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Proceedings of the Pacific Regional Peer Review Meeting on the Development of a Biological Escapement Goal for Taku River Sockeye Salmon

November 5-6, 2019
Nanaimo, British Columbia

Chairperson: John Candy
Editors: Cameron Freshwater & John Candy

Fisheries and Oceans Canada
Science Branch
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

August 2021

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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MPO. 2021. Compte rendu de l'examen par les pairs de la région du Pacifique sur l'Examen de l'évaluation du saumon rouge de Taku et établissement d'un objectif d'échappée biologique; Du 5 au 6 novembre 2019. Secr. can. de consult. sci. du MPO. Compte rendu 2021/019.

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SUMMARY

These proceedings summarize the relevant discussions and conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on November 5, 2019 at the Vancouver Island Conference Centre in Nanaimo, B.C. A working paper to identify the spawning escapements that would produce maximum sustainable yields along with other appropriate biological benchmarks for the Canadian-origin Taku River Sockeye salmon stock aggregate was presented for peer review.

The major topics discussed included the best means of referencing data from a related analysis (Pestal et al. 2020) that were necessary to complete the working paper, but were not yet published at the time of the peer review, and the sensitivity of model estimates to uncertain data at the beginning of the escapement time series.

In-person participation included Alaska Department of Fish and Game (ADF&G), Fisheries and Oceans Canada (DFO), the Taku River Tlingit First Nation (TRTFN), a consultant, and academia.

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

INTRODUCTION

A regional peer review meeting was held on November 5, 2019 at the Vancouver Island Conference Centre in Nanaimo to 1) identify the spawning escapements that would produce maximum sustainable yields (MSY) for the Canadian-origin Taku River Sockeye salmon stock aggregate and 2) identify the appropriate biological benchmarks for the management of the Canadian-origin Taku River Sockeye salmon stock aggregate.

The Terms of Reference (TOR) for the science review (Appendix A) were developed to meet the provisions of Chapter 1, Annex IV Paragraph 3(b)(i) of the Pacific Salmon Treaty (Treaty), which calls for the development of a bilaterally agreed MSY escapement goal prior to the 2020 fishing season. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from ADF&G, DFO, the TRTFN, and non-governmental organizations.

The following working paper was prepared and made available to meeting participants prior to the meeting:

Miller, S. E., and G. Pestal. 2020. Estimates of a Biologically-Based Spawning Goal and Management Benchmarks for the Canadian-Origin Taku River Sockeye Salmon Stock Aggregate. CSAP Working Paper. 2018SAL04.

Prior to the meeting, participants also received copies of the TOR, agenda (Appendix B), written reviews (Appendices C), and a draft technical report describing abundance estimates generated by the Taku Sockeye Working Group (Pestal et al. 2020). The run reconstruction analyses within the draft technical report were highly relevant to the working paper because they were used to generate the abundance data necessary to run the state-space model presented in the working paper and they had not been previously published.

John Candy, the meeting chair, welcomed participants and reviewed the role of CSAS in the provision of peer-reviewed advice. The Chair discussed the role of participants and the definition and process around achieving consensus decisions and advice. In total, 18 people participated in the regional peer review (Appendix D). The rapporteur for the meeting was Cameron Freshwater.

PRESENTATION OF THE WORKING PAPER

Both authors, Sara Miller and Gottfried Pestal, were present. An oral presentation was given by each to summarize the working paper described in the following abstract.

ABSTRACT OF THE RESEARCH DOCUMENT

The purpose of this paper is to identify a range of spawning escapements that would likely result in maximum sustainable yields and identify the appropriate biological benchmarks (management reference points) for management of the Canadian-origin Taku River Sockeye salmon *Oncorhynchus nerka* stock aggregate. A Bayesian state-space Ricker model that included age-structure and a one year-lag autoregressive component was fit to 1980–2018 data for Taku River Sockeye salmon greater than 349 mm mid eye to fork length. Data for the state-space model included: 1) estimates of harvest of naturally spawned and enhanced (hatchery-produced) Sockeye salmon above and below the U.S./Canada border in the lower Taku River; 2) capture-recapture estimates of above-border abundance; and 3) weighted age composition estimates of Taku River Sockeye salmon harvested in the U.S. District 111 traditional commercial drift gillnet fishery and Sockeye salmon captured in the Canyon Island fish wheels

in the lower Taku River. Coefficients of variation were also associated with these data sources. Historical annual terminal run, in-river run, and spawning abundances, as well as stock-recruitment parameters and biological benchmarks were estimated from this model. The median estimate of spawner abundance that maximizes sustainable yield, S_{MSY}, was identified as 43,857 fish. A sensitivity analysis on the beta prior of the Ricker model concluded that a uniform distribution produced similar median estimates of key model outputs and biological reference points as the normal distribution prior, although the computation time was greatly increased with the uniform prior. Likewise, a normal prior on beta that was not constrained to be greater than 1.0×10^{-6} greatly reduced the precision on the reference points, but produced similar median estimates of key model outputs. Based on the analyses from the state space model, consideration for the uncertainty in the stock recruit curve, and the minimal contrast within the time series, the recommendation from the Taku Sockeye Working Group is a biological escapement goal range of 40,000–75,000 fish. This range minimizes the risk of overfishing (less than a 10% probability of overfishing the stock at lower bound if optimal yield based on 80% or more of maximum sustainable yield), and has a greater than 50% probability of achieving at least 70% of maximum sustainable yield at the lower and upper bounds.

PRESENTATION OF WRITTEN REVIEWS

CHARMAINE CARR-HARRIS

Please refer to Appendix C for full written review. The main comments are listed below:

- A considerable portion of the working paper described how Alaskan and Canadian management goals were reconciled. While relevant to transboundary assessment processes, these issues are tangential to the central objective of the working paper and would be better placed in a separate document that could be referenced.
- Some of the uncertainties associated with input data, in particular interannual variation in dropout rates, could be better documented in the working paper.
- Although a lot of pertinent information was included in the technical report, moving back and forth between it and the working paper was cumbersome.
- Would be helpful to identify how the analysis could be modified to meet requirements for Wild Salmon Policy integrated status assessment (but noted that was beyond the scope of the current working paper).
- For readers not familiar with the system, it would be helpful to include a brief description of the relative abundance of enhanced fish in the aggregate, as well as information on the proportional contribution of various stocks to the aggregate.

Authors' Response to Charmaine Carr-Harris

The authors described how interannual variability in dropout rates was intentionally inflated to reflect small sample sizes in certain years and propagate uncertainty into the escapement estimates. The authors also described their rationale for evaluating multiple capture-recapture estimates using the Bayesian Time Stratified Population Analysis System (BTSPAS) package, within the R environment, with custom extensions (Bonner and Schwarz 2020). The authors agreed that additional information explaining how capture-recapture abundance estimates were derived should be added to the working paper from the technical report. The authors agreed to add a paragraph describing hatchery contributions and stock composition with references to an external report.

ANDREW MUNRO

Please refer to Appendix C for full written review. The main comments are listed below:

- Similarly to Carr-Harris, noted that moving information from technical report to working paper is necessary for interpretation and reproducibility. Particularly concerned that any changes in capture-recapture abundance estimates resulting from additional work to the technical report could have cascading effects on working paper.
- Why were year-specific dropout rates not applied in years that they were collected (i.e. 1984 and 2015)?
- Noted that overfishing profiles are not typically used by ADF&G when reviewing escapement goals and should be subsidiary to analyses focused on estimating maximum sustainable yield. Additionally this is not a rigorous risk assessment and the authors should be careful not to present them as such.
- Questioned why sensitivity analyses on priors focused on beta, but not other estimated parameters.
- Why was the analysis constrained to fish >349 mm in length?
- Were other diagnostics of model fit, besides the spread of the residuals, evaluated?

Authors' Response to Andrew Munro

As noted above, the authors agreed to add information from the technical report to the working paper so that the derivation of capture-recapture abundance estimates would be more clear. Dropout data from years 1984 and 2015 were not used as year-specific estimates in the model because they were not representative (biased towards particular run-timing groups). The authors noted that although the technical report had not yet been published, the capture-recapture abundance estimates that are used as inputs in the working paper's state-space model were unlikely to change. The authors agreed to reword text associated with the yield, recruitment, and overfishing profiles. The authors noted that sensitivity analyses focused on priors for beta because the literature indicates stock recruit analyses are relatively robust to the form of priors on other parameters. Only fish >349 mm contributed to recruitment estimates because that is the size defining adult salmon in the Taku River. The authors noted that a range of Bayesian model convergences were used (e.g. chain plots, Gelman-Rubin diagnostics) and that these could be added in an appendix.

GENERAL DISCUSSION

INTEGRATING UNPUBLISHED TECHNICAL REPORT (PESTAL ET AL. *2020.*) AND WORKING PAPER

Both reviewers, as well as multiple participants, noted that interpreting the working paper's methodology and assumptions required knowledge of how capture-recapture abundance estimates were derived. This information was only available in the draft technical report (Pestal et. al 2020). For example, dropout rates were used to reduce bias and increase uncertainty in escapement estimates. However, these rates were based on only a few years of radiotelemetry data and how the authors accounted for this was not readily available.

Participants considered integrating the two documents, but did not choose to pursue this because it would have required a full review of the technical report, which was beyond the scope of the CSAS process. Furthermore, the TOR, which was developed in reference to language in Chapter 1 of the Treaty, was fully addressed by the working paper. Instead, the authors agreed to move key components of the draft technical report to the working paper. These components included information on how dropout rate data was applied to capture-recapture abundance estimates, the data sources that were used to estimate age structure, and more information on size-selectivity adjustments.

DROPOUT RATES

As noted above, dropout rates were used to reduce positive bias in capture-recapture abundance estimates. The authors clarified that the analysis accounted for interannual variation in the magnitude of dropout effects, addressing concerns by participants. Multiple participants noted that although dropout effects are rarely accounted for, they clearly have the potential to strongly impact abundance estimates and favoured continuing to account for dropout impacts in subsequent analyses. Participants also noted that dropout rates can be influenced by many different factors (e.g. water levels, temperature, Pink salmon abundance) and encouraged continued funding of radiotelemetry studies that could be used to update estimates of system-specific dropout rates.

SENSITIVITY TO UNCERTAIN ESCAPEMENT ESTIMATES

Several brood years at the beginning of the time series were data deficient and had relatively uncertain estimates of spawner abundance as a result. Participants and reviewers noted that these data points could have a disproportionate impact on the model's estimates of stock-recruit parameters, and consequently estimates of MSY and biological benchmarks, because they represented some of the smallest escapement values in a stock-recruit dataset that already contained minimal contrast. To address these concerns, the authors conducted a sensitivity analysis to evaluate the relative impact of three alternative scenarios: 1) early escapement values have reduced uncertainty, 2) early escapement values have reduced uncertainty and are 25% smaller, and 3) early escapement values have reduced uncertainty and are 25% larger. The posterior distribution of MSY associated with each of these scenarios will be presented in a table in the working paper to better document the sources of uncertainty associated with the analysis.

INCLUSION OF NON-TERMINAL CATCHES

Some participants questioned why U.S. District 111 purse seine harvest was included in the analysis when the objectives focused on terminal fisheries. The authors noted however that the Treaty refers to *all* U.S. District 111 harvest when identifying how Taku River Sockeye salmon abundance should be calculated. Additionally, participants suggested that best practice for run reconstructions was to include all estimates of harvest wherever available.

MISCELLANEOUS

Participants observed that size and age appear to be declining in many systems, including the Taku River, and advised continuing to run the model in future years to account for these effects when identifying benchmarks.

Although a reviewer questioned why multiple methods for calculating spawning abundance at MSY were included in the analysis, participants noted that the Hilborn approximation is only valid within specific productivity bounds. Given the nature of MCMC sampling, it is possible that these thresholds could be exceeded and best practice may be to use the Lambert function (Scheuerell 2016).

Participants brought up the point that while DFO records harvest in units of individual fish, ADF&G records harvest in units of mass then back-calculates to individual based on average size. As a result, ADF&G estimates of harvest may be more uncertain.

All participants agreed that the authors did a good job in identifying an aggregate goal, but several noted that they hoped that this process did not preclude the identification of Conservation Unit-specific goals as mandated by the Wild Salmon Policy.

There was some uncertainty as to whether enhanced fish were included in estimates of recruitment. The authors clarified that any fish that reached the spawning grounds was included (i.e. there was no attempt to distinguish between wild and hatchery-origin spawners).

Participants noted that stakeholders would be interested in comparing original and updated estimates of escapement to get a sense for how potential yield may have changed.

CONCLUSIONS AND UNCERTAINTIES

The working paper was accepted with revisions. The escapement goal range and associated biological benchmarks will be provided to the Transboundary Panel prior to the 2020 fishing season. Participants noted that the credible interval associated with the model outputs will be sensitive to the abundance data used as inputs; however the state-space that was utilized here is better able to account for these uncertainties than traditional stock-recruit models.

REVISIONS FOR WORKING PAPER

- Clarify how dropout rates incorporated interannual variation.
- Briefly describe the scale of enhancement (i.e. proportion of hatchery-origin fish) in the Taku River and describe how stock composition has changed through time with reference to the relevant Pacific Salmon Commission documentation if necessary.
- Clarify why sensitivity analyses focused on the prior for beta.
- Refine terminology around yield and overfishing profiles.
- Clarify discussion regarding the original and revised estimates of capture-recapture abundance estimates.
- Explain why U.S. District 111 purse seine harvest was included even though it is not strictly terminal.
- Clearly describe how missing capture-recapture abundance estimates at the beginning of the time series were derived. Also, present results demonstrating the potential impact of that uncertainty on estimates of spawning abundance at MSY and biological benchmarks (e.g. table with medians, credible intervals, and coefficients of variation).
- Clarify why specific sources of age composition were or were not used in the run reconstruction.
- Note in discussion that pooled Petersen or size-stratified Petersen estimates of in-river abundance were used throughout the working paper.

RECOMMENDATIONS

- Continue radiotelemetry studies to refine estimates of dropout rates and improve capture-recapture estimates of abundance.
- Finalize abundance estimates for early portion of time series for subsequent modeling exercises.

- Generate a document summarizing distinctions between Canadian and Alaskan management objectives that can be easily referenced in future transboundary working papers.

ACKNOWLEDGEMENTS

We appreciate the time contributed to the RPR process by all participants. In particular, we thank the reviewers, Charmaine Carr-Harris and Andrew Munro, for their time and expertise.

REFERENCES

Bonner, S. J., and C.J. Schwarz. 2020. BTSPAS: Bayesian Time Stratified Petersen Analysis System. R package version 2020.1.1.

Pestal, G., C. J. Schwarz, and R. A. Clark. 2020. Taku River Sockeye Salmon Stock Assessment Review and Updated 1984-2018 Abundance Estimates. Pacific Salmon Commission Technical Report No. 43, Vancouver.

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APPENDIX A: TERMS OF REFERENCE

DEVELOPMENT OF A BIOLOGICAL ESCAPEMENT GOAL FOR TAKU RIVER SOCKEYE SALMON

Regional Peer Review – Pacific Region

November 5-6, 2019
Nanaimo, BC

Chairperson: John Candy

Context

The Taku River is a transboundary river system that originates in the Stikine plateau of northwestern British Columbia and terminates in Taku Inlet in Southeast Alaska. The river produces one of the largest runs of Sockeye Salmon in the region; this is jointly managed by the Department of Fisheries and Oceans Canada (DFO), the Alaska Department of Fish and Game (ADF&G) and the Taku River Tlingit First Nation (TRTFN). The Canada/U.S. Pacific Salmon Treaty (PST) of 1985, and subsequent additions to the original treaty, established conservation and harvest sharing objectives for the Taku River Sockeye Salmon run. Based on current assessment methodologies, in-river run size has averaged 128,000 over the past decade. Terminal run size, which includes marine harvest (U.S. District 111), has averaged 190,000. Average harvest rate is 44%, which results in average spawning escapements of 106,000 fish. Sockeye spawn throughout the Taku River drainage in both river and lake habitats.

Taku River Sockeye Salmon are managed as an aggregate under provisions of Chapter 1, Annex IV of the PST. The spawning objective has been considered an "interim" objective since it was established in 1985. This is because it was based on the very limited harvest and escapement data available at the time. The parameters of this interim objective were a range from 71,000 to 80,000 fish with a point goal of 75,000 fish. A revised interim objective was set for the 2019 season, specifically a range of 55,000 to 62,000 fish with a management target of 59,000 fish. The most recent provisions of Chapter 1, Annex IV call for the development of a bilaterally agreed maximum sustainable yield (MSY) escapement goal prior to the 2020 fishing season. Paragraph 3(b)(i) states:

"(B) The Parties shall develop a joint technical report and submit it through the Parties' respective review mechanisms with the aim of establishing a bilaterally approved maximum sustainable yield (MSY) goal for Taku River Sockeye Salmon prior to the 2020 fishing season..."

The Transboundary Panel requires escapement goal recommendations at the aggregate level to support the management and stock assessment regime that has been developed by the Parties through the joint Transboundary Technical Committee.

In-river abundance has been estimated annually since 1984. The methodology used to date has been mark-recapture, conducted jointly by DFO, ADF&G and the TRTFN. Marks are applied at Canyon Island, Alaska and recoveries are made upstream in the Canadian commercial fishery and, to a lesser extent, test fisheries directed at other species as well as First Nation fisheries. The mark-recapture methodology and past estimates are currently under review, and the results of this review will form the basis for development of a MSY-based escapement goal for the stock aggregate. Review of stock status and escapement goal development are directives of policies in both Canada (Precautionary Approach, Wild Salmon Policy [Fisheries and Oceans Canada 2009, 2005]) and the U.S. (Alaska's Sustainable Salmon Fisheries Policy, and Policy for Statewide Escapement Goals [Alaska Board of Fisheries 2000, 2001]).

DFO Treaties and Fisheries Unit, Yukon-Transboundary Rivers Area (YTRA) has requested that Science Branch provide advice respecting a biologically-based escapement goal for Taku River Sockeye Salmon and the establishment of biological benchmarks that are consistent with DFO's Precautionary Approach (Fisheries and Oceans Canada 2009). This assessment will present an analysis and advice respecting of both MSY-based escapement goal and biological benchmarks. Methods utilized for biological benchmark assessment will reference approaches and criteria previously developed (see Holt 2009a, Holt 2009b, Grant 2011). Advice respecting biological benchmarks will contribute to a future assessment of status to meet Precautionary Approach commitments.

The advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will be used to inform fisheries management decisions and meet treaty/international obligations.

Objective

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

Pestal, G. and S. Miller. Development of a Biological Escapement Goal for Taku River Sockeye Salmon. CSAP Working Paper 2018SAL04

The specific objectives of this review are to:

1. Identify the spawning escapements that would produce maximum sustainable yields for the Taku River Sockeye stock aggregate.
2. Identify the appropriate biological benchmarks for the management of the Taku River Sockeye stock aggregate.

The work will be conducted by a working group led by DFO and ADF&G personnel with expertise in the stock assessment and management of Taku River Sockeye Salmon. The working group will analyze Taku River Sockeye Salmon spawner-recruit data using a Bayesian age-structured state-space model. State-space models are time series models that feature both observed variables and unobserved states. Use of a Bayesian age-structured state-space model will allow for consideration of process variation (natural fluctuations) in stock productivity, recruitment, and age-at-maturation independently from observation error (uncertainty in measurements of observed data) in run size, harvest, and age composition. By correctly specifying annual age-structure in the Bayesian state-space model, missing data, common to salmon stock assessment data sets, can be represented as unknown quantities for which posterior samples are generated. Additional uncertainty then flows through to the remaining model parameters as appropriate (Fleischman et al. 2013). This provides a powerful advantage over traditional spawner-recruit analysis, in which independence of individual quantities of spawners (S) and recruits (R) is assumed and missing data must be imputed before the model is run. Another advantage of the Bayesian age-structured state space model over traditional spawner-recruit methods is on obtaining good quality estimates of spawning abundance at maximum sustained yield in regards to bias reduction and interval coverage. As a result, Bayesian age-structured state-space models have been used with increasing frequency in place of traditional methods in spawner-recruit analysis of Pacific salmon. Other methods may be examined in cooperation between DFO / ADFG staff and consultants.

Data inputs for the state-space model relate directly to the stock assessment program, and the corresponding review of that program may provide insights into how to use and/or adjust inputs to the escapement goal analysis. Data that will be required for the escapement goal review include directed marine harvests by age, in-river harvest by age for commercial, indigenous, test, and personal use fisheries, and escapement estimates by age. Other data may be considered and incorporated into the model. The R code for fully reproducible estimates of biological benchmarks will be incorporated as an appendix in the working paper developed.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Fisheries and Oceans Canada (DFO) - Treaties and Fisheries, YTRA
- Alaska Department of Fish and Game (ADFG) – Commercial Fisheries Division
- Academia or Academics - Simon Fraser University
- Indigenous communities/organizations - Taku River Tlingit First Nation

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Holt, C.A. 2009a. Evaluation of Benchmarks for Conservation Units in Canada's Wild Salmon Policy: Technical Documentation. DFO. Can. Sci. Advis. Sec. Res. Doc. 2009/059. xii + 50 pp.

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APPENDIX B: AGENDA

Canadian Science Advisory Secretariat
Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Development of a Biological Escapement Goal for Taku River Sockeye Salmon

November 5-6, 2019

Vancouver Island Conference Centre
101 Gordon Street, Nanaimo BC.

Chair: John Candy

DAY 1 – Tuesday, November 5

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Sara Miller, Gottfried Pestal
1030	***Break***	
1045	Written Reviews and Authors Response	Chair + Reviewers & Authors
1200	***Lunch Break***	
1300	Identification of Key Issues for Group Discussion	RPR Participants
1330	Discussion & Resolution of Technical Issues	RPR Participants
1445	***Break***	
1500	Discussion & Resolution of Results & Conclusions	RPR Participants
1630	Develop Consensus on Paper Acceptability & Agreed-upon Revisions (TOR objectives)	RPR Participants
1700	Adjourn for the Day	

DAY 2 – Wednesday, November 6

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1 (*As Necessary*)	Chair
0915	Discussion & Resolution of Technical Issues (Continued from Day 1)	RPR Participants
1030	***Break***	
1045	Discussion and Resolution of Working Paper Conclusions	RPR Participants
1130	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1200	***Lunch Break***	
1300	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1445	***Break***	
1500	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair
1545	Other Business arising from the review	Chair & Participants
1600	***Adjourn meeting***	

APPENDIX C: WORKING PAPER REVIEWS

REVIEWER: CHARMAINE CARR-HARRIS, FISHERIES AND OCEANS CANADA

Is the purpose of the working paper clearly stated?

The purpose of this working paper is to provide science advice with respect to developing a biologically based escapement goal for Taku River sockeye salmon. This is a well-written and concise paper that meets the stated objectives to identify a range of spawning escapements and recommend appropriate biological benchmarks for the Taku River sockeye salmon aggregate in a straightforward manner.

While this paper makes an effort to reconcile different frames of reference for establishing biologically based escapement goals in US and Canadian jurisdictions, the results and recommendations for aggregate biological benchmarks presented here are more consistent with biological escapement goals as defined in Alaska's Sustainable Escapement Policy than to Canada's Precautionary Approach/Wild Salmon policy which arguably apply to populations at a higher level of resolution (i.e. Conservation Units).

Are the data and methods adequate to support the conclusions?

The authors use an age-structured Bayesian state-space spawner recruit model to estimate biological benchmarks for the aggregate Taku River sockeye population. This modelling approach is defensible and here applied to relatively rich and complete time series of available data for Taku sockeye. The methods and input data are well presented in a simple format with all input parameters clearly explained and the R code for the model provided.

This paper recommends a revised biologically based escapement goal ranging from 40,000 – 75,000. This range is wider, and the lower end of the range is lower, than previous biological escapement goals for Taku River sockeye, including the previous escapement goal of 71-80,000, or the interim goal of 55-62,000 fish that was set in 2018 to account for new information about historical dropout rates. The authors provide good rationale for both the lower escapement target, which are based on model results, and for a higher range of recommended escapement targets, given uncertainty arising from low data contrast.

Are the data and methods explained in sufficient detail to properly evaluate the conclusions?

The working paper clearly presents the model and input data that are used in the analyses, but there is little information provided to assess potential sources of uncertainty and variability in some of the datasets. For example the overview section on catch data could confirm how the mixed-stock analysis to exclude non Taku and hatchery origin sockeye are applied to D-111 harvests without adding much bulk to the paper.

Some detailed data that are not available in the working paper were provided in a separate draft document that reports the results of a comprehensive review of the Taku River sockeye stock assessment program, including an expert review of the mark-recapture estimation program for in-river abundance. Having this information available in a separate report makes the working paper more concise and improves its readability. However, as a stand-alone document there were a few areas where the working paper would benefit from the inclusion of some information that are currently only available in the technical report. The technical report is also a draft document, and some sections that are referenced in this working paper are still incomplete, such as the results of an alternative estimation technique using ratios of genetic stock composition.

If the document presents advice to decision-makers, are the recommendations provided in a useable form?

This paper meets its stated objective to identify the appropriate biological benchmarks for management of the Taku River stock aggregate, based on a range of Smsy estimated from state-space model results. This is achieved by presenting a range of escapement levels that would result in varying probabilities of attaining X percent of Smsy, and of overfishing below X% of Smsy. This information is provided Table 10, in addition to Figures 9-11, and are well explained in the discussion section.

In addition to Smsy, the authors have provided plausible estimates derived from posterior distributions of the fitted S/R model for a range of biological benchmarks (Smsy, 80% Smsy, Smax, Seq, Sgen). The estimates around some these benchmarks (Sgen, Smax) are very uncertain given low contrast in the data, and no information available about limitations to capacity at high escapement, or productivity at low escapement. While the estimated benchmarks and recommendations that are provided are based on the estimated range of values around Smsy, which are defensible, would this change if there were more data available at the high and low ends of escapement?

If the document presents advice to decision-makers does the advice reflect the uncertainty in the data, analysis or process?

While the modelling approach is strong and the data described are of generally high quality, there are some uncertainties in the input data which could be considered or better acknowledged. The uncertainties identified here are not likely to affect the results or conclusions presented in this working paper.

As with all spawner recruit models, the key input data include catch, escapement and age composition data. For age composition, the authors used a weighted combination of sampled ages from D111 gillnet fishery and Canyon Island fish wheels to estimate the age composition of the terminal run. It is well known that size selectivity in gillnet fisheries result in a bias of larger, presumably older, fish, and for Taku sockeye, this is evident in Tables 3 and 4. While this is not likely to have a large effect on the results presented here, how sensitive are the results to variation age composition, and how would they change if age composition from the fish wheel estimates only were used, or if the age composition from catch and inriver escapement were calculated separately?

In-river abundance estimates are based on capture-recapture estimates where fish are captured and tagged in the Canyon Island fish wheel program and recaptured in Canadian test and commercial fisheries. Historic capture- recapture estimates have been adjusted downwards to account for “dropout” rates, or the proportion of fish that were captured and tagged but didn’t make it upstream to be recaptured in Canadian test and gillnet fisheries. The estimated dropout rates are based on the results observations from radio telemetry studies conducted in 1986, 2015, 2017 and 2018. There was considerable variability in observed dropout rates for the four years in which radiotagging projects were carried out, ranging from 14.6% in 2017 to 32.1% in 2018. A weighted average of 25.5% was applied to all years except for 2017 and 2018 when direct estimates of the dropout rate were available. Given the range in dropout rates observed between these two years, it might be useful to consider how a wider range of different potential dropout rates applied to historic in river escapement estimates would change the estimates of total returns, recruitment and estimated biological benchmarks reported here.

The historic capture-recapture estimates were also revised downwards to account for adoption of size-stratified capture-recapture estimates for in-river abundance. The technical document, which includes an expert review of the Canyon Island capture-recapture program, provides good rationale for adopting size-stratified rather than pooled Petersen estimates. The size-stratified estimates better accounts for size-selective bias in Canadian test and gillnet fisheries where tagged fish marked in the Canyon Island fishwheels are recovered. For years prior to 2003, the 2003-2018 average of -6.5% is applied. In the technical document it is noted that the differences for some years are much larger and for 2018 it was <-20% (Figure 14 of technical document). How would historic estimates change if this data point, which may be an outlier, was dropped from the time series average?

In addition to the standard error from mark recapture estimation procedure, the CVs for capture-recapture estimates could consider uncertainty in dropout rates for years where direct estimates are not available.

Can you suggest additional areas of research that are needed to improve our assessment abilities?

While this paper presents plausible estimates of biological escapement goals for Taku River sockeye at the aggregate level, it does not consider the population dynamics of the different component lake- or river- type populations that spawn in the watershed, which is outside the scope of the paper and the specific objectives set in the CSAS Terms of Reference (to identify spawning escapements and appropriate biological benchmarks for the aggregate stock).

Maintaining the diversity of wild salmon populations is a key consideration of the Wild Salmon Policy and Canada’s Precautionary Approach, and the TOR acknowledges that the advice presented here may contribute to future assessments to meet these commitments. It might be worthwhile to acknowledge that the aggregate parameters and benchmarks presented here will not necessarily meet spawning requirements for the component populations. For example, an aggregate median posterior estimate for Sgen for the aggregate of ~5000 spawners might not be sufficient for rebuilding all component populations to Smsy in one generation.

It would also be helpful for the working paper or the technical data report to include more and higher-resolution information about the relative abundance of wild and hatchery origin Taku river sockeye across years, and the relative abundance of different components of the Taku sockeye aggregate (different lake populations and different life history types) sampled in commercial fisheries and at the fish wheel. The current version of the technical report provides average information across a number of years for each gear type, and there is a placeholder for this information (and alternative abundance estimates based on genetic composition ratio estimates) in the draft technical data report. More information (or a reference) about the year to year abundance of other sockeye salmon stocks captured in D111 fisheries that do not originate in the Taku River watershed would also be useful.

REVIEWER: ANDREW R. MUNRO, ALASKA DEPARTMENT OF FISH AND GAME

Thank you for the opportunity to review CSAS Working Paper 2018SAL04 entitled “Estimates of a Biologically-Based Spawning Goal and Management Benchmarks for the Canadian-Origin Taku River Sockeye Salmon Stock Aggregate.”

This working paper presents a spawner-recruit analysis for Taku River Sockeye and concludes with an escapement goal recommendation. The authors fit an age-structured Bayesian state-space Ricker model to inriver run estimates based on capture-recapture, harvest, and scale age data. A Bayesian state-space model has the advantage of incorporating the uncertainty from the observation model into the process model. Because of this, the advice provided, and the recommended escapement goal incorporate and reflect this uncertainty.

The main motivation behind this report is Paragraph 3(b)(i) of Chapter 1, Annex IV of the 2019 Pacific Salmon Treaty Agreement, which calls for the development of an escapement goal for Taku River Sockeye prior to the 2020 fishing season. Incorporation of new information into the spawner-recruit analysis would also seem to be reason for this working paper. The major pieces of new information include updated information on dropout rates of marked fish and size-selectivity in the capture-recapture projects used to enumerate abundance. The source of this new information is from an unpublished review of the Taku River Sockeye salmon stock assessment program, which is cited as PSC (2019) in this working paper. The results of this spawner-recruit analysis and numerical recommendation for the escapement goal are contingent upon the data provided in the unpublished report. It would seem prudent to complete the PSC (2019) report and have it reviewed prior to making an escapement goal recommendation based upon the spawner-recruit analysis presented in this working paper.

The analysis was very good, and the working paper is well written and organized. The introduction articulated the scope, purpose of the report and clearly stated the objectives. It was a little unclear whether this working paper was to provide scientific advice and a framework for determining an appropriate goal or to provide a recommended escapement goal – both were provided.

In general, the data and methods are adequately explained to support and evaluate the conclusions. However, the inriver run estimates are a key component of the spawner-recruit analysis and recommendations for the escapement goal. Therefore, the assumptions and methods used to estimate inriver run are important – particularly the application of a dropout rate to the abundance estimate. There are limited years of measured dropout estimates and considerable interannual variability thus making it challenging to find an appropriate method for applying a dropout rate to years it was not measured. For this analysis observed dropout rates were applied to the 2017 and 2018 estimates, but a constant was applied to all other years (including 1984 and 2015 despite having measured dropout rates). Unfortunately, the report with the supporting data for the spawner-recruit analyses is still in draft and there are a number of assumptions in that report that perhaps should be explored further to test their influence on the abundance estimates and, therefore, the result of this analysis and the recommendation for a biologically based escapement goal. Other comments and recommendations specific to the data, model, and results include:

- Why were year-specific dropout rates applied to 2017-2018 capture-recapture data (lines 380-383), but not to 1984 and 2015 data?
- It is stated on line 441 that the U.S. personal use harvest below the border is excluded in this analysis because it is accounted for in the capture-recapture dropouts (PSC 2019). However, the table caption in Appendix A2 indicates that *hbelow* in the harvest data object includes U.S. personal use harvest.

- The Abstract and Purpose section of the Introduction indicate that the escapement goal and associated benchmarks pertain to fish 350 mm and greater. However, it is never explained why this is. Is it because the inriver run estimates are based on fish 350 mm and greater because of the fish wheel selectivity? Do the harvest data include fish include fish of all sizes? Is there any information on size range of fish and what proportion are < 350 mm? If not an issue, it would be helpful to explain why an escapement goal based on 350 mm and greater fish is appropriate.
- The authors test the sensitivity of the model to the choice of prior for the β parameter, but it is not clear if, or why they did not, perform similar analyses for other priors. It would be helpful if they explained this choice.
- The rationale for choosing the time period beginning with the 1980 return in the analysis rather than 1984 is not explained. The inriver run estimates start in 1984 and the age data for 1980-1982 were considered missing. Also, the estimates of escapements for 1980-1984 from the Bayesian state-space model are the four lowest in the time series. Given this, did the authors explore the effect of not trying to estimate the pre-1984 escapements on the model results, estimate of S_{MSY} and other biological benchmarks, and the recommended escapement goal? This might be worth considering.
- Other than residuals being spread around 0 (line 645), how else was model fit evaluated? Estimation of β is poor, the contrast in the data is low, none of the observed escapements have failed to replace themselves, so is it a good model fit given the data?

The authors have invested a great deal of consideration into the recommendations provided in this working paper. Their reasonings are clearly and thoroughly explained and the recommendations are provided in a useable form. However, I do not think the risk criteria recommended on page 27 should be used in their present form. As written, the first criterium can be misconstrued as a direct measure of the risk of overfishing (or minimization of that risk).

In addition, overfishing profiles are not typically used to set escapement goals in Alaska. Also, the second criterium mistakenly equates the optimal yield profile to a risk assessment, which it is not. I would suggest that the criteria proposed by the authors be reframed for the reasons explained below. Some additional comments specific to benchmarks and escapement goal recommendation are:

- There seems to be a disconnect between the definition (pg. 12) and calculation (Appendix A1) of the 80% S_{MSY} metric. The calculation in the RJAGS code is simply the spawning escapement that is 80% of the spawning escapement that produces MSY (S_{MSY}), not 80% of MSY as defined. Therefore, in the 'Summary of Outcomes by Objectives' on page 29 it should be rewritten as: Spawner level that is 80% of the spawner level that produced maximum sustained yield (80% S_{MSY}) estimated at…"
- It is not clear why the authors chose to calculate the biological reference points using a variety of methods and then chose the Scheuerell (2016) method for estimating S_{MSY}, U_{MSY}, and 80% S_{MSY}, but also use Hilborn's approximation of S_{MSY} for the calculation of S_{GEN}. While, this is a minor point because the estimates are similar among the methods (although the results of the comparisons are not included), the purported computational advantage indicated in Scheuerell (2016) would seem to be negated by calculating the same metrics using multiple methods. Furthermore, the inclusion of these multiple calculations is not additive to the report. I would suggest simplifying to one method and would suggest using the Hilborn approximation that is the general standard and would provide consistency with the calculation of S_{GEN}. A comparison of the different methods could be included as an appendix but is not necessary to meet the objectives of this analysis and report.

- Overfishing profiles – the terminology is a little misleading in that these profiles depict the probability that sustained yields would be below a fraction of MSY various levels of escapement. (Note that the probabilities on the right-hand side of Table 10 are simply 1 minus the probability of > X% MSY up to almost the estimate of S_{MSY}.) The mechanism may be through fishing hard enough to reduce escapements such that there is a reduction in yield. In other words, the plots and probabilities in the table are really the probability of reduced yield at lower escapements and it is not an indication of conservation concern as suggested by the general connotation of the term overfishing. These profiles are not a direct measurement of fishing pressure.
- In general, overfishing profiles are not used to set escapement goals during the escapement goal review process in the State of Alaska. Optimal yield profiles, overfishing profiles, and optimal recruitment profiles were developed mainly as descriptors (i.e. what managing to a given goal range would mean in terms of yield in relation to MSY or recruitment in relation to maximum recruitment). They were not necessarily developed as tools to determine the lower and upper bounds of escapement goal. I would suggest not recommending an escapement goal range based on the reading of the plots or table, but instead using the plots and table to describe what the expected outcomes in terms of yield over the long-term if the stock is managed to the proposed escapement goal range.
- The inference from optimal yield profiles is not to "minimize the risk of lost potential yields by ensuring" anything. It is not a risk assessment, it does not really speak to lost potential yields, and "ensuring" is a bit of an overstatement. More correctly: The recommended escapement goal should provide a >50% probability of at least 70% MSY over the long-term if the stock is managed to the proposed escapement goal range.
- Is the recommended escapement goal range of 40,000-75,000 a recommendation of the Taku Working Group or is it a recommendation based on the criteria proposed by the authors in this working paper? It should be noted that the lower-bound of 40,000 is very close to the median estimate of S_{MSY} of 43,857 (90% CI: 30,422-99,699). The implications of this should be addressed as part of considerations for selecting the recommended escapement goal.

The authors provide a list of additional areas of research/data needs in the working paper (section 5.2). All the items are reasonable. In addition, I would suggest:

- Consider conducting a sensitivity analysis of the dropout parameter as well as the inclusion of the 1980-1983 return years.
- Consider an integrated model that incorporates the capture-recapture estimation, dropout rate, etc. into a single analysis with the spawner-recruit analysis. This might be challenging and not provide a significant advantage.
- Continued enumeration of the dropout of marked fish from the capture-recapture study and investigation in how best apply dropout rates with appropriate variability to historical inriver run assessment given the large amount of interannual variation. The spawner-recruit analysis results rely upon an appropriate scaling of the inriver run each year; therefore, this would be an important component to get right.

Overall, this was a well-done analysis and the authors should be commended on their efforts and ability to produce a clear and well written report that was easy to follow and understand. Their proposed framework and justification leading to the escapement goal were well articulated. Some additional minor comments to the authors are provided on the final page. Thank you, again, for the opportunity to review this working paper. Randy Peterson contributed input and insights to these review comments. Please contact me if you have questions or wish to discuss any of the review comments.

APPENDIX D: PARTICIPANT LIST

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Erhardt	Richard	TRTFN
Fair	Lowell	ADF&G
Foos	Aaron	DFO
Freshwater	Cameron	DFO Science
Jones	Ed	ADF&G
Miller	Sara	ADF&G
Munro	Andrew	ADF&G
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