig. 12b).

South Thompson (Late runs)

Of the 23 late spawning runs to the south Thompson River complex, the largest runs are to the lower Adams River and the lower Shuswap River. The lower Adams River population is the largest spawning population in the Fraser River system. Spawning escapement to the Lower Adams River were enumerated as a single complex that includes all other late Shuswap Lake runs except the Lower Shuswap system sockeye.

Estimates of returns to the Lower Adams complex averaged 2.1 million returns/yr since 1948. Returns were dominated by the 1986 cycle and, to a lesser extent, by the 1987 cycle. The average 1948-86 return were 6.8 million/yr on the 1986 cycle and 1.4 million/yr on the 1987 cycle. Returns on the 1985 and 1988 cycles were small in comparison and averaged 33,000 and 20,000/yr.

The 1958 escapement of 3.3 million was the largest on the 1986 cycle since 1948 and resulted in the lowest return for the cycle. Following the low returns of 1958 there was a steady increase in returns on the 1986 cycle from 2.9 million in 1968 to 8.2 million in 1982 (Fig. 13a). Escapements also increased over the same period from 1.1 million adults in 1962 to 2.5 million in 1982. Returns on the 1987 cycle increased at a similar rate as the 1986

cycle until 1971 when high exploitation reduced escapements to low levels. Since 1971, the 1987 cycle has shown modest increases.

There is considerable controversy surrounding the significance of the low returns per spawner from the 1958 brood. A fence was constructed at the outlet of the lower Adams River in 1958 to prevent over-escapement. The effect of the fence reportedly resulted in a large number of lake spawners and an unnaturally high egg mortality (Woodey, pers. com.). What ever the cause of the low returns per spawner, 1958 is an pivotal point in the stock-recruitment relationship (Fig. 13b). The estimate of the optimal escapement of 3.5 million is similar to the observed escapement in 1958. However, there is considerable uncertainty in this estimate. This is reflected in the wide 95% confidence limits for the recruitment curve and the relatively large residual standard deviation ($\sigma=1.0$).

Returns and escapements to the Lower Shuswap River increased substantially in the 1970s and 1980s. These increases occurred particularly on the 1986 cycle but also on the 1987 cycle (Fig. 14a). Returns on the 1986 cycle have increased from 50,000-126,000 in the 1950s and 1960s to 1.8 million in 1982. Escapements have increased accordingly, from under 20,000 in the 1950s to over 500,000 in 1982. There is little reliance in the estimates of optimal escapement. This is reflected in the extremely wide 95% confidence limits for the recruitment curve (Fig. 14b) and the large residual standard deviation ($\sigma=2.0$). The true optimal escapement is likely greater than 126,000 adults and, based on preliminary estimates of returns/spawner for the 1982 brood, may exceed 500,000 adults.

North Thompson

Catch and escapement data were collected from the Raft River and Fennel Creek. These systems support two small spawning populations. Beginning in 1972, the 1988 cycle for the Raft River emerged as dominant run (Fig. 15a). The increase on this cycle occurred at the same time as a decline in the abundance of the other three cycles despite no detectable trend in exploitation rates. There was a comparatively good fit of the Ricker model to data for the Raft River ($\sigma=0.7$) (Fig. 15b). Our estimate of optimal escapement of 14,000 adults is well above the 1952-85 mean of 6000 adults/yr.

Returns from Fennel Creek has increased from extremely low escapements in the 1950s and 1960s to a maximum of 73,000 adults in 1979 (Fig. 16a). The average escapement since 1970 was 4,000 adults. There is considerable uncertainty in the relationship between stock and recruits ($\sigma=1.0$) and the optimal escapement may be greater than the 4900 adults estimated from the Ricker model (Fig. 16b).

Anderson and Seton Lakes

The major spawning areas in this system are Gates Creek and Portage Creek. A spawning channel designed for 9,000 females has been operational on Gates Creek since 1968. There was a marked increase in escapement and returns on all four cycles to both systems since the mid-1960s (Fig. 17a and Fig. 18a).

The 1988 cycle is the major producer on Gates Creek and averaged 71,000 adults/yr since 1952. The spawning channel has accounted for 95% of the total production since 1968. Estimates of optimal escapement for Gates Creek of 14,000 adults is near the long-term average for the 1988 cycle. The estimate

of optimal escapement may well be an underestimate caused by outliers in the stock-recruitment curve (Fig. 17b).

Production from Portage Creek was less dependent on a single strong cycle. The average return across all four cycles was of 26,000/yr. The 1986 cycle has produced the largest average return at 50,000/yr. Escapements to Portage Creek averaged 5,000 adults/yr and were considerably less than the estimated optimal of 14,000. The extremely wide 95% confidence limits on the recruitment curve (Fig. 18b) and the large residual standard deviation ($\sigma=1.2$) imply the optimal escapement is not well determined from the stock-recruitment relationship. The curve is unduly influenced by an extreme outlier and the optimal escapement is likely underestimated.

Lillooet and Harrison Lakes

The most important spawning areas are the Weaver Creek, Birkenhead River and Harrison River systems. A spawning channel that facilitates 30,000 females has been operational on Weaver Creek since 1965. Returns and escapements to the Weaver Creek (Fig. 19a) and Birkenhead River (Fig. 20a) have increased since that time on all cycles.

Returns from Weaver Creek were largest on the 1986 cycle and averaged 353,000 adults/yr since 1948 compared to an all-year average of 208,000 adults/yr. Spawning escapements averaged 36,000 adults/yr with an average of 64,000 adults/yr on the 1986 cycle. The estimated optimal escapement based on the Ricker model (Fig. 19b) was 54,000 sockeye.

Returns and escapements to the Birkenhead River during 1948-85 averaged 364,000 and 47,000/yr, respectively. Variations in return strength among the four cycles are less apparent on the Birkenhead River compared to other systems. The average return for all cycle years ranged from 280,000 to 515,000 sockeye/yr. The estimate of optimal escapement of 108,000 adults may underestimate the true optimal due to the effect of outliers on the recruitment model (Fig. 20b).

Unlike the Weaver and Birkenhead systems, returns to the Harrison River system were relatively constant except for two years of large production in the 1950s (Fig. 21a). The average returns were 44,000/yr during 1952-86. However, the rate of returns per spawner is extremely variable (Fig. 21b). Unlike other Fraser River systems, young sockeye from Harrison River have a very short period of freshwater residency (< 1 yr). The early influence of the marine environment on survival may account for the extreme variations in the observed returns per spawner.

Lower Fraser River

The two lower Fraser systems for which data have been collected are Cultus Lake and the Upper Pitt River. Returns for both systems have declined in recent years (Fig. 23a and Fig. 24a). The decline was particularly pronounced on the Cultus Lake system since 1970.

For Cultus Lake, the average return was 11,000 adults/yr during 1974-85 compared to 113,000/yr during 1948-73. Escapements have also declined at a similar rate. Returns on the 1987 cycle have been the main producers with an average of 178,000/yr. The average for the other three cycles ranged from 33,000/yr to 100,000/yr. Cultus Lake returns on the 1988 cycle have averaged 45,000 adults/yr. The estimate of the optimal escapement for Cultus Lake of 80,000 adults is substantially higher than any recorded escapement since 1948.

Although there is uncertainty in the estimate using the Ricker model (Fig. 23b) ($\sigma=1.0$) it is clear than escapements in recent years were below the true optimal.

A small spawning channel (1,000 females) was completed in 1960 at the Upper Pitt River to halt a decline in abundance in the 1950s (Cooper 1977). Following a decline in exploitation rates, the abundance on all four cycles increased. The abundance is currently at low levels and has not responded to a decline in exploitation evident since 1977 (Fig. 23a). The average return for the Upper Pitt River was 77,000/yr since 1948. The average escapement was 21,000 adults/yr compared to the estimated optimal escapement of 20,000 adults from the Ricker model (Fig. 23b).

CONCLUSIONS AND RECOMMENDATIONS

There was considerable success at re-building returns of the major stocks on the dominant cycles since the collapse of upriver populations in the early 1900s. This was particularly evident for the Lower Adams and Shuswap Rivers and the Upper Horsefly River. Increases on the Birkenhead River and Weaver Creek also occurred. The Gates and Portage Creeks are two smaller systems that also increased in production.

The recent declines in returns from the Cultus Lake and Upper Pitt River systems warrants concern for lower Fraser River stocks. There are also upriver populations of historical significance that have remained at low levels, such as the Upper Adams and the Lower Horsefly rivers.

For many stocks there is considerable uncertainty in the correct stock-recruitment relationship and thus the estimates of optimal escapement. With few exceptions, the 95% confidence limits for the recruitment curve encompass a broad range of possible recruitment curves and imply a broad range of possible optimal escapements. This uncertainty is related to two phenomena. First, variability in stock-recruitment data caused by variable environmental effects on survival and measurement errors in the estimates of escapement and catch. Second, and most serious consideration, is the potential influence of year-class interaction and its effect on the cyclic variation observed for many Fraser River stocks. This analysis, and that of Walters and Staley (1987), show that the difference among recruitment curves could be due to biases in applying regression methods to short time-series of data where observed stock sizes are below the unfished equilibrium. Collie and Walters (1987) report the Ricker curve fails to account for year-class interactions and that with existing data neither the depensatory fishing nor depensatory predation hypotheses can be rejected as the cause of cyclic dominance. Until experiments are designed to address these issues the level of uncertainty in estimates of optimal escapement will remain high.

Environmental data was not incorporated in the present analysis. Environmental data may explain the large variation in recruits/spawner data. For example, flooding during egg incubation has reportedly effected survival, particularly on the Birkenhead, in some years (Williams, pers com). Anomalous temperature effects on survival has also been reported for other systems.

Estimates of production capacities derived from independent analysis need to be incorporated into assessment procedures. Estimates of spawning and rearing habits along estimates of optimal egg densities is a procedure currently under study (Williams, per com).

With the signing of the Canada-U.S. fishing treaty in 1985 there is now a greater benefit to Canadian fishermen to increase production of Fraser River sockeye. If a single spawner-return curve is appropriate then the stocks are being overfished and the opportunity for rebuilding the off cycles is tremendous. The potential for rebuilding stocks cannot be ignored. The greatest opportunity lies in re-building off-year runs of the major systems such as the Horsefly River and the Upper and Lower Adams River. The focus of re-building strategies should maximize natural production by increasing escapement levels through fisheries intervention. Enhancement techniques such as spawning channels and lake enrichment should also be considered. However, for most systems spawning habitat appears to be the limiting factor (Williams pers. com).

The level of allowable harvests needed to re-build the Fraser system is a function of the rate and amount of re-building as well as on the specific stocks targeted for re-building. The rate of re-building will be largely dependent on the willingness of the fishing industry to reduce the catch in the face of uncertainties in future production. The stocks with the greatest potential may not necessarily be the ones most easily regulated. There will be a need to develop an in-season plan that allows us to take advantage of those stocks with the greatest potential for re-building.

The most obvious uncertainty in re-building off-year runs is the effect of year-class interaction. It is essential to develop re-building plans in concert with an experimental design that can be used to identify factors influencing productivity.

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Table 1. Methods used to estimate spawning escapements of Fraser River sockeye.

| Stream type | Enumeration method |
|---|--|
| Large population (>25000), closed system | Petersen, sexes separate |
| Large population, but few jacks | Petersen, sexes separate for males and females, but jacks by dead recovery x availability factor x male dead recovery |
| Large population, strays to other streams | Petersen, sexes separate, but subtract stray tags from tags available |
| Large population in a complex of streams where not possible to perform tagging study on separate streams due to high degree of straying | Petersen, sexes separate on the complex, subtract out populations of streams with separate enumeration, then allocate population to remaining streams by dead recovery |
| Medium population (<25000), poor recovery of either sex | Petersen, sexes combined (not commonly used) |
| Medium population, or large population but limited access to stream | (Peak live count + cumulative dead) x factor |
| Medium population, closed system | Dead recovery x factor |
| Spawning Channel | Total dead recovery |

Table 2. Estimates of Ricker stock-recruitment biased and biased corrected parameters caused from time series bias. Parameter estimates were determined for all years of data and for each cycle year where sufficient data were available. The parameter b was multiplied by 10^6 .

| Stock | a | | | b | | |
|--------------------------------|----------------|----------------|-------|----------------|----------------|---------|
| | bias biased | % corrected | error | bias biased | % corrected | error |
| Early Stuart | | | | | | |
| all years | 2.441 | 2.407 | 1.39 | 4.878 | 3.919 | 19.66 |
| 1984 cycle | 2.834 | 2.777 | 2.01 | 62.287 | 51.506 | 17.31 |
| 1985 cycle | 3.237 | 3.172 | 2.01 | 9.673 | 8.987 | 7.09 |
| 1986 cycle | 2.656 | 2.567 | 3.35 | 39.246 | 36.761 | 6.33 |
| 1987 cycle | 3.221 | 3.163 | 1.80 | 37.390 | 30.062 | 19.60 |
| Late Stuart | | | | | | |
| all years | 2.757 | 2.698 | 2.14 | 4.496 | 2.834 | 36.97 |
| 1984 cycle | 4.256 | 4.115 | 3.31 | 1176.723 | 1170.22 | 0.55 |
| 1985 cycle | 3.420 | 3.400 | 0.58 | 8.102 | 1.284 | 84.15 |
| 1986 cycle | 3.750 | 3.711 | 1.04 | 205.178 | 204.191 | 0.48 |
| 1987 cycle | 3.540 | 3.529 | 0.31 | 243 | 242.457 | 0.22 |
| Late Nadina^a | | | | | | |
| all years | 3.2675 | 3.250 | 0.54 | 87.550 | 82.080 | 0.062 |
| Stellako | | | | | | |
| all years | 2.656 | 2.613 | 1.62 | 6.872 | 5.839 | 15.03 |
| 1984 cycle | 2.990 | 2.894 | 3.21 | 24.812 | 21.055 | 15.14 |
| 1985 cycle | 2.938 | 2.888 | 1.70 | 35.814 | 34.449 | 3.81 |
| 1986 cycle | 2.264 | 1.993 | 11.97 | -1.441 | -7.501 | -420.54 |
| 1987 cycle | 3.344 | 3.208 | 4.07 | 12.472 | 10.66 | 14.53 |
| Bowron | | | | | | |
| all years | 2.672 | 2.631 | 1.53 | 66.646 | 59.174 | 11.21 |
| 1984 cycle | 2.780 | 2.705 | 2.70 | 102.405 | 86.469 | 15.56 |
| 1985 cycle | 2.186 | 2.111 | 3.43 | 27.584 | 10.279 | 62.74 |
| 1986 cycle | 3.081 | 3.037 | 1.43 | 199.549 | 193.394 | 3.08 |
| 1987 cycle | 4.156 | 4.186 | -0.72 | 161.944 | 162.35 | -0.25 |
| Horsefly^b | | | | | | |
| all years | 2.786 | 2.753 | 1.18 | -0.879 | -4.789 | -444.82 |
| 1984 cycle | 3.802 | 3.745 | 1.50 | 10401.72 | 9799.556 | 5.79 |
| 1985 cycle | 3.058 | 2.997 | 1.99 | 2.744 | 2.002 | 27.04 |
| 1986 cycle | 2.707 | 2.273 | 16.03 | 5.279 | -387.41 | 7438.70 |
| 1987 cycle | 3.150 | 3.150 | 0.00 | 1496.939 | -819.638 | 154.75 |
| Mitchell^b | | | | | | |
| all years | 2.537 | 2.537 | 0.00 | -49.796 | -51.457 | -3.34 |

Table 2 (cont'd)

| Stock | a | | | b | | |
|-------------------------|----------------|----------------|-------|----------------|----------------|--------|
| | bias biased | % corrected | error | bias biased | % corrected | error |
| Chilko River | | | | | | |
| all years | 2.542 | 2.518 | 0.94 | 2.016 | 1.860 | 7.74 |
| 1984 cycle | 3.023 | 2.965 | 1.92 | 3.507 | 3.290 | 6.19 |
| 1985 cycle | 2.491 | 2.283 | 8.35 | 12.543 | 8.548 | 31.85 |
| 1986 cycle | 3.590 | 3.643 | -1.48 | 16.095 | 16.406 | -1.93 |
| 1987 cycle | 2.953 | 2.813 | 4.74 | 3.985 | 3.109 | 21.98 |
| Early Chilko | | | | | | |
| all years | 3.424 | 3.459 | -1.02 | 59.26 | 59.000 | 0.44 |
| Seymour | | | | | | |
| all years | 2.719 | 2.674 | 1.66 | 25.154 | 25.333 | -0.71 |
| 1984 cycle | 3.069 | 3.057 | 0.39 | 315.856 | 286.460 | 9.31 |
| 1985 cycle | 3.395 | 3.273 | 3.59 | 308.245 | 282.295 | 8.42 |
| 1986 cycle | 3.904 | 3.845 | 1.51 | 63.078 | 60.733 | 3.72 |
| 1987 cycle | 3.857 | 3.891 | -0.88 | 90.066 | 89.062 | 1.11 |
| Scotch | | | | | | |
| all years | 3.168 | 3.119 | 1.55 | 217.46 | 164.420 | 24.39 |
| Lower Adams | | | | | | |
| all years | 2.380 | 2.342 | 1.60 | 0.644 | 0.402 | 37.58 |
| 1984 cycle | 2.709 | 2.735 | -0.96 | 243.944 | 245.930 | -0.81 |
| 1985 cycle | 4.325 | 4.369 | -1.02 | 816.263 | 816.759 | -0.06 |
| 1986 cycle | 3.257 | 3.221 | 1.11 | 1.531 | 1.660 | -8.43 |
| 1987 cycle | 2.532 | 2.529 | 0.12 | 1.886 | -1.064 | 156.42 |
| Lower Shuswap | | | | | | |
| all years | 3.318 | 3.291 | 0.81 | 15.250 | 14.175 | 7.05 |
| Raft^b | | | | | | |
| all years | 2.746 | 2.704 | 1.53 | 154.088 | 137.131 | 11.00 |
| 1984 cycle | 3.341 | 3.235 | 3.17 | 229.700 | 212.412 | 7.53 |
| 1985 cycle | 2.833 | 2.717 | 4.09 | 279.704 | 164.738 | 41.10 |
| 1986 cycle | 2.481 | 2.208 | 11.00 | 107.018 | 34.656 | 67.62 |
| 1987 cycle | 2.865 | 2.888 | -0.80 | 241.995 | 233.007 | 3.71 |
| Fennell | | | | | | |
| all years | 3.545 | 3.531 | 0.39 | 412.083 | 390.670 | 5.48 |
| Weaver | | | | | | |
| all years ^a | 3.448 | 3.428 | 0.58 | 33.293 | 32.411 | 2.65 |

Table 2 (cont'd) showing slopes of spawning stock trends to be expected
in "spurts" with an estimate indicating how life cycle gains will affect
the relative error of estimating off-year ages

| Stock | bias | | bias | | bias | |
|--------------------|--------|-----------|--------|----------|-----------|--------|
| | biased | corrected | % | biased | corrected | % |
| | error | | error | error | | error |
| Birkenhead | | | | | | |
| all years | 3.053 | 3.012 | 1.34 | 17.599 | 16.226 | 7.80 |
| 1984 cycle | 2.844 | 2.766 | 2.74 | 18.937 | 16.686 | 11.89 |
| 1985 cycle | 3.195 | 3.103 | 2.88 | 25.106 | 23.316 | 7.13 |
| 1986 cycle | 3.022 | 2.971 | 1.69 | 9.737 | 8.014 | 17.70 |
| 1987 cycle | 3.575 | 3.496 | 2.21 | 35.853 | 34.636 | 3.39 |
| Harrison | | | | | | |
| all years | 2.983 | 2.973 | 0.34 | 146.356 | 145.394 | 0.66 |
| 1984 cycle | 2.632 | 2.624 | 0.30 | 129.928 | 102.088 | 21.43 |
| 1985 cycle | 2.820 | 2.698 | 4.33 | 191.140 | 107.516 | 43.75 |
| 1986 cycle | 2.857 | 2.862 | -0.18 | 125.719 | 136.040 | -8.21 |
| 1987 cycle | 4.181 | 4.162 | 0.45 | 199.055 | 191.267 | 3.91 |
| Portage | | | | | | |
| all years | 3.409 | 3.393 | 0.47 | 207.219 | 198.257 | 4.32 |
| 1984 cycle | 4.370 | 4.208 | 3.71 | 2037.570 | 1785.962 | 12.35 |
| 1985 cycle | 3.152 | 3.080 | 2.28 | 140.585 | 134.667 | 4.21 |
| 1986 cycle | 3.326 | 3.347 | -0.63 | 170.598 | 170.612 | -0.01 |
| 1987 cycle | 4.190 | 4.773 | -13.91 | 1007.962 | 1053.876 | -4.56 |
| Gates* | | | | | | |
| all years | 3.643 | 3.642 | 0.03 | 175.565 | 174.863 | 0.40 |
| Upper Pitt* | | | | | | |
| all years | 3.233 | 3.233 | 0.00 | 123.358 | 123.362 | -0.00 |
| Cultus | | | | | | |
| all years | 2.280 | 2.229 | 2.24 | 23.856 | 18.061 | 24.29 |
| 1984 cycle | 2.051 | 1.857 | 9.46 | 40.730 | -19.449 | 147.75 |
| 1985 cycle | 2.512 | 2.255 | 10.23 | 120.639 | 117.408 | 2.68 |
| 1986 cycle | 2.340 | 2.396 | -2.39 | 16.040 | 16.121 | -0.50 |
| 1987 cycle | 3.444 | 3.482 | -1.10 | 68.617 | 68.762 | -0.21 |

a: estimates are for data collected since completion of spawning channels; Late Nadina - 1973, Upper Pitt - 1960, Weaver - 1965, Gates - 1968.

b: negative parameter estimates imply exponential population growth (convex curve).

Table 3. Estimates of biased Ricker parameters in cycle years from Monte Carlo simulations using the all-year parameter estimates as the "true" values for each cycle year. The parameter b was multiplied by 10^6 .

| Stock | Ricker a | Ricker b | Optimal Escapement (eff. females) |
|---------------------|-------------|-------------|---|
| Early Stuart | | | |
| all years | 2.4415 | 4.8777 | 172400 |
| 1984 cycle | 2.5898 | 15.2725 | 56000 |
| 1985 cycle | 2.6099 | 28.9825 | 29700 |
| 1986 cycle | 2.4798 | 6.4369 | 131500 |
| 1987 cycle | 2.7113 | 16.1338 | 54000 |
| Late Stuart | | | |
| all years | 2.7571 | 4.4962 | 207500 |
| 1984 cycle | 3.0832 | 9995.9542 | 100 |
| 1985 cycle | 3.0418 | 10.1897 | 92500 |
| 1986 cycle | 3.0701 | 58.3307 | 16200 |
| 1987 cycle | 3.0647 | 88.3722 | 11000 |
| Stellako | | | |
| all years | 2.656 | 6.8724 | 124800 |
| 1984 cycle | 2.853 | 15.3991 | 57000 |
| 1985 cycle | 2.9426 | 16.9973 | 52300 |
| 1986 cycle | 2.9243 | 14.6422 | 60500 |
| 1987 cycle | 2.8327 | 11.4033 | 77000 |
| Bowron | | | |
| all years | 2.6724 | 66.6457 | 13000 |
| 1984 cycle | 2.8084 | 92.6617 | 9500 |
| 1985 cycle | 2.7849 | 93.7779 | 9400 |
| 1986 cycle | 2.8817 | 106.4822 | 8300 |
| 1987 cycle | 2.8222 | 109.9476 | 8000 |
| Chilko River | | | |
| all years | 2.5419 | 2.0161 | 419700 |
| 1984 cycle | 2.7516 | 5.421 | 160300 |
| 1985 cycle | 2.7482 | 2.9408 | 296000 |
| 1986 cycle | 2.8396 | 7.6499 | 115000 |
| 1987 cycle | 2.7655 | 10.5134 | 83000 |
| Seymour | | | |
| all years | 2.7188 | 30.3546 | 29100 |
| 1984 cycle | 2.9655 | 63.7236 | 14200 |
| 1985 cycle | 2.8942 | 104.9468 | 8500 |
| 1986 cycle | 2.9596 | 50.9126 | 17700 |
| 1987 cycle | 2.9116 | 70.9853 | 13000 |

Table 3 (cont'd)

| Stock | Optimal population | Ricker a | Ricker b | Optimal Escapement (eff. females) |
|-------------|-----------------------|-------------|-------------|---|
| Adams River | 471,0 | 871,0 | 711,0 | 871,0 |
| all years | 810,0 | 910,0 | 840,0 | 800,0 |
| 1984 cycle | 810,0 | 2.3824 | 0.6662 | 1311400 |
| 1985 cycle | 810,0 | 2.7656 | 6.3061 | 143600 |
| 1986 cycle | 810,0 | 2.8342 | 14.6103 | 62200 |
| 1987 cycle | 810,0 | 2.4466 | 0.678 | 1288500 |
| | 810,0 | 2.5946 | 1.0738 | 830000 |
| Raft | 810,0 | 810,0 | 804,0 | 810,0 |
| all years | 810,0 | 2.7461 | 154.0879 | 5700 |
| 1984 cycle | 810,0 | 2.9132 | 288.4611 | 3100 |
| 1985 cycle | 810,0 | 2.9017 | 230.8504 | 3900 |
| 1986 cycle | 810,0 | 2.9798 | 297.4524 | 3000 |
| 1987 cycle | 810,0 | 2.9297 | 218.0276 | 4000 |
| Birkenhead | 810,0 | 810,0 | 810,0 | 810,0 |
| all years | 810,0 | 3.0532 | 17.599 | 51300 |
| 1984 cycle | 810,0 | 3.278 | 25.7855 | 35700 |
| 1985 cycle | 810,0 | 3.0833 | 18.3112 | 49400 |
| 1986 cycle | 810,0 | 3.12 | 19.9839 | 45400 |
| 1987 cycle | 810,0 | 3.1501 | 18.973 | 48000 |
| Cultus | 810,0 | 810,0 | 810,0 | 810,0 |
| all years | 810,0 | 2.2801 | 23.8556 | 35000 |
| 1984 cycle | 810,0 | 2.4351 | 70.5389 | 12100 |
| 1985 cycle | 810,0 | 2.4931 | 53.6174 | 16000 |
| 1986 cycle | 810,0 | 2.4381 | 50.0295 | 17000 |
| 1987 cycle | 810,0 | 2.4684 | 43.1622 | 20000 |
| | 810,0 | 810,0 | 810,0 | 810,0 |
| | 810,0 | 810,0 | 810,0 | 810,0 |
| | 810,0 | 810,0 | 810,0 | 810,0 |
| | 810,0 | 810,0 | 810,0 | 810,0 |

Estimated
optimal
escapement
values

Table 4. Autocorrelations of residuals for Fraser River sockeye.

| Lag (yr) | Chilko River | Upper Horsefly | Raft | Lower Adams | Lower Shuswap |
|-------------|-----------------|-------------------|----------------|----------------|------------------|
| 1 | 0.097 | -0.176 | 0.111 | 0.170 | -0.173 |
| 2 | -0.111 | -0.008 | -0.249 | -0.019 | -0.069 |
| 3 | -0.125 | 0.033 | 0.172 | -0.203 | 0.177 |
| 4 | 0.148 | -0.316 | 0.140 | -0.160 | 0.296 |
| 5 | 0.072 | -0.057 | -0.091 | -0.150 | -0.239 |
| 6 | -0.148 | 0.011 | 0.039 | -0.245 | 0.129 |
| 7 | -0.366 | 0.042 | -0.202 | -0.082 | 0.042 |
| 8 | 0.079 | 0.217 | -0.409 | -0.010 | -0.110 |
| Lag (yr) | Seymour | Early Stuart | Late Stuart | Stellako | Bowron |
| 1 | 0.008 | 0.254 | 0.147 | -0.220 | 0.232 |
| 2 | -0.224 | 0.318 | 0.182 | -0.300 | -0.022 |
| 3 | -0.050 | 0.033 | 0.256 | 0.173 | 0.106 |
| 4 | -0.101 | 0.213 | 0.011 | -0.028 | 0.100 |
| 5 | 0.207 | 0.001 | -0.042 | -0.037 | -0.211 |
| 6 | -0.088 | 0.008 | -0.100 | -0.017 | -0.215 |
| 7 | -0.041 | -0.192 | -0.172 | -0.080 | -0.121 |
| 8 | 0.045 | 0.020 | -0.395 | 0.214 | -0.148 |
| Lag (yr) | Birken- Head | Harrison | Weaver | Cultus | Upper Pitt |
| 1 | 0.180 | 0.125 | -0.001 | 0.180 | 0.133 |
| 2 | 0.042 | -0.230 | 0.126 | 0.043 | 0.037 |
| 3 | 0.032 | -0.143 | -0.273 | 0.094 | 0.124 |
| 4 | 0.099 | 0.115 | -0.274 | -0.029 | -0.071 |
| 5 | 0.116 | -0.115 | -0.212 | -0.056 | -0.030 |
| 6 | -0.068 | -0.073 | -0.053 | -0.344 | -0.258 |
| 7 | 0.016 | 0.261 | 0.002 | -0.165 | 0.075 |
| 8 | 0.091 | 0.214 | 0.213 | -0.093 | 0.009 |
| Lag (yr) | Gates | Portage | | | |
| 1 | 0.240 | 0.021 | | | |
| 2 | 0.150 | 0.013 | | | |
| 3 | 0.155 | -0.238 | | | |
| 4 | -0.013 | -0.234 | | | |
| 5 | -0.161 | -0.112 | | | |
| 6 | 0.020 | -0.218 | | | |
| 7 | -0.317 | 0.191 | | | |
| 8 | -0.233 | 0.069 | | | |

Table 5. Estimates of biased and bias corrected equilibrium stock size and optimal escapements of adult Fraser River sockeye.

| Stock | Equilibrium stock (effective females) | | Optimal escapement (effective females) | |
|--------------|--|-----------|---|-----------|
| | bias | | bias | |
| | biased | corrected | biased | corrected |
| Early Stuart | | | | |
| all years | 500538 | 614270 | 165093 | 204042 |
| 1984 cycle | 45491 | 53922 | 13822 | 16579 |
| 1985 cycle | 334632 | 352900 | 93359 | 99826 |
| 1986 cycle | 67678 | 69835 | 21345 | 22439 |
| 1987 cycle | 86149 | 105201 | 24115 | 29815 |
| Late Stuart | | | | |
| all years | 613217 | 951858 | 189339 | 297597 |
| 1984 cycle | 3617 | 3517 | 818 | 818 |
| 1985 cycle | 422163 | 2648497 | 113320 | 714016 |
| 1986 cycle | 18279 | 18176 | 4581 | 4592 |
| 1987 cycle | 14567 | 14555 | 3814 | 3819 |
| Late Nadina | | | | |
| all years | 37322 | 39591 | 10345 | 11016 |
| Stellako* | | | | |
| all years | 386474 | 447425 | 121893 | 142407 |
| 1984 cycle | 120494 | 137445 | 35421 | 41231 |
| 1985 cycle | 82022 | 83839 | 24379 | 25180 |
| 1986 cycle | -157117 | -265648 | -537440 | -95978 |
| 1987 cycle | 268129 | 300952 | 73136 | 84476 |
| Bowron | | | | |
| all years | 40098 | 44457 | 12604 | 14096 |
| 1984 cycle | 27150 | 31286 | 8342 | 9766 |
| 1985 cycle | 79235 | 205377 | 27542 | 72470 |
| 1986 cycle | 15439 | 15702 | 4452 | 4570 |
| 1987 cycle | 25662 | 25781 | 5922 | 5915 |
| Horsefly* | | | | |
| all years | -3170714 | -574852 | -973123 | -177657 |
| 1984 cycle | 366 | 382 | 91 | 96 |
| 1985 cycle | 1114333 | 1497057 | 322905 | 439416 |
| 1986 cycle | 512825 | -5867 | 160010 | -2003 |
| 1987 cycle | 2104 | -3843 | 598 | -1092 |
| Mitchell* | | | | |
| all years | -50948 | -47976 | -16474 | -15529 |

Table 5 (cont'd)

| Stock | Equilibrium stock (effective females) | | Optimal escapement (effective females) | |
|--------------------------|--|-----------|---|-----------|
| | bias | | bias | |
| | biased | corrected | biased | corrected |
| Rate | | | | |
| Chilko River | | | | |
| all years | 1260790 | 1353760 | 407257 | 439444 |
| 1984 cycle | 861924 | 901094 | 251587 | 266285 |
| 1985 cycle | 198589 | 267110 | 64834 | 91017 |
| 1986 cycle | 223062 | 222025 | 57785 | 56894 |
| 1987 cycle | 740867 | 904788 | 219504 | 276116 |
| Early Chilko | | | | |
| all years | 57779 | 58627 | 15496 | 15609 |
| Seymour | | | | |
| all years | 89570 | 105307 | 27880 | 33132 |
| 1984 cycle | 9717 | 10671 | 2809 | 3093 |
| 1985 cycle | 11015 | 11595 | 2972 | 3210 |
| 1986 cycle | 61893 | 63309 | 15029 | 15559 |
| 1987 cycle | 42828 | 43692 | 10499 | 10637 |
| Scotch | | | | |
| all years | 14489 | 14499 | 4094 | 4096 |
| Lower Adams ^b | | | | |
| all years | 3575941 | 5389808 | 1193965 | 1817351 |
| 1984 cycle | 11104 | 11122 | 3464 | 3450 |
| 1985 cycle | 5298 | 5349 | 1183 | 1184 |
| 1986 cycle | 2127992 | 1940560 | 591122 | 543274 |
| 1987 cycle ^a | 1342418 | -2376788 | 434498 | -769868 |
| Lower Shuswap | | | | |
| all years | 217338 | 215248 | 59588 | 54922 |
| Raft | | | | |
| all years | 17822 | 19150 | 5515 | 5972 |
| 1984 cycle | 14546 | 15227 | 3970 | 4251 |
| 1985 cycle | 10128 | 16490 | 3078 | 5135 |
| 1986 cycle | 23185 | 63699 | 7584 | 22043 |
| 1987 cycle | 11840 | 12394 | 3573 | 3723 |
| Fennell | | | | |
| all years | 8577 | 8574 | 2243 | 2242 |
| Weaver ^c | | | | |
| all years | 103560 | 107177 | 27637 | 28879 |

Table 5 (cont'd)

| Stock | Equilibrium stock (effective females) | | Optimal escapement (effective females) | |
|-------------------------------|--|-------------------|---|-------------------|
| | bias biased | bias corrected | bias biased | bias corrected |
| Birkenhead | | | | |
| all years | 173488 | 175917 | 50318 | 51179 |
| 1984 cycle | 150193 | 165790 | 45530 | 51090 |
| 1985 cycle | 127275 | 133098 | 35822 | 38197 |
| 1986 cycle | 310318 | 370690 | 90610 | 109405 |
| 1987 cycle | 99709 | 100940 | 25913 | 26668 |
| Harrison | | | | |
| all years | 20384 | 20450 | 6000 | 6032 |
| 1984 cycle | 20260 | 25702 | 6422 | 8161 |
| 1985 cycle | 14754 | 25092 | 4495 | 7845 |
| 1986 cycle | 22726 | 21037 | 6871 | 6354 |
| 1987 cycle | 21006 | 21760 | 4823 | 5016 |
| Portage | | | | |
| all years | 16431 | 17276 | 4417 | 4641 |
| 1984 cycle | 2145 | 2356 | 474 | 538 |
| 1985 cycle | 22420 | 22873 | 6368 | 6596 |
| 1986 cycle | 19494 | 19616 | 5338 | 5347 |
| 1987 cycle | 4157 | 4529 | 953 | 928 |
| Gates^c | | | | |
| all years | 20752 | 20829 | 5317 | 5338 |
| Upper Pitt^c | | | | |
| all years | 26210 | 26205 | 7318 | 7318 |
| Cultus^a | | | | |
| all years | 95579 | 123423 | 32590 | 42524 |
| 1984 cycle | 50353 | -95487 | 17983 | -35428 |
| 1985 cycle | 20823 | 19206 | 6768 | 6583 |
| 1986 cycle | 145864 | 148628 | 49133 | 49485 |
| 1987 cycle | 50188 | 50642 | 13406 | 13418 |

a : Negative values are the result of parameter estimation.

The Ricker stock-recruitment curve for these stocks is convex and implies the optimal escapement is beyond the observed escapements.

b : Lower Adams includes the Lower Adams River, Little River and Late Seymour River.

c : Estimates are for data collected since completion of spawning channels; Late Nadina - 1973, Upper Pitt - 1960, Weaver - 1965; Gate - 1968.

Table 6. Mean adult escapements (1948-85), the estimated optimal escapement, the mean historical adult catch, the estimated maximum catch and the standard deviation of the regression for Fraser River sockeye.

| Stock | Mean Escapement | Optimal Escapement | Mean Catch | Maximum ^a Catch | Standard ^b Deviation |
|-----------------------|-----------------|--------------------|------------|----------------------------|---------------------------------|
| Early Stuart | 76909 | 420270 | 220734 | 606120 | 0.689 |
| Late Stuart | 79414 | 662370 | 292169 | 1260240 | 1.327 |
| Nadina | 9080 | 21630 | 46450 | 93670 | 0.854 |
| Stellako | 15754 | 294850 | 343232 | 554170 | 0.551 |
| Bowron | 11355 | 30030 | 42475 | 55410 | 0.659 |
| Horsefly ^c | 101806 | 500000 | 493169 | 3400000 | — |
| Mitchell ^c | 16808 | 200000 | 99292 | 1100000 | — |
| Chilko River | 245948 | 797670 | 992388 | 1622040 | 0.594 |
| Chilko Lake | 23664 | 31020 | 71216 | 166950 | 1.052 |
| Seymour | 22339 | 69380 | 85822 | 140910 | 0.773 |
| Scotch | 2491 | 11460 | 11027 | 39110 | 1.574 |
| Lower Adams | 474520 | 3450480 | 1602828 | 5794480 | 1.043 |
| Lower Shuswap | 32299 | 125500 | 84647 | 571560 | 1.588 |
| Raft | 6333 | 13920 | 23218 | 25820 | 0.714 |
| Fennell | 2586 | 48790 | 7100 | 272500 | 0.98 |
| Weaver | 35591 | 53990 | 172744 | 295020 | 0.71 |
| Birkenhead | 46807 | 107960 | 317594 | 350470 | 0.587 |
| Harrison | 14463 | 12590 | 29967 | 36710 | 0.966 |
| Portage | 4530 | 9480 | 21318 | 45700 | 1.448 |
| Gates | 4912 | 13560 | 18992 | 66710 | 1.452 |
| Upper Pitt | 20606 | 14520 | 56886 | 60940 | 0.986 |
| Cultus | 14374 | 79670 | 71466 | 106390 | 0.839 |
| Total | 1262589 | 6969140 | 5104734 | 16664920 | |

a: The maximum catch is the theoretical maximum catch achieved at the optimal escapement assuming a single spawner-return curve is appropriate. It was calculated from the Ricker model from the equation
 $C = S \cdot \exp(a - bS^* + \sigma^2/2) - S^*$; where C is the maximum catch.

b: The standard deviation is σ from the Ricker model and is shown here as an index of the relative reliance in the optimal escapement and maximum catch.

c: Optimal escapements were not determined from Ricker model because of exponential growth. Estimates of the optimal escapement and maximum catch were determined from the last observed escapement resulting in an increase in returns and from the mean (1948-81) returns per spawner.

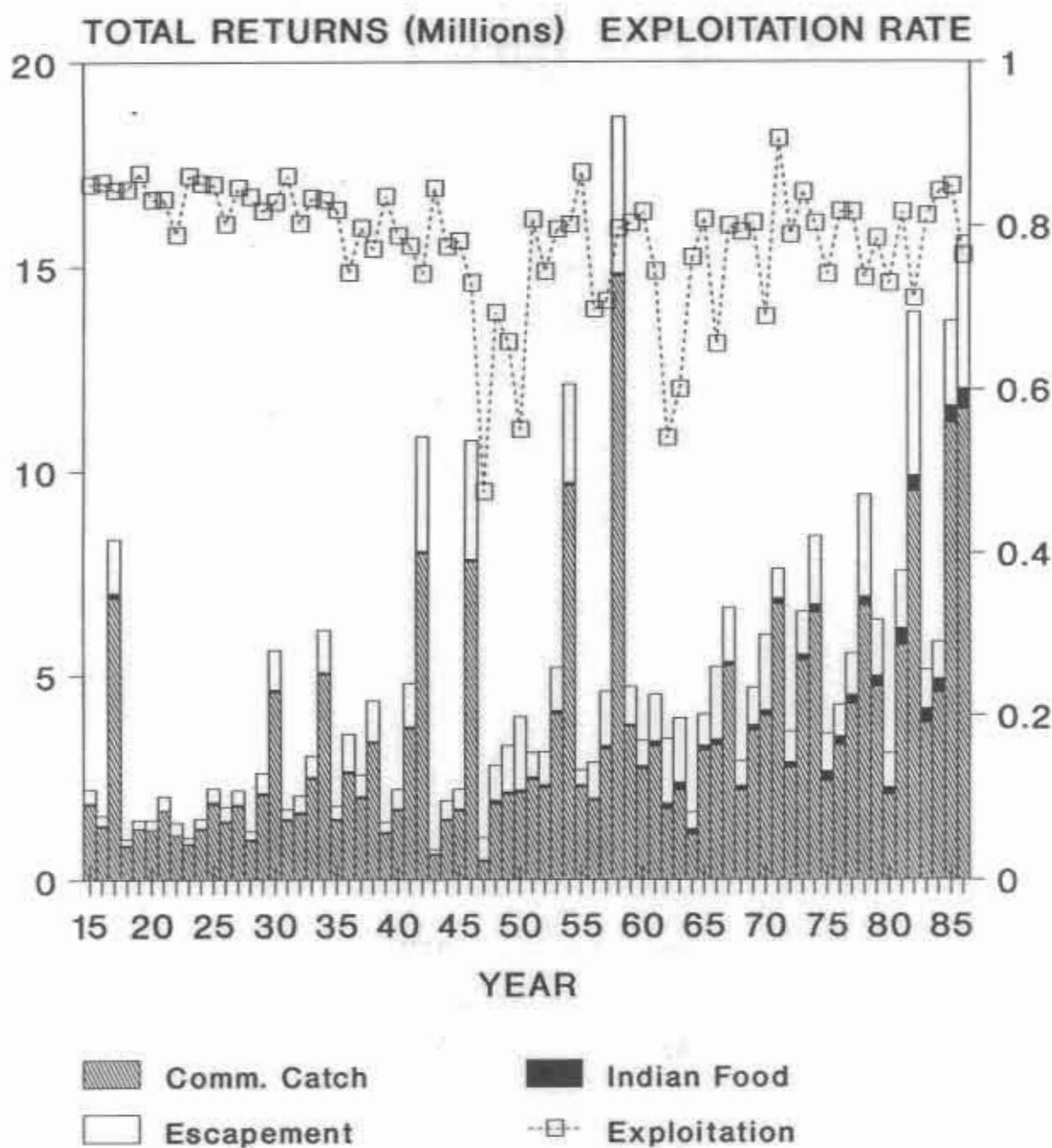


Fig. 1. Adult Returns, catch, escapement and exploitation of Fraser River sockeye, 1915-86 (source: 1915-51 - Killick and Clemens (1963) 1952-86 - IPSFC data).

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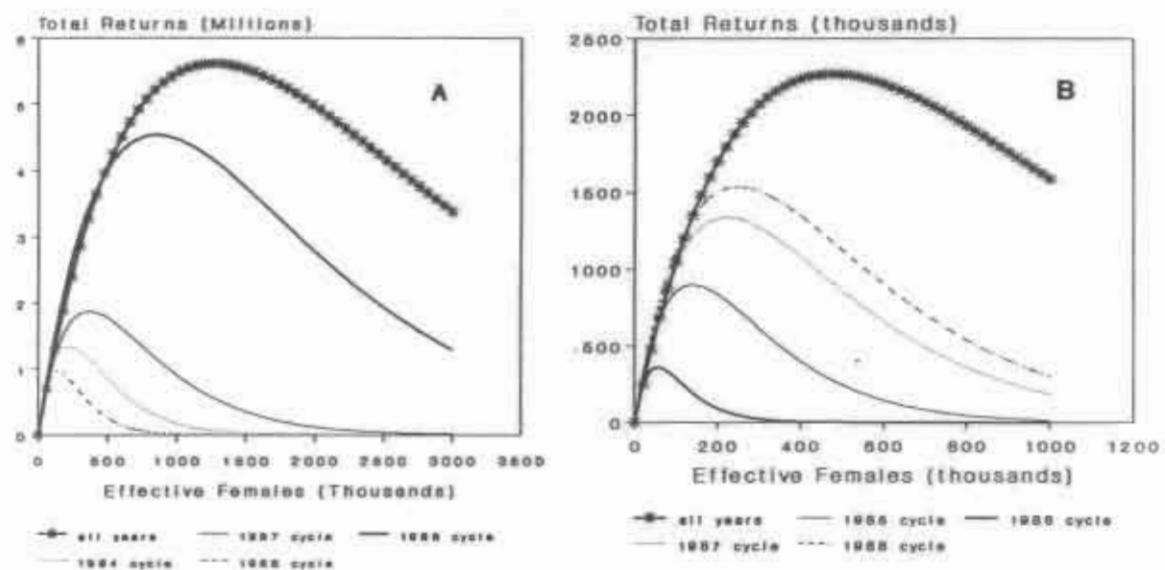


Fig. 2. Results from Monte Carlo simulations ($n=1000$) showing potential time series bias when fitting Ricker models to cycle years data when the all-years assumption is true for A) Lower Adams River and B) Chilko River.

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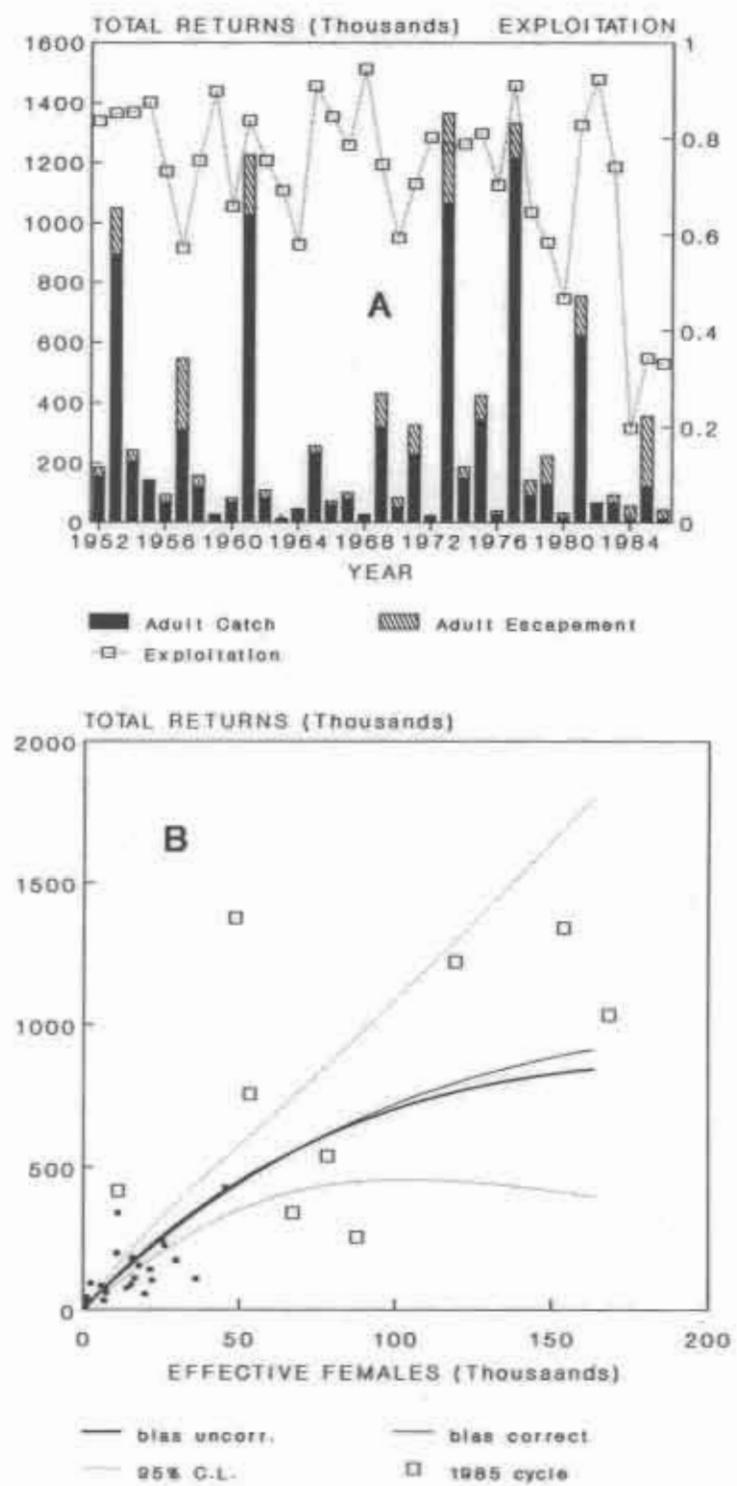


Fig. 3. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Early Stuart sockeye.

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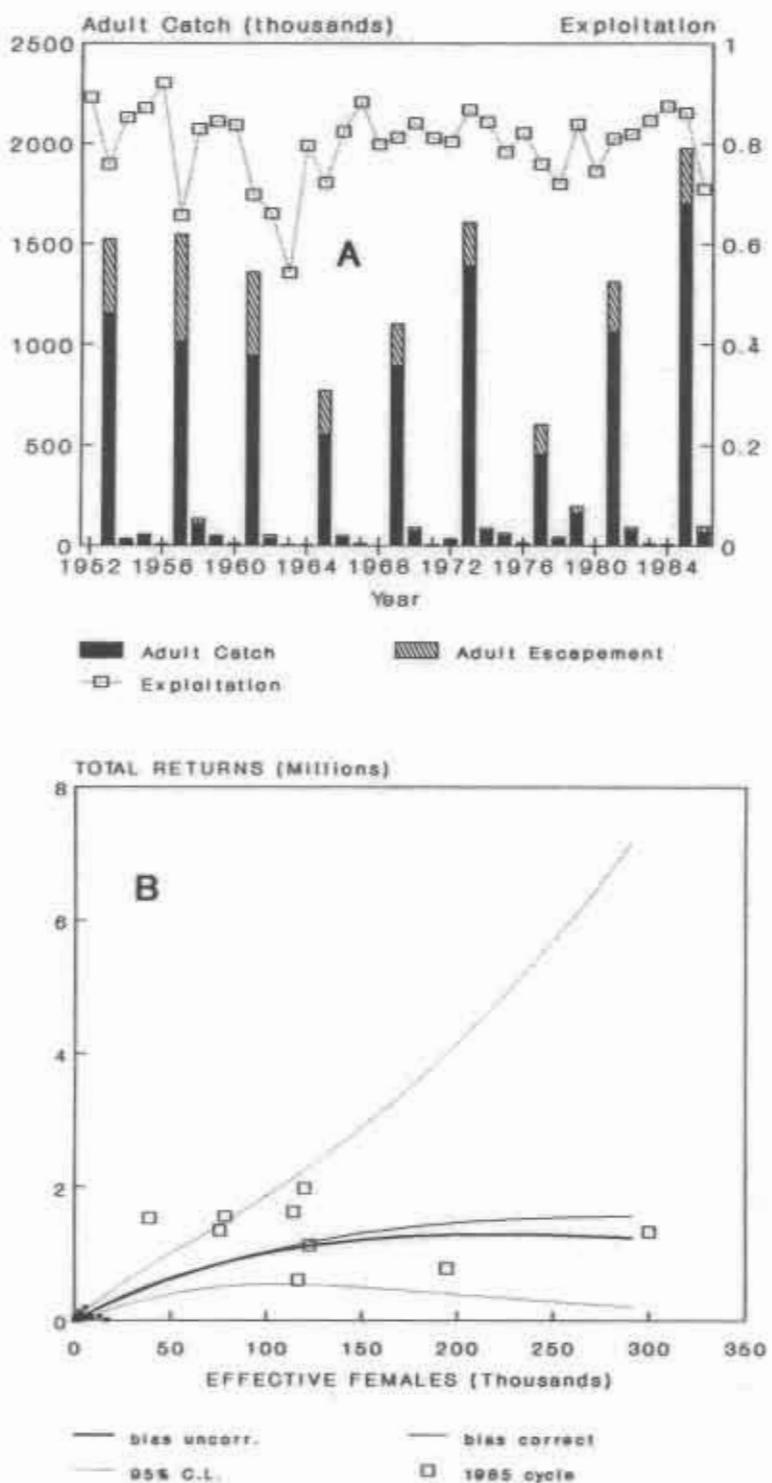


Fig. 4. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Late Stuart sockeye.

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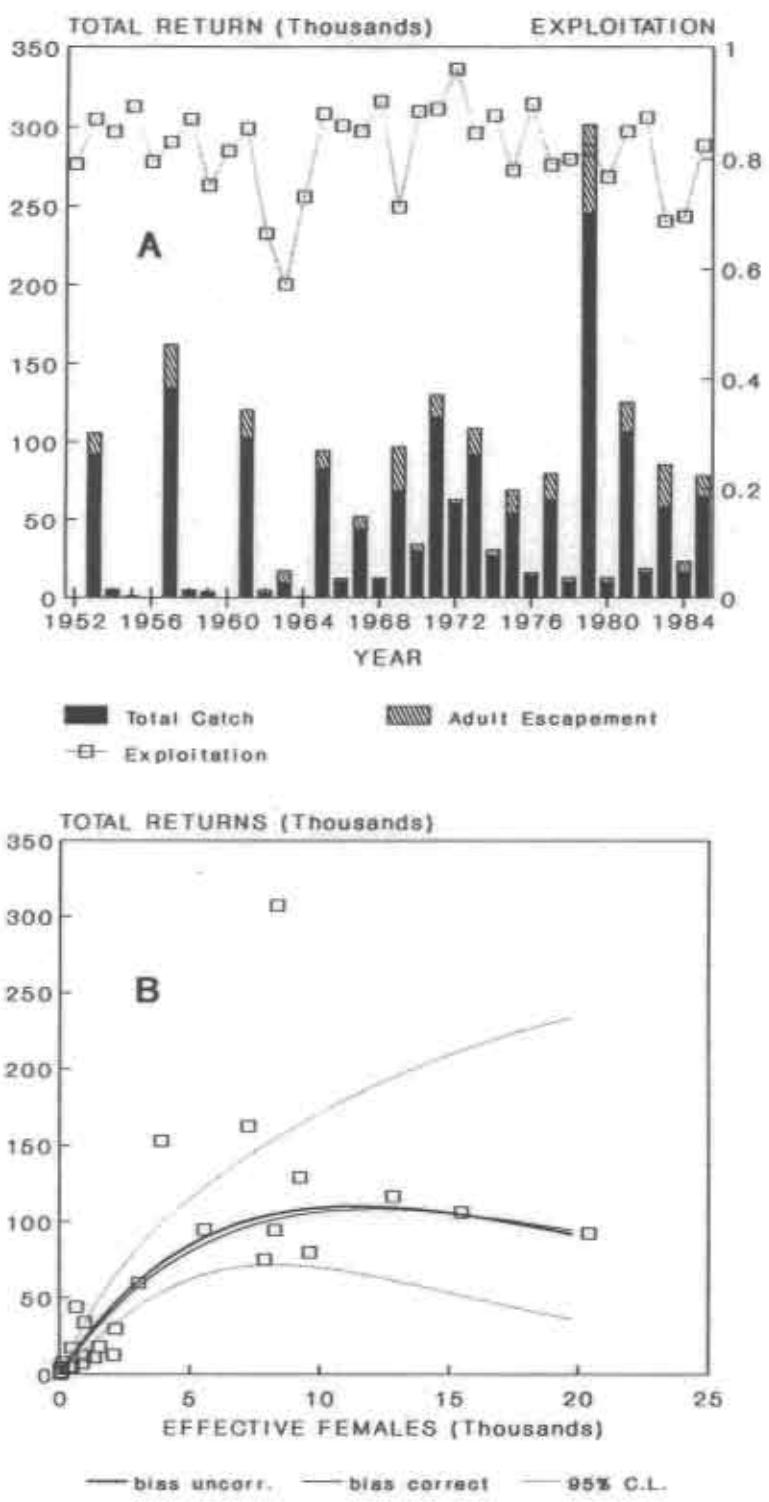


Fig. 5. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Nadina River sockeye.

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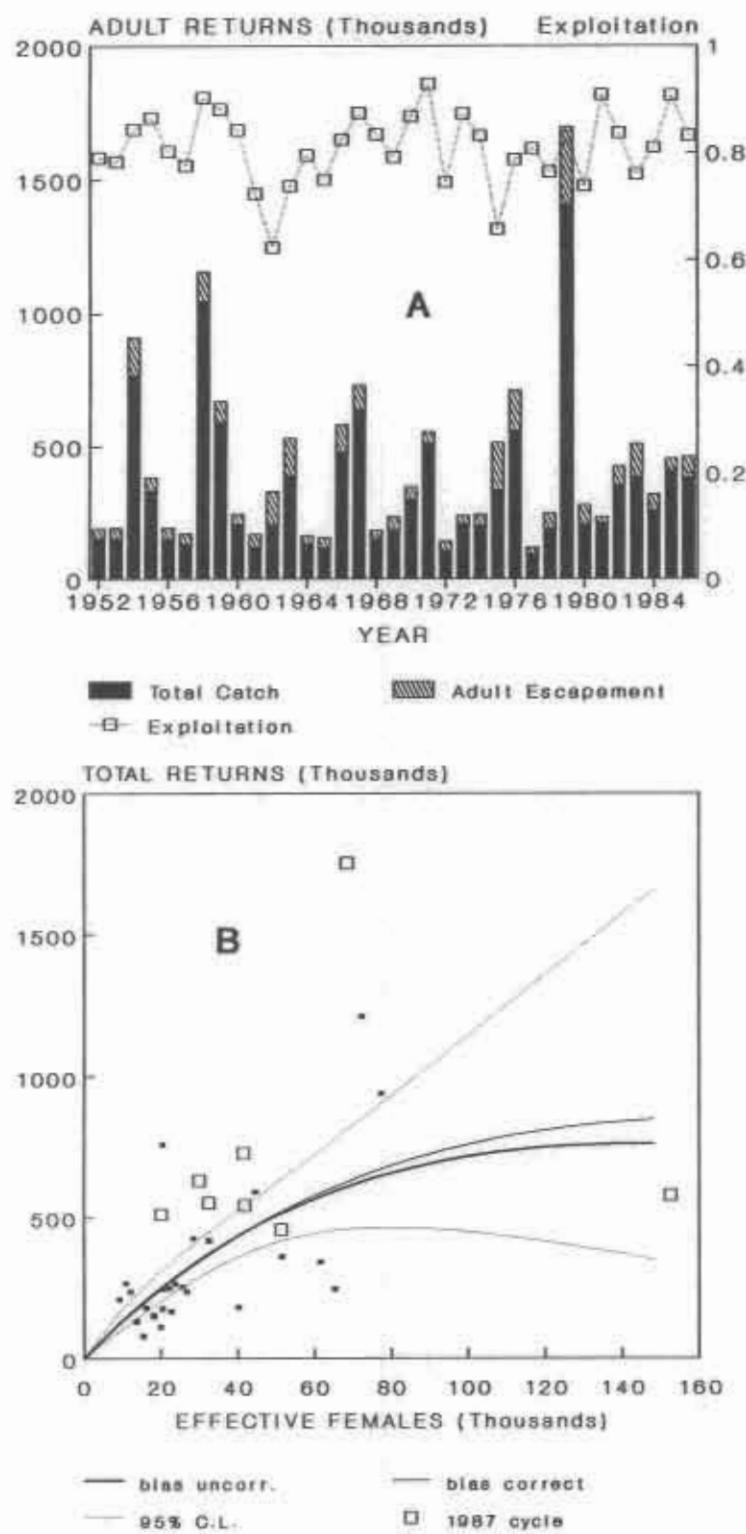


Fig. 6. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Stellako River sockeye.

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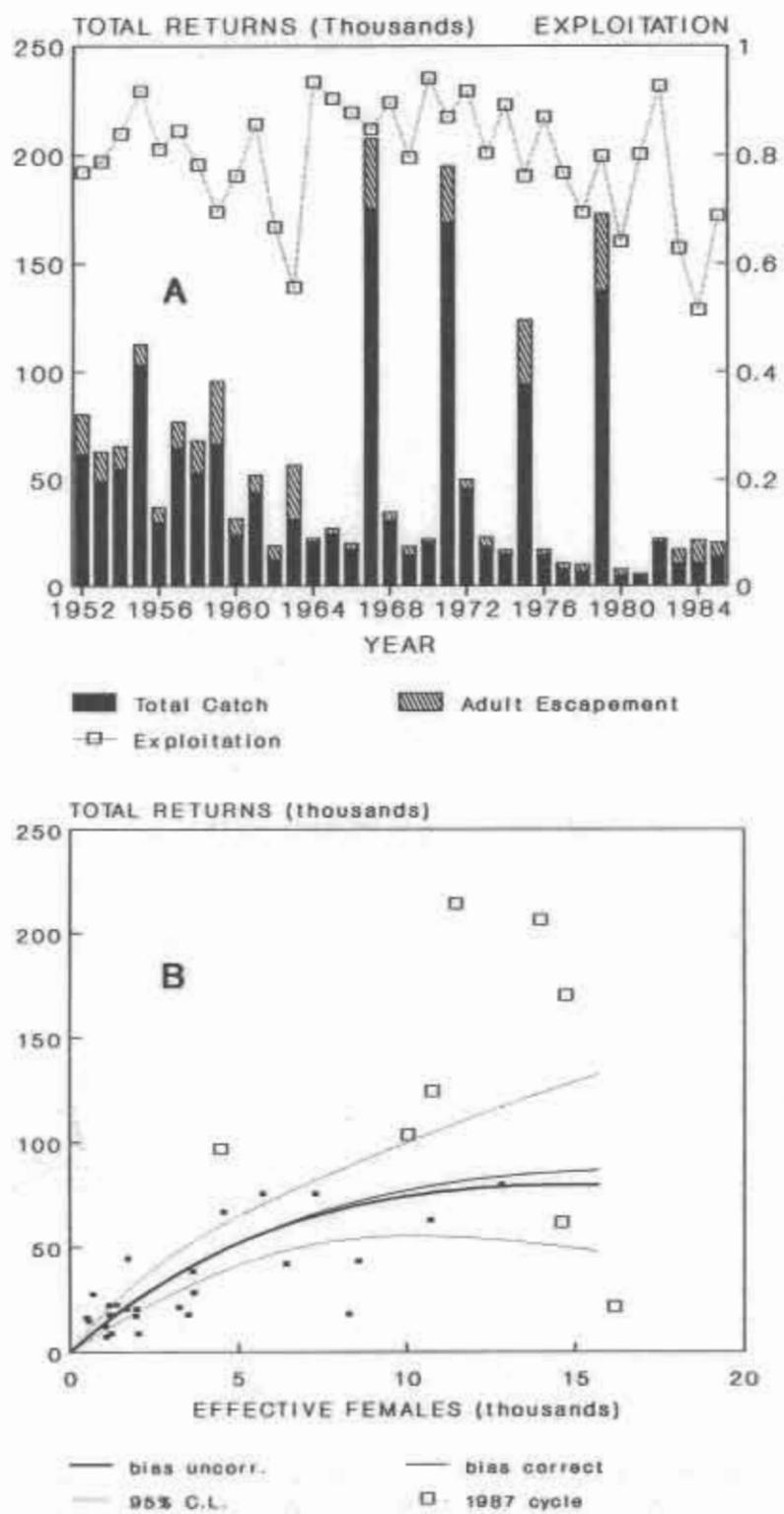


Fig. 7. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Bowron River sockeye.

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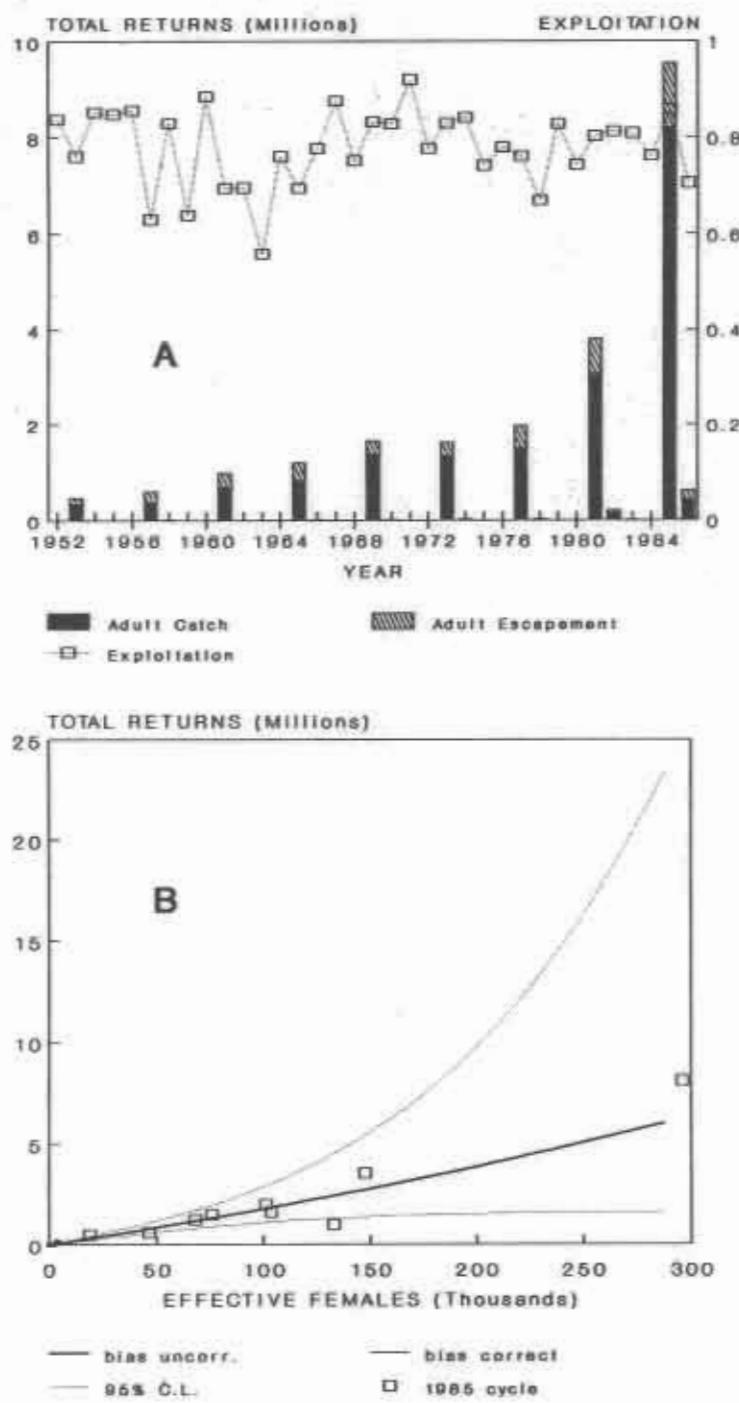


Fig. 8. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Horsefly River sockeye.

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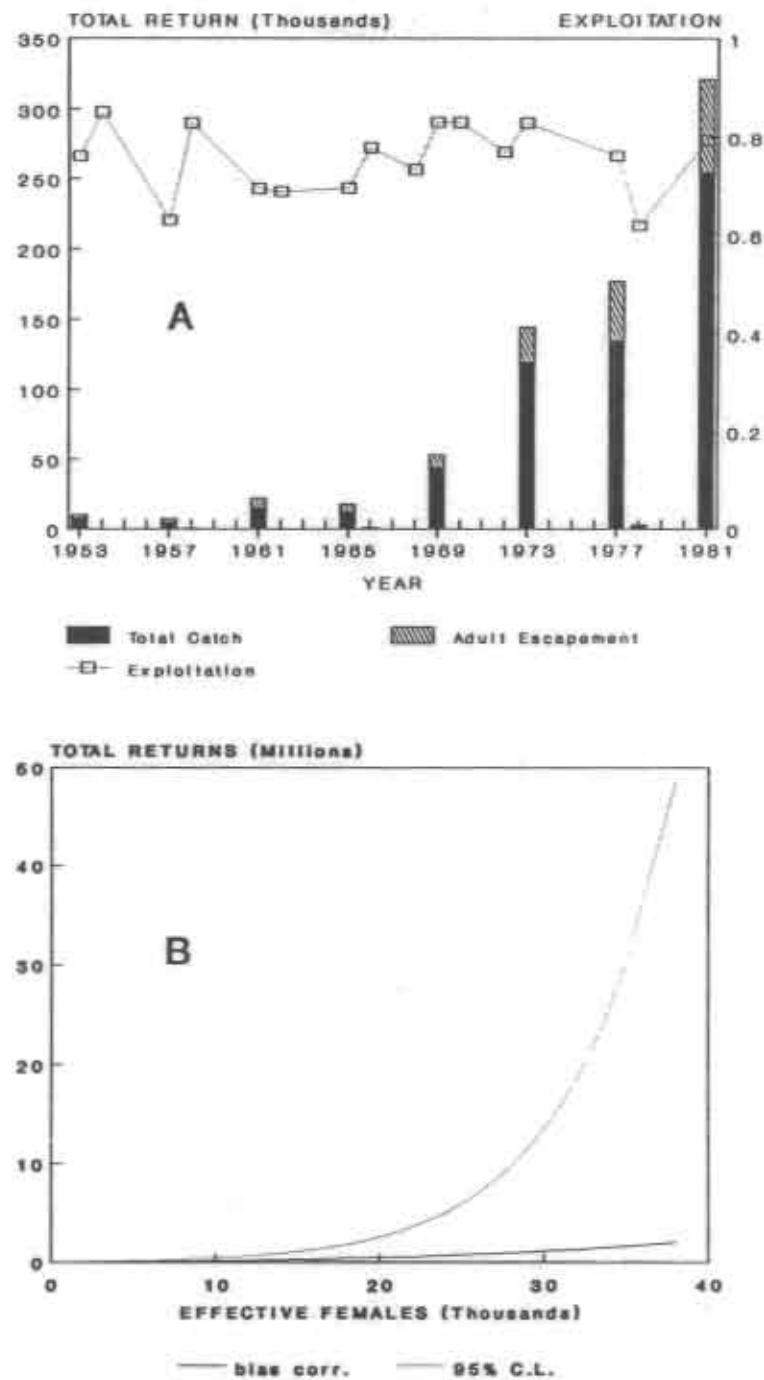


Fig. 9. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Mitchell River sockeye.

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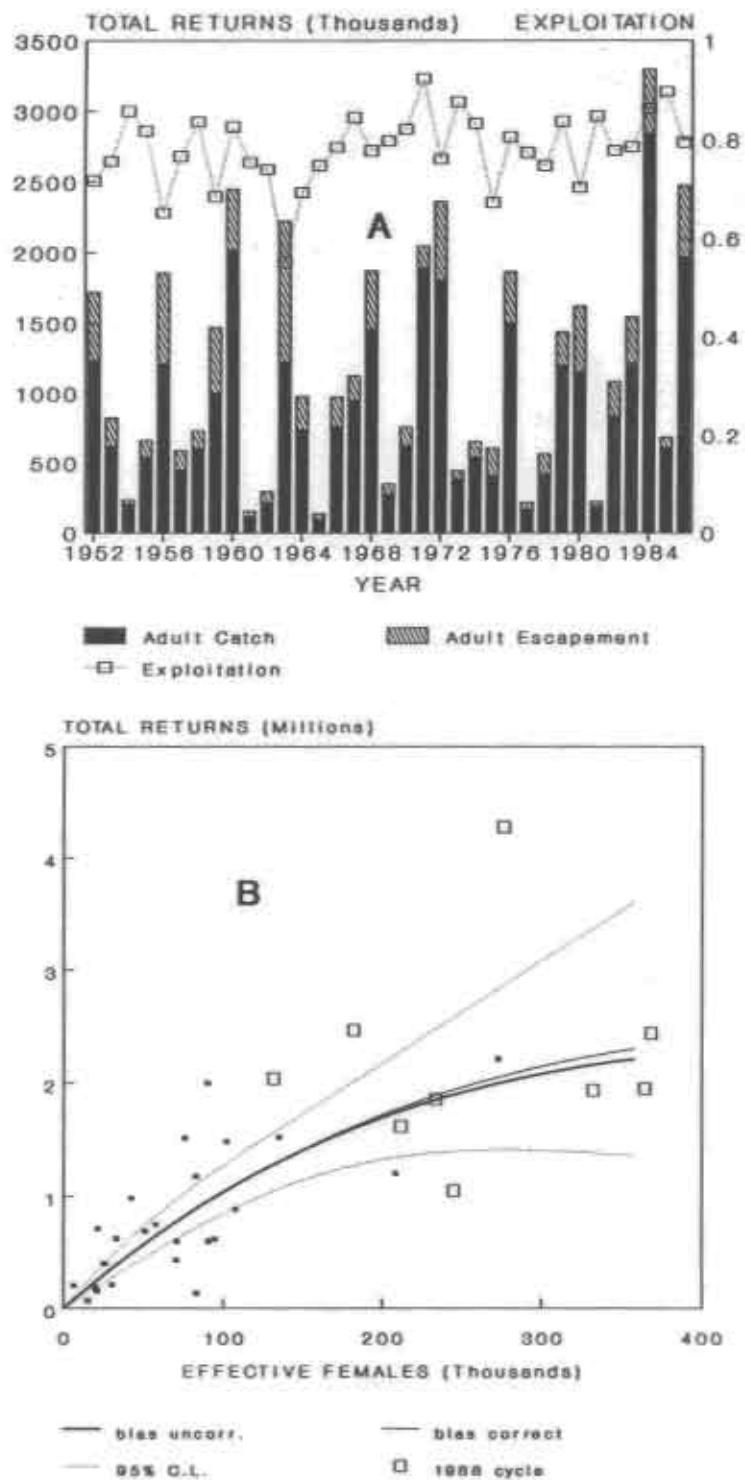


Fig. 10. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Chilko River sockeye.

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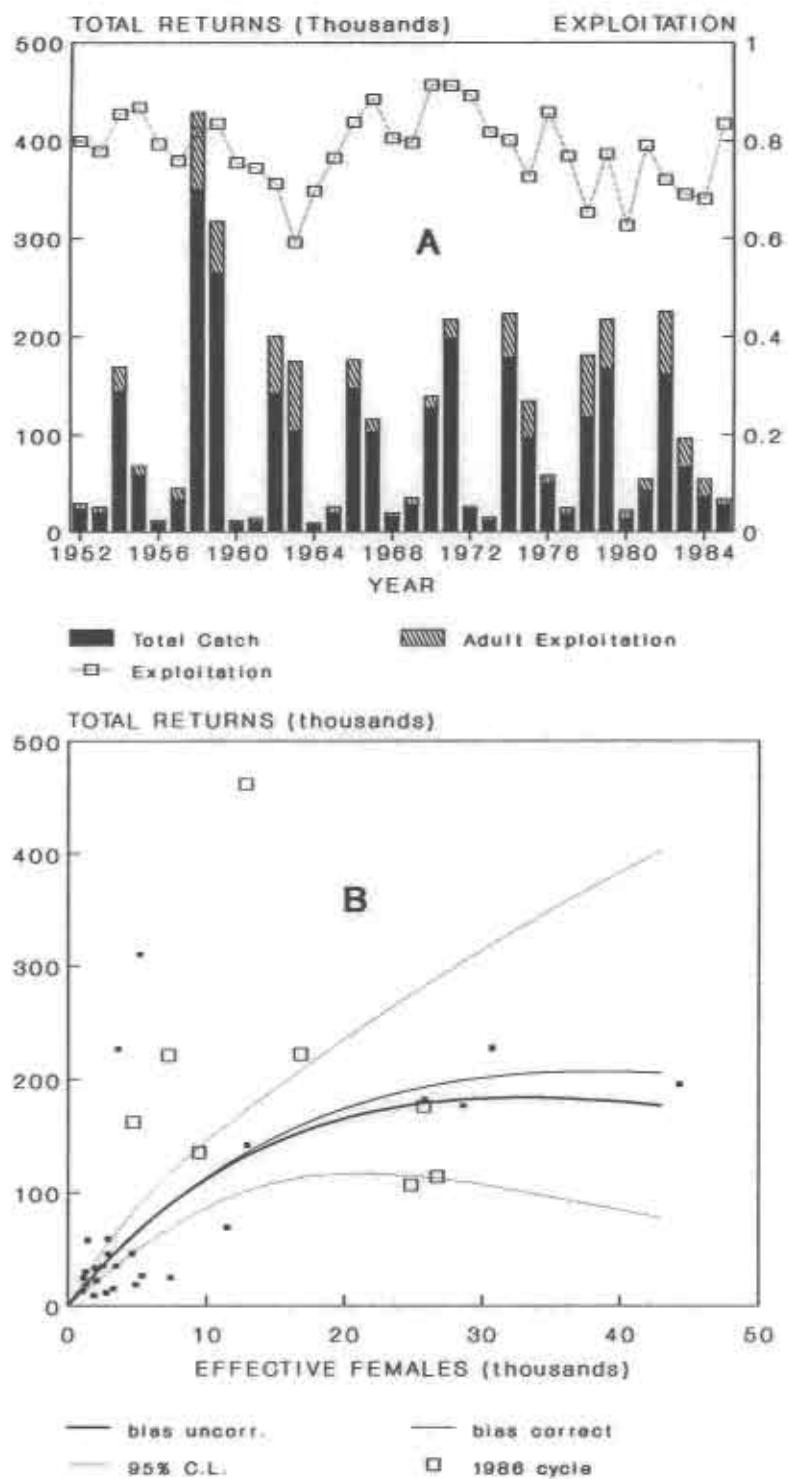


Fig. 11. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Seymour River sockeye.

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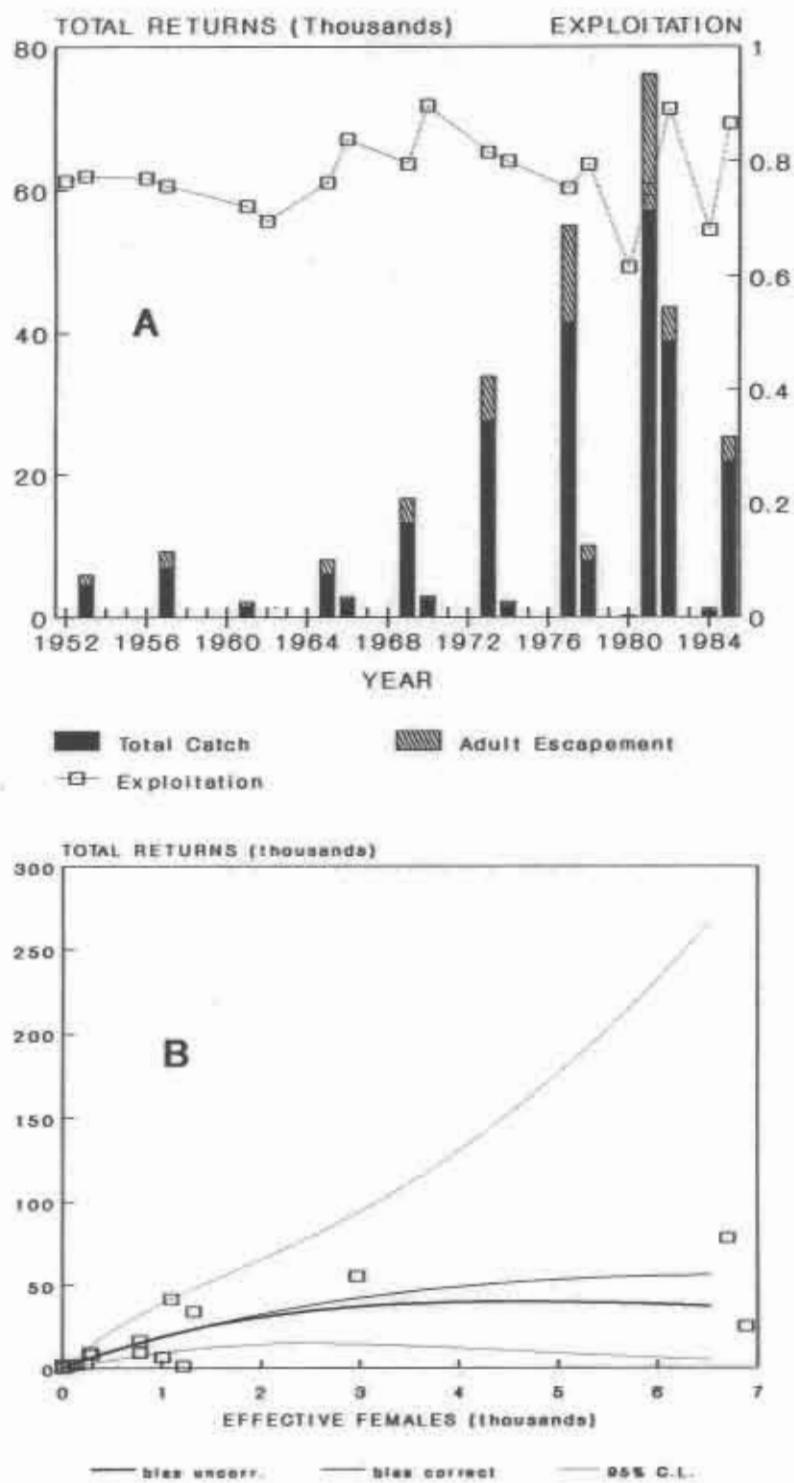


Fig. 12. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Scotch Creek sockeye.

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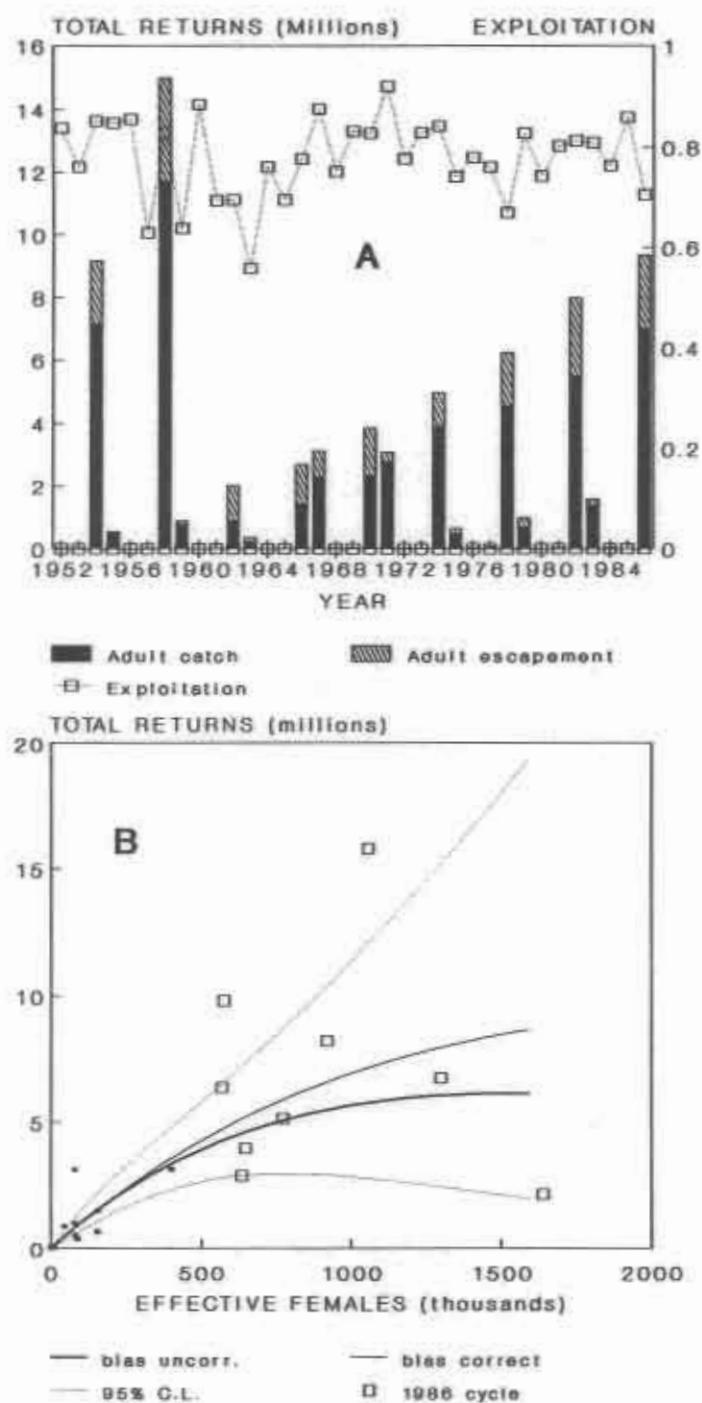


Fig. 13. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Lower Adams sockeye.

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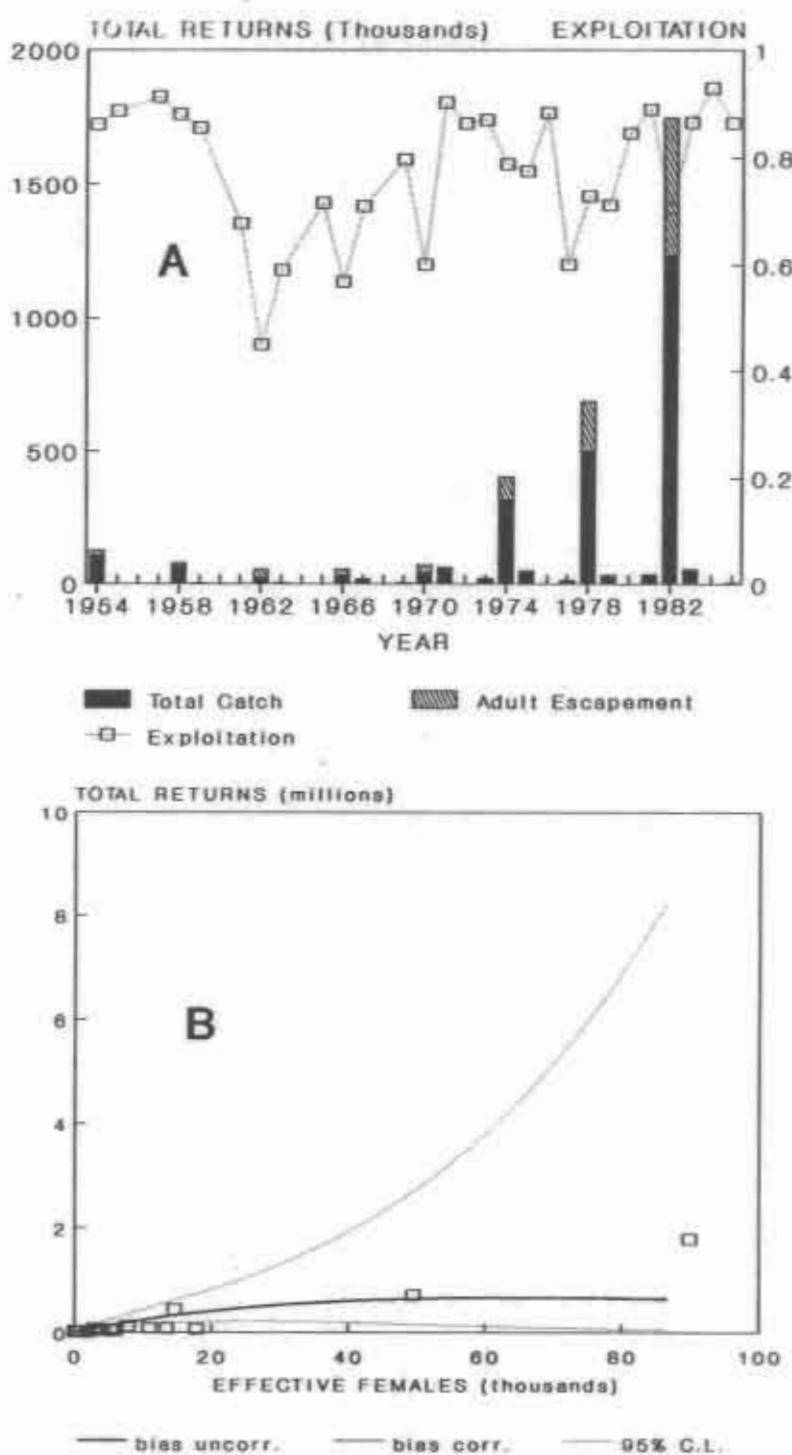


Fig. 14. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Lower River Shuswap sockeye.

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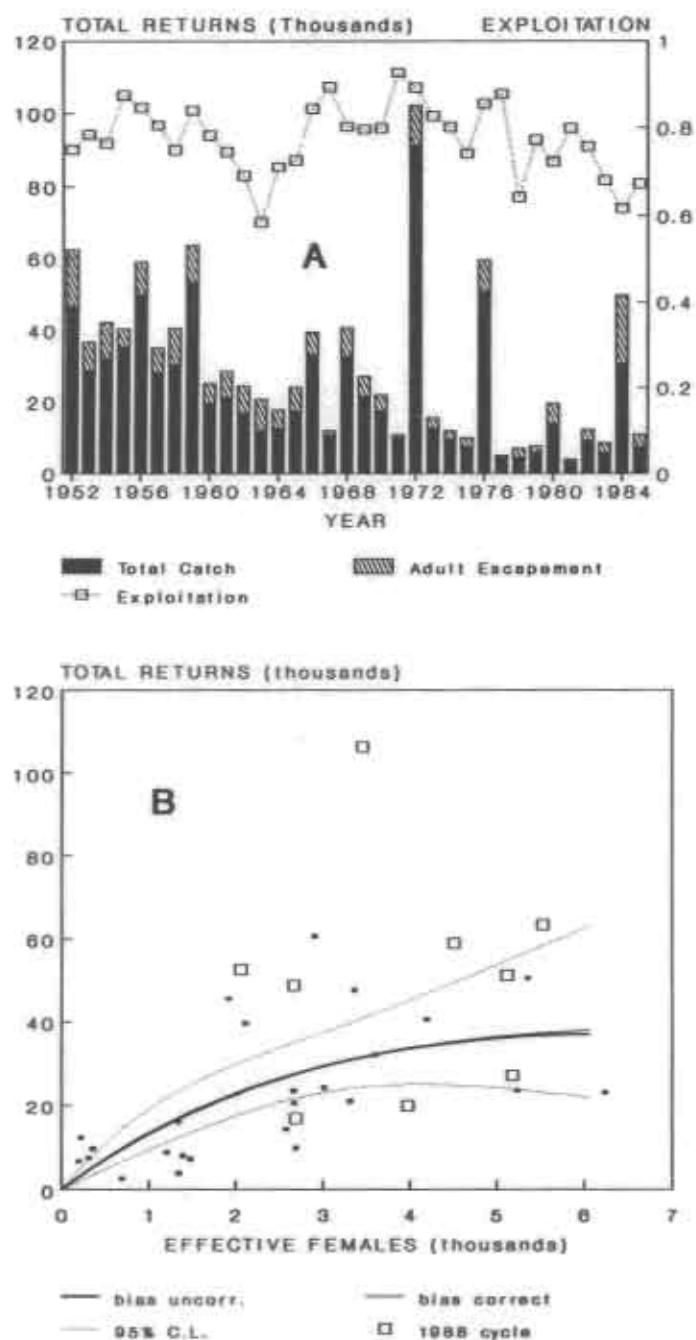


Fig. 15. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Raft River sockeye.

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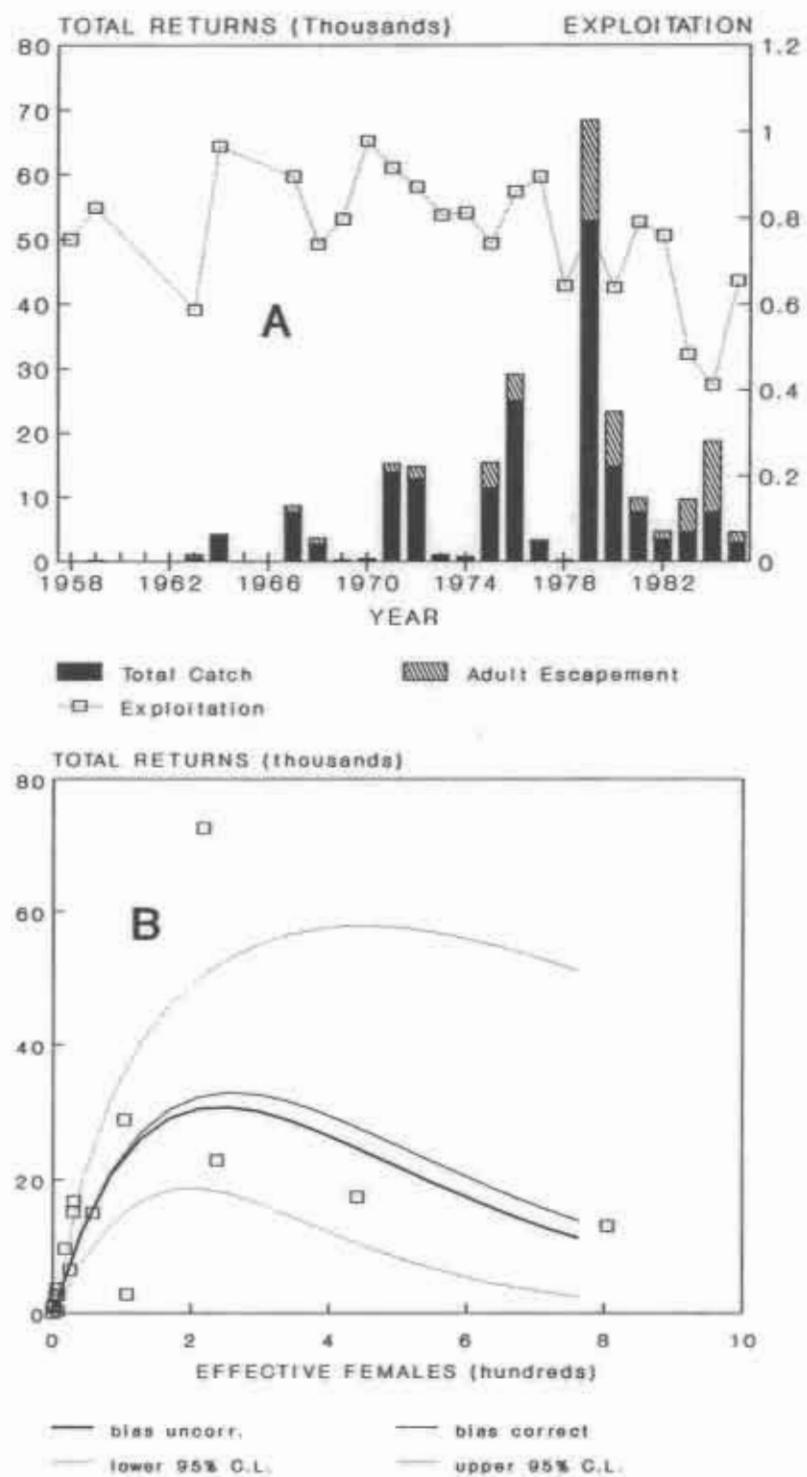


Fig. 16. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Fennell Creek sockeye.

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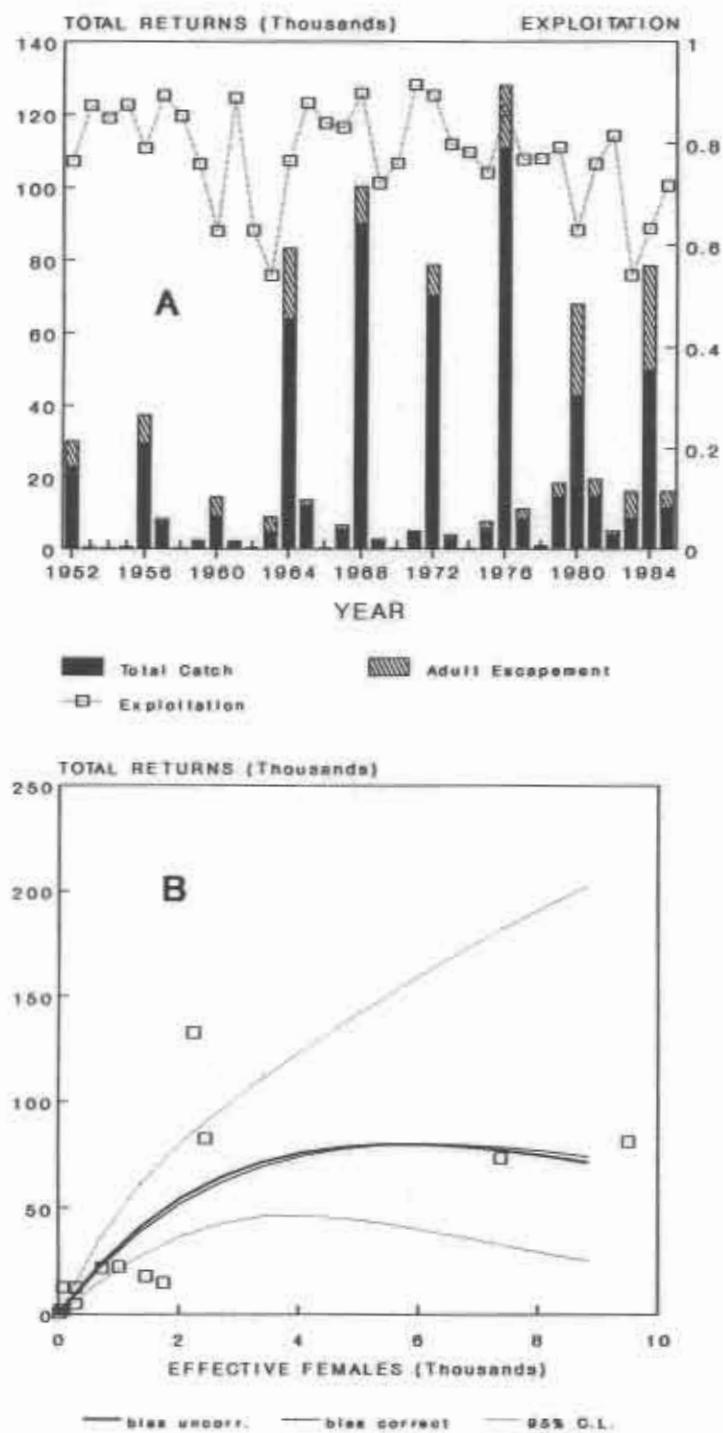


Fig. 17. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Gates Creek sockeye.

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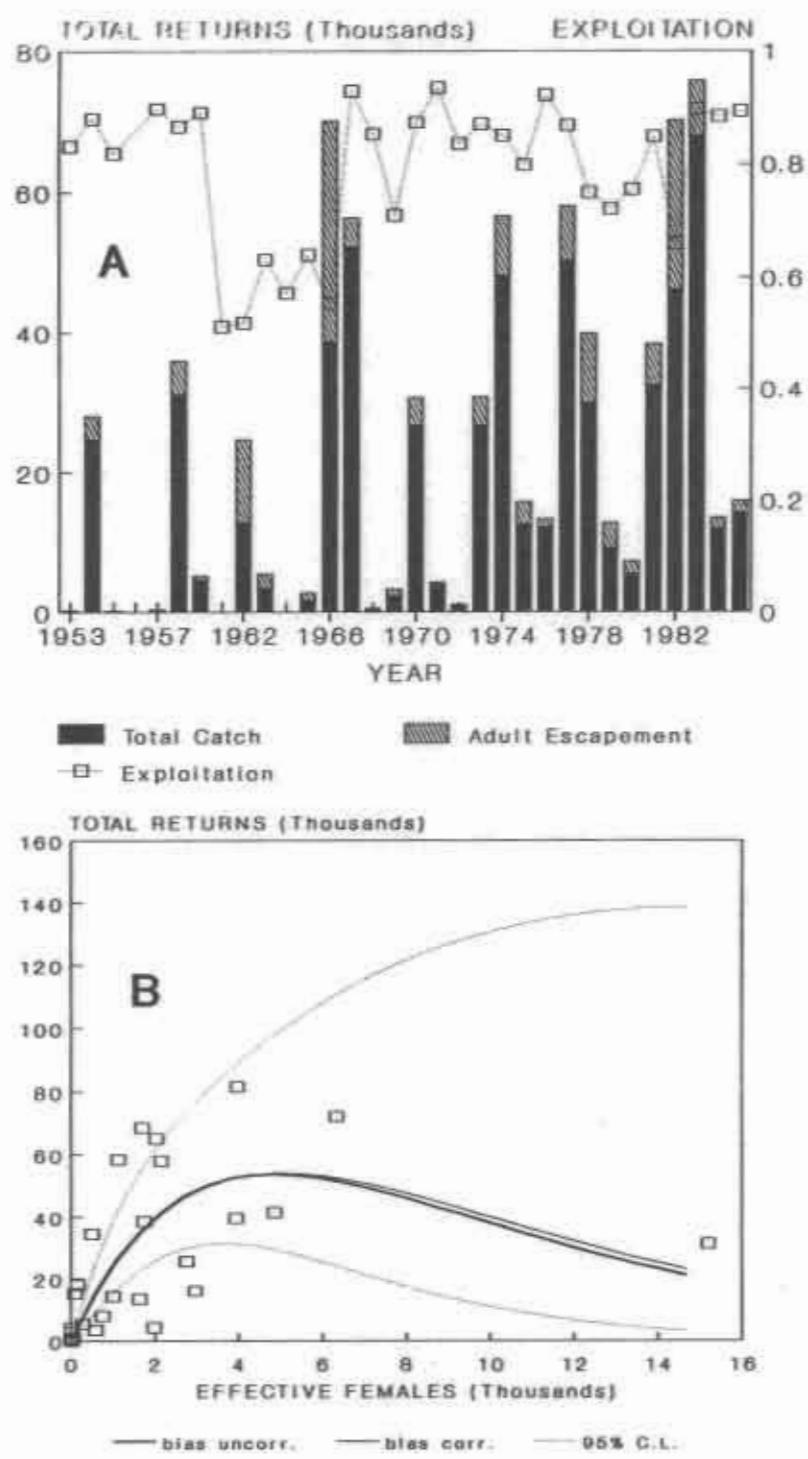


Fig. 18. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Portage Creek sockeye.

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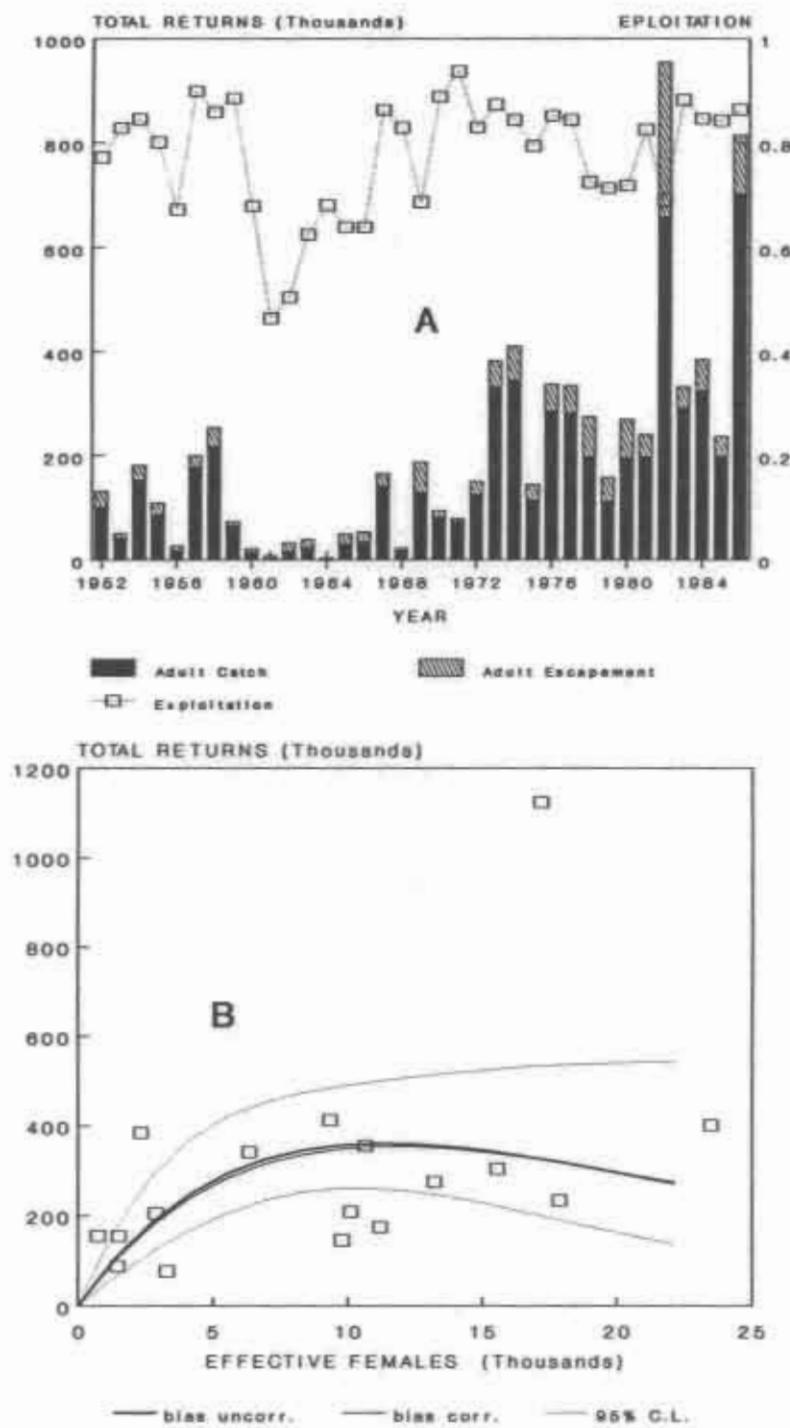


Fig. 19. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Weaver Creek sockeye.

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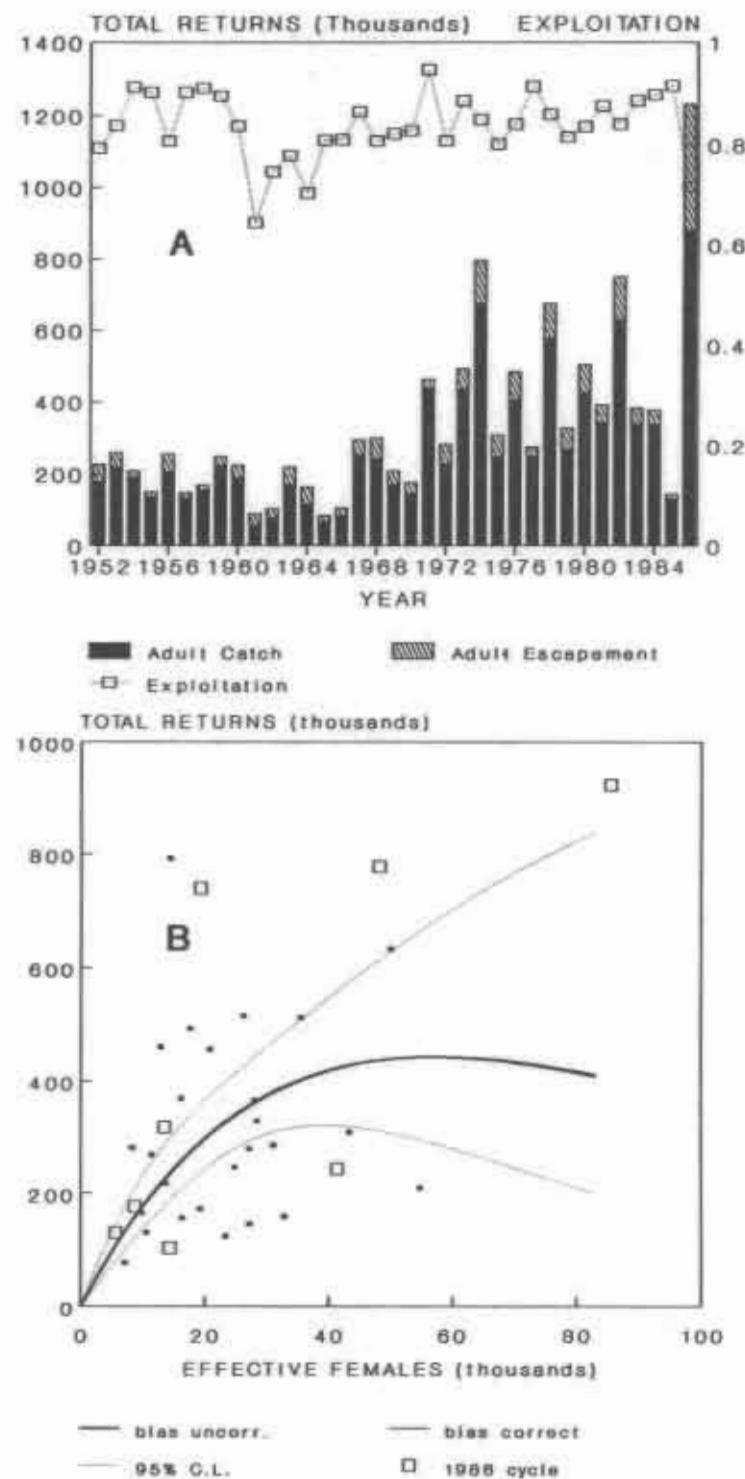


Fig. 20. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Birkenhead River sockeye.

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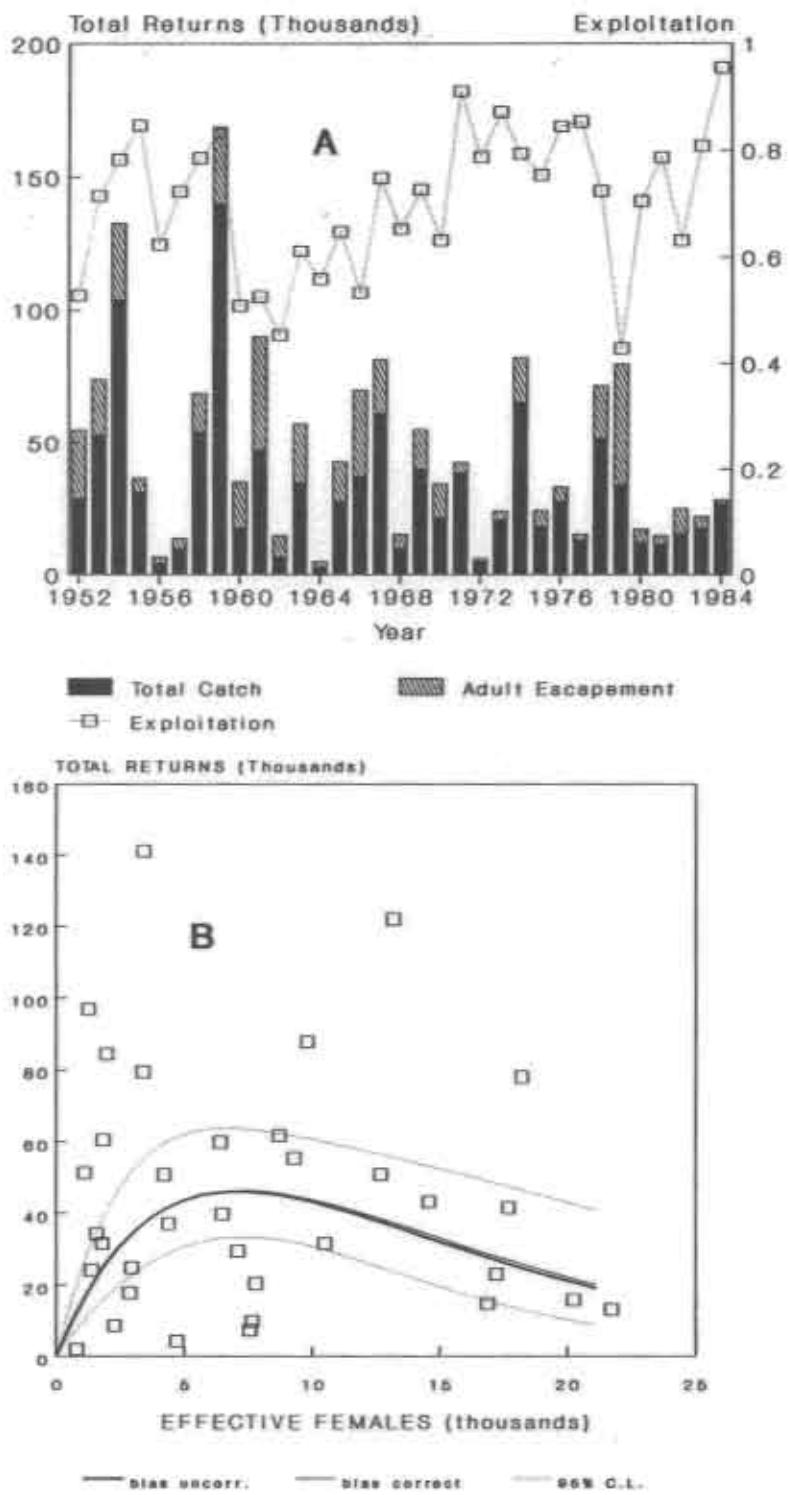


Fig. 21. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Harrison River sockeye.

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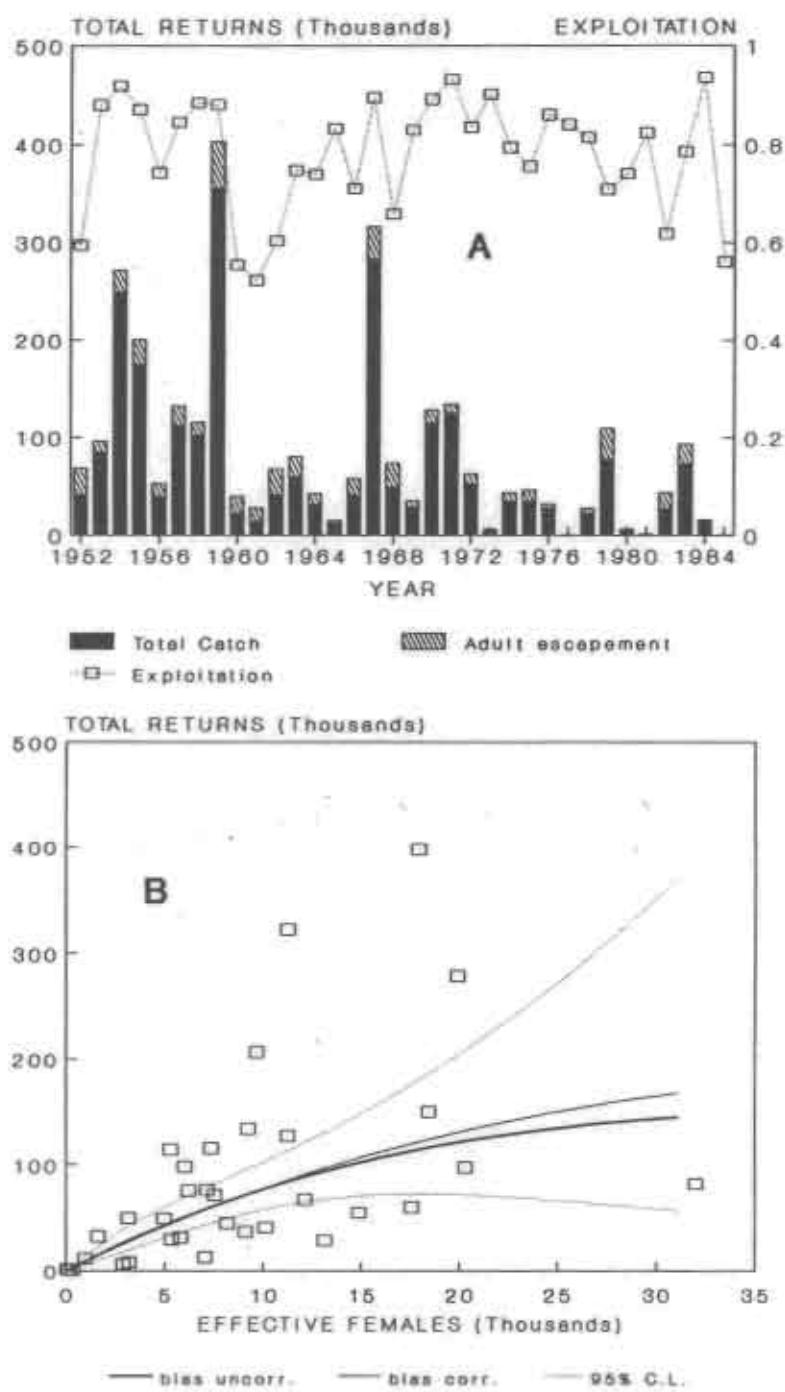


Fig. 22. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for Cultus Lake sockeye.

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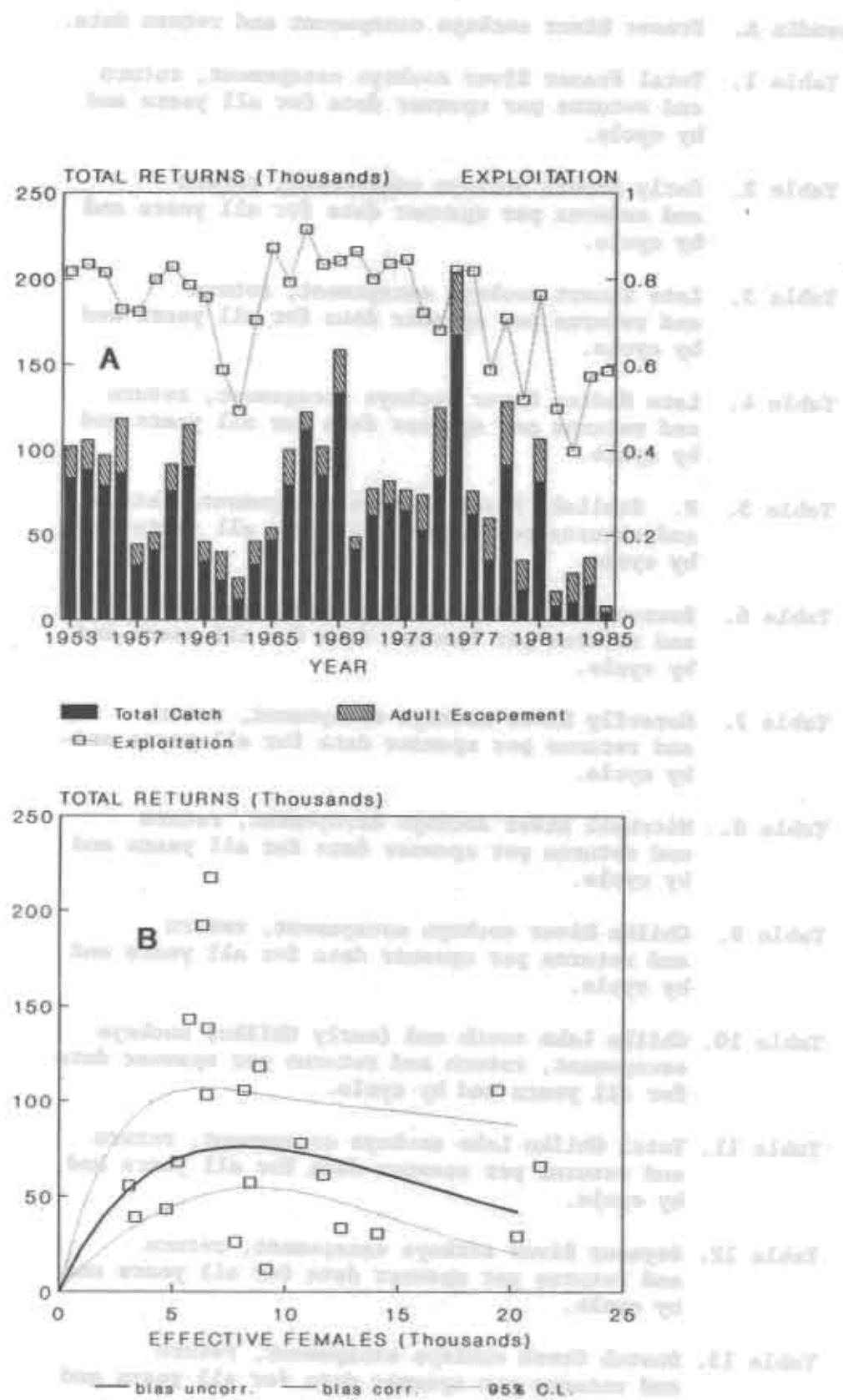


Fig. 23. A) Returns, catch, escapement and exploitation rate and B) the Ricker stock-recruitment relationship for the Upper Pitt River sockeye.

Appendix A. Fraser River sockeye escapement and return data.

Table 1. Total Fraser River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 2. Early Stuart sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 3. Late Stuart sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 4. Late Nadina River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 5. P. Stellako River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 6. Bowron River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 7. Horsefly River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 8. Mitchell River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 9. Chilko River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 10. Chilko Lake south end (early Chilko) sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 11. Total Chilko Lake sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 12. Seymour River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 13. Scotch Creek sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 14. Lower Adams sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 15. Lower Shuswap River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 16. Total Shuswap Lake sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 17. Raft River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 18. Fennel Creek sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 19. Weaver Creek sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 20. Birkenhead River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 21. Harrison River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 22. Portage Creek sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 23. Gates Creek sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 24. Upper Pitt River sockeye escapement, return and returns per spawner data for all years and by cycle.

Table 25. Cultus Lake sockeye escapement, return and returns per spawner data for all years and by cycle.

APPENDIX A, TABLE 1.

FRASER RIVER (TOTAL) SOCKEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | 966,557 | 3,278,908 | 3.39 | 1948 | 966,557 | 3,278,908 | 3.39 | 1949 | 1,066,120 | 5,019,371 | 4.71 |
| 1949 | 1,066,120 | 5,019,371 | 4.71 | 1952 | 795,605 | 2,694,958 | 3.40 | 1953 | 1,058,917 | 4,614,668 | 4.36 |
| 1950 | 1,737,559 | 12,829,594 | 7.38 | 1956 | 858,398 | 3,475,179 | 4.05 | 1957 | 1,340,150 | 4,415,267 | 3.29 |
| 1951 | 564,250 | 2,922,620 | 5.18 | 1960 | 620,915 | 1,713,845 | 2.76 | 1961 | 1,160,439 | 3,121,160 | 2.69 |
| 1952 | 795,603 | 2,694,958 | 3.40 | 1964 | 388,300 | 3,206,742 | 8.26 | 1965 | 774,253 | 4,406,026 | 5.69 |
| 1953 | 1,058,917 | 4,614,668 | 4.36 | 1968 | 592,773 | 3,644,628 | 6.15 | 1969 | 923,071 | 6,994,997 | 7.58 |
| 1954 | 2,415,020 | 19,598,497 | 8.12 | 1972 | 760,641 | 4,323,183 | 5.68 | 1973 | 1,044,355 | 5,604,080 | 5.37 |
| 1955 | 361,443 | 4,689,641 | 12.97 | 1976 | 781,040 | 3,263,859 | 4.15 | 1977 | 1,014,014 | 7,648,192 | 7.54 |
| 1956 | 858,398 | 3,475,179 | 4.05 | 1980 | 829,754 | 5,294,354 | 6.38 | 1981 | 1,384,102 | 13,560,816 | 9.80 |
| 1957 | 1,340,150 | 4,415,267 | 3.29 | 1984 | 922,059 | | | 1985 | 2,077,686 | | |
| 1958 | 3,822,300 | 3,696,304 | 0.97 | Avg: | 751,404 | 3,430,628 | 4.63 (GM) | Avg: | 1,184,311 | 6,153,862 | 5.27 (GM) |
| 1959 | 927,364 | 4,030,988 | 4.35 | Max: | 966,557 | 5,294,354 | 8.26 | Max: | 2,077,686 | 13,560,816 | 9.80 |
| 1960 | 620,915 | 1,713,845 | 2.76 | Min: | 388,300 | 1,713,845 | 2.76 | Min: | 774,253 | 3,121,160 | 2.69 |
| 1961 | 1,160,439 | 3,121,160 | 2.69 | 1986 CYCLE YEAR | | | | 1987 CYCLE YEAR | | | |
| 1962 | 1,575,446 | 5,380,035 | 3.41 | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1963 | 1,577,943 | 6,879,196 | 4.36 | 1966 | 1,797,994 | 6,387,909 | 3.55 | 1967 | 1,331,836 | 7,679,145 | 5.77 |
| 1964 | 388,300 | 3,206,742 | 8.26 | 1968 | 592,773 | 3,644,628 | 6.15 | 1968 | 564,250 | 2,922,620 | 5.18 |
| 1965 | 774,253 | 4,406,026 | 5.69 | 1969 | 923,071 | 6,994,997 | 7.58 | 1969 | 361,443 | 4,689,641 | 12.97 |
| 1966 | 1,797,994 | 6,387,909 | 3.55 | 1970 | 1,860,400 | 8,494,129 | 4.57 | 1970 | 1,737,559 | 12,829,594 | 7.38 |
| 1967 | 1,331,836 | 7,679,145 | 5.77 | 1971 | 719,639 | 3,814,409 | 5.30 | 1971 | 2,415,020 | 19,598,497 | 8.12 |
| 1968 | 592,773 | 3,644,628 | 6.15 | 1972 | 760,641 | 4,323,183 | 5.68 | 1972 | 3,822,300 | 3,696,304 | 0.97 |
| 1969 | 923,071 | 6,994,997 | 7.58 | 1973 | 1,044,355 | 5,604,080 | 5.37 | 1973 | 1,575,446 | 5,380,035 | 3.41 |
| 1970 | 1,860,400 | 8,494,129 | 4.57 | 1974 | 1,656,552 | 9,952,207 | 6.01 | 1974 | 1,797,994 | 6,387,909 | 3.55 |
| 1971 | 719,639 | 3,814,409 | 5.30 | 1975 | 920,793 | 6,194,389 | 6.73 | 1975 | 1,331,836 | 7,679,145 | 5.77 |
| 1972 | 760,641 | 4,323,183 | 5.68 | 1976 | 781,040 | 3,243,859 | 4.15 | 1976 | 719,639 | 3,814,409 | 5.30 |
| 1973 | 1,044,355 | 5,604,080 | 5.37 | 1977 | 1,014,014 | 7,648,192 | 7.54 | 1977 | 920,793 | 6,194,389 | 6.73 |
| 1974 | 1,656,552 | 9,952,207 | 6.01 | 1978 | 2,484,805 | 14,420,431 | 5.80 | 1978 | 1,368,139 | 5,013,251 | 3.66 |
| 1975 | 920,793 | 6,194,389 | 6.73 | 1979 | 4,007,720 | 15,040,100 | 3.75 | 1979 | 964,917 | | |
| 1976 | 781,040 | 3,243,859 | 4.15 | Avg: | 2,373,088 | 10,644,356 | 4.22 (GM) | Avg: | 970,703 | 5,152,955 | 5.59 (GM) |
| 1977 | 1,014,014 | 7,648,192 | 7.54 | Max: | 4,007,720 | 19,598,497 | 8.12 | Max: | 1,577,943 | 7,679,145 | 12.97 |
| 1978 | 2,484,805 | 14,420,431 | 5.80 | Min: | 1,575,446 | 3,696,304 | 0.97 | Min: | 361,443 | 2,922,620 | 5.18 |
| 1979 | 1,368,139 | 5,013,251 | 3.66 | 1988 CYCLE YEAR | | | | 1989 CYCLE YEAR | | | |
| 1980 | 829,754 | 5,294,354 | 6.38 | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1981 | 1,384,102 | 13,560,816 | 9.80 | 1981 | 922,059 | | | 1981 | 1,066,120 | 5,019,371 | 4.71 |
| 1982 | 4,007,720 | 15,040,100 | 3.75 | 1982 | 2,077,686 | | | 1982 | 774,253 | 3,121,160 | 2.69 |
| 1983 | 964,917 | | | 1990 CYCLE YEAR | | | | 1991 CYCLE YEAR | | | |
| 1984 | 922,059 | | | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1985 | 2,077,686 | | | 1985 | 1,066,120 | 5,019,371 | 4.71 | 1985 | 1,331,836 | 7,679,145 | 5.77 |

Appendix A. Table 2.

EARLY STUART SOOYEYE

Appendix A. Table 3.

LATE STUART SOCKEYE

Appendix A. Table 4.

LATE NADINA SOCKEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | | 43 | | 1948 | | 43 | | 1949 | | 105,947 | |
| 1949 | | 105,947 | | 1952 | 9 | 91 | 10.11 | 1953 | 13,617 | 162,560 | 11.94 |
| 1950 | 774 | 5,097 | 6.59 | 1956 | 18 | 4,108 | 228.22 | 1957 | 27,549 | 116,806 | 4.26 |
| 1951 | 175 | 981 | 5.61 | 1960 | 29 | 1,178 | 40.62 | 1961 | 17,542 | 94,420 | 5.38 |
| 1952 | 9 | 91 | 10.11 | 1964 | 209 | 7,735 | 37.01 | 1965 | 11,293 | 95,017 | 8.41 |
| 1953 | 13,617 | 162,560 | 11.94 | 1968 | 1,249 | 43,963 | 35.20 | 1969 | 27,895 | 106,259 | 3.81 |
| 1954 | 770 | 4,725 | 6.14 | 1972 | 2,554 | 10,726 | 4.20 | 1973 | 16,720 | 79,726 | 4.77 |
| 1955 | 106 | 3,953 | 37.29 | 1976 | 1,625 | 7,257 | 4.47 | 1977 | 16,858 | 129,205 | 7.66 |
| 1956 | 18 | 4,108 | 228.22 | 1980 | 3,017 | 18,774 | 6.22 | 1981 | 18,912 | 73,315 | 3.88 |
| 1957 | 27,549 | 116,806 | 4.24 | 1984 | 7,070 | | | 1985 | 13,807 | | |
| 1958 | 635 | 5,083 | 8.00 | | | | | | | | |
| 1959 | 1,013 | 17,000 | 16.78 | Avg: | 1,753 | 10,431 | 18.59 (GM) | Avg: | 18,244 | 107,029 | 5.77 (GM) |
| 1960 | 29 | 1,178 | 40.62 | Max: | 7,070 | 43,963 | 228.22 | Max: | 27,895 | 162,560 | 11.94 |
| 1961 | 17,542 | 94,420 | 5.38 | Min: | 9 | 43 | 4.20 | Min: | 11,293 | 73,315 | 3.81 |
| 1962 | 1,683 | 12,045 | 7.16 | | | | | | | | |
| 1963 | 7,304 | 59,653 | 8.17 | | | | | | | | |
| 1964 | 209 | 7,735 | 37.01 | 1986 CYCLE YEAR | | | | 1987 CYCLE YEAR | | | |
| 1965 | 11,293 | 95,017 | 8.41 | | | | | | | | |
| 1966 | 1,724 | 34,010 | 19.73 | | | | | | | | |
| 1967 | 7,790 | 153,066 | 19.65 | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1968 | 1,249 | 43,963 | 35.20 | | | | | | | | |
| 1969 | 27,895 | 106,259 | 3.81 | | | | | | | | |
| 1970 | 3,929 | 29,884 | 7.61 | 1950 | 774 | 5,097 | 6.59 | 1951 | 175 | 981 | 5.61 |
| 1971 | 14,481 | 75,454 | 5.21 | 1954 | 770 | 4,725 | 6.14 | 1955 | 106 | 3,953 | 37.29 |
| 1972 | 2,554 | 10,728 | 4.20 | 1958 | 635 | 5,083 | 8.00 | 1959 | 1,013 | 17,000 | 16.78 |
| 1973 | 16,720 | 79,726 | 4.77 | 1962 | 1,683 | 12,045 | 7.16 | 1963 | 7,304 | 59,653 | 8.17 |
| 1974 | 3,730 | 12,482 | 3.35 | 1966 | 1,724 | 34,010 | 19.73 | 1967 | 7,790 | 153,066 | 19.65 |
| 1975 | 15,309 | 307,348 | 20.08 | 1970 | 3,929 | 29,884 | 7.61 | 1971 | 14,481 | 75,454 | 5.21 |
| 1976 | 1,625 | 7,257 | 4.47 | 1974 | 3,730 | 12,482 | 3.35 | 1975 | 15,309 | 307,348 | 20.08 |
| 1977 | 16,858 | 129,205 | 7.66 | 1978 | 2,584 | 17,832 | 6.90 | 1979 | 55,681 | 92,270 | 1.66 |
| 1978 | 2,584 | 17,832 | 6.90 | 1982 | 2,349 | | | 1983 | 26,876 | | |
| 1979 | 55,681 | 92,270 | 1.66 | | | | | | | | |
| 1980 | 3,017 | 18,774 | 6.22 | Avg: | 2,020 | 15,145 | 7.30 (GM) | Avg: | 14,304 | 88,716 | 9.97 (GM) |
| 1981 | 18,912 | 73,315 | 3.88 | Max: | 3,929 | 34,010 | 19.73 | Max: | 55,681 | 307,348 | 37.29 |
| 1982 | 2,349 | | | Min: | 635 | 4,725 | 3.35 | Min: | 106 | 981 | 5.61 |
| 1983 | 26,876 | | | | | | | | | | |
| 1984 | 7,070 | | | | | | | | | | |
| 1985 | 13,807 | | | | | | | | | | |
| | Avg: | 9,080 | 55,530 | 9.40 (GM) | | | | | | | |
| | Max: | 55,681 | 307,348 | 228.22 | | | | | | | |
| | Min: | 9 | 43 | 1.66 | | | | | | | |

Note - Includes Early Nadina, Nithi & Endako.

Appendix A. Table 5.

STELLANICO RIVER SIDENEYE

Appendix A. Table 6.

BOWRON RIVER SOOYEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | 25,205 | 80,266 | 3.18 | 1948 | 25,205 | 80,266 | 3.18 | 1949 | 22,283 | 62,791 | 2.82 |
| 1949 | 22,283 | 62,791 | 2.82 | 1952 | 18,645 | 43,304 | 2.32 | 1953 | 13,277 | 75,579 | 5.69 |
| 1950 | 16,146 | 75,548 | 4.68 | 1956 | 6,954 | 38,484 | 5.53 | 1957 | 12,011 | 41,966 | 3.49 |
| 1951 | 21,731 | 103,821 | 4.78 | 1960 | 7,620 | 17,733 | 2.33 | 1961 | 7,449 | 28,148 | 3.78 |
| 1952 | 18,645 | 43,304 | 2.32 | 1964 | 1,500 | 27,507 | 18.34 | 1965 | 2,659 | 17,849 | 6.71 |
| 1953 | 13,277 | 75,579 | 5.69 | 1968 | 3,611 | 44,642 | 12.36 | 1969 | 3,872 | 17,211 | 4.44 |
| 1954 | 10,515 | 66,916 | 6.36 | 1972 | 4,138 | 20,361 | 4.92 | 1973 | 4,598 | 8,564 | 1.88 |
| 1955 | 9,350 | 96,955 | 10.37 | 1976 | 2,250 | 7,112 | 3.16 | 1977 | 2,500 | 8,609 | 3.44 |
| 1956 | 6,964 | 38,484 | 5.53 | 1980 | 2,894 | 22,407 | 7.74 | 1981 | 1,170 | 14,726 | 12.58 |
| 1957 | 12,011 | 41,966 | 3.49 | 1984 | 10,461 | | | 1985 | 6,395 | | |
| 1958 | 14,843 | 18,155 | 1.22 | | | | | | | | |
| 1959 | 29,247 | 61,865 | 2.12 | Avg: | 8,329 | 33,535 | 5.16 (90) | Avg: | 7,617 | 30,605 | 4.31 (90) |
| 1960 | 7,620 | 17,733 | 2.33 | Max: | 25,205 | 80,266 | 18.34 | Max: | 22,283 | 75,579 | 12.58 |
| 1961 | 7,449 | 28,148 | 3.78 | Min: | 1,500 | 7,112 | 2.32 | Min: | 1,170 | 8,564 | 1.88 |
| 1962 | 6,286 | 21,327 | 3.39 | | | | | | | | |
| 1963 | 25,141 | 214,316 | 8.52 | | | | | | | | |
| 1964 | 1,500 | 27,507 | 18.34 | | | | | | | | |
| 1965 | 2,659 | 17,849 | 6.71 | | | | | | | | |
| 1966 | 2,470 | 22,249 | 9.01 | | | | | | | | |
| 1967 | 31,695 | 206,494 | 6.52 | | | | | | | | |
| 1968 | 3,611 | 44,642 | 12.36 | | | | | | | | |
| 1969 | 3,872 | 17,211 | 4.44 | | | | | | | | |
| 1970 | 1,305 | 16,197 | 12.41 | | | | | | | | |
| 1971 | 25,497 | 124,507 | 4.88 | | | | | | | | |
| 1972 | 4,138 | 20,361 | 4.92 | | | | | | | | |
| 1973 | 4,558 | 8,564 | 1.88 | | | | | | | | |
| 1974 | 1,850 | 12,396 | 6.70 | | | | | | | | |
| 1975 | 29,700 | 170,357 | 5.74 | | | | | | | | |
| 1976 | 2,250 | 7,112 | 3.16 | | | | | | | | |
| 1977 | 2,500 | 8,609 | 3.44 | | | | | | | | |
| 1978 | 3,141 | 20,314 | 6.47 | | | | | | | | |
| 1979 | 35,000 | 21,542 | 0.62 | | | | | | | | |
| 1980 | 2,894 | 22,407 | 7.74 | Avg: | 6,467 | 31,638 | 5.27 (90) | Avg: | 23,757 | 124,982 | 4.22 (90) |
| 1981 | 1,170 | 14,726 | 12.58 | Max: | 16,146 | 75,548 | 12.41 | Max: | 35,000 | 214,316 | 10.37 |
| 1982 | 1,647 | | | Min: | 1,305 | 12,396 | 1.22 | Min: | 6,451 | 21,542 | 0.62 |
| 1983 | 6,451 | | | | | | | | | | |
| 1984 | 10,461 | | | | | | | | | | |
| 1985 | 6,395 | | | | | | | | | | |
| Avg: | 11,355 | 53,830 | 4.72 (90) | | | | | | | | |
| Max: | 35,000 | 214,316 | 10.37 | | | | | | | | |
| Min: | 1,170 | 7,112 | 0.62 | | | | | | | | |

Note - Includes Indianpoint Creek.

Appendix A. Table 7.

HORSEFLY RIVER SOCKEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | 100 | 1,132 | 11.32 | 1948 | 100 | 1,132 | 11.32 | 1949 | 30,000 | 476,070 | 15.87 |
| 1949 | 30,000 | 476,070 | 15.87 | 1952 | 184 | 562 | 3.05 | 1953 | 108,573 | 602,993 | 5.55 |
| 1950 | 398 | 1,927 | 4.84 | 1956 | 81 | 2,553 | 31.52 | 1957 | 220,990 | 976,515 | 4.42 |
| 1951 | 49 | 413 | 8.43 | 1960 | 292 | 1,475 | 5.05 | 1961 | 295,964 | 1,223,026 | 4.13 |
| 1952 | 184 | 562 | 3.05 | 1964 | 254 | 2,797 | 11.01 | 1965 | 359,371 | 1,614,217 | 4.49 |
| 1953 | 108,573 | 602,993 | 5.55 | 1968 | 695 | 484 | 0.70 | 1969 | 270,022 | 1,496,320 | 5.54 |
| 1954 | 281 | 10,312 | 36.70 | 1972 | 108 | 1,392 | 12.89 | 1973 | 253,388 | 1,983,829 | 7.83 |
| 1955 | 63 | 180 | 2.86 | 1976 | 298 | 1,233 | 4.14 | 1977 | 473,803 | 3,547,060 | 7.49 |
| 1956 | 81 | 2,553 | 31.52 | 1980 | 274 | 886 | 3.23 | 1981 | 682,515 | 8,125,619 | 11.91 |
| 1957 | 220,990 | 976,515 | 4.42 | 1984 | 895 | | | 1985 | 1,113,172 | | |
| 1958 | 1,798 | 3,396 | 1.89 | | | | | | | | |
| 1959 | 65 | 165 | 2.54 | Avg: | 318 | 1,390 | 5.79 (94) | Avg: | 380,780 | 2,227,294 | 6.72 (94) |
| 1960 | 292 | 1,475 | 5.05 | Max: | 895 | 2,797 | 31.52 | Max: | 1,113,172 | 8,125,619 | 15.87 |
| 1961 | 295,964 | 1,223,026 | 4.13 | Min: | 81 | 484 | 0.70 | Min: | 30,000 | 476,070 | 4.13 |
| 1962 | 1,073 | 6,700 | 6.24 | | | | | | | | |
| 1963 | 83 | 956 | 11.52 | | | | | | | | |
| 1964 | 254 | 2,797 | 11.01 | | | | | | | | |
| 1965 | 359,371 | 1,614,217 | 4.49 | | | | | | | | |
| 1966 | 1,607 | 7,342 | 4.57 | | | | | | | | |
| 1967 | 119 | 1,761 | 14.80 | | | | | | | | |
| 1968 | 695 | 484 | 0.70 | | | | | | | | |
| 1969 | 270,022 | 1,496,320 | 5.54 | | | | | | | | |
| 1970 | 1,345 | 20,339 | 15.12 | | | | | | | | |
| 1971 | 171 | 747 | 4.37 | | | | | | | | |
| 1972 | 108 | 1,392 | 12.89 | | | | | | | | |
| 1973 | 253,388 | 1,983,829 | 7.83 | | | | | | | | |
| 1974 | 4,459 | 18,336 | 4.11 | | | | | | | | |
| 1975 | 193 | 1,713 | 8.88 | | | | | | | | |
| 1976 | 298 | 1,233 | 4.14 | | | | | | | | |
| 1977 | 473,803 | 3,547,060 | 7.49 | | | | | | | | |
| 1978 | 7,377 | 172,439 | 23.38 | | | | | | | | |
| 1979 | 511 | 4,828 | 9.65 | | | | | | | | |
| 1980 | 274 | 886 | 3.23 | | | | | | | | |
| 1981 | 682,515 | 8,125,619 | 11.91 | | | | | | | | |
| 1982 | 36,012 | 514,400 | 14.28 | | | | | | | | |
| 1983 | 2,036 | | | | | | | | | | |
| 1984 | 895 | | | | | | | | | | |
| 1985 | 1,113,172 | | | | | | | | | | |
| Avg: | 101,806 | 59,975 | 6.82 (94) | | | | | | | | |
| Max: | 1,113,172 | 8,125,619 | 36.70 | | | | | | | | |
| Min: | 49 | 165 | 0.70 | | | | | | | | |
| 1986 CYCLE YEAR | | | | 1987 CYCLE YEAR | | | | 1988 CYCLE YEAR | | | |
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1950 | 398 | 1,927 | 4.84 | 1951 | 49 | 413 | 8.43 | 1952 | 184 | 562 | 3.05 |
| 1954 | 281 | 10,312 | 36.70 | 1955 | 63 | 180 | 2.86 | 1956 | 81 | 956 | 11.52 |
| 1958 | 1,798 | 3,396 | 1.89 | 1959 | 65 | 165 | 2.54 | 1960 | 292 | 1,475 | 5.05 |
| 1962 | 1,073 | 6,700 | 6.24 | 1963 | 83 | 956 | 11.52 | 1964 | 254 | 2,797 | 11.01 |
| 1966 | 1,607 | 7,342 | 4.57 | 1967 | 119 | 1,761 | 14.80 | 1968 | 695 | 484 | 0.70 |
| 1970 | 1,345 | 20,339 | 15.12 | 1971 | 171 | 747 | 4.37 | 1972 | 108 | 1,392 | 12.89 |
| 1974 | 4,459 | 18,336 | 4.11 | 1975 | 193 | 1,713 | 8.88 | 1976 | 298 | 1,233 | 4.14 |
| 1978 | 7,377 | 172,439 | 23.38 | 1979 | 511 | 4,828 | 9.65 | 1980 | 274 | 886 | 3.23 |
| 1982 | 36,012 | 514,400 | 14.28 | 1983 | 2,036 | | | 1984 | 895 | | |
| 1985 | 1,113,172 | | | 1986 | 101,806 | 59,975 | 6.82 (94) | 1987 | 36,012 | 514,400 | 36.70 |
| Avg: | 101,806 | 59,975 | 6.82 (94) | Max: | 36,012 | 514,400 | 36.70 | Min: | 49 | 165 | 0.70 |

Appendix A. Table 8.

MITCHELL RIVER SOCKEYE

Appendix A, Table 9.

CHIUD RIVER SOCKEYE

Appendix A. Table 10.

CHILKAT SOUTH END LAKE SOCKEYE

Appendix A. Table 11.

CHILKO LAKE TOTAL SOCKEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | 670,622 | 1,947,973 | 2.90 | 1948 | 670,622 | 1,947,973 | 2.90 | 1949 | 58,247 | 623,138 | 10.70 |
| 1949 | 58,247 | 623,138 | 10.70 | 1952 | 485,585 | 1,858,476 | 3.83 | 1953 | 200,691 | 619,456 | 3.09 |
| 1950 | 17,308 | 205,875 | 11.89 | 1956 | 646,906 | 2,435,670 | 3.77 | 1957 | 138,464 | 138,228 | 1.00 |
| 1951 | 100,116 | 752,327 | 7.51 | 1960 | 426,546 | 1,053,335 | 2.47 | 1961 | 39,101 | 69,453 | 1.78 |
| 1952 | 485,585 | 1,858,476 | 3.83 | 1964 | 238,272 | 2,040,082 | 8.56 | 1965 | 35,335 | 158,944 | 4.50 |
| 1953 | 200,691 | 619,456 | 3.09 | 1968 | 413,862 | 2,476,069 | 5.98 | 1969 | 70,902 | 402,283 | 5.67 |
| 1954 | 34,296 | 712,749 | 20.78 | 1972 | 564,533 | 2,033,998 | 3.60 | 1973 | 55,675 | 220,403 | 3.96 |
| 1955 | 121,167 | 1,513,275 | 12.49 | 1976 | 384,390 | 1,697,694 | 4.42 | 1977 | 51,330 | 194,068 | 3.78 |
| 1956 | 646,906 | 2,435,670 | 3.77 | 1980 | 497,759 | 4,695,216 | 9.43 | 1981 | 34,540 | 185,253 | 5.36 |
| 1957 | 138,464 | 138,228 | 1.00 | 1984 | 580,178 | | | 1985 | 71,975 | | |
| 1958 | 120,104 | 433,371 | 3.61 | Avg: | 490,865 | 2,248,501 | 4.52 (GM) | Avg: | 75,626 | 290,136 | 3.67 (GM) |
| 1959 | 463,060 | 2,212,583 | 4.78 | Max: | 670,622 | 4,695,216 | 9.43 | Max: | 200,691 | 623,138 | 10.70 |
| 1960 | 426,546 | 1,053,335 | 2.47 | Min: | 238,272 | 1,053,335 | 2.47 | Min: | 34,540 | 69,453 | 1.00 |
| 1961 | 39,101 | 69,453 | 1.78 | 1986 CYCLE YEAR | | | | 1987 CYCLE YEAR | | | |
| 1962 | 77,713 | 985,562 | 12.68 | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1963 | 998,231 | 1,206,303 | 1.21 | 1950 | 17,308 | 205,875 | 11.89 | 1951 | 100,116 | 752,327 | 7.51 |
| 1964 | 238,272 | 2,040,082 | 8.56 | 1954 | 34,296 | 712,749 | 20.78 | 1955 | 121,167 | 1,513,275 | 12.49 |
| 1965 | 35,335 | 158,944 | 4.50 | 1958 | 120,104 | 433,371 | 3.61 | 1959 | 463,060 | 2,212,583 | 4.78 |
| 1966 | 209,619 | 889,200 | 4.24 | 1962 | 77,713 | 985,562 | 12.68 | 1963 | 998,231 | 1,206,303 | 1.21 |
| 1967 | 174,715 | 1,999,484 | 11.44 | 1966 | 209,619 | 889,200 | 4.24 | 1967 | 174,715 | 1,999,484 | 11.44 |
| 1968 | 413,862 | 2,476,069 | 5.98 | 1970 | 135,388 | 694,456 | 5.13 | 1971 | 168,396 | 852,842 | 5.06 |
| 1969 | 70,902 | 402,283 | 5.67 | 1974 | 110,026 | 620,588 | 5.64 | 1975 | 244,631 | 1,640,640 | 6.71 |
| 1970 | 135,388 | 694,456 | 5.13 | 1976 | 384,390 | 1,697,694 | 4.42 | 1977 | 51,330 | 194,068 | 3.78 |
| 1971 | 168,396 | 852,842 | 5.06 | 1977 | 51,330 | 194,068 | 3.78 | 1978 | 146,842 | 1,227,233 | 8.36 |
| 1972 | 564,533 | 2,033,998 | 3.60 | 1978 | 146,842 | 1,227,233 | 8.36 | 1979 | 258,391 | 1,659,275 | 6.42 |
| 1973 | 55,675 | 220,403 | 3.96 | 1982 | 249,578 | | | 1983 | 382,833 | | |
| 1974 | 110,026 | 620,588 | 5.64 | Avg: | 122,319 | 721,129 | 7.64 (GM) | Avg: | 323,504 | 1,479,591 | 5.86 (GM) |
| 1975 | 244,631 | 1,640,640 | 6.71 | Max: | 249,578 | 1,227,233 | 20.78 | Max: | 998,231 | 2,212,583 | 12.49 |
| 1976 | 384,390 | 1,697,694 | 4.42 | Min: | 17,308 | 205,875 | 3.61 | Min: | 100,116 | 752,327 | 1.21 |
| 1977 | 51,330 | 194,068 | 3.78 | 1988 CYCLE YEAR | | | | 1989 CYCLE YEAR | | | |
| 1978 | 146,842 | 1,227,233 | 8.36 | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1979 | 258,391 | 1,659,275 | 6.42 | 1982 | 249,578 | | | 1983 | 382,833 | | |
| 1980 | 497,759 | 4,695,216 | 9.43 | Avg: | 122,319 | 721,129 | 7.64 (GM) | Avg: | 323,504 | 1,479,591 | 5.86 (GM) |
| 1981 | 34,540 | 185,253 | 5.36 | Max: | 249,578 | 1,227,233 | 20.78 | Max: | 998,231 | 2,212,583 | 12.49 |
| 1982 | 249,578 | | | Min: | 17,308 | 205,875 | 3.61 | Min: | 100,116 | 752,327 | 1.21 |
| 1983 | 382,833 | | | 1990 CYCLE YEAR | | | | 1991 CYCLE YEAR | | | |
| 1984 | 580,178 | | | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1985 | 71,975 | | | 1982 | 249,578 | | | 1983 | 382,833 | | |
| Avg: | 254,667 | 1,189,809 | 5.14 (GM) | Avg: | 122,319 | 721,129 | 7.64 (GM) | Avg: | 323,504 | 1,479,591 | 5.86 (GM) |
| Max: | 998,231 | 4,695,216 | 20.78 | Max: | 249,578 | 1,227,233 | 20.78 | Max: | 998,231 | 2,212,583 | 12.49 |
| Min: | 17,308 | 69,453 | 1.00 | Min: | 17,308 | 205,875 | 3.61 | Min: | 100,116 | 752,327 | 1.21 |

Includes Chilko River, North End Lake and South End (Early Chilko).

Appendix A. Table 12.

SEYMOUR RIVER SOCKEYE

Appendix A. Table 13.

SCOTCH RIVER SOCKEYE

Appendix A. Table 14.

LOWER ADAMS SOCKEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | 10,356 | 22,876 | 2.21 | 1948 | 10,356 | 22,876 | 2.21 | 1949 | 3,593 | 34,871 | 9.71 |
| 1949 | 3,593 | 34,871 | 9.71 | 1952 | 7,317 | 17,932 | 2.45 | 1953 | 3,472 | 30,998 | 8.95 |
| 1950 | 1,259,381 | 9,814,596 | 7.79 | 1956 | 3,321 | 8,227 | 2.48 | 1957 | 2,807 | 25,825 | 9.20 |
| 1951 | 143,498 | 529,379 | 3.69 | 1960 | 1,907 | 2,606 | 1.37 | 1961 | 1,118 | 6,419 | 5.74 |
| 1952 | 7,317 | 17,932 | 2.45 | 1964 | 604 | 19,478 | 32.25 | 1965 | 1,795 | 50,849 | 28.33 |
| 1953 | 3,472 | 30,998 | 8.95 | 1968 | 3,686 | 20,773 | 5.64 | 1969 | 4,986 | 12,652 | 2.54 |
| 1954 | 2,009,231 | 15,789,570 | 7.86 | 1972 | 4,153 | 42,522 | 10.24 | 1973 | 1,014 | 74,447 | 73.42 |
| 1955 | 63,836 | 863,549 | 13.53 | 1976 | 4,750 | 13,494 | 2.84 | 1977 | 6,151 | 56,776 | 9.23 |
| 1956 | 3,321 | 8,227 | 2.48 | 1980 | 2,482 | 34,999 | 14.08 | 1981 | 6,218 | 3,427 | 0.55 |
| 1957 | 2,807 | 25,825 | 9.20 | 1984 | 4,248 | | | 1985 | 471 | | |
| 1958 | 3,287,678 | 2,132,621 | 0.65 | Avg: | 4,282 | 20,319 | 4.80 (GM) | Avg: | 3,163 | 32,918 | 7.92 (GM) |
| 1959 | 134,545 | 378,352 | 2.81 | Max: | 10,356 | 42,522 | 32.25 | Max: | 6,218 | 74,447 | 73.42 |
| 1960 | 1,907 | 2,606 | 1.37 | Min: | 604 | 2,606 | 1.37 | Min: | 471 | 3,427 | 0.55 |
| 1961 | 1,118 | 6,419 | 5.74 | | | | | | | | |
| 1962 | 1,113,088 | 2,867,521 | 2.58 | | | | | | | | |
| 1963 | 156,454 | 3,112,002 | 19.89 | | | | | | | | |
| 1964 | 604 | 19,478 | 32.25 | | | | | | | | |
| 1965 | 1,795 | 50,849 | 28.33 | | | | | | | | |
| 1986 CYCLE YEAR | | | | | | | | | | | |
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1950 | 1,259,381 | 9,814,596 | 7.79 | 1951 | 143,498 | 529,379 | 3.69 | | | | |
| 1954 | 2,009,231 | 15,789,570 | 7.86 | 1955 | 63,836 | 863,549 | 13.53 | | | | |
| 1958 | 3,287,678 | 2,132,621 | 0.65 | 1959 | 134,545 | 378,352 | 2.81 | | | | |
| 1962 | 1,113,088 | 2,867,521 | 2.58 | 1963 | 156,454 | 3,112,002 | 19.89 | | | | |
| 1966 | 1,255,883 | 3,947,763 | 3.14 | 1967 | 838,945 | 3,120,311 | 3.72 | | | | |
| 1967 | 838,945 | 3,120,311 | 3.72 | 1970 | 1,495,504 | 5,146,834 | 3.44 | 1971 | 283,791 | 655,449 | 2.31 |
| 1968 | 3,686 | 20,773 | 5.64 | 1966 | 1,255,883 | 3,947,763 | 3.14 | 1974 | 1,061,774 | 6,394,532 | 6.02 |
| 1969 | 4,986 | 12,652 | 2.54 | 1973 | 1,014 | 74,447 | 73.42 | 1975 | 155,517 | 994,994 | 6.40 |
| 1970 | 1,495,504 | 5,146,834 | 3.44 | 1976 | 1,061,774 | 6,394,532 | 6.02 | 1978 | 288,777 | 1,473,585 | 5.10 |
| 1971 | 283,791 | 655,449 | 2.31 | 1972 | 4,153 | 42,522 | 10.24 | 1980 | 2,482 | 34,999 | 14.08 |
| 1972 | 4,153 | 42,522 | 10.24 | 1974 | 1,014 | 74,447 | 73.42 | 1982 | 2,506,038 | 6,760,897 | 2.70 |
| 1973 | 1,014 | 74,447 | 73.42 | 1976 | 1,061,774 | 6,394,532 | 6.02 | 1984 | 4,248 | | |
| 1974 | 1,061,774 | 6,394,532 | 6.02 | 1978 | 1,699,329 | 8,246,094 | 4.85 | 1985 | 471 | | |
| 1975 | 155,517 | 994,994 | 6.40 | 1980 | 2,482 | 34,999 | 14.08 | Avg: | 1,743,102 | 6,788,956 | 3.54 (GM) |
| 1976 | 4,750 | 13,494 | 2.84 | 1982 | 2,506,038 | 6,760,897 | 2.70 | Max: | 3,287,678 | 15,789,570 | 7.86 |
| 1977 | 6,151 | 56,776 | 9.23 | 1984 | 4,248 | | | Min: | 1,061,774 | 2,132,621 | 0.65 |
| 1978 | 1,699,329 | 8,246,094 | 4.85 | 1985 | 471 | | | | | | |
| 1979 | 288,777 | 1,473,585 | 5.10 | Avg: | 474,520 | 2,077,348 | 5.20 (GM) | | | | |
| 1980 | 2,482 | 34,999 | 14.08 | Max: | 3,287,678 | 15,789,570 | 7.86 | | | | |
| 1981 | 6,218 | 3,427 | 0.55 | Min: | 1,061,774 | 2,132,621 | 0.65 | | | | |
| 1982 | 2,506,038 | 6,760,897 | 2.70 | | | | | | | | |
| 1983 | 204,030 | | | | | | | | | | |
| 1984 | 4,248 | | | | | | | | | | |
| 1985 | 471 | | | | | | | | | | |
| Avg: | 474,520 | 2,077,348 | 5.20 (GM) | | | | | | | | |
| Max: | 3,287,678 | 15,789,570 | 7.86 | | | | | | | | |
| Min: | 471 | 2,606 | 0.55 | | | | | | | | |

Includes all late run Shuswap Lake except Lower Shuswap system sockeye

Appendix A. Table 15.

LOWER SUSHAP RIVER SOOYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | | | | 1948 | | | | 1949 | 13 | 13,994 | 1076.46 |
| 1949 | 13 | 13,994 | 1076.46 | 1952 | | | | 1953 | | 29 | |
| 1950 | 12,000 | 126,844 | 10.57 | 1956 | | | | 1957 | 2 | 1,040 | 520.00 |
| 1951 | | 203 | | 1960 | | 22 | | 1961 | 32 | 1,956 | 61.13 |
| 1952 | | | | 1964 | | 5 | | 1965 | 292 | 4,892 | 16.75 |
| 1953 | | 29 | | 1968 | | 1,154 | | 1969 | 999 | 21,427 | 21.45 |
| 1954 | 17,462 | 79,766 | 4.57 | 1972 | 39 | 379 | 9.72 | 1973 | 2,794 | 17,604 | 6.30 |
| 1955 | 23 | 1,971 | 85.70 | 1976 | 30 | 648 | 21.60 | 1977 | 6,359 | 36,869 | 5.80 |
| 1956 | | | | 1980 | 18 | 631 | 35.08 | 1981 | 4,075 | 6,039 | 1.48 |
| 1957 | 2 | 1,040 | 520.00 | 1984 | 75 | | | 1985 | 817 | | |
| 1958 | 9,367 | 57,231 | 6.11 | | | | | | | | |
| 1959 | 281 | 3,950 | 14.06 | Avg: | 41 | 473 | 19.45 (G) | Avg: | 1,709 | 11,539 | 30.05 (G) |
| 1960 | | 22 | | Max: | 75 | 1,154 | 35.08 | Max: | 6,359 | 36,869 | 1076.46 |
| 1961 | 32 | 1,956 | 61.13 | Min: | 18 | 5 | 9.72 | Min: | 2 | 29 | 1.48 |
| 1962 | 31,027 | 57,484 | 1.85 | | | | | | | | |
| 1963 | 2,014 | 19,344 | 9.60 | | | | | | | | |
| 1964 | | 5 | | | | | | | | | |
| 1965 | 292 | 4,892 | 16.75 | | | | | | | | |
| 1966 | 26,415 | 73,379 | 3.01 | | | | | | | | |
| 1967 | 5,951 | 63,912 | 10.74 | | | | | | | | |
| 1968 | | 1,154 | | | | | | | | | |
| 1969 | 999 | 21,427 | 21.45 | | | | | | | | |
| 1970 | 28,799 | 429,887 | 14.93 | 1950 | 12,000 | 126,844 | 10.57 | 1951 | | 203 | |
| 1971 | 6,117 | 46,676 | 7.63 | 1954 | 17,462 | 79,766 | 4.57 | 1955 | 23 | 1,971 | 85.70 |
| 1972 | 39 | 379 | 9.72 | 1958 | 9,367 | 57,231 | 6.11 | 1959 | 281 | 3,950 | 14.06 |
| 1973 | 2,794 | 17,604 | 6.30 | 1962 | 31,027 | 57,484 | 1.85 | 1963 | 2,014 | 19,344 | 9.60 |
| 1974 | 85,950 | 709,941 | 8.26 | 1966 | 26,415 | 73,379 | 3.01 | 1967 | 5,951 | 63,912 | 10.74 |
| 1975 | 11,622 | 31,579 | 2.72 | 1970 | 28,799 | 429,887 | 14.93 | 1971 | 6,117 | 46,676 | 7.63 |
| 1976 | 30 | 648 | 21.60 | 1974 | 85,950 | 709,941 | 8.26 | 1975 | 11,622 | 31,579 | 2.72 |
| 1977 | 6,359 | 36,869 | 5.80 | 1978 | 187,134 | 1,786,270 | 9.55 | 1979 | 10,048 | 30,191 | 3.00 |
| 1978 | 187,134 | 1,786,270 | 9.55 | 1982 | 513,897 | | | 1983 | 7,308 | | |
| 1979 | 10,048 | 30,191 | 3.00 | | | | | | | | |
| 1980 | 18 | 631 | 35.08 | Avg: | 101,117 | 415,100 | 6.11 (G) | Avg: | 5,421 | 26,728 | 9.64 (G) |
| 1981 | 4,075 | 6,039 | 1.48 | Max: | 513,897 | 1,786,270 | 14.93 | Max: | 11,622 | 63,912 | 85.70 |
| 1982 | 513,897 | | | Min: | 9,367 | 57,231 | 1.85 | Min: | 23 | 203 | 2.72 |
| 1983 | 7,308 | | | | | | | | | | |
| 1984 | 75 | | | | | | | | | | |
| 1985 | 817 | | | | | | | | | | |
| Avg: | 32,299 | 116,946 | 12.89 (G) | | | | | | | | |
| Max: | 513,897 | 1,786,270 | 1076.46 | | | | | | | | |
| Min: | 2 | 5 | 1.48 | | | | | | | | |

*All data are specific year class ages at time of return.

Appendix A. Table 16.

SHUSWAP LAKE TOTAL Sockeye

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | 14,255 | 52,585 | 3.69 | 1948 | 14,255 | 52,585 | 3.69 | 1969 | 16,142 | 90,089 | 5.58 |
| 1949 | 16,142 | 90,089 | 5.58 | 1952 | 13,292 | 29,216 | 2.20 | 1953 | 10,528 | 85,794 | 8.15 |
| 1950 | 1,282,474 | 10,103,466 | 7.88 | 1956 | 5,819 | 21,942 | 3.77 | 1957 | 15,909 | 52,668 | 3.31 |
| 1951 | 167,818 | 598,525 | 3.57 | 1960 | 4,820 | 11,465 | 2.38 | 1961 | 5,370 | 49,483 | 9.21 |
| 1952 | 13,292 | 29,216 | 2.20 | 1964 | 3,349 | 38,203 | 11.41 | 1965 | 10,086 | 107,268 | 10.64 |
| 1953 | 10,528 | 85,794 | 8.15 | 1968 | 7,524 | 44,035 | 5.85 | 1969 | 16,556 | 82,957 | 5.01 |
| 1954 | 2,051,467 | 16,330,858 | 7.96 | 1972 | 6,994 | 101,620 | 14.53 | 1973 | 12,747 | 172,535 | 13.54 |
| 1955 | 72,830 | 1,175,522 | 16.14 | 1976 | 13,120 | 36,671 | 2.80 | 1977 | 31,805 | 230,064 | 7.23 |
| 1956 | 5,819 | 21,942 | 3.77 | 1980 | 10,916 | 82,641 | 7.57 | 1981 | 40,604 | 61,156 | 1.51 |
| 1957 | 15,909 | 52,668 | 3.31 | 1984 | 21,904 | | | 1985 | 10,293 | | |
| 1958 | 3,375,416 | 2,385,393 | 0.71 | | | | | | | | |
| 1959 | 187,136 | 558,282 | 2.98 | Avg: | 10,199 | 46,486 | 4.25 (90) | Avg: | 17,004 | 103,557 | 6.05 (90) |
| 1960 | 4,820 | 11,465 | 2.38 | Max: | 21,904 | 101,620 | 14.53 | Max: | 40,604 | 230,064 | 13.54 |
| 1961 | 5,370 | 49,483 | 9.21 | Min: | 3,349 | 11,465 | 2.20 | Min: | 5,370 | 49,483 | 1.51 |
| 1962 | 1,201,958 | 3,104,268 | 2.58 | | | | | | | | |
| 1963 | 230,122 | 3,245,432 | 14.10 | | | | | | | | |
| 1964 | 3,349 | 38,203 | 11.41 | | | | | | | | |
| 1965 | 10,086 | 107,268 | 10.64 | | | | | | | | |
| 1966 | 1,309,465 | 4,165,926 | 3.18 | | | | | | | | |
| 1967 | 658,257 | 3,405,074 | 3.97 | | | | | | | | |
| 1968 | 7,524 | 44,035 | 5.85 | | | | | | | | |
| 1969 | 16,556 | 82,957 | 5.01 | | | | | | | | |
| 1970 | 1,536,578 | 5,805,326 | 3.78 | | | | | | | | |
| 1971 | 308,956 | 857,474 | 2.71 | | | | | | | | |
| 1972 | 6,994 | 101,620 | 14.53 | | | | | | | | |
| 1973 | 12,747 | 172,535 | 13.54 | | | | | | | | |
| 1974 | 1,192,759 | 7,296,148 | 6.12 | | | | | | | | |
| 1975 | 203,957 | 1,244,503 | 6.10 | | | | | | | | |
| 1976 | 13,120 | 36,671 | 2.80 | | | | | | | | |
| 1977 | 31,805 | 230,064 | 7.23 | | | | | | | | |
| 1978 | 1,951,327 | 10,300,948 | 5.28 | | | | | | | | |
| 1979 | 348,131 | 1,610,405 | 4.63 | | | | | | | | |
| 1980 | 10,916 | 82,641 | 7.57 | Avg: | 1,887,707 | 7,744,124 | 3.75 (90) | Avg: | 290,956 | 1,584,402 | 5.41 (90) |
| 1981 | 40,604 | 61,156 | 1.51 | Max: | 3,375,416 | 16,330,858 | 7.96 | Max: | 658,257 | 3,405,074 | 16.14 |
| 1982 | 3,087,915 | 10,204,780 | 3.30 | Min: | 1,192,759 | 2,385,393 | 0.71 | Min: | 72,830 | 558,282 | 2.71 |
| 1983 | 241,408 | | | | | | | | | | |
| 1984 | 21,904 | | | | | | | | | | |
| 1985 | 10,293 | | | | | | | | | | |
| | Avg: | 523,158 | 2,392,078 | 4.93 (90) | | | | | | | |
| | Max: | 3,375,416 | 16,330,858 | 16.14 | | | | | | | |
| | Min: | 3,349 | 11,465 | 0.71 | | | | | | | |

Includes Adams, Lower Shuswap, Little River, Shuswap Lake, Scotch, Seymour.

Appendix A. Table 17.

RAFT RIVER SOOKEYE

Appendix A. Table 18.

PEINELL CREEK SOCKEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | | | | 1948 | | | | 1949 | | | |
| 1949 | | | | 1952 | | | | 1953 | | | |
| 1950 | | | | 1956 | | | | 1957 | | | |
| 1951 | | | | 1960 | | 4,120 | | 1961 | | | |
| 1952 | | | | 1964 | 146 | 3,637 | 24.91 | 1965 | | 259 | |
| 1953 | | | | 1968 | 954 | 15,037 | 15.76 | 1969 | 52 | 881 | 16.94 |
| 1954 | | 20 | | 1972 | 1,881 | 28,899 | 14.97 | 1973 | 205 | 2,805 | 13.68 |
| 1955 | | 152 | | 1976 | 4,090 | 23,900 | 5.84 | 1977 | 355 | 8,855 | 24.94 |
| 1956 | | | | 1980 | 8,437 | 17,581 | 2.08 | 1981 | 2,076 | 4,444 | 2.14 |
| 1957 | | | | 1984 | 11,021 | | | 1985 | 1,598 | | |
| 1958 | 5 | 27 | 5.40 | | | | | | | | |
| 1959 | 27 | 1,114 | 41.26 | Avg: | 4,430 | 15,529 | 9.35 (90) | Avg: | 857 | 3,449 | 10.55 (90) |
| 1960 | | 4,120 | | Max: | 11,021 | 28,899 | 24.91 | Max: | 2,076 | 8,855 | 24.94 |
| 1961 | | | | Min: | 146 | 3,637 | 2.08 | Min: | 52 | 259 | 2.14 |
| 1962 | | 2,145 | | | | | | | | | |
| 1963 | 436 | 6,534 | 14.99 | | | | | | | | |
| 1964 | 146 | 3,637 | 24.91 | | | | | | | | |
| 1965 | | 259 | | | | | | | | | |
| 1966 | | 411 | | | | | | | | | |
| 1967 | 916 | 15,201 | 16.59 | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1968 | 954 | 15,037 | 15.76 | | | | | | | | |
| 1969 | 52 | 881 | 16.94 | | | | | | | | |
| 1970 | 9 | 740 | 82.22 | | | | | | | | |
| 1971 | 1,295 | 16,707 | 12.92 | | | | | | | | |
| 1972 | 1,931 | 28,899 | 14.97 | | | | | | | | |
| 1973 | 205 | 2,805 | 13.68 | | | | | | | | |
| 1974 | 140 | 299 | 2.14 | | | | | | | | |
| 1975 | 4,005 | 72,617 | 18.13 | | | | | | | | |
| 1976 | 4,090 | 23,900 | 5.84 | | | | | | | | |
| 1977 | 355 | 8,855 | 24.94 | | | | | | | | |
| 1978 | 107 | 4,527 | 42.31 | | | | | | | | |
| 1979 | 15,565 | 11,238 | 0.72 | | | | | | | | |
| 1980 | 8,437 | 17,581 | 2.08 | Avg: | 279 | 1,167 | 14.15 (91) | Avg: | 3,888 | 17,652 | 10.96 (91) |
| 1981 | 2,076 | 4,444 | 2.14 | Max: | 1,132 | 4,527 | 82.22 | Max: | 15,565 | 72,617 | 41.26 |
| 1982 | | 1,132 | | Min: | 5 | 20 | 2.14 | Min: | 27 | 152 | 0.72 |
| 1983 | | 4,977 | | | | | | | | | |
| 1984 | | 11,021 | | | | | | | | | |
| 1985 | | 1,598 | | | | | | | | | |
| | Avg: | 2,586 | 9,686 | 11.00 (91) | | | | | | | |
| | Max: | 15,565 | 72,617 | 82.22 | | | | | | | |
| | Min: | 5 | 20 | 0.72 | | | | | | | |

Appendix A. Table 19.

LEMMER CREEK SODIETE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | 19,431 | 131,635 | 6.77 | 1948 | 19,431 | 131,635 | 6.77 | 1949 | 12,725 | 55,002 | 4.32 |
| 1949 | 12,725 | 55,002 | 4.32 | 1952 | 28,050 | 11,006 | 0.39 | 1953 | 8,789 | 218,207 | 24.83 |
| 1950 | 30,539 | 184,157 | 6.03 | 1956 | 8,690 | 21,608 | 2.49 | 1957 | 20,237 | 8,862 | 0.44 |
| 1951 | 12,856 | 117,511 | 9.14 | 1960 | 7,033 | 4,623 | 0.66 | 1961 | 4,246 | 57,809 | 13.61 |
| 1952 | 28,050 | 11,006 | 0.39 | 1964 | 1,196 | 25,040 | 20.94 | 1965 | 17,924 | 205,659 | 11.47 |
| 1953 | 8,769 | 218,207 | 24.83 | 1968 | 3,799 | 155,396 | 40.90 | 1969 | 58,727 | 412,913 | 7.03 |
| 1954 | 28,137 | 235,297 | 8.36 | 1972 | 25,738 | 342,374 | 13.30 | 1973 | 48,541 | 355,612 | 7.33 |
| 1955 | 21,636 | 72,868 | 3.37 | 1976 | 49,952 | 304,515 | 6.10 | 1977 | 52,627 | 234,642 | 4.46 |
| 1956 | 8,690 | 21,608 | 2.49 | 1980 | 73,830 | 401,627 | 5.44 | 1981 | 42,002 | 209,727 | 4.99 |
| 1957 | 20,237 | 8,862 | 0.44 | 1984 | 59,602 | | | 1985 | 36,545 | | |
| 1958 | 35,939 | 31,072 | 0.86 | Avg: | 27,730 | 155,314 | 4.90 (94) | Avg: | 30,236 | 195,379 | 5.88 (94) |
| 1959 | 8,363 | 39,259 | 4.69 | Max: | 73,830 | 401,627 | 40.90 | Max: | 58,727 | 412,913 | 24.83 |
| 1960 | 7,033 | 4,623 | 0.66 | Min: | 1,196 | 4,623 | 0.39 | Min: | 4,246 | 8,862 | 0.44 |
| 1961 | 4,246 | 57,809 | 13.61 | 1986 CYCLE YEAR | | | | 1987 CYCLE YEAR | | | |
| 1962 | 15,924 | 47,938 | 3.01 | 1966 | 19,489 | 76,161 | 3.91 | 1967 | 22,581 | 88,405 | 3.92 |
| 1963 | 14,469 | 166,479 | 11.51 | 1968 | 3,799 | 155,396 | 40.90 | 1969 | 58,727 | 412,913 | 7.03 |
| 1964 | 1,196 | 25,040 | 20.94 | 1969 | 58,727 | 412,913 | 7.03 | 1970 | 10,435 | 384,038 | 36.80 |
| 1965 | 17,924 | 205,659 | 11.47 | 1970 | 30,539 | 184,157 | 6.03 | 1971 | 4,990 | 155,255 | 31.11 |
| 1966 | 19,489 | 76,161 | 3.91 | 1971 | 28,137 | 235,297 | 8.36 | 1972 | 25,738 | 342,374 | 13.30 |
| 1967 | 22,581 | 88,405 | 3.92 | 1972 | 35,939 | 31,072 | 0.86 | 1973 | 48,541 | 355,612 | 7.33 |
| 1968 | 3,799 | 155,396 | 40.90 | 1973 | 19,489 | 76,161 | 3.91 | 1974 | 66,095 | 276,337 | 4.31 |
| 1969 | 58,727 | 412,913 | 7.03 | 1974 | 10,435 | 384,038 | 36.80 | 1975 | 29,736 | 145,953 | 4.91 |
| 1970 | 10,435 | 384,038 | 36.80 | 1975 | 6,095 | 276,337 | 4.31 | 1976 | 49,952 | 304,515 | 6.10 |
| 1971 | 4,990 | 155,255 | 31.11 | 1976 | 75,171 | 1,125,838 | 14.95 | 1977 | 52,627 | 234,642 | 4.46 |
| 1972 | 25,738 | 342,374 | 13.30 | 1977 | 294,083 | 815,200 | 2.77 | 1978 | 75,171 | 1,125,838 | 14.95 |
| 1973 | 48,541 | 355,612 | 7.33 | 1978 | 10,435 | 31,072 | 0.86 | 1979 | 45,026 | 175,741 | 3.90 |
| 1974 | 66,095 | 276,337 | 4.31 | 1979 | 39,341 | | | 1980 | 45,026 | 175,741 | 3.90 |
| 1975 | 29,736 | 145,953 | 4.91 | 1980 | 12,725 | 55,002 | 4.32 | Avg: | 22,111 | 120,181 | 6.66 (94) |
| 1976 | 49,952 | 304,515 | 6.10 | 1981 | 209,727 | 4.99 | | Max: | 45,026 | 175,741 | 31.11 |
| 1977 | 52,627 | 234,642 | 4.46 | 1982 | 39,341 | | | Min: | 4,990 | 39,259 | 3.37 |
| 1978 | 75,171 | 1,125,838 | 14.95 | Avg: | 63,757 | 352,671 | 5.31 (94) | 1986 CYCLE YEAR | | | |
| 1979 | 45,026 | 175,741 | 3.90 | Max: | 294,083 | 1,125,838 | 36.80 | 1983 | 39,341 | | |
| 1980 | 73,830 | 401,627 | 5.44 | Min: | 10,435 | 31,072 | 0.86 | 1984 | 59,602 | | |
| 1981 | 42,002 | 209,727 | 4.99 | Avg: | 35,591 | 206,335 | 5.65 (94) | 1985 | 36,545 | | |
| 1982 | 294,083 | 815,200 | 2.77 | Max: | 294,083 | 1,125,838 | 36.80 | Avg: | 22,111 | 120,181 | 6.66 (94) |
| 1983 | 39,341 | | | Min: | 1,196 | 4,623 | 0.39 | Max: | 45,026 | 175,741 | 31.11 |
| 1984 | 59,602 | | | Avg: | 35,591 | 206,335 | 5.65 (94) | Min: | 4,990 | 39,259 | 3.37 |
| 1985 | 36,545 | | | Max: | 294,083 | 1,125,838 | 36.80 | Min: | 4,990 | 39,259 | 3.37 |

Appendix A. Table 20.

BIRKINHEAD RIVER SOCKEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|-------------|-----------------|------------------|--------------|-------------|-----------------|------------------|--------------|-------------|
| Brood Year | Adult Escapement | Total Return | Per Spawner | Brood Year | Adult Escapement | Total Return | Per Spawner | Brood Year | Adult Escapement | Total Return | Per Spawner |
| 1948 | 83,787 | 206,696 | 2.47 | 1948 | 83,787 | 206,696 | 2.47 | 1949 | 70,504 | 308,662 | 4.38 |
| 1949 | 70,504 | 308,662 | 4.38 | 1952 | 47,041 | 244,678 | 5.20 | 1953 | 42,491 | 156,143 | 3.67 |
| 1950 | 64,440 | 242,740 | 3.77 | 1956 | 49,754 | 279,109 | 5.61 | 1957 | 14,536 | 75,666 | 5.21 |
| 1951 | 21,296 | 216,719 | 10.18 | 1960 | 36,838 | 168,936 | 4.59 | 1961 | 31,681 | 131,851 | 4.16 |
| 1952 | 47,041 | 244,678 | 5.20 | 1964 | 48,908 | 365,993 | 7.48 | 1965 | 16,230 | 165,901 | 10.10 |
| 1953 | 42,491 | 156,143 | 3.67 | 1968 | 57,947 | 285,925 | 4.95 | 1969 | 37,382 | 791,710 | 21.18 |
| 1954 | 18,213 | 175,704 | 9.65 | 1972 | 54,516 | 515,310 | 9.45 | 1973 | 56,653 | 328,391 | 5.80 |
| 1955 | 14,533 | 280,383 | 19.27 | 1976 | 77,305 | 632,531 | 8.18 | 1977 | 23,845 | 460,202 | 19.30 |
| 1956 | 49,754 | 279,109 | 5.61 | 1980 | 78,613 | 170,015 | 2.16 | 1981 | 49,023 | 109,423 | 2.23 |
| 1957 | 14,536 | 75,666 | 5.21 | 1984 | 38,644 | | | 1985 | 11,905 | | |
| 1958 | 15,166 | 130,954 | 8.63 | Avg: | 57,335 | 318,799 | 5.02 (94) | Avg: | 35,425 | 280,661 | 6.42 (94) |
| 1959 | 26,159 | 268,572 | 10.27 | Max: | 83,787 | 632,531 | 9.45 | Max: | 70,504 | 791,710 | 21.18 |
| 1960 | 36,838 | 168,936 | 4.59 | Min: | 36,838 | 168,936 | 2.16 | Min: | 11,905 | 75,666 | 2.23 |
| 1961 | 31,681 | 131,851 | 4.16 | 1986 CYCLE YEAR | | | | 1987 CYCLE YEAR | | | |
| 1962 | 26,369 | 103,783 | 3.94 | Brood Year | Adult Escapement | Total Return | Per Spawner | Brood Year | Adult Escapement | Total Return | Per Spawner |
| 1963 | 48,893 | 455,775 | 9.32 | | | | | | | | |
| 1964 | 48,908 | 365,993 | 7.48 | 1966 | 20,116 | 317,710 | 15.79 | 1967 | 39,876 | 492,216 | 12.34 |
| 1965 | 16,230 | 165,901 | 10.10 | 1968 | 57,947 | 255,925 | 4.95 | 1969 | 11,905 | 127,367 | 2.07 |
| 1966 | 20,116 | 317,710 | 15.79 | 1970 | 30,656 | 736,305 | 24.02 | 1971 | 24,629 | 371,401 | 15.08 |
| 1967 | 39,876 | 492,216 | 12.34 | 1968 | 57,947 | 255,925 | 4.95 | 1972 | 54,516 | 127,367 | 2.07 |
| 1968 | 57,947 | 255,925 | 4.95 | 1969 | 37,382 | 791,710 | 21.18 | 1973 | 56,653 | 328,391 | 5.80 |
| 1969 | 37,382 | 791,710 | 21.18 | 1970 | 30,656 | 736,305 | 24.02 | 1974 | 119,637 | 918,986 | 7.68 |
| 1970 | 30,656 | 736,305 | 24.02 | 1971 | 24,629 | 371,401 | 15.08 | 1975 | 61,538 | 127,367 | 2.07 |
| 1971 | 24,629 | 371,401 | 15.08 | 1972 | 54,516 | 515,310 | 9.45 | 1976 | 77,305 | 632,531 | 8.18 |
| 1972 | 54,516 | 515,310 | 9.45 | 1973 | 56,653 | 328,391 | 5.80 | 1977 | 23,845 | 460,202 | 19.30 |
| 1973 | 56,653 | 328,391 | 5.80 | 1974 | 119,637 | 918,986 | 7.68 | 1978 | 94,782 | 776,704 | 8.19 |
| 1974 | 119,637 | 918,986 | 7.68 | 1975 | 61,538 | 127,367 | 2.07 | 1979 | 60,988 | 511,892 | 8.39 |
| 1975 | 61,538 | 127,367 | 2.07 | 1976 | 77,305 | 632,531 | 8.18 | 1980 | 78,613 | 170,015 | 2.16 |
| 1976 | 77,305 | 632,531 | 8.18 | 1977 | 23,845 | 460,202 | 19.30 | 1981 | 49,023 | 109,423 | 2.23 |
| 1977 | 23,845 | 460,202 | 19.30 | 1978 | 94,782 | 776,704 | 8.19 | 1982 | 119,738 | 1,231,700 | 10.29 |
| 1978 | 94,782 | 776,704 | 8.19 | 1979 | 60,988 | 511,892 | 8.39 | Avg: | 56,569 | 514,952 | 8.76 (GM) |
| 1979 | 60,988 | 511,892 | 8.39 | 1980 | 78,613 | 170,015 | 2.16 | Max: | 119,738 | 1,231,700 | 24.02 |
| 1980 | 78,613 | 170,015 | 2.16 | Min: | 15,166 | 103,783 | 3.77 | Min: | 14,533 | 127,367 | 2.07 |
| 1981 | 49,023 | 109,423 | 2.23 | 1986 CYCLE YEAR | | | | 1987 CYCLE YEAR | | | |
| 1982 | 119,738 | 1,231,700 | 10.29 | Avg: | 46,807 | 364,401 | 7.12 (GM) | Max: | 119,738 | 1,231,700 | 26.02 |
| 1983 | 44,029 | | | Min: | 11,905 | 75,666 | 2.07 | Avg: | 37,996 | 340,541 | 9.39 (GM) |
| 1984 | 38,644 | | | Max: | 61,538 | 511,892 | 8.39 | Max: | 61,538 | 511,892 | 19.27 |
| 1985 | 11,905 | | | Min: | 14,533 | 127,367 | 2.07 | Min: | 14,533 | 127,367 | 2.07 |

Appendix A, Table 21.

HARRISON RIVER SOCKEYE

Appendix A. Table 22.

PORTAGE CREEK SOCKEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | | | | 1948 | | | | 1949 | | | |
| 1949 | | | | 1952 | | | | 1953 | 50 | 394 | 7.88 |
| 1950 | | | | 1956 | | | | 1957 | 40 | 47 | 1.18 |
| 1951 | 29 | 264 | 8.41 | 1960 | | | | 1961 | 23 | 2,723 | 118.39 |
| 1952 | | | | 1964 | 9 | 624 | 69.33 | 1965 | 981 | 3,463 | 3.53 |
| 1953 | 50 | 394 | 7.88 | 1968 | 85 | 1,046 | 12.16 | 1969 | 963 | 34,612 | 35.94 |
| 1954 | 3,369 | 38,700 | 11.49 | 1972 | 190 | 15,283 | 80.44 | 1973 | 3,963 | 68,692 | 17.33 |
| 1955 | 41 | 4,392 | 107.12 | 1976 | 1,042 | 8,042 | 7.72 | 1977 | 7,610 | 39,710 | 5.22 |
| 1956 | | | | 1980 | 1,800 | 14,340 | 7.97 | 1981 | 5,755 | 16,077 | 2.79 |
| 1957 | 40 | 47 | 1.18 | 1984 | 1,701 | | | 1985 | 1,703 | | |
| 1958 | 4,736 | 25,645 | 5.41 | | | | | | | | |
| 1959 | 572 | 5,565 | 9.73 | Avg: | 805 | 7,867 | 21.09 (GM) | Avg: | 2,343 | 20,715 | 8.77 (GM) |
| 1960 | | | | Max: | 1,800 | 15,283 | 80.44 | Max: | 7,610 | 68,692 | 118.39 |
| 1961 | 23 | 2,723 | 118.39 | Min: | 9 | 624 | 7.72 | Min: | 23 | 47 | 1.18 |
| 1962 | 11,935 | 72,180 | 6.05 | 1986 CYCLE YEAR | | | | 1987 CYCLE YEAR | | | |
| 1963 | 2,011 | 58,437 | 29.06 | | | | | | | | |
| 1964 | 9 | 624 | 69.33 | | | | | | | | |
| 1965 | 981 | 3,463 | 3.53 | | | | | | | | |
| 1966 | 31,343 | 31,339 | 1.00 | | | | | | | | |
| 1967 | 4,025 | 4,286 | 1.06 | | | | | | | | |
| 1968 | 85 | 1,046 | 12.16 | | | | | | | | |
| 1969 | 963 | 34,612 | 35.94 | | | | | | | | |
| 1970 | 3,873 | 58,068 | 14.99 | | | | | | | | |
| 1971 | 281 | 18,043 | 64.21 | | | | | | | | |
| 1972 | 190 | 15,283 | 80.44 | | | | | | | | |
| 1973 | 3,963 | 68,692 | 17.33 | | | | | | | | |
| 1974 | 8,475 | 41,580 | 4.91 | | | | | | | | |
| 1975 | 3,175 | 13,549 | 4.27 | | | | | | | | |
| 1976 | 1,042 | 8,042 | 7.72 | | | | | | | | |
| 1977 | 7,610 | 39,710 | 5.22 | | | | | | | | |
| 1978 | 9,978 | 81,592 | 8.18 | | | | | | | | |
| 1979 | 3,575 | 65,073 | 18.20 | | | | | | | | |
| 1980 | 1,800 | 14,340 | 7.97 | Avg: | 12,197 | 49,872 | 5.82 (GM) | Avg: | 2,384 | 21,199 | 13.85 (GM) |
| 1981 | 5,755 | 16,077 | 2.79 | Max: | 31,343 | 81,592 | 14.99 | Max: | 7,747 | 65,073 | 107.12 |
| 1982 | 23,867 | | | Min: | 3,369 | 25,645 | 1.00 | Min: | 29 | 264 | 1.06 |
| 1983 | 7,747 | | | | | | | | | | |
| 1984 | 1,701 | | | | | | | | | | |
| 1985 | 1,703 | | | | | | | | | | |
| Avg: | 4,530 | 25,848 | 10.55 (GM) | | | | | | | | |
| Max: | 31,343 | 81,592 | 118.39 | | | | | | | | |
| Min: | 9 | 47 | 1.00 | | | | | | | | |

Note - Includes Seton Creek and Bridge River.

Appendix A. Table 23.

GATES CREEK SOCKEYE

| ALL YEARS | | | | 1984 CYCLE YEAR | | | | 1985 CYCLE YEAR | | | |
|------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|-----------------|------------------|--------------|--------------------|
| Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner | Brood Year | Adult Escapement | Total Return | Return Per Spawner |
| 1948 | | 30,026 | | 1948 | | 30,026 | | 1949 | | 590 | |
| 1949 | | 590 | | 1952 | 7,070 | 38,000 | 5.37 | 1953 | 74 | 7,885 | 106.55 |
| 1950 | | 300 | | 1956 | 7,807 | 15,990 | 2.05 | 1957 | 891 | 1,163 | 1.31 |
| 1951 | | 623 | | 1960 | 5,413 | 84,049 | 15.53 | 1961 | 248 | 14,706 | 59.30 |
| 1952 | 7,070 | 38,000 | 5.37 | 1964 | 19,396 | 105,060 | 5.42 | 1965 | 1,642 | 3,087 | 1.88 |
| 1953 | 74 | 7,885 | 106.55 | 1968 | 10,113 | 82,525 | 8.16 | 1969 | 777 | 5,001 | 6.44 |
| 1954 | 45 | 698 | 15.51 | 1972 | 8,323 | 132,617 | 15.95 | 1973 | 795 | 12,525 | 15.75 |
| 1955 | 77 | 2,505 | 32.53 | 1976 | 17,133 | 73,413 | 4.28 | 1977 | 2,582 | 21,804 | 8.44 |
| 1956 | 7,807 | 15,990 | 2.05 | 1980 | 25,066 | 81,226 | 3.24 | 1981 | 4,670 | 14,931 | 3.20 |
| 1957 | 891 | 1,163 | 1.31 | 1984 | 28,801 | | | 1985 | 4,578 | | |
| 1958 | 61 | 441 | 7.25 | | | | | | | | |
| 1959 | 582 | 10,655 | 18.31 | Avg: | 14,349 | 71,434 | 6.00 (90) | Avg: | 1,806 | 9,077 | 8.98 (90) |
| 1960 | 5,413 | 84,049 | 15.53 | Max: | 28,801 | 132,617 | 15.95 | Max: | 4,670 | 21,804 | 106.55 |
| 1961 | 248 | 14,706 | 59.30 | Min: | 5,413 | 15,990 | 2.05 | Min: | 74 | 590 | 1.31 |
| 1962 | 159 | 524 | 3.30 | | | | | | | | |
| 1963 | 4,113 | 7,648 | 1.86 | 1986 CYCLE YEAR | | | | 1987 CYCLE YEAR | | | |
| 1964 | 19,396 | 105,060 | 5.42 | | | | | | | | |
| 1965 | 1,642 | 3,087 | 1.88 | | | | | | | | |
| 1966 | 65 | 956 | 14.40 | | | | | | | | |
| 1967 | 1,138 | 6,661 | 5.85 | | | | | | | | |
| 1968 | 10,113 | 82,525 | 8.16 | | | | | | | | |
| 1969 | 777 | 5,001 | 6.44 | | | | | | | | |
| 1970 | 78 | 580 | 7.44 | | | | | | | | |
| 1971 | 426 | 12,647 | 29.69 | | | | | | | | |
| 1972 | 8,323 | 132,617 | 15.95 | | | | | | | | |
| 1973 | 795 | 12,525 | 15.75 | | | | | | | | |
| 1974 | 70 | 1,992 | 28.46 | | | | | | | | |
| 1975 | 1,982 | 22,413 | 11.31 | | | | | | | | |
| 1976 | 17,133 | 73,413 | 4.28 | | | | | | | | |
| 1977 | 2,582 | 21,804 | 8.44 | | | | | | | | |
| 1978 | 258 | 1,806 | 7.00 | | | | | | | | |
| 1979 | 3,828 | 17,860 | 4.67 | | | | | | | | |
| 1980 | 25,066 | 81,226 | 3.24 | Avg: | 208 | 910 | 9.67 (90) | Avg: | 2,491 | 10,127 | 10.02 (90) |
| 1981 | 4,670 | 14,931 | 3.20 | Max: | 950 | 1,992 | 28.46 | Max: | 7,784 | 22,413 | 32.53 |
| 1982 | 950 | | | Min: | 45 | 300 | 3.30 | Min: | 77 | 623 | 1.86 |
| 1983 | 7,784 | | | | | | | | | | |
| 1984 | 28,801 | | | | | | | | | | |
| 1985 | 4,578 | | | | | | | | | | |
| Avg: | 4,912 | 23,908 | 8.42 (90) | | | | | | | | |
| Max: | 28,801 | 132,617 | 106.55 | | | | | | | | |
| Min: | 45 | 300 | 1.31 | | | | | | | | |

Source: Alaska Department of Fish and Game.

Appendix A. Table 24.

UPPER PITT RIVER SODKEYE

Appendix A. Table 2.

CULTUS LAKE SOCKEYE

Appendix B. Table 1. Estimates of bias in Ricker a and b parameters in Monte Carlo simulations ($n=100$). Results are based on runs with 33 stock and recruit data pairs. Exploitation rates were applied to maintain the stock at the optimal escapements for each a-b combination.

| Ricker a/b | Percent Deviation from true a | | | | | | | | | | |
|---------------|-------------------------------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
| 0.05 | 6.86 | 2.18 | 4.31 | 0.56 | 0.20 | 2.93 | 2.29 | 0.45 | 0.63 | 0.36 | -0.18 |
| 0.10 | 6.90 | 6.15 | 1.77 | 1.15 | 4.63 | -0.22 | 1.31 | 2.06 | 0.50 | 0.09 | 1.07 |
| 0.15 | 7.84 | 2.38 | 4.84 | 2.96 | 2.19 | 0.17 | 2.56 | 1.13 | -0.93 | 2.05 | 1.15 |
| 0.20 | 6.79 | 3.78 | 5.73 | 0.69 | 1.87 | 2.84 | 1.74 | -0.34 | 1.58 | 1.28 | 0.51 |
| 0.25 | 8.67 | 7.10 | 2.32 | 0.57 | 3.03 | -0.08 | 2.23 | 2.34 | 1.64 | -0.22 | 0.51 |
| 0.30 | 9.69 | 3.38 | 2.69 | 4.39 | 1.42 | -0.16 | 2.72 | 0.12 | 0.44 | 1.92 | 2.86 |
| 0.35 | 13.21 | 5.07 | 5.19 | -0.88 | 2.15 | 1.09 | 1.92 | 2.07 | 1.11 | 0.40 | 0.03 |
| 0.40 | 4.57 | 4.96 | 5.08 | 4.81 | 1.09 | 2.53 | 0.02 | 1.75 | 0.99 | 1.70 | 0.61 |
| 0.45 | 5.94 | 0.68 | 3.76 | 4.59 | 1.24 | 3.29 | -0.17 | -0.40 | 0.31 | 0.90 | 0.63 |
| 0.50 | 7.56 | 1.33 | 2.13 | 3.47 | 1.52 | 4.19 | 2.46 | 0.92 | -0.73 | 0.24 | 0.75 |
| 0.55 | 6.85 | 9.55 | 2.33 | 1.57 | -0.10 | 1.92 | 1.59 | 3.20 | 1.40 | -0.64 | 0.30 |
| 0.60 | 3.76 | 5.70 | 3.87 | 4.42 | 3.86 | 0.32 | -0.39 | 1.40 | 0.32 | 2.01 | 1.39 |
| 0.65 | 6.20 | 2.79 | 3.87 | 1.44 | 0.87 | 4.97 | 1.24 | 0.28 | 1.80 | 0.42 | 0.45 |
| 0.70 | 6.76 | 3.43 | 2.12 | 5.25 | 1.96 | 1.75 | -0.33 | 2.78 | 2.77 | 0.81 | 1.73 |
| 0.75 | 3.34 | 4.47 | 1.77 | 7.20 | 2.03 | 2.61 | 1.08 | -1.02 | -0.54 | 2.02 | 3.04 |
| 0.80 | 7.53 | 4.53 | 5.48 | 2.35 | 1.82 | 0.35 | 3.01 | 2.02 | 0.71 | 0.95 | -0.64 |
| 0.85 | 6.92 | 3.83 | 4.06 | 2.27 | 2.86 | 1.09 | 1.33 | 0.06 | 2.07 | 0.44 | 0.81 |
| 0.90 | 4.32 | 3.90 | 3.01 | 3.43 | 2.63 | 1.55 | 1.54 | 0.47 | 0.99 | 0.66 | 0.60 |
| 0.95 | 7.10 | 4.33 | 1.71 | 3.28 | 0.33 | 1.75 | 1.71 | 0.49 | 0.73 | 1.79 | -0.25 |
| 1.00 | 9.15 | 8.05 | 2.55 | 3.00 | 0.19 | 2.53 | 1.05 | 0.94 | 2.45 | 1.29 | -0.20 |

| Ricker a/b | Percent deviation from true b | | | | | | | | | | |
|---------------|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
| 0.05 | 18.51 | 10.79 | 12.04 | 4.93 | 5.90 | 8.72 | 5.15 | 2.67 | 3.62 | 2.45 | 1.99 |
| 0.10 | 17.24 | 14.49 | 4.41 | 4.85 | 10.93 | 0.76 | 5.47 | 5.05 | 1.97 | -0.54 | 5.23 |
| 0.15 | 17.68 | 11.11 | 11.62 | 9.72 | 7.11 | 0.62 | 7.58 | 4.70 | -0.97 | 6.41 | 5.04 |
| 0.20 | 18.06 | 11.73 | 10.34 | 5.64 | 5.58 | 6.26 | 5.15 | 3.17 | 4.73 | 4.73 | 2.43 |
| 0.25 | 20.64 | 15.28 | 10.85 | 4.85 | 7.73 | 2.23 | 7.37 | 6.00 | 5.63 | 1.51 | 2.37 |
| 0.30 | 20.70 | 10.13 | 6.29 | 9.35 | 4.54 | 3.45 | 5.14 | 0.91 | 3.11 | 6.47 | 7.55 |
| 0.35 | 21.77 | 17.48 | 16.64 | 0.36 | 6.20 | 2.83 | 3.77 | 6.99 | 6.46 | 2.75 | 2.28 |
| 0.40 | 13.39 | 11.51 | 12.61 | 10.62 | 4.68 | 6.03 | 2.85 | 4.78 | 3.58 | 5.39 | 3.49 |
| 0.45 | 14.56 | 5.00 | 7.85 | 12.14 | 2.55 | 8.37 | 2.80 | -0.15 | 2.50 | 1.18 | 1.81 |
| 0.50 | 13.05 | 6.86 | 5.05 | 8.51 | 7.13 | 9.54 | 5.66 | 3.32 | -1.39 | 0.78 | 4.70 |
| 0.55 | 17.45 | 19.26 | 5.87 | 5.14 | 0.41 | 5.89 | 10.72 | 7.86 | 3.40 | 0.07 | 1.49 |
| 0.60 | 5.33 | 21.96 | 12.83 | 9.93 | 7.77 | 2.62 | -2.61 | 5.62 | 2.21 | 6.40 | 3.34 |
| 0.65 | 18.30 | 9.31 | 6.74 | 5.23 | 6.25 | 9.56 | 4.10 | 4.49 | 4.05 | 0.84 | 3.73 |
| 0.70 | 16.12 | 6.28 | 7.43 | 13.99 | 3.17 | 5.10 | 2.17 | 5.32 | 7.12 | 4.91 | 5.48 |
| 0.75 | -0.09 | 12.28 | 5.51 | 13.66 | 6.91 | 13.21 | 1.22 | -2.38 | -0.73 | 4.75 | 8.31 |
| 0.80 | 12.94 | 12.51 | 14.75 | 6.90 | 5.35 | 2.32 | 8.21 | 4.81 | 4.08 | 5.24 | -2.14 |
| 0.85 | 13.25 | 9.93 | 7.74 | 6.22 | 10.77 | 4.09 | 3.85 | 2.28 | 5.45 | 0.23 | 2.69 |
| 0.90 | 11.62 | 11.20 | 6.87 | 7.17 | 4.90 | 4.50 | 4.50 | 2.18 | 4.06 | 2.75 | 2.26 |
| 0.95 | 20.34 | 10.54 | 4.00 | 7.77 | 3.62 | 4.70 | 2.66 | 0.84 | 1.85 | 5.27 | 0.61 |
| 1.00 | 23.44 | 15.42 | 6.57 | 7.68 | 1.25 | 6.21 | 7.24 | 3.82 | 5.70 | 4.17 | 0.17 |

Appendix B Table 2. Estimates of bias in Ricker a and b parameters in Monte Carlo simulations ($n=100$). Results are based on runs with 10 stock and recruit data pairs. Exploitation rates were applied to maintain the stock at the optimal escapements for each a-b combination.

| Ricker a/b | Percent deviation from true a | | | | | | | | | | |
|---------------|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
| 0.05 | 16.91 | 16.19 | 18.52 | 17.05 | 10.36 | 11.32 | 2.70 | 2.56 | 0.62 | 0.29 | 4.35 |
| 0.10 | 33.23 | 25.60 | 19.95 | 17.28 | 2.38 | 2.71 | 2.71 | -0.21 | 6.77 | 6.61 | 5.75 |
| 0.15 | 33.53 | 23.96 | 6.51 | 4.88 | 3.89 | 0.99 | 7.77 | 6.54 | 7.40 | 7.02 | 6.93 |
| 0.20 | 25.09 | 13.12 | 11.43 | 8.83 | 8.55 | 12.32 | 8.93 | 10.67 | 5.37 | 0.33 | 1.82 |
| 0.25 | 24.55 | 13.73 | 13.34 | 12.63 | 12.38 | 8.68 | 10.30 | 5.12 | 3.80 | 0.69 | 1.02 |
| 0.30 | 28.04 | 26.91 | 20.49 | 19.05 | 13.52 | 4.20 | 1.38 | 0.32 | -1.74 | 2.49 | 5.60 |
| 0.35 | 28.43 | 26.59 | 18.57 | 7.37 | 5.07 | 4.78 | 2.36 | 6.09 | 9.97 | 9.38 | 6.36 |
| 0.40 | 26.89 | 11.96 | 9.49 | 9.12 | 7.72 | 6.55 | 9.65 | 6.85 | 6.00 | 4.53 | 2.98 |
| 0.45 | 18.26 | 18.53 | 10.15 | 13.88 | 12.77 | 11.18 | 9.38 | 6.89 | 3.08 | 2.34 | 1.22 |
| 0.50 | 32.96 | 16.80 | 14.55 | 14.78 | 6.94 | 8.53 | 6.61 | 3.63 | 2.74 | 1.47 | 2.55 |
| 0.55 | 19.87 | 18.31 | 13.67 | 14.62 | 15.56 | 11.46 | 9.82 | 8.34 | 6.77 | 3.52 | 2.03 |
| 0.60 | 29.04 | 21.62 | 11.39 | 7.50 | 6.35 | 3.87 | 1.93 | 1.13 | 0.46 | -0.31 | 1.41 |
| 0.65 | 27.42 | 25.60 | 20.99 | 15.35 | 13.85 | 8.75 | 7.90 | 8.03 | 3.96 | 3.34 | -0.34 |
| 0.70 | 8.35 | 7.75 | 4.49 | 5.25 | 4.54 | 3.54 | 1.86 | 5.54 | 7.89 | 8.80 | 7.99 |
| 0.75 | 37.85 | 16.08 | 19.20 | 9.67 | 7.75 | 4.63 | 3.34 | 2.21 | 1.12 | 0.69 | 1.20 |
| 0.80 | 16.04 | 12.16 | 9.51 | 15.07 | 13.95 | 12.48 | 11.04 | 7.24 | 4.32 | 3.68 | 2.69 |
| 0.85 | 18.80 | 12.11 | 5.55 | 5.05 | 3.76 | -0.34 | 1.63 | 2.20 | 3.28 | 4.78 | 5.44 |
| 0.90 | 31.21 | 23.20 | 12.91 | 13.76 | 9.51 | 4.45 | 5.73 | 3.39 | 0.02 | -0.49 | -0.90 |
| 0.95 | 6.89 | 7.26 | 10.37 | 9.59 | 7.95 | 6.98 | 8.56 | 7.55 | 4.87 | 4.85 | 3.30 |
| 1.00 | 22.92 | 11.16 | 8.21 | 1.76 | 0.65 | 0.52 | 0.12 | 4.42 | 3.57 | 4.52 | 3.21 |

| Ricker a/b | Percent deviation from true b | | | | | | | | | | |
|---------------|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
| 0.05 | 128.59 | 69.41 | 83.84 | 64.88 | 40.73 | 38.08 | 23.29 | 16.89 | 10.19 | 9.84 | 22.71 |
| 0.10 | 85.56 | 76.24 | 53.53 | 57.88 | 24.23 | 22.84 | 19.18 | 10.57 | 29.70 | 26.13 | 22.29 |
| 0.15 | 103.95 | 94.91 | 50.81 | 30.10 | 21.25 | 17.62 | 25.63 | 24.46 | 25.65 | 23.25 | 25.05 |
| 0.20 | 78.25 | 44.45 | 51.18 | 51.47 | 29.50 | 41.28 | 31.27 | 27.60 | 21.83 | 6.23 | 8.45 |
| 0.25 | 111.97 | 65.60 | 41.76 | 34.14 | 29.37 | 20.88 | 26.67 | 23.59 | 20.57 | 14.52 | 16.83 |
| 0.30 | 80.93 | 70.83 | 54.91 | 44.60 | 31.82 | 22.47 | 14.98 | 11.83 | 9.30 | 10.75 | 18.78 |
| 0.35 | 46.56 | 47.55 | 36.41 | 30.28 | 32.61 | 34.19 | 13.90 | 22.20 | 30.12 | 25.72 | 19.34 |
| 0.40 | 48.14 | 73.01 | 52.49 | 46.12 | 32.61 | 23.24 | 20.29 | 19.35 | 18.13 | 11.62 | 21.88 |
| 0.45 | 80.87 | 63.34 | 45.71 | 45.47 | 30.63 | 29.10 | 21.45 | 19.41 | 13.56 | 15.75 | 14.31 |
| 0.50 | 98.18 | 48.88 | 29.46 | 33.10 | 12.40 | 21.81 | 20.97 | 20.32 | 18.40 | 11.24 | 11.55 |
| 0.55 | 38.49 | 39.84 | 30.79 | 35.14 | 23.42 | 26.56 | 25.45 | 22.64 | 21.42 | 29.62 | 15.93 |
| 0.60 | 82.85 | 57.00 | 22.01 | 15.01 | 5.68 | 5.19 | 8.24 | 17.33 | 12.36 | 5.55 | 11.30 |
| 0.65 | 53.29 | 52.49 | 44.35 | 41.11 | 39.34 | 34.88 | 32.70 | 29.37 | 22.31 | 9.71 | -4.19 |
| 0.70 | 5.51 | 9.09 | 8.92 | 30.25 | 21.36 | 25.47 | 11.82 | 16.71 | 20.14 | 25.57 | 26.80 |
| 0.75 | 78.59 | 60.28 | 56.77 | 33.06 | 24.66 | 10.40 | 2.52 | 0.87 | 2.37 | 0.47 | 10.04 |
| 0.80 | 63.03 | 60.96 | 37.98 | 38.59 | 35.06 | 34.91 | 27.28 | 26.15 | 24.07 | 17.57 | 17.10 |
| 0.85 | 38.83 | 16.04 | 6.67 | 5.81 | 4.30 | 3.19 | 12.07 | 12.35 | 16.06 | 15.90 | 18.60 |
| 0.90 | 70.37 | 57.46 | 36.70 | 44.39 | 30.59 | 17.94 | 19.10 | 12.47 | -1.63 | -1.67 | -3.26 |
| 0.95 | 10.37 | 17.81 | 34.35 | 36.73 | 26.74 | 24.03 | 26.27 | 24.08 | 18.19 | 15.09 | 16.31 |
| 1.00 | 47.41 | 29.30 | 17.95 | 5.85 | -0.54 | 2.12 | 1.99 | 12.13 | 12.84 | 14.98 | 21.08 |

Appendix B Table 3. Estimates of bias in Ricker a and b parameters in Monte Carlo simulations ($n=100$). Results are based on runs with 33 stock and recruit data pairs. Exploitation rates were applied to overexploit the stock at 10% below the optimal escapements for each a-b combination.

| | | Percent deviation from true a | | | | | | | | | | |
|--------|-------|-------------------------------|------|------|------|------|------|------|-------|-------|------|------|
| Ricker | a/b | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
| 0.05 | 11.53 | 8.83 | 3.88 | 0.76 | 1.37 | 3.70 | 4.87 | 3.90 | 0.77 | -0.15 | 0.82 | |
| 0.10 | 12.18 | 7.68 | 3.24 | 1.99 | 2.17 | 4.29 | 4.53 | 3.69 | 0.64 | 0.39 | 0.86 | |
| 0.15 | 14.67 | 6.15 | 2.77 | 1.01 | 3.56 | 4.86 | 3.90 | 4.32 | 1.17 | 0.07 | 0.60 | |
| 0.20 | 8.95 | 2.20 | 1.43 | 2.74 | 3.47 | 5.40 | 3.53 | 4.62 | 1.21 | -0.75 | 0.94 | |
| 0.25 | 8.71 | 2.05 | 2.70 | 4.53 | 4.58 | 3.26 | 3.73 | 6.03 | 1.12 | -0.67 | 0.60 | |
| 0.30 | 6.00 | 3.94 | 3.82 | 3.65 | 4.16 | 2.74 | 3.50 | 5.23 | 0.09 | -0.81 | 0.94 | |
| 0.35 | 6.77 | 4.01 | 5.74 | 3.53 | 0.90 | 3.14 | 3.03 | 5.03 | -0.20 | -0.43 | 0.44 | |
| 0.40 | 11.07 | 7.72 | 3.18 | 4.98 | 3.37 | 2.75 | 2.16 | 2.28 | 1.33 | 0.49 | 0.86 | |
| 0.45 | 7.48 | 5.73 | 4.94 | 4.21 | 3.56 | 1.89 | 1.90 | 4.19 | 1.08 | 0.15 | 0.32 | |
| 0.50 | 10.21 | 5.62 | 5.37 | 2.39 | 0.82 | 1.96 | 2.14 | 4.65 | 1.03 | -0.26 | 0.42 | |
| 0.55 | 10.92 | 5.98 | 3.30 | 3.18 | 2.77 | 2.42 | 2.05 | 4.76 | 0.75 | 0.31 | 0.23 | |
| 0.60 | 7.36 | 6.25 | 0.48 | 3.92 | 3.27 | 2.48 | 3.90 | 4.05 | 0.15 | 0.43 | 0.43 | |
| 0.65 | 3.53 | 5.71 | 1.41 | 2.24 | 1.79 | 3.22 | 4.14 | 3.57 | 0.22 | 0.47 | 0.39 | |
| 0.70 | 5.77 | 2.65 | 1.85 | 2.34 | 4.22 | 4.10 | 4.17 | 2.76 | 0.18 | 0.63 | 0.47 | |
| 0.75 | 6.70 | 5.82 | 2.23 | 3.33 | 3.06 | 4.42 | 3.98 | 2.21 | 0.53 | 0.23 | 0.39 | |
| 0.80 | 4.47 | 6.11 | 4.01 | 4.12 | 3.90 | 4.29 | 3.88 | 2.99 | 0.76 | 0.45 | 0.03 | |
| 0.85 | 7.35 | 5.74 | 4.49 | 3.81 | 3.74 | 4.52 | 3.26 | 4.09 | 0.70 | -0.04 | 0.26 | |
| 0.90 | 5.67 | 4.11 | 3.17 | 5.16 | 2.19 | 5.00 | 3.09 | 4.18 | 0.52 | 0.23 | 0.37 | |
| 0.95 | 5.00 | 8.07 | 4.31 | 4.01 | 3.56 | 4.18 | 3.37 | 3.38 | 0.62 | -0.24 | 0.28 | |
| 1.00 | 11.16 | 5.14 | 3.30 | 4.42 | 4.08 | 3.21 | 3.82 | 3.11 | 0.51 | -0.34 | 0.08 | |

| | | Percent deviation from true b | | | | | | | | | | |
|--------|-------|-------------------------------|-------|-------|-------|-------|-------|--------|---------|----------|---------|------|
| Ricker | a/b | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
| 0.05 | 40.21 | 25.36 | 13.95 | 5.57 | 15.24 | 22.15 | 64.34 | 299.04 | 1014.80 | 6307.23 | 2132.03 | |
| 0.10 | 34.08 | 25.83 | 11.83 | 10.08 | 15.96 | 28.87 | 39.02 | 249.94 | 847.59 | -1164.41 | 880.36 | |
| 0.15 | 35.30 | 18.89 | 13.10 | 6.40 | 15.67 | 27.65 | 56.29 | 285.20 | 937.05 | -4721.15 | 618.70 | |
| 0.20 | 21.51 | 12.33 | 13.40 | 16.88 | 15.69 | 27.42 | 48.15 | 345.10 | 996.10 | -6063.18 | 348.40 | |
| 0.25 | 27.97 | 13.17 | 15.98 | 18.11 | 18.85 | 15.39 | 54.90 | 420.73 | 670.70 | -4130.04 | 272.50 | |
| 0.30 | 23.24 | 19.97 | 20.69 | 9.82 | 12.82 | 21.95 | 72.48 | 364.97 | 253.90 | -4056.09 | 264.50 | |
| 0.35 | 35.21 | 23.26 | 19.14 | 9.98 | 5.72 | 26.92 | 46.04 | 408.43 | -62.46 | -4633.93 | 331.69 | |
| 0.40 | 25.33 | 21.61 | 16.38 | 21.66 | 18.75 | 15.19 | 17.62 | 127.36 | 559.47 | 2111.61 | 86.29 | |
| 0.45 | 18.92 | 16.85 | 23.38 | 21.39 | 18.95 | 12.39 | 18.36 | 250.85 | 458.81 | 654.89 | 288.71 | |
| 0.50 | 29.09 | 22.74 | 25.31 | 16.85 | 6.38 | 10.52 | 27.28 | 216.48 | 306.78 | -717.67 | 211.75 | |
| 0.55 | 30.58 | 21.87 | 14.88 | 14.99 | 9.89 | 17.71 | 32.74 | 186.27 | 146.87 | -895.53 | 87.95 | |
| 0.60 | 23.80 | 20.92 | 4.26 | 15.30 | 14.56 | 19.90 | 36.67 | 143.84 | 33.03 | -179.27 | -42.53 | |
| 0.65 | 17.08 | 18.15 | 6.91 | 14.13 | 13.69 | 23.73 | 46.19 | 118.10 | 48.28 | 651.45 | -214.30 | |
| 0.70 | 17.38 | 8.93 | 6.41 | 12.75 | 20.59 | 26.25 | 43.84 | 82.37 | 125.29 | 1340.68 | -240.85 | |
| 0.75 | 15.77 | 14.79 | 9.69 | 16.80 | 17.81 | 27.69 | 38.18 | 71.05 | 271.53 | 1484.95 | -141.72 | |
| 0.80 | 9.76 | 14.70 | 15.01 | 18.54 | 19.48 | 24.17 | 30.71 | 125.13 | 290.91 | 1536.21 | -8.04 | |
| 0.85 | 15.05 | 13.80 | 17.13 | 20.71 | 22.13 | 22.97 | 28.00 | 170.57 | 307.02 | 1055.14 | 83.99 | |
| 0.90 | 14.24 | 13.24 | 14.44 | 24.51 | 9.42 | 24.83 | 24.91 | 180.14 | 257.49 | 210.05 | 89.15 | |
| 0.95 | 15.89 | 24.73 | 19.00 | 20.12 | 11.71 | 16.54 | 39.66 | 140.28 | 204.27 | -624.47 | 117.69 | |
| 1.00 | 25.10 | 19.83 | 16.63 | 15.90 | 17.34 | 19.55 | 44.54 | 114.93 | 137.51 | -969.35 | 106.33 | |

Appendix B Table 4. Estimates of bias in Ricker a and b parameters in Monte Carlo simulations (n=100). Results are based on runs with 10 stock and recruit data pairs. Exploitation rates were applied to overexploit the stock at 10% below the optimal escapements for each a-b combination.

| Ricker | | Percent deviation from true a | | | | | | | | | |
|--------|-------|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| a/b | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
| 0.05 | 16.85 | 4.53 | 4.09 | 18.60 | 24.77 | 25.60 | 22.57 | 16.18 | 6.33 | 1.00 | -0.44 |
| 0.10 | 20.23 | 31.20 | 32.15 | 25.64 | 22.06 | 14.00 | 12.84 | 12.36 | 6.60 | 1.65 | 2.90 |
| 0.15 | 49.48 | 34.32 | 30.16 | 10.58 | 6.17 | 9.14 | 12.19 | 12.23 | 1.89 | -2.46 | 2.69 |
| 0.20 | 31.93 | 16.34 | 17.01 | 10.82 | 8.79 | 14.14 | 15.15 | 12.01 | 4.09 | -1.72 | 0.94 |
| 0.25 | 28.49 | 20.33 | 15.51 | 16.19 | 14.32 | 14.41 | 10.91 | 8.05 | 4.28 | 0.33 | -0.08 |
| 0.30 | 16.12 | 28.63 | 26.71 | 21.60 | 22.49 | 23.30 | 16.57 | 10.67 | 3.29 | -0.01 | -0.82 |
| 0.35 | 31.53 | 20.68 | 15.43 | 13.76 | 10.04 | 7.09 | 6.83 | 9.32 | 4.92 | 0.98 | 0.31 |
| 0.40 | 22.74 | 26.36 | 24.73 | 22.11 | 18.66 | 15.70 | 10.65 | 8.17 | 2.04 | -0.10 | 1.78 |
| 0.45 | 18.22 | 13.36 | 12.02 | 13.17 | 10.31 | 10.05 | 10.00 | 9.00 | 5.18 | -0.02 | 1.70 |
| 0.50 | 39.06 | 21.50 | 15.64 | 10.06 | 8.55 | 8.86 | 5.74 | 4.14 | 0.15 | -1.18 | -0.69 |
| 0.55 | 19.80 | 17.74 | 16.93 | 21.11 | 16.67 | 16.18 | 13.06 | 9.99 | 1.91 | 0.16 | -0.37 |
| 0.60 | 16.81 | 12.66 | 6.41 | 3.33 | 5.15 | 8.48 | 12.08 | 14.71 | 3.99 | -0.11 | 1.43 |
| 0.65 | 30.17 | 22.56 | 20.11 | 12.58 | 11.96 | 8.62 | 6.34 | 2.38 | -1.15 | -0.68 | 0.41 |
| 0.70 | 19.96 | 21.42 | 14.88 | 14.49 | 13.92 | 11.86 | 11.93 | 12.52 | 3.67 | 1.10 | -0.79 |
| 0.75 | 13.62 | 4.52 | 3.50 | 4.66 | 6.56 | 8.27 | 7.42 | 7.87 | 2.18 | 0.15 | 0.85 |
| 0.80 | 31.05 | 25.21 | 16.05 | 15.38 | 11.83 | 6.46 | 3.95 | 0.28 | 0.76 | -0.67 | -0.11 |
| 0.85 | 18.76 | 15.61 | 11.28 | 13.69 | 12.86 | 12.85 | 15.03 | 12.56 | 2.86 | 0.31 | 0.60 |
| 0.90 | 24.34 | 10.51 | 10.94 | 10.69 | 8.08 | 7.85 | 4.34 | 3.68 | 1.80 | 0.05 | 0.95 |
| 0.95 | 40.41 | 31.71 | 23.02 | 11.58 | 10.60 | 11.07 | 11.89 | 6.43 | 0.49 | -0.84 | -0.01 |
| 1.00 | 9.28 | 7.04 | 11.22 | 12.91 | 13.52 | 14.01 | 13.04 | 10.77 | 0.46 | -0.21 | -0.12 |

| Ricker | | Percent deviation from b | | | | | | | | | |
|--------|--------|--------------------------|--------|--------|--------|--------|--------|--------|---------|----------|----------|
| a/b | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 |
| 0.05 | 323.73 | 169.25 | 134.71 | 190.69 | 215.74 | 244.78 | 320.79 | 996.31 | 5773.00 | 22605.61 | -4573.42 |
| 0.10 | 350.40 | 98.04 | 89.44 | 81.08 | 97.39 | 134.89 | 370.88 | 877.09 | 1960.05 | 7768.19 | 851.44 |
| 0.15 | 117.24 | 97.72 | 92.55 | 95.72 | 151.69 | 227.49 | 395.05 | 552.95 | -34.31 | -5020.71 | 331.42 |
| 0.20 | 62.79 | 125.53 | 133.65 | 118.35 | 162.42 | 117.55 | 105.14 | 122.91 | 70.99 | -4905.48 | -1411.74 |
| 0.25 | 195.91 | 147.44 | 138.25 | 61.95 | 47.39 | 54.98 | 47.40 | 163.65 | 939.59 | 4704.19 | -1194.46 |
| 0.30 | 180.24 | 69.11 | 54.73 | 61.22 | 83.88 | 108.13 | 115.51 | 161.76 | 59.69 | -2806.61 | -439.54 |
| 0.35 | 134.55 | 99.68 | 80.46 | 44.49 | 30.21 | 28.64 | 33.69 | 188.68 | 821.28 | 3228.35 | -550.14 |
| 0.40 | 116.37 | 72.40 | 72.21 | 91.67 | 87.67 | 101.66 | 151.16 | 159.39 | 184.74 | 355.52 | 104.81 |
| 0.45 | 25.73 | 24.74 | 26.54 | 72.43 | 116.09 | 154.58 | 164.57 | 284.46 | 105.82 | -2336.63 | 286.78 |
| 0.50 | 123.92 | 90.94 | 67.65 | 55.78 | 44.78 | 36.06 | 26.65 | 22.14 | -19.15 | 128.80 | -407.30 |
| 0.55 | 108.11 | 97.56 | 100.51 | 74.06 | 74.08 | 105.58 | 133.84 | 225.01 | 146.59 | 446.10 | -35.79 |
| 0.60 | 42.25 | 21.79 | 14.37 | 9.88 | 17.15 | 82.98 | 181.68 | 372.67 | 359.64 | -241.65 | 231.44 |
| 0.65 | 89.13 | 76.70 | 85.07 | 58.53 | 52.95 | 44.62 | 46.70 | 29.65 | -24.35 | -178.08 | 18.62 |
| 0.70 | 39.73 | 95.19 | 66.17 | 69.60 | 75.83 | 90.65 | 94.12 | 270.97 | 286.09 | 728.46 | -24.80 |
| 0.75 | 34.36 | 15.89 | 11.16 | 10.47 | 21.86 | 36.10 | 53.20 | 133.25 | 235.63 | -46.58 | 112.21 |
| 0.80 | 103.48 | 86.05 | 67.12 | 73.56 | 84.63 | 46.65 | 30.66 | 15.58 | 0.63 | -312.16 | 13.11 |
| 0.85 | 35.69 | 41.14 | 47.26 | 64.68 | 75.02 | 91.50 | 136.57 | 186.26 | 254.15 | 742.77 | -159.84 |
| 0.90 | 117.30 | 26.71 | 25.57 | 26.15 | 21.29 | 32.94 | 40.46 | 69.23 | 118.17 | 464.96 | 119.49 |
| 0.95 | 109.16 | 95.81 | 61.37 | 59.28 | 74.51 | 98.90 | 164.50 | 177.16 | -0.31 | -355.58 | 69.31 |
| 1.00 | 11.82 | 29.52 | 45.24 | 51.14 | 65.73 | 89.62 | 99.14 | 141.67 | -53.95 | -1006.57 | -168.13 |