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Proceedings Series 2004/006 | **Série des compte rendus 2004/006**

Proceedings of the PSARC Salmon Subcommittee Meeting

March 16-17, 2004
Nanaimo, BC

G. Thomas

Fisheries and Oceans Canada
Pacific Scientific Advice Review Committee
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Nanaimo, British Columbia V9T 6N7

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ISSN 1701-1272 (Printed / Imprimé)

Published and available free from:
Une publication gratuite de:

Fisheries and Oceans Canada / Pêches et Océans Canada
Canadian Science Advisory Secretariat / Secrétariat canadien de consultation scientifique
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Ottawa, Ontario
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Printed on recycled paper.
Imprimé sur papier recyclé.

Correct citation for this publication:
On doit citer cette publication comme suit:

Thomas G., 2004. Proceedings of the PSARC Salmon Subcommittee Meeting March 16-17, 2004 DFO Can. Sci. Advis. Sec. Proceed. Ser. 2004/006.

PACIFIC SCIENTIFIC ADVICE REVIEW COMMITTEE (PSARC) SALMON SUBCOMMITTEE MEETING

SUMMARY

The Pacific Scientific Advice Review Committee (PSARC) Salmon Subcommittee met March 16-17, 2004 at the Pacific Biological Station, Nanaimo, B.C. to review two Working Papers.

Working Paper S2004-03: Forecast for southern and central British Columbia coho salmon in 2004

The subcommittee accepted 2004 forecasts of coho survival and abundance in south and central B.C., as well as, forecasts of distribution of Georgia Basin coho. Forecasts were derived using previously approved methods.

Coho survivals based on indicator streams are anticipated to be low in the Georgia Basin, the lower Fraser and west coast Vancouver Island management units. Distribution of Georgia Basin coho are expected to be intermediate ("inside/outside"). Interior Fraser area abundances are expected to remain low with a total return to the Thompson R. forecasted to be about 35,000 coho. Abundances in Johnstone St. (PFMAs 12 and 13) are expected to remain well below average though prospects for escapements are somewhat more optimistic because of low anticipated harvests. Similarly, in the central coast (PFMAs 7, 8 and 11), abundances are expected to be about average with escapements average or greater.

Working Paper S2004-04: Forecasted status of Cultus and Sakinaw sockeye salmon in 2004

The subcommittee supported a new Baysian forecast methodology and accepted the 2004 forecast returns for Cultus and Sakinaw sockeye derived from the model. The model employs both brood year smolt abundances and age-3 (jack) abundances from the brood year to estimate total return.

Abundance declines observed since the 1980's has lead to a COSEWIC designation of "endangered" for both Cultus and Sakinaw stocks. The declining trend has continued in recent years with returns reduced to 1485 spawners in Cultus and 3 in Sakinaw in 2003. Prospects in 2004 are for returns to remain low relative to historic levels. The recommended 2004 median forecasts for Cultus and Sakinaw sockeye are estimated to be 281 and 390, respectively. As a result, the endangered status of both of these stocks is unlikely to change in 2004.

The probability of achieving returns of 500 spawners, the short term minimum viable escapement as defined by the recovery teams, for Cultus and Sakinaw stocks is low. For example, with 0% exploitation and assuming pre-spawn mortality levels of 30% for Cultus and 10% for Sakinaw, the estimated probability of achieving 500 spawners is only 2% for Cultus and 21% for Sakinaw. The impact of increasing levels of exploitation disproportionately decreases the odds of achieving 500 spawners.

There is considerable uncertainty about migration timing of Sakinaw sockeye in Johnstone St. and potential fishery impacts. The direct evidence comes from a single tag recovery from a fish marked in PFMA 13 and recovered eight days later at Sakinaw Ck. in 1925. The authors provided a number of fishery scenarios based on migration timing derived from escapement data. However, the subcommittee acknowleged that other scenarios, based on different migration timing assumptions, could be evaluated for planning purposes.

SOMMAIRE

Le sous-comité du saumon du Comité d'examen des évaluations scientifiques du Pacifique (CEESP) s'est réuni les 16 et 17 mars 2004 à la Station biologique du Pacifique, située à Nanaimo, en Colombie-Britannique, pour passer en revue deux documents de travail.

Document de travail S2004-03 : Prévisions concernant le saumon coho du sud et du centre de la Colombie-Britannique pour 2004

Le sous-comité accepte les prévisions de survie et d'abondance du saumon coho dans le sud et le centre de la C.-B. pour 2004, ainsi que les prévisions de la répartition du saumon coho du bassin de Georgia. Les prévisions ont été calculées par des méthodes déjà approuvées.

Selon les prévisions fondées sur les cours d'eau indicateurs, les taux de survie du saumon coho devraient être faibles dans les unités de gestion du bassin de Georgia, du bas Fraser et de la côte ouest de l'île de Vancouver. La répartition du saumon coho du bassin de Georgia devrait être intermédiaire (« intérieur/extérieur »). On s'attend à ce que les abondances dans la région du bassin intérieur du Fraser restent faibles; la remonte totale dans la rivière Thompson devrait se chiffrer à environ 35 000 saumons cohos. On prévoit que les abondances dans le détroit de Johnstone (zones 12 et 13) resteront bien inférieures à la moyenne, bien que les prévisions concernant les échappées soient un peu plus optimistes en raison des faibles captures prévues. La situation est semblable sur la côte centrale (zones 7, 8 et 11), où l'on prévoit des abondances à peu près moyennes et des échappées moyennes ou supérieures à la moyenne.

Document de travail S2004-04 : Prévisions de l'état des stocks de saumon rouge des lacs Cultus et Sakinaw pour 2004

Le sous-comité appuie une nouvelle méthode de prévision bayesienne et accepte les prévisions de remonte du saumon rouge pour 2004 des lacs Cultus et Sakinaw calculées à l'aide du modèle. Le modèle permet d'estimer la remonte totale à partir de l'abondance des saumoneaux et de celle des saumons de trois ans lors de l'année d'éclosion.

Les baisses d'abondance observées depuis les années 1980 ont incité le COSEPAC à désigner les stocks de saumon rouge des lacs Cultus et Sakinaw « en voie de disparition ». La tendance à la baisse s'est poursuivie ces dernières années, les remontes étant réduites à 1 485 géniteurs au lac Cultus et à seulement 3 au lac Sakinaw en 2003. On prévoit qu'en 2004 les remontes seront faibles par rapport aux niveaux historiques. Les prévisions de remontes médianes recommandées pour 2004 sont estimées à 281 pour le stock du lac Cultus et de 390 pour le stock du lac Sakinaw. Le statut « en voie de disparition » de ces stocks ne sera donc sans doute pas modifié en 2004.

La probabilité est faible que la remonte de ces deux stocks atteigne 500 géniteurs, soit l'échappée viable minimale à court terme, telle qu'établie par les équipes de rétablissement. Par exemple, pour un taux d'exploitation nul et en supposant que le taux de mortalité avant la fraie sera de 30 % pour le stock du lac Cultus et de 10 % pour le stock du lac Sakinaw, on estime que la probabilité qu'il y ait 500 géniteurs n'est que de 2 % pour le stock du lac Cultus et de 21 % pour le stock du lac Sakinaw. Une hausse des taux d'exploitation réduirait de façon disproportionnée cette probabilité.

Il y a une grande incertitude quant au moment de la migration du saumon rouge du lac Sakinaw dans le détroit de Johnstone et à ses effets possibles sur la pêche. La recapture dans la rivière Sakinaw d'un poisson marqué huit jours plus tôt dans la zone 13, en 1925, constitue la seule indication directe. Les auteurs présentent quelques scénarios de pêche fondés sur le moment de la migration estimé à partir de données d'échappée. Le sous-comité a cependant reconnu que d'autres scénarios, fondés sur des suppositions différentes concernant le moment de la migration, pourraient être évalués à des fins de planification.

INTRODUCTION

The PSARC Salmon Subcommittee met March 16-17, 2004 at Pacific Biological Station in Nanaimo, British Columbia. External participants from First Nations, Sports Fishing Advisory Board, Fishing Vessel Owners Association and industry attended the meeting. A consultant also attended the meeting. The Subcommittee Chair, Greg Thomas, opened the meeting by welcoming the participants. During the introductory remarks, the objectives of the meeting were reviewed, and the Subcommittee accepted the meeting agenda.

The Subcommittee reviewed two Working Papers. A Summary of the Working Papers is in Appendix 1. The meeting agenda appears as Appendix 2. A list of meeting participants is included as Appendix 3.

DETAILED COMMENTS FROM THE REVIEW

S2004-03: Forecast for southern and central British Columbia coho salmon in 2004

K. Simpson, M. Chamberlain, J. Fagan, R. Tanasichuk, D. Dobson ** Accepted subject to revisions**

Subcommittee Discussion

The working paper provides forecasts of marine survival, abundance and distribution for coho in the central coast and south coast of B.C. The forecasting methodologies employed were generally consistent with those approved in previous years. However, the subcommittee noted that the euphausiid model, which provides the best WCVI forecast, had been slightly modified by removing one explanatory variable.

Forecasts of marine survival for Georgia Basin and WCVI coho are provided in a table in the working paper summary (Appendix 1). Forecast survivals of both hatchery and wild St. of Georgia indicator stocks remain at low levels. Similarly, forecasted survivals for lower Fraser stocks remain low.

Distribution of Georgia Basin coho is anticipated to be intermediate in 2004 which amounts to more of an "inside" orientation than observed in several years in the last decade.

While the abundance of WCVI wild and hatchery stocks is forecasted to be low, abundance of these stocks has varied historically without any apparent long-term trend.

Forecasts of total abundance for Thompson River coho are provided in the working paper summary (Appendix 1; Table A1). Thompson returns in 2004 (34,600) are forecast to be higher than 2003 returns (15,100), but this number is still lower than the parental brood return in 2001 (53,000).

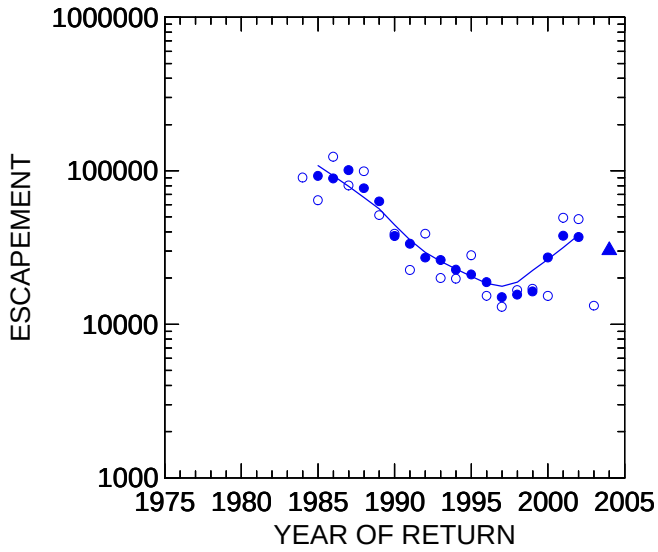
Though 2004 abundances are expected to be average to well below average for central coast stocks, escapements are forecast to be average to above average under current fishery regimes everywhere except in Area 13, where stocks remain a particular concern (See Appendix 1; Table A2).

The subcommittee noted that forecasts for coho in southern B.C. management units are all low, and stock status remains low. For the purposes of this review, stock status designations; ie. low, moderate and abundant, represent the definitions used within the Pacific Salmon Treaty process. The authors were requested to provide an assessment of stock status consistent with PST abundance designations. This assessment is summarized in the table below for Black Creek (Georgia Basin West (GBW)), Salmon River (Lower Fraser River (LFR)) and Carnation Creek (West Coast Vancouver Island (WCVI). It was further requested that the authors provide generational trends in abundance using a 3-yr moving average, to compliment the 2004 status information. This information is depicted in Figures 1 a-e below. It should be noted that the escapement trends provide a somewhat optimistic view of stock status relative to total abundance given that recent fishery removals have been small.

	Confidence Limits[1]	Forecast Return	Optimum Escapement	Optimum ER[2]	Previous Status[3]	Forecast Status[4]
Black	25%	2,797	3,150	0%		
(GBW)	50%	3,867		19%	Low	Low
	75%	5,430		42%		
Salmon	25%	747	4,000[5]	0%		
(LFR)	50%	1,034		0%	Low	Low
	75%	1,408		0%		
Carnation	25%	21	90	0%		
(WCVI)	50%	29		0%	Moderate	Low
	75%	42		0%		

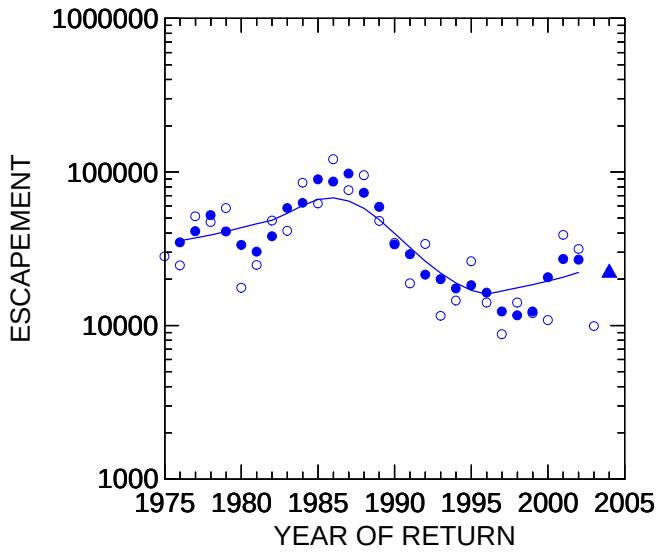
[1] The 50% value is the point estimate.
[2]ER that will result in the optimum escapement at the forecast abundance.
[3]From status designations for previous years and observed returns and escapements in 2003.
[4]PST status based on ER needed to achieve optimum escapement. Exploitations of Low status stock aggregates are not to exceed 20%.
[5]Optimum escapement for Salmon R. (Langley) is particularly uncertain.

Figure 1 a-e. Trends in wild coho escapements to southern BC management units. Open circles are annual estimates of escapement; filled circles are the corresponding estimates smoothed over one generation (3 yr); the line is fitted to smoothed data by LOWESS; triangles depict the escapements expected in 2004 if exploitations do not change from 2003. The smoothed data and line do not include the 2004 forecast. Where an optimum (MSY) escapement has been estimated, it is shown as a dashed line.

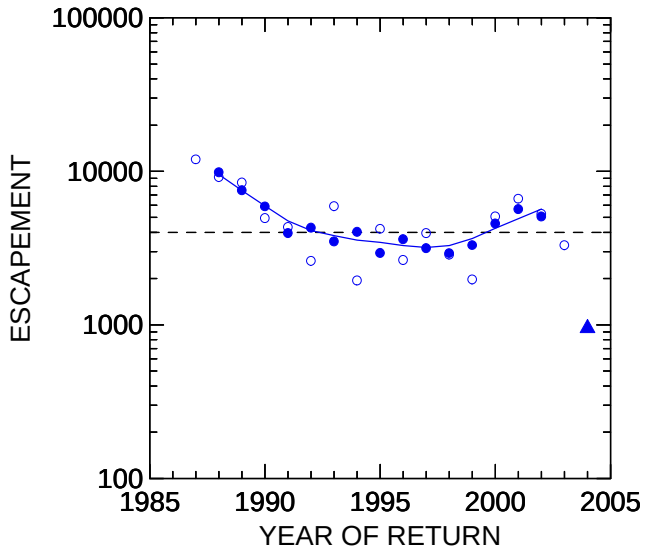


a. Total Thompson River watershed (N. and S. Thompson and lower Thompson)

Figure 1 (cont'd)

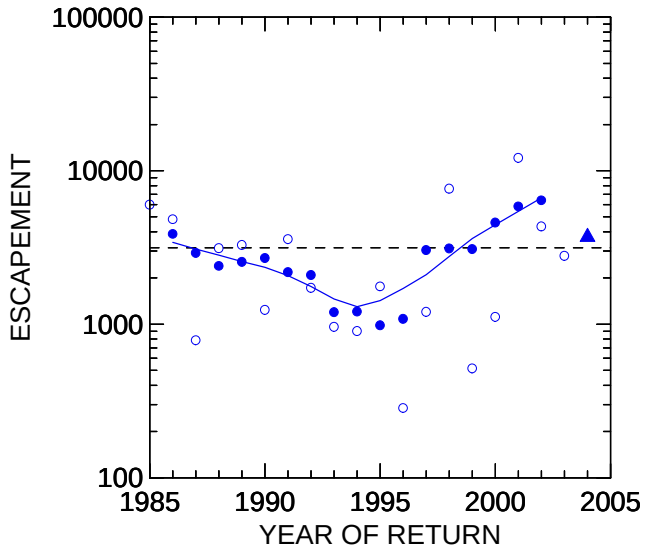


b. North and South Thompson watersheds

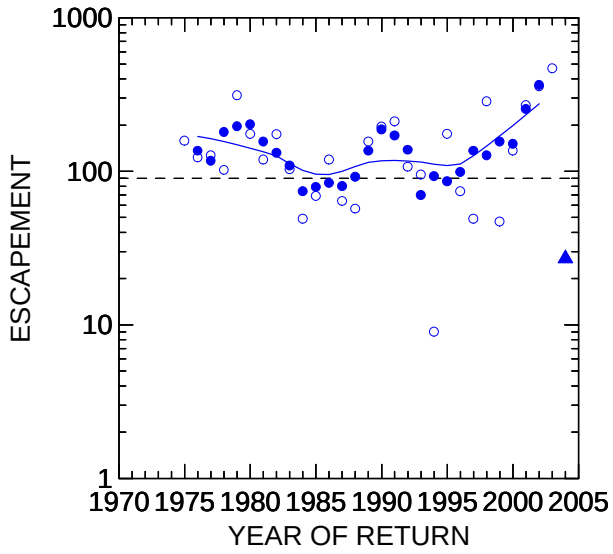


c. Lower Fraser (Salmon R. (Langley))

Figure 1 (cont'd)



d. Georgia Basin West (Black Creek)



e. West Vancouver Island (Carnation Creek)

Subcommittee Conclusions

1. The subcommittee accepted the working paper with revisions, noting the forecasts were generally derived from previously reviewed and approved methodologies.

2. The subcommittee concluded that coho status has been, and continues to be low (as defined by the criteria developed within the Pacific Salmon Treaty process) for southern Johnstone St., Georgia Basin West, Georgia Basin East, lower Fraser, and interior Fraser (Thompson) stocks. WCVI also remains low but does not show the same longer term declining trends as do the other southern stocks.

3. A downturn in returns of interior Fraser coho was observed in 2003 to the lowest level ever recorded. The 2004 forecasted returns represent a decrease from the 2001 brood abundance. Based on this information, the subcommittee concluded that interior Fraser coho remains a stock of concern.

Subcommittee Recommendations

1. The subcommittee recommended the acceptance of the forecasts presented in this working paper.

2. It was recommended that a revised euphausiid model should be used for the WCVI forecast.

3. The subcommittee recommended that future forecasting working papers evaluate stock status relative to consistent standards (most recent abundance estimate, most recent generational mean abundance and generational trends).

4. The subcommittee recommended that no significant increase in harvest of coho stocks originating from inside waters (from PFMA 12 and south) as well as WCVI, occur in 2004, relative to recent harvest levels.

S2004-04: Forecasted status of Cultus and Sakinaw sockeye salmon in 2004

Chris Wood, Charles Parken **Accepted subject to revisions**

Subcommittee Discussion

Two reviewers provided comments on the working paper. Both reviewers felt that the data, methods and analyses were thorough given the limited data. Each reviewer suggested alternative forecast models for the authors to consider. The subcommittee agreed that more clarity in the definition of terms be provided in revisions to the working paper.

Data

The working paper describes trends in abundance of spawners for Cultus and Sakinaw relative to COSEWIC *endangered* and *threatened* status. A smolt-to-adult survival index based on recent data (1990-1998) for Chilko Lake sockeye was used for both Cultus and Sakinaw populations. Smolt-to-adult survival data for Cultus were available but not used because of concerns about large data gaps for smolt-to-adult survival estimates in recent decades and reliability of adult return estimates. One reviewer did not support the use of Chilko smolt-to-adult survival data as a surrogate index of survival for Cultus and Sakinaw and suggested using the Cultus data with the Bayesian model. The Subcommittee agreed that the use Chilko smolt-to-adult survival data for forecasts in 2004 given a lack of recent Cultus data was appropriate. An index of age-3 sockeye returning to Cultus in each brood year was developed based on the proportion of age-3 fish in the spawner escapement and returns of age-4 and age-5 fish in the next year. Only 1 data point (1971) for age-3 sockeye was available for the Sakinaw population, as a result, the Cultus data were used for Sakinaw.

Forecasting methods

Forecast models were based on smolt information only (Prior model), smolt and jack information (Bayesian model), or average total adult returns (4-year mean model). The authors present forecasts for age-4 returns only (age-5 returns were assumed negligible). A reviewer proposed an alternative smolt model based on a Cultus marine survival index, but pointed out that the forecast return was similar to forecasts presented in the working paper. The other reviewer was concerned with the form of the Bayesian model presented by the authors and suggested another formulation of the model to account for additional uncertainty in the age-3 index (Full Bayesian model).

The authors presented results for the Cultus smolt model, as proposed by one reviewer, and the Full Bayesian model, as proposed by the other reviewer, using both Cultus and Chilko marine survival indices. Results indicated that the choice of survival index did not have a large impact on forecasts, but median forecasts were reduced for models that used Cultus marine survival indices. The authors questioned whether there might be an error in the Sakinaw results presented by the reviewer for the Full Bayesian model (median forecast was higher for Full Bayesian model). After discussing this issue with the reviewer, it appears the difference in the forecast for Sakinaw for the Full Bayesian model was a result of including age-4 and age-5 returns. The authors working paper only includes forecast returns of age-4 fish for Sakinaw given poor expectations for age-5 returns in 2004 (only 3 age-4's were observed in 2003).

The Subcommittee discussed the possibility of including a traditional stock-recruitment (S-R) model for Cultus. This was considered inappropriate because the brood year spawner number was derived indirectly from smolt production estimates to account for pre-spawn mortality of adult escapement.

Model Performance
Forecast performance was evaluated retrospectively by comparing forecasts to observed returns for Cultus sockeye. Forecast errors were quantified with mean absolute percent error (MAPE) and root mean square error (RMSE) criteria. Forecast bias and the Pearson correlation coefficient (r) between the forecasted and observed returns for each candidate model were also computed. Evaluation of forecast performance was not possible for Sakinaw due to insufficient smolt and adult return data. The Subcommittee and reviewers did not identify any problems with these performance measures.

Implications of the forecast
Cumulative probability distributions for the predicted 2004 return (best model) were used to provide probabilities of exceeding spawner thresholds given various conditions of fixed pre-spawn mortality and exploitation (for Cultus) or fixed pre-spawn mortality and hypothetical fishery scenarios (for Sakinaw). For Sakinaw sockeye, a simulation of fishery scenarios was done to incorporate year-to-year variation by selecting from historical cumulative probability distributions of escapement and using a 2 week lag in the timing to evaluate potential fishery impacts in marine areas. One reviewer was concerned about the methodology for the Sakinaw population because alternative assumptions about delay behavior prior to entry into the fish way (e.g. marine timing may be earlier and fish delay longer prior to entry into freshwater than assumed) and migration routes (e.g. Juan de Fuca) were not considered.

The reviewer suggested the authors provide a sensitivity analysis to address the uncertainty of the Sakinaw migration timing and migration route (Johnstone St. vs Juan de Fuca). Alternatively the reviewer suggested omitting the fishery simulation and doing only the simple exploitation rate analysis that was done for Cultus in the working paper. The authors indicated that there is currently a lack of definitive information to determine the marine timing of Sakinaw sockeye and, as such, the fishery simulation for Sakinaw is uncertain and only hypothetical. The authors based their estimate of travel time on data from one tagged fish captured August 10 in PFMA 13 that took 8 days to travel to the terminal area (in 1925) and travel rates of Fraser River sockeye stocks to support the assumption of a 2 week lag. The Subcommittee recognized that the assumption about the migration lag for Sakinaw may be a critical uncertainty in the fishery simulation. Alternative views on timing were expressed during the meeting by some external participants. The Subcommittee recognized that alternative assumptions for Sakinaw (in addition to the hypothetical scenario provided by the authors) could be explored during fishery planning to assess their effects.

Subcommittee Conclusions

1. The Subcommittee accepted the working paper with revisions. The Subcommittee supports the use of the new Bayesian forecast method for Cultus and Sakinaw presented by the authors. This methodology may be appropriate for broad application to other stocks/species. Additional revisions requested by the Subcommittee include:
    a. Provide the results for Bayesian and smolt forecast models using both the Cultus and Chilko survival indices for comparison purposes.
    b. Provide a table of results showing the probability of Sakinaw sockeye spawners exceeding thresholds of 500 successful spawners under hypothetical scenarios for pre-spawn mortality and fishery exploitation rates and only show the results for the 500 spawner threshold for Cultus.
    c. The recommended forecast for Cultus should be based on the Bayesian model with 0 jacks in 2003. Evidence suggests that the age-3 "jack" reported for 2003 was likely of freshwater origin i.e. a residual smolt or kokanee and should not be counted as a "jack".

2. The COSEWIC *endangered* status of both of these stocks is unlikely to change in 2004. The future status of these populations will be influenced by actual returns in 2004 and the number of successful spawners remaining after fishing and pre-spawning mortality. However, there are opportunities for recovery of these populations given that Cultus sockeye have shown increases in successful spawners over the last 3 years relative to brood levels. While the situation is more serious for Sakinaw, there are good rebuilding opportunities in 2004 and 2005 given relatively higher expectations for returns relative to the other cycle years.

3. The subcommittee recognized the uncertainty in marine migration timing of Sakinaw (and exposure to fisheries) in Johnstone St. and the effect on fishery simulations. The subcommittee concluded that further studies would be required to reduce uncertainties associated with marine timing of Sakinaw sockeye.

4. The subcommittee concluded that forecast distributions from the Bayesian methodology could be used in an assessment of the potential fishery impacts on the Sakinaw and Cultus populations.

Subcommittee Recommendations

1. The recommended median abundance forecast for Cultus sockeye in 2004 is 281 individuals with odds of 9 in 10 (90% probability) that the return will exceed 150, and 3 in 4 (75% probability) that the return will exceed 203 individuals. The recommended forecast is based on a Bayesian model that considers both the smolt abundance observed in 2002 and age-3 ("jack") returns from the same brood year in 2003. This forecast uses the Chilko marine survival index and Cultus age-3 index (see Appendix 1; Table A3).

2. The recommended median abundance forecast for Sakinaw sockeye in 2004 is 390 individuals with odds of 9 in 10 (90% probability) that the return will exceed 215, and 3 in 4 (75% probability) that the return will exceed 286 individuals. The recommended forecast is based on the Bayesian model that considers both the smolt abundance observed in 2002 and the age-3 ("jack") returns from the same brood year observed in 2003. This forecast uses the Chilko marine survival index and an expected age-3 index for Cultus sockeye (see Appendix 1; Table A3).

3. The subcommittee recommended the use of Table A4 in Appendix 1 to evaluate alternative assumptions of pre-spawn mortality and exploitation rate. Based on Table A4, the probability of achieving 500 viable spawners for the Cultus and Sakinaw populations is low even in the absence of fishing and pre-spawning mortality. Any fishing and pre-spawn mortality, will decrease the probability of achieving 500 viable spawners.

4. The Subcommittee recommends that forecast distributions from the Bayesian methodology could be used as one of the inputs into an assessment of potential fishery impacts on the Sakinaw and Cultus populations.

5. The Subcommittee recommends that future forecast papers consider alternative forecast methods (e.g. Full Bayesian model) as new information and forecast models become available.

6. The Subcommittee recommends that multi-year forecasts be considered for future forecast papers to provide a management context for the current year relative to the following years.

APPENDIX 1: Working Paper Summaries

S2004-03: Southern and Central British Columbia coho salmon in 2004

K. Simpson, M. Chamberlain, J. Fagan, R. Tanasichuk, D. Dobson

This Working Paper presents 2004 forecasts of marine survival, abundance and distribution of coho in southern and central British Columbia (PFMAs 7 to 29: the Fraser River system and coastal waters south of approximately 53° N).

Table A1. Forecasts for hatchery and wild coho indicator stocks in southern BC.

Management Unit	Indicator	Recommended Model	Predicted Survival in 2004 (Carnation is abundance) (50% CI)		Change (2004 forecast minus 2003 observed survival)
GB West	Big Qualicum	LLY	0.006	(0.004 - 0.010)	0%
	Quinsam	3YRA	0.013	(0.010 - 0.017)	35%
	Black (wild)	3YRA	0.047	(0.034 - 0.066)	60%
Lower Fraser	Chilliwack	RAT3	0.022	(0.015 - 0.031)	-13%
	Inch	LLY	0.010	(0.006 - 0.018)	0%
	Salmon (wild)	LLY	0.036	(0.026 - 0.049)	0%
SWVI, NWVI	Robertson	Sibling	0.029	(0.018 - 0.048)	-69%
	Carnation (wild)	Euphausiid	29	(21 - 42)	-94%

Survival of coho on the east coast of Vancouver Island is expected to be poor, ranging from approximately 1% for hatcheries to 4.7% for higher productivity wild stocks. Although the wild forecast and the Quinsam hatchery forecast are larger than the survivals in 2003, there is an increased risk this year, based on sibling forecasts of hatchery survival, that survivals may be lower than last year. Survivals are forecast to remain about the same in the lower Fraser (LowFr) area. Although there is not a time series of survivals for the mainland shore of the Strait (the Georgia Basin East Management Unit), recent measured survivals suggest that coho survivals are poorer in this Unit than elsewhere in the Georgia Basin. Overall for the Georgia Basin, we characterize survivals as poor, basing this qualitative assessment on previously higher survivals and on calculations of the survivals needed to sustain stocks of low to average productivity.

We forecast that an average proportion of coho that originated in the Georgia Basin will rear in the Strait of Georgia in the spring and summer before spawning. Although not a prediction of either an' inside' year or an 'outside' year, the proportion is expected to be more 'inside' than several of the last 10 years.

On the west coast of Vancouver Island (wVI), survival of coho is forecast to be approximately 3%. This is about one third of the very good survival in 2003. Survival of Robertson Hatchery coho is forecast to be more than Georgia Basin hatcheries, as it has been for many years. The return of coho to the wild indicator, Carnation Creek, is forecast to decline from above average in 2003 to well below average. In summary the forecast is for a sharp reduction in survival and returns to below average or well below average levels.

The abundance of Thompson River coho in 2004 is expected to be ~34,646 animals. This is significantly more then the ~15,100 coho observed in 2003, but less then the brood year (2001) abundance of ~53,000. Returns in 2003 did not exceed their brood year return as well. While some individual Interior Fraser River populations are remaining stable or have increased slightly over the brood abundance, as a whole it appears that the abundance of this stock aggregate continues to remain low and is declining.

The abundance forecasts for central coastal British Columbia remain the only method of forecasting for this area. Forecasting methods conform to those of past forecasts in this area. The forecasts of total abundance and escapement for the five Central Coast aggregates are given in the following table. Note that the abundance of coho in Area 13 (Johnstone St.) is expected to be very poor:

Table A2. Forecasts of Total Return and Escapement for central coast coho stocks

			total return (abundance)		escapement		
aggregate	group	model	forecast *P* [†]	characterization	forecast *P*	characterization	% of S_{max}
Area 7	4	3YRA	35%	average	61%	average	35%
Area 8	5	3YRA	20%	below average	44%	average	59%
Area 11	5	3YRA	56%	average	78%	well above average	109%
Area 12	5	3YRA	10%	well below average	57%	average	33%
Area 13	6	3YRA	4%	well below average	22%	below average	5%

[†] Proportions of observed abundance or escapement less than the forecast value. These calculations assume a log-normal cumulative probability distribution with mean and standard deviation calculated over the observation period 1950 (1953 for Areas 11,12 & 13) to 2003 (return years).

S2004-04: Forecasted status of Cultus and Sakinaw sockeye salmon in 2004

Chris Wood, Charles K. Parken

This working paper was prepared in response to requests from Fisheries Management, DFO for advice on the levels of fishing mortality in 2004 that would pose an imminent threat to the survival and recovery of Cultus and Sakinaw sockeye salmon populations (hereafter called Cultus sockeye and Sakinaw sockeye). Both populations were assessed on an emergency basis by the Committee on Status of Endangered Wildlife in Canada (COSEWIC) in fall 2002 and designated as *Endangered* "wildlife species"; the designation was confirmed by COSEWIC in May 2003. COSEWIC's definition of *Endangered* is "facing imminent extirpation or extinction". The designation for Cultus and Sakinaw sockeye was based largely on IUCN criteria A (over 50% decline in abundance over 3 generations) and C (single population with fewer than 2,500 mature individuals and a continuing decline). Sakinaw sockeye also triggered criterion D (fewer than 250 mature individuals).

Current status: The declining trend in number of mature individuals (spawners) has continued in both populations since the COSEWIC assessment of May 2003, falling to 1,485 and 3 (or fewer) spawners in Cultus and Sakinaw, respectively, in 2003 (Figures 1 and 2). Thus, there is no basis for recommending a change in designation, but there are reasons to be optimistic about recovery. Pre-spawn mortality in Cultus sockeye, considered by COSEWIC to be one of the principal threats, was less severe during the past two years; as a result, the number of spawners in 2002 and 2003 has increased relative to the brood (parental) years in 1998 and 1999 when pre-spawn mortality was much higher. For Sakinaw sockeye, two years of intensive supplementation with hatchery-reared fry should significantly increase adult returns in 2004 and 2005. However, it must be emphasized that little or no supplementation has occurred in subsequent years when few (2002) and no (2003) broodstock were available; thus, prospects for survival and recovery depend almost entirely on the number of spawners achieved in 2004 and 2005.

Minimum Viable Population: Pending legal listing under SARA, recovery teams for Cultus and Sakinaw sockeye have been appointed to prepare formal recovery strategies that specify, among other things, objectives for recovery and criteria for viability. A viable population is an independent population that has a negligible chance (<5%) of extinction within 100 years (McElhany et al. 2000). At the time of writing, both the Cultus and Sakinaw sockeye recovery teams have defined the minimum population size for viability as 1,000 spawners computed as the 4-year average over one generation (4 years) with no fewer than 500 spawners in any year. Over 3,800 spawners would be required in 2004 to return the Sakinaw population to viability by this criterion, because of very low numbers in the preceding three years (estimated total was only 169). The Sakinaw Sockeye Recovery Team recognizes that this is not biologically feasible and has adopted an interim (until 2008) objective of using intensive fish culture to increase the number of spawners to 500 annually, implying that the Sakinaw population will remain at imminent threat in the foreseeable future.

Forecast model and performance: A new conditional Bayesian forecast model is recommended that considers both the smolt abundance observed in 2002 and the age-3 ("jack") returns from the same brood year observed in 2003. The prior distributions of age-4 adult returns used in the Bayesian model were generated by multiplying estimated smolt abundance in 2002 by "smolt-to-adult survival", considered as a log-normally distributed random variable whose parameters were estimated from recent data (brood years 1990-1998) for Chilko sockeye (mean -2.77 = 6% survival, SD 0.584). An alternate prior distribution was also computed from historical data for Cultus sockeye (mean -2.97 = 5% survival, SD 0. 854). No survival data are available for Sakinaw sockeye. The Bayesian model is conditional on the assumption that the age-3 proportion (by brood year) is known exactly. In reality, the age-3 proportion is uncertain and was estimated as the median age-3 index (0.005) calculated from recent returns to Cultus Lake (brood years 1990-1998). By choosing the median age-3 index, the median posterior probabilities for adult returns should be unbiased, although the uncertainty (distribution tails) will be under-estimated. Sensitivity of forecasts to errors in the age-3 index assumption was evaluated for both Cultus and Sakinaw populations. An alternative, higher estimate of the age-3 index for Sakinaw sockeye (0.025) was also estimated from age composition data available from a single brood year (1971). The conditional Bayesian forecasts performed better in 3 out of 4 performance measures than the corresponding (prior distribution) forecasts based on smolt abundance alone in retrospective analyses using historical data for Cultus sockeye. As expected, the median posterior estimates were unbiased (over-forecasting in 50% of retrospective comparisons) compared with the prior distribution (which over-forecast in 67% of comparisons).

Forecast for 2004: The recommended median forecast for total returns (before any fishing or pre-spawn mortality) of Cultus sockeye in 2004 is 281 individuals based on the Bayesian model using Chilko smolt survival parameters. The odds are 9 in 10 (90% probability) that total returns will exceed 150, and 3 in 4 (75% probability) that the return will exceed 203 individuals (Table 1). The recommended median forecast for total returns of Sakinaw sockeye in 2004 is 390 individuals with odds of 9 in 10 (90% probability) that returns will exceed 215, and 3 in 4 (75% probability) that returns will exceed 286 individuals. The Sakinaw forecast is considered highly uncertain, and potentially very optimistic, because the underlying assumptions of smolt-to-adult survival and age-3 proportions are based on speculation that Sakinaw sockeye smolts will survive and mature precociously ("jack") like Cultus sockeye. It seems plausible that Sakinaw sockeye smolts are experiencing unusually poor marine survival which could account for the current status of the population. The Sakinaw forecast procedure could not be evaluated in retrospective analyses because no historical data are available.

Potential impact of fishing and pre-spawn mortality: Probabilities for achieving the minimum viable population size threshold of 500 spawners in 2004 were also computed under alternative assumptions about exploitation rate and pre-spawn mortality, and for Sakinaw sockeye, for opening dates in a plausible but hypothetical fishery. The forecasts imply that with no fishing mortality and no pre-spawn mortality, the odds of achieving 500 viable spawners in 2004 are only about 1 in 10 (10.5%) for Cultus Lake and 2 in 7 (28.7%) for Sakinaw. Any fishing mortality or pre-spawn mortality will decrease these odds as shown in Table 2. For example, in the most plausible scenario that pre-spawn mortality would be 30% for Cultus and 10% for Sakinaw, an exploitation rate of 20%

would decrease the odds of achieving 500 spawners from 1 in 50 (1.9%) to 1 in 250 (0.4%) for Cultus and from 1 in 5 (21%) to 9 in 100 (9%) for Sakinaw. Reducing the exploitation rate further to 10% would improve these odds to 1 in 100 (1%) for Cultus and 3 in 20 (14.5%) for Sakinaw. It is worth noting that an incremental decrease in exploitation rate improves the odds disproportionately; that is, the probability of achieving 500 spawners increases faster as exploitation rate decreases (Figure 3).

In conclusion, both populations are likely to remain at imminent threat of extinction even with no incidental fishing mortality in 2004. However, fishing restrictions would significantly improve the status of both populations and hasten recovery. It bears repeating that prospects for survival and recovery of the Sakinaw population depend almost entirely on the numbers of spawners achieved in 2004 and 2005 because very few returns in 2006 and 2007 are expected given the extremely low numbers of spawners observed in 2002 (44 spawners) and 2003 (3 of fewer spawners).

References:

McElhany, P, M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of Evolutionarily Significant Units. U.S. Dept. Commer., NOAA Tec. Memo. NMFS-NWFSC-42, 156 p.

Table A3. Recommended forecasts for 2004 based on Bayesian model using smolt production and age-3 returns in 2003.

	Probability (odds) of exceeding specified total returns					
	95%	**90%**	**75%**	**50%**	**25%**	**10%**
Population	(19 in 20)	(9 in 10)	(3 in 4)	(1 in 2)	(1 in 4)	(1 in 10)
Cultus	124	150	203	281	386	507
Sakinaw	180	215	286	390	525	678

Table A4. Probability of achieving 500 spawners in 2004 under hypothetical scenarios for pre-spawn mortality and fishery exploitation.

Scenario		Probability of …		
Pre-spawn mortality (%)	Exploitation rate (%)	surviving to spawn	achieving 500 spawners	
			Cultus	Sakinaw
0	0	1.000	0.105	0.287
0	5	0.950	0.086	0.248
0	10	0.900	0.068	0.210
0	15	0.850	0.052	0.173
0	20	0.800	0.039	0.139
0	25	0.750	0.028	0.108
0	30	0.700	0.019	0.079
10	0	0.900	0.068	0.210
10	5	0.855	0.054	0.177
10	10	0.810	0.041	0.145
10	15	0.765	0.031	0.117
10	20	0.720	0.022	0.090
10	25	0.675	0.015	0.067
10	30	0.630	0.010	0.048
20	0	0.800	0.039	0.139
20	5	0.760	0.030	0.114
20	10	0.720	0.022	0.090
20	15	0.680	0.016	0.069
20	20	0.640	0.011	0.052
20	25	0.600	0.007	0.037
20	30	0.560	0.004	0.025
30	0	0.700	0.019	0.079
30	5	0.665	0.014	0.063
30	10	0.630	0.010	0.048
30	15	0.595	0.007	0.035
30	20	0.560	0.004	0.025
30	25	0.525	0.003	0.017
30	30	0.490	0.002	0.010
40	0	0.600	0.007	0.037
40	5	0.570	0.005	0.027
40	10	0.540	0.003	0.020
40	15	0.510	0.002	0.014
40	20	0.480	0.001	0.009
40	25	0.450	0.001	0.006
40	30	0.420	0.000	0.003
50	0	0.500	0.002	0.012
50	5	0.475	0.001	0.008
50	10	0.450	0.001	0.006
50	15	0.425	0.000	0.004
50	20	0.400	0.000	0.002
50	25	0.375	0.000	0.001
50	30	0.350	0.000	0.001

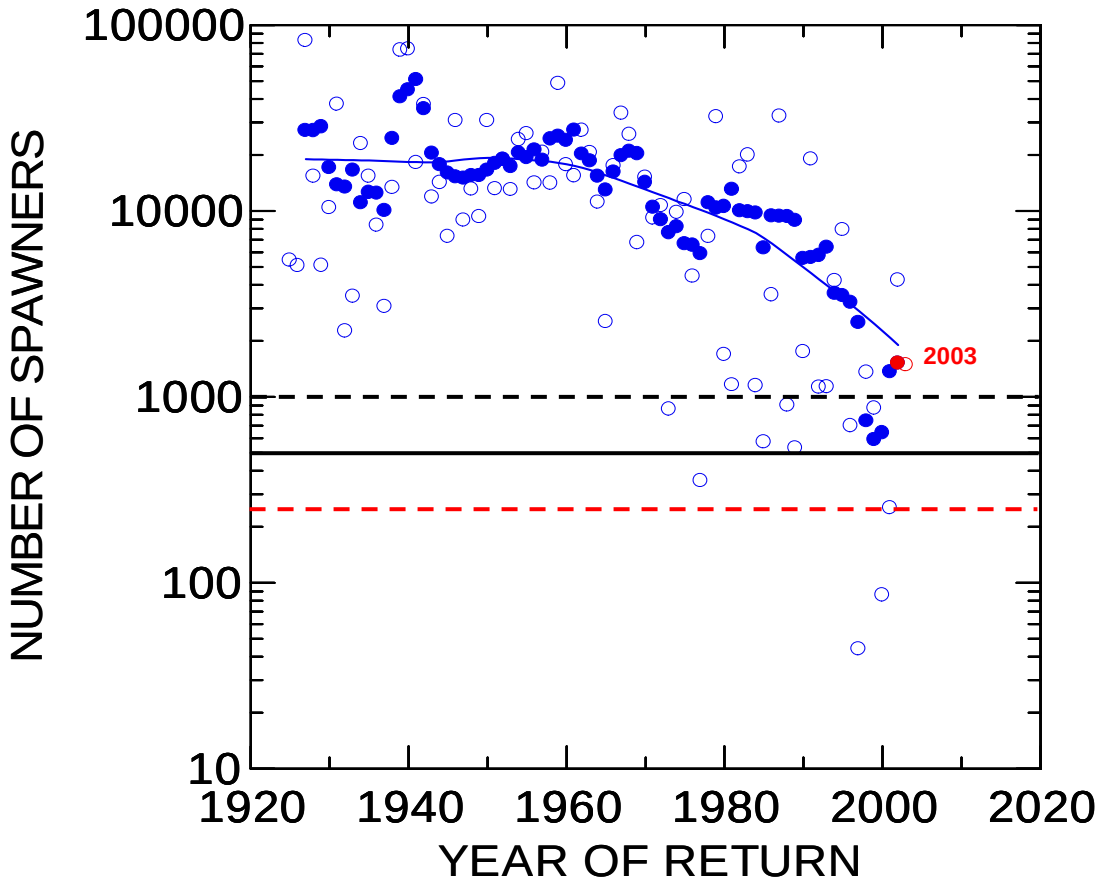


Figure A1. Trend in the number of mature individuals in the CULTUS SOCKEYE salmon population. Open circles are annual estimates of spawning escapement; filled circles are the corresponding estimates averaged over one-generation (4 yr); line is fitted to smoothed data by LOWESS. Red symbols are updated since COSEWIC assessment of status. Horizontal lines correspond to thresholds of 250 (COSEWIC *Endangered* status under Criterion D, red dash), 500 (minimum viable population threshold for 2004), and 1000 (minimum viable population threshold for 4-yr average; also COSEWIC *Threatened* status under Criterion D, black dash).

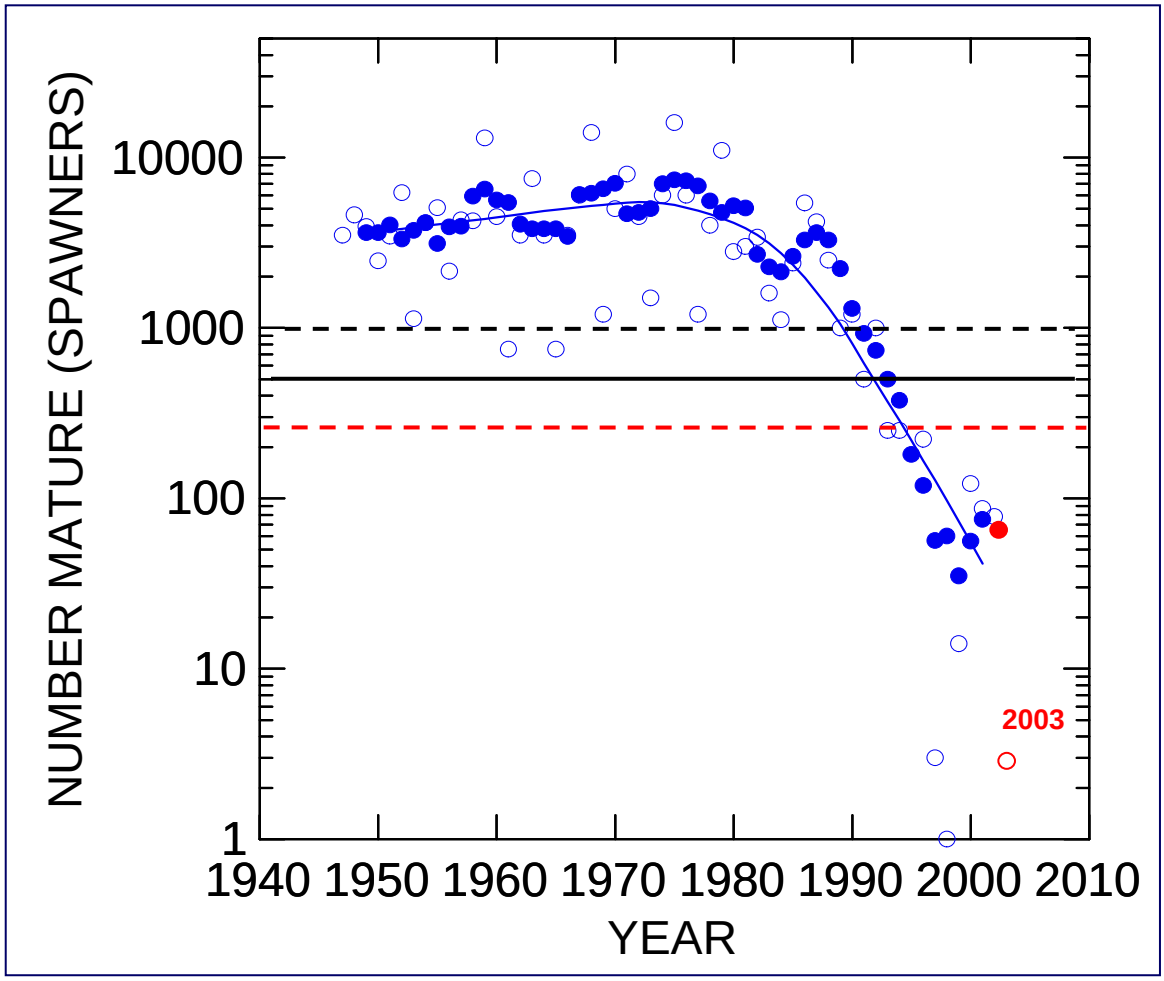


Figure A2. Trend in the number of mature individuals in the SAKINAW SOCKEYE salmon population. Open circles are annual estimates of spawning escapement; filled circles are the corresponding estimates averaged over one-generation (4 yr); line is fitted to smoothed data by LOWESS. Red symbols are updated since COSEWIC assessment of status. Horizontal lines correspond to thresholds of 250 (COSEWIC *Endangered* status under Criterion D, red dash), 500 (Recovery Team's interim objective for 2004), and 1000 (minimum viable population threshold for 4-yr average; also COSEWIC *Threatened* status under Criterion D, black dash).

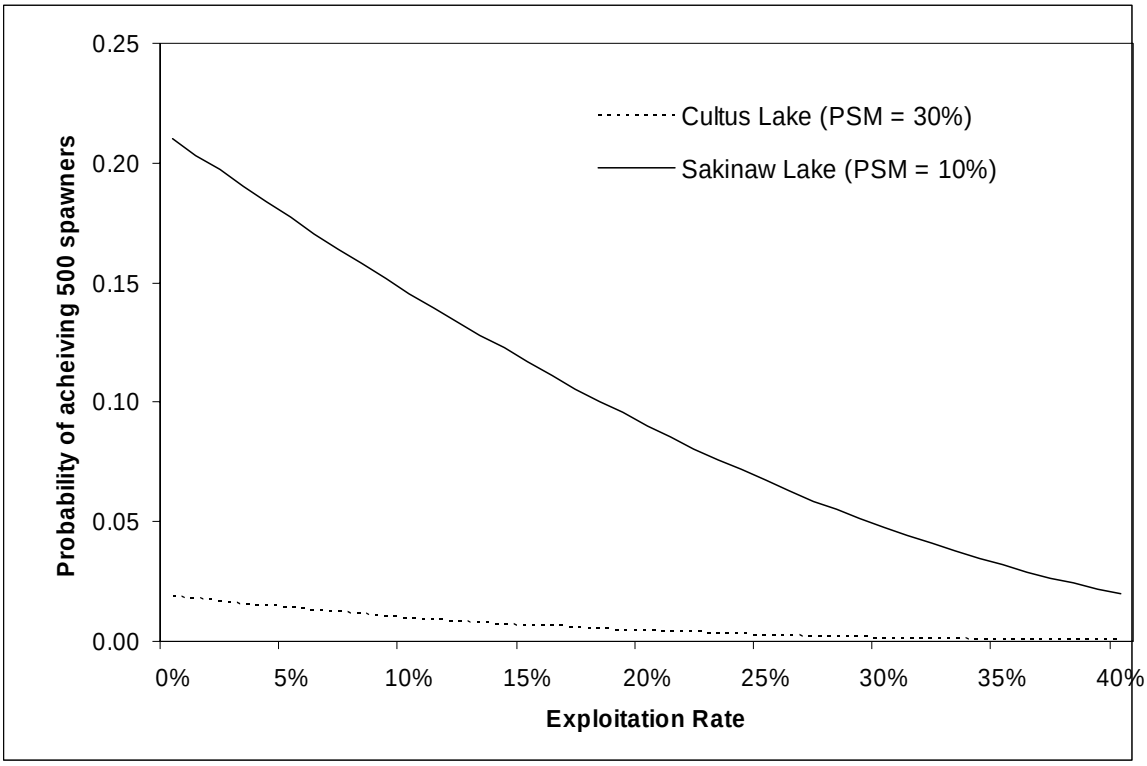


Figure A3. Impact of incidental fishing mortality (exploitation rate) on the probability of achieving 500 spawners in 2004 under the most plausible scenarios for pre-spawn mortality (PSM, 30% for Cultus and 10% for Sakinaw sockeye).

APPENDIX 2: PSARC Salmon Subcommittee Meeting Agenda, March 16-18, 2004

PSARC Salmon Subcommittee Meeting
Re: 2004 Return Forecasts
March 16-17, 2004
Seminar Room, Pacific Biological Station
Nanaimo, B.C.

Tuesday March 16, 9:00

9:00 – 9:30	Introduction and procedures
9:30 – 12:00	Sakinaw and Cultus sockeye
12:00 – 1:00	Lunch
1:00 – 4:00	Sakinaw and Cultus sockeye

Wednesday March 17, 8:30

8:30 - 12:00	Sakinaw and Cultus sockeye - if required
12:00 - 1:00	Lunch
1:00 – 4:00	Strait of Georgia coho

APPENDIX 3: List of Attendees

Subcommittee Chair: Greg Thomas

PSARC Chair: Al Cass

NAME	Tuesday (16)	Wednesday (17)	AFFILIATION
EXTERNAL PARTICIPANTS			
Blackbourn, Dave	X	X	Consultant
Carpenter, Fred			
Gable, Jim	X		Pacific Salmon Commission
Galesloot, Mike	X		Shuswap First Nations
Gazey, Bill	X	X	W.J. Gazey Research
Lapointe, Mike	X		Pacific Salmon Commission
Marshall, Doug	X	X	VP, GTA (Area H) Association
Maynard, Jeremy		X	Sports Fishing Advisory Board
Morley, Rob	X		Canadian Fishing Company
Pestes, Lynsey	X		Student, SFU
Peterman, Randall	X		Simon Fraser University
Riddell, Brian	X		PFRCC
Rombough, Les	X	X	Fishing Vessel Owners Assoc.
Wilson, Ken	X	X	Fraser River Aboriginal Fisheries
DFO MEMBERS			
* Subcommittee Members			
Baillie, Steve	X		
Bradford, Mike*	X		
Brown, Gayle*	X		
Cass, Al*	X	X	
Chamberlain, Mike	X	X	DFO – BCI
Cook, Roberta*	X	X	
Curry, Gordon	X	X	
Dobson, Diana*		X	
Folkes, Michael	X		
Godbout, Lyse	X	X	
Grout, Jeff*	X	X	

NAME	Tuesday (16)	Wednesday (17)	AFFILIATION
Holtby, Blair*	X		
Ionson, Bert*	X	X	
Luedke, Wilf*	X	X	
McNicol, Rick*	X	X	
Meerburg, Dave*	X	X	
Parken, Chuck*	X		
Simpson, Kent*	X	X	
Tanasichuk, Ron	X	X	
Tompkins, Arlene*	x	X	
Van Will, Pieter*	X	X	
Wood, Chris*	X	X	
Yockey, Cindy*	X	X	

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. Anonymous reviewers are not listed.

Gable, Jim	Pacific Salmon Commission
Lapointe, Mike	Pacific Salmon Commission