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Report of the PSARC Salmon Subcommittee Meeting, October 24 – 25, 2001

M. Stocker and A. Macdonald (Editors)
Pacific Scientific Advice Review Committee
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

December 2001
*****REVISED*****

Report of the PSARC Salmon Subcommittee Meeting October 24 – 25, 2001

M. Stocker and A. Macdonald[1] (Editors)
Pacific Scientific Advice Review Committee (PSARC)
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PACIFIC SCIENTIFIC ADVICE REVIEW COMMITTEE

PSARC ADVISORY DOCUMENT 2001-06
December 2001

SALMON

SUMMARY

The PSARC Salmon Subcommittee met October 24 and 25, 2001 at the Pacific Biological Station in Nanaimo. External participants from the Pacific Fisheries Resource Conservation Council, the Sport Fish Advisory Board and the Fraser River Aboriginal Fisheries Council attended the meeting.

Working Paper S2001-15: Pre-season run size forecasts for Fraser River Sockeye in 2002.

The Subcommittee accepted the juvenile-based forecast for the Shuswap salmon stocks and the forecasts for all other stocks as presented (Table 1). The total Fraser sockeye run size forecast for 2002 is 12.9 million at the 50% probability level and 7.7 million at the 75% probability level.

The Subcommittee recommended an extremely cautious management approach for all stocks because the forecasts assumed average survival conditions and do not reflect the potential impacts from profound shifts in salmon survival schedules due to new but poorly understood risk factors (i.e., the high incidence of *Parvicapsula* infestations in smolts).

The Subcommittee recommended that future forecast papers should include escapement trends of small stocks not included in the forecast and consideration of factors potentially affecting forecasts.

Working Paper S2001-16: A Spawning Escapement Goal for Harrison River Fall Chinook Based on a Stock-Recruit Analysis

The Subcommittee recommended acceptance of the escapement goal of 98,500 (75 percent confidence bound about the S_{MSY}, 1984-96 data) chinook. The sustainable exploitation rate at this goal would equal 0.55.

The Subcommittee recommended that the lowest limit in spawning escapement should be no lower than 34,000 based on the historical pattern of recruitment and the 1984-96 data.

The Subcommittee recommended development of a harvest rate/escapement goal policy to minimize the risk of approaching the minimum escapement and to evaluate potential production.

The Subcommittee recommended acceptance of the escapement goals provided at the probability distribution levels of 25% (65,000), 50% (73,000), and 75% (86,000).

SOMMAIRE

Le sous-comité du CEESP sur le saumon s’est réuni les 24 et 25 octobre 2001, à la Station biologique du Pacifique, située à Nanaimo. Des représentant du Conseil pour la conservation des ressources halieutiques du Pacifique, du Sport Fish Advisory Board et du Fraser River Aboriginal Fisheries Council ont assisté à la réunion à titre de participants externes.

Document de travail S2001-15 : Prévisions pré-saison de la taille de la remonte du saumon rouge dans le Fraser en 2002

Le sous-comité a accepté la prévision, reposant sur le nombre de juvéniles, pour les stocks de saumon de la Shuswap et les prévisions pour tous les autres stocks, telles que présentées (tableau 1). La prévision de la remonte totale de saumon rouge dans le Fraser en 2002 la situe à 12,9 millions de poissons, à un niveau de probabilité de 50 %, et à 7,7 millions de poissons, à un niveau de probabilité de 75 %.

Le sous-comité a recommandé un mode de gestion extrêmement prudent pour tous les stocks parce que les prévisions supposent une survie moyenne et ne reflètent pas les impacts potentiels des profonds changements dans les régimes de survie du saumon imputables à des facteurs de risque nouveaux mais mal compris (c.-à-d., l'incidence élevée d'infestations à *Parvicapsula* chez les smolts).

Le sous-comité a en outre recommandé que les futurs documents des prévisions comprennent les tendances des échappées chez les petits stocks qui ne sont pas inclus dans les prévisions et examinent les facteurs qui peuvent avoir une incidence sur les prévisions.

Document de travail S2001-16 : Objectif d'échappée du saumon quinnat d’automne dans la rivière Harrison fondé sur une analyse par recrue au stock

Le sous-comité a recommandé que l'objectif d'échappée de 98 500 saumons quinnats (limite de confiance à 75 % de part et d'autre du S_{RMS}, données pour 1984-1996) soit accepté. Le taux d'exploitation durable à ce niveau d'échappée serait égal à 0,55.

Le sous-comité a aussi recommandé que la limite inférieure de l'échappée de géniteurs ne devrait pas être moindre que 34 000 saumons d'après les tendances historiques du recrutement et les données pour la période 1984-1996.

Le sous-comité a en outre recommandé qu'une politique sur le taux de capture et l'objectif d'échappée soit élaborée afin de réduire au minimum le risque d'atteindre l'échappée minimum et d'évaluer la production potentielle.

En dernier lieu, le sous-comité a recommandé que soient acceptés les objectifs d'échappée présentés aux niveaux de probabilité de 25 % (65 000), 50 % (73 000) et 75 % (86 000).

INTRODUCTION

The Subcommittee Chair opened the meeting welcoming the participants. During the introductory remarks the objectives of the meeting were reviewed, and the Subcommittee accepted the meeting agenda (Appendix 1).

The Subcommittee reviewed two Working Papers. Working Paper titles and authors are listed in Appendix 2. A list of meeting participants, observers and reviewers is included as Appendix 3.

WORKING PAPER SUMMARIES, REVIEWS AND DISCUSSION

S2001-15: Pre-season run size forecasts for Fraser River Sockeye in 2002.

A. Cass **Accepted subject to revisions**

Summary

The 2002 cycle line is noted for the historically dominant Lower Adams River (Shuswap Lake) sockeye returns. This cycle line was once the highest of the four cycle lines averaging 15.5 million/yr since 1980 compared to 8.9 million/yr for the other three cycles. Together Adams River sockeye and other late run Shuswap Lake stocks accounted for about 50% of the total returns on the 2002 cycle. The sub-dominant Quesnel run has rebuilt within the last two decades and escapements in the 1998 brood year were equal to the dominant Late Shuswap escapement at 1.2 million sockeye.

Forecasts for 2002 are provided at various probability levels of achieving specified run sizes by stock and run-timing group (Table 1). The forecast of sockeye at the 50% level for all stocks combined is 12.9 million fish (105,000 Early Stuart, 493,000 Early Summer, 9.0 million Mid Summer and 3.3 million Late Summer). This forecast compares to an average return on the 2002 cycle of 15.5 million sockeye/yr (1980-2000). The reason for the disparity between the forecast and mean return since 1980 is due primarily to a decline in returns of Late run stocks. The Mid Summer Run forecast in 2002 accounts for 69% of the total forecast. Quesnel (6.7 million) and Late Shuswap (2.3 million) sockeye together account for 70% of the total forecast.

The Late Shuswap sockeye forecast is based on a method that pools results from an escapement-based model (Ricker model) and a fry-based model (power model). Table 2 shows the forecast, forecast variance ($\log_e$ of the forecast) and the forecast root-mean-square (RMSE) performance criteria. The time series of fry, measure acoustically near the end of the freshwater rearing period, and corresponding adult return data is available mainly for dominant and subdominant years (n=13). The time series of escapement and adult return data extends to 1948 (n=49). The RMSE was computed both with all years of available data (1948-2000) and for the years that fry data are available. The RMSE for the Ricker model based on all years of data was the lowest of all the candidate models. The lowest RMSE based on the years with only fry data was the pooled model. The additional years included in the all-year RMSE calculation are mainly the off-cycle years. Data for off-cycle years are less reliable because errors in estimates of escapement and catch are known to be larger than in dominant and subdominant years. Theoretically, fry abundance excludes most of the freshwater mortality effects that are not excluded in escapement-based forecasts. For these reasons, the "best" forecast for Late Shuswap sockeye was deemed to be the model with the lowest RMSE for years that includes only years with fry data (the pooled model).

Migratory conditions in the Fraser River in brood year 1998 were poor for many stocks as a result of high water temperatures. The effect of stress on survival of the progeny from those fish that spawned in 1998 is not known. Indicators of freshwater survival throughout the watershed for the brood were variable. Low freshwater survival was evident for Early Stuart sockeye at two of three sites as well as for Chilko and Shuswap lakes. Channel fry survival rates, however, showed no indication of poor egg-to-fry conditions. Oceanographic and meteorological conditions in the northeast Pacific returned to near normal values in 1999 (2002 age-5 ocean entry year). Moderate La Nina conditions occurred in 2000 and ocean temperatures were normal to slightly below normal and salinity was near normal in the north Pacific region in 2000 (2002 age-4 ocean entry year).

Subcommittee Discussion

The Subcommittee noted that the data sources, methods, and forecast models used to develop the 2002 returns were previously reviewed and accepted by the Subcommittee.

Results of two forecast models for the Shuswap stock was presented to the Subcommittee (Table 2) for review: one based on a long time series of spawning escapement data, and the other based on a shorter time series of in-lake juvenile data. The escapement-based model performed better than the juvenile-based model in the retrospective analyses. The Subcommittee noted that the juvenile-based model incorporated information on freshwater survival and that the escapement-based model included off-cycle years with a higher likelihood of measurement error. On this basis the juvenile-based model was considered more valid and accepted by the Subcommittee.

The author noted that the contribution of age-5 sockeye has been increasing for some stocks on the 2002 cycle. This trend was attributed to higher numbers of age-5 returns from the 2001 cycle and lower age-4 returns on the 2002 cycle.

As the 2002 forecast included both age-4 and age-5 sockeye, the Subcommittee requested an examination of sibling models if age-5 proportions continue to increase. While the Subcommittee recognised that sibling models forecasting age-5's from age-4's performed poorly in previous forecast assessments, the author agreed to examine the sibling models when the 2001 data becomes available. The author expected results of the sibling analyses to be available in the spring 2002. If the forecast required revision, the Subcommittee would be notified to ensure PSARC advice was provided in a timely manner.

The Subcommittee questioned whether there were alternative models (e.g. the "hockey stick" model) or additional variables that would improve the forecast error and whether this should be considered for future forecasts. The author responded that fitting alternate recruitment models to escapement data would not offer much scope for improving forecasts. The Subcommittee encourages authors to continue to search for models that include new variables that may improve forecasts.

The Subcommittee discussed at length the potential implications to stock forecasting and management of profound shifts in salmon survival schedules due to new but poorly understood risk factors (new diseases; climate shifts, etc.). Recent observations on the impact of the parasite *Parvicapsula* on adult survival of Late Run Fraser sockeye stocks was highlighted as an example of how a new mortality agent might have the potential to radically alter the "normal" range of production variations reflected in historic return observations and forecasts. New studies confirm that sockeye and other salmon smolts can become infected with *Parvicapsula* during downstream migration. This suggests that all salmon stocks are potentially vulnerable to *Parvicapsula* infection, and that these infections may cause mortality in all salmon stocks.

To assist in identifying changes in survival patterns that may be associated with factors not reflected in the forecasts, the Subcommittee requested the author to include time series plots of the forecast model residuals (for the best performing models).

The forecasts of the 18 stocks provided in the current paper account for approximately 93% of the estimated escapements in 1998. The Subcommittee suggested examination of escapement trends of the remaining small stocks not included in the forecast would assist in evaluating their status and impacts on fisheries management.

The Subcommittee noted the depressed state of the small Cultus Lake sockeye stock for the second consecutive year.

Subcommittee Recommendations

1. The Subcommittee accepted the juvenile-based forecast for the Shuswap salmon stocks and the forecasts for all other stocks as presented (Table 1). The total Fraser sockeye run size forecast for 2002 is 12.9 million at the 50% probability level and 7.7 million at the 75% probability level.

2. The Subcommittee recommended an extremely cautious management approach for all stocks because the forecasts assumed average survival conditions and do not reflect the potential impacts from profound shifts in salmon survival schedules due to new but poorly understood risk factors (i.e., the high incidence of *Parvicapsula* infestations in smolts).

3. The Subcommittee recommended that future forecast papers should include escapement trends of small stocks not included in the forecast and consideration of factors potentially affecting forecasts.

S2001-16: A Spawning Escapement Goal for Harrison River Fall Chinook Based on a Stock-Recruit Analysis

G. Brown, B. Riddell, D. Chen, M. Bradford. **Accepted subject to revisions**

Summary

The Harrison River fall white chinook (*Oncorhynchus tshawytscha)*, also known as the 'Fraser Lates', constitute the largest natural spawning population of chinook salmon in British Columbia. Due to their natural abundance and importance in numerous British Columbia and Washington State fisheries, Harrison River chinook were designated as an escapement indicator stock (i.e., 'key stream' indicator) to aid in fulfilling commitments under the 1985 Pacific Salmon Treaty. In 1986, an interim escapement goal for Harrison River chinook was established at 241,700 fish, based on doubling of the escapement estimate obtained from a mark-recapture program in 1984. This method of establishing an interim escapement goal was applied to key streams where new quantitative methods were available for estimating chinook spawning populations.

With the signing of the 1999 Pacific Salmon Treaty (PST), bilaterally agreed escapement goals are now required in order for populations to receive consideration under the international agreement regarding implementation of conservation actions. Since 1984, a consistent and standardized mark-recapture program has resulted in a reliable time series of spawning abundances for aged-three and older fish (i.e., for adults larger than jack chinook; Figure 1). The optimal abundance of spawners obtained from fitting a stock-recruitment function constitutes an acceptable escapement goal for key stream indicators under the

1999 agreement. The primary objective of this working paper was to develop an escapement goal for the Harrison River fall white population based on a stock-recruitment approach to secure consideration under the PST. This working paper is an extension of an earlier paper and responds to the reviewer's concerns related to the methods and data used in this assessment.

We calculated production for Harrison River chinook by applying age-specific maturation rates, ocean exploitation rates and adult equivalent rates obtained through cohort analysis of coded-wire tag groups of fall white chinook smolts from Chilliwack River Hatchery. This approach assumes that naturally spawned fish from Harrison River and fish released from the hatchery behave similarly and will, therefore, be exposed to similar fishing pressure. Since these fall white chinook at Chilliwack Hatchery were founded solely from Harrison River spawning adults, this assumption is unlikely to be seriously violated. This assumption was tested and supported in this paper.

A time series of Harrison River stock-recruitment data was created for year classes 1981-1996. The first three spawner abundances in the series (1981-83) were obtained by applying a mean expansion factor to estimates derived from aerial surveys prior to the mark-recapture program thus permitting use of all available production estimates (N=16). A comparison of the time series of the survival rates of Chilliwack Hatchery smolts to age 2 with the Harrison River recruits/spawner ratios (R/S) indicated a severe mismatch for year class 1982 (Figure 2). While estimated productivity for that year class was the highest in the time series, the decision was made to exclude 1982 from the stock-recruitment series due to its overwhelming impact on these analyses. A Ricker model based on the rest of the time series (N=15) that included the Chilliwack smolt-age 2 survival rates as a co-variate (transformed by natural logarithms and normalized) resulted in a highly significant fit (Figure 3a). The optimal spawning abundance, S_{MSY}, resulting from this function was 77,000 adult (age 3+) chinook. A bootstrap procedure based on sampling the residuals from the fitted stock-recruitment function (N=1000 bootstrap samples) provided lower and upper 90% confidence limits of 59,318 and 118,992, respectively. By the same approach, the optimal exploitation rate, U_{MSY}, estimated for the population was 0.65 with 90% bootstrap confidence limits of 0.52 and 0.75.

We examined several potential sources of bias in the data submitted to the stock-recruitment analysis, especially those stemming from uncertainties in the Chilliwack River escapement time series used in the cohort analysis and in the mean expansion factor applied to the 1981-83 Harrison River aerial escapement survey estimates. A simulation model was developed to test the effect of varying both sources of uncertainty. The effect of uncertainty in the Chilliwack escapement estimates had virtually no effect on the magnitude of the Harrison River production estimates (and therefore, the stock-recruit parameter estimates) regardless of which time series was included in the simulations. The effect of the mean expansion factor applied to the 1981-83 Harrison River aerial escapement estimates on the calculated recruits/spawner ratios used in the stock-recruit analyses varied substantially depending on the set of year classes used in the simulations. For either time series that did not include 1982 (i.e., 1981 plus 1983-96, or 1984-96), the chosen mean expansion factor had little effect on parameters resulting from the stock-recruit analysis. When 1982 was included in the time series (1981-96), however, the chosen expansion had large effects on the stock-recruit parameters. For example, a 30% increase in the mean expansion factor translated into a 26% increase in the estimated S_{MSY}. This large effect was due to the combination of two factors: 1) the estimated production for 1982 was by far the largest in the series, and 2) the estimated escapement was one of the larger ones as well. Not surprisingly, a shift upwards in the escapement estimate (by applying a larger expansion factor) had a large effect on the form of the stock-recruit function and the point estimate of S_{MSY}.

The results of the simulations, and general concern about using the 1981-83 Harrison River escapement estimates, led us to repeat the stock-recruit analysis based only on the year classes for which the escapement estimates were from the mark-recapture program (1984-96). The Ricker model with the standardized log survival rate term again resulted in a highly significant fit. The stock productivity parameter was reduced somewhat reflecting the absence of the high R/S values of 1982 and 1983 but S_{MSY} was essentially unchanged at 75,100 (Figure 3b). A bootstrap procedure based on the residuals from the linear regression function resulted in new 90% confidence limits for S_{MSY} and U_{MSY} (point estimate = 0.61) of 56,570 and 117,139, and 0.45 and 0.73, respectively. Table 3 shows the estimated spawner abundances at various probability levels in the bootstrap distribution of S_{MSY} (N = 974 determinate solutions for S_{MSY} out of 1000 samples). Figure 4 presents the frequency and density distribution of results and indicates the spawner abundances at the 75%, 90%, and 95% probability levels in the cumulative density distribution.

Concern over the lack of data points at very low spawning abundances and the possibility of greater production at moderate and higher spawner abundances (as indicated by year class 1990), led us to apply a hockey stick stock-recruitment model to the Harrison River data. We fit the model to two time series, one excluding only the 1982 data point and the other excluding the 1981-1983 points (Figure 5). Both were based on recruitment estimates adjusted by the Chilliwack smolt-to-age 2 survival rate and both resulted in an optimal abundance of spawners (S^*) slightly larger than the lowest historical escapement estimate in the series (28,616 adults). S^* was 39,000 in the first case and 34,000 in the latter case, but the latter had substantially greater confidence limits due to the exclusion of 1983 from the time series (i.e., one of the lower spawner abundances). The estimation of S^* may provide a repeatable and empirical method for establishing an escapement 'floor', or prudent minimum desirable spawning number, for this population.

While no statistical limitations to the stock-recruitment analysis were identified, the variability between years and the short time series (1984-96) suggest adopting a conservative escapement goal at this time. Therefore, for Harrison River fall white chinook we make the following recommendations:

- That the escapement goal adopted for this important chinook population should be larger than the point estimate of S_{MSY} derived from the stock-recruit analysis (i.e., 75,100 age 3+ adults, 1984-96)
- That the 75% upper confidence bound of the bootstrap distribution for S_{MSY} be adopted as a potential conservative escapement goal (i.e., 98,500 age 3+ adults; see Table 4)
- That S^* derived from fitting the hockey stick stock-recruit model be considered as a minimum escapement floor (i.e., 34,000)

Reviewers' Comments

Reviewer #1

The scope of the paper was much more limited than the title suggested. The paper needed an introduction that stated its objectives more clearly and justified the approach by referencing the Pacific Salmon Treaty or other policy documents. Most of the paper dealt with technical issues associated with estimating the parameters of a Ricker stock-recruitment (S-R) relation for the Harrison River chinook from data collected between 1981-96. Although there were alternatives to the approach taken by the authors, their S-R analysis was technically acceptable and quite thorough in its consideration of potential biases arising from use of visual estimates of escapement in 1981-84. There were only a few technical issues that might greatly alter their parameter estimates: (1) the possibility of severe time-series bias if the period of record represents a depressed population subject to heavy fishing mortality. The population was considered "depressed" in the early 1980's when escapements averaged 100,000 fish. Escapements did not increase greatly (maximum of 180,000) while fishing mortality averaged about 0.6 throughout most of the period. Bias is possible. Although the only satisfactory resolution of this question is to allow much larger escapements, the authors could have hindcasted the dynamics of the population using their current parameter estimates to see if the increased abundance during the 1970s could be plausibly accounted for; (2) systematic bias in the estimates of survival to age 2 that were used to adjust the recruitment data (e.g., if tag recovery efficiency varies with survival); and (3) the possibility that the Ricker S-R model used by the authors misrepresents the uncertainty in the stock productivity parameter. Beverton-Holt and "hockey stick" S-Rs fit the adjusted data well but give more realistic statements about uncertainty in the α parameter in the absence of data along the descending limb of the S-R relation.

The determination of escapement goals was less satisfactory because the authors did not provide explicit comparisons of the performance of alternative escapement targets, as might be expected. Escapement goals are policy parameters whose calculation and comparison requires clear statements of policy objectives and the set of harvest control rules that may be used to manage the fishery. These are needed to define value functions that permit quantitative comparisons among alternative escapement goals. The authors calculated the likely distribution of S_{MSY} as well as several limit reference points (LRP's) whose purpose was unstated. The analysis did not consider the expected performance of these escapement targets over time horizons of interest to fishery managers. Because much of the variation in recruitment is driven by variation in survival to age 2 rather than by variation in spawner abundance, the performance of S_{MSY} as a target escapement over short time horizons will deviate considerably from its expected long-term performance. Because over 25% of observed escapements failed to reproduce themselves, the proposed escapement and harvest rate targets may pose considerable risk of population decline. Dynamic programming or Monte Carlo simulation should be used to define operational escapement targets that optimize performance measures over shorter time horizons.

LRPs #3 and #4 in Table 23 of the working paper did not follow the approach used for steelhead: if so, a Conservation Concern Threshold would be about $0.25^*R_{max} \approx 59{,}300$ and the LRP would be 0.10 to $0.15^*R_{max} \approx 23{,}700$ to 35,500.

Reviewer #2

This reviewer complimented the authors for carrying out significant new analyses since an earlier version of this report was submitted to PSARC. However, the reviewer also had several significant concerns.

There are various sections of the report that needed to be extensively revised. The title was misleading. The purpose of the working paper needed to be stated more clearly. In addition, there was no abstract and the authors needed to list or summarize their conclusions and/or recommendations.

The stock recruitment analyses should be re-done excluding the 1981-1983 estimates of Harrison escapement. In the report, visual estimates for these years are expanded using results from 1968, 1984, 1985, and 1986, when visual surveys and mark recapture surveys were carried out. However, it is known that the 85-86 visual estimates were biased by the concurrent mark-recapture study.

The reviewer was concerned with the appropriateness of using one sex ratio for the entire Harrison time series. Sample sizes were often large and a consistent sampling protocol was generally followed. The reviewer suggested the use of a mean sex ratio for years when sample sizes were small, and to use the measured ratios for those years when sample sizes were adequate.

The reviewer felt the authors should consider factors other than spawning habitat that might be limiting production, including competition within the Fraser estuary.

A target and several limit reference points were provided in the report. All calculations appeared to be analytically sound but the reviewer was concerned with the use of the terms target and limit. For instance, the proposed target reference point is related to maximum sustained yield and yet the management objectives for this population are not defined; values should be presented as a range of reference points.

Subcommittee Discussion

The authors indicated to the Subcommittee that this paper was a revision of the working paper (S00-18) presented at the Subcommittee meeting in May 2000.

Both reviewers indicated a need to better describe the objectives of the paper, which the authors clarified during their presentation to the Subcommittee. The objectives were to: 1) establish a biologically-based goal for management of the Harrison River chinook stock; 2) fulfill a Pacific Salmon Treaty requirement to establish a bi-laterally agreed escapement goal; and 3) begin development of escapement goals based on reference points.

Considerable discussion focused on the use of the 1981 to 1983 visual escapement estimates and the mean expansion ratio from the mark recapture programs conducted for the years 1968 and 1984 to 1986. The authors initially included these years in the analysis as they came from a period of high production in the Harrison system and indicated that inclusion of the 1981-1983 period encompassed an estimate of production for 1982 that far exceeded the range bound by all other years in the 1981-1999 time series. One reviewer and the Subcommittee expressed a concern about the potential biases associated with the years of visual estimates and agreed that the 1981-1983 data should be excluded from the analysis to determine the escapement targets.

The Subcommittee accepted that the authors successfully addressed the concerns of the previous reviewers and that they provided a spawning escapement objective consistent with the data available. The Subcommittee noted however, that the following issues were associated with the recommended escapement goal of 98,500 Age 3+ chinook:

1) the data has been collected following an extensive period of over-fishing of chinook stocks coastwide and during a period when reduced ocean production has generally been observed. Consequently, the data used may not be representative of future production patterns. This concern however could be raised about any stock-recruitment analysis based on a relatively short time-series of observations;

2) the production function that resulted following adjustment for the marine survival co-variate was very flat above an escapement of 34,000 spawners, with the exception of only the 1990 brood year. The data were consistent with a population regulated by density-dependent freshwater production effects, and that varied due to density-independent environmental effects. Under this interpretation of the data, the use of an escapement objective greater than the S* (the inflection point in the "hockey stick model", Fig. 5) has little benefit to the expected production of chinook. Alternately, data limitations may be masking the potential for significantly higher freshwater production levels;

3) the appropriate management policy for this stock is dependent upon the desired fishery objectives. The spawning goal at the recommended S_{MSY} value presented in this paper implies that fisheries should be regulated to achieve the goal (with an appropriate safety margin to deal with implementation and other sources of error). The expected yield is, on average, expected to be maximized at this escapement level. Alternatively, if the principle objective is to minimize impacts to fisheries while preserving the stock, then an alternative escapement goal and harvest rate policy may be more appropriate for the information available on Harrison River fall chinook. For example, establishing a minimum escapement floor and allowing harvest above that level;

4) the Subcommittee also noted that including a "buffer", such as the authors' recommendation of the 75 percent confidence level, is again reducing risk to the stock but may not result in any increase in expected production. Given the production function presented, fishery managers could achieve the implied benefit of this buffer by applying the S_{MSY} as estimated and limiting the maximum harvest rate allowed on the stock. It will continue to be important to provide escapements larger than the goal in order to continue to define the production limits to this important stock; and

5) if an escapement goal larger than the estimated value is accepted, it should be noted that the production function estimated in this working paper should be used by the Chinook Technical Committee in order to most appropriately represent the data available to-date for this stock.

After considerable discussion about the appropriateness of using a Ricker S-R recruit model versus a "hockey stick" S-R model the Subcommittee agreed with the technical approach utilised in this paper to calculate the S_{MSY} escapement goal for Harrison River chinook.

Concern was expressed by one reviewer and the Subcommittee that the calculated escapement goal was from a period of low marine and freshwater productivity, which may result in a lower target than during a period of normal or high productivity. The Subcommittee suggested that escapements both higher and lower than the target of 98,500 should continue to be tested in future years.

One reviewer was concerned about the lack of policy or a management framework with respect to escapement targets. The Subcommittee encouraged the development of reference points for this and other chinook populations. The Subcommittee recognized that the escapement goal, based on S_{MSY} provided in the working paper to address Canada's obligations for the Pacific Salmon Treaty, may differ from Canadian domestic requirements.

Subcommittee Recommendations

1. The Subcommittee recommended acceptance of the escapement goal of 98,500 (75 percent confidence bound about the S_{MSY} , 1984-96 data) chinook (Table 4). The bootstrap distribution of S_{MSY} estimates is presented in Figure 4. The recommended escapement goal represents 87.5 percent of the S_{MSY} distribution in Figure 4. The sustainable exploitation rate at this goal would equal 0.55.

2. The Subcommittee recommended that the lowest limit in spawning escapement should be no lower than 34,000 chinook based on the historical pattern of recruitment and the 1984-96 data (Fig. 5).

3. The Subcommittee recommended development of a harvest rate/escapement goal policy to minimize the risk of approaching the minimum escapement and to evaluate potential production.

APPENDIX 1: PSARC SALMON SUBCOMMITTEE MEETING AGENDA, OCTOBER 24 - 25, 2001

PSARC Salmon Subcommittee Meeting
October 24 - 25, 2001
Seminar Room, PBS, Nanaimo

Agenda

Wednesday, October 24 - 9:00 am

Introductions, procedures and review of Agenda
Pre-season run size forecasts for Fraser River Sockeye in 2002 (A. Cass)
A Biologically-Based Escapement Goal for Harrison River Fall Chinook (G. Brown et al)

Thursday, October 25 - 9:00 am

Review of and finalization of rapporteur's reports
Concluding comments

APPENDIX 2: PSARC SALMON WORKING PAPERS FOR OCTOBER 2001

S2001-15	Pre-season run size forecasts for Fraser River Sockeye in 2002.	A. Cass
S2001-16	A Spawning Escapement Goal for Harrison River Fall Chinook Based on a Stock-Recruit Analysis	G. Brown B. Riddell D. Chen M. Bradford

APPENDIX 3: PARTICIPANTS AT SALMON SUBCOMMITTEE MEETING, OCTOBER 24 - 25, 2001

Subcommittee Chair: Allan Macdonald
PSARC Chair: Max Stocker

DFO Participants	**Wed**	**Thurs**
* Subcommittee Members		
Bailey, Donald*	✓	
Bailey, Richard*	✓	✓
Benner, Keri	✓	
Bradford, Mike*	✓	
Brown, Gayle	✓	✓
Cass, Al*	✓	✓
Cox-Rogers, Steven*	✓	✓
Dobson, Diana	✓	
Holtby, Blair*	✓	✓
Hyatt, Kim*	✓	
Ionson, Bert*	✓	✓
Irvine, Jim*	✓	✓
Jantz, Lester*	✓	✓
Parker, Chuck	✓	
Riddell, Brian*	✓	✓
Stocker, Max	✓	✓
Sullivan, Melanie*	✓	✓
Wood, Chris*	✓	✓
External Participants:		
Atkinson, Mary-Sue	✓	
Blackbourn, Dave	✓	
Harling, Wayne	✓	
Johnston, Tom	✓	
Wilson, Ken	✓	✓
Observers:		
Scarfo, Kathy	✓	

Reviewers for the PSARC papers presented at this meeting are listed below, in alphabetical order. Their assistance is invaluable in making the PSARC process work.

James Irvine	DFO, Pacific Region
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TABLES AND FIGURES

Table 1. Fraser River sockeye run size forecasts by stock and timing group for 2002. Forecasts include age-4 and age-5 sockeye.

stock/timing group	forecast model[b]	mean run size[c] all cycles	mean run size[c] 2002 cycle	Probability of Achieving Specified Run Sizes[a] 25%	50%	75%	80%	90%
Early Stuart	Power	**392000**	**134,000**	**184,000**	**104,600**	**59,400**	**51,600**	**35,500**
Early Summer		**489,000**	**735,000**	**1,059,000**	**493,100**	**237,100**	**198,100**	**124,100**
Fennell	Power	27,000	21,000	52,200	27,300	14,300	12,100	7,900
Bowron	Power	23,000	23,000	46,100	25,900	14,600	12,600	8,600
Raft	Power	21,000	9,000	48,900	26,700	14,600	12,600	8,400
Gates	R/S	65,000	21,000	51,500	30,200	17,800	15,500	10,900
Nadina	Fry	78,000	20,000	52,900	29,900	16,900	14,600	9,900
Pitt	Power	46,000	40,000	118,100	62,600	33,200	28,300	18,600
Seymour	Power	168,000	411,000	191,600	101,800	54,100	46,200	30,400
Scotch	R/S	61,000	190,000	497,700	188,700	71,600	56,200	29,400
Mid Summers		**6,166,000**	**5,283,000**	**15,931,400**	**9,005,600**	**5,203,800**	**4,549,400**	**3,194,800**
Chilko	Smolt/esc[d]	1,976,000	2,252,000	1,671,300	945,700	535,100	464,200	318,200
Quesnel	pooled[e]	2,671,000	1,978,000	11,223,000	6,720,600	4,024,400	3,541,200	2,520,900
Stellako	Ricker	540,000	609,000	967,600	614,900	390,700	348,900	258,400
Late Stuart	Power	979,000	444,000	2,069,500	724,400	253,600	195,100	97,300
Late Summer		**3,498,000**	**9,340,000**	**5,134,100**	**3,312,600**	**2,194,100**	**1,981,100**	**1,504,800**
Birkenhead	Power	547,000	824,000	779,400	421,000	227,400	195,000	129,500
Late Shuswap	pooled[e]	2,399,000	7,615,000	3,138,900	2,300,400	1,678,500	1,545,200	1,225,900
Cultus	Power	29,000	26,000	13,000	6,700	3,400	2,900	1,900
Portage	R/S	70,000	113,000	457,900	208,100	94,600	77,700	46,000
Weaver	R/S	453,000	762,000	744,900	376,400	190,200	160,300	101,500
TOTAL		**10,545,000**	**15,492,000**	**22,308,500**	**12,915,900**	**7,694,400**	**6,780,200**	**4,859,200**

[a] probability that the actual run size will exceed the specified projection

[b] see text for model descriptions

[c] 1980-2000 mean

[d] based on multiple regression using juveniles and escapement as the independent variables

[e] pooling based on combining smolt and power (return - escapement) forecasts weighted by inverse of variance

Table 2. Late Shuswap sockeye forecasts (millions), variance ($\log_e$ of the forecast) and root-mean-square (RMSE) performance criteria by model.

Model	forecast	variance	$rmse_1$	$rmse_2$
Escapement-based				
Ricker	4.04	0.64	2.63	1.80
Power	3.90	0.66	2.95	2.02
recruits-per-spawner	4.47	0.64	3.59	2.46
Fry-based				
fry	1.86	0.32	2.73	
fry+escape	2.15	0.37	2.80	
pooled (fry and escapement)	2.40	0.21	2.26	

$rmse_{1:}$ based on years with fry data only

$rmse_2$: based on years all years data

Table 3. Estimated Harrison River fall chinook spawner abundances at various probability levels based on the probability distribution of the bootstrap S_{MSY} values (N = 974 bootstrap cases for which there was a determinate solution for S_{MSY}). The bootstrap distribution was based on an analysis including only year classes 1984-96. 'ER' refers to exploitation rate and is derived by solving for the ER at each spawner abundance substituted into the Ricker function (with the survival rate co-variate).

Probability Level	**Spawner Abundance in the S_{MSY} Distribution**	**Exploitation Rate at Spawner Abundance**
25%	64,700	0.64
50% (median)	72,400	0.62
75%	85,700	0.58
90%	104,100	0.51
95%	117,139	0.45
Point Estimate	75,100	0.61

Table 4. Lower and upper bootstrap confidence limits for the point estimate of S_{MSY} (75,100 age 3+ chinook) of Harrison River fall chinook derived from the Ricker stock-recruit model with survival rate as a co-variate fitted to the time series of year classes 1984-96.

Confidence Interval	**Lower CL**	**Upper CL**
75%	60,522	98,467
90%	56,570	117,139
95%	55,142	137,900

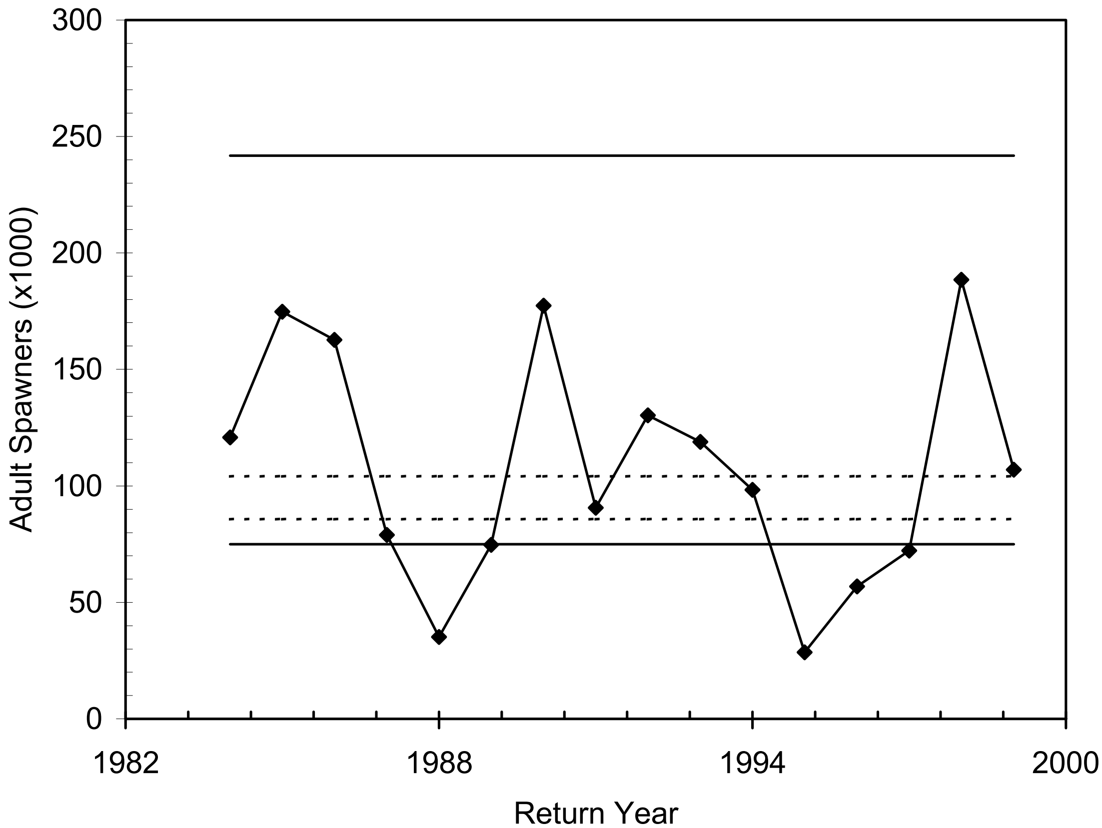

Figure 1. Trend in adult spawning abundance of Harrison River fall chinook since the start of the mark-recovery program (solid line with diamonds) in 1984. The upper solid horizontal line is the 1986 interim escapement goal (241,700) based on doubling the escapement estimate obtained from a mark-recapture program in 1984. The lower solid horizontal line is the optimal spawner abundance (75,100) obtained from the Ricker stock-recruit function fitted with survival rate as a co-variate (based on year classes 1984-96). The lower and upper dashed horizontal lines are, respectively, the spawning abundance at the 75% (85,700) and 90% (104,100) probability levels from the cumulative density function based on the bootstrap distribution for S_{MSY}. (Table 3).

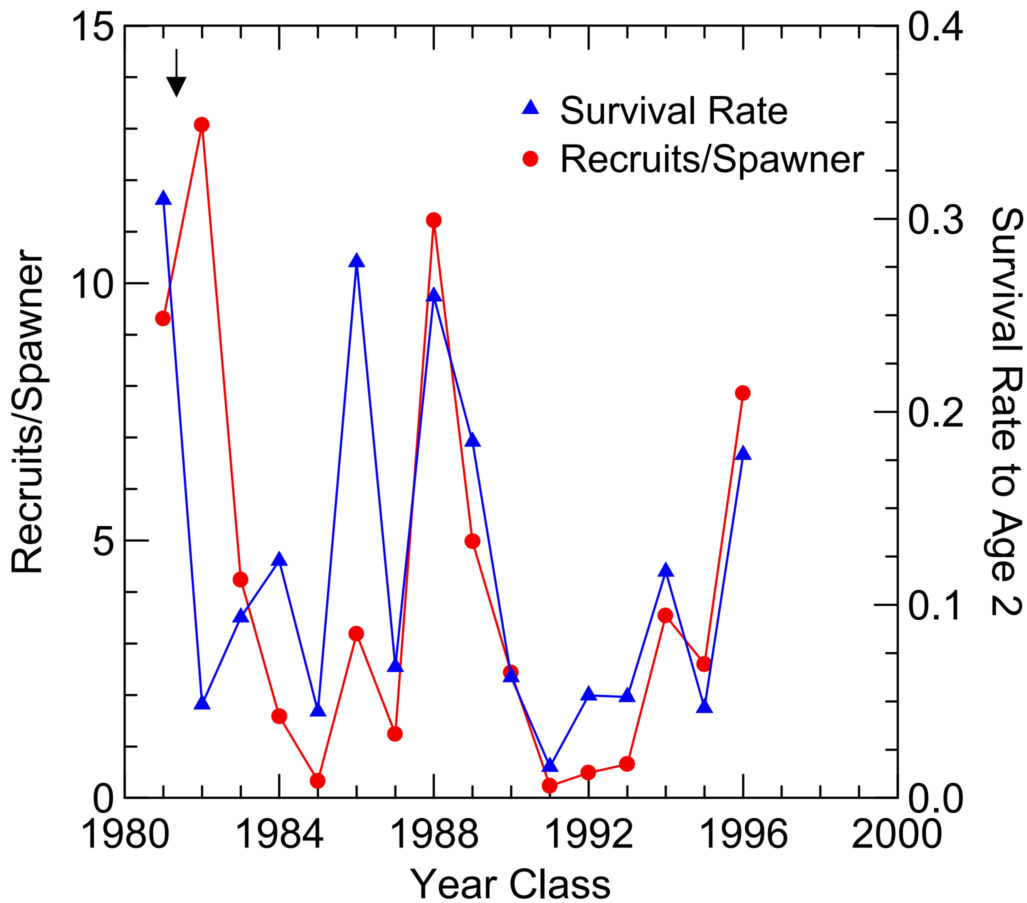

Figure 2. Recruits per Harrison River fall chinook spawner and Chilliwack Hatchery fall chinook smolt-to-age 2 survival rate versus year class. Recruitment estimates for the Harrison River population were derived using survival rates and other results from chinook cohort analysis based on coded-wire tag recoveries of chinook reared and released from Chilliwack Hatchery. The arrow positioned in the top left corner indicates that R/S and SR were opposite in trend in 1982.

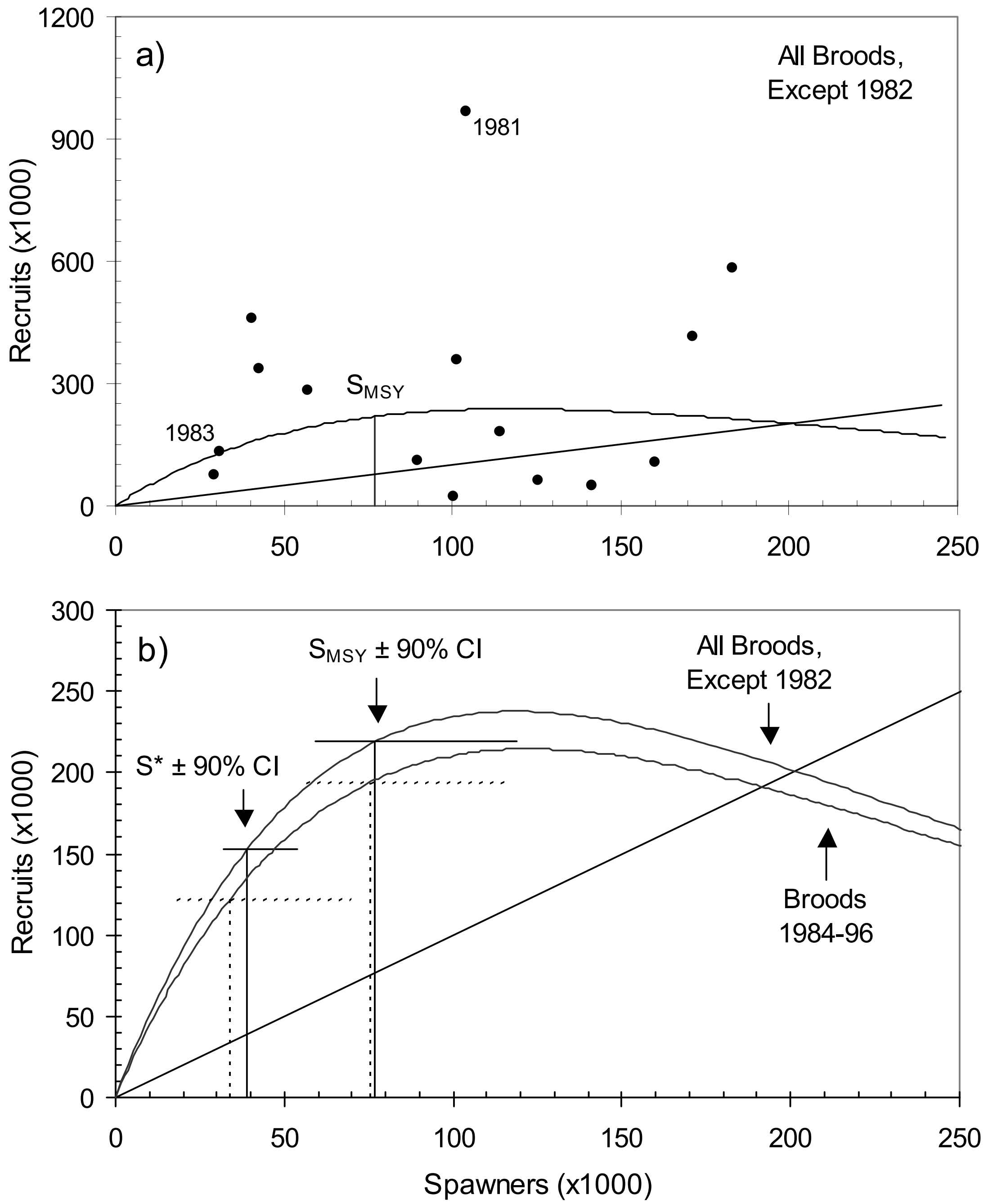

Figure 3. (a) Harrison River fall white chinook estimated adult spawers and recruits and fitted Ricker function with the smolt-to-age 2 survival rate covariate (year class 1982 excluded). (b) Estimated optimal spawning abundance, *S_{MSY}*, (from the Ricker stock-recruit model) and the associated 90% confidence interval (from the bootstrap distribution), and the optimal transition point in the hockey stick model, *S, and the associated 90% confidence interval. The upper curve is based on all brood years except 1982, whereas as the lower one is based on only brood years 1984-96.**

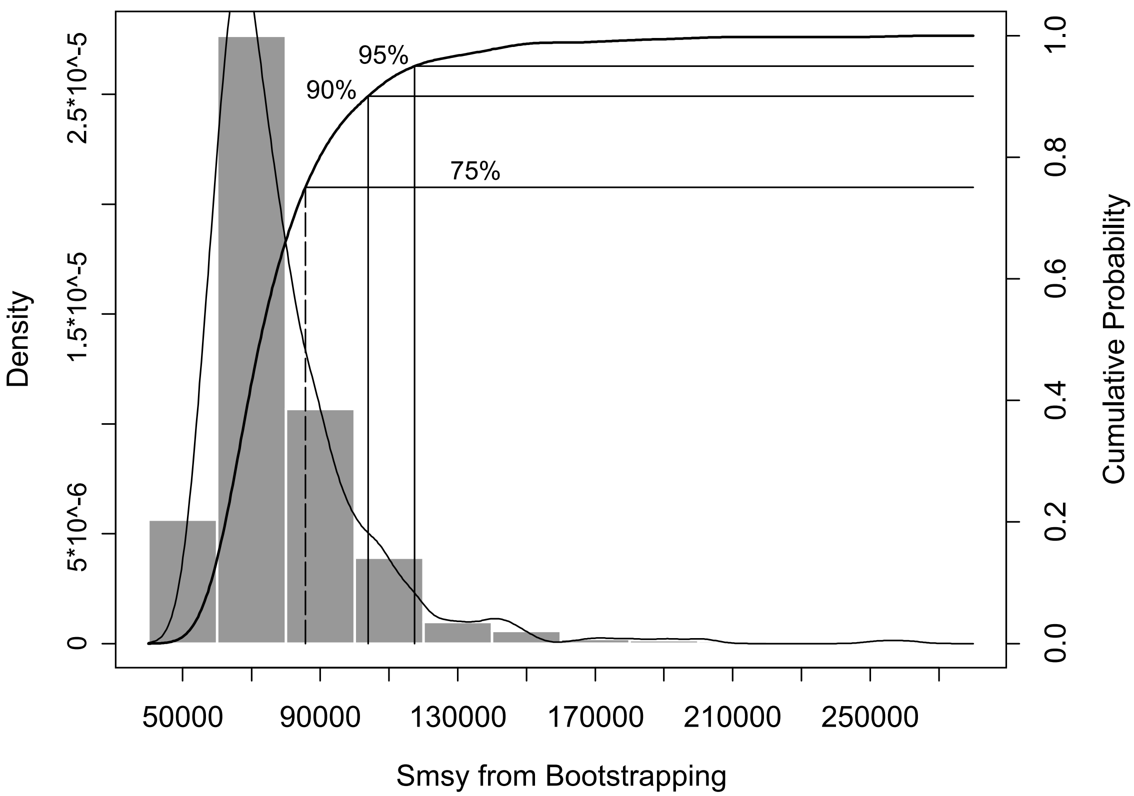

Figure 4. The cumulative probability curve derived from the bootstrap distribution of *S_{msy}* (N=974) based on the time series with year classes 1981-83 excluded. Harrison River fall chinook spawning abundances at the 75%, 90% and 95% probability levels are specifically indicated.

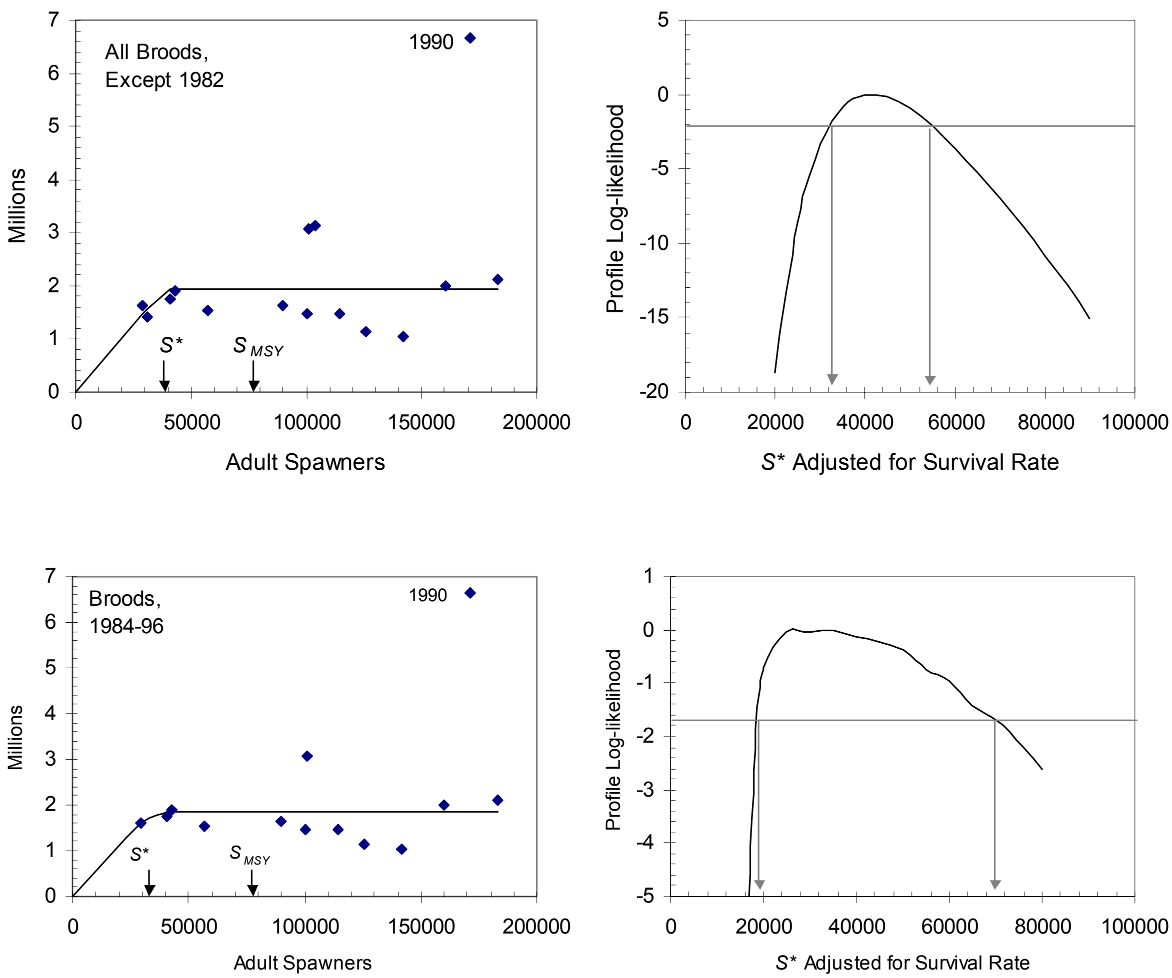

Figure 5. Harrison River chinook stock and recruit data (recruits adjusted for smolt-to age 2 survival rate) and the maximum likelihood fit of the hockey stick model (left panels). The optimal transition point in the hockey stick model, *S, and S_{MSY} from the fitted Ricker model, are indicated with arrows along the horizontal axis. The profile log-likelihood of *S** and the approximate 90% confidence limits of the maximum *S** (i.e., the points indicated along the horizontal axis by the two arrows descending from where the horizontal line intersects the profile log-likelihood curve) are shown in the right panels. The maximum *S** occurs at zero because the maximum log-likelihood has been subtracted. The upper panels are based on the time series excluding brood year 1982. The lower panels are based on the time series excluding brood years 1981-83.**