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Proceedings of the Pacific regional peer review on Estimates of Biological Benchmarks for the Canadian-origin Yukon River Mainstem Chinook Salmon Stock Aggregate

January 18-20, 2022
Virtual Meeting

Chairperson: Erika Anderson
Editor: Jill Campbell

Fisheries and Oceans Canada
Pacific Biological Station
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Canada

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 on January 18-20, 2022 via video teleconference. The working paper focusing on estimates of biological benchmarks for the Canadian-origin Yukon River mainstem Chinook Salmon stock aggregate was presented for peer review.

Due to the COVID-19 pandemic, in-person gatherings have been restricted and a virtual format for this meeting was adopted. Participation included DFO Science and Fisheries Management staff; and external participants from Council of Yukon First Nations, Selkirk First Nations, Yukon First Nations Salmon Stewardship Alliance, National Oceanic and Atmospheric Administration, United States Fish and Wildlife Service, Alaska Department of Fish and Game, Pacific Salmon Foundation, Auburn University, and University of Alaska.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report providing advice to DFO Treaties and Fisheries Unit, Yukon-Transboundary Rivers Area to inform subsequent fisheries management recommendations to meet treaty/international obligations and Precautionary Approach commitments.

The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat website.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) was held on January 18-20, 2022 via an online meeting platform (Zoom) to review the working paper on estimates of biological benchmarks for the Canadian-origin Yukon River mainstem Chinook Salmon stock aggregate.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Treaties and Fisheries Unit, Yukon-Transboundary Rivers Area. Notifications of the science review and conditions for participation were sent to DFO Science and Fisheries Management staff as well as representatives with relevant expertise from Council of Yukon First Nations, Selkirk First Nations, Tanana Chiefs Conference, Yukon First Nations Salmon Stewardship Alliance, National Oceanic and Atmospheric Administration, United States Fish and Wildlife Service, Alaska Department of Fish and Game Commercial Fisheries Division, Alaska Department of Fish and Game Division of Sport Fish, Bering Sea Fishermen's Association, Association of Village Council Presidents, Sustainable Salmon Alliance, Pacific Salmon Foundation, University of Alaska, and Auburn University.

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

Connors, B.M., Cunningham C., Bradley C.A., Hamazaki T., and Liller, Z.W. 2021. Estimates of biological benchmarks for the Canadian-origin Yukon River mainstem Chinook salmon (*Oncorhynchus tshawytscha*) stock aggregate. CSAP Working Paper 2013SAL02

The meeting Chair, Erika Anderson, 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, the purpose of the various RPR publications (Science Advisory Report, Proceedings, and Research Document), 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. All participants confirmed they had received copies of the Terms of Reference, working papers, written reviews, and agenda.

The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting, highlighting the objectives and identifying Jill Campbell as the Rapporteur for the review. The Chair then reviewed the ground rules and process for discussion, reminding participants that the meeting was a science review and not a consultation. The virtual meeting was held via video teleconference, where audio and text conversations were conducted. Members were reminded that everyone at the meeting had equal standing as participants and that they were expected to contribute to the review process if they had information or questions relevant to the paper being discussed. In total, 26 people participated in the RPR (Appendix D).

Detailed formal reviews were requested from Matt Catalano (Auburn University, Alabama USA), Ben Staton (Independent Consultant), and Joel Harding (DFO Salmon Enhancement Program) and these reviewers shared their comments during the meeting to facilitate the peer-review process. Additionally, all participants were required to provide reviews of the working paper and the main topics identified in the participant reviews were presented to the group (see Appendix E for the three formal reviews and a summary of the participant reviews).

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to DFO Treaties and Fisheries Unit, Yukon-Transboundary Rivers Area to inform subsequent fisheries management recommendations to meet treaty/international obligations and Precautionary Approach commitments. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat website.

GENERAL DISCUSSION

Following a presentation by the authors, the Chair presented a summary of the participant reviews and the three formal reviewers, Matt Catalano (Auburn University, Alabama USA), Ben Staton (Independent Consultant), and Joel Harding (DFO Salmon Enhancement Program), shared their comments and questions on the working paper. The authors were given time to respond to the reviewers in turn before the discussion was opened to all participants. This proceedings document summarizes the discussions that took place by Terms of Reference objective, where points of clarification presented by the authors in their presentations and questions and comments raised by the reviewers and participants are captured within the appropriate topics.

TOR OBJECTIVE 1 TOPICS

Diagnostics of model fits to data

Reviewers requested the authors generate plots of residuals of model fit to data to determine if there were time trends or obvious covariance amongst systems that might warrant further analysis or bias inference. The authors presented a suite of residual plots and the group determined that autocorrelation may be occurring in some tributary data sets, however this was not considered a major concern. It appeared there were more negative deviations at the tail end of the time series for some tributaries, but this was not thought to indicate violations of model assumption of stationarity. A reviewer pointed out that the leave-one-out sensitivity analysis also did not indicate that any individual time series of tributary spawner data strongly influenced estimates of Canadian run-size.

These plots and text to interpret the findings from them will be included in the Research Document in Appendix C.

Data gaps, biases, and their consequences

The authors presented a qualitative analysis table of some known or potential biases, indicating the possible degree of bias, and if that bias is anticipated to result in an over or under estimate of Canadian run size or stock-recruit (SR) productivity.

The authors will add this table to the Research Document in Appendix B and will include rows on underestimation of Canadian First Nation harvest and en-route mortality in Canada and will also add a column indicating the implications for each bias on S_{MSY}/S_{MSR}.

A participant indicated that a First Nation harvest study has not been done since the early 2000s and that more work around this should be done, but with community support or community led.

Model assumptions

A reviewer requested a more explicit definition of assumptions (e.g., observation errors are time-independent, observations errors are project-independent) and an assessment of whether they have been met, and if not, what that would mean for the model outputs.

The authors will add in-text clarification in the Research Document.

Integration of the run reconstruction and spawner recruit models

The approach taken in this analysis to integrate these two models differs from what is typically done. Some reviewers were not sure the approach taken here is truly 'integrated' and wondered why both models estimate the Canadian-origin run size as opposed to sharing a single estimate. A reviewer indicated the way the authors explained the model integration in their presentation helped to address their concerns and that since both models suggested similar estimates of run-size this approach appears to be effective. They indicated that a full integration of the two models would be a great deal of work, and is not needed.

The authors will add text in the Research Document to justify their approach and to better explain how the models integrate.

Use and treatment of Whitehorse Hatchery fish counts

A reviewer questioned why this data set was included since it is influenced by hatchery production. It would be anticipated that the stock-recruit dynamics may not be similar to wild populations. The authors responded that the data set was weighted with this in mind, the model abundance estimates were given high coefficients of variations (CVs), the abundance estimate trends are similar to the abundance estimate trends detected at the Eagle monitoring station, and the leave-one-out sensitivity analysis did not raise any concerns with including this data set. The technical report (Pestal et al. in press) has more information on this data set.

The authors will add text in the Research Document Appendix B to further discuss this data set and the efforts undertaken to ensure the inclusion of this data set is warranted.

Consideration of en route mortality

The model does not directly account for en route mortality which was a concern for a participant given these stocks have an exceptionally long migration. The participant noted potential links between en route mortality and decreasing age-at-maturity, reduced female egg mass size, sex bias, and increasing river temperatures. Two components of en route mortality were discussed, en route mortality between Pilot Sonar and Eagle Sonar and en route or pre-spawn mortality in Canada which has implications for escapement estimates. Since en route mortality is not accounted for, it is possible that the spawning stock aggregate abundances are overestimated resulting in underestimations of productivity and biological benchmarks. The group discussed if the data exist to calculate estimates of Canadian en route mortality (e.g., by seeing if the residuals from the fits to escapement data are correlated with instream temperatures). However, it was determined that the escapement project data sets in Canada are not robust enough or of long enough duration to run those calculations. As well since many of the tributary populations are small, it would require larger genetic sample sizes at the Eagle Sonar test fishery to determine any differences in abundances between Eagle station and the tributaries. A participant noted that in high stress years it appears that the return timing in some of the Canadian tributaries is delayed and fewer fish return. These factors may help modelers explore Canadian en route mortality in future work.

The group highlighted the need for long term monitoring data for all high priority research questions, as inconsistent data sets do not often yield the results that are necessary to fully understand these systems.

The authors will clarify in the Research Document how the model handles en route mortality, en route mortality will be included in the bias table that will be included in Appendix B, and this topic will be identified as a future research need. This could also be identified as an important priority in a future, potential Management Strategy Evaluation (MSE).

Habitat considerations

Some of the participants would have liked to see habitat-related priors in the SR model, and indicated that Chuck Parken (DFO) has developed habitat models based on SR models that may be appropriate. An author indicated that these models are based on watershed size and relationships to estimates of S_{MSY}, and the data are likely not available. However, it is valuable future work. Others supported the author, saying that it is important to understand productivities among the Conservation Units (CUs) within the Canadian stock aggregate as it has implications for management decisions.

The authors will mention that future research on the spawning habitat based measures of carrying capacity be conducted to better inform stock-recruitment modeling.

Alpha log normal bias correction

Log-normal bias corrections on the parameter alpha are routinely applied, however, here the authors conducted an analysis in Appendix F, using an uncorrected alpha parameter. A participant indicated that including the analysis using an uncorrected alpha prior was not necessary, stating in their written comment:

> "I don't think distinction between frequentist and Bayes estimation is justification for applying lognormal bias correction in one and not the other, despite the arguments of Stow et al. (2006). The Bayes algorithm provides the posterior predictive distribution, whereas frequentist provides the MLE of the predicted value; they both predict the same point. For the Bayesian approach, when the priors are uninformative, then the MLE matches the median of the posterior, so it doesn't really make sense to apply a log-normal adjustment to one and not the other. However, non-salmon fisheries assessments include the bias correction directly in the likelihood instead of post-hoc adjustment to the alpha parameters (references above). In this case, the Eqn 28 would be adjusted to include the term, - σ^2/2(1-φ^2), so that the alpha' that is subsequently estimated within the estimation algorithm is a little higher than the original alpha. This was the approach applied in the Southern BC Chinook RPA. Ideally, this approach would be used as opposed to post-hoc."

It was agreed that the authors will remove this analysis from the Research Document, any reference to Stow et al. 2006, and remove Appendix F.

Correlation of escapement observation errors

Two types of correlation of escapement observation errors were identified: correlation among tributaries and autocorrelation within a tributary. Participants indicated that further discussion of these errors and factors that may drive these correlations would be useful in the paper. Examples of factors brought up by the group include: changes over time that would influence observations from aerial surveys like water visibility or tree coverage, freshet timing, juvenile outmigration timing, high flows restricting the use of fish traps/screws/weirs, erosion of banks limiting placement of fish screws or weirs.

The authors will acknowledge that these correlations were not explored in this paper and provide justification for this omission, however, it will be identified as a source of future work.

Rationale for excluding potentially informative data

A participant was concerned that data from the Teslin, Pelly, and Klondike tributary escapement projects were not included in this analysis. The authors indicated that information on those data sets is located in the technical report (Pestal et al., in press) and presented slides showing those data sets. The time series for those projects are very short which is why they were not included in the analysis. Considering the quality of the data from Eagle Sonar station and that this research focuses on the stock aggregate not individual tributaries or CU populations, these data sets did not provide much additional information.

The authors will provide in text clarification on the data used, referencing Pestal et al., (in press), as necessary.

This discussion also highlights the importance of long term, robust data sets and their incredible value in properly assessing these systems.

US aggregate stock inclusion

A participant questioned why the United States (US) aggregate stock data was retained in the models and if the removal of this information would impact the benchmark values or reduce the credible intervals (CI), potentially making the CIs more useful. The authors indicated that the Lower and Middle stock data allowed for a fuller consideration of other datasets that are informative of Canada stock size (like Pilot Station Sonar, U.S. harvest, and Genetic Stock Identification). Removing these projects may artificially narrow CIs, while considering them provided a more realistic representation of uncertainty.

The order of harvest and escapement in the Middle River

A reviewer wondered if the order in which the model accounts for harvest and escapement in the Middle River would affect the model outputs. It is not clear in the paper if it is assumed that all harvest occurs directly above Pilot station and then escapement occurs after this point. The authors responded that the order should not matter as the model is doing a simple accounting exercise: the stock-specific escapement is equal to stock-specific abundance minus stock-specific harvest. However, the authors do not assume that all harvest occurs directly above Pilot station, rather, harvest occurs above Pilot station and below the tributary escapement projects.

The authors will provide in text clarification as to how the model accounts for harvest and escapement in the Middle River. The authors will also consider if the map could be updated to better indicate this.

TOR OBJECTIVE 2 TOPICS

Usage of S_{GEN} is not appropriate for a stock aggregate

Several participants indicated that the biological benchmark S_{GEN} has a specific interpretation in the Wild Salmon Policy and estimating S_{GEN} at a stock aggregate level is inconsistent with the meaning of S_{GEN}. In order to use this biological benchmark the authors would want to ensure all component populations are above S_{GEN}, for example to derive a Limit Reference point. However, this is well outside the scope of this work and data availability. It was determined that S_{GEN} was not a requirement of the TOR as it is listed only as an example of a biological benchmark that could be explored. There are no consequences to removing it from the paper.

All mention of S_{GEN} will be removed from the Research Document.

TOR OBJECTIVE 3 TOPICS

Prior justification, diagnostics, and sensitivity

Reviewers and participants were interested in the proximity of some model parameter estimates to the boundaries of their priors. The authors indicated the prior distributions were a legacy of how these models were specified in the past. The authors presented histograms of each tributary prior and posterior for the K parameter to demonstrate this concern to the group. The skewed distribution of some of the K parameter tributary priors may indicate that the Eagle sonar and fishwheel data are not informing the posteriors or alternatively, that these data indicate that the prior is correct. It was suggested that the distribution limits could be relaxed and the model rerun to determine if the outputs change, however, the authors indicated this may result in model convergence issues. A reviewer indicated that looking at the likelihood values for the priors could indicate if the prior and the data are indicating the same value, although they did not recommend the authors take this step. An author noted the prior values were calculated on a log scale which may be affecting how they appear on the plots. However, if the priors were suggesting different values than the data, then the model predictions would not have been able to run through the time series. Since the model was able to run through the time series, this indicates that the K parameter scalers are likely correct, further supported by the fact that the model predictions run through the center of the data. As well, the leave-one-out sensitivity analysis did not indicate any issues with model fit to the data.

The authors will add text to justify the distribution boundaries for the model parameters and will include the figure they presented showing how the K parameter prior and posterior distributions vary for the Canadian tributaries.

A reviewer questioned that the way in which the K parameter is incorporated in the model results in very little weight being placed on it. They suggested using the alternative prior $1/K_i \sim$ uniform(0,1) would place more weight on this parameter and will also address the concern of distribution boundary limits that was previously discussed.

The authors will acknowledge this alternative method of calculating K in the Research Document and will provide further justification for their usage of the parameter K.

Effective sample size - harvest proportions

A reviewer indicated there appeared to be a positive bias between the age composition data and the lower river harvest model fits during the early portion of the time series (see Figures C5 and F2a), however, they did not see any discussion about this in the paper. The authors indicated that they aimed to capture the time trends in the age composition while not forcing the model to fit to those data perfectly given their lack of confidence in the historical data. Given the lack of data prior to 1995, the model may be estimating higher harvests during the earlier portion of the time series which would then result in increased historic run size. The authors conducted a sensitivity analysis exploring the sample sizes of the historic versus recent data to explore these concerns. The authors also explained that in the model, harvest stock composition effective sample size serves only to enable estimation fishing mortality. This unconstrained parameter is not anticipated to have a large impact on the model outputs. The reviewer and authors discussed the impact of the weighting of the age composition data set from the lower river harvest in the SR model on the model outputs, but determined that ultimately this issue is not of major consequence to the model results.

The authors will provide context in the Research Document to indicate that the impact of harvest stock composition effective sample size on model outputs is thought to be minimal. They can reference Appendix D in the data report (Pestal et al. in press) that discusses the history of stock identification and age analysis to provide further context.

Spawner-recruitment structural form

There was concern among participants that how density dependence is handled in the spawner-recruit model might not be biologically relevant for this stock aggregate. It was noted that the long migration time for these stocks may be a greater limiting factor than the survival of eggs and offspring due to density dependence limitations in the natal streams. A reviewer noted that in the Columbia River, density dependence among spawners and juveniles in the natal streams is not a concern as the juveniles are able to move downstream. A participant indicated that a future effort to define the recruitment dynamics of the individual component populations would be very useful in understanding aggregate production and informing escapement goal analyses. The authors identified this same point and highlighted it in the Working Paper. This increased understanding of the ecology of the system could also impact the SR relationship and could inform the best SR model to use to describe the system. Another topic raised is that this model is aggregating across numerous populations, each with its own abundance and productivity, which might not be accurate at this aggregate level. The authors had identified this issue in the working paper and provided input as to why it could not be addressed at this time and the data requirements needed. There was some discussion over how various SR models may impact the results, with the Ricker, Beverton-Holt, and hockey stick models being discussed. However, an author pointed out that the main limitation to the stock recruit analysis model is the lack of data, not the type of SR model used. Participants noted that a possible future MSE could explore how the various SR models impact forward projection abundances.

The authors will add text indicating that other SR models exist, but that they did not explore alternative forms of the SR relationship other than the Ricker and Beverton-Holt models. They will acknowledge that explorations of alternative SR models is important future work with implications for forward simulations of stock abundances.

TOR OBJECTIVE 5 TOPICS

Contextualize uncertainty of biological benchmarks into advice

Reviewers and participants commented that the discussion section did not adequately contextualize the model and sensitivity analysis uncertainties in a way that could best support decision makers. Specifically, participants asked for more context around data gaps, how the cumulative uncertainties may impact model results, what the implications of these uncertainties may mean for decision makers, and what these results can and cannot address or inform. However, participants did not indicate that discussion of these uncertainties would erode the confidence in the overall results. The authors indicated that this work is only one step of a larger body of work to follow, and therefore providing context in the introduction on where this research fits into the whole would help to situate the readers.

The authors will add more context around the uncertainties and caveats discussed as well as frame the overall context of this research in the broader scope.

Sub stock diversity

There was discussion throughout the meeting that the Canadian stock aggregate is composed of distinct populations with diverse ecologies and that this point should be further emphasized in the paper. A participant noted that an implication for calculating benchmarks on an aggregate stock frequently is that there is a risk of negatively impacting these small populations. A participant cautioned the authors to provide enough context for managers in the discussion indicating that these benchmarks do not take stock-specific diversity or concerns into account, that some stocks may be less able to sustain certain escapement goals that others, and that management goals and decisions would benefit from involving those who would be impacted by those goals and decisions in the decision making process. The authors indicated they have discussed the context for management decisions in the working paper and it is beyond the authority of the authors to involve all parties who may be impacted in the decision making process.

The authors will provide additional detail on the life history and biology of the stock aggregate in the introduction and can mention that specifics about individual populations are not considered within their analysis. However, population specific modeling could be identified as valuable future work.

Time varying population parameters

Some participants questioned the assumption that productivity is a stationary parameter. The authors indicated that they do not have clear guidance to choose a time frame to average productivity reference points over. They indicated that there are differing opinions on whether to manage for the average state or the current state, and if the stocks are managed over the current state, how often should the escapement goals be re-evaluated. Another participant said that if time varying models indicate potential changes in productivity it does not necessarily need to translate into changes in the escapement goals, as there are other long term approaches managers can consider. Time varying productivity and how to best incorporate it in models and management decisions was identified as an area for future work.

Participants asked the authors if they explored allowing productivity to vary over time in the model or if they considered truncating the data. The authors explored estimating time-varying productivity (as a random walk) on the outputs of the base model. The authors did not truncate the data, however to determine the consequences of changes to spawning stock demographics, they did look at the first decade, last decade, and time series average estimates of S_{MSY} and S_{MSR} in the escapement quality analysis.

There was a great deal of concern among some participants that there is evidence of a recent regime shift, potentially as a result of climate change, migration stress, and/or demographic shifts, which may also be impacting recruitment dynamics. Specifically, the 2020 and 2021 return abundances were extremely low in some Canadian tributaries, but data from these years was not included in this analysis. There was concern that the past may no longer be a good indicator of the future and that caution should be exercised. There was also concern among participants that the benchmarks explored here may not be the best benchmarks to manage these stocks going into the future.

The authors will add text to recommend time-varying population processes be included in future work (e.g., escapement quality extensions, MSE).

GENERAL DISCUSSION TOPICS

Additional background on the stock biology and fisheries

A participant indicated that some readers might not be familiar with the biology of Yukon River Chinook Salmon or of the historic work done on these populations. It was recommended the authors address this in the Introduction of the Research Document.

Terminology definitions and consistent usage

Mainstem: This term was thought to imply a natal group to the mainstem, which is not the case. The authors indicated this terminology originates from the Yukon River Salmon Agreement and Yukon River Panel. They will add text to clarify the term and to clarify how the stocks are represented within this term (e.g. Porcupine River stock).

Population, run, stock: These terms need clear definitions as they sometimes seemed to be used interchangeably in the paper. Stock is often used to refer to either an individual spawning population or management unit (which may be an aggregation of multiple spawning populations), therefore, using the term aggregate may be more reflective of what is being modeled than the terms stock or population. The authors will clearly define the terms they use in the Introduction of the Research Document. They will also acknowledge that biological processes are occurring at a finer scale than the model is able to capture.

Border passage objective versus escapement goal: A reviewer indicated that they believe in general, not necessarily in this paper, these two terms are used interchangeably, however they are not referring to the same thing. The reviewer indicated that in all prior analyses, including this one, it is assumed that border passage minus Canadian harvest equals escapement and that is an oversimplification. No analysis (including this one) considers en route mortality in Canada. The impact however is for a more conservative estimate of reference points. The spawning escapement goal (set by the Yukon River Panel) and Canadian harvest share (specified in the Pacific Salmon Treaty) are two distinct metrics. Canada's harvest share is not necessarily always included in the border escapement metric.

Benchmark re-evaluation interval

There was discussion on how often this analysis should be conducted again. Participants suggested re-evaluation on a generational timescale (5-7 years), if escapement abundances appear to change drastically, when there is a change in assessment methodology, improvements in salmon stock assessment statistical methodologies, or changes in data treatment methodologies. The timeline should also consider the management reasons for re-evaluation. A participant indicated that if the data were available, the assessment should be conducted at the population or CU level and summed up rather than at the stock aggregate level. The group acknowledged that determining a timeline is out of the scope of this work, but is important future work. The frequency of assessment could be evaluated as part of a future MSE process.

The authors indicated that the Yukon River Salmon Agreement lays out how re-evaluations will be determined and that the Joint Technical Committee reviews this annually.

CONCLUSIONS

Meeting participants agreed the working paper satisfied all Terms of Reference objectives. The working paper was accepted with minor revisions (see Appendix E for table of proposed revisions, some suggested edits did not generate discussion and are therefore not mentioned above).

ACKNOWLEDGEMENTS

We appreciate the time contributed to the RPR process by all participants. In particular, we thank the formal reviewers, Matt Catalano (Auburn University, Alabama USA), Ben Staton (Independent Consultant), and Joel Harding (DFO Salmon Enhancement Program) for their time and expertise. We also thank Jill Campbell as the Rapporteur.

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Pestal, G., Mather, V., West, F., Liller, Z., and Smith, S. (In press). Review of available abundance, age, and stock composition data useful for reconstructing historical stock specific runs, harvest, and escapement of Yukon River Chinook salmon (*Oncorhynchus tshawytscha*), 1981-2019. Fisheries and Oceans Canada Technical Report.

APPENDIX A: TERMS OF REFERENCE

ESTIMATES OF BIOLOGICAL BENCHMARKS FOR THE CANADIAN-ORIGIN YUKON RIVER MAINSTEM CHINOOK SALMON STOCK AGGREGATE

Regional Peer Review – Pacific Region

January 18-20, 2022
Virtual Meeting

Chairperson: Erika Anderson

Context

In 2002, Canada and the United States (U.S.) confirmed the Yukon River Chapter of the Pacific Salmon Treaty (1985) where the spawning escapement goal of Canadian-Origin Yukon River Chinook was set at 33,000 to 43,000. This escapement goal was set based on the understanding of the dynamics of the stock and the specific assessment metrics used at that time. Since then, the metrics of assessment and associated data have become more informative and expansive, resulting in variations in this spawning escapement goal over the last two decades. These revised spawning escapement goals have always been considered interim in nature, until such time that a comprehensive review can be completed, and the Yukon River Salmon Agreement can be updated to reflect a new goal. There have been multiple analyses of the stock's dynamics relevant to escapement goal considerations (Sandone 2010; Jones et al. 2012; Bue and Hamazaki 2014; Hamazaki and Decovich; Jones et al, 2018), but there have been no comprehensive reviews that were carried out entirely through joint Canada and U.S. efforts.

The Joint Technical Committee (JTC) is comprised of multiple Canadian and U.S. entities (including Fisheries and Oceans Canada [DFO]) and provides technical support to the Yukon River Panel (Panel). The JTC is charged to review existing assessment techniques and investigate new ways for determining total return and escapement and make recommendations on optimum spawning escapement objectives. Furthermore, based on recommendations of the JTC, the Yukon River Panel may from time to time recommend spawning escapement objectives for implementation by the Governments of Canada and U.S. through their management entities (DFO and Alaska Department of Fish & Game [ADFG]), and the Panel may revise the spawning escapement objectives for rebuilt stocks.

In April 2019, the JTC signaled its decision to undertake a quantitative review of the Canadian-origin Chinook salmon escapement goal in response to the Panel's expressed desire to explore the possibility of establishing a biologically-based escapement goal for this stock. As a critical first step, the JTC formed a bilateral working group comprised of individuals with expertise in the assessment and management of Yukon River Chinook salmon and individuals with expertise in modeling salmon population dynamics. The working group was tasked to review available data, develop statistical models, and estimate key biological benchmarks for the purpose of informing escapement goal recommendations.

DFO Treaties and Fisheries Unit, Yukon-Transboundary Rivers Area (YTRA), on behalf of the Joint Technical Committee of the Yukon River Panel, has requested that DFO Science Branch provide advice regarding estimates of biological benchmarks for Canadian-Origin Mainstem Yukon River Chinook Salmon. This assessment will present an analysis and advice respecting biological benchmarks. Methods utilized for biological benchmark assessment will reference approaches and criteria previously developed (see Holt 2009a, Holt 2009b, Grant 2011, Fleischman and McKinley 2013). The advice arising from this Canadian Science Advisory

Secretariat (CSAS) Regional Peer Review (RPR) will be used to inform subsequent fisheries management recommendations to meet treaty/international obligations and Precautionary Approach commitments. Specifically, advice respecting biological benchmarks is needed to ensure that estimates are appropriate for informing future recommendations to the Yukon River Panel regarding escapement goals consistent with DFO's Precautionary Approach (Fisheries and Oceans Canada 2009), emerging requirements under the 2019 amendments to Canada's *Fisheries Act* (Fisheries Act, RSC 1985, c. F-14), and the State of Alaska's Policy for the Management of Sustainable Salmon Fisheries and Policy for Salmon Escapement goals.

Objectives

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

Authors TBD. Estimates of Biological Benchmarks for the Canadian-origin Yukon River Mainstem Chinook Salmon Stock Aggregate*. CSAP Working Paper 2013SAL02*

The specific objectives of this working paper are, for the Canadian-Origin Yukon River Chinook stock aggregate, to:

1. Develop a Bayesian integrated state-space run reconstruction and spawner recruitment model and fit it to available data.
2. Derive estimates of biological benchmarks (e.g., Smsy, Seq, Smax, Sgen) and associated profiles (e.g., yield, recruitment, and overfishing).
3. Document, and examine the consequences of, key data and methodological assumptions related to data weighting, biases in data, priors, and model structure.
4. Explore, to the extent possible with available data, the sensitivity of biological benchmarks to change in escapement quality (e.g., total fecundity and egg mass) over time.
5. Provide guidance on key considerations for next steps to identify an escapement goal and recommendations for future analyses and research to further develop them.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Yukon River Panel Joint Technical Committee and associated organizations
- Fisheries and Oceans Canada (DFO)
- Alaska Department of Fish and Game (ADF&G)
- U.S. Fish and Wildlife Service
- Academia or Academics
- Indigenous and stakeholder communities/organizations

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APPENDIX B: WORKING PAPER ABSTRACT

The Yukon River Basin is one of the largest salmon producing river basins in the world and Chinook salmon (*Oncorhynchus tshawytscha*) from the river have historically supported commercial, subsistence, and First Nations fisheries in both Alaska and Canada. In 2002, Canada and the United States finalized the Yukon River Chapter of the Pacific Salmon Treaty where a spawning escapement goal for Canadian-Origin Mainstem Yukon River Chinook salmon was set. This escapement goal has been revised over time, but has always been considered interim in nature, until such time that a comprehensive review and analysis of available data could be completed, and the Yukon River Salmon Agreement could be updated.

We developed an integrated state-space run reconstruction and spawner-recruitment model fit to data (1981-2019) from various assessment projects that estimate mainstem passage, harvests, tributary escapements, stock-proportions, and age-composition, under a single Bayesian estimation framework. The run reconstruction component of the model reconstructed historical harvest and escapement for three Chinook salmon stock aggregates: the lower, middle, and upper (Canada) portions of the Yukon River basin. The key quantities estimated by the spawner-recruitment component of the model applied only to the Canada stock, and included intrinsic population productivity and the magnitude of within-stock density dependence from which biological benchmarks and inference about expected yield and recruitment across a range of future spawning escapements were derived.

We found that the Canadian-origin Yukon Chinook salmon stock aggregate is moderately productive with positively correlated survival from year-to-year that was above average in 1980s, variable in the 1990s, below average in the 2000s, and has since increased back towards the long-term average in the most recent decade. Equilibrium stock size (S_{EQ}) was estimated to be 111,131 (CI: 81,595-252,704), the spawner abundance expected to maximize long-term sustainable yield (S_{MSY}) was estimated to be 43,364 (29,764-97,664) and the spawner abundance expected to maximize recruitment (S_{MSR}) was estimated to be 70,834 (40,638-192,642).

Female Chinook salmon age composition, and to a lesser extent the proportion of females in the spawning population, has declined over time. These demographic changes have resulted in declines in per capita reproductive output such that for the same number of spawners, early years (1980s) produced above average total eggs or eggs mass, whereas recent years (2010s) produced below average total eggs and egg mass. We adapted the integrated state-space run reconstruction and spawner-recruitment model to account for these changes and found that the spawner abundance expected to maximize yield or recruitment was estimated to be on average 13% and 18% greater, respectively, in recent years than in our baseline analysis that did not take demographic changes in escapement into consideration.

Our analyses provide a quantitative foundation upon which to base the development of an escapement goal recommendation, but they do not prescribe one. We therefore describe key considerations when developing an escapement goal based on the information we provide including defining the decision context and objective(s) of the escapement goal, identifying the magnitude of acceptable risk (i.e., risk tolerance) of not meeting stated objectives, and identifying key uncertainties to help ground the degree of precaution that should be taken when establishing an escapement goal in the face of imperfect information.

We conclude with recommendations for future work. These include a more comprehensive consideration of the consequences of demographic change in the spawning stock and explicit consideration of trade-offs between the harvest rates, and escapement goals, predicted to maximize aggregate yield (or recruitment) and risk to individual weak (less productive) populations within the Canada stock aggregate. We also recommend undertaking a

Management Strategy Evaluation that quantifies trade-offs among a broad range of objectives and evaluates the ability of alternative management strategies to meet them as part of a collaborative process with fishery participants, Traditional Knowledge holders, and resource managers.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat
Centre for Science Advice Pacific
Regional Peer Review Meeting (RPR)

Estimates of biological benchmarks for the Canadian-origin Yukon River mainstem Chinook salmon stock aggregate

January 18 - 20, 2022
Virtual

Chair: Erika Anderson

DAY 1 – Tuesday, January 18

Time (PST)	Subject	Presenter
1300	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
1330	Presentation of Working Paper (Overview)	Authors
1415	Clarification Questions	Participants
1430	***Break***	
1445	Summary of Participant and Formal Reviews	Chair & Authors
1500	Formal Reviews and Authors Response	Chair, Reviewers, & Authors
1550	Wrap Up Day 1	Chair
1600	**Adjourn for the Day**	

DAY 2 - Wednesday, January 19

Time (PST)	Subject	Presenter
0900	Review Agenda, Housekeeping & Status of Day 1	Chair
0915	Carry Forward Outstanding Issues from Day 1	Participants
1030	***Break***	
1045	Formal Reviews & Response Continued	Reviewers & Authors
1200	***Lunch Break***	
1300	General Discussion	Participants
1445	***Break***	
1500	General Discussion	Participants
1550	Develop Consensus on Paper Acceptability & Agreed upon Revisions (TOR objectives)	Chair
1600	***Adjourn for the day***	

DAY 3 - Thursday, January 20, 2022

Time	Subject	Presenter
0900	Review Status of Day 1 & Day 2	Chair
0915	Carry Forward Outstanding Issues from Day 1 & Day 2	Participants
1030	***Break***	
1045	General Discussion	Participants
1115	Introduction of the Science Advisory Report ● Preliminary list of conclusions (bullets)	Chair
1200	***Lunch Break***	
1300	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: ● Summary Bullets ● Results & Conclusions ● Sources of Uncertainty ● Figures/Tables	Participants
1445	***Break***	
1500	SAR Finalization ● SAR review, approval process, and timelines ● Research Document & Proceedings timelines ● Other follow-up or commitments (as necessary) Other Business arising from the review	Chair & Participants
1600	***Adjourn the Regional Peer Review Meeting***	

APPENDIX D: PARTICIPANT LIST

Last Name	First Name	Affiliation
Anderson	Erika	Fisheries and Oceans Canada, Science
Bradford	Mike	Fisheries and Oceans Canada, Science
Bradley	Catherine	US Fish and Wildlife Service
Brazil	Charles	Alaska Department of Fish and Game
Campbell	Jill	Fisheries and Oceans Canada, Centre for Science Advice Pacific
Catalano	Matt	Auburn University, Alabama USA
Christensen	Lisa	Fisheries and Oceans Canada, Centre for Science Advice Pacific
Connors	Brendan	Fisheries and Oceans Canada, Science
Cunningham	Curry	University of Alaska Fairbanks
Hamazaki	Toshihide (Hamachan)	Alaska Department of Fish and Game
Harding	Joel	Fisheries and Oceans Canada, Science
Holt	Carrie	Fisheries and Oceans Canada, Science
Jones	Mike	Council of Yukon First Nations
Lea	Ellen	Fisheries and Oceans Canada, Fisheries Management
Lee	Elizabeth	Alaska Department of Fish and Game
Liller	Zachary	Alaska Department of Fish and Game
MacDonald	Elizabeth (BJ)	Yukon First Nations Salmon Stewardship Alliance
Mather	Vesta	Pacific Salmon Foundation
Murphy	Jim	National Oceanic Atmospheric Administration
Pestal	Gottfried	Independent Consultant
Pfisterer	Carl	Alaska Department of Fish and Game
Savereide	James	Alaska Department of Fish and Game
Smith	Steve	Fisheries and Oceans Canada, Fisheries Management
Staton	Ben	Independent Consultant
Toews	Don	Selkirk First Nations
West	Fred	Alaska Department of Fish and Game

APPENDIX E: REVIEWS

FORMAL REVIEWER: MATT CATALANO (AUBURN UNIVERSITY, ALABAMA USA)

I reviewed the working paper entitled “Estimates of biological benchmarks for the Canadian-origin Yukon River mainstem Chinook salmon (*Oncorhynchus tshawytscha*) stock aggregate” by Connors et al. Overall, this is an impressive piece of work that uses appropriate methods to derive estimates of biological benchmarks for this stock. The authors have clearly met the objectives of the Terms of Reference.

The model is well-described, and the purpose of the paper and the analysis is made very clear. One of the great advantages of the analytical approach taken by the authors is that it allows for the incorporation of multiple sources of uncertainty. This approach will facilitate a management decision-making process that explicitly considers uncertainty and risk. The authors have done a nice job emphasizing this point in Section 5. They have also provided a sound recommendation that their work be used in the context of a formal management strategy evaluation process.

The model structure appears appropriate for this system and the nature of the data. I could find no fatal flaws in the analysis that would call into question the validity of the estimates. I have a few points for clarification and suggestions for additions that I will now provide below, roughly in order of decreasing importance.

1. It would be helpful to have a bit more information from which to judge the model and its fits to the data. The fits to the data look reasonable overall, but it is difficult to assess residuals without explicitly plotting the residuals. I recommend adding an appendix with residual plots for each of the data sources.

   The only fit that looks poor was for the Pilot Station Sonar prior to 2002. The model appears to be biased high here. I was surprised to see this because the model estimates proportionality coefficients (qplt) for Pilot. Thus, I would expect these q parameters would be able to adjust the Pilot predictions downward to fit better. Perhaps the code for the plot is incorrect? If it is not a coding issue, I think these residuals need to be looked into further.

   Additionally concerning Pilot Sonar, the text at lines 453-455 indicates that the model allowed Pilot Sonar to be biased for 1986-1994, and 1995-2001, but was assumed accurate for 2002 and after. However, in Table C1 there are 3 Pilot q parameter estimates (ie the qplt) which indicates that perhaps Pilot Sonar was allowed to be biased for all three time periods? Or is the third qplt for the mark recap? If Pilot is allowed to be biased for the period after 2001, is this a problem for the model? In other words, does at least one of Pilot’s time periods need to be “locked in” by assuming it’s unbiased? I would guess that the stock proportion data at Pilot combined with the Eagle sonar passage having very low observation error would be enough to hold it all together. And the posteriors show no signs that these abundance parameters are not identifiable.

2. Many of the priors are on uniform distributions with somewhat narrow bounds, which could be providing more constraint on the estimates than is desirable. For example, the posterior medians/means of the K parameters for Tincup, Tachun, and Wolf air surveys are pretty close to the upper bound of exp(6)=403 (Table 2). The authors have put a huge amount of effort into providing a mountain of plots and tables for diagnostics, so I don’t want to be greedy. But another diagnostic that would be nice to have is the posterior distributions for each of the parameters. I’m sure these have been looked at by the authors, but I did not have them so was unable to assess the degree to which any of the parameters are bumping up against boundaries. The table of posterior means/medians and 95%CI is very nice but it’s difficult to fully assess the boundary issue with the table alone. If the boundaries are a

problem, relax the bounds and re-run. If course the sigma_add parameters are fine to bump up against 0, but I think the rest of the parameters need to stay clear of bounds except for those rare extreme values that would cause the model to run into a computational error.

3. From a model structure perspective, I did not quite understand the need for the estimation of an additional set of annual abundance parameters for the Canada stock. Could not the RR abundance parameters be fed directly into the SR model? If one were to take this more direct approach, then I think the leading abundance parameters for the Canada stock in the RR would have to be the brood year recruitment state variables rather than the annual abundance parameters that are used to populate the lower and middle river stocks. Essentially, estimating a new set of leading abundance parameters for the Canada stock is somewhat analogous to inputting the posteriors from the RR into the SR model as a separate analysis, although not really because parameter correlations are preserved in the integrated approach that the authors have taken. I don't think the author's approach is inappropriate, it just different that how I was thinking about it. That said, it's possible that I am overlooking some reason why the author's approach is in fact entirely necessary to even make this work. Perhaps the issue is the weighting of the age composition data? Because the age data are from multiple components, they must be weighted to obtain an overall age composition estimate for apportionment of the annual run to cohorts. As far as I can tell, the weighting factors are calculated quantities of the RR model and are thus variable. To prevent circular reference, maybe the abundances in the SR model must be kept separate from the RR, I think. If this is in fact the case, then this is quite clever of the authors and makes sense because it allows the age data to be weighted appropriately rather than averaged outside the model and plugged in as invariant.
4. Appendix C: The errors appear correlated over time for multiple escapement projects. I'm not sure if that is a problem, or if there is much that could be done about it. A previous version of the Canada stock model had correlated observation errors. Incorporating this sort of modeling approach would perhaps increase the uncertainty in the estimates from the model, but I would venture a guess that biological benchmarks would not be altered substantively, assuming this approach would even be estimable.
5. On line 673 of Pestal et al, the EGSC recommends exploring the implications of overestimating the wild Canada Mainstem stock proportions on the integrated run reconstruction and spawner-recruitment model results. Has this been done?
6. How do the Smsy and Smsr estimates compare to running the model the "old" way by modelling just the CA portion and inputting harvest of CA-bound fish in Alaska as data after estimating that harvest outside the model? Presumably the posterior medians/means would be similar.
7. Line 595: I'm surprised that 10,000 iterations are sufficient to achieve convergence. The reported convergence diagnostics clearly indicate that convergence was achieved. Perhaps these models mix much better in STAN than JAGS/BUGS?
8. The assumption of negligible escapement below Pilot, aside from the Andreafsky, appears reasonable. How good is the assumption that middle river harvest occurs immediately above pilot? And what is the effect if that assumption is incorrect? Presumably this violation would have no effect on the Canada stock estimates, but I'm trying to work through the effects on the other stocks.
9. An alternative model structure that could be explored, but I don't view as essential, is one that incorporates time-varying productivity in the form of a random walk on the ln_alpha parameter. In that case, the question then becomes which ln_alpha to use for the estimation

of management benchmarks. Perhaps the last 5 years or last 10 years of the time series could be averaged.

10. Appendix E. This is a very nice treatment of a few examples of data conflicts and how the model is or is not able to sort that out, along with potential ways to handle hypotheses for these behaviors in the future.
11. I agree with the author’s recommendation to further explore spawner quality by including the estimation of size/age based vulnerability to harvest. The size-selective nature of these fisheries, when accounted for in the model, could substantially influence the estimates of Smsy and Smsr.
12. Appendix F.4: I recommend putting the sensitivity to data weighting in terms of management benchmarks as was done for the other sensitivity analyses.
13. Figure 3: Canada stock region on fig 3 should not include the CA portion of porcupine, if I understand correctly.
14. Figure C6 and C7 are too difficult to assess model fit. Replot using the format of the pilot run composition figures (fig C4).
15. I think Table F3 refers to Smsr not Smsy
16. Line 415: change ‘es’ to ‘we’
17. I like the inclusion of the overfishing profile. This will seed the next steps of the decision process with those sorts of downside biological risk metrics.

FORMAL REVIEWER: BEN STATON (INDEPENDENT CONSULTANT)

I have thoroughly reviewed the working paper and I appreciate the opportunity to do so. Overall, I think this is very impressive work that will be useful to the next steps in the recommendation of a biological escapement goal for the Canadian-origin stock of Yukon River Chinook salmon. In this document, I have responded to each of the five questions posed to reviewers; all text written by myself is formatted in italics. I also have many line-by-line comments that are more editorial in nature; I have placed these comments in a separate document for consideration by the authors.

Question #1: Is the purpose of the working paper clearly stated?

Based on the text of the introduction, particularly that found on L158-174, I believe the purpose of the working paper is clearly stated. To paraphrase, the Yukon River Panel has expressed interest in developing a biologically-based escapement goal for Canadian-origin Chinook salmon and this working paper documents the most current (and sophisticated to-date) analysis that could be used to inform such a goal.

Question #2: Has the working paper fulfilled the objectives written in the Terms of Reference?

The five objectives stated in the terms of reference are repeated here as numbered points below; for each stated objective I have placed my assessment on the extent to which each was fulfilled by the working paper.

1. Develop a Bayesian integrated state-space run reconstruction and spawner recruitment model and fit it to available data.

   The authors have developed a state-space spawner-recruitment model that is integrated (in the sense that it occurs within the same Bayesian estimation framework) with the run reconstruction, and it has been fitted to the available data. In this regard, the authors should be commended – these methods are difficult to implement as there are many analytical choices on how they should be best structured, and they are often computationally difficult to fit.

   The run reconstruction model is particularly well constructed and deserves to be recognized as such. Relative to other run reconstructions I have seen (i.e., the one for Kuskokwim River Chinook salmon), this model is a substantial improvement. Specifically, it acknowledges that harvest and escapement are spatially oriented (emphasized in Figure 4): fish that are removed in one location due to harvest or escapement cannot escape and be counted by index projects further upriver. This should increase the validity of the proportionality assumption required by these run reconstruction models (i.e., that each index represents some time-constant fraction of the stock-specific escapement). I found the narrative and mathematical description of the progression of fish up-river and the different processes that occur to the different stocks (i.e., L318-L382) very useful, and Figure 4 is an excellent visual representation of this narrative.

   However, I feel compelled to highlight what I see as an inconsistency with the approach taken by the authors versus what I have most commonly seen done for the integration of the spawner-recruit dynamics model and the run reconstruction. This model has two run abundances for the Canadian-origin stock: one generated by the run reconstruction and one generated by the spawner-recruit model. The model then fits the former to the latter in a log-normal likelihood (via eq. 35). The way a typical integration would be conducted would be to have the run reconstruction only estimate (i.e., have priors for) run abundances for the lower and middle Yukon stocks (since there is no process model to create them otherwise), and have the spawner-recruit model-predicted run abundance for the Canadian stock serve as the run abundance used by the run reconstruction equations and likelihoods. In fact, I am a bit confused by how the model allows the formulation described by the authors. The run reconstruction abundance is defined as a parameter with a prior (as evidenced by Table 2) but is then again defined as an observed random variable with the expected value equal to the spawner-recruit model-predicted run abundance (via eq. 35). Although I have never used Stan to fit a model like this, in JAGS (a very similar software for fitting these kinds of models) this would not be allowed – an error similar to "attempt to redefine node N_RR[y,s]" would be returned. Essentially, the same quantity falls on the left-hand side of two stochastic relations: one being a prior and another being a likelihood. My understanding is that this should be forbidden, regardless of the software used.

I do not think this is a major problem that invalidates the modeling approach taken by the authors or that inherently renders it unreliable – this judgement is based primarily on Figure C8, which shows a high degree of similarity between the two models with respect to Canadian origin run abundance (though the spawner-recruitment time series appears more uncertain in nearly all years). I believe this indicates that similar results would be obtained if the model was more fully integrated as I describe above. However, I do think it lessens the extent to which this model can be considered an integrated state-space model – rather, it is two separate models (i.e., no quantities are shared among them) fitted simultaneously that are linked by a non-intuitive likelihood. I am curious as to why the authors chose this route rather than more fully integrating the population dynamics model with the run reconstruction, and I think it should receive some acknowledgement in the methods section, perhaps several sentences in a devoted paragraph following L590.

2. Derive estimates of biological benchmarks (e.g., Smsy, Seq, Smax, Sgen) and associated profiles (e.g., yield, recruitment, and overfishing).

   This objective was certainly accomplished: eqs. 36, 37, 38, and 39 illustrate the specific calculations used to obtain benchmark estimates based on parameters from the spawner-recruitment model, and the text on L636-651 describes how the associated profiles were obtained – the posterior distributions are shown in Figure 7. The probability profile approach is very useful for expressing the likely outcomes of different escapement abundances weighted by the posterior probability that each recruitment curve is the correct one.

3. Document, and examine the consequences of, key data and methodological assumptions related to data weighting, biases in data, priors, and model structure.

   I believe this objective was mostly accomplished – I have separated my assessment of this objective into data weighting, data biases, priors, and model structure.

   Regarding the data weighting topic, the authors investigated alternative effective sample size scenarios for age composition and stock composition – I would consider this essential to investigate since, as pointed out by the authors, these values were not informed by data (e.g., L713). It was good to see that the model was not terribly sensitive to these choices. However, I would think the same reasoning should apply to the harvest stock composition effective sample size, but the this was not investigated. The authors state that that this investigation was not needed because, "the a priori selection of an ESS of 100 allowed for a precise fit to the harvest data without constraining the model fit to other data sources." (L729-L731). It is not exactly clear what the authors mean by this, and further, it appears as though there may be some model-fitting issues to the harvest data, specifically "Total

Harvest Downriver" (Figure C.5, bottom panel) – the majority of years prior to ~1996 show negative residuals (easier to see on Figure F.2a, which I believe are from the same model fit). I think harvest stock composition data weighting would have been a good analysis to see whether this behavior was sensitive to that data input data. Data weights were additionally investigated for the subjectively assigned observation CVs on escapement indices – this was a good addition and I agree with the authors' assessment that this had little impact on the model results.

Regarding the data biases topic, I do not recall seeing directed analyses on this topic, but there were some issues documented, particularly in Appendix E about the apparent inconsistencies between counts at the sonar sites Pilot Station and Eagle. I appreciated this acknowledgement and agree with the authors' assessment that models like this are useful for identifying and reconciling inconsistencies in monitoring programs like this. Further, the authors identified years where Pilot Station sonar counts were likely under-estimates of the total passage and used catchability parameters to correct for this issue.

Regarding the prior sensitivity topic, I do not believe this was investigated. And, given the role that many of the parameters in the run reconstruction play in scaling counts up to a total abundance that is consistent among many index counts (e.g., the "K", "q", and "p" parameters in Table 2), perhaps prior sensitivity should have been investigated and documented here. Further, each of the "sigma_add" parameters have different priors, and I do not recall seeing a justification for this. The authors often used priors on the log(parameter) in many cases, and the resulting prior on the natural scale parameter can look quite different due to this transformation – in this specific case, the uniform priors that go negative on the log scale put a lot of prior weight on very small values when back-transformed to the natural scale that the model uses. Perhaps this was justified and the authors have a reason for doing so, but I do not recall seeing it discussed. That said, the model appears to fit the index data reasonably well, and if the priors put spuriously too much weight in parts of the parameter space the data did not support, then this would manifest in poor fits to the data. To conclude my thoughts on this topic, I would have liked to see more justification of the priors used for the run reconstruction (I have no concerns for those of the spawner-recruit model), and perhaps some alternatives tried, but relative to the other topics in this objective, this is probably the least important in terms of altering the ultimate inferences that this model provides.

Regarding the model structure sensitivity, this was assessed primarily in the form of (a) escapement quality concerns (see below objective 4, below, for my thoughts on this topic specifically) and (b) the Ricker vs. Beverton-Holt curve. It was prudent of the authors to fit both recruitment models, but I agree with their adoption of the Ricker curve as the primary model for inference since the Beverton-Holt curve would recommend fairly aggressive fishing policies could be adopted. Surely there are other model structures that could have been evaluated (and likely were during the model development process) beyond the form of the recruitment function, however I doubt any of them are critical uncertainties that would vastly change the inference regarding the spawner-recruitment curve for the Canadian stock. I would think most of the potential model structures for the run reconstruction were ruled out because of data limitations, and the spawner-recruitment model is fairly standard. Regarding model structure sensitivity, I believe the authors have sufficiently characterized and documented the primary sources of uncertainty.

4. Explore, to the extent possible with available data, the sensitivity of biological benchmarks to change[s] in escapement quality (e.g., total fecundity and egg mass) over time.

The authors have devoted much attention to incorporating changing demography into their analysis and assessing the sensitivity of biological benchmarks to the alternative model structure that recruitment is a function of total egg (or egg mass) production rather than total spawners (i.e., the base model assumption). They found a similar pattern as that shown by the recent Staton et al. (2021) Kuskokwim River analysis cited by the authors, which is unsurprising since so far as I can tell, the two methods were fairly similar in how changes in demography feedback into population dynamics were modeled. Of note, however, is the reduced magnitude in the extent of temporal change in Smsy suggested by this Canadian-origin Yukon stock analysis relative to the Kuskokwim analysis. This was almost surely a result of the less exaggerated time trends in sex ratio and size-at-age (Figure 9) used by this analysis, and because this analysis assumed a flat age-specific selectivity function for all calculations. When compared to a subset of the Kuskokwim analyses that assumed flat selectivity and no length-at-age trends, the percent change in Smsy is more consistent with what the authors found for the Canadian-origin Yukon stock.

I think this is a sufficient initial analysis of the consequences of time-trending demography on spawner-recruitment dynamics and the resulting sensitivity of biological benchmarks that will be useful to decision makers wishing to account for this issue. This topic of research is relatively new, so no answer provided on the topic at this point should be considered “final”, rather, it is good to now have an indication of the direction we should expect biological benchmarks to be affected by it and initial estimates of the magnitude of its importance. I expect future research on analytical methods for accounting for this to be applicable for the Canadian stock and encourage the authors to continue exploring them. I fully support all four of the recommendations listed in section 5.2.1 (L1063 – 1089).

5. Provide guidance on key considerations for next steps to identify an escapement goal and recommendations for future analyses and research to further develop them.

The authors have certainly accomplished this objective – the entirety of the Conclusions section (L939-1181) is devoted to this topic, which is divided into two subsections – below, I summarize my take-home messages from these sections, and give my assessment of their utility.

The first section details three primary considerations that should be taken into account when using the output of this analysis to inform an escapement goal recommendation. These three considerations include (a) being explicit about the objective of the escapement goal (e.g., maximize yield, minimize variability in yield, etc.), (b) being explicit about the acceptable level of risk tolerance of failing to meet the stated objectives, and (c) additional sources of uncertainty not quantified by the present (base) analysis, such as (i) whether future population productivity will be similar to that observed in the past, (ii) whether demographic changes need to be accounted for, (iii) and whether heterogeneity in subpopulation productivity is substantial enough to warrant finer scale consideration when developing an escapement goal for the stock aggregate. I agree that all three considerations are critical for a formal decision framework to consider as these will almost certainly affect which goal is selected, how it is justified, and what expectations stakeholders and managers should (and should not) have for it. At the conclusion of this section, the authors propose a three-step process detailing the next steps in arriving at an escapement goal recommendation – these proposed steps follow logically from the considerations they raise, and I see them as useful advice for the likely audience of this report.

The second section outlines recommendations for future work, and these take the form of three topics: (a) escapement quality, (b) risks to biological diversity when multiple populations are managed as an aggregate stock, and (c) a management strategy evaluation process. As stated above, I fully support all four recommendations surrounding escapement quality – I think incorporating these features into the analysis would result in more comprehensive and robust inferences about the importance of escapement quality on the likely performance of any candidate escapement goal. Relative to the population diversity recommendations, I agree this should be a part of the discussion of an escapement goal recommendation for the Canadian-origin stock, for all of the reasons highlighted by the authors. Regarding the management strategy evaluation recommendation, I, like the authors, think this is a worthwhile exercise. As the authors state, it would be a more explicit way of incorporating structural uncertainty, additional objectives, and implementation uncertainty into the evaluation of the likely performance of candidate escapement goals. Involving managers and stakeholders could garner more trust in the process and add a sense of ownership over the ultimate decision as well. The authors outline six key steps to complete as part of a management strategy evaluation – although they are worded in simple terms, each of these items takes a lot of work and careful planning and could easily turn into a multi-year process (the idea is to be comprehensive in the set of operating models and management procedures considered). Thus, it may be important to consider whether the goal should be updated to another interim (biological) escapement goal while such an analysis and decision process is completed.

Question #3: Are the data and methods adequate to support the conclusions?

Even in the face of my comment about the modeling framework not being as integrated/state-space as it could be, I believe this is a high-quality analysis that is valid for making the inferences that the authors draw. Models like these are widely recognized as among the most statistically sound approaches to analyzing data that (a) have inherent uncertainty, (b) have temporal gaps, (c) have inherent time linkages (i.e., recruits from a given brood year are observed as spawners in future years) and (d) fall into several distinct categories (i.e. direct estimates of abundance, indices of abundance, and composition by stock or age). I wish to (re)emphasize that there are many decisions to be made in the development of models like these and oftentimes it is not clear which approach is best. These models are highly tailored to the specific spatial structure of the system being modeled and are often made even more specific based on the complexities and changes in monitoring activities over time. Thus, each model is unique and has created a paucity of general-purpose and research-backed advice to guide their development. As such, it is often up to the analysts to make judgements about how each part of the model should be structured, based on their knowledge of the system, its monitoring complexities and limitations, and which parts of the model are likely to be most influential on the ultimate inferences. In navigating these difficulties, I believe the authors have done an excellent job. I did not see any inference in the results, discussion, and conclusions sections of the report as invalid based on my understanding of the model or data presented.

I was especially impressed to see that a comprehensive review of the availability and reliability of the escapement index data sources was performed prior to the analysis (i.e., Pestal et al. In press). Models like these are only as reliable as the data they are tasked with fitting, and I completely agree that such a rigorous review of the extensive escapement index data was necessary. A clear result of this review was the exclusion of a fair number of observations that could have been included but were excluded due to data concerns (red crosses, Figure 2). Although I would liked to have seen a bit more context about the types of data concerns that led to these data points being excluded, I still appreciate the level of transparency involved in Figure 2 to highlight that not all available data were used.

Another area of the model I was pleased to see and that I think makes it more robust than it could otherwise have been, was how multiple age-composition data sources were combined into a single reconstruction of the unfished return age composition (i.e., eq. 32). I have seen this done multiple ways ranging from a combination external to the model to complete integration via independent likelihoods for different age composition data sets. The former approach should be least robust and acknowledge uncertainty the least, whereas the latter should be the most robust. The approach taken by the authors falls somewhere in-between these two endpoints, and although it discards the sampling variability for each of the individual age-composition data sets, the signal from each is weighted by the abundance of fish that it samples (again, via eq. 32); this should be far better than weighting by some other measure such as sample size.

Question #4: If the document presents advice to decision-makers, are the recommendations provided in a useable form, and does the advice reflect the uncertainty in the data, analysis, or process?

This document provides quantitative output and estimates that could be used to inform an escapement goal recommendation, although the authors do not make a specific recommendation from the estimates they derive. However, they have been thorough about reflecting the uncertainty in the data and analysis, as well as in the process they believe should be followed to arrive at an escapement goal recommendation. They provide general advice to decision-makers in terms of the next steps for developing an escapement goal recommendation, specifically those found on L1049-L1062. I believe the management strategy evaluation recommendation they make is especially good and worthwhile to perform, but in the absence of that approach, the probability profiles for equilibrium quantities should be most useful in selecting an escapement goal recommendation. These curves (i.e., Figure 8) incorporate the uncertainty in the recruitment relationship, and although the exact curves (i.e., only those showing 70%, 80%, and 90% of Smsy or Smsr are shown) may not be used, this overall approach makes intuitive sense and decision-makers should find it useful.

Question #5: Can you suggest additional areas of research that are needed to improve the analysis and advice presented in the working paper?

I have several recommendations for additional analyses that could be conducted to increase the readers' confidence in the analysis, but please note that none of my recommendations are strictly essential to complete before considering this work valid.

Sensitivity to harvest stock composition multinomial effective sample size – I highlighted this topic above in my response to Question #2 objective #2. Just like the other effective sample sizes, this data weighting term was selected without being informed by data (this practice is not uncommon). The authors use this as a justification for investigating the sensitivity to age composition and stock composition data sets, but not for the harvest stock composition data set. I would have liked to have seen an analysis that assesses model sensitivity to this value.

Run reconstruction sensitivity to prior selection – I also highlighted this topic above in my response to Question #2 objective #2. Each of the parameters in the run reconstruction has an important role, and many of them serve as proportionality constants that scale an index count up to a total abundance. Thus, a prior on these constants translates into what is essentially a prior on abundance. Table 2 shows that different priors were used for parameters that functionally serve the same role (e.g., the "q" parameters, the "sigma_add" parameters), but I do not recall seeing reasoning for this. I would have liked to have seen some alternative priors tried, or at a minimum, a discussion of why the specific priors were selected and why the authors believe they were unlikely to influence the posterior.

Fully integrating spawner-recruitment dynamics with run reconstruction – I highlighted this topic above in my response to Question #2 objective #1. Please see that text for details of what is meant by "fully integrating". Before reaching eq. 35, I was under the impression that this model was fully integrated and was reasonably confused by eq. 35 for a while. I suggest the authors explore fully integrating the two submodels, as nearly the entirety of the report reads as though they have been fully integrated. I wish to re-emphasize that Figure C8 shows high similarity between the abundances from the two models, so this integration is unlikely to vastly change the inferences. However, the authors state (L207-208) that their intention of integrating the run reconstruction and spawner-recruitment models was to "…preserve the complete information content of the data", and given the lack of full integration (and greater uncertainty in the spawner-recruit abundance than the run reconstruction abundance, Figure C8), I'm not certain this has been accomplished.

More validation of the run reconstruction model assumptions surrounding proportionality constants – this model assumes that each escapement index counts a time-constant fraction of the escapement for the stock to which it belongs (first discussed at eq. 3). I think this is an important assumption, and I appreciate that the authors have acknowledged it to the extent that they do in the text. Additionally, they provide some supporting evidence that has given them confidence in applying the assumption (i.e., that escapement indices are correlated). However, I think more evidence should be presented within this document so readers can verify the authors' claims about the correlations among tributary escapements – I think additional figures showing the correlations are justified. I also think there could be some additional analyses conducted that could help validate whether this assumption is largely valid (as suggested by the model) or if it appears problematic. In particular, I think it would be a good diagnostic to calculate the model-predicted "K parameter" each year and to plot it as a time series and investigate cross correlations in deviations from the model-estimated "K_i" parameter across index projects. That is, take (stock-and-year-specific escapement)/(project-and-year-specific count) to obtain the model-predicted scaler that includes measurement error, and investigate if there are patterns in that quantity: if the model assumptions are reasonably satisfied, variability in the year-specific K estimates should be white noise (no time series patterns) and it should be uncorrelated across index projects.

FORMAL REVIEWER: JOEL HARDING (DFO SALMON ENHANCEMENT PROGRAM)

1. Is the purpose of the working paper clearly stated?

   Yes, however the purpose could be more clearly stated in the introduction prior to section 1.2.

2. Has the working paper fulfilled the objectives written in the Terms of Reference?

   Yes, the working paper has done an impressive job, however the document could use additional advice regarding the considerable uncertainties in the data and model outputs. The authors strengthened the work considerably by conducting post hoc sensitivity analyses, however the discussion and conclusions section seem short and limited in terms of contextualizing the actual results (currently they are more re-summarizing them). Although broad sequential considerations when developing an escapement goal (which I recommend being identified as a border passage goal) are presented, most of the text is quite general in nature. Additional commentary on the model outputs, associated uncertainties and consideration of trade-offs within the context of risk-tolerance and advice on EG development in the discussion and conclusion would strengthen the work.

The paper is somewhat devoid of critical biological information on Canadian-origin Yukon River Chinook salmon. It would benefit from an intro section that provides an overview of the Canadian population aggregate. For example:

- X number spawning aggregations of which many are likely biological populations that occupy tributary streams (refer to Brown et al. 2017)
- Migration timing, potential drivers of recruitment etc..
- Life cycle overview etc.. all populations are stream type, spending one year in freshwater and returning at total ages of x and y.
- X number Conservations Units (provisional) as per WSP, this is the level of aggregation for conservation considerations in Canada.
- This collection of CUs will be referred to as the Canadian “stock” (although Management Unit is probably more consistent with WSP usage.
- Alaskan populations are organized into 2 other MUs/stocks as per map….
- “Run” needs a definition.
- Most of the harvest has occurred in mainstem fisheries in Alaska and in Yukon near the border, although some (%) occurs within tributaries (is tributary harvest ignored in this paper?)

3. Are the data and methods adequate to support the conclusions?

   Yes. This represents the most comprehensive effort to date to estimate spawner-recruitment dynamics of Canadian-origin Yukon River Chinook salmon. The data is a patchwork from various methods with associated limitations across a very broad spatial scale. Inherent uncertainty is considerable and notably models produced asymmetrical, with credible intervals extending considerably higher than median estimates for SMSY and SMSR. This could be more clearly stated throughout the paper.

4. If the document presents advice to decision-makers, are the recommendations provided in a useable form, and does the advice reflect the uncertainty in the data, analysis or process?

   See comments under questions 2. Uncertainty is adequately identified in the paper in terms of results, however contextualizing this uncertainty into advice is somewhat lacking in Discussion and Conclusion. Also, I commend the authors for addressing notable data gaps in Appendix B. where three gaps are identified (hatcheries, Porcupine Chinook population and US harvest in District 5). Each gap is addressed separately and generally bias is thought to be small (2% for hatchery, 2.5-3.5% for Porcupine Chinook harvest and 5% for district % US harvest). Cumulatively this amounts a considerable level of potential bias. Although there are limited options currently for explicitly accounting for this, additional commentary on the consideration of this cumulative bias is warranted. What are the associated risks in tandem with inherent model uncertainties?

   There are considerable model assumptions identified in these analyses. Additional rationalization as to whether these model assumptions are realistic, or more necessary analytical precursors is required for decision makers to consider. See comments throughout.

5. Can you suggest additional areas of research that are needed to improve the analysis and advice presented in the working paper?

Yes. Explicit consideration of enroute mortality and genetic accounting of Porcupine Chinook via reanalysis of US harvest samples under revised SNPs baseline. See additional commentary below.

There are instances where terminology needs to be more consistent throughout this working paper:

- Use of mainstem in ‘Canadian-origin Yukon River mainstem Chinook Salmon’ is not clear, it implies this is a unique assemblage of salmon natal to the mainstem of the Yukon River. Suggest replacing with Canadian-origin Yukon River Chinook salmon and add a definition at the front end of the paper indicating this refers tot eh Canadian aggregate not including Porcupine River Chinook. Could also state that ‘Canadian-origin Yukon River Chinook salmon’ == ‘Canadian-origin Chinook’ through the rest of the paper to streamline.
- The word population is improperly used to describe the Canadian aggregate (see line 195). It is necessary to use consistent wording when describing the basin-wide aggregate, the Canadian-origin aggregate and discrete natal populations.
- Use of term ‘Canada stock’ throughout the paper is awkward, suggesting replacing with ‘Canadian stock(s)’ or even better ‘Canadian aggregate’.
- Use of the word ‘stock’ and ‘run’ throughout is also a bit vague and interchanged or combined, suggest replacing with ‘aggregate’ or ‘management unit’ (MU) where appropriate.
- Order of Lower, Middle and Canadian stocks needs to be consistent throughout paper.

Major Comments

1. En-route/ pre-spawn mortality: it is a very large assumption that escapement = border passage minus harvest, particularly with an aggregate such as Canadian Yukon River Chinook (extreme migration, recent demographic changes towards younger/smaller fish). Process model and elsewhere requires consideration of mortality during migration. Lines 762-763: data conflicts with Pilot and Eagle, mention enroute mortality. Appendix E lines 1164-166 suggest accounting for enroute mortality, I am suggesting this as a high priority to increase effectiveness of these analyses. Frameworks already exist for both Fraser and Columbia salmon populations where enroute mortality is explicitly accounted for.
2. Notion of aggregate stock density dependence/ productivity is a complex one as these ideally apply to discrete populations. In addition, WSP benchmarks (e.g. SGEN) are intended to be implemented at the CU scale. Using at the aggregate level could have conservation implications as the diversity in productivity and size at the CU scale is not incorporated. Therefore SGEN is not appropriate for this aggregate Canadian management unit that encompasses multiple populations and CUs. Mentioned in lines 813 &1040-1046.
3. Commend the team for integrating changes in female size and reproductive potential in this paper. It is an emerging but important consideration in light of demographic shifts observed in salmon in the Yukon and elsewhere. Although limitations exist in the inference of age and sex composition from the fishwheels (pre-2007) this is not unique in this working paper given the numerous limitations in the data and the numerous assumptions made.
4. Escapement goals are typically confirmed by assessment of natal spawning systems, in this case we are assuming all fish that pass Eagle sonar, and are not intercepted in fisheries, make it to spawning grounds and successfully reproduce. Given the distance these fish still have to travel this is a considerable assumption. There could be consideration of changing the term from escapement goal, to border passage target or a more appropriate term. There

would then be opportunity to assess actual effective spawning escapement in natal systems to confirm, and opportunity to consider other factors such as enroute mortality.

PARTICIPANT REVIEW SUMMARY

Below is a summary of the major topics identified by the reviewers.

TOR Objective 1

- Tributary indices of drainage-wide escapement and constant proportionality
- Diagnostics of model fits to data
- More discussion on data gaps (bycatch, hatchery, harvest bias, Porcupine, and/or cumulative impacts)
- Model assumptions and whether met
- Integration of run reconstruction model and stock recruit analysis
- Use of US stock information to inform Canada Stock
- Data weighting (including Pilot Station catchability)
- Harvest bias in US or Canada
- Use and treatment of Whitehorse Hatchery fish counts
- Consideration of en route mortality
- Habitat considerations (including habitat-based priors to inform Seq)
- Alpha – log normal bias correction
- Correlation of escapement observations errors
- Rationale for exclusion of potentially informative data

TOR Objective 2

- Use of S_{GEN} not appropriate for aggregate stocks
- Large uncertainties for biological benchmarks

TOR Objective 3

- Prior justification, diagnostics, and sensitivity
- Effective sample size - harvest proportions
- Stock Recruit Analysis structural form (consideration of depensation)

TOR Objective 4

- Age-Sex-Length (ASL) datasets
- More context to understand limitations and relationship with other work
- Use of alternate spawner metrics in Ricker

TOR Objective 5

- Contextualize uncertainty of biological benchmarks into advice
- Sub-stock diversity and risks
- Clarify text pertinent to domestic policy

- Time varying population parameters, including concerns about climate change

Other comments

- Additional background on stock biology and fisheries
- Terminology definitions and consistent usage
- Recommendations for edits and clarification
- Border passage vs. objective terminology
- Implications of environmental variability
- Comparison of estimates to “old” or published results

Suggestions for future work

- Escapement quality – model extensions and size selective fisheries
- Management Strategy Evaluation
- Genetic heterogeneity of Canadian Stock Aggregate
- Improved assessment and treatment of hatchery fish
- Improved assessment of stocks impacted by Whitehorse Hatchery and Dam
- Extending datasets to include 2020, 2021, future years
- Implications of Pilot Station Sonar bias or en route mortality on in-season management
- Incorporation of juvenile marine abundance to inform time trends in adult abundance
- Retire Ricker model

APPENDIX F: REVISION TABLE

ToR Objective (if applicable)	Topic	Revisions
1	Tributary indices of drainage wide escapement and constant proportionality	In-text clarification of support for assumption (e.g., no time trends in residuals, include median pairwise correlations in abundance among tributaries within stocks and reference specific figures of this in data report). Include alternative prior as option in text and more justification of priors chosen.
1	Diagnostics of model fits to data	Include additional figures of scaled residuals over time for each index in Appendix C and prior and posterior distributions with additional justification for choice of priors. Revise plot of fit to Pilot data (Figure C.1) to account for catchability in early part of time series.
1	More discussion on data gaps, biases and their consequences (bycatch, hatchery, harvest bias, Porcupine, and/or cumulative)	In-text clarification including discussion of cumulative consequences of potential biases and additional potential biases (underestimation of CDN FN harvest, en route mortality in Canada). Include table from Brendan's presentation on biases with column to explain impacts and implications on Smsy/Smsr. What does these mean
1	Model assumptions and whether assumptions were met	In-text clarification of model assumptions, assessment of them being met (e.g., tributary proportionality, harvest upstream of pilot)
1	Integration of RR and SRA	In-text clarification with justification for approach used, caveat term "integrated".
1	Use and treatment of Whitehorse Hatchery fish counts	Add text to discussion of hatchery influence in Appendix B referencing results of LOO sensitivity analyses which indicated removal of Whitehorse index has little/no effect on Canada run estimate
1	Consideration of en route mortality	In-text clarification of issue, Context/implications from existing literature on thermal tolerances in Chinook. Need more context and justification. Priority in MSE.
1	Habitat considerations (including habitat-based priors to inform Seq)	Acknowledge future extensions could investigate use of accessible spawning habitat based measures of carrying capacity to inform spawner-recruitment analyses (e.g., as priors). Parken model
1	alpha - log normal bias correction	Revise text in main body of report to point out that in marine fish assessments log-normal bias corrections are routinely applied in Bayesian estimation (typically directly in likelihood), remove reference to Stow (2006) and only keep appendix F if required by other reviewers.

ToR Objective (if applicable)	Topic	Revisions
1	Correlation of escapement observation errors	Add text acknowledging this could have been done but that we did not, include rationale. Two types: autocorrelation vs amongst tributaries. Possible causes: Envt conditions, water, freshet, juvenile out-migration timing? Direction for future work and in context with others
1	Rationale for exclusion of potentially informative data	In-text clarification, reference to Pestal et al.
2	Usage of Sgen is not appropriate for a stock aggregate	Remove from text, SGen in ToR objectives so address why not appropriate in text (e.g., not appropriate at at the stock aggregate scale and instead was developed for application at the scale of conservation unit under Canada's Wild salmon Policy)
2	Large uncertainties for biological benchmarks	In-text clarification that despite large uncertainty there is still information content in posterior estimates and that when combined with probability profiles there is sufficient information to understand tradeoffs and expected outcomes across a range of potential spawner abundances
3	Prior justification, diagnostics, and sensitivity	In-text clarification of justification for priors used, inclusion of figures of priors/posterior distribution, explain why additional variance terms for abundance estimates and escapement counts (sigma_add) were mildly informative and constructed based on intuition from regarding specific projects.
3	Effective sample size - harvest proportions	In-text clarification that we did not explore sensitivity to harvest stock comp ESS since it is derived from fishing mortality and fishing mortality is a free (unconstrained) parameter, which means their influence is considered minimal.
3	Spawner-recruitment structural form (e.g., scale at which DD occurs, overcompensation, etc.)	Add acknowledgement of this to discussion and emphasize importance of considering alternative structural forms of SR relationship in future work, particular forward simulations. Consider other stock recruit models for considerations (eg hockey stick). More context for Yukon stream type salmon biology. Consider implications of aggregating many populations in SR
4	Age-Sex-Length (ASL) datasets	In-text clarification with discussion/interpretation of sex-ratios that result from fishwheel selectivity correction (e.g., quite high, which might be red flag, but also point out that CDN stock has very high proportion of old (e.g., 7 yr) females and know sex datasets (R. Brown) indicate majority of 7-yr olds are females which could explain high sex-ratio)

ToR Objective (if applicable)	Topic	Revisions
4	Context to understand limitations and relationship with other work	In-text clarification interpreting findings in WP in context of other recent work (e.g., Kuskokwim Chinook salmon) specific to escapement quality
4	Use of alternate spawner metrics in Ricker	WP currently acknowledges assumptions associated with structural form we considered and recommends considering alternatives in the recommendations section.
5	Contextualize uncertainty of biological benchmarks into advice	In-text clarification that despite large uncertainty there is still information content in posterior estimates and that when combined with probability profiles there is sufficient information to understand tradeoffs and expected outcomes across a range of potential spawner abundances. Include caveats to other considerations of biological benchmarks in introduction
5	Sub stock diversity	Currently discussed in conclusions. Stock biology within introduction, including diversity.
5	Clarify text pertinent to domestic policy (e.g., benchmarks vs. reference points, WSP, Sgen, etc)	In-text clarification in introduction/discussion
5	Time varying population parameters, including concerns about climate change	Add recommendation to consider time-varying population processes in future work (e.g., escapement quality extensions, MSE). Changing assumptions about mortality along the way.
-	Recommendations for copy editing and clarification	In-text clarification
-	Additional background on the stock biology and fisheries	In-text clarification using content at beginning of WP presentation on day 1 and suggestions from reviewers.
-	Terminology definitions and consistent usage	In-text clarification
-	Implications of environmental variability	In-text clarification