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# Proceedings of the PSARC Salmon Subcommittee Meeting July 7, 2003.

# Compte rendu de la réunion du sous-comité du saumon du CEESP, 7 juillet 2003.

**July 7, 2003**
**Nanaimo, B.C.**

**R. Tanasichuk**
**Salmon Subcommittee Chair**

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

**August 2003**

Canada

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# PACIFIC SCIENTIFIC ADVICE REVIEW COMMITTEE (PSARC)
# SALMON SUBCOMMITTEE MEETING

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**SUMMARY**

The Pacific Scientific Advice Review Committee (PSARC) Salmon Subcommittee met July 7, 2003 at the Pacific Biological Station, Nanaimo, B.C. to review one Working Paper.

**Working Paper S2003-14: Methods for assessing harvest rules for Fraser River sockeye salmon**

This Working Paper presented an analytical framework for developing harvest rules for Fraser River sockeye which will consider biological and socio-economic objectives. Data for Chilko and Quesnel lakes sockeye were used. The framework uses Bayesian stock-recruitment models to solve for the optimal harvest rule given a value function that captures stakeholder objectives. The Authors presented examples of sensitivity analyses to show that the analytical framework can be used to assess the effects of alternative population dynamics models or preference choices in the value function.

The Subcommittee complimented the Authors on their work and accepted the paper with revisions. The Subcommittee concluded that the Working Paper does provide the basis for developing an analytical tool to allow the Fraser River Sockeye Spawning Initiative to proceed and develop optimal harvest rules. Revisions to the paper include assessing the effect of different forms of value functions (i.e. additive, multiplicative, non-linear) and expressing performance using the “maxi-min” objective.

**SOMMAIRE**

Le sous-comité du saumon du Comité d'examen des évaluations scientifiques du Pacifique (CEESP) s’est réuni le 7 juillet 2003 à la Station biologique du Pacifique, située à Nanaimo (C.-B.), pour examiner un document de travail.

**Document de travail S2003-14 : Méthodes d’évaluation des règles de pêche au saumon rouge du fleuve Fraser**

Ce document de travail présentait un cadre analytique pour l’établissement de règles de pêche au saumon rouge du fleuve Fraser compatibles avec des objectifs biologiques et socio-économiques. Des données sur le saumon rouge des lacs Chilko et Quesnel ont été utilisées. Le cadre analytique utilise des modèles stock-recrutement bayesiens afin d’établir la règle de pêche optimale, selon une fonction valeur qui tient compte des objectifs des parties intéressées. Les auteurs ont présenté des exemples d’analyses de sensibilité afin de montrer que le cadre analytique peut être utilisé pour évaluer les effets de divers modèles de dynamique des populations ou choix de préférence sur la fonction valeur.

Le sous-comité a félicité les auteurs pour leur travail et a accepté le document sous réserve de révisions. Il a conclu que le document de travail peut servir de fondement à l'élaboration d'un outil d'analyse qui permettrait de réaliser le projet de reproduction du saumon rouge du fleuve Fraser et d'établir des règles de pêche optimales. Les révisions devront comprendre l'évaluation des effets de différentes formes de fonction valeur (c.-à-d. additive, multiplicative ou non linéaire) et l'expression de la performance à l'aide de l'objectif « maxi-min ».

**INTRODUCTION**

The PSARC Salmon Subcommittee met July 7, 2003, at Pacific Biological Station in Nanaimo, British Columbia. External participants from the Ministry of Agriculture, Food and Fisheries, Pacific Fisheries Resource Conservation Council, Shuswap First Nation, Chemainus First Nation, Pacific Salmon Harvester's Society, Fishing Vessel Owners Committee, Fraser River Aboriginal Fisheries Secretariat, and the Sport Fishing Advisory Board attended the meeting. A consultant also attended the meeting. The Subcommittee Chair, R. Tanasichuk, 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 one Working Paper. A Summary of the Working Paper is in Appendix 1. The meeting agenda appears as Appendix 2. A list of meeting participants, observers and reviewers is included as Appendix 3.

## DETAILED COMMENTS FROM THE REVIEW

### S2003-14: Methods for assessing harvest rules for Fraser River sockeye salmon

A. Cass, M. Folkes, and G. Pestal **Accepted subject to revisions**

Subcommittee Discussion

*Data and methods*

This Working Paper presents the details of a model developed for assessing harvest rules for Fraser River sockeye in the context of conservation needs and other management objectives. Chilko and Quesnel sockeye were used as examples and the results of preliminary sensitivity analyses were presented. A flow diagram of the simulation is presented in Fig. 1. The model simulates the population dynamics of Fraser River sockeye stocks using three alternative stock-recruitment model formulations which make different assumptions about cycle interactions. A systematic subset of 250 sets of stock-recruitment parameters were sampled from the Bayes joint posterior distribution determined by the form of the stock-recruit relationship being assessed. The optimal harvest rule is a feedback policy that defines the optimal harvest rate as a function of run size. The harvest rule is estimated for each stock-recruit parameter set by maximizing the value function. The value function is additive and multi-attribute. It allows the trade-off between various economic and conservation objectives to be explored in a gaming environment. The example simulations in the Working Paper were based on 40-year forward simulations using the most recent 4 years of stock-recruit data to seed each trial in the simulation. Parameters for the harvest rule were estimated using specific curve shapes. The harvest rule that a manager could apply given stock-recruitment parameter uncertainty was computed from the mean of the 250 stock-recruitment parameters. The mean harvest rule is then applied in a Monte Carlo simulation to generate 40 years of simulated catch and escapement from which specific performance measures are calculated (Table 1). With respect to mixed-stock fisheries, the Authors' intent was not to perform a rigorous assessment of the effects of mixed-stock fisheries on individual stock components but to show that the general form of the model would allow managers and stakeholders to assess mixed-stock fishery effects.

The data used in the analyses were estimates of annual escapement and total returns from that escapement for brood years 1949-95. Chilko Lake sockeye data are considered to be the best available, and data for Quesnel Lake high abundance cycle years are also of high quality. Low abundance cycle year data for Quesnel Lake sockeye are less reliable.

The Ricker stock-recruitment model was used to model Chilko sockeye because the abundance for this stock does not cycle. In contrast, the abundance of Quesnel sockeye cycles with a persistent 4-year pattern. Therefore, in addition to the Ricker form of the model being fit to all years of data, it was also fit to two subsets (two adjacent years low years in the 4-year cycle and the two adjacent high years in the cycle). This second fit was referred to as the Ricker cycle-aggregate (CA) models. The Larkin model extension of the Ricker model considers cross-cycle interactions by including lag terms that act as surrogates for density impacts of escapements in brood years *t-1*, *t-2* and *t-3* years on recruitment survival in year *t*. The Larkin model was also applied to Quesnel data and was the third fit used in the analysis.

The Authors presented examples of sensitivity analyses to show that the analytical framework can be used to assess the effects of alternate hypotheses or differing preferences. They stressed that this Working Paper describes an objective-based, systems approach to harvest policy and decision-making and does not advocate a particular harvest policy.

The Subcommittee complimented the Authors on the effort expended to produce this Paper. They had some concerns about the data. Data for Chilko Lake may be biased because 1989, a year of fertilization, was included and there may be a carry-over of fertilization effects; the Authors will review the data. Second, the Subcommittee noted that data for Chilko and Quesnel are some of the best available and there was concern about how the model would deal with systems for which the data are poorer. The Authors responded that there would be increased uncertainty in the model results for these systems. The model could assist with assessing sensitivity to these assumptions by showing the effects in the performance measures. Finally, the Subcommittee felt that effort should be expended to collect information sufficient to apply the method; in other words, for many systems, the current level of data collection would be inadequate to determine if the harvest rules would be effective.

The Subcommittee accepted that the methodology was mathematically sound because neither Reviewer, both with strong quantitative skills, commented on it. The Subcommittee discussed a procedure to ground truth the model by using simulated stock-recruitment data generated from each alternative stock-recruitment model. Stock-recruitment parameters could then be estimated using the fake data. Model performance could be evaluated given the knowledge about the true (i.e. simulated) underlying population dynamics. Several scenarios could be devised to assess how robust the harvest rule and methods are to different types of uncertainties (data quality, recruitment function, depensatory mortality). The Subcommittee was concerned about the choice of stock-recruit relationship used to describe population dynamics. There may be a false expectation of future production from the model if the simple Ricker approach to describe stock dynamics is incorrect because ecological relationships have a meaningful influence on production. The Authors responded that the framework is cast in such a way that one could consider the utility of adaptive management experiments designed to test assumptions in the population dynamics models. Uncertainty in the parameter estimates and the underlying recruitment function will likely continue, and perhaps the focus should be on how the harvest rule may change depending on which recruitment function is used. The Subcommittee echoed the second Reviewer’s concern (see below) about the value function and added that future direction could include more consideration of mixed stock fishery aspects of the value function. The Authors indicated that input from stakeholders is required and the value function will be refined as the project moves towards implementation.

The first Reviewer felt that the complex work was presented in a concise manner. This Reviewer was concerned that different benchmarks were being used for the dominant and subdominant aggregates in the Ricker CA models. The Authors responded that the benchmarks were calculated the same way and that the differences reflect stock dynamics. This Reviewer was also concerned that harvest rules for the Ricker CA-low model were higher than for the Ricker CA-high model. The Authors responded that this was a consequence of scale.

The second Reviewer complimented the Authors on the work. This Reviewer felt that there were problems in writing style and clarity. It was essential that readers should be provided a “roadmap” of key ideas given the complicated framework of the analysis. It was suggested that a "dynamic hierarchical information system" on the Internet be developed which would allow readers with different levels of expertise to understand the model details and even access to a demonstration model. This Reviewer’s technical comments focused on deficiencies in the scope of the model and the value function. The model is formulated assuming that temporal survival patterns are not correlated among stocks. Although this may be true for the test stocks (Chilko and Quesnel), it is not true for Fraser sockeye in general, with important implications for the optimal harvest rule. Next, it is critical to report separately the different indicators that make up the value function to reflect the important measures so that the trade-offs implied by each increment of the harvest rule can be seen. Also, a simple value function may be misleading because trade-offs among components are masked and there are conditional weightings such that the components of a value function cannot be weighted independently. The Reviewer was especially concerned about the form of the value function. Simple constant weights will not reflect the diminishing rate of returns frequently observed as some indicator variables increase. Also, the value function could be non-linear, include a multiplicative interaction term and include asymmetric loss functions. The Reviewer suggested "decision choice modeling experiments" to solicit stakeholder preferences and quantify the outcome using a multi-variate statistical model. The Authors felt that this was beyond the scope of the Working Paper. This Reviewer suggested that the Authors express the outcomes in the context of a "maxi-min" objective rather that weighting each outcome by its probability of occurrence. Using the "maxi-min" objective would entail examining the outcomes estimated for each state of nature, choosing the worst-case outcome and then choosing a harvest rule which has the lowest probability of resulting in that outcome. The Authors will re-express their results using this format in the revision. This Reviewer felt that depensatory mortality effects at low stock sizes and implementation error must be considered in the model.

Subcommittee Conclusions

The Working Paper was accepted with revisions. The Subcommittee concluded that the Working Paper does provide the basis for developing an analytical tool to allow the Fraser River Sockeye Spawning Initiative to develop optimal harvest rules. Subsequent work should focus on aggregates and their components. The Subcommittee noted that soliciting preferences for the value function will be difficult and requires careful planning. Also, it is not clear how the method will manage the designatable units in cases with sparse stock-recruit data. Finally, the framework should be able to deal with changing climate and consider aspects of the Wild Salmon Policy and SARA. Revisions should include the Reviewer's suggestions dealing with alternative forms of the value function. The Subcommittee also concluded that depensatory mortality effects, implementation error and maxi-min objectives be considered in the revised Working Paper.

Subcommittee Recommendations

The Subcommittee recommended that the framework presented be used as a basis for discussion for the Fraser River Sockeye Spawning Initiative workshop.

The Subcommittee recognized that the analysis presented in the Working Paper and the risk assessment required for implementation of the Wild Salmon Policy has similarities. The Subcommittee recommended that the separate processes dealing with Fraser River sockeye assessment and management need to be linked and include better articulation of management objectives.

## APPENDIX 1: Working Paper Summaries

### S2003-14: Methods for assessing harvest rules for Fraser River sockeye salmon

A. Cass, M. Folkes, and G. Pestal

This paper is part of a long-term initiative to review and revise the management of Fraser River sockeye salmon. The Fraser River sockeye spawning initiative began in early 2002, and has since evolved through a series of workshops and feedback from stakeholders. In this application of formal policy analysis, we develop a quantitative modeling tool for assessing harvest rules for Fraser River sockeye salmon with respect to conservation needs and other management objectives. Harvest rules generally specify target exploitation rates over a range of run sizes, but can also be expressed as target escapement levels. The modeling framework is intended to help assess the following questions:

- For each stock and stock aggregate, what are the optimal harvest rules curves given different management objectives and assumptions about population dynamics?
- How does performance compare between mixed-stock and selective fisheries?
- How do assumptions about potential cycle line interactions affect the optimal harvest rule?
- What are the implications of assumed conservation limits
- What is the value of adaptive learning about stock characteristics and limits of capacity?
- How sensitive is the model to biases in SR parameter estimation?
- What is the expected effect of different future patterns of productivity and survival?
- How can annual fluctuations in catch be reduced?

The model allows stakeholders to assess these questions consistently. Through a series of different simulation runs, optimal exploitation rates at different abundance levels can be explored, given assumptions about stock-dynamics and preferences for different objectives.

This paper describes the details of the modeling methodology, illustrates the range of possible analyses for two examples (Chilko, Quesnel), and summarizes the results of preliminary sensitivity analyses. It includes neither comprehensive sensitivity analyses nor recommended policy options. These will be the next steps once the methodology has been reviewed. As part of the future analyses, stakeholders will be asked to provide feedback on all the components of the framework through workshops and consultation. Specific questions include:

- Which policies and objectives would you like explored?
- Which performance measures are most important to you?
- Does the model have the features or characteristics that would allow the technical group to model the Fraser system as you believe it to be?

The analysis follows four distinct steps:

- *Capture management objectives* for Fraser River sockeye in a quantitative form useful for the analysis. This includes defining specific attributes, such as the probability of the annual spawning escapement falling below a low threshold or benchmark, and weights that specify conservation and socio-economic preferences in a multi-attribute value function.
- *Capture the population dynamics* of Fraser River sockeye in a quantitative form useful for the analysis. This step includes estimating parameters using established Bayesian methods to capture uncertainty and testing the effect of assuming different stock-recruitment models.
- *Estimate the optimal harvest feedback policy or rule* using simulation. Using the input information from steps 1 and 2, solve for the optimal harvest rule. More specifically, the model uses a systematic subsample from the Bayes posterior distribution of stock-recruitment parameter estimates to capture uncertainty in the population dynamics, calculates the optimal harvest rules for each, and averages the results.
- *Evaluate the performance* using simulation. The average harvest rule determined in step 3 is the mean optimal harvest rule that a manager could apply given uncertainty in stock dynamics and a particular value function. The mean optimal harvest rule is applied in a second set of Monte Carlo simulations across the uncertain parameter estimates, and summary performance measures are calculated.

**The value function**

Choices regarding harvest policies depend on a wide range of conservation and socio-economic objectives. The relative importance placed on the different objectives is critical to determining the appropriate management actions that will ultimately determine future escapements and catches. For example, a conservation objective could be a low spawning level below which there is a high chance the population will collapse or result in low sustained future economic benefit. An economic objective could be the catch level below which an industry can no longer remain viable.

The objectives are introduced into the model as attributes in an additive value function for optimization and can include benchmarks or biological reference points such as desirable levels of run size, spawning escapement or catch. Conservation and economic objectives are included in the value function with appropriate penalty weights that depend on the probability, for example, that undesirable outcomes are to be avoided.

**Stock-recruitment parameter estimation**

Both model and parameter uncertainty are considered. We use three stock-recruitment models: 1) The Ricker model, 2) The Larkin model that models year-class interaction for highly cyclic stocks, and 3) a Ricker cycle aggregate model that fits separate Ricker models separately to high years in the four-year cycle (dominant plus subdominant years) and low years (off cycle years). A Bayes posterior inference function for parameter estimation is used to capture parameter uncertainty. Parameter estimation was based on non-linear Bayesian estimation methods. The method uses the posterior sampling methods obtained by the Metropolis version of the Markov chain Monte Carlo (MCMC) algorithm.

### The simulation / optimization model

The simulation model is age-structured and includes the main age classes present in the fishery. The value function, along with the parameters describing the population dynamics, is used in the simulation model to estimate the optimal harvest rule. Rather than requiring analysts and decision makers to compare the performance in many different combinations of simulated scenarios and harvest rules, the optimization procedure automatically searches for the specific harvest rule that performs best (i.e. maximizes the value function). Different weightings in the value function can be used to investigate how optimal exploitation rates and performance are affected by different management priorities.

### Performance measures

The performance of average harvest rules can not be directly assessed from the simulation trials used in the optimization step, where a separate optimal harvest rule is determined for each manifestation of uncertain stock-recruitment parameters. It is more realistic to apply one average harvest rule over the complete set of parameters, such as a manager might use to guide decision-making. In the absence of performance measures derived from stakeholder input, five performance measures were identified that show key outcomes of the model in terms of conservation and economic preferences. These are: 1) the probability the escapement in any given year falls below some low threshold, 2) mean long-term catch, 3) the probability that the annual catch falls below a low threshold level, 4) the probability that the annual catch falls below some higher level, and 5) the probability that the annual catch is zero.

### Sensitivity analysis

Sensitivity analyses investigate the effect of applying harvest rules developed under one specific set of assumptions about the underlying population dynamics, choice of value function and harvest rule shape. In this paper, only a few of the possible sensitivity analyses are summarized. The intent is to illustrate that the analytical framework can be used to assess the effects of alternate hypotheses or differing preferences. A much more exhaustive sensitivity analysis will be required before the analytical results can be used to inform policy development.

## APPENDIX 2: PSARC Salmon Subcommittee Meeting Agenda July 7, 2003

**PSARC Salmon Subcommittee Meeting**
**Re: Fraser River Sockeye**
**July 7, 2003**
**Seminar Room, PBS, Nanaimo**

Monday July 7, 9:00

9:00 – 9:30 Introduction and procedures
9:30 – 12:00 Methods for assessing harvest rules for Fraser River sockeye salmon
12:00-13:00 Lunch
13:00 – 14:30 Methods for assessing harvest rules for Fraser River sockeye salmon cont'd
14:30 – 16:00 Subcommittee Discussion and Recommendations

## APPENDIX 3: List of Attendees

Subcommittee Chair: Ron Tanasichuk
PSARC Chair: Al Cass

| **DFO Participants** | |
|---|---|
| * denotes Subcommittee Members | |
| Beamish, Dick | |
| Brown, Gayle* | |
| Cass, Al* | |
| Cook, Roberta* | |
| Folkes, Michael | |
| Fraser, Sandy | |
| Goruk, Ron | |
| Grout, Jeff | |
| Holtby, Blair* | |
| Hyatt, Kim* | |
| Ionson, Bert* | |
| Irvine, Jim* | |
| Jantz, Les* | |
| McNicol, Rick* | |
| Parken, Chuck* | |
| Paterson, Cory | |
| Saunders, Mark | |
| Simpson, Kent* | |
| Tanasichuk, Ron* | |
| Tompkins, Arlene* | |
| Yockey, Cindy* | |
| | |
| **External Participants:** | **Affiliation** |
| Argue, Sandy | Ministry of Agriculture, Food and Fisheries |
| Atkinson, Mary-Sue | Pacific Fisheries Resource Conservation Council (PFRCC) |
| Bird, Tom | Sport Fishing Advisory Board (SFAB) |
| Galesloot, Mike | Shuswap First Nation |
| Johnnie, Warren | Chemainus First Nation |
| Kristianson, Gerry | SFAB |
| Otway, Bill | SFAB |
| Pestal, Gottfried | Consultant |
| Riddell, Brian | PFRCC |
| Rombough, Les | Pacific Salmon Harvesters Society |
| Tautz, Art* | BC Ministry of Fisheries |
| Webb, Lloyd | Fishing Vessel Owners Committee |

| | |
|---|---|
| Wilson, Ken | Fraser River Aboriginal Fisheries Secretariat |
| Woodey, Jim | Consultant |

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.

| | |
|---|---|
| Fu, C. | Fisheries and Oceans |
| Peterman, R. | Simon Fraser University |

Tables and Figures

Table 1: Examples of management objectives, performance measures, benchmarks and components of the value function.

| Objective | Possible Performance Measure | Possible Benchmarks | Possible Value Function Components |
|---|---|---|---|
| • Ensure conservation of stock units<br>• Ensure long-term sustainability of populations<br>• Maintain existing levels of genetic and phenotypic diversity<br>• Maintain abundance at levels needed to maintain ecosystem processes | • Smallest escapement observed over next 40 years<br>• Average long-term escapement<br>• Variability in spawning escapement<br>• Average long-term returns<br>• Variability in returns | • Spawning escapement level which produces 10% of the maximum recruits on average | • Proportion of simulated years in which spawning escapement level falls below the benchmark. |
| • Provide sustainable fishing opportunity for all harvesters | • Smallest annual catch observed over next 40 years<br>• Long-term average total catch<br>• Variability in total catch<br>• Maximum decrease in catch from one year to the next<br>• Harvest reduction over status quo during first four years<br>• Measure of short-term economic viability (e.g. 4-year moving average of catch) | • Recent average of total catch<br>• 10% of Catch at MSY<br>• 50% of recent average | • Average catch<br>• Proportion of simulated years in which total catch falls below the benchmark.<br>• Proportion of years with 0 catch |

Figure 1: Flow diagram of the simulation model