



Fisheries and Oceans
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Pêches et Océans
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Ecosystems and
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Sciences des écosystèmes
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Canadian Science Advisory Secretariat (CSAS)

Proceedings Series 2018/001

Pacific Region

Proceedings of the Regional Peer Review Meeting on Evaluating Benchmarks of Biological Status for Data-limited Populations (Conservation Units) of Pacific Salmon, Focusing on Chum Salmon in Southern BC

**July 12-13, 2017
Nanaimo BC**

**Chairpersons: Bruce Patten
Editors: Erika Anderson and Bruce Patten**

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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.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

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csas-sccs@dfo-mpo.gc.ca](http://www.dfo-mpo.gc.ca/csas-sccs/csas-sccs@dfo-mpo.gc.ca)



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ISSN 1701-1280

Correct citation for this publication:

DFO. 2018. Proceedings of the Regional Peer Review Meeting on Evaluating Benchmarks of Biological Status for Data-limited Populations (Conservation Units) of Pacific Salmon, Focusing on Chum Salmon in Southern BC; July 12-13, 2017. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2018/001

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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 July 12-13, 2017 at the Pacific Biological Station in Nanaimo, B.C. A working paper evaluating types of Wild Salmon Policy benchmarks of biological status for data-limited Conservation Units of Pacific salmon, focusing on Chum Salmon in southern BC was presented for peer review.

In-person and web-based participation included Fisheries and Oceans Canada (DFO) Science and Fisheries and Aquatic Management Sectors staff; and external participants: PST Chum Salmon Technical Committee members, academia, First Nations, non-governmental organizations, Alaska Department of Fish and Game, commercial and recreational fishing interests.

Percentile benchmarks align or are more precautionary than those obtained through traditional stock-recruitment model results, according to retrospective analysis and simulation modelling in southern BC Chum Salmon. The specific percentile benchmark recommended depends on the productivity and harvest rate combination. However, percentile benchmarks perform poorly in medium to high harvest rates with low to medium productivity combinations. The regional peer review included the following discussions: context, appropriateness of the upper benchmark $80\% S_{MSY}$ identified in a previous CSAS process, percentiles ratcheting down when Conservation Units (CUs) are depleted, variability in percentile-based benchmarks, the use of metrics on total recruitments instead of spawner abundances for status assessments, appropriateness of the stock-recruitment models to explain variability in CUs of Chum Salmon, the spatial scale of CUs of Chum Salmon, and the use of data contrast to inform performance and applicability of percentile-based benchmarks. In addition, percentile benchmark recommendations were discussed to maximize clarity, while still providing the appropriate level of detail, including probabilities. Future work is recommended to evaluate their applicability to other salmon species and the identification of management reference points.

The Research Document and Proceedings will be made publicly available on the [Canadian Science Advisory Secretariat](#) (CSAS) website.

Compte rendu de la réunion régionale d'examen par les pairs concernant l'évaluation des points de référence biologiques pour les populations de saumon du Pacifique pour lesquelles les données sont limitées (unités de conservation) – Accent sur le saumon kéta du sud de la Colombie-Britannique

SOMMAIRE

Le présent compte rendu résume l'essentiel des discussions et conclusions de la réunion régionale d'examen par des pairs de Pêches et Océans Canada (MPO) et du Secrétariat canadien de consultation scientifique (SCCS), qui s'est tenue les 12 et 13 juillet 2017 à la Station biologique du Pacifique de Nanaimo, en Colombie-Britannique. Un document de travail évaluant les types de points de référence biologiques de la Politique concernant le saumon sauvage pour les populations de saumon du Pacifique pour lesquelles les données sont limitées (unités de conservation), mettant l'accent sur le saumon kéta du sud de la Colombie-Britannique, a été présenté aux fins d'examen par les pairs.

Au nombre des participants en personne ou par conférence Web, il y avait des représentants du Secteur des sciences et du Secteur de la gestion des pêches et de l'aquaculture de Pêches et Océans Canada (MPO) et des participants externes : des membres du Comité technique travaillant sur le chapitre du TSP sur le saumon kéta, des universitaires, des représentants des Premières nations, des organismes non gouvernementaux et aussi, de l'Alaska Department of Fish and Game [ministère de la pêche et de la chasse de l'Alaska] ainsi que des représentants des groupes d'intérêt du secteur de la pêche commerciale et récréative.

Les points de référence fondés sur le centile sont plus prudents ou conformes à ceux obtenus au moyen des résultats des modèles stock-recrutement traditionnels, d'après l'analyse rétrospective et la modélisation par simulation du saumon kéta du sud de la Colombie-Britannique. Le point de référence fondé sur le centile recommandé dépend à la fois de la productivité et du taux de prélèvement. Toutefois, les points de référence fondés sur le centile affichent un mauvais rendement lorsque les taux de prélèvement varient de moyen à élevé et que la productivité varie de faible à moyenne. L'examen régional par les pairs a inclus les discussions suivantes : le contexte, la pertinence du point de référence supérieur (S_{MSY} de 80 %) identifié lors d'un processus précédent du Secrétariat canadien de consultation scientifique, la réduction progressive des centiles lorsque les unités de conservation (UC) sont épuisées, la variabilité des points de référence fondés sur le centile, l'utilisation des paramètres sur le recrutement total plutôt que ceux de l'abondance des reproducteurs pour les évaluations de l'état, la pertinence des modèles stock-recrutement traditionnels pour expliquer la variabilité des UC de saumon kéta, l'échelle spatiale des UC de saumon kéta, et l'utilisation de contrastes de données pour appuyer le rendement et l'applicabilité des points de référence fondés sur le centile. En outre, les recommandations liées aux points de référence fondés sur le centile ont été discutées pour maximiser la clarté tout en fournissant un niveau de détail approprié, dont des probabilités. Il est recommandé de mener d'autres recherches pour évaluer leur applicabilité à d'autres espèces de saumons et déterminer des points de référence pour la gestion.

Le document de recherche et les procédures seront rendus publics sur le site Web du [Secrétariat canadien de consultation scientifique](#) (SCCS).

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held July 12-13, 2017, at the Pacific Biological Station (PBS) in Nanaimo to evaluate percentile-based benchmarks of biological status for data-limited populations (Conservation Units) of Pacific Salmon, focusing on Chum Salmon in southern BC.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Science, specifically the Aquatic Resources Research & Assessment Division (ARRAD). Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from PST Chum Salmon Technical Committee, academia, First Nations, environmental non-governmental organizations, and commercial and recreational fishing interests.

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

Holt, C., Davis, B., Dobson, D., Godbout, L., Luedke, W., Tadey, J., Van Will, P. Evaluating Benchmarks of Biological Status for Data-limited Populations (Conservation Units) of Pacific Salmon, Focusing on Chum Salmon in Southern BC. CSAP Working Paper. 2015SAL04.

The meeting Chair, Bruce Patten 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 Terms of Reference (Appendix A) and the Agenda (Appendix C) 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, 39 people participated in the RPR (Appendix D).

REVIEW

Working Paper: "Evaluating Benchmarks of Biological Status for Data-limited Populations (Conservation Units) of Pacific Salmon, Focusing on Chum Salmon in Southern BC." (Abstract in Appendix B) by Holt, C., Davis, B., Dobson, D., Godbout, L., Luedke, W., Tadey, J., Van Will, P. (2015SAL04).

Rapporteur: Erika Anderson

Presenters: Carrie Holt and Brooke Davis

PRESENTATION OF WORKING PAPER

Holt provided an introduction to the working paper. She included information on the Wild Salmon Policy (WSP) Strategy 1, biological benchmarks and how they differ from limit reference

points defined in DFO's Precautionary Approach framework, and Chum Salmon biology. Holt highlighted the definition of data-limited from the working paper glossary. The use of percentile benchmarks in BC and Alaska was briefly reviewed. Two approaches were used to evaluate percentile-based benchmark (meeting objective #1): retrospective analysis and simulation modelling.

Davis described the retrospective analysis used within the working paper. Standard and hierarchical Ricker Models were compared to the percentile benchmarks for seven CUs of Chum Salmon in southern BC. Percentile benchmarks were based on the 25th and 75th spawner abundance. The main conclusions were that results from standard and hierarchical Ricker models were very similar and those statuses from the percentile benchmarks either matched or were more precautionary than those from the stock recruit models. Davis emphasized that there was high uncertainty in data.

Holt described the simulation model, which included population dynamics, observation, assessment, harvest, and performance. The true and estimated benchmarks were compared and the mean percentage error (MPE) calculated using the simulation model. Univariate sensitivities showed that productivity and target harvest rates had the largest impact on performance of all parameters tested. Bivariate plots were used to recommend percentile benchmarks under different productivity and harvest combinations (Table 6 of working paper).

Holt summarized sources of uncertainties in benchmark estimates, and demonstrated an approach for documenting and communicating resulting uncertainty in status. Holt provided recommendations on the applicability of benchmarks and acknowledged the coauthors of the working paper. It was recommended that percentile benchmarks be evaluated for applicability for other salmon species. Clarification questions were addressed on the generational averages, context of biological benchmarks, and specifics of the populations within the simulations.

PRESENTATION OF WRITTEN REVIEWS

JAMES HASBROUCK

Please refer to Appendix E for full written review.

Hasbrouck appreciated the descriptions of Chum Salmon biology and BC policies included in presentation by author. The retrospective analyses were limited due to quality and quantity of data, but the simulations greatly improved the evaluation of percentile benchmarks. The recommended percentiles appear conservative, although likely acceptable, given that Chum Salmon do not handle high harvest rates well. Hasbrouck acknowledged several other people who contributed insights to his review (Appendix E).

Main Concerns

1. Retrospective analyses only considers 25th and 75th percentiles, however, other percentiles may give better solutions.
2. Simulation analyses incorporate productivity and harvest rate giving insightful results, but wouldn't these be unknown in data deficient populations? How does this relate to real world? This was addressed in presentation, but not in working paper.
3. Escapement contrast is related to productivity and harvest rate, but not enough discussion of this relationship in working paper.
4. Some text and figures were hard to understand, including Figures 6, 7, and 10, due to the degree of detail. Author explained the details well in presentation and reviewer would prefer similar level of detail in research paper.

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5. Comparison to Clark et al. (2014) of Alaska percentiles may not be accurate. Alaska examined percentiles to develop benchmark range (escapement goals) that should include S_{MSY} (not S_{gen} and 80% S_{MSY}) and Alaska benchmarks within flatter portion of stock-recruitment curves so more stable. Please be clear in paper about different policies and management objectives.

GERALD CHAPUT

Please refer to Appendix F for full written review.

- Chaput reviewed the context and objectives of the working paper. Although the working paper is thorough, some additional details were requested:
 - Stock recruit data reconstruction from a report by Van Will (2014).
 - Subscripting in Ricker equations, to distinguish if CU specific or hierarchical.
 - Estimates for process error (value used in simulations seems less than what was estimated from Ricker modelling).
 - Hierarchical fit of alpha for West Vancouver Island group only based on two CUs.
- **Main Concerns**
 1. The use of percentiles should be considered interim measure at best.
 2. Percentile benchmarks show a wide range across CUs. This range may reflect differences in productivity among geographic area and carrying capacity. Consider scaling the percentile values to some even coarse metric of freshwater carrying capacity of the geographic size of CUs (km of river). The same comment was made for the stock and recruitment modelling with the carrying capacity parameter, S_{max} , potentially scaling to a measure of freshwater habitat.
 3. There is a shifting baseline issue if percentile benchmarks and model based references are adjusted annually.
 4. The use of S_{gen} as lower benchmark is defensible, but S_{MSY} (or a proportion of) as an upper benchmark is problematic. Large and frequent overlap between estimates of S_{gen} and $0.8S_{MSY}$ (stock-recruitment lower and upper benchmarks on spawner abundances, respectively) means that one stock-recruitment benchmark may be inappropriate and should be reconsidered. Reviewer proposed alternate benchmarks such as R_{max} .
 5. In the context of the Precautionary Approach, the stock status axis in the bivariate plot would best refer to recruitment before fishing as would the upper stock reference. This metric differs from the metric used for percentiles, which are spawners, i.e. after fishing.
 6. Low productivity and high exploitation from Table 6 is contradictory from a management perspective. When productivity is low, exploitation should be scaled back.

AUTHORS RESPONSE TO REVIEWERS

- The working paper focused on 25th and 75th percentiles since those values are currently applied in BC. Alternative percentiles for lower benchmark were considered in increments of 5% from S_{25th} - S_{50th} . Performance at S_{50th} adequately captured an upper bound on plausible values for the lower benchmark. Only looked at 75th and 50th for upper benchmarks. S_{50th} was more consistent with WSP-based metrics on long-term trends and was chosen as alternative to S_{75th} . A full optimization was not done.

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- There is an intention to publish a revised time series of reconstructed run size estimates, currently reported in Van Will's (2014) report. This will depend on analytical capacity to evaluate the revised estimates.
 - Previous WSP assessment have identified that 80% of S_{MSY} is often close to S_{gen} and the amber zone is small. These values are based on text for WSP. Providing probabilities of approaching the red zone may be helpful for managers, as it provides information on the probability of dropping below lower benchmark in either the Amber or Green zones.
 - Process variance was derived from literature with a range of sigma values. Author will make this more explicit, and consider the sigma values estimated in the retrospective analyses.
 - The frequency of reassessment is generally based on generations, but it was only done once, five years ago. There is an intention to update and change benchmarks with new information. It is a valid concern that percentiles may drift down as populations are depleted. Recommendations on percentiles to be applied that vary with productivity and harvest rates account for this. Author questioned whether they should be adjusted based on the newest information.
 - Using recruitment on x-axis (rather than spawners) and harvest on y-axis is interesting. An example of this was given Figures 4 & 5 of DFO (2015). The challenge is that recruitment is not tied directly to harvest rate under the WSP, and so cannot be used for WSP assessments.
 - Authors believe that the third objective from the terms of reference has been met as relevant to current WSP benchmarks. If the upper benchmark of 80% of S_{MSY} is changed, then other recommendations may be possible.
 - Potential to use capacity in future as a habitat characteristic as covariance in stock-recruitment curves. There is similar research in Coho and Chinook salmon.
 - The working paper attempted to reduce complex results into useable recommendations in Table 6. Authors will add text for situations where productivity information is lacking. Escapement contrast could be used on harvest rate axis.

GENERAL DISCUSSION

CONTEXT

- There are broader issues of reference points being confused with biological benchmarks, and differences between the national Precautionary Approach Framework and Strategy 1 of the Wild Salmon Policy (focus of the current Working Paper). DFO's Precautionary Approach Framework may be more relevant to Strategy 4 of the WSP that pertains to integrated planning and program delivery, and address harvest control rules (as in the PA framework).
- How should benchmarks inform the development of reference points? How should scientists communicate biological status to management? Benchmarks have in some cases, been applied as operational reference points. Management needs operational control points.
- Upper benchmarks that delineate Green and Amber zones differ from management targets, which may be higher than the upper benchmark.
- Does the Pacific Salmon Treaty (PST) have an expectation of consistency of benchmarks between Canada and US? There is interest in the critical threshold used in management of

Inner South Coast (Johnstone Strait) mixed-stock fisheries, as PST will stop harvest below that level.

- Fraser Sockeye and Chinook WSP status evaluations considered more than one metric with uncertainty to get status. Multiple metrics are integrated into a single overall status accounting for uncertainties in status on individual metrics and weighting among metrics using expert judgement.
- S_{gen} based on avoiding extirpation. The term “serious harm” (used to define Limit Reference Points in DFO’s Precautionary Approach) is not used within WSP.
- Escapement goals include biological and management considerations.
- This working paper defines biologically meaningful benchmarks that relate to CU status. There is potential to apply percentile-based benchmarks to other species and other locations.
- All hatchery salmon were removed by assuming that the proportion of hatchery catch was the same as spawners. This assumption was necessary to measure wild salmon only.
- There will be no Science Advisory Report as Science is informing Science, not informing management. It is important that participants review the Proceedings to ensure that it records all ideas discussed.
- Proceedings will collect comments for future work. Participants should note whether their comment refers to revision in working paper or suggested future work item.

UPPER BENCHMARK

- Upper benchmarks and management reference points can differ. The standard 80% of S_{MSY} gives a consistent scale for comparison across species and CUs, although it was chosen somewhat subjectively in a previous CSAS process, based on guidance from DFO’s Precautionary Approach Framework. One participant mentioned that it is naïve to think that 80% of S_{MSY} will not be applied by managers as a target. In contrast to the upper benchmark, the lower benchmark of S_{gen} is more biologically meaningful, as reviewed in a previous CSAS process.
- S_{gen} has a foundation in biology, whereas the upper benchmark does not have a biological basis. The upper benchmark of 80% of S_{MSY} is most useful with associated probabilities of status.
- Upper benchmarks may be too close to the lower benchmarks to allow sufficient time for management to respond in the absence of information on uncertainties. However, the authors demonstrate an approach to providing assessments that includes uncertainty in status. As a CU is depleted near the upper benchmark, the probability of Amber and Red status increases, allowing time for managers to respond. Changing the percentage from 80% to 100% of S_{MSY} is likely a minor change to the benchmark value.
- Considering the proximity and occasional overlap of S_{gen} to 80% of S_{MSY} should be recommended work.
- One participant asked how would using an alternative upper benchmark such as S_{max} change the recommendations for percentiles in Table 6 of the working paper? Is it even feasible?
- A participant suggested that using a portion of R_{max} (i.e., on the scale of recruitment instead of spawner abundances) is worth considering as an upper benchmark since it incorporates

low productivity and the capacity of the stock to rebuild. The author noted that this may result in cases where recruitment is above benchmarks (resulting in relatively healthy status), but heavy exploitation results in very depleted spawner abundances. This can occur because biological benchmarks are not directly tied to harvest rates within Strategy 1 of the WSP.

- Alternative upper benchmarks that could be considered: S_{max} , S_{MSY} , S_{rep} , R_{max} .
- If the upper benchmark is reduced, more CUs will be in amber zones, increasing management attention. However, some participants argued that many healthy CUs would be in the amber zone.
- Re-evaluation of the upper benchmark of 80% of S_{MSY} is recommended. An upper benchmark with biological justification would be preferred, though there is no policy (WSP) guidance on where it should be placed, besides from MSY levels.

PERCENTILES RATCHETING DOWN

- Percentiles go down over time with declining stock size. This is not desirable property in a benchmark. The paper presents a way to account for this effect in low productivity and highly harvested CUs, by adapting the percentiles used as benchmarks depending on productivity and harvest rate.
- Other statistical methods for summarizing distributions such as trimmed means could also be considered as a basis for benchmarks for data-limited CUs. In the future, a range of alternatives could be considered, given that percentiles are vulnerable to this movement.
- The WSP specifies that benchmarks should consider the most recent time period, and current environmental conditions. A previous assessment of Fraser River sockeye considered different time-periods for assessment, but used the entire time-series in the final assessment. Evaluating different time periods for including data in the benchmark estimates was considered outside the scope of the current paper. Nevertheless, historic high values of abundances would provide the highest (most precautionary) percentile benchmarks.
- An integrated assessment of status that combines information across multiple metrics using expert opinion will allow the “ratcheting down” effect to be captured and accounted for in the overall status assessments.
- Caution is recommended when using percentiles during a regime change. Addressing regime changes was deemed outside the scope of the current paper.

BENCHMARK VARIABILITY

- Biases and observation error associated with spawner abundance estimates may limit the value of assessing spawner abundances against percentiles by not allowing sufficient feedback for management decisions. Similar concerns can apply to assessments of spawner abundances against stock-recruitment based benchmarks. The working paper included sensitivity analyses of benchmark performance to plausible ranges of observation errors and biases, and found that these were smaller than effects of productivity and harvest rates. In addition, an integrated assessment of status that combines information across multiple metrics can limit the influence of shortcomings in any individual metric.
- For one Chum Salmon CU (Southern Coastal Streams), percentile-based lower benchmarks had high interannual variability at the beginning of the time-series (Figure 5a(iii) in the working paper). Percentile-based lower benchmarks were relatively stable over time for other CUs and for upper benchmarks.

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- Bootstrapping with replacement was used to estimate uncertainty in the working paper. Modelling autocorrelation within the bootstrapping procedure would improve uncertainty estimates.
 - Spawner abundances and percentile benchmarks may be impacted by immigration from and emigration to neighbouring CUs. Movement among sub-populations within a CU was incorporated within the simulation evaluation, but external sources and sinks were not considered. Immigration and emigration were not explicitly considered in the retrospective analysis or benchmark evaluation.

HARVEST AND EXPLOITATION RATES

- The retrospective analyses included historical periods of relatively high exploitation, prior to 2002. In the model, the harvest rate in the Strait of Georgia was fixed at 20% in 2002. Previously, the exploitation rate in the Strait of Georgia was more variable, according to the “Clockwork Approach” to management, a stepped harvest rate based on return abundance.
- Results of the retrospective analysis included variable exploitation rates over the time series.
- Participants requested that the Research Document include time-series of exploitation rates to show how harvest rates influenced time-series of spawner abundances.
- Authors provided time-series of CU-specific exploitation rates that did not indicate heavy and increasing exploitation. Authors will add exploitation figures to the research document.
- Mixed stock exploitation rates are not as variable as exploitation rates in terminal fisheries. Variability in exploitation means more noise in percentile benchmarks.
- Simulations used long-term averages of modelled exploitation rates. Sensitivity analysis showed minimal influences from harvest variability
- For some CUs the estimates for the number of spawners may be biased low at high abundance due to limitations in processing capacity. Harvest sub module could have nuances such as these added in future iterations. The data to inform those biases are lacking for Chum Salmon and are currently not included in the model.

RECRUITMENT DATA

- Chaput, recommended using recruitment rather than spawner abundances as the metric on which to assess status on abundances. Authors responded that Chum Salmon CUs are data-limited and recruitment data are lacking.
- Chaput argued that from a harvest rule perspective, recruitment is more relevant as an independent variable than spawning escapement. Within harvest control rules it may be dangerous to focus only on spawners as the independent variable. However, within Strategy 1 of the WSP, benchmarks are not intended to be directly linked to harvest decisions.
- Data from Westcoast Vancouver Island are of relatively poor quality, at least for some species. One participant mentioned large differences in escapement using radio tags in Burman River for Chinook and Chum salmon. The simulation model evaluated a plausible range of observation errors in sensitivity analyses, including spawner observation biases.

RICKER MODEL

- Are stock-recruitment models appropriate for Chum Salmon CUs? Stock-recruitment data were largely located to the left of the curve, providing little evidence for density-dependence or even a relationship between spawner abundances and recruitment.
- The poor stock-recruitment model fit for some CUs may be due to the relevant scale of density-dependence differing from the spatial scale of the CU. Density-dependence may occur at spawning locations that area at much finer scales than a CU. In contrast, density dependence may occur at the larger scale of the Strait of Georgia, which encompasses numerous CUs. In the absence of additional biological information on the spatial scale of density dependence, and given support for Ricker stock-recruitment models for Chum Salmon in the scientific literature, this model was used by the authors as a basis for data-rich benchmarks.
- The replacement line should be added to all of the stock-recruitment plots.
- Ricker model fits should use autocorrelation and residuals to calculate uncertainty.
- Future work is recommended to identify if Ricker curves apply to Chum Salmon populations, and at what spatial scale.

CONSERVATION UNITS

- The appropriateness of stock-recruitment model for Chum Salmon is linked to the spatial scale of CUs for this species.
- Chum Salmon CUs contain aggregations of populations, which may not be appropriate for stock-recruitment modelling.
- The authors indicated that preliminary stock-recruitment modelling on west coast Vancouver Island Chum Salmon CUs and the smaller Stock Management Unit (SMU) scales were similar. The results were not in the working paper.
- One participant indicated that the size of CUs is appropriate (based on consistent methodology derived in a previous CSAS process), but that the distribution of spawners within CUs is relevant for Chum Salmon (and Pink Salmon), and should be considered in future WSP integrated assessments of status.
- Defining the distribution of spawning streams in CUs is recommended future work.
- One participant recommended using new genetic methods to evaluate Chum Salmon stream fidelity.

GEOGRAPHY

- Covariates related to available habitat for spawning and rearing could be included in stock-recruitment modelling and derivation of benchmarks in future assessments, to gain some insight into the relative credibility of the benchmark values and the S_{\max} values across CUs. This would also allow reference points, such as the 75th percentile or S_{\max} or 80% S_{MSY} to be transferrable from data rich CUs to data-limited CUs.
- Spawner abundances could be divided by area of spawning habitat or kilometres of streams to develop standardized benchmarks of habitat capacity. One participant suggested that our understanding of the biological limitations of spawning success is relatively poor for Chum Salmon, limiting our ability to rapidly develop habitat-based benchmarks for this species.

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- Future work should estimate the stream capacity and distribution of Chum Salmon over spawning and rearing sites.

CONTRAST

- For CUs where we do not have long-term average harvest rates or productivity, data contrast could be used as proxy, where low contrast tends to be associated with high harvest rates and low productivity.
- Results may be more relevant to “real world” (i.e., populations without productivity and harvest rates estimates) by using contrast in escapement data to approximate benchmark performance. (See Figure 19 of working paper).

MISCELLANEOUS

- The research of Clark et al. (2014) was different from this working paper so direct comparisons may not be appropriate. This is because percentile benchmarks of escapement in Alaska tend to be on the flatter portion of the stock-recruitment curve to include S_{MSY} , not on S_{gen} and escapements less than S_{MSY} on the steeper portion of the stock recruit curve. Hasbrouck suggested de-emphasizing that section of the Working Paper.
- Within the retrospective analyses, gap filling was used to develop CU-specific time-series of escapement. Authors confirmed that infilling used standard methods that have been found to be robust, and was mostly limited to within CUs, and therefore had minimal impacts on results.
- A participant requested new visual surveys using snorkel surveys to better estimate escapements for Chum Salmon.
- For cyclic CUs of Sockeye Salmon in the Fraser River, assessments methods differ among cycle lines. The simulation model developed here for Chum Salmon would be helpful to evaluate the impact of variability in assessment methods (and corresponding observation errors) for cyclic Sockeye Salmon CUs.

BIVARIATE PLOTS

- Holt explained how bivariate plots (Figures 13 & 14 of working paper) were used to develop the recommendations for percentile values from the stock-recruitment analyses. The lower percentile was risk averse, i.e. underestimating the lower benchmark was penalized but overestimating it was not, to avoid CU extirpation, according to its definition in the WSP. The upper benchmark was evaluated differently, with overestimating and underestimating penalized equally, considering its definition in the WSP to approximate MSY levels. Participants requested that different approaches to evaluating lower and upper benchmarks, and associated risk aversion be better explained in the Research Document.
- The y-axis on bivariate plots (Figures 13 to 17 of working paper) was chosen based on plausible productivities of Chum Salmon in the literature. Participants requested minimizing this range to reflect values within BC, and emphasize in text that the contours formed the basis for Table 6.

RECOMMENDATIONS TABLE

- Participants suggested including that recommendations in Table 6, be matched with CU specific values in Table 2.

-
- With the high uncertainties in Table 2, Table 6 may be too prescriptive.
 - One participant suggested that the recommendations in Table 6 may be overcautious in some cases, so may be best to let an individual choose the percentile level. Authors cautioned that this would result in inconsistent benchmarks across regions. It would be challenging to compare results if analysts use different percentiles in different areas.
 - There was consensus that current Table 6 was appropriate for providing recommendations to analysts within and outside DFO. If assessing status, one participant preferred to have probabilities of dropping below benchmarks summarized for each category of CU in Table 6.
 - Authors agreed to include a series of boxplot summaries from Figures 13 & 14 describing the distribution of estimated benchmarks relative to “true” S_{gen} and $80\%S_{MSY}$ benchmarks, to inform Table 6, under realistic harvest-exploitation combinations. One participant suggested that the figure caption should include that the lower benchmark is risk averse and upper benchmarks are more neutral. Another participant cautioned against using the term “risk-averse” to pertain to development of biological benchmarks, reserving that term to the application of harvest control rules in management.
 - Modify Table 6 from “not recommended” to “percentile benchmarks not recommended”, “requires further investigation”, or “percentile benchmarks perform poorly”.
 - If no information on CU productivity, then need to include recommendation on what to do in Table 6.

PERCENTILE BENCHMARKS

- This working paper was a methods paper informing science, not management. It shows how percentiles match stock recruit in certain circumstances. Additional steps and information are needed to translate these percentile benchmarks into management reference points. Processes should be developed that are practical for scientists and fishery managers. Participant noted that WSP addresses this issue in strategies 4 & 5.
- Managers should not rely solely on biological benchmarks to inform management decisions. Spawner abundance is just one metric among numerous metrics that can be integrated to derive a final status determination.
- Recommendations on page 42 of the working paper are not intended to be management advice. Additional socio-economic factors should be considered when developing reference points for management.
- Long-term trend metrics used in WSP status assessment are similar to percentile-based benchmarks on spawner abundances evaluated here. Should long-term metrics be replaced by percentiles? How do percentile benchmarks fit in with integrated status assessments under the WSP? One participant requested advice on how to (or if) percentile-based benchmarks should be considered in integrated status assessments.
- How would replacing long-term metrics with percentiles affect cyclic stocks since percentiles are based on medians instead of geometric means (as in long-term trend metric)?
- It was recommended that applications of percentile benchmarks use uncertainties that account for autocorrelation in the bootstrapping procedure.
- Participants requested context for when to use which benchmarks, including percentiles. The current working paper addresses Chum Salmon specifically; other species were outside the scope of the report. The metric on spawner abundances combined with percentile benchmarks can be applied within synoptic surveys to provide provisional information to

inform prioritization for further monitoring and assessments. In other species where integrated status assessments have been developed, numerous metrics and benchmarks can be combined in a multi-dimensional assessment. Each metric has caveats and shortcomings, so expert integration is useful when combining information across numerous metrics. If percentile-based benchmarks are used as proxies for stock-recruitment based benchmarks in integrated statuses, their shortcomings should be considered in the expert-driven integration.

CONCLUSIONS

The working paper was accepted with the revisions.

Percentile benchmarks tend to align or be more precautionary than traditional stock-recruitment models when productivity is moderate to high and harvest rates are low to moderate, according to retrospective analysis and simulation modelling in southern BC Chum Salmon. The specific percentile benchmarks recommended depends on the productivity and harvest rate combination. However, percentile benchmarks perform poorly in medium to high harvest rates with low to medium productivity combinations. Future work is recommended to evaluate their applicability to other Chum Salmon stocks and other salmon species.

REVISIONS FOR WORKING PAPER

- Summarize the biology of Chum Salmon in introduction.
- Add text regarding stock-recruitment applicability to Chum Salmon.
- Reduce comparisons to Clark et al. (2014) within the working paper.
- Add exploitation rate plots to support the retrospective analysis section.
- In Figures 13-17 of the working paper, trim the y axis to 5, aligning better with BC Chum Salmon productivity.
- Describe the use of data contrast, where there is no known productivity or harvest rates.
- Create a series of boxplots based on percentiles of spawners to inform Table 6 with realistic harvest-exploitation combinations and including S_{gen} and 80% of S_{MSY} lines.
- Improve justifications for recommendations within Table 6 in reference to bivariate contour plots. Modify Table 6 from “not recommended” to “percentile benchmark not recommended”, “requires further investigation”, or “percentiles perform poorly”.
- Within recommendations, suggest that status assessments that use percentile-based benchmarks include probabilities of status assignment.
- Describe the ratcheting down of percentiles in regards to southern coastal streams within lines 1214-1217.
- Plus editorial and minor clarification comments from reviewers and participants.

RECOMMENDATIONS FOR FUTURE WORK

- Reevaluate upper benchmark of 80% of S_{MSY} and its applicability to Chum Salmon. Propose upper benchmark with biological justification, if possible.
- Examine applicability of Ricker stock-recruitment model to Conservation Units of Chum Salmon.

-
- Identify if/how percentile-based benchmarks can be included into integrated status assessments under the WSP that already include long-term trend metrics that relate current spawner abundances to the long-term geometric mean.
 - Apply the simulation model to evaluate the influence of cyclic salmon populations on percentile benchmarks.
 - Incorporate habitat quality or size into stock-recruitment modelling as a covariate for S_{max} .
 - Expand analysis of percentile benchmarks to other Chum Salmon stocks and other salmon species.
 - Develop guidance on selection of benchmarks depending on type of data, outcomes of advice, and acceptable uncertainties (Data Limited Methods Toolkit).
 - Consider how to develop management reference points for data-limited CUs.

ACKNOWLEDGEMENTS

We appreciate the time contributed to the RPR process by all participants. In particular, we thank the reviewers, Gérald Chaput (DFO, Maritimes Region), and James Hasbrouck, Rich Brenner, and their team at the Alaska Department of Fish and Game, for their time and insight.

REFERENCES

- Clark, R. A., D. M. Eggers, A. R. Munro, S. J. Fleischman, B. G. Bue, and J. J. Hasbrouck. 2014. An evaluation of the percentile approach for establishing sustainable escapement goals in lieu of stock productivity information. Alaska Dept. Fish and Game Fish. Man. No. 14-06.
- DFO. 2015. Development of reference points for Atlantic salmon (*Salmo salar*) that conform to the Precautionary Approach. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/058.
- Van Will, P. R. 2014. Inner South Coast Chum Salmon Stock Reconstructions. Report submitted to the Marine Stewardship Council.

APPENDIX A: TERMS OF REFERENCE

Evaluating Benchmarks of Biological Status for Data-limited Populations (Conservation Units) of Pacific Salmon, Focusing on Chum Salmon in Southern BC

Regional Peer Review Process – Pacific Region

July 12-13, 2017

Nanaimo, British Columbia

Chairperson: Bruce Patten

Context

The Pacific Salmon Treaty (PST) Chum Annex requires biological benchmarks to inform the use of the critical threshold level for chum salmon to Johnstone Strait (currently set at 1 million) in upcoming PST renegotiations of the chum salmon Annex. Reference points that are currently being used for management have not been recently updated and may not reflect current trends in productivity, stock statuses, or other ecosystem considerations. Advice on biological benchmarks, and their applications as fisheries reference points, will also inform assessments for Marine Steward Council (MSC) certification of chum salmon and future stock assessments for terminal fisheries of chum salmon.

Biological information is needed to inform domestic and international assessment and management (e.g. PST, Wild Salmon Policy, and Marine Stewardship Certification). At this time however, most Conservation Units of chum salmon in southern BC have significant data limitations. Biological benchmarks for data-limited populations have been proposed and are currently being applied to Conservation Units (CUs, population units of biological assessment under Canada's Wild Salmon Policy) of chum salmon in southern BC. These methods which are based on percentiles of historical spawner abundances have not been rigorously evaluated against standard abundance-based benchmarks recommended under Canada's Wild Salmon Policy for data-rich CUs.

DFO Science has requested that Science Branch provide advice on the use of biological benchmarks for southern BC chum salmon in light of acknowledged data limitations. Specifically, an evaluation of percentile-based benchmarks will include the biological, assessment, and management conditions where those benchmarks are higher (more precautionary) or lower (less precautionary) than standard abundance-based benchmarks derived previously under the Wild Salmon Policy (Holt et al. 2009; Holt 2009).

Objectives

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

Holt, C., Davis, B, Dobson, D., Godbout, L., Luedke, W., Tadey, J., Van Will, P. Evaluating Benchmarks of Biological Status for Data-limited Populations (Conservation Units) of Pacific Salmon, Focusing on Chum Salmon in Southern BC. *CSAP Working Paper 2015SAL04*

The specific objectives of this review are to:

1. Evaluate biological benchmarks for data-limited Conservation Units of Chum Salmon based on percentiles of observed abundances and compare to standard model-based benchmarks accounting for high uncertainties and possible biases in spawner abundances, catches, recruitment estimates, and age-at-maturity.

-
- a. This evaluation will include simulation and retrospective analyses using data from Chum Salmon in southern BC, where available.
 - b. A sensitivity analysis of evaluations will be performed in simulation to identify the conditions under which benchmarks meet conservation objectives.
2. Examine and identify uncertainties in the data, methods, and benchmarks. Develop and demonstrate a tool to report uncertainties in the assessments.
 3. Provide advice on the applicability of percentile-based benchmarks for data-limited populations of chum salmon in southern BC.

Expected Publications

- Proceedings
- Research Document

Participation

- Fisheries and Oceans Canada (DFO) (Ecosystems and Oceans Science and Ecosystems and Fisheries Management sectors)
- PST Chum Technical Committee members
- Academia
- First Nations
- Non-governmental organizations
- Commercial and recreational fishing interests

References

- Holt, C.A., Cass, A., Holtby, B., Riddell, B. 2009. Indicators of Status and Benchmarks for Conservation Units in Canada's Wild Salmon Policy. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/058. viii + 74 p.
- Holt, C.A. Evaluation of Benchmarks for Conservation Units in Canada's Wild Salmon Policy: Technical Documentation. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/059. x + 50 p.

APPENDIX B: WORKING PAPER ABSTRACT

Status assessments for Chum salmon under the Wild Salmon Policy (WSP) have been limited, in part because recruitment time-series required to calculate stock-recruitment based benchmarks are not consistently available. Alternative benchmarks have been proposed for data-limited Conservation Units (CUs) using percentiles of the observed spawner abundance time-series. However, these benchmarks have not been evaluated against stock-recruitment benchmarks currently used to assess status on abundances for data-rich CUs under the WSP. Our goals were to evaluate percentile-based benchmarks against stock-recruitment based benchmarks accounting for high uncertainties and possible biases in spawner abundances, catches, recruitment estimates, and age-at-maturity. We used two approaches to evaluate benchmarks based on a retrospective comparison through the historical record and a prospective simulation model under numerous hypothetical future scenarios. We also demonstrate an approach for providing assessments that accounts for uncertainties in benchmarks, and provide advice on the applicability of percentile-based benchmarks for data-limited CUs of Chum salmon in southern BC. In general, our results support the application of percentile-based benchmarks for data-limited CUs of Chum salmon, but we suggest that the percentile values be adjusted based on estimated productivity and harvest rates. By combining retrospective analyses on empirical data and simulation modelling of hypothetical CUs, our results and recommendations are robust to a wide range of stock characteristics and assessment uncertainties, and are grounded in empirical data.

APPENDIX C: AGENDA

Regional Peer Review Meeting (RPR)

Canadian Science Advisory Secretariat
Centre for Science Advice Pacific

Evaluating Benchmarks of Biological Status for Data-Limited Populations (Conservation Units) of Pacific Salmon, Focusing on Chum salmon in Southern BC

July 12 & 13, 2017

Nanaimo, British Columbia

Chair: Bruce Patten

DAY 1 - Wednesday, July 12

Time	Subject	Presenter
0900	Introductions, Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Authors
1030	Break	-
1050	Overview Written Reviews	Chair + Reviewers & Authors
1200	Lunch Break	-
1300	Identification of Key Issues for Group Discussion	Group
1330	Discussion & Resolution of Technical Issues	RPR Participants
1430	Break	-
1450	Discussion & Resolution of Technical Issues	RPR Participants
1600	Check in on progress and confirmation of topics for discussion on Day 2	RPR Participants
1615	Adjourn for the Day	-

DAY 2 - Thursday, July 13

Time	Subject	Presenter
0830	Introductions, Review Agenda & Housekeeping Review Status of Day 1	Chair
0845	Discussion & Resolution of Technical Issues (Continued from Day 1)	RPR Participants
1000	Break	-
1020	Discussion and Resolution of Working Paper Conclusions	-
1130	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1130	Next Steps – Chair to review <ul style="list-style-type: none">• Research Document & Proceedings timelines• Other follow-up or commitments (as necessary)	Chair
1145	Other Business arising from the review	Chair & Participants
1200	Adjourn meeting	-

APPENDIX D: PARTICIPANTS

Last Name	First Name	Affiliation
Anderson	Erika	DFO CSAP
Ashton	Chris	Commercial Salmon Advisory Board (CSAB)
Bradford	Mike	DFO Science
Brenner	Richard	Alaska Department Fish and Game
Brown	Gayle	DFO Science
Chaput	Gérald	DFO Science
Cox-Rogers	Steve	DFO Science
Davies	Shaun	DFO
Davis	Brooke	DFO Science
Dobson	Diana	DFO Science
Dunlop	Roger	Uu-a-thluk (NTC Fisheries)
Folkes	Michael	DFO Science
Grant	Sue	DFO Science
Grout	Jeff	DFO Fisheries Management
Hasbrouck	James (Jim)	Alaska Department Fish and Game
Hawkshaw	Sarah	DFO Science
Hertz	Eric	UVic
Holt	Carrie	DFO Science
Holt	Kendra	DFO Science
Huang	Ann-Marie	DFO Science
Irvine	Jim	DFO Science
Kristianson	Gerry	Sports Fishing Advisory Board
Kronlund	Rob	DFO Science
Laliberte	Bernette	Cowichan Tribes
Lewis	Dawn	DFO Salmon Stock Assessment
Luedke	Wilf	DFO Science South Coast
MacDonald	Bronwyn	DFO Science
MacDougall	Lesley	DFO Science
MacDuffee	Misty	Raincoast Conservation Foundation
Maxwell	Marla	DFO Resource Management
Neill	Aiden	Lower Fraser Fisheries Alliance (LFFA)
Patten	Bruce	DFO Science
Porszt	Erin	DFO Stock Assessment Biologist
Rosenberger	Andrew	Raincoast Conservation Foundation
Sawada	Joel	DFO Science
Staley	Mike	Fraser River Aboriginal Fisheries Secretariat
Tadey	Joe	DFO Science Fraser and Interior Area
Taylor	Greg	Marine Conservation Caucus
Tompkins	Arlene	DFO Science
Van Will	Pieter	DFO Science

APPENDIX E: WRITTEN REVIEWS

JAMES HASBROUCK



THE STATE
of **ALASKA**
GOVERNOR BILL WALKER

Department of Fish and Game

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28 June 2017

Bruce A. Patten, Head
Fishery & Assessment Data Section, Science Branch
Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

Dear Mr. Patten:

Thank you for the opportunity to review CSAS Working Paper 2015SAL04 entitled "Evaluating Benchmarks of Biological Status For Data-Limited Conservation Units of Pacific Salmon, Focusing on Chum Salmon in Southern BC."

This study was well-done and the report well written. The Introduction articulates the background justifying the purpose and clearly states the objectives of the study. The remaining sections of the report were structured to describe and relate the methods and results to each of the stated objectives.

The authors did a good job exploring in much detail, in some instances perhaps overly so, comparisons between percentile-based benchmarks of southern BC chum salmon escapement to benchmarks based on stock-recruitment relationships. By evaluating percentile-based benchmarks across a range of conservation units (CUs) and scenarios, and including a sensitivity analysis, they developed a relatively robust approach and provided sufficient detail to support their recommendations.

Comments specific to the retrospective analyses:

- The comparisons are somewhat limited because the data are likely of poor quality (and quantity?) for the conservation units considered. Escapements and stock-specific harvests are likely based on assumptions difficult to, and likely not, evaluated. That's the reality and the authors do a good job not overstating conclusions and recommendations based on these analyses, but this section does not provide very convincing information on percentile-based benchmarks.
- The authors only considered the 25th and 75th percentiles and did not examine other percentiles that may give more optimal solutions relative to S_{gen} and 80% of S_{msy} .

Comments specific to the simulation analyses:

- The simulation analyses were very well thought out. Some of the text and figures are hard to understand, the information presented required a fair degree of re-reading and pondering to grasp, but this is perhaps a function of my ignorance in how this information is generally

presented in CSAS Working Papers, and stock assessment and fisheries management in BC.

- The analyses and recommendations on percentile-based benchmarks from the simulations incorporate productivity and harvest rate. Results of these analyses are insightful but how do they relate to recommendations for data-limited stocks? Doesn't data limited mean a lack of productivity and harvest rate information (though perhaps some modicum of knowledge about long term average harvest rate)? If one has information about productivity and harvest rate, wouldn't a stock-recruit analysis rather than percentiles be used to establish benchmarks for the stock (or conservation unit)?
- The authors state contrast in escapement is related to productivity and harvest rate, but provide the reader no information on what the relationship looks like, which could be a crucial piece of information in developing percentile-based benchmarks. Again, if productivity and harvest rate data are available, are percentile-based benchmarks appropriate? If productivity and harvest rate are unknown, contrast in escapement encapsulates all the factors one cannot discern from escapement data alone, including process and measurement error, and serial correlation in production.
- The recommendation on percentiles appears fairly conservative given results of the analyses, but this is just an observation and not a flaw in the analyses or report. Chum salmon typically do not handle high harvest rates well, so it makes sense and better to err on the conservative side.

Please know the comparison of results of this study to percentile-based sustainable escapement goal recommendations proposed by Clark et al. (2014) may be an apples-to-oranges exercise. The percentile-based benchmarks evaluated and recommended in this report are based on different salmon management objectives and criteria for escapement goal development in Alaska. Matching S_{gen} and 80% of S_{msy} with percentiles of observed escapement in this study will provide very different advice than those examined in Alaska that provides a range around S_{msy} . Alaska's percentile-based benchmarks are also in the flatter part of the stock-recruit curve and more stable over a range of productivities than something like S_{gen} , which is on the ascending limb of the stock-recruit curve.

I thank you again for the opportunity to review this report. Bob Clark, Bill Templin, Rich Brenner, Andrew Munro and Steve Fleischman contributed input and insights to these review comments. Please contact me if you have questions or wish to discuss our review comments.

Sincerely,

[original signed by reviewer]

James J. Hasbrouck

Chief Fisheries Scientist

Cc: Tom Brookover, Director, Division of Sport Fish, ADF&G
Bill Templin, Salmon Chief Fisheries Scientist, Division of Commercial Fisheries, ADF&G
Scott Kelley, Director, Division of Commercial Fisheries, ADF&G



28 June 2017

Bruce A. Patten, Head
Fishery & Assessment Data Section, Science Branch
Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

Dear Mr. Patten:

Below please find specific editorial comments for the authors in conjunction with our review of CSAS Working Paper 2015SAL04 entitled "Evaluating Benchmarks of Biological Status For Data-Limited Conservation Units of Pacific Salmon, Focusing on Chum Salmon in Southern BC."

Lines 325-337: Nice statement of goal and objectives of this evaluation.

327-328: Objective that accounts for uncertainties and biases in spawner abundance, catches, recruitment and age-at-maturity is considered data limited?

351: Might be worth stating that Y_i refers to brood years.

358-361: The data for data-limited stocks was simulated?

414-417: Since hatchery stocks can sustain greater exploitation than wild stocks, was there differential management on hatchery vs. wild returns? In other words, is it valid to assume that proportion of wild fish in harvest = proportion of wild fish in the escapement?

In Alaska, hatchery fish are often harvested in the marine environment adjacent to hatcheries and these hatchery stocks are exploited at a much higher rate than the wild stocks.

420-421: On average, less than half of the sampling sites were surveyed? I think this could be a major problem as it means that the majority of the data are not independent, but rather were infilled from adjacent sites. This suggests escapement data were also not available for the majority of sites.

425-427: Return data was infilled, too? Because of infilled escapement data or from other reasons?

466-525: Models are nicely presented throughout this section. Please note the existence of exact method for calculating S_{msy} by M. Scheuerell.

520: Why only 25th and 75th percentile calculated? Perhaps remind reader that these are the only percentiles evaluated here because they are the proposed and provisionally implemented percentiles.

524: Insert "be" – S_{gen} tends to **be** higher . . .

580: Figure 4 is very confusing and should be constructed differently so that it is clear what is being displayed and why.

630-633: Text doesn't seem to match Figure 6, and is about NE Vancouver Island which is Figure 6b, not Figure 6a.

643-644: The terms "higher" and "lower" status is confusing and perhaps opposite of how some readers may interpret wording. Some readers may interpret "lower status" means less precautionary.

688-689: This agrees with results of Clark et al. (2014), though in their evaluation percentiles are designed to encompass S_{msy} ; therefore, the upper bound is likely to be greater than S_{msy} .

726: How was straying included in the model? Was this only for straying of hatchery-origin fish? How was straying assessed – genetics?

762-764: Perhaps inform reader model included 75 years: 5 years pre-initial + 20 years initial + 50 years simulation run. This appears in Figure 10 but a bit confusing in explanation of model description.

794-796: Again, just for hatchery chum salmon?

798: This depends upon the type of visual survey. For example, a weir-based survey could be described as "visual" but is relatively precise. In contrast, an aerial survey of a location with mixed species would likely be imprecise. In addition, is this about precision or accuracy?

804: Is it really uncertainty in catch or uncertainty in stock-specific catch?

824: Insert "a" – ". . . each input parameter one at a time . . ."

867-873: Describe results shown in figure 10 rather than basically reiterate figure legend.

878: Figure 10. It is difficult to separate the dots and dashes in Figure 10(a). Hard to determine whether the upper most dashed line is 80% S_{msy} or the S_{75th} . What do grey solid dots in Figure 10(b) represent?

901-906: These sentences are hard to understand. Lots of "high", "low", "more", "less" which becomes hard to read and interpret.

912-918: Figure 11 caption narrative is difficult to understand.

927-928: Figure 12 perhaps make (a) S_{25th} and (b) S_{gen} so is consistent presentation with figures 11, 13-14.

970-971: See comment above lines 688-689.

Figures 13-17. Inform reader the isopleth lines are the MPEs? Inform reader what darker color/shade in figures means? Figures 13-16 have "data points" for reader to visualize results presented in text, but Figure 17 the visualization is based on color/shade in figure that has been non-issue in previous figures.

1073-1090: Nicely written!

1103: Change "of" to "or" – ". . . <4 recruits/spawner, or harvest rates . . ."

1117-1124: These are the percentile tiers evaluated by Clark et al. (2014), not percentile tiers recommended be used based on their evaluation.

1140-1146: Clark et al. (2014) evaluation was for stocks in which productivity is unknown.

1184-1222: Not clear what is meant by "true" benchmarks. Doesn't this depend on what management goal a benchmark is designed to achieve? This section is well written and you

provided good justification to support the recommendations; however, it could be worth reiterating these benchmarks may also depend on a particular combination of management utility and available information.

1206: Insert “in” – “. . . moderate to low and trends in abundances are . . .”

1219: Delete second “data” – “. . . in data quality and quantity data (spawner . . .”

Sincerely,

[original signed by reviewer]

James J. Hasbrouck

Chief Fisheries Scientist

Cc: Tom Brookover, Director, Division of Sport Fish, ADF&G

Bill Templin, Salmon Chief Fisheries Scientist, Division of Commercial Fisheries, ADF&G

Scott Kelley, Director, Division of Commercial Fisheries, ADF&G

GERALD CHAPUT

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat (CSAS)
Regional Peer Review Process - Pacific

Date: July 7, 2017

Reviewer: Gérald Chaput, DFO Science Gulf Region

CSAS Working Paper: 2015SAL04

Working Paper Title: "Evaluating Benchmarks of Biological Status for Data-Limited Conservation Units of Pacific Salmon, Focusing on Chum salmon in Southern BC"

Overall comments

This is a very thorough working paper and it has addressed all the terms of reference specified for the review.

The modelling exercise is very complete and considered a number of issues around estimation of benchmarks / reference points and assessment of stock status.

I found no issues with analyses conducted, a few specific comments on some aspects are provided below.

Percentiles as benchmarks

Fundamentally, the question is how useful percentiles of historical spawning escapements are in assessing status and presumably provided advice to management. I am not familiar with the entire history of the use of percentiles in Pacific salmon assessments but from analyses presented in this paper, they should be considered interim measures at best. The historical series of spawning escapements reflect a wide range of conditions, driven in large part by fishing. A productive stock that has fished very hard and with low spawning escapements could be assessed as being in a "healthy" state (or green status) even though it is substantially below its productive potential and would be considered overfished. Percentiles can be defined from a white noise time series with no trend in mean level and very small variance but what would those percentiles mean? An analysis of correspondence to relevant states of abundance is warranted as was done in this paper.

The percentile values used for the CUs, as shown in Table 1, show a wide range across CUs. In part, this must reflect differences in productivity among geographic area but also the carrying capacity of the CUs. Has there been an attempt to estimate the freshwater areas that Chum salmon utilize by CU – in terms of kms of stream for example or some other metric? This would be useful to put in context the percentile values of the CUs, recognizing that some of the differences are due to differing productivities (alpha in the SR analyses) but a large part must also be due to gross size of rivers. This is obvious from the SR analyses in which productivity estimates (alpha) vary by a factor of two (1.6 to 3.1) but Smax values vary by a factor of 200 + across CUs.

Appropriateness of proposed lower and upper benchmarks

Sgen as a lower benchmark or in the context of the PA is a defensible lower reference value. If recruitment before fishing is at or below Sgen, the stock would be assessed as being in the critical zone of the PA framework and mortality from fishing should be at the lowest level possible.

The choice of the upper benchmark is more problematic. There is no biological or economic justification for selecting 0.8Smsy as an upper benchmark; it is not consistent with a PA

reference point. The upper reference point or benchmark should ideally be in units of recruitment. If the stock before fishing is at an abundance equal to or above R_{msy} for example, then the maximum removal rate would be at F_{msy} (default value). If the stock at R_{msy} is fished at F_{msy} , then spawners are S_{msy} . In that logic of using spawners to define the benchmarks, it should be spawners that produce 80% of R_{msy} rather than simply 80% S_{msy} as described; the two are not numerically equivalent although in practice they are frequently very close.

$$0.8R_{msy} = 0.8 (\alpha S_{msy} \exp(-\beta S_{msy})) = \alpha 0.8 S_{msy} \exp(-\beta S_{msy}) \neq \alpha 0.8S_{msy} \exp(-\beta 0.8S_{msy})$$

In this exercise of evaluating percentiles based on spawners, then the benchmarks are translated in spawner life stage rather than recruitment.

In the stock and recruitment analyses presented for the informative CUs, there is a large and frequently complete overlap in the posterior distributions of S_{gen} and 80% S_{msy} (Figures 4 and 5; as mentioned in text lines 588-592) which makes one of the benchmarks inappropriate. The upper value must be sufficiently high as to never overlap with the lower benchmark, as a principle in the elaboration of reference points under the PA.

Were alternatives for the upper benchmark considered?

It is very informative to draw the replacement line in the stock and recruitment plots of Figure C1 and to derive the replacement point for each analyzed CU. In several cases, $S_{max} > S_{rep}$, because of very low estimated productivity.

Defensible alternatives are S_{msy} and S_{max} (spawners that produce maximum recruitment), the latter being a good strategy in conditions of poor marine survival or for low productivity stocks. In other cases, for example where $S_{max} > S_{rep}$ (replacement point on the SR curve), spawners that produce a proportion of R_{max} , such as 80% or 90% R_{max} could be considered. R_{max} also tends to be substantially higher than R_{msy} , as are S_{max} relative to S_{msy} . There are two solutions to proportions of R_{max} and proportions of R_{msy} ; if the choice is in terms of a proportion of R_{msy} , the greater value of S_{msy} would be favoured whereas for proportions of R_{max} , the lower value could be considered.

I produced deterministic estimates of alternate stock and recruitment points, S at 80% R_{msy} (when credible), S_{rep} , S for percentages of R_{max} (80%; 90%) using the hierarchical point estimates of alpha and S_{max} values in Table 2. They are summarized in the table that follows.

Note that for 8 of 9 CUs analyzed, S_{rep} is less than S_{max} .

Using S that gives a percentage of R_{max} results in upper benchmarks that are 3 to 4 times S_{gen} whereas 80% S_{msy} as an upper benchmark is always less than 2 times S_{gen} . $S_{XX\%R_{max}}$ values are also closer to the 75th percentile values defined for these CUs. But note also that for some CUs, the upper (75th) percentile benchmarks are greater than S_{rep} for CUs of low productivity.

Table E1. Deterministic estimates of alternate stock and recruitment points, S at 80% R_{msy} (when credible), S_{rep} , S for percentages of R_{max} (80%; 90%) using the hierarchical point estimates of α and S_{max} values in Table 2 of working paper.

CU	from tables 1 and 2 of working paper					Deterministic					
	alpha	Smax	Sgen	25 th perc	75 th perc	Smsy (ER)	80% S_{msy} (ER)	R_{msy}	S_{rep}	S for 80% R_{msy} (ER)	S for 0.9 R_{max} (ER) / 0.8 R_{max} (ER)
South Coast Streams	1.60	67,219	9,636	5,425	54,350	14,757 (0.22)	11,806 (0.26)	18,957	31,593	~ 11,000 (0.27)	~41,000 (> S_{rep}) / ~31,500 (<0.01)
North Vancouver Island	1.70	101,040	16,292	16,519	75,136	24,816 (0.25)	19,853 (0.28)	33,000	53,615	~19,000 (0.28)	~61,300 (> S_{rep}) / ~47,500 (0.06)
Upper Knight	2.18	16,756	2,944	2,006	11,191	5,817 (0.35)	4,653 (0.39)	8,961	13,058	~4,200 (0.41)	~10,100 (0.16) / ~7,900 (0.27)
Loughborough	2.24	64,033	12,227	17,313	46,303	22,905 (0.36)	18,194 (0.41)	35,878	51,641	~16,500 (0.43)	~38,500 (0.18) / ~ 30,300 (0.28)
Bute Inlet	2.32	111,430	21,257	11,275	85,517	41,364 (0.38)	33,091 (0.42)	57,046	93,776	~29,500 (0.44)	~68,000 (0.21) / ~52,300 (0.31)
Georgia Strait	2.67	608,911	116,883	202,269	445,139	257,890 (0.43)	206,312 (0.47)	392,543	597,998	~185,000 (0.49)	~370,000 (0.31) / ~290,000 (0.39)
Howe Sound	2.47	559,155	107,571	85,394	303,280	220,797 (0.40)	176,638 (0.44)	318,117	505,598	~155,000 (0.47)	~340,000 (0.26) / ~265,000 (0.35)
NWVI	2.51	62,597	11,997	24,811	73,650	25,092 (0.41)	20,074 (0.45)	36,562	57,607	~18,000 (0.47)	~38,000 (0.27) / ~29,500 (0.36)
SWVI	2.78	348571	66,202	204,065	433,640	150,875 (0.44)	120,700 (0.49)	236,352	352,159	~105,500 (0.51)	~210,000 (0.34) / ~163,000 (0.42)

Benchmarks or reference points for an entire CU versus individual populations

In the simulation portion of the paper, the dynamics of a CU are modelled as a combination of sub-populations, each of which presumably had sub-population specific alpha and Smax parameter values. In Section 3, it is indicated that the model was for a single generic CU with multiple sub-populations and CU-level benchmarks were estimated by aggregating data across individual sub-populations. The model used 5 sub-populations (appendix E, line 1451) with productivities and Seq set at similar values for the 5 sub-populations (Seq = 10,000) (page 25, lines 781-782). Similar straying rates of 5% (line 794). These details should be provided in one location (appendix E for example).

The dispersion function described in appendix E, lines 1481 to 1489 is not clear. The sub-populations are in a single river and dispersion is based on a random draw of distances between sites between 0 and 100. Is this realistic and what is it adding, other than increased uncertainty to the model?

Does the sum of individual population reference values equal the CU reference value? If each sub-population has a stock and recruitment dynamic, and their corresponding benchmarks or reference values, then the CU derived benchmarks based on aggregated data are not likely simply the sum of the sub-population benchmark values. There is added risks of sub-optimal escapement to populations within an aggregate unit when managing at an aggregated scale. This was shown by Chaput (2004. Considerations for using spawner reference levels for managing single- and mixed-stock fisheries. ICES Journal of Marine Science 61: 1379-1388) and discussed in Prévost et al. (2003. Setting biological reference points for Atlantic salmon stocks: transfer of information from data-rich to sparse-data situations by Bayesian hierarchical modelling. ICES Journal of Marine Science, 60).

Comments on conclusions

I generally agree with the discussion on appropriateness or not of using percentiles for establishing benchmarks. I do not entirely agree however on the idea of trying to adjust percentiles that are not validated with population dynamics analyses based on contrasts in historical spawner escapement series. All the proposed adjustments appear to be ad hoc. Productivity and size of the CU rather than harvest rate should be considered when establishing percentile based benchmarks, if that is the only option available. Modelling Smax hierarchically should be considered, with CU size as the covariate.

The use of $0.8S_{msy}$ as an upper reference level needs to be discussed, in light of the analyses presented. It does not have the desired properties of an upper reference value, i.e. is sufficiently above the lower reference value (low risk of falling to the LRP if the stock is managed at the upper level).

Comments on recommendations

Seems based on the analyses presented for Chum salmon CUs, that the use $80\%S_{msy}$ as an upper benchmark as defined in WSP needs to be reconsidered. I would recommend alternate reference values based on spawners that produce a percentage of R_{max} .

Specific comments and questions:

1. Short section on Chum salmon biology

It would be useful for the non-Pacific salmon reviewers to have in the working paper a short summary paragraph on biology of the species, with specifics on the components of life history that relate to the stock and recruitment dynamics being modelled. Of particular interest is the fact that Chum salmon migrate to the ocean as fry immediately after emergence or somewhat around that time and this has consequences for when density dependence occurs. I assume it

occurs at spawning time, driven primarily by redd superposition or spawning habitat quality variation and red guarding.

2. Modelling Smax hierarchically

Alpha is modelled hierarchically across CUs but not Smax. Alpha being dimensionless can be easily modelled hierarchically, and represents productivity across all habitats (freshwater and marine) although it is presumably affected most by the quality of the spawning habitat and perhaps by the biological characteristics of spawners across populations (for example, fecundities and egg size as discussed by Salo 1991. In Groot and Margolis 1991). Carrying capacity estimates (as defined by Smax) are quite variable, with some small CUs (Upper Knight at ~ 16,000 fish) to a three large CUs (Georgia Strait and Howe Sound to Burrard Inlet at ~ 500,000) and many more at intermediate size (~60,000 to ~110,000) (Table 2). Is this variation in estimated Smax due to the geographic size of the CUs? Is there not a proxy for CU size that could be used to model Smax hierarchically as well, for example, sum of kms of stream used by Chum salmon in each CU?

It would have been informative to show bivariate scatter plots of MCMC values of alpha and Smax. Generally, the estimates are highly negatively correlated. This is seen in Table 2 contrasting results from standard vs hierarchical, when estimate of alpha is higher in one version, corresponding Smax estimates are lower. Are the apparent small changes in parameter estimates between the two versions due to one of the parameters being modelled freely and the negative correlation in parameter values?

For the WCVI group, there are only two CUs to estimate $\mu\alpha$ and $\tau\alpha$ (line 497). Can you show the posterior of those parameters versus the prior? The prior for $\mu\alpha$ is centered on $\sim\exp(1) = 2.7$ and the posterior for the CUs in that regional group have a central value that is very close to that (2.51, 2.78).

3. Figure 3b. It would be helpful to place Ricker alpha axis on a common scale across CUs.
4. Line 437. Time series for WCVI ends in 2015 but figure 3b caption has to 2016 for WCVI CUs.
5. Lines 483 (end) and 484: this sentence is just left hanging; belongs elsewhere.
6. Line 487. τ_S in equation 5 belongs in appendix B?
7. Line 529-530: bootstrap with replacement of the spawner abundances. Implies no autocorrelation in the time series of spawner values. Is this reasonable?
8. Lines 536 – 542: This is not clear at all. Is the first approach described in lines 536-537 used for Figure 6 and the second approach used for Figure 7 but they are not combined as seems to be described in lines 540-543? I think I understand them if they are separate.
9. Figure 6. Why are there gaps in the retrospective analyses for the Ricker method, especially when there are values for the hierarchical method but not for the standard method (Southern Coastal Streams and North East Vancouver, for example)?
10. Productivity over time section, section 2.2.5 and results on page 21 lines 667+. By incorporating a time varying alpha parameter, was the process error (v) smaller? I would expect so. It would be informative to show the difference in values.
11. Figure 11. The figure panel labels (a and b) and the labels in the caption are reversed.
12. Table 5 is better placed in Appendix E.
13. Figure C1. Add the replacement line to the figures.

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14. Appendix D age 59, lines 1431 – 1432. Should read: “These figures show that the upper percentile benchmark is always higher than the Ricker-based ~~lower benchmark (S_{gen})~~ upper benchmark ($0.8S_{msy}$), while at...”. This is in reference to figure D1, panel on the right.
 15. Lines 1587 to 1588. “Harvest rates were constrained to be between 0 and 1.” Does that mean values greater than 1 were set to 1? Why not use a logit transformation?