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Proceedings of the Pacific regional peer review on the determination of Reference Points for Status Determination and Associated Allowable Exploitation Rates for Canadian Pacific Salmon Treaty (PST) Southern Coho Management Units

September 20-21, 2017
Nanaimo, British Columbia

Chairperson: Mary Thiess
Editor: Erika Anderson

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting of September 20-21, 2017 at the Vancouver Island Conference Centre in Nanaimo, B.C. A working paper titled “Determination of Reference Points for Status Determination and Associated Allowable Exploitation Rates for Canadian Southern Coho Salmon Management Units” was presented for peer review.

In-person and web-based participation included current and retired DFO Science, Salmon Enhancement Program, and Fisheries Management staff; and external participants: Pacific Salmon Commission Southern Panel and Coho Technical Committee members, First Nations, non-governmental organizations, and commercial and recreational fishing interests.

The working paper presented a simulation model as an approach for incorporating marine survival for determining status benchmarks and allowable fishery exploitation rates. A retrospective analysis was used to verify the model and explore alternate exploitation rates. Results indicated that Interior Fraser (IF) and Strait of Georgia (SoG) Coho Salmon populations have sustainable exploitation rates under the current low marine survival rates. Conversely, much lower exploitation rates are required to consistently meet conservation benchmarks based on reasonable conservation biology arguments (IFCRT 2006).

Meeting discussions covered data issues, the inclusion of unpublished, related research, use of marine survival indices as indicators of population status, density dependence dynamics among Coho populations, alternate model choices, performance measures, Pacific Salmon Treaty (PST) categories, implementation error and uncertainties. Major revisions included more descriptive information on the data and model, reanalysis with logistic hockey stick models at a conservation unit (CU) level (where possible), management unit (MU) level and the addition of a depensation point at low spawner abundance, further discussion on choices of performance measure, documentation of estimated wild-to-hatchery marine survival correlations, and additional text documenting uncertainties, conclusions, and recommendations.

The working paper was accepted with major revisions, pending review by an editorial board. The editorial board meeting took place by Webex on November 6, 2017 at the Pacific Biological Station, Nanaimo, B.C. and a summary of those discussions is also provided here.

The Research Document and Science Advisory Report will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website as they become available.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held September 20-21, 2017, at the Vancouver Island Conference Centre in Nanaimo to evaluate a framework for assessing potential benchmarks of population status and associated allowable exploitation rates for Strait of Georgia and Fraser River Coho Salmon management units.

The Terms of Reference (TOR; Appendix A) for the RPR were developed in response to a request for advice from DFO Fisheries Management. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from Pacific Salmon Commission Coho Technical Committee and Southern Panel, First Nations, environmental non-governmental organizations, and commercial and recreational fishing interests.

The following working paper (WP) was prepared and made available to meeting participants prior to the meeting (Abstract provided in Appendix B):

Korman, J., Sawada, J. Reference Points for Population Status and Associated Allowable Exploitation Rates for Canadian Southern Coho Management Units. CSAP Working Paper 2014SAL03.

The meeting Chair, Mary Thiess, welcomed participants, reviewed the role of CSAS in the provision of peer-reviewed advice, and gave a general overview of the CSAS process. The Chair discussed the role of participants and the definition and process around achieving consensus decisions and advice. Everyone was invited to participate fully in the discussion and to contribute knowledge to the process, with the goal of delivering scientifically defensible conclusions and advice. It was confirmed with participants that all had received copies of the Terms of Reference, the background information, and supporting documents.

The Chair reviewed the Agenda (Appendix C) and Terms of Reference (Appendix A) for the meeting. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting provided an opportunity for participants to provide feedback on the proposed framework. The rapporteur for the meeting was Erika Anderson.

Members were reminded that everyone at the meeting had equal standing as participants and they were expected to contribute to the review process if they had information or questions relevant to the materials being discussed. In total, 44 people participated in the RPR (participants list included in Appendix D).

REVIEW

Working Paper:	Determination of Reference Points for Status Determination and Associated Allowable Exploitation Rates for Canadian PST Southern Coho Management Units. Korman, J. and Sawada, J. CSAP Working Paper 2014SAL03.
Rapporteur:	Erika Anderson
Presenters:	Josh Korman and Joel Sawada

PRESENTATION OF WORKING PAPER

The authors presented background information and terminology used within the working paper (WP): Pacific Salmon Treaty (PST, Annex IV, Chapter 5), management units (MUs) versus conservation units (CUs), and biological benchmarks versus reference points. They explained the limited escapement data available for Canadian populations of Coho salmon, the need to develop a method to determine reference points using marine survival rates rather than absolute measures of abundance and reviewed the objectives of the WP.

In general terms, this work is dependent on the assumption that stock productivity and escapement vary over time and is largely dependent on variation in marine survival rate. When marine survival rates are high, stocks will be more productive and can withstand greater harvest rates compared to when marine survival rates are lower. Further, stock productivity can vary among component populations within each MU, which under the Wild Salmon Policy, are termed Conservation Units (CUs). Harvest rates that maximize yield for some CUs in the MU may be too high for less productive CUs in the MU, subsequently leading to low escapements to the weaker CUs, to the point where the persistence of the weaker CU is threatened. Thus, reference points intended to meet fishery and conservation objectives must be allowed to vary across CUs and over time.

The analysis consisted of three steps:

1. Estimate stock-recruitment relationships that account for variation in marine survival.
2. Use simulation to quantify the relationship between exploitation rate and conservation performance under different marine survival regimes.
3. Demonstrate how simulation results can be used to set exploitation rates.

The authors reviewed some fundamental assumptions of stock-recruitment (S-R) analyses (that they are confident in): zero spawners equals zero recruits, survival rates decrease with increases in spawner density, and an average S-R relationship exists even if there is scatter around the curve in annual observations. A key implication of these assumptions is that reducing exploitation rate will result in a proportional increase in escapement in that year, but not a proportional increase in recruitment 3 years later (unless stock size is extremely low).

Two key problems with S-R analyses were identified: there can be substantial non-stationarity in the average relationship over time, and there is evidence that long-term declines in marine survival have led to a downward shift in S-R relationships. The implications of this are that productivity (α), Smsy, and Umsy will decline along with marine survival, Sgen actually increases when marine survival declines, and these changes need to be accounted for in management policies to meet yield and conservation objectives. Further, although depensatory mortality can exist, it can be very difficult to quantify. This analysis showed that marine survival index (M) estimates are likely too low, likely because hatchery survival rates are lower than for wild, and due to CWT reporting issues. Subsequently, the productivity parameter (α) absorbs the bias (i.e., it will be higher if M is too low). A key issue here is that it does not allow variation in bias in M over time. Sample Ricker S-R curves at two marine survival levels were presented to illustrate how they can vary. Information was presented on data sources and quality for escapement, exploitation rate and marine survival timer series for each MU, in response to written reviewer comments.

The authors demonstrated how a marine survival covariate improved the fit of both independent and Hierarchical Bayesian S-R curves for Interior Fraser (IF) CUs, although it was noted that there is considerable variability in the fits. (This could be due to variation in freshwater survival or a sign that the IFC MU marine survival index is not a reliable indicator of survival for naturally produced fish.) The Ricker S-R curve was chosen based on arguments presented by unpublished research by Parken et al. in 2014[1] (advice arising from the RPR is described in DFO 2015a). Based on 1.1% average marine survival, harvest rates have been well below Umsy since 1998 fisheries closures began.

Despite the uncertainties, the retrospective analysis demonstrated that estimated S-R parameters provided a reasonably accurate reconstruction of escapement trends for the IFC CUs. Minor discrepancies were likely due to brood stock, fence mortality and/or First Nations exploitation not included in the model. Three alternate exploitation rate (ER) scenarios were then presented for the period since 1998 (illustrating what would have resulted from these ERs under historic conditions). Forward simulations were initialized based on the most recent four years of Coho salmon data (2012-2015), and included estimated implementation error when generating realized ERs. The model simulated variation in recruitment among years as determined by estimates of residual variation around the S-R curve. It also simulated implementation error in harvest rates. The extent of harvest implementation error was estimated based on a comparison of historical annual exploitation rate targets and estimated exploitation rates.

Three PST categories were developed from three equal percentiles of marine survival for each conservation objective (short- and long-term Interior Fraser Coho Recovery Team (IFRCT) recovery objectives plus a modified IFCRT short-term objective, “ConObj1.5”). A target conservation performance of 50% was used as an example in a decision table. The Fraser Canyon CU, in particular, has large uncertainties. Even in the absence of exploitation, the IFCRT long term conservation objective cannot be met at low marine survival.

The marine survival covariate improved the model fit for Black Creek within the Strait of Georgia (SoG). The hatchery marine survival rate index (derived from Quinsam and Big Qualicum Hatchery data) was used, instead of the Black Creek wild index, due to ongoing uncertainty in funding for the Black Creek program. Comparable conservation objectives (such as those available for the IFC MU) have not been established for the SoG MU, so a suite of commonly reported spawner abundance-related benchmarks (e.g., Sgen, Smsy) were provided instead.

Uncertainties (data deficiencies and hatchery fish survival as surrogate for natural salmon) and implementation issues (reporting bias of coded wire tags (CWT) and target ERs) were discussed. The authors acknowledged their contributors for data, methods and reviews.

CLARIFICATION QUESTIONS FOLLOWING THE PRESENTATION

- A participant questioned the definition of the abundance status classes and the brood years included in the cumulative smolt-to-adult survival rates. It was agreed to discuss the abundance classes and the underlying data later.
- The title mentioned reference points, which include social and economic considerations; however, biological benchmarks were used throughout paper and objectives. A title change and clarity throughout the WP was requested.

[1] Wild Salmon Policy Biological Status Assessment for Conservation Units of Interior Fraser River Coho Salmon (*Oncorhynchus kisutch*) by Charles Parken, Lynda Ritchie, Bronwyn Macdonald, Richard Bailey, Pete Nicklin, Mike Bradford, Hillary Ward, Paul Welch, Ian Boyce, Arlene Tompkins, Marla Maxwell, Katie Beach, Jim Irvine, Sue Grant, Pieter Van Will, David Willis, Mike Staley, Michelle Walsh, Joel Sawada, Jamie Scroggie and Elinor McGrath (2013SAL05). Meeting Nov. 6-7, 2014.

- The source of the exploitation rates was questioned: Fishery Regulation Assessment Model (FRAM), decay model, marine survival, and/or CWT estimates. Participants agreed to discuss data sources after the reviews.

PRESENTATION OF WRITTEN REVIEWS

MIKE BRADFORD

Please refer to Appendix E.1 for full written review.

The reviewer congratulated the authors and supported the general approach taken, nevertheless, more information is needed on the following items:

- More fully describe the approach (assumptions/uncertainties), define productivity categories based on biological/management criteria, define and discuss the choice of performance measures (conservation/exploitation), choose indicator/predictor for productivity, and the evaluate performance of management system.
- Discuss risks of using S-R methods on metapopulations or aggregate populations: lower productivity components may decline unnoticed, small individual populations may not be adequately conserved when pooled into aggregates, increasing risks to diversity (population and habitat use), metapopulation dynamics, and smaller-scale management objectives (local watershed objectives).
- The choice of S-R model form was questioned. The reviewer has seen no evidence for overcompensation in Coho Salmon and the Ricker model affects performance in the simulation.
- The use of hatchery survival as an indicator needs more discussion and an alternative framework was discussed (Table 1). The hatchery survival data was not a consistent time series and was averaged across three CUs, with data gaps. Would a single hatchery survival index be better? How much CWT data do you need to implement this management system?
- The reviewer would prefer wild salmon population survival to be aligned with hatchery survival index. Is this relationship consistent over time? How would the hatchery survival index be implemented? For consistency, he recommended running a three year average.
- Similar issues were present in the SoG. In addition, it was questioned how accurate it is for Black Creek to represent the entire SoG MU. Could data be included from Salmon River, Langley or Keogh River?

Table 1. Alternate PST Management Framework proposed by M. Bradford during reviewer presentation.

Status Category	Productivity R/S, 3-year average	Exploitation Rate	Conservation Risk	Hatchery survival indicator
A (low)	<2	<x%	% of years with R/S<1 % years not meeting conservation goals Low resilience	<2%
B (moderate)	2-4	>x% <y%	Conservation goals usually met	>2%, <4%
C (abundant)	>4	>y% <z%	Conservation goals regularly met, Resilience high	>4%

Questions for clarification

- An author requested clarification for hatchery index category definitions. Bradford gave three options based on stock characteristics (hatchery survival binned into three groups, or divided by absolute values, or hatchery survival related to benchmarks based on wild population productivity).
- A participant questioned the choice of the Ricker S-R model, over the Beverton-Holt S-R model. They agreed with the reviewer that there is no biological evidence of density-dependent mortality in Coho Salmon. Low escapement values mean that spawners are having difficulty finding a mate.

MIKE STALEY

Please refer to Appendix E.2 for full written review.

The reviewer agreed that the authors presented a state-of-the-art model that will be useful; however, there are data quality issues and potential bias from marine survival estimates.

- Staley maintained that the results are premature as they should include the results from previous incomplete CSAS processes on marine survival and Coho assessment (see unpublished processes section; DFO 2015a, 2015b).
- The marine survival method is limited by the data: exploitation rates are sparse for this time period, fisheries mortalities are largely unknown, there are limited CWT and SoG data. Although the data limitations are not the fault of the authors, it does impact the results of the WP. In addition, there is a problem with transparency of data in the WP.
- An important result from this WP, that should be included in the Science Advisory Report (SAR), is that the long term conservation goal in the Fraser Canyon may not be possible, even with zero exploitation, at current marine survival levels.
- The WP suggests a management prescription for ERs, but we have little reliable data on allowable ERs.
- It would be useful to see what fisheries mortality is sensitive to and use this information for a risk assessment to see trends in bias.

Questions for clarification

- The authors agreed that it would be worthwhile to describe the WP data sources further in an appendix. The retrospective analysis shows Coho are more productive than originally thought, although the ER uncertainties make it difficult to project forward.
- The reviewer proposed that fisheries-related mortality may have increased dramatically with the reduction in directed fishing (i.e. mortality associated with release of non-target and/or unmarked fish), so the retrospective analysis may be biased. The model may be most useful to illuminate where data gaps exist.
- Participants agreed with the reviewer that data quality is an issue in the WP, including in the given exploitation rates and CWT estimates associated with limited fisheries exploitation (i.e., insufficient CWT recoveries).

GENERAL DISCUSSION

DATA

- Participants agreed that the data sources used in the WP (exploitation rates and survival estimates) need better documentation. This is particularly important given that the data was assembled from a mixture of sources and years. Authors agreed to provide this as a table or appendix in their revisions.
- There is limited exploitation data available for Canadian Coho Salmon since 1998, when fisheries were significantly reduced. In particular, WP Table 1 shows low numbers of tagged salmon contributing to the CWT-derived estimates of ER for IFC after 1998.
- Mark selective fisheries were gradually implemented after 1998, through to 2004. Fisheries-related mortality would have differentially influenced marine survival during this period of change. A related but unpublished research paper may contribute more information regarding mark selective fisheries (DFO 2015b).
- CWTs were designed for active fishing regimes. Perhaps alternative assessment frameworks should be considered, such as Parental Based Tagging (PBT).
- Salish Sea Coho Technical Working Group reconstructed ERs and found that CWT estimates were similar to FRAM estimates in recent years. Geographic areas seem to average out any differences (Zimmerman et al. 2015).
- IFC CWTs were recovered and expanded to calculate estimates. Black Creek used projected ER from marine effort-based model (2000 to present) for CWT estimates from unclipped salmon.
- CWT expansions are from catch estimate and marked catch rate from Creel surveys. Creel surveys used to include full fishery season, now calculations are projected from shorter surveys. There are increased uncertainties due to these expansion factors.
- How would better reporting of CWT catch or fisheries regime changes affect the model? It is counter-productive to have better information in turn result in a reduction of fishing.
- This model requires a considerable amount of often costly input data. If we do not have good escapement and/or catch data, how can we ensure this model's utility going forward?
- Could Beamish/Neville trawl data time series (Beamish et al 2010) of juvenile Coho Salmon in the Strait of Georgia be correlated to marine survival or recruitment?

- LFR MU escapement data is missing from this analysis, since no current data is available. Salmon River has escapement data, but it was opportunistic, questionable quality and discontinued, so not suitable for use in this project. Overall, more data is needed to be able to assess the LFR MU.
- It is uncertain the degree to which Black Creek represents the entire SOG MU, although it was considered representative of the “average” of well-monitored systems. What are the risks if we manage to the “average” river? Alternative data sources suggested included Keogh River (not within the SoG MU) and Merle Creek (limited size). Could data from these other systems be correlated with portions Back Creek data? There are further concerns about Black Creek data due to strays from other systems (e.g., Oyster River) straying into it.
- At the conclusion of discussions about available data, the chair confirmed with participants that the authors had used the best available data from the sources indicated. Future work could evaluate the utility of incorporating/replacing with additional/alternative data sources. The authors will provide additional documentation in the revised working paper.

MARINE SURVIVAL

- The terminology should be made consistent; change “marine survival” to “smolt-to-adult survival” to be more precise. (The terms are used interchangeably within the WP.)
- Is a hatchery survival index suitably representative of wild escapement? Marine survival assumes the freshwater environment is constant, whereas escapement includes this variability. There is statistical support for including marine survival (higher R^2 of model including the covariate). In the absence of information, marine survival will work, but using both escapement and marine survival is preferred.
- There was a recommendation to use biological parameters of the population, such as recruits per spawner, then assess correlation of recruits per spawner to hatchery marine survival information.
- The example PST management framework proposed by a reviewer presented an alternative framework using recruits per spawner as a measure of productivity (Figure 1). If escapement data is available, then a framework like this may be better than using the hatchery survival index.
- The ratio of recruits to spawners works in the current low marine survival regime, but could be misleading in abundant populations that may have low status.
- Figure 14 of WP shows that some MUs had higher marine survivals but these are averaged within the model so they are not represented.
- Participants requested that the relationship between hatchery survival and wild survival be demonstrated. Data may exist for Salish Sea and already analyzed (Zimmerman et al. 2015). Black Creek smolt-to adult survival data could also be used for this, although continued funding for the Black Creek program is uncertain.
- A temporal analysis of correlations between hatchery survival indices would be interesting.
- Hatchery survival indices should provide confidence intervals; however, with Coho we can only get integer-level precision. There is insufficient data to produce reasonable confident intervals.

DENSITY DEPENDENCE

- Density dependence occurs shortly after emergence in other salmon species, but Coho Salmon are carried away on currents and dispersed. Lower Fraser Coho Salmon rearing populations have little fidelity to streams within a watershed. Biology and stock recruitment biologists should work together to see if density dependence occurs in Coho and at what life cycle stage.
- Density dependence is possible in overwintering or spawning populations in constrained habitats, although no evidence of this has been found so far. Research on Mann Creek in the North Thompson CU may have shown density dependence, but it was on a side channel and not a large population.
- Authors should include a paragraph in the WP about density dependence and review whether it occurs at lower spawner populations in the IFC MU.

STOCK-RECRUIT MODELS

- Reviewers and participants questioned the choice of the Ricker stock-recruit (S-R) model over other possible forms. It was requested that the Beverton-Holt and logistic hockey stick models be evaluated and the most precautionary chosen. Beverton-Holt has little contrast at low productivity and the logistic hockey stick model can be more precautionary.
- Authors agreed to re-do the simulation analyses with a logistic hockey stick model for three runs of IFC data: i) unconstrained, ii) with informative priors to limit the effects of overcompensation, and iii) with informative priors to limit overcompensation and with an inflection point at lower spawner abundance to account for depensation. The results of the re-analysis will be reviewed by an editorial board comprised of a subset of RPR participants.
- There was extensive discussion regarding the choice of time series input into the retrospective model and the effects of the time series: either due to inclusion of values prior to 1992 (during higher productivity period) or the effects of the extremely poor marine survival years since 2002. Analyses should be constrained by the actual marine survival (IFC 6% and Black Creek <13%). A reanalysis with longer time series to see how gamma changed was discussed, but it is problematic due to data quality issues.
- Small populations are at a higher risk of experiencing depensation and loss of genetic diversity (CU dependent). This work may have been done empirically for Cultus Lake. Authors should incorporate some discussion of the costs of allee effects or potential predator pits for small escapement CUs.
- Authors agreed to provide additional documentation for the model: populations and sub-populations, brood years versus calendar year cycles, define ER as PST ER and not domestic ER, and provide the R source code for the analyses, if possible.
- A second retrospective analysis on IFC has been done using a deterministic model by Fraser Area staff (unpublished). This deterministic model had lower returns compared to the WP model. Authors agreed to work with area analysts to determine why results differed between them.
- Common gamma and single marine survival were used in model, but could choose to vary this depending on the individual CU. This complicates implementation, if CUs have different values or no data.
- The correlation structure among IFC CUs needs to be re-parameterized to accurately reflect the interdependency among the CUs.

CONSERVATION PERFORMANCE MEASURES

- Participants requested more information evaluating the conservation objectives or performance measures (IFCRT conservation objectives 1 and 2, Sgen, empirical distributional analysis, Smsy, other indicators). Authors should assess which biological benchmark is most appropriate and why.
- Wild Salmon Policy assessments look at multiple indicators and there needs to be justification for the indicators chosen here. Survival is proposed to characterize the abundance status, but stock status is based on reviewing and interpreting several types of information (e.g. WSP dashboards used for IFC status assessment, unpublished).
- The short term conservation benchmark is hard to meet for all CUs in the same year. Inter-stock covariance should be modelled, so the short and long term conservation objectives align better. Alternatively, could use historic records to see when both conservation objectives were met.
- Sgen most useful for a single population, so appropriate for SOG MU, but not for IFC. Peer-reviewed conservation objectives, similar to the IFCRT (2006) conservation objectives in IFC, should be developed for SoG and LFR MUs.
- Holt et al. (2009) did not recommend Ugen as a lower benchmark on fishing mortality, suggesting Umsy given the risks of overestimating productivity at low spawner abundances and implications for overestimates of Ugen. With the uncertainty associated with estimates of fishing mortality, it would be easy to exceed Umsy, so perhaps a metric with more precautionary buffer would be more appropriate.

PST STATUS CATEGORIES

- Final consensus on the definition of PST categories was to provide a series of tables (similar to Table 7 and 11 from WP) derived from the isopleths of marine survival rate and exploitation rate with up to ten categories for the IFC MU and describe how these tables might be used to determine PST categories within a consultation process. The categories could not be fully assessed without the results from the proposed reanalysis. The main points from the discussions are shown below.
- There was disagreement over the time series to be used to create the PST categories and whether it should be constrained to the recent low marine survival period or include the longest time series possible, including periods of higher productivity. The PST categories would be different depending on the time series chosen.
- Recent Coho data may only represent two productivities, and deriving three status categories from it may not be biologically possible. It was determined that it is still useful to have an intermediate step for management, plus the PST prescribes three status categories, so delivering only two is not an option.
- The low PST category in the WP may be too narrow to be useful. Some IFC populations go below that line even without any fishing.
- The difference between low and moderate categories is quite small, but it has large implications. The authors should include text describing the potential risk of misidentification of moderate status in the WP.
- A participant prefers renaming categories low, medium and high to something with less judgement. WP to follow PST category names: low, moderate, and abundant.

- The use of category ranges instead of mid points was recommended to give a measure of uncertainty for each category. Present credible intervals for each probability rather than midpoints. Alternatively, assign bins with standard deviations around the midpoints.
- The use of the IFCRT conservation objectives of 20,000 spawners (MU low) and 40,000 spawners (MU high) were discussed as PST category limits. Marine survival could be back-calculated from these values for IFC. Would spawner abundance or brood be incorporated? Changes to exploitation rates would change categories.
- Breakpoint suggestions from hatchery survival were considered (Figure 1). Low: < 2% moderate: 2-4% and high: >4%. The values are somewhat arbitrary and would need justification.
- Another suggestion involved providing a continuous range from 0-15% of marine survival with 0.5 to 2% increments along with interactions with ER to get short or long term conservation objectives. The raw output would be provided in an appendix or electronically as supplemental information.
- Isopleths between 1-5 % marine survival rates have a sharp drop and are very sensitive. Table resolution will likely provide results at a level of precision that is not measurable in reality (e.g., discerning the difference between 0.025% and 0.05% survival would not be possible from the data).
- The use of multiple exploitation rates and marine survival rates in table format essentially provides a sensitivity analysis of the model.
- Sensitivity analysis of the years included in the S-R model could be used to see if gamma term changes. In historic data from the 1980s, ER was more accurate and escapement was less accurate. However, the historic data would make stock look more productive and bias the gamma term.
- Uncertainty around productivity and exploitation rates may mean PST categories are insufficient for management.
- Difficult to include marine survival uncertainty in the simulation model. Participant would like tests around implementation rules, but this is not possible until categories are chosen.
- What is the advice on exploitation rates within a status zone? There is a concern about wide range in ER within status zones of the WP.

FRAMEWORK IMPLEMENTATION

- The consensus was that, after the additional reanalysis was complete, advice could be provided on implementation (such as using a moving three-year average) and potential triggers for reevaluation (e.g., a change in method for ER estimation, changes to Coho retention rules, an update to FRAM or productivity regime change). Subsequent consultation, including DFO Science and Fisheries Management, may then recommend reference points and provide information on uncertainties.
- It is recommended that DFO Science provides guidance on data collection requirements to improve alignment of current monitoring programs to support fisheries management response. Fisheries Management changes result in cost changes (i.e. mass marking requires direct electronic sampling) and impacts DFO Science’s ability to provide data. These shifts cause lags in monitoring following policy changes.

- If implementation is within the scope of the WP, text covering specific aspects of simulations and available data should inform fisheries management.
- It is important to allow managers to choose from a possible range. Use of highlighting specific values, as an example, is misleading. If highlighting is used in the text, table and figures, a range of possible scenarios should be used (i.e., at 25%, 50% and 75%, instead of just 50%). This may not be necessary given the use of tables instead of isopleth figures, but the text will have to be revised.
- This paper informs benchmarks and the implied sustainable exploitation rates are benefits of the WP. A change to higher exploitation rates would require re-assessment.
- This model should not inform annual changes, and stocks should remain at low category until proven otherwise. Caution is suggested when the index changes, such as improved estimates of Coho Salmon mortality, without actual changes to the system.
- Future work: it may be useful to test implementation rules in historic scenarios.
- How would post season production such as marine survival index help with pre-season planning? A participant shared how Lower Columbia River uses hatchery jack return and wild Coho seeding data to forecast marine survival. IFC has few to no jacks so cannot use this method. Coastal Oregon uses seeding levels and environmental conditions.
- Future work will need to assess whether this approach is applicable to other MUs. Can this approach be applied to the LFR? Is this approach applicable to other CUs such as West Coast Vancouver Island, with marine survival up to 10%?

INFORMATION FROM OTHER CSAS PROCESSES

Participants requested the inclusion of information from three related CSAS research documents into this analysis:

Korman, J., Sawada, J., Bradford, M.J. 2019. Evaluation framework for assessing potential Pacific Salmon Commission reference points for population status and associated allowable exploitation rates for Strait of Georgia and Fraser River Coho Salmon Management Units. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/001. vii + 81 p.

Parken, C.K., Ritchie, L., Macdonald, B., Bailey, R., Nicklin, P., Bradford, M., Ward, H., Welch, P., Boyce, I., Tompkins, A., Maxwell, M., Beach, K., Irvine, J., Grant, S., Van Will, P., Willis, D., Staley, M., Walsh, M., Sawada, J., Scroggie, J., and McGrath, E. Wild Salmon Policy Biological Status Assessment for Conservation Units of Interior Fraser River Coho Salmon (*Oncorhynchus kisutch*) (CSAS Peer Review 2014/15SAL12, November 6-7, 2014). Unpublished CSAS Research Document. See DFO 2016.

Van Will, P., Luedke, W., and Dobson, D. Interior Fraser River Coho Marine Fishery Planning Model and Updated Exploitation Rates (CSAS Peer Review 2013SAL005a/ 2014SAL13, March 3-5, 2015). (Unpublished CSAS Research Document). See DFO 2015.

UNCERTAINTIES

- The limitations of the data introduced uncertainties. Authors should extend their discussion by considering how the uncertainties in different data sources affect the model results. Decker et al. (2014) has a table of uncertainties (Table 3) that should be updated for the other MUs and included in the WP.

- There are risks associated with applying S-R analysis on a metapopulation or aggregate (i.e., IFC MU) rather than more discrete populations/CUs.
- There is insufficient information on fishing related incidental mortality and the impacts of mark selective fisheries.
- Climate change may introduce further uncertainties (i.e., flow rates or water levels in spawning beds).

MISCELLANEOUS COMMENTS

- A conclusion and recommendations section is required in the WP.
- It was clarified that the PST is not being renegotiated but Annex IV, Chapter 5 is being renewed in 2019.
- A story was shared regarding catch data for Juan de Fuca seine on Coho for 2 million fish in 1966 and 1 million in 1970. The original PST Coho agreement capped Canada Coho at 5 million fish. These values illustrated how much things have changed since the days of higher Coho Salmon abundance under a higher productivity regime.

EDITORIAL BOARD REVIEW

The WP was accepted with revisions, pending review of additional analyses to be completed by the authors. The additional review was conducted by an editorial board consisting of Richard Bailey, Mike Bradford, Jeff Grout, Mike Hawkshaw, Carrie Holt, Jim Irvine, Wilf Luedke, Gary Morishima, Mike Staley, and Lynda Ritchie. The editorial board review took place by Webex on November 6, 2017 at the Pacific Biological Station. Written reviews were received by Mike Bradford, Jim Irvine and Richard Bailey ahead of the meeting (provided in Appendix E).

The authors were charged with providing additional analyses to the editorial board, based on four elements of the WP:

REVIEW ELEMENT 1

Re-do S-R analysis with logistic hockey stick model for three runs of IFC MU data: MU-level results based on CU-specific estimates with appropriate correlation structure, MU level (as a model verification step) and MU level with added depensatory point (at low spawner abundance—i.e. at 1,000 spawners).

Response

Although the authors agreed during the RPR to include logistic hockey stick models as potential S-R model forms, these cannot be fit using Bayesian approaches so were not considered further. Instead, the authors tried different models to address specific concerns about S-R dynamics (i.e., to adjust for depensation with flat top, Deriso model and Power models were fit with flat asymptotic capacity properties or to reflect depensatory mortality). Beverton-Holt models had low capacity and steep initial slope (productivity), suggesting even higher exploitation rates and less effects of marine survival. WP Table 3 shows fit of original Ricker model DIC (where lower values indicate better fit), compared to other models tested. Models 4 & 5 represent assumptions about the S-R relationship, in the form of informative priors on model parameters, such as α and β (simulating depensatory mortality and minimizing effects due to overcompensation). Ultimately, the choice of S-R model depends on the assumptions made about true S-R dynamics and the representativeness of the observed S-R data.

Reviewers highlighted that there is little available data at low levels of escapement and therefore, reduced ability to accurately estimate productivity. The authors agreed that the lack of data near the origin creates higher uncertainty in the productivity estimates. It was also acknowledged that the observed escapement was estimated with error (and with bias that is inconsistent from year to year), but with no direct data to estimate the error or to correct bias, it was not incorporated in the model.

REVIEW ELEMENT 2

Re-do S-R analysis with logistic hockey stick model for SOG MU.

Response

The same models used for the IFC MU were fit to the SOG MU, with comparable summaries provided.

REVIEW ELEMENT 3

Provide table from isopleths of marine survival rate and exploitation rate with up to ten categories in appendix and describe how these values can determine PST categories with consultation process.

Response

WP Tables 8 and 9 were provided, showing mean conservation performance probabilities and 80% credible intervals over a range of exploitation rates (0 to 0.7) and survival rates (0.0025 to 0.1), as well as three different S-R models.

The table required additional rows and columns to adequately capture the steepness of the slope over small changes in marine survival at the low end (i.e. the sensitivity of the results to small changes in marine survival when it is low). The authors pointed out that the scale is too fine for measurable marine exploitation rates during low marine survival periods (i.e., available estimates of marine exploitation and survival are too coarse to resolve the differences in conservation performance, as illustrated). The tables presented in the WP will likely use uneven increments to try to capture as much of the detail at the low end as possible.

An Appendix will be included in the Science Advisory Report illustrating how the tables can be used to set PST status category reference points.

REVIEW ELEMENT 4

The authors are to work with Fraser Area analysts to reconcile differences between the WP results and the Area-derived one.

Response

This was resolved when an error in a spreadsheet formula was discovered.

ADDITIONAL EDITORIAL BOARD DISCUSSION

The Editorial Board reviewed each of the written reviewers' comments in detail and noted where revisions to the WP would be required (see Appendix E). The authors were asked to ensure that back transformation bias was consistent with past processes (i.e., DFO 2015a).

The authors and Mike Bradford dealt with an issue in the retrospective simulation after the conclusion of the Editorial Board meeting. The resulting revision to the methods used to allow for variable estimated age composition across years is summarized in Appendix E.1.3. As a result of this change, Mike Bradford was added as a co-author of the working paper/research document.

CONCLUSIONS

The WP was accepted with revisions at the conclusion of the initial RPR. An editorial board was formed to review updates to the data modeling and results. The editorial board approved the updated results. An initial list of WP revisions was updated at the end of the editorial board review. A list of future work to resolve some of the many data limitations and uncertainties noted during all stages of the review was documented.

Despite the significant data limitations noted during this review, the proposed approach provides an alternate method using marine survival to determine status and associated allowable fishery exploitation rates, based on established conservation objectives. The S-R analysis indicated that the Interior Fraser Coho Salmon CUs have seen sustainable exploitation rates under the low marine survival rates that have persisted since 1998. In contrast, much lower exploitation rates are required to consistently meet previously established conservation benchmarks (i.e., as stated in IFCRT 2006).

RECOMMENDATIONS & ADVICE

This analysis is intended to evaluate potential management implications of alternative approaches for setting management reference points to establish low, moderate and abundant status zones under the PST and associated allowable fishery exploitation rates.

The S-R and simulation-based methods described in this assessment provide a useful means to inform decision makers of the relationships between productivity, exploitation rates, and ability to meet policy-driven objectives for fishery management for the IFC MU. Given limitations of the available data, the methods are sufficiently robust to examine effects of uncertainty and produce information to help evaluate implications for consideration of alternative fishery exploitation rates and risks to achieving conservation objectives. At this time, no analytically derived method to define smolt-to-adult survival rate management reference points to demarcate low, moderate and abundant PST status categories has been established, although visually the data suggest breakpoints of 2% and 4% to demarcate the three status levels. In addition, no recommendation is provided on the selection of associated fishery exploitation rates associated with each PST status category.

The likelihood of achieving a suite of conservation objectives across a range of smolt-to-adult survivals and fishery exploitation rates for IFC has been provided through a series of tables (one table for each combination of assumed S-R dynamics and conservation objective). By selecting an appropriate S-R dynamics model (table version), hatchery smolt-to-adult survival rate (table row) and level of acceptable conservation performance (cell value), the associated exploitation rate (table column) can be determined. It is critical to note that this assessment of conservation performance is particularly sensitive to changes in exploitation rate at low smolt-to-adult survival rates, and that the inherent data uncertainties are likely too large to fully discern these sensitivities at this time (i.e., when smolt-to-adult survival rates are less than 1%).

Given the uncertainties associated with the S-R data, there are several S-R model forms that might be used to represent true underlying Coho Salmon population dynamics (Appendix A, Figure 3). In the context of this analysis, the choice of S-R model influences the estimation of exploitation and smolt-to-adult survival rates, as well as the resulting forward simulations of potential conservation performance. As a result, determination of management reference points and allowable fishery exploitation rates cannot be determined solely from the scientific advice provided here. Ultimately, the choice of management reference points and associated allowable fishery exploitation rates will require input from government, First Nations and stakeholders on acceptable probabilities of achieving conservation outcomes given the known data gaps and uncertainties.

At this time, it is not possible to use the forward simulation tool on data-limited MUs (e.g., SOG and LFR MUs), and it would take a considerable investment of time and program funds to re-instate or establish suitable indicator stocks and smolt-to-adult survival indices. In the short term, additional work is recommended to investigate the extent to which IFC CUs with similar productivities could be used to represent the data-limited MUs. Further, a comprehensive sensitivity analysis is recommended to better understand how sensitive the S-R parameters are to changes in the underlying population dynamics.

Other sources of data were suggested for use in this analysis during the peer review, but it was ultimately determined that this analysis already utilizes the best available data. A number of data limitations and assumptions were identified. Key sources of uncertainty and bias include:

- Exploitation rates: uncertainty about how representative the base period is to the current period given substantial changes in fisheries (e.g., from Coho-directed fisheries to release of wild fish in most areas); unreported catch, drop-off and release mortality not fully accounted for.
- Escapement data: survey qualities vary over time and space; only relative measures of abundance (rather than true abundance) are available for some streams.
- Hatchery smolt-to-adult survival: sample size of recovered marked fish is insufficient to give accurate estimates of the proportion of hatchery fish present; potential for hatchery fish to stray to unenhanced streams; representativeness of hatchery smolt-to- adult survival indices for wild stocks; uncertain numbers of coded wire tags (CWTs) released, due to predation after tagging but prior to release.
- Stock-recruit relationship: biases in escapement and exploitation rate time series carry forward to the S-R analysis, affecting the ability to fit and select a suitable model.

These sources of uncertainty are also suspected to vary in direction and magnitude between populations and across years. As such, it is recommended that the assumptions and findings of this assessment be re-evaluated as new research becomes available, in particular with respect to estimation of in-river and marine exploitation rates and smolt-to-adult survival indices.

RECOMMENDATIONS FOR FUTURE WORK

- The assumptions and findings of this assessment should be reevaluated as new research and/or data becomes available; in particular, with respect to estimation of in-river and marine exploitation rates and possible inclusion of freshwater survival covariate.
- The (re-)establishment of an indicator stock within the Lower Fraser is recommended. The resulting information should be compared to Interior Fraser and Strait of Georgia Coho Salmon populations.
- Investigation is recommended into whether this marine survival approach is applicable in other CUs such as West Vancouver Island with higher marine survivals.
- More analysis is required to inform implementation of this assessment framework, including development of reference points for assessing status.

- If there were changes in the fisheries or productivity regimes, this framework would need to be reapplied to ensure results remained applicable.
- Further guidance is required to improve the alignment of stock and fishery monitoring, analysis and science advice with fisheries management objectives and strategies. Development of a framework to adequately inform management response (risk-based approach) is recommended.
- Monte Carlo simulations could be used to conduct a sensitivity analysis to assess the effects of variable bias across years in the escapement estimates.

ACKNOWLEDGEMENTS

The Chair thanks the authors (Josh Korman and Joel Sawada) for delivering the working paper and subsequent re-analyses and revisions under challenging timelines; Mike Bradford, Mike Staley, Jim Irvine and Richard Bailey for providing thoughtful reviews; Erika Anderson for her support as rapporteur, both during the RPR and for the follow-up editorial board review; all of the participants for the time they contributed to the RPR process; and finally, the CSAS office (Lesley MacDougall, Lisa Christensen, Kiran Dhesi, and Jillian Campbell) for their assistance in coordinating the meeting and producing the final documents.

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APPENDIX A: TERMS OF REFERENCE

DETERMINATION OF REFERENCE POINTS FOR STATUS DETERMINATION AND ASSOCIATED ALLOWABLE EXPLOITATION RATES FOR CANADIAN PACIFIC SALMON TREATY (PST) SOUTHERN COHO MANAGEMENT UNITS

Regional Peer Review Process – Pacific Region

September 20-21, 2017
Nanaimo, British Columbia

Chairperson: Mary Thiess

Context

The current Pacific Salmon Treaty (PST) identifies four Southern BC Coho management units (MU): Interior Fraser River (including Thompson), Lower Fraser, Strait of Georgia Mainland, and Strait of Georgia Vancouver Island. The objective of the bilateral Canada/US Southern Coho Management Plan, outlined in Annex IV, Chapter 5 of the Treaty, is to manage total fishery exploitation to enable MUs to produce Maximum Sustainable Harvest (MSH) over the long term, while maintaining the genetic and ecological diversity of the component populations and to improve long-term prospects for sustaining healthy fisheries in both countries. For each MU, the current Coho chapter requires the development of management reference points (MRPs) for the determinations of 3 status categories, Low, Moderate and Abundant, as well as associated exploitation rates (ER) for each status that achieves the goals set out in Annex IV, Chapter 5.

Interior Fraser Coho (IFC) is the only Canadian MU where informative escapement data have been collected (DFO 2014), and biological abundance-based benchmarks have been established (DFO 2015a). The PST however, requires that all MUs within the treaty identify MRPs and status associated ER caps. For MUs where escapement information is deficient, escapement-based benchmarks would not be informative.

Previous efforts to address these requirements funded by the Pacific Salmon Commission's (PSC) Southern Endowment Fund, include development of a pilot Coho harvest optimization model by Ecometric Research Inc. (Korman et al. 2014) in collaboration with the PSC Coho Technical Committee (CoTC), and work undertaken by LGL Ltd. and Ecometric Research in 2014 that examined a habitat-based method to obtain the desired reference points and allowable exploitation (DFO 2015b). Both of these projects identified that the lack of escapement data prevented the determination of escapement benchmarks that could then be used to establish reference points.

DFO Fisheries Management has requested that Science Branch provide benchmarks and associated reference points for all Southern BC Coho MUs.

The current project builds on this earlier work by exploring alternative assessment methods that make use of marine survival or productivity patterns either separately or in combination with other metrics to establish benchmarks for determining the biological status and associated management reference points for data deficient Canadian MUs. In addition, analytical tools will be developed to enable the evaluation of a range of exploitation rate caps under alternative assumptions about future marine survival or productivity.

The assessment, and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR), will be used to inform consultations and decision making regarding management reference points and associated ER caps for three Canadian MU's;

Interior Fraser River, Lower Fraser and Strait of Georgia which is a combination of the current Mainland and Vancouver Island component MUs.

Objectives

The following working paper will be reviewed and provide the basis for discussion and advice on the specific objectives outlined below.

Korman J. and Sawada, J. Determination of Reference Points for Status Determination and Associated Allowable Exploitation Rates for Canadian PST Southern Coho Management Units. CSAP Working Paper 2014SAL03.

The specific objectives of this review are to:

1. Develop and review the methods for identifying Interior Fraser Coho PST MU benchmarks at low, moderate and abundant PST Status categories (stock recruit and marine survival), and evaluate how they meet WSP and IFCRT objectives.
2. Using simulations, determine the likelihood of achieving SR and distributional lower and upper benchmarks across a range of marine survivals and exploitation management actions (exploitation rates) for IFC.
3. Review the status categories developed from the marine survival method and evaluate their applicability to data-deficient MUs for Southern BC Coho (i.e. Lower Fraser and Strait of Georgia).
4. Examine and identify uncertainties, limitations and risks in the data and methods and suggest potential approaches to their mitigation.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Participation

- Fisheries and Oceans Canada (Aquatic Resources Research and Assessment, Ecosystems and Fisheries Management)
- Academia
- First Nations
- Recreational and Commercial Fishing Representatives
- PSC Coho Technical Committee
- Canadian Southern Panel, Coho Working Group
- Marine Conservation Caucus representatives

References

DFO. 2014. Assessment of the interior Fraser River Coho Salmon Management Unit. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/032.

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Korman, J., and Tompkins, A. 2014. Comparison of the Fishery and Conservation Performance of Fixed- and Abundance-Based Exploitation Regimes for Coho Salmon in Southern British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/090. viii +39p.

APPENDIX B: WORKING PAPER ABSTRACT

The work presented here continues the development and implementation of a bilaterally-reviewed methodology to establish reference points and associated allowable exploitation rates for Coho Salmon management units detailed in the Pacific Salmon Treaty (PST) Southern Coho Agreement (Annex IV, Chapter 5). Marine survival has been identified as a major factor influencing escapement. However, accurate escapement estimates for many Coho Salmon populations in British Columbia are limited. This project therefore focuses on evaluating effects of exploitation rate across a range of marine survival rates that can be used to define PST abundance classes. We fit a variety of stock-recruitment models with a hatchery-based smolt-adult survival covariate to data from the five conservation units (CUs) in the Interior Fraser Coho Salmon management unit (IFC MU) (brood years 1998-2012), and to Black Creek (1986-2012), the sole monitored population representing the Strait of Georgia (SOG) MU. We used a simulation framework based on posterior distributions of stock-recruit parameters to determine the probability of meeting previously established conservation benchmarks over a range of exploitation and smolt-adult survival rates.

Based on best fit Ricker models, productivity (adult recruits/spawner at low stock size) of IFC CU's ranged from about 2.2-2.6 recruits/spawner at the geometric mean hatchery smolt-adult survival rate since 1998 (1.1%). Exploitation rates that maximized yield (Umsy) at these productivities ranged from 0.36 to 0.42. The range in Umsy declined to 0.27-0.32 based on a Ricker model with an assumed higher carrying capacity, which eliminated overcompensatory dynamics over the range of stock sizes, but reduced stock productivity. Productivity of Black Creek based on the average smolt-adult survival for the SOG hatchery indicator stock since 1998 (0.84%) was 2.3 recruits/spawner, resulting in a Umsy of 0.37, and these values declined to 2.0 and 0.32, when using a Ricker model with higher carrying capacity, respectively.

A retrospective simulation analysis of IFC stock-recruit data demonstrated that the majority of variation in escapement to IFC CUs since 1998 has been driven by variation in smolt-adult survival rate. Historical simulations indicated that increasing exploitation from 10% (geometric average since 1998 was 11%) to 30% decreased the probability of achieving the short-term MU conservation benchmark (20,000 spawners) from 71% to 43%. However a fixed exploitation rate of 20% resulted in a 50% probability of exceeding the short-term benchmark, which was similar to the observed probability when hatchery-origin fish are not included in the conservation statistic. The modest effects of slight increases in exploitation rate occurred because the increase in escapement associated with lower exploitation did not produce a proportional increase in recruitment in the next generation owing to density-dependence. Forward simulations quantified conservation performance over a wide range of exploitation and smolt-adult survival rates and included effects of harvest rate implementation error. This information can be used by decision-makers to set exploitation rates for the IFC MU for marine-survival based PST status categories. However, there is not sufficient information to make these determinations for SOG and lower Fraser River (LFR) MUs.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat

Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Reference points for population status and associated allowable exploitation rates for Canadian Southern Coho Management Units

Vancouver Island Conference Centre – Dodd Narrows Room

September 20-21, 2017
Nanaimo, BC

Chair: Mary Thiess

Day 1: Wednesday September 20, 2017

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Mary Thiess
0915	Review Terms of Reference	Mary Thiess
0930	Presentation of Working Paper	Authors
1030	***Break***	
1050	Continue Working Paper presentation	Authors
1200	***Lunch***	
1300	Presentation of Written Reviews	Mike Bradford Mike Staley
1400	General Discussion • Technical Issues (data, model, approach) • Results & Conclusions	RPR Participants
1445	***Break***	
1500	General Discussion: • Identify major points of agreement • Review items for further discussion	RPR Participants
1645	Develop Plan for Day 2	Mary Thiess
1700	***Adjourn for the Day***	

Day 2: Thursday September 21, 2017

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1	Mary Thiess
0915	General Discussion & Resolution of Technical Issues	RPR Participants
1030	***Break***	
1050	General Discussion & Resolution of Results & Conclusions	RPR Participants
1145	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1200	***Lunch Break***	
1300	Draft Science Advisory Report Establish consensus on the following: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1430	***Break***	
1450	Continue Working on SAR	RPR Participants
1550	Next Steps & Concluding Remarks: • SAR review/approval process and timelines • Timelines for other documents • Other follow-up or commitments required • Summarize any other business arising from the review	Chair & RPR Participants
1600	***Adjourn meeting***	

APPENDIX D: MEETING PARTICIPANTS

Last Name	First Name	Affiliation
Anderson*	Erika	DFO Science
Bailey*	Richard	DFO Science, Fraser River
Baillie	Steve	Retired, DFO Science South Coast
Beach	Katie	DFO Stock Assessment
Bradford*	Mike	DFO Science Freshwater
Carr-Harris	Charmaine	DFO Stock Assessment
Christensen	Lisa	DFO CSAP
Cook-Tabor	Carrie	U.S. Fish & Wildlife Service, PST Coho Tech. Cttee (CoTC)
Cox-Rogers	Steve	DFO Science North Coast
Davies	Shaun	DFO Stock Assessment
Dobson	Diana	DFO Science
Fraser	Kathy	DFO Science
Freshwater	Cameron	DFO Science
Grant	Sue	DFO Science
Grout*	Jeff	DFO Fisheries Management (FM)
Hawkshaw*	Mike	DFO Science
Holt	Kendra	DFO Science
Holt*	Carrie	DFO Science SAFE Core
Huang	Ann-Marie	DFO Science
Irvine*	Jim	DFO Science
Jenewein	Brittany	DFO Stock Assessment, Fraser River
Johnstone	Cynthia	DFO Science
Kadowaki*	Ron	DFO Science
Komick	Nick	DFO Science
Korman*	Josh	Consultant , Co-Author
Luedke*	Wilf	DFO Science South Coast
Lynch	Cheryl	DFO Salmon Enhancement Program
MacDonald	Bronwyn	DFO Science
MacDougall	Lesley	DFO Science CSAP
Maxwell	Marla	DFO FM Fraser River
Maynard	Jeremy	Southern Panel
Morishima*	Gary	Quinault Nation, PST CoTC
Neill	Aidan	Fraser River Aboriginal Fisheries Secretariat
Nicklin	Pete	Upper Fraser Fisheries Conservation Alliance & PST CoTC
Parken	Chuck	DFO Science Fraser River
Rankis	Andy	PST Coho Technical Team
Ritchie*	Lynda	DFO Science Fraser River, PST CoTC
Sawada*	Joel	DFO Science, Co-Author, PST CoTC
Scroggie	Jamie	DFO Fisheries Management Fraser River
Staley*	Mike	Fraser River Aboriginal Fisheries Secretariat
Taylor	Greg	Marine Conservation Caucus
Thiess*	Mary	DFO Science, Chair
Van Will	Pieter	DFO Science South Coast
Weitkamp	Laurie	National Marine Fisheries Service, PST CoTC

*Editorial board participant

APPENDIX E: WORKING PAPER REVIEWS

MIKE BRADFORD REVIEWS

Initial Review: Korman and Sawada, Reference points for population status and associated allowable exploitation rates for Canadian Southern Coho Management Units.

This working paper analyses data from IF and Black Creek coho salmon with the goal of generating a productivity-based benchmark scheme that can potentially be used in lieu of abundance-based tools for management, based on the requirements of the Pacific Salmon Treaty. The stated goals for the paper and CSAS review are:

1. Develop and review the methods for identifying Interior Fraser Coho PST MU benchmarks at low, moderate and abundant PST Status categories (stock recruit and marine survival), and evaluate how they meet WSP and IFCRT objectives.
2. Using simulations, determine the likelihood of achieving SR and distributional lower and upper benchmarks across a range of marine survivals and harvest management actions (i.e., target exploitation rates) for IFC.
3. Review the status categories developed from the marine survival method and evaluate their applicability to data-deficient MUs for Southern BC Coho (i.e. Lower Fraser and Strait of Georgia).
4. Examine and identify uncertainties, limitations and risks in the data and methods and suggest potential approaches to their mitigation.

The working paper contains some of the analyses needed to address these objectives although it is not organized in a manner that allows the reader to easily link results to those objectives. Some additional work may be needed, particularly with respect to objectives 3 and 4.

My review begins with three concerns that are general in nature for the analysis of coho salmon populations and follows with specific comments about the paper.

Clarification of management goals and indicators

The terms of reference for this project are framed in the context of the PST, and TOR objective 1 also suggests that objectives of the WSP and IFCRT should also be considered in the analysis.

As noted in the terms of reference the Treaty sets the management objective to “constrain total fishery exploitation to enable MUs to produce MSH over the long term while maintaining the genetic and ecological diversity of the component populations” (PST Annex IV Ch 7 Para 7(a)). The WSP contains 3 objectives related to diversity, habitat and sustainable exploitation, and the IFCRT set out specific recovery objectives for IF coho. Appropriate indicators for these objectives are needed to evaluate the performance of the management framework, particularly with reference to diversity components.

Georgia Strait and Fraser River coho salmon populations have experienced a large decline in productivity in the past 3 decades, and have moved from populations that directly supported large fisheries, to those of conservation concern such that management measures are largely designed to avoid mortality in fisheries for other management units or species. When abundance and productivity are high, metrics such as Smsy and Umsy are appropriate as resulting spawner abundances are sufficient such that the risks of protracted declines to levels that could impair diversity or other objectives are low.

However, as productivity declines standard stock-recruit management parameters are less appropriate as indicators of risk to the diversity aspects captured in the Treaty, WSP and IFCRT objectives. When a population complex is modelled as a single homogenous using a SR relation Smsy will decline with productivity until productivity falls below unity. However, this simplistic approach belies risks to population diversity that result from managing aggregates at very low abundances. In the current low productivity setting metrics such as Smsy or Umsy do not inform the current management objectives to minimize risk to coho MUs when they are exposed to fishing directed at other species.

While this is acknowledged in the paper as a conflict between msy-based management parameters and those associated with “conservation”, my interpretation of the Treaty language is that there are no objectives related to MSY per se, but rather the objective is to find exploitation rates that enable harvest while maintaining diversity and viability of affected populations. The analysis in the paper does suggest MSY-based management parameters may be inappropriate metrics for managing to Treaty and other objectives. More work is needed to establish the relation between productivity and SR-derived management parameters (including those derived for WSP assessments) and risks to diversity.

Stock-Recruit Analyses and Population Complexes

Stock recruit models are appropriate for analyzing dynamics of single “closed” populations, but there are potential risks to management objectives when these models are applied to large population complexes that may be comprised of a number of independent populations, or non-independent metapopulations. The IF CUs vary considerably in composition, from the Fraser Canyon CU that contains one population, to the Upper Fraser that is comprised of a number of demographically independent populations, to the metapopulations that likely occur in the stream networks of the North and South Thompson CUs. Within CUs populations vary in size and productivity, and the contribution of different components to overall abundance likely varies when the CU is at low abundance and productivity relative to periods when productivity is high. Similar, the SOG MUs are comprised of coastal streams that will vary in productivity and abundance. As first demonstrated by Ricker (1958 JFRBC 15:991) and noted in the working paper , there will be a balancing act between maximizing yield and maintaining diversity when there are a diverse group of populations under a single analytical or management regime.

This concern arises from the observation that derived parameters (Sgen, Smsy) for IF coho CUs are low relative to abundances that have been observed since the productivity shift in the early 1990s; Sgen summed over all CUs is 6400 and Smsy is 16,800. Total abundances at these levels that have previously been identified to pose risks to diversity objectives by IFCRT. These risks include demographic and genetic risks for individual, isolated populations within a CU as CU-level abundances approach Sgen, and the reduction in habitat use and life history diversity that results when metapopulations contract in range during periods of low abundance (Decker et al. 2014). The consequences of these changes are not understood, but must be considered risks in the absence of understanding.

Further assessment of these risks is needed but is beyond the scope of current work. For now, it is important to recognize that they exist if management parameters based on stock-recruit models that aggregate over populations are being used to establish the management regime.

Model selection

While the parameter estimation in the working paper is modern and appropriate, there is an insufficient rationale for the choice of model being employed. Often, the stock-recruit information is uninformative with respect to the choice of model, and attention needs to be paid to the underlying biology of the species when making model choices as the model choice may be more important than parameter estimation procedures in affecting outcomes of the analysis.

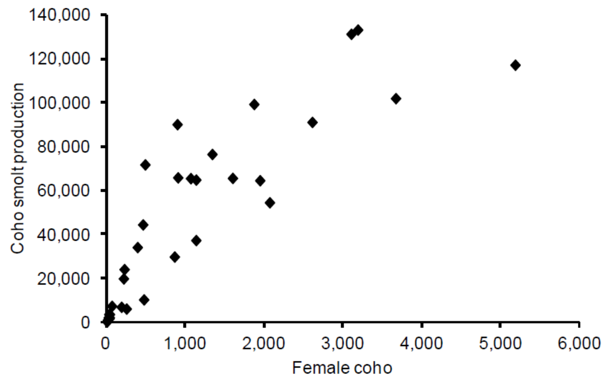

Figure 1. Coho smolt production as a function of female spawners in the Deschutes River, Washington, brood year 1987-2010.

Specifically, in earlier reviews of coho assessments I have questioned the use of the Ricker model when there is no evidence of "over compensation" for this species. Numerous detailed studies have shown in small coastal watersheds the production of smolts is limited by the availability of suitable habitat for juveniles, and that limitation serves to keep spawner densities below levels where the mechanisms that cause overcompensation on spawning grounds (red superimposition, oxygen depletion etc.) or nursery areas (food depletion). Further, adult production from juveniles that migrate or are forced out of natal streams does occur, in the form of juveniles using estuaries and coastal areas, or moving to alternative downstream habitats such as lakes and off-channel areas of larger river networks. This type of density-dependent dispersal is likely to result in a gentle stock-recruitment curve where juvenile dispersal in years of high abundance will continue to contribute to production, albeit as a diminished rate are there are likely costs, in terms of survival, to migration to other locations. An example of this type of relation is shown for the Deschutes River WA (from the 2017 WDFW wild Coho forecast) and for Black Creek:

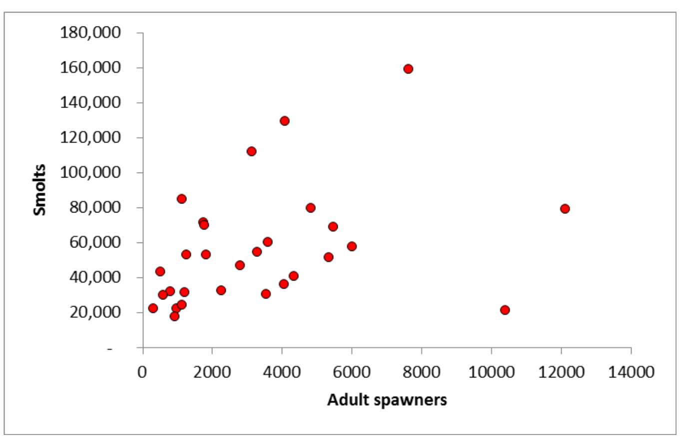

Figure 2. From the 2017 WDFW wild Coho forecast, for Black Creek and Deshcutes River, Washington.

The Ricker model is convenient and familiar, and when fitted tends to produce lower productivity parameter estimates than the Beverton-Holt model which is precautionary when the focus is on population dynamics of depleted populations. However, it has pathological deficiency of generating strong overcompensation when fitted to uninformative stock-recruitment data. In the current application it appears that the overcompensation is having an impact on some of the simulations by generating reduced recruitment at spawner levels are unlikely to be large enough to result in overcompensation.

I suggest bias in results caused by using a model that may not match the biology of the species should be noted in discussion of simulations results particularly with respect to cases where CUs increase in abundance to the point of overcompensation.

Comments on the paper

Introduction/Methods

The first objective of the TOR is to develop and review methods for benchmarks. Although there is brief discussion of the proposed approach a fuller description of the method and particularly the assumptions is needed. In particular, the use of an independent smolt survival index to describe management benchmarks requires the satisfaction of a number of assumptions:

- That the SR relation that is not explained by the survival index (presumably the freshwater phase) is stationary and annual deviations are random. This assumption may be reasonable in many contexts but the potential role of climate change on stream flows and temperatures may be accelerating, and could impact freshwater productivity. Trends in freshwater survival will confound the hatchery index. The very large negative deviations observed for most CUs in the last 2 years of the analysis (Figure 3) are intriguing.
- That the relation between the hatchery index and wild smolt survival remains constant. This requires that hatchery practises (and tagging and survival estimate efforts) remain constant, and there is not long-term trend in the fitness of hatchery fish associated with domestication.
- That there is a degree of predictability and stability in the hatchery index. The assigned status of a coho MU will depend on the current hatchery survival providing a reasonably accurate prediction in the following one or more years. There is some evidence to support this as hatchery survival has shown trends and serial autocorrelation (from high to low survival).
- For the SOG MU productivity distribution of unsampled populations relative to Black Creek or other sites that have detailed population data is characterized by the database, and can be used in a risk-based context.

As noted above a description of the performance measures (indictors) used to evaluate performance of the management scheme is needed that reflect the objectives set out in the TOR.

2.1 Data

More analysis could be conducted on the hatchery survival data. From Parken et al. it appears the IF index is the simple average of 3 series of data however, only one (Coldwater) is reasonably complete. Average survival of the three series appears to be different, and this may impact the survival index when different missing values are involved. A more elaborate approach to computing the historical average may be appropriate to account for missing data. It may also be useful consider the Coldwater series alone to evaluate the relative utility of having intermittent data from 2 other systems. Comparisons between this series and the older Salmon River (Langley) data for wild coho (and Inch) are also useful.

Some comment on the quality and stability of exploitation rate estimates is needed. It is my understanding that reviews of the models used to make estimates are pending, in response to concerns about the estimates.

2.2 Stock-recruitment analysis

It is unclear why data from 1998 forward are used for the SR analysis. Although there have been changes in data availability and quality over time there are such striking differences in productivity among periods that it would seem to be informative for the modelling. Since it appears that hatchery smolt survival data prior to 1998 are used in the development of the benchmark categories, it seems important to test these values in the model since all the post 1998 are for the low productivity regime.

Line 94: It's not quite true that marine survival affects productivity at low population size only although the effect will be greater at low abundance than at larger abundances where the density effects kick in.

2.3.2 Exploitation Rate Analyses

It should be noted that the conservation objectives in the IFC recovery plan are slightly different to those here. The original Objective 1 is at the management unit (all CUs) level, and the overall abundance level (~20,000) is designed to achieve the distributional goal at the subpopulation level. The consistency of the original relation between total abundance and distribution has been confirmed by Decker et al (2014). As the authors have indicated the original Objective (total escapement>20000) is likely easier to implement in a modelling or analysis framework than the CU-specific indicators.

ConObj2 is one of 6 “possible long-term objectives” identified in the IFC plan and the IF recovery team did not identify a preference for one or the other. Given that the low productivity regime has continued for two decades it is possible that this list should be reconsidered. It is also worth noting ConObj2 is not Objective 2 of the recovery plan.

3.1 IFC Stock recruitment

This section contains the results of the stock-recruit analysis and describes a variety of derived parameters and estimates. However, the primary purpose of this section should be to establish that a hatchery survival index is a useful surrogate for the average productivity of the MU as identified in Objective 1 of the TOR, thus providing rationale for its use in the benchmarks setting. This could be enhanced with diagnostic plots including an MU level plot of R/S (or residuals) vs the survival index as well as time series plots.

The estimate of γ for IFC is about 0.5. This means that R/S residuals (density-independent effects) vary non-linearly with hatchery survival approximating a square-root function. It would be informative to examine this relation in more detail, particularly with respect to time trends in the relation, and the use of higher values associated with the pre-1998 data and alternative SR models.

The next step for Objective 1 is to describe a method to divide the hatchery index into three categories as required by the Treaty. This appears in a later section at lines 418. The authors have effectively chosen to divide the historical hatchery survival series into three evenly sized groups and use category midpoints to define the benchmarks. The categories would be quite different if the analysis had been conducted in 1996 when few of the low productivity years were available. In my view it would be preferable to have a more biologically-based approach to setting the category breakpoints as the method chosen entirely depends on data that are available. For example, the high category may reflect the pre-1990 conditions that resulted in larger R/S values such that directed fisheries can occur, while the low category could be range where conservation objectives may be difficult to meet even with the lowest (<20%) implementable exploitation rates.

Some analysis related to implementability is needed. For example, is status based on the previous year's hatchery index, or a 3 (or more) year running average? How often will a change in category occur? If the categories are too narrow, status could be vulnerable to chance events affecting the hatchery index (or measurement errors). Frequent changes in status (without a corresponding change in meaningful biological status) are undesirable.

Table 7a is useful to inform the last part of TOR Objective 1, seeking to determine the performance of the proposed exploitation/hatchery index categories with respect to IFC recovery objective 1. The highlighting of the 50^{th} percentile pre-supposes a level of risk tolerance and is not needed as the table allows consideration of all risk tolerances.

It's implied that the hatchery index is given a fixed value based on category midpoints as it enters into equation 1 for the simulations. It immediately comes to mind whether simulating a range of survival index values within the category (eg bootstrapping the empirical data) would yield significantly different results.

The correlation among SR residuals is very strong (Figure 3) but is not incorporated in the model. Some comment on how the results may be impacted is needed.

It is unclear what the percentiles in Table 7 represent (variation among runs?).

A similar table to 7a that presents results for Sgen and 80%Smsy is required to satisfy TOR Objectives 1 and 2.

Sgen

Sgen values for each CU are very low relative to abundances described by IFCRT Objective 1, and appear lower than the lowest observed generational average for any individual CU. It is important to note that WSP assessments typically integrate information from a number of abundance and distributional metrics rather than a single one. While it may be useful to model Sgen to evaluate its performance as a performance measure in the proposed benchmark scheme, no inference relative to WSP status can be drawn. It is difficult to imagine that the total abundance inferred by the sum of CU-specific Sgens (6,423) is an abundance benchmark for the MU that "results in a substantial buffer between a COSEWIC endangered listing".

Analysis similar to that for IFCRT Objective 1 that resulted in the global escapement objective may be useful for Sgen. That is, the probability of a fraction of the CUs falling below Sgen at different levels of total abundance could lead to an escapement level that achieves a desired level of performance for this metric. Unfortunately this cannot be determined empirically as abundances are largely greater than Sgen. Simulation will require modelling the correlation structure of residuals.

3.3 Strait of Georgia SR

445:Some caution may be warranted when suggesting Black Creek is "typical" of SOG coho streams as some of the streams in Table 8 have been selected as research or monitoring locations based on being "good" coho streams.

471: A summary of evidence that hatchery coho survival rates are usually lower than wild rates can be found in Zimmerman et al. (2015; Marine and Coastal Fisheries 7:116) although similar analysis are available in earlier PSARC and CSAS assessment documents for coho salmon.

474: Backcalculating smolt production from adult returns is particularly hazardous as alternative life history variants do exist to yearling smolts. In particular adult returns from juveniles that migrate below the smolt fence outside of the spring sampling window will confound the analysis although can be sorted out by examination of CWT mark rates

3.4 Simulations

496: As was the case for IFC, further analysis could be conducted to confirm the utility of the hatchery survival index as a metric for setting benchmarks as set out by the objectives in the TOR. In the case of SOG there are data from Inch hatchery, and wild survival rates for both Black and Salmon. Characteristics, correlations, and time trends in each should be evaluated as well as the relation between Black Creek productivity and the index. As before, a biologically-based evaluation of potential benchmarks for the marine survival index is needed to contrast with the purely data-driven approach.

A useful analysis would be to single hatchery survival index and benchmarks could be used for both IF and SOG MUs.

If Black Creek is an "average" SOG coho stream, then managing to Black Creek will result in about one half of the other populations not meeting objectives as they will have a lower productivity. This could compromise the diversity goal as set out in the Treaty. Some analysis of the trade-offs associated with a more risk adverse approach would be useful.

Figures

To avoid confusion, figures labelled "marine survival rate" should be changed to "hatchery survival index" or similar. The same change should be applied throughout the text as marine survival estimates for most of the target populations do not exist.

Review provided to Editorial Board (November 2)
Comments on Korman Sawada, Draft#2

I have some concerns about some of the results, and a few editorial comments on the revision.

Retrospective simulations

It is my expectation that the retrospective simulations should exactly map the historical data as there are no unexplained sources of mortality in the retrospective analysis- year-specific residuals and exploitation rates are used along with a SR curve and escapements to generate the recruitment series. However, inspection of Figure 11 reveals in most years there is a positive bias in the retrospective recruitment values that, when summed, lead to significant differences between observed and simulated abundances at the MU level. These differences are explained as being the result of unaccounted mortality (broodstock/terminal fishing) but are far greater than expected based on conversations with Lynda Ritchie and an examination of the CU-specific exploitation rates in the data spreadsheet. As a result there is large difference in conservation performance (MU>20,000) for observed relative to retrospective reconstructed spawners when the historical exploitation rate series is used. The conservation goal is met in 64% of years in the empirical series compared to values >90% for the simulated series (Table 7, using the 10% exploitation pattern and observation based on Figure 11). This bias effects conclusions resulting from the retrospective analysis, and may have implications for the forward simulations.

On inspection of the code I note that the residuals being used in the retrospective simulations are not the deterministic residuals resulting from using the "best" fit of the model to the empirical data, but are apparently the mean residual from MCMC runs. I wonder if in some years the mean of the MCMC trials is higher than the deterministic residual because of some skewness in the MCMC values. This should be evaluated.

If this is true then the analysis needs to be redone and table 7 repopulated. Further, for the purposes of results, there should be a statement at Lines 469 that increasing the exploitation rate to 30% caused the performance to change by x percent rather than vague phrases as "very similar". Judging by the difference in abundances between the 10 and 30% retrospective runs I suspect that once unbiased residuals are implemented the conservation performance will deteriorate noticeably at a 30% ER relative to the historical performance. Text at Lines 470 and 691 may need to be revised.

Forward simulations

Moving to the forward simulations, results at line 520 suggest the model, on average, suffers the same bias as the retrospective simulations. That is, that generational mean spawners in the model with the historic average exploitation exceeds the 20K goal with >95% probability whereas the empirical result is 64%. Although this difference is opined to be "non concerning" (Line 524) if the 30 percentage point difference extends to other simulation results it will have a significant effect on the tables and figures used to determine the benchmark exploitation rates.

In looking at the code I wonder if there's a bias being generated by using the mean of residuals per year (MU_mu), (CU_mu); the expectation for these parameters should be 0 but perhaps some bias is being generated by an unusual distribution in the residuals or some interaction between the SR parameters and the resulting residual set.

Another subtle difference might be from potential double counting in the generation of the DEV deviates. In this line of code (last one on page 69) the MU and CU deviates are summed. Since MUdev and CUdev are generated using the mean and variation of the deviates, the mean for the CU specific deviates is also included in the calculation of the MU deviates. Is it possible that this process is generating a larger positive bias in those deviates? I would expect both CU-mu and MU-mu to be close to 0; I wonder if MU-mu should be set to zero. In any event some diagnostic analysis is needed to determine if a positive bias exists within the deviates being used for the modelling.

Discussion

Line 744; as discussed in my earlier review the assumption/limitation that for 4 of 5 CUs a single SR relation can characterize all of the dimensions encompassed by the goals of the IFCRT and WSP needs to be identified. Those CUs are aggregations of both independent populations and metapopulations and there are likely risks to some of the diversity considerations when modelling the CU as a single homogenous population. The IF recovery goals were an early attempt to incorporate those risks. I don't think it should be characterized as a conflict between SR and "conservation biology" but more of a recognition that SR only considers one dimension of the abundance and diversity considerations of the IFC plan and the WSP.

Misc Comments:

Section 2.2 – as written the SR equations need an error term or R-hat needs to be defined as the median (?) of simulated values (it's not the expectation).

Line 308- there is no recommended long-term objective for IFC coho but the plan did put forward a number of possibilities of which 40K spawners is one. It should be identified that the use of the 40K is a choice made by the authors for this analysis.

Line 373 It is true that the residuals reflect variation not captured the model. It should also be noted that this variation can also include exploitation variation due to inaccuracies in the modelled exploitation rate. And since the same values are applied to all CUs, errors in the ERs can contribute to the covariation among CUs (as does the hatchery survival index) (this applies to text at 395 as well).

Line 411—In my view recalculating the IFC goals is beyond the scope of this work- the existing (and CSAS reviewed) goals should be used; a revalidation of the IFC goals should include a good look at everything given the years of data that are now available. There may be better approaches that emerge that meet conservation goals and WSP objectives especially given all the work on WSP that's occurred since the IFC recovery team conducted its work.

Line 537: Unlikely that 0.25 (or even 0.5) probability of achieving a conservation goal is relevant for management; I would suggest the range should extent between 0.5 and something closer to 1.

Line 619: The finding that hatchery survival is lower than wild is well established, and the Zimmerman paper provides a good recent review of that. Why not cite the existing work on this point?

Line 648: What does "support" mean? My intuition based on the comments above would suggest that prolonged exploitation at 40% and higher would lead to poor performance relative to the conservation goal or other diversity-related measures. The statement is based on the unit population assumption implied by the CU-level SR analysis. This should be revisited once the simulations have been double-checked.

Line 652- It's not true that recruitment is the sum of catch and escapement, recruitment is based on observed estimates of escapement inflated by estimates of exploitation rate derived from a variety of sources (mostly modelled).

Figure 12C is the wrong panel of graphs as it looks the same as 12A.

Figure 23- include Black Creek (if that's correct) in the caption.

Various typos at lines: 554 277 285

Lastly as a point of curiosity, I wonder if there's an advantage to treating the ER series the same way as the hatchery survival index, especially if the primary output of interest is spawners, not recruitment. That is for the Ricker:

$$S_{t+3} = S_t e^{\alpha+\gamma \log(M)+\varepsilon Log(1-ER)-\beta S_t}$$

(ignoring age 4s for the moment). It is interesting that γ takes a value near 0.5 in model; some flexibility in the ER parameter may improve model fit (effectively it's currently assumed to be 1).

Summary of revisions to age composition treatment in IFC retrospective analysis (November 17, 2017)

In reviewing the revised Working Paper for the November 6 Editorial Board review, some issues regarding the retrospective analysis were identified. Discrepancies between the observed and modelled escapements were greater than expected given the explanation that differences were due to small removals for broodstock or local harvest. After some sleuthing it was discovered that the differences were due to the way that age structure for these populations were being managed. Korman and Sawada followed the same approach as used in Parken et al., in that the average age composition (~90% age-3, 10% age-4) was applied to the return data to generate the brood table. The simulations are done by brood year, not return year, and age compositions of individual broods differ from the return years largely due to differences in the size of each cohort. This effect also generates a bias that causes productivity to be overestimated because there is often a positive bias in the reconstructed abundance of smaller broods.

It was also discovered that hatchery produced fish were inadvertently included in the recruitment estimates, so estimates of productivity will decrease for those CUs with significant hatchery production.

A revised stock-recruit dataset has been generated that addresses the issues raised in the review. A method to calculate brood-year specific age composition was devised and will be presented in an appendix of the WP. The analyses in the paper will be re-run with the revised data.

I expect a slight reduction in productivity for all CUs, and a larger reduction for the Lower Thompson CU that has the largest fraction of hatchery fish. This will have some impact on the performance with respect to the conservation objectives and may lower the exploitation rates to meet specific risk tolerances within the PSC framework.

MIKE STALEY INITIAL REVIEW

RPR Objectives

The specific objectives of this review are to:

1. Develop and review the methods for identifying Interior Fraser Coho PST MU benchmarks at low, moderate and abundant PST Status categories (stock recruit and marine survival), and evaluate how they meet WSP and IFCRT objectives.
2. Using simulations, determine the likelihood of achieving SR and distributional lower and upper benchmarks across a range of marine survivals and harvest management actions (i.e., target exploitation rates) for IFC.
3. Review the status categories developed from the marine survival method and evaluate their applicability to data-deficient MUs for Southern BC Coho (i.e. Lower Fraser and Strait of Georgia).
4. Examine and identify uncertainties, limitations and risks in the data and methods and suggest potential approaches to their mitigation.

General Comments

- This working paper develops a method for identifying interior Fraser coho PST MU benchmarks. The model fitting technology and the simulation analysis are state-of-the-art. I have no doubt that the quality is excellent, however, as with any scientific result it should be replicated and verified.
- Where this paper falls short is in the review of the data and the identification of uncertainties and limitations associated with them, particularly regarding fisheries related exploitation and mortality rates. Errors and biases in fisheries impact projections (some of which may have time trends) may mask other trends and confound exploitation and marine survival estimates.
- While the spawning ground estimates for interior Fraser coho appear adequate as far as they go they are only part of the puzzle. The marine and to some extent in river exploitation rates and associated fisheries related mortalities are not adequately identified and analyzed.
- The intention of this work is to provide advice to managers on how to prescribe appropriate fishing and exploitation mortalities. However, direct observations on the catch and fishing related mortalities on these stocks of salmon over the last 2 decades is nonexistent for most fisheries. This paper, like others such as Decker et al and Parkin et al., relies on projections of changes from historical patterns that predate the period analysed. Marine fisheries related mortalities are projected by indirect means such as effort and the hypothesized impacts of regulations such as bag limits and spot area closures.
- An acceptable description and approval of a methods for assessing fisheries impacts of marine and in river fisheries has not been completed yet. Furthermore, the treatment of fisheries induced mortalities needs to be advanced consistent with (CSAS FIM Paterson et al?). Therefore, the results of the analysis in this paper are subject to further work on the basic data of how many fish are being caught and killed.
- At a minimum, this paper should have done a thorough review and assessment of the quality of these data. Furthermore, the methods of simulations and model fitting could be used to help examine and identify risks of these uncertainties (point 4 in Objectives)

- Even the basic assumption of marine survival (used as a covariant) is tainted with the uncertainties about these exploitation rates.
- Prescriptions for exploitation rate benchmarks based on unreliable exploitation data and related doubts of these data is not acceptable. Extreme caution and with vivid transparency is required.

JIM IRVINE EDITORIAL BOARD REVIEW

Preamble

The report is improved – thanks to the authors for their work on the revision.

The authors state (lines 723-724) that “Decision makers need to determine which stock-recruitment model and recovery objective(s) to use and the minimum acceptable conservation probability for setting exploitation rates.” Chances are that most decision makers will read (at most) the abstract and the SAR. It is vitally important that these convey a balanced perspective.

In my view, the abstract and much of the report as currently written is not sufficiently balanced, and some sections of the text are not appropriate for a scientific document. It will be important for the SAR to be complete and balanced, particularly because this report has the potential to have significant implications to the way salmon in the Pacific Northwest are managed in the future.

Following are some “major concerns” followed by minor, sometimes editorial comments. In my view, the major concerns should be reflected in the SAR if they are not dealt with adequately by the authors. Feel free to forward these to the authors.

Major Concerns

1. Title – insert “Pacific Salmon Commission” between “potential” and “reference”

- This is important because the “reference points” are not DFO WSP reference points but are more akin to DFO WSP benchmarks. This is a DFO CSAS document, not a PSC document. Ideally the authors would include a paragraph in the Introduction explaining the difference between benchmarks and reference points with respect to salmon in the Pacific Region, perhaps referring to Holt and Irvine (2013).

2. Abstract, especially paragraph 3- In my view, this paragraph is not balanced. To provide more balance, suggest authors insert statement beginning “In contrast…” on line 750. As well:

- Line 1 – remove “very”
- Line 3 – add “recent (1998-2014)” before “historical”
- Line 4 – there is huge uncertainty with the stock recruit data. How confident are we in the 2 points that cause the curve to bend? Perhaps remove “owing to density-dependence”.

3. Manuscript

- Line 85-88, Sentence starting “We did not use…..” This is speculation and not appropriate for a science report, in my view.
- Lines 297-307. Confirm that the tests of ConObj1 and ConObj2 were performed at the subpopulation level, not the CU level and then clarify wording.
- Lines 308-309. Document cites IFCRT (2006) as stating that the short and long term recovery objectives were 20,000 and 40,000. The “short term” objective in IFCRT was actually 20,000-25,000 wild spawners. There were various longer term objectives in IFCRT including: To recover each of the five populations to the Green Zone and: To recover each of the five populations to their maximum historic abundance levels.” CSAS document should provide better documentation.

- Line 493 – define “overexploit”. How does this advice compare with the recent COSEWIC analysis/report that was not referenced – if it differs, how and why?
- To provide perspective, acknowledge that exploitations on this MU have been as high as 75% historically and that abundances (catch plus escapement) once exceeded 200,000 adult salmon (cite IFCRT).
- Line 463 – 474. How sensitive is status to exploitation? What would happen if exploitation was reduced from 12% to 0% instead of increased to 30%? Would stock status as defined by the conservation objectives still be “very” similar?
- Line 515-516 – DFO should be concerned about CU status even if PSC is not.
- Lines 536-538 and Figs 19-20. These results are important. I recommend (Fig 19) that the authors add a curve for 0.95% probability and (Fig 20) replace 50% probability of achieving conservation benchmarks with 75%. Refer to these results in text and expand abstract accordingly.

Minor Concerns

- Line 36 – add “Pacific Salmon Commission” before “reference”
- Line 40 – South Coast should be Southern BC
- Line 41-42 – “The IFC MU has relatively reliable stock recruitment data for all its CU’s”. I do not think this is correct, suggest delete statement
- Line 46 – benchmarks misspelled
- Line 49 – Add SoG before MU at tend of sentence
- Line 55 – replace “no” with “limited”. There **are** stock recruit data for LF (e.g. Salmon River). The authors chose not to look at these, or perhaps they were not provided, presumably because they are somewhat dated.
- Line 90 – “no wild indicator”, Salmon River (Langley) and upper Pitt were wild indicators. Funding to maintain these programs was cut. There are publications. Why not mention the studies/data? Statement incorrect as given.
- Lines 79-106. The recent paper by Zimmerman et al concluded that survivals of coho populations within the Salish Sea co-varied, including Black Creek, and differed from populations outside the Salish Sea (e.g. WCVI, Oregon coast, Columbia). This is because “inside populations” enter a very different early marine environment than “outside populations” How does this differ from what Korman and Tompkins found? I do not understand how Josh and Joel can conclude that Black Creek is not representative of the SoG MU?
- Line 267 – insert “recent” before “historical”
- Line 275-276 – why only 4 years (2012-2015) to seed the simulation? Will this limit the variability and perhaps bias the forward simulation results?
- Line 285 – delete “many”
- Line 308 – replace “long” with “longer” and provide units. Long term objectives were much more ambitious than 40,000 spawners.
- Line 463 – 474 – are the authors confident that mechanism was compensatory mortality? If 95% of smolts that go to sea die, and you reduce the exploitation of the remaining 5% from

30% to 12%, granted the benefits to the population will be difficult to see, but they will be positive.

- Lines 470, 473, remove “similar”. I suggest it is not appropriate to say results are similar to something that has not been published or reviewed (Parken and Richie).
- Line 513 – “long-term” should be “longer-term”
- Line 519 (and elsewhere, please search) – insert “recent” before exploitation
- Line 524 – “not concerning”. To whom? Delete “not concerning”. Replace “upper” with “higher”. Point is that there were more ambitious goals in Recovery Document so semantics are important here.
- Line 554 – “a number” is too vague a term to use in scientific writing.
- Line 635 and elsewhere (please search) – delete “very”
- Line 659 – An exploitation of only 4.4% for Black Creek coho is not realistic in my view. Must be higher. Perhaps catch and release mortalities were not adequately estimated? Some of the datasets I have seen present Canadian exploitations as total exploitations – don’t know about this example or the source of the data. We estimated exploitation for SoG coho as part of our analyses for the Zimmerman analyses and they were similar (as I recall) to hatchery stocks in SoG..
- Lines 671-673. Sentence beginning “It may be more….”. This is not correct. Fig 13 shows the survival decline began by 1991 brood. Fig 17 in IFCRT shows exploitations were reduced in 1997. It has been well documented in the literature that coho survivals had been declining well before exploitations were reduced. In fact, we were severely criticised for “acting too slow” in response to declines. The Discussion includes much speculation that I don’t think is justifiable in a peer reviewed document.
- Lines 691-693. What does marginally mean? As mentioned previously, how sensitive is conservation status to exploitation? What if exploitation was reduced to 0%? Would status change then?
- Lines 696-699. In my view, the fact that the majority of the variation of escapement since 1998 has been driven by variation in smolt-adult survival is a “dazzling glimpse of the obvious” rather than an important and potentially controversial result”. I do not think it is appropriate to state that “little conservation benefit has been gained from almost 20 years of costly commercial fisheries closures”. If our goal is the persistence of the MU, this is probably true. In my view, the authors are straying too far into the policy area than is warranted.
- Line 708 – insert “some” before “conservation”
- Line 709 (and elsewhere) – avoid using “a number” (too vague)
- Lines 707-729. Why focus on ConObj1.5 (1st para) and 50% probability (2nd para). As mentioned earlier, suggest a range of probabilities be provided that would include 95%.
- Lines 735-736 – I think there “are” data available, just not used here.
- Lines 736-739 – “The only defensible conclusion…”. I do not think the analysis has been sufficient to reach this conclusion. OK for authors to reach this conclusion although not sure what is meant by “harm”.
- Line 747 – replace “are sustainable” with “will persist”

- Lines 750-752. Statement beginning "In contrast…". Good point – why is this sentiment not included in Abstract?
- Line 782 – Bailie should be Baillie
- References – is Parken et al finished and citable? Why not refer to recently completed COSEWIC analysis and report?

RICHARD BAILEY EDITORIAL BOARD REVIEW

General Comments

Thanks to the authors for undertaking a comprehensive set of re-analyses, along the lines requested by the “small editorial group” convened at the September CSAS meeting in Nanaimo. There has been much effort expended to address the requests to align the stock-recruitment approach with the biology of the Interior Fraser Coho. In particular, investigating models that removed overcompensation and models to incorporate depensation, although it is noteworthy that the authors then put considerable effort into discrediting those models because they did not fit the observations as well as the more conventional Ricker models. The authors note other Coho S/R papers failed to find evidence of overcompensation. Again, it may be worth noting that the two data points that cause the models to support the idea of overcompensation both occurred in years of ultra-low productivity, which Hawkshaw et al postulated might be representing some 3rd, “uber-low” productivity regime. That low productivity was not just in the marine environment, but also in freshwater, thus not accounted for by the hatchery smolt-adult survival covariate.

Another comment regarding the contrasting of the conservation biology versus the S/R modeling relates to the attempt to determine likelihood of meeting various conservation objectives defined by the IFC Recovery Team (IFCRT). The objectives laid-out by the IFCRT reflect the dispersed nature of the available spawning locations within each sub-population and population (=CU). It may or may not be appropriate to apply stock recruitment principles to large spatially disaggregated groups of fish when there may be very real chances of spawners failing to successfully mate or even to find each other at lower escapements. Scattering <1000 fish throughout the thousands of kilometres of the Fraser and tributaries above Bridge River Rapids will likely result in returning fish failing to find receptive mates, before they are found by the waiting predators. Others have documented depensation in IFC, despite the authors attempts to not acknowledge that it occurs (Chen, Irvine and Cass, CJFAS 2002).

In order of work items listed in M. Thiess memo:

- The analysis cannot currently incorporate products of the related CSAS processes until those process are completed. Hopefully the code is available to efficiently re-run these analyses once those products are available to incorporate.
- Further work is proposed for LFA via Southern Boundary EF of PSC. Success of proposals will be known late this winter
- This work is supposed to inform possible changes to the fisheries regimes……
- Hard to comment on plausibility of a marine-survival-linked approach. It is very difficult to measure the marine survival with much confidence and at such low levels of survival, small changes (+/- 0.1%) can have a profound influence on the availability of harvestable surpluses. In the absence of robust predictors of marine survival, a conservative approach may be managers only option. Further, the two very low points on the recruitment graph were likely driven by very poor FW survival (not some form of density dependent overcompensation!), as well as poor marine conditions. Many other yearling smolt populations (such as Fraser 4_2 and 5_2 Chinook) also experienced very poor FW productivity in those years and using a hatchery surrogate to capture the marine survival will provide no information to parse-out unusually poor FW conditions (non-average) that are at least partly driven by marine climate events. Therefore, a marine survival only-linked approach may fail to recognize those types of events, however this may be immaterial if the ER is set very low for the two lower categories.

- Title change: Done as per request
- Data uncertainties table and descriptions still need updating for SoG. IFC uncertainties table is now in place. It is still challenging to determine how much blind faith to place in S/R analyses given the listed uncertainties including how the recruitment data are derived and the inherent issues with the CWT data used to estimate smolt-adult survival.
- Documentation of the simulation modeling exercise and results have been improved. Were the conservation results really that similar amongst the 3 Ricker models that only the standard model with the marine survival covariate was employed? Surely, attaining the upper benchmark was much more likely with the models where there was no overcompensation, especially as the equilibrium stock state for those models is ~60K. There is no table presented to contrast results among models against the upper conservation objective ConObj2. Similarly, as depensation has been documented, should the authors not examine conservation performance using the depensation model?
- There is a difference between conservation objectives, benchmarks for delineating ranges of status and management reference points for managing PSC fisheries. While they may be related, they are different. The IFCRT defined their lower bound (conservation objective) as >50% of the sub-populations within each population exceeding 1000 spawners. Period. Not meeting that objective 50% or 75% of the time. They defined that as their lower bound. If you are going to use a logistic regression approach, determine the exploitation rate that meets the IFCRT lower bound 95% of the time. Similarly, while the simulation results described say you cannot reliably achieve the upper bound (All sub-pops >1K, or MU> 40,000); that is not true in reality. We have achieved the upper bound several times and doing the simulations using the Ricker with no-overcompensation model may result in understanding that it is possible to do so. If it doesn’t, the model is not representing what is actually occurring in real life! There has to be some reason that we are seeing a persistent broodline with escapements over 50K. Again, no table is presented to contrast model performance in attaining the upper objective, likely because it is only achievable with models that are being discredited!
- Similarly, if you use a model that is driven by overcompensation, achieving 16K spawners in the South Thompson would be unlikely, but if overcompensation is removed, surely, that becomes quite probable!

APPENDIX F: RESEARCH DOCUMENT REVISIONS

The authors agreed to make the following revisions prior to publication of the research document:

1. Title change: "Evaluation framework for assessing potential **Pacific Salmon Commission** reference points for population status and associated allowable exploitation rates for Strait of Georgia and Fraser River Coho Salmon Management Units"
2. Include more description about data used in table 1: data sources, years covered, direct or indirect measurements, references, and change in quality/methods of data over time. Consider appendix with raw data used in analysis such as exploitation rates, survival rates and data behind Table 8.
3. Add Table XXa (IFC) and XXb (SOG) outlining sources of uncertainty and bias (based on Decker et al. 2014). Area people responsible for the data will need to provide information/updates as necessary (SoG updates to be provided by Pieter VanWill).
4. Improve consistency in terminology:
    a. smolt-to-adult survival not "marine" survival [Done]
    b. "exploitation" not "harvest" (what about Maximum Sustainable Harvest?)
    c. "Low/Medium/High" to "Low/Moderate/Abundant" status categories
5. Add text:
    a. Include additional explanation of the simulation modelling exercise (part of re-analysis work).
    b. Include additional discussion of the choice of conservation objective/performance measure. Assess which biological benchmark is most appropriate and why. [Suggestion to use Umsy instead of Ugen, as per Holt et al. 2009]
    c. Demonstrate correlation between wild and hatchery marine survival indices.
    d. Expand uncertainty section: Highlight considerable uncertainty at low levels of escapement due to insufficient data.
    e. Include a conclusion and recommendation section, major points will align with SAR
    f. Rephrase text (around line 767) regarding "flaw" in PST status categories in research document
    g. Address additional revisions noted in Jim Irvine's editorial board review
    h. Include subheadings in discussion section, including "Implementation Considerations"
    a. Text on what monitoring and evaluation necessary to inform future work adequately such as in Decker et al.
6. Analyses/graphic presentation:
    a. New Tables 8 & 9 added (3 sub-tables each; one table for each combination of S-R model and Conservation Objective); guidance provided on resolution, scale and presentation.
    b. Add example of how to use Tables 8 & 9 in research document using 75% as example, consider shading or bold break lines.

c. For completeness, a table equivalent to Tables 8/9 for the 40,000 IFCRT long-term conservation objective should be added to the Research Document and SAR.

d. Label points with years on Figure 14.