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Proceedings of the Pacific regional peer review on Recovery Potential Assessment – Fraser River Sockeye Salmon (*Oncorhynchus nerka*) – Ten Designatable Units

October 7-10, 2019
Richmond, BC

Chairperson: Gilles Olivier
Editors: Steve Healy, Emily Townend, and John Candy

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Foreword

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

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting of October 7-10, 2019 at the Sheridan Hotel in Richmond, B.C. to review the Recovery Potential Assessment (RPA) of Endangered Cultus Lake Sockeye Salmon (*Oncorhynchus nerka*) and elements 12, 13, 15, 19-21 of a Recovery Potential Assessment (RPA) for nine designated units (DU) for Fraser Sockeye Salmon (*Oncorhynchus nerka*). Shortly before the meeting it was felt that the Research Document for nine DUs covering elements 1-11, 14, 16-18 required additional work and would be reviewed at a future date.

In-person and web-based participation included a total of 56 participants.

The conclusions and advice resulting from this review are provided in the form of a Science Advisory Report (SAR) and a Research Document to inform SARA recovery planning, help develop a recovery strategy and action plan. The advice generated via this process will update and/or consolidate any existing advice regarding these populations of Fraser River Sockeye Salmon.

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

INTRODUCTION

Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), regional peer review (RPR) meeting was held on October 7-10, 2019 at the Sheraton Hotel in Richmond, BC. This process was to review elements 12, 13, 15, 19-21 of the Recovery Potential Assessment (RPA) for nine designated units (DU) for Fraser Sockeye Salmon as defined by Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as either Threatened or Endangered. These DUs were Bowron-ES (Bowron), Takla-Trembleur-EStu (Early Stuart), Harrison (U/S)-L (Weaver), Seton-L (Portage), Quesnel-S (Quesnel), Takla-Trembleur-Stuart-S (Late Stuart), Taseko-ES (Taseko) considered Endangered and Widgeon-River (Widgeon), North Barriere-ES (Upper Barriere, previously Fennell) considered Threatened. A separate working paper written for the nine DUs covering elements 1-11, 14, 16-18 (habitat and threats 2015SAR09-2) required additional work and would be reviewed at a future date. A tenth, Fraser River Sockeye DU, Cultus-L (Cultus); listed as Endangered by COSEWIC was reviewed as a separate working paper covering all 22 elements.

The Terms of Reference (ToR) for the science review (Appendix A) were developed in response to a request for advice from the Species At Risk (SARA) program. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise which resulted in attendance of 56 participants (Appendix D): DFO Science (25), DFO Fisheries Management (5), DFO SARA (4), DFO Salmonid Enhancement Program (2), DFO Fish and Fish Habitat Protection Program (1), First Nations (7), Non-governmental organizations (4), Pacific Salmon Commission (4), Province of BC (2), Academia (1), and Contractor (1).

The following two working papers were written and made available to meeting participants prior to the meeting:

> Recovery potential assessment for Fraser River Sockeye Salmon (*Oncorhynchus nerka*) Nine populations- excluding cultus-L population- Elements 12,13,15,19-22 by Ann-Marie Huang, Gottfried Pestal, and Ian Guthrie. CSAP Working Paper 2015SAR09-3.
>
> Recovery potential assessment for the endangered Cultus Lake Sockeye Salmon (*Oncorhynchus nerka*) by Daniel T. Selbie, Josh Korman, Lucas B. Pon and Michael J. Bradford. CSAP Working Paper 2015SAR09-1

The meeting Chair, Gilles Olivier, 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. It was confirmed with participants that all had received copies of the Terms of Reference, working papers, reviews of the working paper, and agenda.

The Chair reviewed the ToR (Appendix A) and Agenda (Appendix C) for the meeting, highlighting the objectives and identifying the Rapporteur for each review. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. The room was equipped with microphones to allow remote participation by web-based attendees, and in-person attendees were reminded to address comments and questions so they could be heard by those online.

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. Stephen Healy and Emily Townend were identified as the Rapporteurs for the meeting.

Participants were informed that Scott Decker, Michael Price, Carrie Holt, and Will Atlas provided detailed written reviews of the working papers. Participants were provided with copies of the written reviews in advance of the meeting.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to the SARA program. The Science Advisory Report and supporting Research Document, along with this proceedings will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

REVIEW

Working Paper:	Recovery Potential Assessment for the Endangered Cultus Lake Sockeye Salmon (*Onchorhynchus nerka*). (2015SAR09-1)
Rapporteur:	Stephen Healy
Presenters:	Dan Selbie and Mike Bradford

PRESENTATION OF WORKING PAPER

The presentation of the working paper began with Mike Bradford providing some background of the Cultus Lake Sockeye population, including their biology, migrations, history of research, as well as some context of past assessments by COSEWIC. A time-series of spawner abundances dating back to the 1920's was shown, highlighting variable returns and general declines in adult abundances since the ~1970's. Adult/smolt ratios were discussed, showing no clear temporal trends, however, marine survival for smolts in recent years has been low, and many years the number of smolts per spawner has been below replacement rate. The role of the current hatchery program was explained.

Dan Selbie took over the presentation to discuss many of the factors influencing the population. Fisheries exploitation of the population was presented, and exploitation rate estimates were shown, with exceedance of exploitation rates dating back to the early 2000's, particularly in dominant Shuswap years (i.e. every four years). Dan explained that the primary production of Cultus Lake is one of the highest of all Fraser River watershed lakes, but indicated that there appears to have been a shift towards increasing eutrophication starting sometime in the ~1950's. Next, the presentation focused on nutrient loading sources to the lake, including from atmospheric deposition, septic, agriculture, and wildlife. The authors described poor conditions in the lake for Sockeye including anoxia/hypoxia at the lake bottom, high surface water temperatures, redox-induced contaminant releases pollution, invasive species, and decreases in suitable spawning habitat for adults.

The presentation then shifted to review the modelling and recovery potential for the population. Mike Bradford discussed the rationale for a survival target of 2500, a recovery target of 7000, and >0.72 (PNI Proportionate Natural Influence). The population projection modelling was discussed, as well as how the authors accounted for hatchery fish in models and the potential implications for including hatchery-origin fish in population size assessments. The simulation model was summarized, and the authors explained several potential limitations and caveats of the approach. Next, model output figures were shown based on different scenarios (e.g. hatchery production, exploitation rates) as well as the probabilities of meeting the survival and/or recovery targets based on each scenario. Multiple additional figures were shown throughout the presentation that were not in the working paper.

Dan Selbie walked the group through the proposed threats and limiting factors table and gave a short explanation of how threats tables are developed using the *Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk* document framework. A brief explanation and justification for the proposed ranking for Cultus Lake Sockeye (e.g. Level of Impact, Causal Certainty, Population Level Threat Risk) for both tables were discussed.

PRESENTATION OF WRITTEN REVIEWS

SCOTT DECKER

The first formal review, provided by Scott Decker, explained that the authors had done a commendable job outlining threats and limiting factors for Cultus Lake Sockeye, and highlighted the extensive data and methods used to support their conclusions and recommendations. Most of the reviewer's critiques (Elements 1-11, 14, 16-18) involved suggestions for clarification and/or additional explanation. A summary of the major suggestions identified by the reviewer are provided below. For the full written review, see Appendix B.

- Add some information about marine spatial distribution for Fraser Sockeye, due to potential implications of competition with hatchery pink and chum salmon in the Pacific.
- Clarify some of the phrasing in Section 4.1.1 regarding statistics of the Integrated Fisheries Management Plan (IFMP) maximum allowable limits (e.g. 47% annual and 75% annual). The authors clarified these statistics in the meeting, saying they were year-by-year rates above the IFMP limits, but agreed to clarify this in the text.
- The paper has strong emphasis on freshwater, but not a lot on marine threats or limiting factors.
- The authors should include the nature of Cultus Lake Sockeye existing at a single lake/site population as another limiting factor to the document. This was agreed by the authors and other reviewers, and later added to the limiting factors table.
- Include some examples of mitigation success stories related to reducing cumulative contamination issues (e.g. agriculture) to reflect what are realistic mitigation measure recommendations from a science perspective.
- More explanation of the current hatchery strategy (e.g. number of fry being stocked, number of smolts/fry released above the fence annually) are warranted, as well as some discussion on the risks and benefits of such activities.

CARRIE HOLT

The second reviewer, Carrie Holt, complimented the authors for their thorough job of identifying objectives, and particularly their considerations of hatchery enhancement in relation to recovery targets. The reviewer's comments and questions focused on the modelling and recovery potential aspects of the working paper (Elements 12, 13, 15, 19-22), and primarily involved suggestions for clarification or further explanation. A summary of the major points identified by the reviewer are provided below. For the full written review, see Appendix B.

- PNI values should be more explicitly emphasized in relation to the recovery goals in the paper.
- More explanation is needed to justify the rationale of 7000 adults as a recovery target for the population.

- Explain the implications of not including inter-annual variability of age-at-maturity in the modelling approach. Similarly, more explanation on recommended harvest exploitation rates and uncertainties around the outcomes of implementing target exploitation rates (e.g. potential harvest management strategies) is needed.
- Provide some examples of possible mitigation projects that may result in increased freshwater survival that is assumed in the modelling approach, as well as some discussion on the plausibility of the model used to simulate freshwater production mitigation (i.e. Figure 13).
- Explain why the current hatchery strategy hasn't helped to increase abundance of the population.
- Include a timeframe for when human-induced mortality of the population may be allowed, and put in context with potential for genetic introgression with long term hatchery supplementation and ongoing exploitation of the population (i.e. Section 7.1).

WILL ATLAS

The third reviewer, Will Atlas, was not able to attend the meeting; however, the authors had reviewed his written comments (on elements 12, 13, 15, 19-22) prior to the meeting and were able to speak to many of them. A summary of the major points identified by the reviewer are provided below. For the full written review, see Appendix B.

- The paper does not model the fitness effects of the hatchery specifically despite smolt production per adult declining since hatchery production began. Consider adjusting the code to account for potential fitness differences between wild and hatchery fish.
- No density-dependent model was used to simulate recovery of the population. The authors should consider using such a modelling approach. The authors explained that there is no evidence of density-dependent effects with Cultus Sockeye; however, more clarification could be added to the working paper.

MICHAEL PRICE

The fourth reviewer, Michael Price, began by thanking the authors for writing a very clear, detailed, and easy to read working paper. The reviewer's discussion (Elements 1-11, 14, 16-18) largely focused on the need for more background and limitations to be included for some of the threats, as well as to clearly highlight knowledge gaps. Several new threat categories were suggested. A summary of the major points identified by the reviewer are provided below. For the full written review, see Appendix B.

- Show spawner abundance further back in time in Element 2 (Figure 3), as those data extend back to the 1920's. Such a figure was presented by the authors in the first day of the meeting.
- Density-dependent interactions in the marine environment with other salmonids (e.g. pink salmon) should be included in the paper. This topic was later added to the threats table by the committee during the meeting.
- No discussion about the potential for the open-net pen farming industry was mentioned as a threat. This topic was agreed upon and added to the threats table at the meeting.
- Alterations to the migratory habitat was not included in the working paper, as well as the potential effects of the bottleneck of the Sweltzer Creek fence on the population. This topic was agreed upon and added to the threats table at the meeting.

- More knowledge gaps should be identified in Element 11, particularly in reference to open-net pen aquaculture and marine competition, as well as changes in genetic and life-history diversity.
- Consider adding discussion on the removal of open-net pen salmon farms along juvenile migration routes as a potential mitigation measure within Element 16.
- Provide further justification or references to support the use of high proportions (up to 50% of returning adults) being used for brood-stock, and/or discuss how current hatchery production could impact the population.

GENERAL DISCUSSION

The primary focus of the discussion was the topics in the threats and limiting factors tables (Tables 2, 3), as well as any corresponding information in the body of the working paper for each topic. The aim was to ensure the committee agreed with these tables, as they were to be provided in the Science Advisory Report (SAR) for Cultus Lake Sockeye.

THREATS TABLE

The first threat discussed was *Fisheries Interactions*. There was considerable discussion about exploitation rates for Cultus Lake Sockeye. Reviewers pointed out that in years of high abundance co-migrating Shuswap Sockeye (i.e. once every four years), exploitation rates of Cultus Sockeye might be high, but in the other three of four years, exploitation might be low; therefore, how can the authors justify a level of impact as high. The authors clarified that changing the exploitation rates in the simulations did not make significant differences to modelling results and highlighted that the evidence points towards any exploitation being detrimental to the population from an allowable harm perspective. Similarly, the committee discussed Figure 5 and the sources the authors used to produce the estimates of exploitation rats for Cultus Lake Sockeye. Reviewers pointed out that other estimates (and high uncertainty) of pre- and post-season exploitation rates exist for the population; however, the authors only used one of these estimates in the working paper. The committee eventually agreed that the threat ranking for fisheries interceptions remain as originally presented by the authors, but the working paper should be amended to reflect more clearly the sources of data used as well as possible limitations and uncertainties around exploitation rates for Cultus Lake Sockeye. Additionally, it was agreed that the authors should meet with Fisheries Management, Pacific Salmon Commission, CSAS office, and others present at the meeting to discuss best ways to approach exploitation rates in the paper.

Several reviewers wanted clarification about how *Hatchery Production* is listed as a threat to the population but is also described as a mitigation measure in the working paper. The authors agreed to bring this forward in the working paper, but clarified that the hatchery is a short term solution to recover the population, but can have negative implications over the long term (e.g. genetic depression of the population), so PNI values should also remain > 0.72. The committee agreed on the threat classification of hatchery production presented in the threats table.

For the *Pollution* threat, there was some confusion what types of pollutants were being considered, as other threats in the table were also pollution related (e.g. eutrophication). The authors clarified that this category was for pollutants other than nutrients but would explain this more clearly in the document. The committee agreed on the classification for this threat.

Reviewers wanted some more discussion in the working paper for the threat of *Spawning Substrate Oxygen Demand*. Specifically, the committee agreed that there is no strong link between low dissolved oxygen and spawning success. Although the committee agreed with the ranking for this threat, it was decided that more rationale for how the authors arrived at a causal certainty of 'medium' was warranted.

The committee had reservations with listing the level of impact for *Invasive Eurasian Watermilfoi*l as 'unknown' in the table. Reviewers pointed out that milfoil has potential direct negative effects to spawning habitat, and data suggests spawning occurrence has moved deeper. The authors explained there is little evidence between milfoil and reduction in spawning, and changes to spawning distribution and/or depth could be a result of other factors such as elevated water temperatures. One reviewer also had concerns with concluding that spawning occurrence had contracted based on historic spawning maps, and one ROV survey in 2004. After discussions, the committee agreed to re-classify the impact for this category as 'low', with the paper to be amended to highlight the uncertainties associated with evidence of spawning habitat contractions and the effects of milfoil on spawning – likely to a section highlighting knowledge gaps and future research.

For *Lake Sediment Internal Loading*, reviewers asked for more clarification of the causal certainty in the text; however, the committee agreed to keep the ranking as it was presented in the working paper.

Reviewers pointed out that 'Smallmouth Bass' was not bolded in the text, whereas 'Invasive Eurasian Watermilfoil' was bolded, so the table should be corrected so both were treated the same as they are both invasive species.

Four additional categories were brought up by reviewers that could be added to the threats table, including: Climate Change - Marine, Climate Change - Freshwater, Marine Competition with Other Species, and Migration Corridor Habitat Modifications. Discussion on each topic is explained below.

Climate Change – Marine was added to the threats table by the committee after it was brought up by several reviewers. The committee discussed ensuring that clear differences are made between the marine environment being a limiting factor, and the effects of climate change (i.e. make sure the definitions here are for anthropogenic effects). Authors and reviewers agreed that the text in this section should reflect similar aspects of climate change effects (e.g. the warm water blob in the North Pacific) in other RPA's, such as for Chinook. The committee agreed on a likelihood of occurrence of 'known', level of impact of 'medium', and causal certainty of 'medium'.

The committee debated whether climate change impacts in freshwater and marine environments should be included as separate threats. The authors explained that there is more evidence linking climate patterns to impacts in freshwater, and more uncertainty in impacts in the marine environment, so the committee agreed that the two should remain separate. *Climate Change – Freshwater* was added with likelihood of occurrence of 'known', level of impact of 'high', and causal certainty of 'high' to reflect the direct evidence of temperature on lake stratification, surface temperatures, as well as interactions with eutrophication. The authors agreed to add some text in the body of the document to reflect the addition of this threat to the table.

Marine Competition with Other Species was brought up several times throughout the meeting by multiple reviewers and was added to the threats table. There was some discussion on the causal links between pink and chum abundances and effects to Sockeye in the ocean. The causal certainty was agreed to be 'low' to reflect the fact that the literature has shown some evidence of negative effects to Sockeye (e.g. with pink salmon), however, reviewers noted that it can be hard to distinguish between competition effects and larger scale oceanographic factors. The level of impact was 'unknown' and likelihood of occurrence as 'likely'. The authors agreed to discuss this topic further in the body of the paper.

The committee discussed the addition of a new threat category to the table: *Migration Corridor Habitat Modifications*. This topic was brought up by a reviewer in reference to alterations to the migration corridor such as channelization and diking to the Chilliwack, Vedder, and Sumas Rivers. Reviewers also pointed out that the enumeration fence in Sweltzer creek could be a potential threat to the population, and literature from the similar Chilko Lake fence has shown increased juvenile predation around the fence. The category was agreed to be added to the threats table, with a likelihood of occurrence of 'known', level of impact of 'unknown', and causal certainty of 'low'. Additional text will have to be added to the body of the paper to reflect the addition of this category.

Net-pen Aquaculture was discussed as another potential addition to the threats table, after the suggestion by one of the reviewers. The committee agreed that this category would be added to the threats table but highlighted the limited evidence of the physical effects of open net-pen aquaculture on wild stocks and the potential for disease interactions between wild and farmed fish. It was suggested the authors discuss with Richard Bailey who would provide some reference how this topic was handled in a recent Chinook RPA, so it was not officially added at the meeting.

Limiting Factors Table

Next, the committee reviewed the limiting factors table presented in the working paper. The group reviewed each category in order. Discussion on each topic is shown below, including any agreed upon modifications made in the meeting.

For *Disease & Pathogens*, the group discussed how there is likely an interaction between disease and aspects of climate change. For example, the longer Cultus fish spend in freshwater, the higher incidence of disease. There is higher incidence of pre-spawn mortality in more recent years for fish arriving to the system earlier, although some reviewers pointed out that pre-spawn mortality estimates for the Cultus population may be biased high. The group discussed how it can be hard to consider pre-spawn mortality, disease and change in migration timing separately, as they are all linked, but the committee agreed to keep these limiting factors separate. The committee agreed on this topic in the limiting factors table, and suggested the role of pre-spawn mortality, disease and interactions between climate change should be addressed more clearly in the paper.

Discussion on *Changes in Migration Timing* focused on the evidence linking migration timing to the population, as well as how changes in timing could impact the population. The committee agreed that changes in migration timing are, at a minimum, likely to jeopardize the survival and/or recover of the population, and one reviewer suggested it might be reasonable to list the level of impact from 'unknown' to 'high' to reflect the ~40% pre-spawn mortality that is seen in some years. The group agreed that the level of impact should be adjusted to 'high', and causal certainty to 'medium' to reflect the evidence linking changes in migration timing to the population, while taking into account the high amounts of uncertainty of pre-spawn mortality estimates for the population. One reviewer pointed out that changes in migration timing might be a result of the timing of the enumeration fence being installed, while another explained that there are other additional sources suggesting changes in migration timing (e.g. marine and in-river test fisheries). It was concluded that there should be some clarifications in the body of the paper for the limitations of using the fence data and/or highlight that there are other sources of data which corroborate changes in migration timing.

For the *Freshwater Predation* limiting factor, several reviewers wanted clarification that this is only considering native predators (e.g. cutthroat trout, pikeminnow), but otherwise agreed with this category.

The topic of marine mammal predation in freshwater/intertidal zones was discussed in reference to the *Marine Predation* section. The authors and committee agree that marine mammal predation is seen in the lower river, but not in the lake. Therefore, the group agreed the name of this topic be amended to ‘Marine and Intertidal Predation’, as well as discussed in the actual body of the document itself. The discussion focused on the effects of pinniped predation, and one reviewer pointed to tagging studies from the United States, however, there isn’t direct evidence of the effects to Cultus Sockeye specifically. The level of impact was agreed to be changed to ‘low’, and causal certainty to ‘high’ for this topic.

Both *Variability in Freshwater Conditions* and *Variability in Marine Conditions* were agreed upon by the committee. For *Variability in Marine Conditions*, one reviewer was concerned about potentially double listing some issues from the threats table, but it was agreed the limiting factors referred to variability that is not anthropogenically-induced.

One further limiting factor was added after discussion by the committee: *Limited Freshwater Distribution*. The committee agreed to add this to the limiting factors table, as Cultus Lake Sockeye return to one nursery lake, and to reflect the susceptibility of the population to stochastic events. The likelihood of occurrence was listed as ‘known’, level of impact of ‘medium’, and causal certainty of ‘low’.

Mitigation Measures

After the committee agreed on the threats and limiting factors tables, the group focused on the mitigation measures sections (Elements 17-19). Reviewers wanted further discussion in the paper of potential mitigation measures for dealing with smallmouth bass, and whether to include measures to deal with native predators such as cutthroat trout and pikeminnow. Some evidence of increased survivorship with pikeminnow removals in the early 2000’s exists; however, the effects are hard to disentangle from other impacts on the lake, and removals could cause expansions of other predator species. It was agreed mitigation measures should only focus on threats, and thus not include native species control. Invasive species mitigation measures could be discussed under a separate mitigation measures knowledge gaps section in the paper.

Open Discussion, Questions and Edits

The meeting shifted to open discussion and questions. One reviewer was concerned about the fact that the model incorporated the number of adults in the system, and not necessarily spawners. The authors explained that this was because we don’t have final data on spawner numbers, but it was suggested to clarify this fact in the text a bit more when discussing the recovery/survival targets in the body of the paper, as we have data on the number of adults at the fence, but not specific numbers of spawners. Additionally, reviewers pointed out that the recovery targets of 7000 adults was based on data from the 1970-80’s fence data, yet pre-spawn mortality is thought to be much higher in more recent years.

There were suggestions to add explanation of the limitations around Figure 13 in terms of the modelling approach, as the current approach assumes a steady increase in productivity with time and with assumed habitat improvements (i.e. a potentially over-optimistic approach). Additionally, reviewers pointed out that there appears to be two clusters of smolt/spawner values depending on the time-series considered (periods of low/high productivity), which could also be discussed as a limitation of this figure. The authors had another figure extrapolating over a longer time period that might be brought in to help address some concerns.

There was some discussion focusing around potentially including mitigation factors addressing limiting factors (e.g. native predator control), even though SARA focuses primarily on mitigation measures for threats. This was left somewhat open for the authors to make the final decision, who could look to other documents (e.g. 2002 Conservation document) to capture what was included there.

It was agreed that the authors would add some text to incorporate some of the uncertainties in the modelling approach in reference to the sampling data from the recent past. Specifically, with climate change we likely are going to expect poorer survivals in future years, yet the current modelling approach uses data from past years and doesn't explicitly consider the effects of climate change.

The committee discussed ensuring that certain sections of the working paper be addressed in such a way to maintain consistency with other recent Pacific salmon RPA's when possible. Specifically, the group highlighted how allowable harm thresholds were approached with Cultus Sockeye, and the potential inclusion of open-net pen fish farm effects.

During the meeting, other suggestions for edits to the working paper were discussed. These are briefly summarized below:

- Consider adjusting the code to sample using all population years separately. The authors said they would consider this, look at the feasibility of incorporating this into the model code.
- It was suggested that the appendix be expanded to include some equations and/or further data to explain the modelling approach in more detail.
- Reviewers wanted some of the additional figures and tables that were presented on the first day of the meeting to be added to the working paper. Examples include figures showing density-dependent smolt production and spawner abundance back to the 1920's. The authors agreed to potentially bring some of these into the paper itself.
- The potential for captive brooding as a mitigation method was suggested. It was agreed the authors would investigate feasibility and include discussion of this in the paper.
- One reviewer suggested the paper should have some discussion on the minimum number of smolts per spawner needed for the population. For example, how many were needed to maintain the population, how many would be needed to sustain fisheries, or recover the population.
- The recovery and survival targets put forth in the paper be clarified that they are interim goals.
- The allowable harm section should be amended to also reference other sources of harm that are not just fisheries-related (e.g. nutrient/pollution runoff into the lake).
- There was some confusion around using corresponding smolt-adult numbers from some years (2002-2017), but the paper appears to use a different # series (1999-2017). It was agreed that this would be cleared up in the paper to explain that this was to use a period where there was both hatchery and wild smolts.
- Clarify the caption of Table 6 to explain why the mixed strategy would be used when smolts survived more poorly. The authors explained in the meeting that this was based on the current strategy which assumes poor conditions in the lake, so therefore smolts are also released. This should be clarified in the text.
- There was a suggestion to the authors to clearly look over tables and ensure consistent bolding in the threats and limiting factors tables. A specific example was given in the threats

table where ‘Lake Eutrophication’ (under ‘Spawning Substrate Interstitial Dissolved Oxygen’) is not bolded, yet ‘Lake Eutrophication’ is the threat.

- Reviewers suggested to adjust the first paragraph under section 7.1 to reflect that no allowable harm should be permitted until the intrinsic growth rate is above one.

CONCLUSIONS

The committee agreed that the document provided a thorough background on threats and limiting factors influencing Cultus Lake Sockeye. Reviewers felt that the paper was clearly laid out, and there were no significant disagreements with the conclusions presented. The working paper was accepted, pending some revisions and comments provided by reviewers. A summary of the major conclusions and suggestions discussed at the meeting are listed below.

- Add four additional categories to threats table (Climate Change – Freshwater, Climate Change – Marine, Marine Competition with Other Species, and Migration Corridor Habitat Modifications), and incorporate associated discussion for each to the body of the paper
- Clarify what exploitation values were used for the population, or highlight other estimates of exploitation. Discuss associated uncertainties and limitations of those data. Additionally, authors should have a meeting with Fisheries Management, Pacific Salmon Commission, CSAS and others to better determine how to present and discuss exploitation rates used in the paper
- Add a glossary of terms to the working paper
- Throughout the paper, clearly discuss the uncertainties and limitations of the data being used to draw conclusions, as well as how data were used in simulation models
- Add a Mitigation Measures Knowledge Gaps section to the paper
- Include discussion on potential mitigation measures for smallmouth bass
- Incorporate some of the figures presented at the meeting to the working paper.

RECOMMENDATIONS & ADVICE

The committee worked collectively on producing the summary points for the Scientific Advisory Report during the meeting. The summary points are as follows:

- Cultus Lake Sockeye salmon are the Designatable Unit (DU) of Sockeye Salmon (*Oncorhynchus nerka*) that spawn in Cultus Lake, British Columbia (BC). This DU was first assessed as Endangered in an emergency assessment by the Committee on the Status of Wildlife in Canada (COSEWIC) in 2002 and confirmed as Endangered by COSEWIC in 2003 and again in 2017.
- Historically (1921-1970), the 4-year average abundance was 19,890 spawners but in the mid-1970s the population began to decline in abundance. Since 2006 the spawning population has been augmented by hatchery supplementation. The most recent (2015-2018) generational average of adults spawning entering the lake was 254 natural-origin and 941 hatchery-origin adults.
- Since 2010, the poor status of the population can be primarily attributed to very low rates of smolt production from the lake. Smolt-to-adult survival has also declined over time.

- Cultus Lake is undergoing cultural eutrophication, mainly resulting from excess anthropogenic nutrient loadings to the lake from the watershed and atmospheric deposition from the nutrient-contaminated regional airshed. These reversible changes are generating conditions in the lake that are unsuitable for all freshwater life stages occurring there.
- The main anthropogenic threats and limiting factors identified for Cultus Lake Sockeye salmon include: fisheries interceptions, lake eutrophication, adult mortality associated with change in migration timing, and climatically-mediated variability and change in freshwater habitat conditions.
- Redds, the spawning nests constructed by Pacific salmon and other species, meet the definition of a “residence” under SARA.
- A recovery target based upon a 4-year mean of 7,000 adults entering the lake was proposed. A survival target of 2,500 adults entering the lake was also proposed. These targets may include hatchery fish if the hatchery program is designed to minimize risks to the wild population. Quantitative guidelines for hatchery supplementation are provided.
- An empirically-based population model was used to estimate the probability that the population would reach the survival and recovery targets under scenarios that evaluated key mitigation measures: hatchery supplementation, limits to fishing mortality and improving freshwater population productivity. The results showed that the probability of reaching either the survival or recovery target in 12 years (3 generations) under current conditions is unlikely, although some scenarios that included hatchery supplementation and freshwater mitigation resulted in population growth that could result in recovery over a longer time frame.
- Recovery or survival of a natural, self-sustaining, population will require successful mitigation of the cause of the poor smolt production in the lake. This includes measures to mitigate nutrient inputs to address cultural eutrophication that has increased over the last decade in Cultus Lake. Otherwise, the population in the wild is predicted to continue to decline.
- The negative population growth rate suggests there is no allowable harm for this population. If freshwater productivity can be mitigated, and rates of ocean survival do not decline further, it is possible that recovery could occur under limited allowable harm.
- Key uncertainties that may impact the potential for recovery are the rate and efficacy of measures to improve conditions in Cultus Lake for Sockeye Salmon, future changes in the survival of smolts in the ocean and rates of pre-spawning mortality, and the long-term effects of hatchery supplementation on the fitness of the population in the wild.

In addition to producing a summary SAR at the meeting, several recommendations for future research were discussed:

- More research should focus on assessing critical spawning habitat for Cultus Lake Sockeye, including more ROV surveys to determine where Sockeye are spawning in the lake, and the extent of spawning habitat contraction.
- Further surveys of the lake should take place, for example determining the extent of the effects and impacts of Eurasian Watermilfoil and smallmouth bass in the lake, as well as the consequences of deep water oxygen levels (including behavioural responses by salmon to hypoxic conditions) and potential for interactive effects among threats.

REVIEW

Working Paper: Recovery potential assessment for Fraser River Sockeye Salmon (*Oncorhynchus nerka*) Nine populations- excluding Cultus-L population- Elements 12,13,15,19-22 (2015SAR09-3)

Rapporteur: Emily Townend

Presenter: Ann-Marie Huang and Gottfried Pestal

WORKING PAPER PRESENTATION

Ann-Marie Huang and Gottfried Pestal began the presentation with a brief orientation of their assessment on the recovery potential of 9 Designatable Units (DU's) of Sockeye salmon from the Fraser Watershed. They developed a simulation model using stock recruitment time series data to respond to the endangered and threated designation by the Committee on the status of Endangered Wildlife in Canada (COSEWIC). Stocks were organized by endangered and threatened stocks downstream of Big Bar, endangered and threatened stocks upstream of Big Bar, and stocks of special concern.

Their first priority was to clarify the caveat's and condition's in Section 3.2 of the RPA. The recovery targets developed for this RPA are modified COSEWIC and Wild Salmon Policy (WSP) benchmarks. They are not intended to replace these highly detailed assessment metrics. Ann-Marie also made it clear that there were uncertainties in estimates of recruitment data points because the data sets themselves contain uncertainties on error in run size, exploitation rate and spawner abundance which can be exacerbated at low abundance and can create a tendency to be overly optimistic on the degree and speed of recovery. The key uncertainties and knowledge gaps are stated in Section 7 of the RPA.

The author's assembled a pathway of methods to produce a 3 generation (12 years) forward simulation at current productivity and at alternative productivities. They also primitively created yearly forward simulations incorporating potential impacts of the Big Bar landslide using preliminary information available at the time of assessment. These mitigation results should only be used carefully while more stock-specific and project-specific mitigation measures are developed. This RPA is only Part 1 providing recovery targets, and the probability of achieving recovery targets and mitigation effects. The final statement on allowable harm will be produced in Part 2 Threats and Habitat. The sub-headed paragraphs that follow, summarize the slide presentations of the elements.

ELEMENT 12

The author introduced recovery targets #1 and #2 used to determine how well a stock performed through their modified WSP metrics and COSEWIC criteria benchmarks over a range of productivities and exploitation rates. The projections were used to predict the likelihood of achieving the nested recovery targets (meaning the first recovery target #1 must be reached to achieve recovery target #2) in a 3 generation forward simulation.

1. Recovery target #1: designed to approximate the objective of a stock that is not characterized as Endangered or Threatened (EN/ TH) by COSEWIC or as a Red biological status by the Wild Salmon Policy (WSP).
2. Recovery target #2: designed to approximate the objective of COSEWIC Not At Risk or WSP Green.

The time series data used was total adult spawner's which includes both successful spawner's and pre-spawn mortalities in the spawner recruit relationship. These targets are based on only biological information about the stock and do not consider social, economic, cultural or ecosystem information. Authors aimed to track where stocks drop off or when they're unable to achieve the outlined quantitative performance measures and test questions created for this assessment.

ELEMENT 13

A plot handout was distributed to the CSAS panel prior to the review that displayed spawning trends for endangered and threatened stocks log smoothed over all generations, with the most recent 3 generations parsed out to show the difference between the most recent 12 year period and the historical average. Almost all stocks showed a dramatic decline in the 3 generational line. Authors set stringent checks to try to reduce unequal weight between pessimistic and optimistic performance. It was highlighted and called upon the CSAS attendees to agree up on the assumption that the last 4 years of productivity from Figure 1, Appendix 1, Section 11.2 in the RPA could be used to construct future productivity estimates in the forward simulation**.**

ELEMENT 15

The author then brought up the adoption points, stating that they used the Intergovernmental Panel on Climate Change (IPCC) likelihood outcome categories to summarize the plotted results in Appendix 3. The authors presented their results of their forward simulations and performance measures used to weight the achievement of recovery targets 1 and 2. There was a thorough discussion on the acceptance of the metric used as the lower benchmark to produce a 'as likely as not', or 'likely' achievable designation for COSEWIC designated EN/TH DU's.

For the peer review participants to be comfortable accepting this RPA, the model was re-run overnight using a suite of modified WSP benchmarks whose application was dependent on data availability and cyclic or non-cyclic generational characteristic. The benchmark applied to a specific stock directly related to whether or not WSP had a data rich bench mark established for that stock already. If the stock did not, and was not cyclic, the author's averaged across 2 WSP benchmarks, and if the stock was cyclic, they averaged across 4 WSP benchmarks to create a more precautionary metric.

ELEMENT 19

The Big Bar landslide was an emergency event affecting the in-river mortality rate of returning 2019 salmon stocks in the Fraser River severely affecting Takla-Trembleur-EStu (Early Stuart) and Bowron-ES, and Taseko-ES Sockeye. The methods developed for incorporating the effects of this event will be subject to the updated capacity of the river and productivity targets estimated if mitigation were to occur in the winter of 2019. The authors simulated the base case referred to as 1st generation Big Bar with blocked passage, and simulated scenarios for two, three, and four years post Big Bar as normal, as if the rock had been cleared in winter of 2019 with no lingering passage effects. These methods are only a theoretical approach to mitigating an event of impact like Big Bar.

The presentation concluded with the adoption of the summary bullets for the SAR.

PRESENTATON OF WRITTEN REVIEWS

CARRIE HOLT

As the primary reviewer in attendance, the reviewer complimented the author's on the expansive undertaking of working with 9 DU's. Comments and recommendations verbalized are listed below. For the full formal written review, see Appendix B. Brooke Davis and Sue Grant from DFO, and Merran Hague from the Pacific Salmon Commission also contributed valuable amounts to the review process and their recommendations can also be read in this section.

- In Caveat's and Condition's when speaking to assumed error, could authors clarify directional error rather than an umbrella of uncertainty. This is worrisome when discussing smaller stocks. Could author's provide a general indication of increase and challenges of modelling a smaller aggregate, and where there could be challenges in the underlying data.
- Could the authors clarify if they had to model average and where the performance difference was when they did perform similarly during the retrospective analysis. If they did not project forward well, where were the differences among those models? It was proposed that this could be shown by including more optimistic matrixes with some interpretation, followed by some forward projection plots to reduce nervousness about model averaging.
- During discussion on the retrospective stock recruit model selection some confusion was stated concerning whether authors were looking at residual error or forecasting error. It should be stated in the RPA that forecast performance was not tested, goodness of fit was tested.
- Could the authors describe the range of stock recruitment models they looked at and identify differences between freshwater and marine components. A model that could separate freshwater and marine mortality would be extremely valuable.
- Could the authors add a description of the biological processes included in the metrics used in the benchmarks. Is recovery target 1 an indicator of a WSP metric more than COSEWIC. What are the nuances on metrics for low productivity DU's?
- There was stated uncertainties on mean's (geometric or arithmetic) when doing a COSEWIC assessment among different species of wildlife. This is a knowledge gap that needs to be clarified for species, and what is appropriate for species of salmon.
- Need to have an objective of making work reproducible. Could the authors add a table where each DU falls out at each of the performance criteria to know where decisions come from.
- Regarding the assumptions of age proportions from the full time series, it was discussed that authors will recommend and use post 1980's time series data because of a shift in age at marine migration acknowledged in past work.
- Can it be clearer in the written language on how a stock makes it through the performance criteria to meet recovery target 1.
- It was stressed that it needs to be made clear in the SAR what the expectation rate component of allowable harm is because the peer review panel does not want allowable harm to be interpreted as a target. Could authors also include simulated patterns for forward exploitation in Part 2 Habitat and Threats to continue transparency with the exploitation rate used in Cultus-Lake RPA.

- Could the summary table containing the results from the re-run simulations also contain value on allowable exploitation rate and probability of reaching recovery target 1. The peer review panel does not want to frame recovery target 1 as only a target; they would like measures put in place to surpass recovery target 1 and be closer to recovery target 2 for a stock to be considered improving.
- Could Birkenhead and Raft be included formally in the Research Document because they are in the endangered zone as a way to try to not let them get caught up in process (reduce the lag time). If they were evaluated this year they probably would have been listed endangered.

WILL ATLAS

The second reviewer Will Atlas, was not able to attend the meeting. His formal written review is included in Appendix B. No content was contributed on his behalf during the peer review workshop because it was felt that his questions and recommendations were brought up in discussion. A summary of the major points provided in his written review are listed below.

- Could the authors clarify how the outcome of their analysis was affected by not incorporating observation error when it could have reduced the uncertainty in the process error associated with productivity conclusions of the model based off Catherine Michielsens' code.
- Additional areas of research that would improve upon future assessment abilities would link spawner abundance in the parent generation to juvenile abundance, size and condition. More focus should put be where we can get boots on the ground… which is to assess anthropogenic and climate impacts in freshwater habitats to create lifecycle models that partition density-dependence and survival into specific life stages to more clearly understand limiting factors so better management and conservation measures can be applied.

GENERAL DISCUSSION

The following paragraphs are a more detailed description of the major discussion topics regarding the quantitative analysis of recovery targets, probability of achieving recovery targets and mitigation effects.

The peer review participants worked though an exhaustive discussion on the initial benchmark the authors selected as the lower bound for one of the test question criteria employed to achieve the recovery targets. The 25th percentile of the generational average was the lower benchmark for the average number of mature individuals in a population to achieve recovery 1 and 2. It was chosen because it was easily applicable across all 9 DU's in the assessment. The science panel viewed the benchmark as too optimistic and therefore not a precautionary choice. They also remarked that the 25th percentile is not a credible benchmark since it is based solely on escapement information and goes against past work when stocks are at low productivity, shown in Table 6 by Holt et al. 2018.

The main problem lies in the fact that the 25th percentile of the average decreases as the population abundance gets smaller, which applies to cyclic stocks of Sockeye with dominant and off cycle abundant years. Cyclic patterns can also divert detection in decrease in productivity. The DU's in this assessment that display cyclic characteristics are Takla Trembleur- EStu (Early Stuart), Quesnel-S (Quesnel), and Takla-Trembleur-Stuart-S (Late Stuart). Authors and experts discussed a possibility that the 25th percentile could be used using X number of years before the generational average declines began, however choosing which years to pull out becomes arbitrary and therefore does not suit the demand of this assessment. Dialogue continued and authors were asked to re-run their simulations using a more data rich benchmark with stock recruit data models. The re-run was truncated to look at the time series of productivity and exploitation rate using the average of the Ricker and Larkin stock recruit benchmarks presented in the most recent WSP status assessment by Grant et al (2020). The new benchmark that the science panel proposed was referred as the WSPish benchmark. The simulation results were visually depicted through what authors named ice cream plots which showed the percent likelihood of reaching recovery target 1 and recovery target 2 through colour coded cells that correlate to the IPCC's likelihood scale (i.e., very unlikely, unlikely, about as likely as not, likely, and very likely) in Table 7, Element 15. Examples of cyclic and non-cyclic stocks affected and un affected by Big Bar showed evidence for experts to agree that the lower bench mark for both cyclic and non-cyclic stocks had to be revised to only use the WSPish benchmark because it was a more precautionary measure. However, the advice attached to this revision has to be framed pertinently for short term forecasting and allowable harm, and must outline the limited value of this assessment as a guidance tool showing a distribution of productivities over a range of exploitation rates with uncertainties around it clearly articulated in the written language.

Auxiliary discussion aimed to incorporate Global Climate Change Models into the simulations since a climate regime shift influenced marine age structure in salmon life history from ~1980 onward (Grant et al., 2010, Grant et al. 2011, Grant et al. 2012, Holt and Peterman 2004). The peer review panel would like to see post 1980's cut off recommended for all future iterations, including those done in Part 2 Threats and Habitat of this assessment. They agreed it will be important to set precedence for other stocks of salmon under assessment, especially those stocks that show dramatic changes in maturation schedules and stocks that are less abundant with more data uncertainties. Representatives agreed that SARA would be receptive to advice from the authors and the peer review panel to produce multiple benchmarks addressing multiple recovery objectives as criteria for recovery targets in future assessments.

The Big Bar landslide blocked nearly all salmon migration until the end of August 2019 when water velocities decreased over the nearly 5 m waterfall. The main Sockeye stocks affected by Big Bar were primarily Takla Trembleur- EStu (Early Stuart), Bowron-ES and Taseko-ES, with considerable impact on Quesnel-S and Takla- Trembleur- Stuart (Late Stuart). Given the cyclic nature of Early Stuart, Quesnel and Late Stuart, experts thought it would be best to ask advice from SARA to whether specific mitigation measures would be identified for individual DU's in Part 2 as there is limited time and bodies within this assessment. The proposed mitigation measures include explosive removal of rock in the coming winter with hopes that fragments will be dispersed during spring freshet. Another mentioned idea was the construction of a fish way that would probably not be operational before the coming migration season. Hatchery supplementation was proposed in discussion, however there is scepticism on the effectiveness and value in supplementing these stocks as there has not been much success in the past and would require more investigation into more recent findings with Sockeye at the Cultus Lake hatchery. With current climate change information, and decreasing time between the occurrence of events of impact, it will be important to recognize that the conditions resulting from the Big Bar land slide occurred on an off cycle with generationally low abundance. The simulation methods and mitigation effects supplied in this paper are a broad brushing on what could be done for this event remembering that 2019 is not included, but is experiencing lows, not far lower than the predicted low cycle year for some stocks. These results are an example of a theoretical approach only showing ranges in productivity that could be integrated into future work by teams defining allowable harm for specific stocks.

This document does not hold the final allowable harm statements and doesn't cover habitat, threats and limiting factors of these DU's, which will be stated in Part 2. The future of the stocks that spawn above Big Bar is too uncertain to provide any advice on allowable harm at this time.

There was an idea for the authors to construct a model to simulate the mitigation ability at life history stages to be more explicit on the difference between estimates used and the impact on the stock . Partial addressing of allowable harm after concluding the results of the new benchmarks during the CSAS review can be read below in the Recommendations section in the SAR summary bullets.

CONCLUSIONS

The committee agreed that the document will be accepted with revisions described in the discussion and recommendation sections, although there was some significant disagreement with details regarding model selection and appropriate benchmarks suitable across 9 DU's. Authors were able to re-run simulations and present a benchmark that was accepted with caveats to be explained in explicit language that these data are an improvement on previous work and should be elaborated on with future work to work through uncertainties and knowledge gaps.

- There are directional uncertainties surrounding model selection criteria and benchmark selection. Workshopping is required to create repeatable methods for selecting these metrics.
    - E.g., should have a standard procedure for the last 4 years to project forward with current climate change predictions if the assumption is that the recent past can predict the near future.
- It would be pertinent to have a work shop to decide how and when recovery targets are established. Should recovery targets be work shopped by a peer review group before the RPA process begins?
- The results of the developed simulation can provide a range of productivities and exploitation rates to produce a likelihood of recovery for DU's but are limited in their use. These benchmarks come with many uncertainties and should only be used as a guidance document to show a range of productivities and different exploitation rates.
- Looking at simulation results that extensively cover stock recruit data sets for all DU's is a useful tool in identifying stocks that are wandering into the "endangered zone". For example, Raft and Birkenhead that are in continuous decline should be pulled out and highlighted as entering into the endangered zone distinguishable with an asterisk to help ensure that they don't fall into a bureaucratic time lag.
- An example of a theoretical approach to project stocks after an event like the Big Bar Landslide was outlined, but would need further development and input to become a working approach for any real mitigation capacity.
- Stocks effected by Big Bar like Taseko which are data limited should be considered if they are a proxy to a DU designated in this assessment.
- There was a proposal for the authors to construct a model that could simulate the mitigation ability at life history stages to be more explicit on the difference between estimates used. The impact on the stock could be outlined in part 2 threats habitat and limiting factors.
- Could the naming reference to the stocks follow the Canadian Gazetteer. Names that need correction are Fennell Creek to Upper Barriere River, and Widgeon Creek to Widgeon Slough.

RECOMMENDATIONS & ADVICE

The committee worked collectively on producing the summary points for the Scientific Advisory Report during the meeting. The summary points are as follows:

- Ten Designatable Units (DUs) of Sockeye salmon that spawn in the Fraser River watershed in British Columbia were designated as Endangered or Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2017). Nine of them are the subject of this report (DU name followed by common stock name in parentheses):
    - Endangered: Bowron-ES (Bowron), Takla-Trembleur-EStu (Early Stuart), Harrison (U/S)-L (Weaver), Seton-L (Portage), Quesnel-S (Quesnel), Takla-Trembleur-Stuart-S (Late Stuart), Taseko-ES (Taseko)
    - Threatened: Widgeon-River (Widgeon), North Barriere-ES (Upper Barriere, previously Fennell)
    - The tenth: Cultus-L (Cultus); Endangered, has a separate Recovery Potential Assessment (2015SAR09-1).
- A further five DUs were categorized as Special Concern, and the three with a stock-recruit time series are also included in this analysis: Kamloops-ES (Raft), Lillooet-Harrison-L (Birkenhead), and Francois-Fraser-S (Stellako). The remaining two are Harrison (D/S)-L (Misc. Lates), and Nahatlatch-ES (Nahatlatch).
- Stock-recruit time series do not exist for two of the DUs (Widgeon and Taseko) so the type of quantitative analyses conducted for the other DUs were not possible.
- Productivity has been declining since at least the 1990s for all Endangered, Threatened, and Special Concern stocks with stock-recruit time series.
- Two related recovery targets are proposed:
    - Recovery target #1: designed to approximate the objective of a stock that is not characterized as Endangered or Threatened by COSEWIC or as a Red biological status by the Wild Salmon Policy (WSP).
    - Recovery target #2: designed to approximate the objective of COSEWIC Not At Risk or WSP Green.
- Stock specific stock-recruitment models were used to estimate the percentage of projections that would reach the two recovery targets in three generations (12 years) under scenarios using plausible population dynamics conditions across a range of mortality rates and productivity levels, including recent ones (brood years 2010-2013).
- In the summer of 2019, a large landslide was discovered in the Fraser River mainstem. The Big Bar landslide blocked virtually all of the natural migration of Fraser Sockeye until 26-August. Six (Early Stuart, Late Stuart, Bowron, Quesnel, Taseko, and Stellako*) out of the twelve assessed DUs were affected by the landslide in 2019. Of those, Early Stuart, Bowron and Taseko are most affected as they were migrating at a time when passage was completely blocked.
- A method for incorporating potential impacts of Big Bar landslide was developed using very preliminary information available in early August 2019 and was incorporated into the projections.
- Under the assumption that current productivity will continue the projections show:

- Unlikely to Very Unlikely (0-33%) to reach Recovery Target #1 even at low mortality rates for Early Stuart and Bowron.
- As Likely as Not (34-65%) to reach Recovery Target #1 at low mortality rates for Upper Barriere, Portage, Weaver Creek, Raft*, Late Stuart and Birkenhead*.
- Likely or Very Likely (66-100%) to reach Recovery Target #1 at low mortality rates for Quesnel, and Stellako*.

- This report covers elements 12, 13, 15, 19-21 (i.e., quantitative analysis of recovery targets, probability of achieving recovery targets, and mitigation effects) and summarizes how these elements would contribute to element 22 “allowable harm”. **The allowable harm assessment in this document does not include the elements covering habitat, threats, and limiting factors and should not be interpreted as being the final allowable harm statement for these DUs.**
- Recognizing that activities in support of the survival and recovery of the species can result in possible mortalities (e.g., stock assessment, research, conservation, or mitigation activities), all sources of harm should be reduced to the maximum extent possible for: Early Stuart and Bowron DUs in order to provide the *best opportunity for the survival* of these DUs.
- Recognizing that activities in support of the survival and recovery of the species can result in possible mortalities (e.g., stock assessment, research, conservation, or mitigation activities), all sources of harm should be reduced to the maximum extent possible for: Weaver, Raft, Birkenhead, Portage, Late Stuart and Upper Barriere DUs in order to provide the best opportunity for the DUs to meet Recovery Target #1.
- Preliminary results are presented for Quesnel and Stellako DUs. However, no allowable harm statement can be made at this time. Additional information will be available in the next four months which will allow for updated estimates of the impacts and an associated allowable harm statement based on the modelling results.
- For Taseko and Widgeon DUs, the available data does not allow for the assessment of allowable harm using the methods described in this paper. However, using the other small stocks assessed in this papers as proxies: all sources of harm should be reduced to the maximum extent possible for Taseko and Widgeon.

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APPENDIX A: TERMS OF REFERENCE

RECOVERY POTENTIAL ASSESSMENT – FRASER RIVER SOCKEYE SALMON (*ONCORHYNCHUS NERKA*) – TEN DESIGNATABLE UNITS

Regional Peer Review – Pacific Region

October 7-11, 2019
Richmond, BC

Chairperson: Gilles Olivier

Context

After the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses an aquatic species as Threatened, Endangered or Extirpated, Fisheries and Oceans Canada (DFO) undertakes a number of actions required to support implementation of the *Species at Risk Act* (SARA). Many of these actions require scientific information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for consideration of peer-reviewed scientific analyses into SARA processes including recovery planning.

The following ten populations of Fraser River Sockeye Salmon (*Oncorhynchus nerka*) were designated as Endangered or Threatened by COSEWIC in 2017 based on population declines (COSEWIC 2017).

1. Cultus Lake population (**Endangered**): This population was first designated by COSEWIC as Endangered in an emergency assessment in October 2002. Status was re-examined and confirmed in May 2003 and November 2017. Cultus Lake is one of the most heavily utilized lakes in BC and it has been developed for recreational, residential and agricultural purposes. The lake's water quality has been degraded as a result of seepage from septic systems, agricultural runoff and domestic use of fertilizers as well as by an introduced Eurasian water-milfoil (Myriophyllum sp.). The spawning population has declined steadily since 1950 and the current population size remains very small.
2. Bowron – early summer (ES) population (**Endangered**): The number of mature individuals in this population has been declining since the mid-1950s and there has been a large decline in the past 3 generations.
3. Harrison - upstream (U/S) population (**Endangered**): The number of mature individuals increased from a low level in 1960 to a peak in 1980. Since then, the numbers have fluctuated in a downward direction to reach an historical minimum in the most recent period.
4. Quesnel - summer (S) population (**Endangered**): The population has declined consistently since 2000.
5. Seton – late (L) population (**Endangered**): The number of mature individuals in this population was relatively high and stable from the mid- 1970s to the late-1990s. Since then the numbers have declined considerably to very low abundance and are close to a historical minimum.
6. Takla-Trembleur- Early Stuart (EStu) population (**Endangered**): The number of mature individuals has been declining steadily for over 20 years despite reductions in fishing mortality. Productivity is currently very low.

7. Takla-Trembleur-Stuart – summer (S) population (**Endangered**): The number of mature individuals has been declining steadily for three generations yet removals by fishing remained high.
8. Taseko - early summer (ES) population (**Endangered**): The number of mature individuals was relatively high in the late 1990s. Since then the numbers have declined considerably and are close to a historical minimum.
9. North Barriere – early summer (ES) population (**Threatened**): Since 1980, there has been a continuous decline to a low number today.
10. Widgeon (River-Type) population (**Threatened**): The number of mature individuals was relatively stable from 1950 to 1990, and then declined considerably to a minimum in 2000. Over the past 3 generations the number of fish has returned to pre-1990 abundances. However, the small population size makes them vulnerable to stochastic events and increasing threats.

DFO Science has been asked to undertake a Recovery Potential Assessment (RPA), for these 10 populations based upon the national RPA Guidance. The advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing decision, development of a recovery strategy and action plan, and to support decision making with regards to the issuance of permits or agreements, and the formulation of exemptions and related conditions, as per sections 73, 74, 75, 77, 78 and 83(4) of the *Species at Risk Act* (SARA 2002). The advice in the RPA may also be used to prepare for the reporting requirements of SARA section 55. The advice generated via this process will update and/or consolidate any existing advice regarding these populations of Fraser River Sockeye Salmon.

Typically, when an RPA is undertaken all 22 different elements are complied into one working paper for review to inform not only a listing decision under SARA, but subsequent recovery planning. For Fraser River Sockeye Salmon there will be three separate working papers, presented and reviewed together. The three working papers are as follows:

- Working Paper#1: Fraser River Sockeye Salmon (Cultus Lake population) – 22 elements.
- Working paper #2: Fraser River Sockeye Salmon (9 populations: excluding Cultus-L population) – Elements 1-11, 14, 16-18.
- Working paper #3: Fraser River Sockeye Salmon (9 populations: excluding Cultus-L population) – Elements 12, 13, 15, 19-22.

Objective

To provide up-to-date information, and associated uncertainties, to address the following elements:

Biology, Abundance, Distribution and Life History Parameters

Element 1: Summarize the biology of Fraser River Sockeye Salmon (10 populations).

Element 2: Evaluate the recent species trajectory for abundance, distribution and number of populations.

Element 3: Estimate the current or recent life-history parameters for the 10 populations of Fraser River Sockeye Salmon.

Habitat and Residence Requirements

Element 4: Describe the habitat properties that Fraser River Sockeye Salmon populations need for successful completion of all life-history stages. Describe the function(s), feature(s), and attribute(s) of the habitat, and quantify by how much the biological function(s) that specific habitat feature(s) provides varies with the state or amount of habitat, including carrying capacity limits, if any.

Element 5: Provide information on the spatial extent of the areas for Fraser River Sockeye Salmon distribution (10 populations) that are likely to have these habitat properties.

Element 6: Quantify the presence and extent of spatial configuration constraints, if any, such as connectivity, barriers to access, etc.

Element 7: Evaluate to what extent the concept of residence applies to the species, and if so, describe the species' residence.

Threats and Limiting Factors to the Survival and Recovery of Fraser River Sockeye Salmon (10 populations)

Element 8: Assess and prioritize the threats to the survival and recovery of the 10 populations of Fraser River Sockeye Salmon.

Element 9: Identify the activities most likely to threaten (i.e., damage or destroy) the habitat properties identified in elements 4-5 and provide information on the extent and consequences of these activities.

Element 10: Assess any natural factors that will limit the survival and recovery of the 10 populations of Fraser River Sockeye Salmon.

Element 11: Discuss the potential ecological impacts of the threats identified in element 8 to the target species and other co-occurring species. List the possible benefits and disadvantages to the target species and other co-occurring species that may occur if the threats are abated. Identify existing monitoring efforts for the target species and other co-occurring species associated with each of the threats, and identify any knowledge gaps.

Recovery Targets

Element 12: Propose candidate abundance and distribution target(s) for recovery.

Element 13: Project expected population trajectories over a scientifically reasonable time frame (minimum of 10 years), and trajectories over time to the potential recovery target(s), given current Fraser River Sockeye Salmon population dynamics parameters.

Element 14: Provide advice on the degree to which supply of suitable habitat meets the demands of the species both at present and when the species reaches the potential recovery target(s) identified in element 12.

Element 15: Assess the probability that the potential recovery target(s) can be achieved under current rates of population dynamics parameters, and how that probability would vary with different mortality (especially lower) and productivity (especially higher) parameters.

Scenarios for Mitigation of Threats and Alternatives to Activities

Element 16: Develop an inventory of feasible mitigation measures and reasonable alternatives to the activities that are threats to the species and its habitat (as identified in elements 8 and 10).

Element 17: Develop an inventory of activities that could increase the productivity or survivorship parameters (as identified in elements 3 and 15).

Element 18: If current habitat supply may be insufficient to achieve recovery targets (see element 14), provide advice on the feasibility of restoring the habitat to higher values. Advice must be provided in the context of all available options for achieving abundance and distribution targets.

Element 19: Estimate the reduction in mortality rate expected by each of the mitigation measures or alternatives in element 16 and the increase in productivity or survivorship associated with each measure in element 17.

Element 20: Project expected population trajectory (and uncertainties) over a scientifically reasonable time frame and to the time of reaching recovery targets, given mortality rates and productivities associated with the specific measures identified for exploration in element 19. Include those that provide as high a probability of survivorship and recovery as possible for biologically realistic parameter values.

Element 21: Recommend parameter values for population productivity and starting mortality rates and, where necessary, specialized features of population models that would be required to allow exploration of additional scenarios as part of the assessment of economic, social, and cultural impacts in support of the listing process.

Allowable Harm Assessment

Element 22: Evaluate maximum human-induced mortality and habitat destruction that the species can sustain without jeopardizing its survival or recovery.

Expected Publications

- Science Advisory Report
- Proceedings
- 3 Research Documents (working papers 1, 2, and 3)

Expected Participants

- Fisheries and Oceans Canada (Ecosystems and Oceans Science, and Ecosystems and Fisheries Management sectors)
- Province of BC
- Academia
- First Nations
- Industry
- Environmental non-governmental organizations

References

COSEWIC. 2017. COSEWIC Assessment and Status Report on the Sockeye Salmon (*Oncorhynchus nerka*) 24 Designatable Units in the Fraser River Drainage Basin in Canada 2017. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 179 pp.

APPENDIX B: WORKING PAPER REVIEWS

REVIEWER: SCOTT DECKER – FISHERIES AND OCEANS CANADA

Recovery Potential Assessment for Endangered Cultus Lake Sockeye Salmon – Elements 1-11, 14, 16-18

The following six questions provide general guidance for your review:

1. Is the purpose of the working paper clearly stated?
2. Are the data and methods adequate to support the conclusions?
3. Are the data and methods explained in sufficient detail to properly evaluate the conclusions?
4. If the document presents advice to decision-makers, are the recommendations provided in a useable form?
5. If the document presents advice to decision-makers does the advice reflect the uncertainty in the data, analysis or process?
6. Can you suggest additional areas of research that are needed to improve our assessment abilities?

Overall evaluation

Overall, the authors have done a thorough and commendable job completing Elements 1-11, 14, and 16-18. Moreover, the structure and content of these Elements conforms very well to current COSEWIC and RPA guidelines. The data and methods are adequate to support the conclusions and recommendations the authors have made, and are explained in sufficient detail to allow the conclusions to be properly evaluated. The authors have extensive personal involvement in a substantial amount of the research that supports this assessment, and clearly have a strong familiarity with the body of research available for Cultus Lake and expertise in limnology. They have supported their conclusions about key threats and limiting factors with highly detailed and informative descriptions of the underlying mechanisms and complex interactions and processes occurring in Cultus Lake.

The recommendations provided to decision-makers are constructive and at a level appropriate for the scope/intent of this work. For example, the authors indicate which types and sources of nutrient should be prioritized for reduction, and what the benefits would likely be, and provide examples where this has been done successfully in other jurisdictions. With respect to threats and limiting factors in freshwater, the available research for Cultus Lake is quite extensive and robust relative to what is typically available for Pacific salmon populations, allowing the authors to present advice and recommendations with a relatively high degree of certainty, and they have done so here. One mitigation measure they suggest for which they may be understating the associated challenges and uncertainty as to whether it could be implemented is reducing nitrogen and phosphorus concentrations in the regional airshed.

The authors have themselves provided several suggestions for additional areas of research that are needed to improve future assessments. I have provided a number of suggestions with respect to additions and revisions to some of the Elements included in the assessment. These are detailed below. I have also provided editorial comments embedded in the document using the Word Track Changes function.

Section by section comments

- Would have been helpful to include line numbering!

- Use ‘population’ in place of ‘stock’ whenever possible to be consistent with COSEWIC terminology (‘stock’ appears a few times throughout)
- Check Table and Figure # references in the text, there are some errors
- Section 2.2 (Element 2)
    - I agree that adult returns is the most relevant metric to assess species trajectory. However, the 3 and 4 years of adult and smolt data that is now available since the 2017 COSEWIC suggests the decline in the Cultus population is possibly accelerating. Natural smolt production in the lake during 2015-2019 is particularly alarming, suggesting a quasi-recruitment failure. The concluding sentence for Element 2, “*This continued low abundance does not suggest a re-assessment of the current COSEWIC endangered status is warranted*” implies there is no evidence to suggest the situation has improved, but the more relevant question is: has the situation gotten worse since the last assessment. I suggest some rewording here.
    - Consider adding a sentence explaining the lack of useful data to assess trend in distribution
- Section 3.2.2 – it would be nice to see some more specific marine distribution information for Fraser Sockeye here. This has implications with respect to identifying threats such as competition with hatchery pink and chum salmon.
- Section 4.1 (Element 8)
    - “Threats and limiting factor risks are calculated using rankings for level of impact and likelihood of occurrence and plotting them in the Threat Risk Matrix to derive an overall threat or limiting factor risk.” I am a bit confused by this statement. To develop Tables 2 and 3, I assume what the authors have done is to:

1. Go through the COSEWIC Threats Assessment exercise outlined in DFO 2014 guidance doc., and assign qualitative scores (high, medium, low, etc.) for each category based on available information and their own professional judgement as SMEs
2. Use the COSEWIC *Threats Risk Matrix* to obtain a score for *Population-Level Threat Risk* category with *Casual Certainty* score in brackets as an appendage.
3. Rank the threats in the table according to *Population-Level Threat Risk* score

I would recommend that part 2 of Section 4.1 be revised/augmented to clarify the approach taken. In the document, I have a suggested a revision to the captions for Tables 2, 3.

- Section 4.1.1 – “Despite the intent, and some uncertainties in estimating exploitation rates for Cultus Lake Sockeye Salmon and the conservation efficacy of the IFMP limits, published exploitation rate estimates indicate incidental marine harvests have removed significant amounts of the Cultus Lake Sockeye Salmon population in some years, and have exceeded pre-season Integrated Fisheries Management Plan maximum allowable limits ~47% annually over the past 15 years (period since last SARA listing consideration), and 75% annually, in years coinciding to the dominant Adams River Sockeye Salmon run over the same period (Figure 5; DFO 2018b, 2019)”. – This sentence is a bit awkward and confusing. The wording around the 47% and 75% statistics is also confusing , by 47% annually, are you saying that the actual ER has exceeded the limit by an average of 47% across years, or exceeded the limit by some degree in 47% of the last years. If limit was 50% ER, than exceeding it by 75% would equate to ER of 87.5%, yes?

- Section 4.1.2 – “For Cultus Lake Sockeye Salmon, poor natural smolt production has resulted in the population being dominated by hatchery production, a scenario that is likely to continue for at least the next generation” . Table 5 in Element 15 suggests the population will be dominated for the next 3 generations and beyond, unless the current recovery strategy is shifted towards more reliance on wild production, which seems unlikely given these projections.
- Section 4.1.4 – With respect to a Pacific salmon RPA, this is an somewhat rare example where a important freshwater impact is relatively well studied and well described, as oppose to the usual generic laundry list (forestry, roads, dams, etc). Nice job DFO Lakes Research Program.
- Section 4.1.5 – Climate change effects on ocean productivity (growth, survival, fecundity) is missing here, some discussion is warranted to be consistent with RPAs for other Pacific salmon.
- Another potential limiting factor that should possibly be considered (included in Sackinaw Sockeye COSEWIC assessment) is single population/single site. As the population occupies only a single, relatively small lake, any catastrophic event impacting the lake could eliminate one or more year classes. This applies equally (perhaps more so) to the hatchery where Cultus Sockeye are reared, given that enhancement currently contributes the large majority of smolts annually.
- Tables 2-3 – the work you have done here should make the Threats Calculator workshop go very smoothly.
- Section 6.1.2
    - “Eutrophication resulting from known anthropogenic nutrient sources (N and P) is directly impacting Cultus Lake (Putt et al. 2019), critical habitat for Cultus Lake Sockeye Salmon, and is a primary forcing on their persistence in the wild, with freshwater survival now the dominant mediator of overall population abundance.” This statement is a bit

      confusing/misleading. Eutrophication is limiting freshwater survival for fry rearing the lake that originate from natural spawning and hatchery fry plants, but not for fry grown in the hatchery to the smolt stage and released below the weir. These latter fish now represent the majority of total smolt outmigrants and returning adults, so freshwater survival in the lake isn’t actually the dominant mediator of overall population abundance.
    - Reduction of airshed N and P inputs: the authors have provided supporting information to indicate the technical feasibility of reducing airshed inputs, but what about the overall feasibility? This obviously delves into socio-economic and political realms, but if the authors could provide some case study examples from other jurisdictions where airshed contamination was reduced on a sufficiently large scale, such that lake eutrophication or some other issue (acid rain?) was effectively mitigated, this might lend support to their argument. What progress, if any has the GVRD made in regard to planning or action around this issue? Along with reducing harvest, reduce airshed contamination is the principle mitigation measure the authors are recommending to recover Cultus Sockeye, so any additional relevant information here is helpful.
- Section 6.2 (Element 17) – the authors have perhaps missed the mark here. Element 17 calls for a simple inventory od activities that could increase survivorship or productivity parameters. Instead they have provided methods and results for a simulation exercise, in addition to that already provided in Elements 13 and 15, to look at projections of future smolts/spawner under different scenarios. This is very confusing and seemingly redundant.

Some of the methods text about how hatchery production is modelled is already provided as part of the Cultus Model description in Appendix A. Harvest and freshwater survival mitigation are already addressed in Element 16 and don't need to be included here. A description of hatchery supplementation and the risks and benefits of this activity should be included here along with any other relevant activities that increase survival that are not mitigation of threats (e.g., NPM control).

- Section 6.3 (Element 18) – same comments as Section 6.1.2. Need to provide more support for the assertion that 'feasibility of restoring habitat quality is high'.

REVIEWER: MICHAEL PRICE – SIMON FRASER UNIVERSITY

Recovery Potential Assessment for Endangered Cultus Lake Sockeye Salmon – Elements 1-11, 14, 16-18

Thank-you for the opportunity to review this Recovery Potential Assessment (RPA). Broadly, I found the report to be a well-written and detailed evaluation of the threats and factors limiting the survival and productivity of Cultus Lake Sockeye Salmon, and I conclude that the objectives of the RPA - as set out in the Terms of Reference - have been met. In my opinion, the extensive information provided on threats from rearing lake eutrophication was fascinating and necessary, yet it highlighted the general absence of detail that exists for other threats to the population. For example, I found the information contained in Element 8 (*threats to the population*) to be incomplete for threats that currently contribute to the underlying vulnerability of this population, which I strongly recommend be included. This thread runs through the document in that more information on threats should be included regarding knowledge gaps (Element 11), and feasible mitigation measures (Element 16). While I appreciated the authors distinction between threats and limiting factors, and their inclusion of threat severity ratings at the end of each threat sub-section, I believe that more information also should be provided on the limitations of the threat assessment. For example, how were biological risk scores calculated, and what are some of the limitations of such an assessment? Finally, I have suggested changes for minor typos and format inconsistencies throughout the document via Track Changes. My comments are organized by RPA Element.

Element 2. *Evaluation of the recent species trajectory for abundance, distribution and number of populations*. While I appreciate the inclusion of recent adult spawner data (up to 2018), and the separation of returns into natural and hatchery components, it would be helpful to see spawner abundances further back in time considering that a counting fence has been in operation since the 1920s.

Element 8. *Threats to the survival and recovery of Cultus Lake Sockeye Salmon*. I appreciate the level of detail the authors provided regarding threats to the population, particularly their focus on Nursery Lake eutrophication. However, several threats that currently contribute to the underlying vulnerability of this population are absent, and I argue should be included. One of these is density-dependent interactions during marine rearing in the north Pacific. There is no mention of a growing body of evidence linking the abundance of Pink salmon in the north Pacific and reduced productivity of Fraser Sockeye in general, and the Cultus population specifically (see Ruggerone and Connors 2015). Marine open net-pen salmon farming also was not mentioned as a threat. This is surprising given the time spent on the topic during the Cohen Commission of Inquiry, and the inclusion of this threat in the 2017 COSEWIC assessment. Indeed Connors et al. (2012) showed how the production of farmed salmon along the juvenile Fraser Sockeye Salmon migration route can exacerbate the negative influence of pink salmon abundance in the north Pacific on Fraser River Sockeye Salmon. Furthermore, given that there is ongoing research by DFO on the disease mediated risk to wild salmon from marine salmon farms, this seems an important topic to include.

While I commend the authors on their description of fishing-related mortality as a threat to the current endangered status of the Cultus population, I feel that there should be some acknowledgement regarding the indirect and likely unintended consequences of the removal of fish from the Cultus population over the last 150 years of commercial fishing. Such as the loss of fine-scale population structure, biocomplexity, and adaptive capability to forces such as climate change.

Finally, of perhaps minor significance, I found it odd that there was no mention of major alterations to migratory habitat between Cultus Lake and the Fraser River; specifically, along Sweltzer Creek, Chilliwack River, and Sumas River. There are a series of dykes and substantial hardening of shorelines, and it would be helpful for the authors to describe these alterations and how they might affect out-migrating juveniles and in-migrating adults in terms of predation threat. Furey et al. (2016) reported that predation rates on juvenile sockeye are highest at low population sizes, and that landscape structure can influence predator aggregations. Specifically, survival of Sockeye was poorest in areas with physical bottlenecks; once such bottleneck was a counting fence. Might such habitat modifications be a current threat to the Cultus population given their low abundance? This also could be discussed in Element 11.

Element 11. *Discussion of the potential ecological impacts of the threats identified in Element 8 to the target species and other co-occurring species. Existing monitoring efforts and any knowledge gaps*. While I realize that the intent of the RPA is not to identify all gaps in our current knowledge, I believe that more needs to be included in this section, particularly with regards to potential threats from marine competition and salmon farms, but also in terms of changes in genetic and life-history diversity; how much has been lost for this population over the last century or more?

Element 16. *Inventory of feasible mitigation measures and reasonable alternatives to the activities that are threats to the species and its habitat*. To follow through on a previous thread, one feasible mitigation measure for the threat of marine open net-pen salmon farms is to remove such farms from juvenile Sockeye migration routes. I feel that this should be considered.

Element 17. *Inventory of activities that could increase the productivity or survivorship parameters*. When describing hatchery brood-stock in this Element, the authors state that no more than 50% of returning adults in any year would be used, up to a given maximum. This seems far too high a proportion. It seems to me that the majority of returning adults should be allowed to spawn naturally, and not more than 10% of the population should be removed for hatchery production if indeed we want to minimize domestication effects. Could the authors please provide references to support the use of such high proportions? If no support can be found, I feel that the authors should elaborate on how current hatchery production may indeed impact the population; perhaps best incorporated into Element 8 section 4.1.2 on Hatchery production.

Literature cited

Connors, B.M., Braun, D.C., Peterman, R.M., Cooper, A.B., Reynolds, J.D., Dill, L.M.,Ruggerone, G.T., and Krkosek, M. 2012. Migration links ocean-scale competition and local ocean conditions with exposure to farmed salmon to shape wild salmon dynamics.

Conservation Letters 5: 1-9.Ruggerone, G.T., and Connors, B.M. 2015. Productivity and life history of Sockeye salmon in relation to competition with pink and Sockeye salmon in the North Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences 72: 1-16.

COSEWIC. 2017. COSEWIC assessment and status report on the Sockeye Salmon *Oncorhynchus nerka*, 24 Designatable Units in the Fraser River Drainage Basin, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xli + 179 pp.

Furey, N.B., Hinch, S.G., Bass, A.L., Middleton, C.T., Minke-Martin, V., and Lotto, A.G. 2016. Predator swamping reduces predation risk during nocturnal migration of juvenile salmon in a high-mortality landscape. Journal of Animal Ecology 85: 948-959.

REVIEWER: CARRIE HOLT – FISHERIES AND OCEANS CANADA

Review #1: Recovery Potential Assessment for Endangered Cultus Lake Sockeye Salmon – Elements 1-11, 14, 16-18

The following six questions provide general guidance for your review:

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

Yes

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

Yes, though I have suggested emphasizing genetic impacts on fitness from hatchery enhancement in the conclusions on allowable harm.

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

Yes

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

Yes, though further exploration of specific mitigation measures would be valuable. If these measures cannot be modelled quantitatively, then a description of the gaps and challenges would be helpful. The guidelines for RPAs suggest the use of information from other species to inform impacts when data are limiting. For Pacific salmon, information from other DUs may be particularly useful.

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

Yes, the recommendations reflect uncertainty in stock-recruitment relationships, which is driven in part by uncertainty in the data. However, it does not fully account for variability in age-at-maturity and outcome uncertainty. I suggest further exploring the implications of ignoring those uncertainties, especially in terms of recommendations to decision makers. See further comments on this below

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

See comments below.

The authors have done a thorough job of identifying objectives and evaluating projected abundances against those objectives. In particular, the contribution of this work towards evaluating impacts of hatchery enhancement on recovery objectives is commendable.

General comments

Section 5.1 Recovery targets (Element 12)

- I suggest being explicit about how the PNI values should be used to interpret recovery. For example, if abundance-based goals are met but PNI value are not >0.72, then presumably recovery has not been achieved? The application of PNI to recovery targets is an important contribution of this paper and the implications of including them deserve more emphasis.
- The application of 7,000 to objective 3 is not entirely clear and could be strengthened. The general goal is to support a delisting decision, where the Endangered designation for Cultus Sockeye is due to ongoing threats, long-term declines since the 1950s, and a small populations size. it's not clear why 7,000 would meet this given that criterion C2aii was used to trigger this designation, which requires abundances less than 2,500 for Endangered and 10,000 for Threatened. I suggest 10,000 as a more appropriate value.
- Either way, citation from the primary literature for those values would helpful (e.g., Reed et al. 2003 for 7,000 number)

  Reed, D. H. et al. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation, 113: 23–34.
- To what extent does increasing distribution among spawning areas contribute to the sustainability of the DU? The text describes how spawning may become more widely distributed as abundances increase, but it's not clear to what extent the population is more resilient when distribution is greater. I'm not sure what "it is sensible" really means here.

Section 5.2 and 5.4 Projections under baseline conditions (Element 13 and 15)

- Why such a large drop in the last year of the simulated time-series (top-right panel)? If this is a random deviation, was a sufficient number of MC trials run in the simulation?
- Suggest including a bit more justification for excluding fitness impacts from genetic introgression from hatcheries. Is it that the incremental increase in those impacts is likely negligible over 3 generations? What about reduced reproductive success of hatchery origin fish and epigenetic effects, as described in Withler et al. (2018)? Presumably these are captured in the hatchery survival rate data used to simulate abundances?
- The model does not include variability in age-at-maturity. What are the implications of ignoring age structure (e.g., on autocorrelation), and inter-annual variability in age structure (e.g., uncertainty may be underestimated).
- Because uncertainties in the outcomes from implementing target exploitation rates are not included, these models describe the probability of achieving recovery given a specified exploitation, not the probability of achieving recovery given a management strategy with those as target exploitation rates. Including outcome uncertainties and providing recommendations on target exploitation rates may be more useful for decision makers.

Section 6.4 Estimate reduction in mortality rates from Elements 16 and 17 (Element 19)

- Specific activities to increase survivorship are not provided outside of hatchery production and reducing exploitation. Instead an increase in freshwater survival is simulated to represent hypothesized mitigation efforts. I suggest providing a list of possible mitigation projects and identifying the knowledge gaps that limit the modelling of impacts of those projects. It's not clear why "It is currently not possible to develop more explicit quantitative estimates of the effects of mitigation measures on salmon mortality or productivity ".

- Also, the linear trend in freshwater survival hypothesized in Fig. 12 (Section 6.2) and incorporated in the simulation model would benefit from further justification. How plausible are those freshwater survival rates in the future given mitigation efforts? How do they compare to survival rates in more pristine environments, e.g., prior to 1999 or elsewhere? Perhaps these are best described as an upper bound on increases in survival from freshwater mitigation?
- Do the hatchery supplementation scenarios bound the possible measures given constraints of the facilities? Or is larger supplementation possible, but experts chose these 4 alternatives as moderate/feasible options? The 2nd sentence of Section 6.2 isn't entirely clear.

Section 6.5 Projections with mitigation measures (Element 20)

- "Results show all hatchery strategies can significantly increase the number of spawners returning to the lake (Table 7)". If this is the case, why hasn't the current hatchery strategy ("mixed" strategy, as inferred in Section 5.2) worked to increase abundances? Fig. 3 suggests that abundances remain low.
- "The results also show that the current hatchery program is sized appropriately so that PNI values increase to the target range as the population increases to the recovery goal". This assumes habitat mitigation measures are in place? Without those measures, abundances and PNI values remain low.

Section 6.6 Parameter values (Element 21)

- I suggest mentioning that model was simulated (entirely?) from empirical data, and including tables of those empirical values in the Appendix. They are currently hidden in the code.

Section 7.1 Allowable Harm (Element 22)

- "Hatchery supplementation can maintain a small, mostly hatchery, population at the lake under the various scenarios of fishing mortality but it is unlikely that survival or recovery or a wild population will occur". Is this referring to recovery within the 3 generation time period, or over the long-term, and with or without freshwater mitigation measures? Although the simulation model suggests a trajectory towards recovery with increasing abundances and PNI values for scenarios with mixed hatchery production, genetic fitness impacts are not included in the model and long-term impacts of low PNI values are therefore not accounted for.
- "… the population will continue to be assessed as endangered, or may become extinct in the wild, having been effectively replaced with a hatchery population". This is confusing as I think it conflates the proposed approach by COSEWIC to remove non-wild fish from assessments, and a possible trend to increasing hatchery production relative to wild (which may occur due to low survival of naturally spawning fish associated with various threats including genetic fitness impacts from hatchery enhancement). My apologies if I've misinterpreted this sentence.
- "Some level of limited human-induced mortality may be allowable if measures to increase natural-origin smolt production to levels observed historically are successful". I suggest adding a time-frame. Long-term hatchery production may result in fitness consequences due to introgression reducing the potential for recovery. Indeed, exploitation may slow the rate of recovery and allowing time for possible detrimental fitness impacts from hatcheries to occur. I suggest emphasizing these generic risks here.

Editorial suggestions

1. Abstract. Second last sentence. "..unlikely to reach survival or recovery targets.." within the 3 generation time frame, or at all?
2. Introduction, last paragraph. I suggest including text on the requirement for net positive influence of supplementation by COSEWIC, as described later in this document. Also, this analysis considered two options, not just the one highlighted in the last sentence here. Indeed, it's not clear that COSEWIC will always consider hatchery enhanced fish as part of the DU.
3. Table 1, smolt survival rows. Presumably, these are for wild fish only?
4. Section 5.1 Method 2 for accounting for hatchery supplementation removes all "non-wild" fish (fish that didn't spawn in the wild or that had parents that didn't spawn in the wild). The text cites COSEWIC 2017's Fraser Sockeye Report, but I think this approach has only been considered by COSEWIC for Southern BC Chinook so far, and this has not yet been approved.
5. All references to Figures and Tables should be checked. I think there are some misalignments.
6. Section 5.2. Suggest clarifying if the "mixed" strategy that is currently in place is exactly as described in Section 6.2, or only similar to current methods in that both pars and smolts released, but the numbers differ.
7. Table 4. Suggest clarifying if row 5 is the mean among all MC trials, or only those MC trials where the population did not become extinct (i.e., where those trials were removed from the calculation?). If only trials that weren't extinct, then this mean last generation abundance will underestimate total risks when compared to recovery targets.
8. Figure 11. Y-axis label of top right panel should be "wild spawners" (?) to align with text on previous page. Why such a large drop in the last year of the simulated time-series (top-right panel)? If this is a random deviation, was a sufficient number of MC trials run?

Review #2: Recovery Potential Assessment for Fraser River Sockeye Salmon (*Oncorhynchus nerka*) Nine populations - excluding Cultus-L population – Elements 12, 13, 15, 19-22

The following six questions provide general guidance for your review:

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

Yes, though the RPA includes DUs of special concern, not listed in the TOR. The purpose of this is not clear. How would those results be used?

Also, a clearer link between parts 1 and 2 of the paper would be helpful, specifically in terms of Elements, 19, 20, 21, and 22. Although we are not able to review Part 1 at this time, a place holder for linking mitigation actions to models would be useful.

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

Elements 19 and 20 (projections given mitigation) would be strengthened with more specific details on mitigations. Although there are a large number of possible mitigation actions, could these be scoped the most feasibly ones for this analysis? Also, Element 22 might be strengthened by simulating reasonable bounds on mortality rates for Big Bar impacted DUs to provide some information on allowable harm.

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

I have recommended several places where more details would strengthen the results and conclusions. See comments below.

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

The Figures/Tables provide a clear way of communicating the probability of achieving recovery goals under different productivity and exploitation scenarios. Because outcome uncertainties (uncertainties in the outcomes from implementing a harvest strategy) were not included in the models, the advice provided here is the probability of recovery If specific exploitation rates are achieved, not the probability of recovery given specific exploitation rate targets since they would be applied with uncertainty.

Going forward, more specific analyses and recommendations for individual mitigation actions will be important, but this is currently difficult to address without Part 1 of this RPA and the data to support the underlying quantitative relationships in many cases.

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

Yes, the recommendations reflect uncertainty in stock-recruitment relationships, which is driven in part by uncertainty in the data. However, it does not fully account for variability in age-at-maturity and outcome uncertainty. As mentioned above, I suggest further exploring the implications of ignoring those uncertainties, especially in terms of recommendations to decision makers.

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

See below.

Comments to Authors

I commend the authors on a thorough quantitative analysis of recovery potential for these DUs, given existing data limitations. This involved a significant amount of work, using input from a large group of technical experts. Below are some general comments followed by editorial suggestions.

Section 3.2 Caveats and Conditions

- The subsection on data limitations describes those related to errors in variables, though time-series biases can also be significant especially when time-series are autocorrelated. The extent of this bias depends on the contrast in the abundance data. Time-series biases can result in either over or underestimates of productivity depending on historical pattern of exploitation and true underlying productivity (i.e., it's difficult to tell the direction of the bias)
- In the sub-section on SR models, a broader range of SR models could be considered in future analyses and could be listed as caveats here, such as those that include time-varying capacity alone, or in combination with time-varying productivity (as in Britten et al.2016). Another variant is models that account for changing propensity for cyclic behaviour (e.g., demonstrate cyclic dynamics for a period, followed by non-cyclic dynamics).
- Most importantly, models that separate freshwater and marine mortality would be extremely valuable. This would allow for a comparison of the relative magnitude of threats to freshwater vs marine survival or productivity, as well as a comparison of the relative magnitude of possible mitigation in freshwater vs marine environment. Smolt data are

currently lacking to develop DU-specific life-stage models for most stocks (Chilko being an exception), but I wonder what advances could be made by borrowing information among DUs. For example, given that productivity trends are thought to be roughly coherent among most stocks likely related to events early marine life (with a few exceptions, e.g., Harrison), could marine survival of Chilko be used to roughly approximate marine survival for other DUs and then back calculate a rough estimate of smolt abundances? DFO's "Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk" suggest that "inferences and using information derived from surrogate species is acceptable". Although uncertainties would be large (and could be bounded by plausible values in sensitivity analyses), the analyses may provide a rough indication of the value of habitat mitigation in freshwater vs reductions in marine exploitation/mortality. At the very least, a discussion of the merits of life-stage specific modelling is warranted. Such life-stage specific models do exist for evaluating impacts of mitigation efforts for salmon (e.g., Lundin et al. 2019)

- For the sub-section on mitigation, why not evaluate the impacts of hatchery supplementation? These seems like a tractable and realistic first step. I agree the number of possible mitigation projects is large. Will these possible projects be listed elsewhere in the RPA is not here? This would be a first step, from which you could highlight the specific gaps or data needs to develop and implement a model of their impacts.
- For the sub-section on future productivity, I suggest including a scenario where the current trend in productivity continues over the next 3 generations. Although this is likely within the bounds of the ranges considered already, it's not clear where this scenario would end up relative to them. Also, this section focuses on persistent changes in productivity, but instead we may experience increased interannual variability in productivity if extreme events become more common. This is described in an anecdotal way in the text (section 3.2.5 paragraph 2), but wasn't explicitly modelled.
- The section on allowable harm focuses on the contribution of non-fishery sources of mortality in modelled exploitation rate, which I agree is an important caveat. Are directional trends in those other sources of mortality expected over the next 3 generations? (or historical trends?) If not, they may contribute to noise in the relationship, but I think the underlying idea that ER scenarios represent increases or decreases in harvest still holds.

Section 5.1 Recovery Targets (Element 12)

- I think some justification or context for the choice of the recovery targets would be helpful. How do these compare to those for other salmon DUs, and especially the 4 generic goals set for Cultus: genetic integrity, increase in abundances, de-listing, and restore ecosystem function. I find it useful to identify aspirational goals first, which are linked to quantifiable (S.M.A.R.T.) goals such as those listed in Table. 4.
- I recommend that Not Endangered/Threatened (Not EN/TH) recovery target be broadened in its description and further explained. In particular, because being above a WSP lower benchmark on spawner abundances (25^{th} percentile of spawner abundances) is a component of this objective, it might be described as Not EN/TH/Red. This target achieves genetic integrity goal and is associated with COSEWIC not-at-risk or special concern designations, and WSP amber or green status on a metric of abundance. In general, these components are associated with relatively low risk of extinction.
- Element 12 states, "propose candidate abundance and distribution targets". To what extent are distribution targets required? Although there may some work on the distribution of spawning in the Stuart system that could be relevant (Doug Braun's recent work), other DUs

likely do not have this information. Any guidance on sub-population structure would helpful, even if just to inform future work on distributional targets.

- These objectives assume that distribution of abundances across the cycle line do not affect sustainability. For example, a strongly cyclic DU with small and declining off-cycle lines and stable dominant line is not at more risk than a non-cyclic DU with stable abundances. Some discussion on the extent to which this is true may be warranted. See Grant et al. *in press* for a short discussion on this.
- A few additional sentences on choice of 25th percentile of historical spawner abundances would be helpful. Why was this benchmark chosen? To represent a lower biological benchmark that is consistent among cyclic and non-cyclic CUs? There seems to be an inconsistency between this lower benchmark and the upper benchmark used for recovery target 2. The lower benchmarks are estimated here using updated data, whereas the upper benchmarks are taken from Grant et al. *in press*, averaged over all values proposed (suggest including which ones these were). Why use different approaches for lower and upper benchmarks? Since stock-recruitment benchmarks are not very reliable for cyclic stocks, consider sticking with percentiles benchmarks for upper benchmarks as well (50th) with caveats about use of percentiles for DUs exhibiting consistent declines over time (one-way trips). Also, Grant et al. *in press* chose different models to represent each CU than those used here (Table 1, Table 6). How can this be reconciled?

Section 5.2 Methods (Element 13)

- How sensitive are results to assumptions about priors in the Bayesian models? Are results similar if less informative priors on alpha are used ? (they seem quite informative, with possible double-use of data)
- What are the priors on alpha and beta0 for the Larkin model? The beta0 from the Larkin model cannot be interpreted the same ways as the beta0 from Ricker, and so priors may not be transferable, unless very uninformative.
- It would be helpful to have a chart/table in the Appendix describing how each DU fell in Figure A. To make these analyses reproducible, documentation on the decisions for each DU are needed. The data to inform those decisions are in the Appendix, but not the specific decision at each step of the tree in Fig. A.

Section 5.3 Projections (Element 13)

- A table of parameter values used in the simulation model would be helpful. I assume that multiplicative error in step 2 would be derived from sigma of best fit SR model(s)?
- These steps do not include interannual variability in age-at-maturity and outcome uncertainties, and therefore may underestimate total uncertainty associated with each ER/productivity scenario. If those uncertainties were included, the distribution of abundance outcomes may be more diffuse (less certain) than those provided here, affecting risk profiles (i.e., a more precautionary exploitation rate would be required to achieve targets with a specific probability such as 66%). I suggest more fully describing this caveat in the limitations section (which is currently only very briefly mentioned in Section 7.1). See also my comment on advice without outcome uncertainties in response to question 5 above.
- Is a pseudo-extinction threshold included below which the DU is lost? If variability is high, what is the probability that any DU becomes extinct (or drops below that threshold) before the 3 generations simulated period is complete? .

Section 5.4 (Element 15)

- Was the likelihood scale from DFO's "Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk" (Table 10 in that document) considered? It differs from IPCC's (Table 7)
- Section 5.4.1. "General results" sub-section. The result that achieving WSP lower benchmark is the limiting factor is not surprising given COSEWIC criteria are largely driven the directional trends, and these are expected to be positive for all DUs given 0% ER if productivity parameter is greater than replacement. The model has no other drivers that would cause a continued decline.
- I suggest moving time-series and matrix plots from the Appendix to the paper. Or, at the very least, I suggest referring to specific figures in the Appendix when describing DU-specific results.
- Can we say anything about allowable harm to non-modelled stocks, especially Widgeon given very low abundances recently, variable ER, and likely low productivity (assuming similar trends to other Fraser Sockeye DUs). It seems unlikely that this DU can withstand ongoing exploitation.

Section 6.1 Mitigation (Element 19)

- This section requires input form Sections 16 and 17, which are not currently available, specifically a list of mitigation measures for reducing mortality and increasing productivity or survivorship (asides from mitigation on Big Bar impacts).
- Further analyses on impacts of specific threats and mitigation efforts would be beneficial. A first step could be include those related to hatchery enhancement. My interpretation of the text was that this was not included because of time/resource limitations and not due to lack of data or information.

In regards to mitigations, the RPA Best Practices (2014) state:

"Provide sufficient details regarding specific changes in current practices if restrictions to season, area, gear, etc. are proposed as mitigations. Avoid general statements such as "restore watersheds" or "remove barriers"; where possible, specific watersheds / barriers should be identified." (p.6)

"It is important, therefore, that this section include more information than just a simple list or inventory of possible mitigation measures. To be useful to recovery planners and managers, mitigation measures should be prioritized based on the likelihood of increasing the probability of survival and recovery of the species." (p.6)

And from RPA Guidelines (2014):

"It is likely that information will not be available equally for estimating the degree to which the measures in elements 16 and 17 can reduce mortality or improve the productivity of the species. In every case, the best estimates possible should be provided, rather than seeking a common (and often low) standard for all estimates" (p.21)

- Four scenarios of Big Bar impacts and mitigations are suggested and modelled. When examined individually each scenario might underestimate true uncertainty as the same mortality rates are applied for each MC trial. Did authors consider applying a distribution of mortality rates around the identified values (e.g., distribution around 95% mortality in BB1 scenario) to better capture that uncertainty? To some extent uncertainty is considered by modelling various scenarios, e.g., BB1, BB2, etc. This would be an issue if decision makers decide to examine one Big Bar scenario for decisions, separate from the others, therefore excluding the uncertainty the authors have included by modelling those multiple scenarios.

Section 6.2 Projected trajectory with mitigation (Element 20)

- No additional major comments

Section 6.3 Recommend parameter values (Element 21)

- These could possibly be drawn from Element 3 ("Estimate the current or recent life-history parameters") with the addition of the productivity change information provided. Since the parameters are used directly in previous elements in this paper, I suggest including a table of these parameters for each DU (e.g., Stock-recruitment alpha, beta, sigma, age compositions, etc.)
- It's unclear why Sgen values are provided here.
- One concern with comparing benchmarks from Grant et al. *in press* (Sgen as in Table 12 and upper Biological Benchmarks, as in Table 5), is that they used different models and different model specifications than those applied here. This highlights the more fundamental question as to if benchmarks are static or should be adapted as data and models improve, and conditions change.

Section 8.1 Allowable Harm (Element 22)

- Given the lack of information on impacts of mitigation on Big Bar for Quesnel, Late Stuart, and Stellako, I suggest broadening the mortality rates to a distribution bounded by plausible values, and providing an allowable harm statement based on that analysis. In addition, the text could highlight that the analyses could be repeated in early 2020, perhaps providing a narrower range of uncertainties. However, what type of review would be required of that analysis if this CSAS process is complete?

Editorial Suggestions

1. Abstract paragraphs 3 and 4 seem to repeat each other word-for-word with different DUs listed. Can these be combined into one sentenced with all DUs?
2. The "common" names for stock in the Abstract differ from the DU names in the ToR which is confusing. I suggested using the DU names (or both).
3. Last sentence of section 3.2.4. I suggest rewording to "Here we bound the plausible range of impacts from slide mitigations". As worded, it's too easy to dismiss the modelling work entirely, which I think has value.
4. Section 3.2.5 last sentence of 1st paragraph, it's not clear what "changes" refers to.
5. I found Table 4 hard to follow. Placing x's on the blank cells may help indicate that those rows are not relevant or used for specific versions of the targets. I suggest highlighting which COSEWIC criteria are for which row (as labelled in Table 3). Note, criterion C2aii requires a continuing decline, not just a historical decline. This requires subjective consideration of threats that have caused recent declines continuing into the future.
6. Section 5.1.2. Further explanation on why total spawners and not effective total spawners was used here would be helpful. According to Grant et al. *in press*, EFS is the female and male escapement estimates multiplied by spawning success, which is calculated as the proportion of eggs (0%, 50%, 100%) successfully spawned based on spawning ground carcass surveys. It's not clear if/how this relates to pre-spawn mortality as describe in this text.

7. Section 5.2, first paragraph last sentence. Suggest adding, “and so structural uncertainties would swamp variability due to different management actions (ERs)”.
8. Section 5.2.1, 3rd bullet “We considered the pattern in rank *performance*…”. I suggest adding explanations as to why changes in ranks over time, i.e., simply to capture time trends in performance related to changes in conditions or ecosystem interactions.
9. Section 5.2.2. define what RBB stands for in the text. It’s not entirely clear in the title.
10. Section 5.2.3, first sentence of 2nd paragraph. Should it start with “All else being equal, …”. Same applies with the last sentence of this paragraph?
11. Table 8, suggest replacing 0 with NAs or asterisks. Zero infers that zero ER resulted in likely achieving recovery targets.
12. Section 6.1.3, 2nd paragraph. I don’t follow the 2nd sentence: “Keep in mind,…”. Consider re-wording.
13. Section 6.2.1. I suggest showing DU-specific plots in the paper.
14. Section 6.2.1., to make the flow of the text a little smoother, I suggest referring to “likely to achieve recovery target 1” instead of “likely to become Not EN/TH”. Also, because recovery target 1 also includes a WSP benchmark, that label Is not entirely accurate.
15. Section 6.2.2. Another possible justification for focusing on Fishway scenario is that it bounds the other scenarios?
16. Section 8.1.1. “Quesnel system is worryingly close to the Sgen value”. Can this be replace with, there is a X% probability that abundances are below Sgen? (given uncertainty in Sgen value).
17. Appendix 1: Section 11.1 What diagnostics were used?
18. Section 11.1.6.6. Cite 2006 Tech Report.
19. Section 11.1.8.8 The text in the last paragraph should be fleshed and shown with plots (it’s currently on in rough notes)
20. Section 11.2. I suggest putting these figures in the main text. Note the difference in average alpha between the standard and time-varying models are due to time-series biases associated with trends in productivity and exploitation.
21. Appendix 2. Section 12. Mention that 4 and 5 year olds were simulated.
22. Appendix 3. Section 13. Suggest adding asterisk the “best” model in parameter box plots (e.g., LRB or RRB, etc).
23. Fig. 34 and 51. It’s interesting that eh 1yr BB has a higher probability of achieving recovery target1 than noBB. Presumably this is because abundances are consistently above 25th percentile, and 1yrBB allows for a positive trajectory in abundances more often.

REVIEWER: WILL ATLAS – UNIVERSITY OF VICTORIA

Review #1: Recovery Potential Assessment for Endangered Cultus Lake Sockeye Salmon – Elements 1-11, 14, 16-18

The following six questions provide general guidance for your review:

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

Yes, the purpose of the working paper is to identify barriers to recovery for the Endangered Cultus Lake Sockeye population and evaluate the potential for recovery under a variety of future enhancement, habitat restoration and harvest scenarios.

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

The RPA benefits from decades of population monitoring in Cultus Lake, and from a rich dataset on the limnological conditions in the lake. The authors clearly have a high level of familiarity with the dataset and the system and do an excellent job of explain the factors which have contributed to the decline of Cultus Sockeye.

However, I have several concerns about the population model used to evaluate recovery potential and the assumptions made about the contribution of hatchery enhancement to the recovery trajectory of the stock. For example, the authors spend a significant portion of the RPA arguing that hatchery-born Sockeye should be considered wild for the purpose evaluating recovery, and make the assumption throughout that the reproductive success of these hatchery fish is equivalent to that of their wild-born counterparts. However, that assumption appears to never have been tested despite the fact that per-capita smolt production has clearly declined dramatically since hatchery-reared adults began to return to Cultus (Figures 3 & 4). Given the temporal contrast in hatchery releases and the available data on smolt production there are quantitative approaches that could be used to evaluate the effects of hatchery enhancement (e.g. Falcy and Suring 2018 in *Biological Conservation*)

In simulating the recovery trajectory of Cultus Sockeye, the authors state that they chose not to incorporate density dependence into the population model. Instead they parameterized a stochastic model where the population grows continuously into the future. This is a predictable outcome if the population is unbounded by the carrying capacity of the lake and hatchery fry added to the population every generation under the assumption that they have equivalent survival and reproductive success to wild fish. But in my opinion, this represents an unrealistic assessment of the recovery prospects for Cultus Sockeye. In the absence of a density-dependent population model, the authors miss an opportunity to empirically evaluate what the carrying capacity of the lake is under current conditions. Regardless of the current low population size, there is almost certainly an upper bound to the smolt capacity, one that is likely depressed by current anoxic conditions, milfoil invasion, warming and other habitat impacts.

Given the rich dataset on adult abundance and smolt production, the authors missed an opportunity to fit a density-dependent population model (e.g. recursive Ricker as used in the other Fraser RPAs) that could have provided a more robust quantitative foundation for the forward simulation component of the RPA. Since carrying capacity is a function of both the Beta and alpha parameter in a Ricker model, using a model with time-varying alpha would allow the authors to rigorously quantify changes in rearing capacity associated with the stressors they identify in the first part of the report.

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

Much of the RPA focuses on how conditions in the lake have changed due to eutrophication, warming and increasingly anoxic conditions. These data are explained clearly, and the conclusions the authors draw about their consequences for Sockeye rearing and population viability in the lake seem robust.

I have concerns about the population model used to evaluate recovery potential and have stated those above.

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

The document provides minimal advice to decision makers beyond the suggestion that continued hatchery supplementation is the only way to avoid elevated extinction risk.

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

While the authors allude to the potential for reduced fitness among hatchery fish the forward simulations assume that fitness is equal and don't incorporate uncertainty associated with potential differences in hatchery and wild reproductive success.

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

See above. I think the RPA would be much stronger if a density-dependent population model was used to parameterize the forward simulations. I also think evaluating the assumption of equal fitness between hatchery and wild fish is worthwhile, since so much of the recovery plan hinges on the contribution of continued hatchery enhancement. The first part could be easily accomplished with code from the Appendix of the RPA for 9 Fraser populations, and the potential differences in hatchery and wild reproductive success could be evaluated either using a population model that accounts for the proportion of hatchery fish on the spawning grounds (e.g. Falcy and Suring 2018), or with genetic parentage analysis conducted on smolts and returning adults.

Review #2: Recovery Potential Assessment for Fraser River Sockeye Salmon (*Oncorhynchus nerka*) Nine populations - excluding Cultus-L population - Elements 12, 13, 15, 19-22

The following six questions provide general guidance for your review:

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

The paper focused on evaluating recovery potential, changes in productivity and abundance, and how future changes in productivity are likely to affect the recovery of nine Sockeye populations in the Fraser Basin previously listed by COSEWIC as Endangered, Threatened, or Special Concern. The authors generally do a commendable job of outlining their goals, assumptions, and methods, allowing the reviewer to evaluate the robustness of their conclusions and the likely effects of future changes in productivity and exploitation rates on the conservation status and recovery prospects for this group of populations.

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

Compared to many (most) other salmon stocks in Canada, the data used in the RPA is very good. With continuous timeseries of abundance, age, and reasonable harvest and en route mortality estimates for each SMU, the RPA is grounded in robust population timeseries. Methodologically, the authors compare goodness of fit for several different models incorporating a variety of different assumptions about population dynamics and change over time (e.g. Larkin model of cyclic dynamics, recursive alpha model). In general, I like the model evaluation approach taken here, and I feel confident that the authors have made a robust assessment of the suitability and potential biases associated with different stock-recruit model structures. The forward simulations are also consistent with best practices for evaluating future recovery potential under a variety of productivity or harvest scenarios. Predicting the future is always a precarious task, but the authors have employed a robust set of tools and done the best they can given that challenge.

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

Yes, I find the methods are well described and generally well justified. I did have a few minor comments and questions about the methods:

a. Maybe I missed it, but the authors didn't provide detail about the age data they used to reconstruct recruitment.
b. The authors used code from Catherine Michielsens for time varying alpha, and briefly state that they removed observation error from Michielsens' code (state-space) and justify it on the grounds of wanting the time-varying alpha component of the model to be compatible with their Larkin model. While I doubt the conclusions drawn from the model would change appreciably with the incorporation of observation error it might reduce the uncertainty in the process error associated with productivity. The authors never make clear how this decision might have affected the outcome of their analysis.
c. More detail of prior specification and why these decisions were made is always helpful. For example, the authors provide details of the prior specification in the recursive alpha model, but don't speak to or defend their decisions about priors in the simple Ricker model and are unclear about prior specification in the Larkin model (I think it was the same as the simple Ricker?). Since prior specification can influence model outcomes, justification of the choices they made for each model, and more clarity for the reviewer that these choices did not influence the inference they drew would be valuable.

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

The document actually provides very little advice to decision-makers, instead it evaluates population responses to coarse-scale changes in harvest or productivity. The details of how these changes are achieved are not really discussed. Perhaps this is appropriate, and it may also reflect the complexity and wickedness of persistent declines in survival and abundance among Fraser Sockeye. While there are likely policy actions that could support improved productivity among Fraser Sockeye (e.g. removal of open-net pen fish farms) recommendations at that level of detail were clearly not part of the mandate for this RPA.

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

Yes, I find that the authors more than adequately address uncertainty associated with their analysis. One minor recommendation would be to make the 95% CI lines bolder in the forward simulation plots, they're very difficult to see. I also was not clear on the plots that depicted different impact durations for the Big Bar Landslide. It appeared that some of the scenarios detailed in the legend and figure caption were not included in the plot. I really liked the matrix plots depicting the probability of recovery across a range of future productivities and exploitation rates. They effectively speak to the different status of populations even within those designated Endangered/Threatened, where the prospects for recovery range from very unlikely to reasonably probable.

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

I think greater evaluation of freshwater dynamics in Fraser Sockeye (really all Sockeye) populations is warranted. Much of the variation in productivity of stocks presumably has to do with the spawning and rearing environments they use. However, other than Chilko and a few other shorter timeseries, we have very little data linking juvenile abundance, size and condition to spawner abundance in the parent generation. Further, anthropogenic and climate impacts on freshwater habitats are almost certainly occurring in most watersheds and given our limited ability to enact management measures that increase marine survival, more focus on this portion of the life cycle seems warranted. The authors allude to this, but the collection of this data could facilitate the creation of life-cycle models that partition density-dependence and survival into specific life stages, allowing biologists to more clearly evaluate limiting life stages, to support more targeted management and conservation measures.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat

Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Recovery Potential Assessment – Fraser River Sockeye Salmon (*Oncorhynchus nerka*) – Ten Designatable Units

October 7-11, 2019

Richmond, British Columbia
Chair: Gilles Olivier

NOTE: The agenda was developed for a peer review that was scheduled for five days, however, the meeting concluded in four days. The same subject order was followed, but the material was covered quicker than expected.

DAY 1 - Monday, Oct 7th, 2019

Time	Subject	Presenter
0900	Welcome and Introduction CSAS Overview and Procedures	Chair
0930	Review Terms of Reference	Chair
0940	Working Paper#1: Fraser River Sockeye Salmon (Cultus Lake population) – 22 elements.	Authors & Reviewers
1030	***Break***	
1045	Working Paper#1: Fraser River Sockeye Salmon (Cultus Lake population) – 22 elements.	Authors & Reviewers
1200	***Lunch Break***	
1245	Working Paper#1: Fraser River Sockeye Salmon (Cultus Lake population) – 22 elements.	Authors & Reviewers
1445	***Break***	
1500	Working Paper#1: Fraser River Sockeye Salmon (Cultus Lake population) – 22 elements.	RPR Participants
1600	Identification of Key Issues from Day 1 for Group Discussion	RPR Participants
1700	***Adjourn for Day 1***	

DAY 2 - Tuesday, Oct 8, 2019

Time	Subject	Presenter
0900	Introductions, Review Agenda & Housekeeping Review Status of Day 1	Chair
0915	*(As Necessary)* Carry forward outstanding issues from Day 1	RPR Participants
0930	Working Paper#1: Fraser River Sockeye Salmon (Cultus Lake population) – 22 elements.	RPR Participants
1030	***Break***	
1045	Working Paper#1: Fraser River Sockeye Salmon (Cultus Lake population) – 22 elements.	RPR Participants
1200	***Lunch Break***	
1245	Working Paper#1: Fraser River Sockeye Salmon (Cultus Lake population) – 22 elements.	RPR Participants
1445	***Break***	
1500	Working Paper#1: Fraser River Sockeye Salmon (Cultus Lake population) – 22 elements.	RPR Participants
1600	Identification of Key Issues from Day 2 for Group Discussion	RPR Participants
1700	***Adjourn for Day 2***	

DAY 3 - Wednesday Oct 9, 2019

Time	Subject	Presenter
0900	Introductions, Review Agenda & Housekeeping Review Status of Day 2	Chair
0915	*(As Necessary)* Carry forward outstanding issues from Day 2	RPR Participants
0930	*Science Advisory Report (SAR) Working Paper #1* Develop consensus on the following for inclusion: • Summary bullets • Sources of Uncertainty • Results & Conclusions Additional advice to Management (as warranted)	RPR Participants
1030	***Break***	
1045	*Science Advisory Report (SAR) Working Paper #1* Develop consensus on the following for inclusion: • Summary bullets • Sources of Uncertainty • Results & Conclusions Additional advice to Management (as warranted)	RPR Participants
1200	***Lunch Break***	
1245	Working paper #3: Fraser River Sockeye Salmon (9 populations: excluding Cultus-L population) – Elements 12, 13, 15, 19-22.	Authors & Reviewers
1445	***Break***	
1500	Working paper #3: Fraser River Sockeye Salmon (9 populations: excluding Cultus-L population) – Elements 12, 13, 15, 19-22.	Authors & Reviewers
1600	Identification of Key Issues from Day 3 for Group Discussion	RPR Participants
1700	***Adjourn for Day 3***	

DAY 4 - Thursday Oct 10, 2019

Time	Subject	Presenter
0900	Introductions, Review Agenda & Housekeeping Review Status of Day 3	Chair
0915	*(As Necessary)* Carry forward outstanding issues from Day 3	RPR Participants
0930	Working paper #3: Fraser River Sockeye Salmon (9 populations: excluding Cultus-L population) – Elements 12, 13, 15, 19-22.	RPR Participants
1030	***Break***	
1045	Working paper #3: Fraser River Sockeye Salmon (9 populations: excluding Cultus-L population) – Elements 12, 13, 15, 19-22.	RPR Participants
1200	***Lunch Break***	
1245	Working paper #3: Fraser River Sockeye Salmon (9 populations: excluding Cultus-L population) – Elements 12, 13, 15, 19-22.	RPR Participants
1445	***Break***	
1500	Working paper #3: Fraser River Sockeye Salmon (9 populations: excluding Cultus-L population) – Elements 12, 13, 15, 19-22.	RPR Participants
1600	Identification of Key Issues from Day 4 for Group Discussion	Authors & Reviewers
1700	***Adjourn for Day 4***	

Day 5 – Friday Oct 11, 2019

Time	Subject	Presenter
0900	Introductions, Review Agenda & Housekeeping Review Status of Day 4	Chair
0915	*(As Necessary)* Carry forward outstanding issues from Day 4	RPR Participants
1000	*Science Advisory Report (SAR) Working Paper #3* Develop consensus on the following for inclusion: • Summary bullets • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1030	***Break***	
1050	*Science Advisory Report (SAR) Working Paper #3* Develop consensus on the following for inclusion: • Summary bullets • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1200	***Lunch Break***	
1245	Next Steps – Chair to review • SAR review/approval by participants and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)* • Other Business arising from the review	Chair & Participants
1445	***Adjourn meeting***	

APPENDIX D: PARTICIPANTS

Last Name	First Name	Affiliation
Ashton	Chris	Commercial Salmon Advisory Board
Bailey	Richard	DFO Science
Benner	Keri	DFO Science
Bradford	Mike	DFO Science
Braun	Douglas	DFO Science
Campbell	Kelsey	A-Tlegay Fisheries
Candy	John	DFO Centre for Science Advice Pacific
Caron	Chantelle	DFO SARA program
Cone	Tracy	DFO Science
Davies	Trevor	Province of BC
Davis	Brooke	DFO Science
Decker	Scott	DFO Science
Fisher	Aidan	Fraser River Aboriginal Fisheries Secretariat (FRAFS)
Frederickson	Nicole	Island Marine Aquatic Working Group (IMAWG)
Gerick	Alyssa	DFO SARA program
Grant	Sue	DFO Science
Grant	Paul	DFO Science
Hague	Merran	Pacific Salmon Commission
Hawkshaw	Mike	DFO Science
Healy	Stephen	DFO Science
Hollingsworth	Shaun	Sport Fishing Advisory Board
Holt	Carrie	DFO Science
Huang	Ann-Marie	DFO Science
Jantz	Les	DFO Resource Management
Labelle	Marc	Okanagan Nation Alliance
Laliberte	Bernette	Cowichan Tribes
Magera	Anna	DFO Resource Management
May-McNally	Shannan	DFO Science - NHQ
Mcgreer	Madeline	Fraser River Aboriginal Fisheries Secretariat (FRAFS)
Michielsens	Catherine	Pacific Salmon Commission
Morley	Rob	Pacific Salmon Commission Fraser River Panel
Mortimer	Matt	DFO Resource Management
Nener	Jennifer	DFO Resource Management
Nicklin	Pete	Upper Fraser Fisheries Conservation Alliance
Ogden	Athena	DFO Science
Olivier	Gilles	DFO Science - NHQ
Patterson	Dave	DFO Science
Pearce	Robyn	DFO SARA program
Pestal	Gottfried	Contractor
Pillipow	Ray	Province of BC
Pon	Lucas	DFO Science

Last Name	First Name	Affiliation
Price	Michael	Simon Fraser University
Robinson	Kendra	DFO Science
Scroggie	Jamie	DFO Resource Management
Selbie	Dan	DFO Science
Staley	Mike	Fraser River Aboriginal Fisheries Secretariat (FRAFS)
Thom	Michael	DFO Salmonid Enhancement Program
Thompson	Madeline	DFO SARA program
Thorpe	Suzanne	DFO FFHPP
Townend	Emily	DFO Science
Walsh	Michelle	Shuswap First Nation
Weir	Lauren	DFO Science
Welch	Paul	DFO Salmonid Enhancement Program
Whitney	Charlotte	Pacific Salmon Foundation
Wor	Catarina	DFO Science
Xu	Yi	DFO Science

APPENDIX E: ABSTRACT OF WORKING PAPERS

ABSTRACT OF WORKING PAPER #1: RECOVERY POTENTIAL ASSESSMENT FOR THE ENDANGERED CULTUS LAKE SOCKEYE SALMON (*ONCORHYNCHUS NERKA*)

Details of listing – COSEWIC, DATE, Consideration under SARA

Cultus Lake Sockeye Salmon (*Oncorhynchus nerka*) were first identified as endangered in an emergency assessment by the Committee on the Status of Wildlife in Canada COSEWIC in 2002, and confirmed as such in 2003. Due largely to socioeconomic reasons however, Cultus Sockeye were not listed under Schedule 1 of the Species at Risk Act (SARA) at this time. In 2017, as part of a review of 24 Fraser Sockeye Designatable Units (DUs), Cultus Sockeye were again identified as endangered, along with seven other Fraser Sockeye DUs.

This Recovery Potential Assessment (RPA) provides an overview of Cultus Sockeye biology, habitat requirements, threats, and limiting factors in Elements 1-11, and identifies recovery targets, population projections, mitigation assessments and recommendations on allowable harm in Elements 12-22.

Threats to persistence with the highest population risks include direct losses due to harvest in the mixed-stock fishery and degradation of critical freshwater habitats from anthropogenic forcings. Lake eutrophication, in particular, and the interactive effects of climate change, which are relatively newly understood, but highly influential mechanisms of population depression are noted, as are pathways to mitigation of eutrophication.

Recognizing the distinction between recovery and survival of a population or species, an abundance target of 7,000 spawners (four-year average) is proposed for recovery of the Cultus Sockeye DU, and a generational average of 2,500 spawners is proposed as a survival target. Model results suggest that without hatchery supplementation the population will be unable to sustain itself and is predicted to continue to decline over the next three generations (12 years). With ongoing supplementation, extinction is averted, but the population is unlikely to reach survival or recovery targets within this timeframe. Addressing fisheries-related mortality and mitigating freshwater habitat threats (i.e. lake eutrophication), in particular, are anticipated to improve population trends and are recommended.

ABSTRACT OF WORKING PAPER #2: RECOVERY POTENTIAL ASSESSMENT FOR FRASER RIVER SOCKEYE SALMON (*ONCORHYNCHUS NERKA*) NINE POPULATIONS- EXCLUDING CULTUS-L POPULATION

In 2017, the Committee on the Status of Wildlife in Canada (COSEWIC) reviewed 24 Fraser Sockeye (*Oncorhynchus nerka*) designated units (DUs) and determined that eight of them were Endangered, two were Threatened, and five were of Special Concern. This Recovery Potential Assessment (RPA) provides descriptions of possible recovery targets, population projections, mitigation assessments and recommendations on allowable harm for nine of the ten Endangered and Threatened DUs, and the three Special Concern DUs that have long term stock-recruit estimates. Habitat, threats and limiting factors to recovery, and potential mitigation measures for the nine Endangered and Threatened DUs in this paper are covered in a companion RPA (Woodruff, *DRAFT)*. All RPA elements for the tenth Endangered DU (Cultus) is covered in a separate RPA. The DUs covered in this paper are: Bowron-ES, Takla-Trembleur-EStu (Early Stuart), Harrison (U/S)-L (Weaver), Seton-L (Portage), Quesnel-S, Takla-Trembleur-Stuart-S (Late Stuart), Taseko-ES, Widgeon-River, North Barriere-ES (Upper

Barriere/Fennell), Kamloops-ES (Raft), Lillooet-Harrison-L (Birkenhead), and Francois-Fraser-S (Stellako).

Nested recovery goals were proposed for the DUs, the performance metrics and benchmarks associated with the first goal represents not being designated as Endangered or Threatened by COSEWIC, and the second of being Not At Risk by COSEWIC and a Wild Salmon Policy biological status of Green. Stock-specific stock-recruit models that accounted for recent productivity were used in a simulation model to evaluate the likelihood of DUs reaching the two recovery goals over the next three generations (12 years) over a wide range of mortality rates. A method for evaluating the impacts from the Big Bar landslide for the six DUs impacted is introduced and the impacts from future changes in productivity were modelled for all DUs.

The recommendations for Weaver, Portage, Fennell, Raft, and Birkenhead is that only activities in support of the survival and recovery of the species, which may result in possible mortalities (e.g., stock assessment, research, conservation, or mitigation activities), be allowed to provide the best chance for the survival of these DUs.

For Early Stuart and Bowron, it is recommended that only activities in support of the survival and recovery of the species, which may result in possible mortalities (e.g., stock assessment, research, conservation, or mitigation activities), be allowed to provide the best chance for the survival of these DUs.

The future situation for Quesnel, Late Stuart and Stellako, which all spawn above the Big Bar landslide is too uncertain for us to provide any guidance on allowable harm at this time. However, we propose a methodology to employ once additional information becomes known.

For Taseko and Widgeon, the amount of uncertainty associated with these DUs does not allow us to recommend a level of allowable harm using the methods described in this paper.