Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Proceedings Series 2016/025

Pacific Region

Proceedings of the Pacific Regional Peer Review on Recovery Potential Assessment - White Sturgeon, Upper Fraser Designatable Unit

March 30 - April 1, 2016
Prince George, BC

Chairperson and Editor: Dr. Thomas Therriault

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

August 2016

Canada

Foreword

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

Published by:

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

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

ISSN 1701-1280

Correct citation for this publication:

DFO. 2016. Proceedings of the Pacific Regional Peer Review on Recovery Potential Assessment - White Sturgeon, Upper Fraser Designatable Unit; March 30 – April 1, 2016. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2016/025.

TABLE OF CONTENTS

SUMMARY

These proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on March 30 - April 1, 2016 at the Coast Inn of the North, Prince George, British Columbia. One working paper entitled “Recovery Potential Assessment for White Sturgeon (*Acipenser transmontanus*) Upper Fraser Designatable Unit” was reviewed in support of the Recovery Potential Assessment.

Meeting attendees included participants from DFO Science Branch, DFO Ecosystem Management Branch, DFO Policy, the Province of British Columbia, First Nations, and Non-Government Experts. The working paper was accepted subject to specified revisions. The conclusions and advice resulting from this review will be provided in a Science Advisory Report (SAR). The SAR, Research Document and this Proceedings Document will be made publicly available via the CSAS Science Advisory Schedule.

Compte rendu de l’examen par les pairs de la région du Pacifique sur l’évaluation du potentiel de rétablissement de la population d'esturgeon blanc du haut Fraser

SOMMAIRE

Le présent compte rendu résume les discussions pertinentes et les principales conclusions de la réunion régionale d'examen par les pairs du Secrétariat canadien de consultation scientifique (SCCS) de Pêches et Océans Canada (MPO), qui a eu lieu du 30 mars au 1er avril 2016 à l'hôtel Coast Inn of the North de Prince George, en Colombie-Britannique. Un document de travail intitulé « Évaluation du potentiel de rétablissement de l'esturgeon blanc (*Acipenser transmontanus*) de l'unité désignable du cours supérieur du fleuve Fraser » a été examiné à l'appui de l'évaluation du potentiel de rétablissement.

Les participants à la réunion comprenaient des représentants de la Direction des sciences, de la Direction de la gestion des écosystèmes et du Secteur des politiques du MPO, ainsi que de la province de la Colombie-Britannique, des Premières Nations et des experts non gouvernementaux. Le document de travail a été accepté, sous réserve de quelques modifications précises. Les conclusions et avis découlant de cet examen seront présentés sous la forme d’un avis scientifique. L'avis scientifique, le document de recherche et le présent compte rendu seront rendus publics dans le calendrier des avis scientifiques du SCCS.

INTRODUCTION

A Canadian Science Advisory Secretariat (CSAS) Regional Peer Review was held March 30 - April 1, 2016 to review the working paper entitled "Recovery Potential Assessment for White Sturgeon (*Acipenser transmontanus*) Upper Fraser Designatable Unit". The chair, Dr. Thomas Therriault, welcomed participants and facilitated introductions. He reviewed the role of CSAS in the provision of peer-reviewed scientific advice and gave a general overview of the CSAS process, the role of participants, confidentiality requirements and the expected meeting outputs (Science Advisory Report, Proceedings Document and Research Document) pending acceptance of the paper by participants at the meeting. Everyone was invited to participate fully in the discussions and to contribute their scientific knowledge to the process, with the goal of delivering scientifically defensible advice on the Upper Fraser White Sturgeon Designatable Unit (DU). The Chair reviewed the agenda and the terms of reference (Appendices A and B) and confirmed that all participants had received this information along with the working paper prior to the meeting. In total 19 people participated in the review meeting (Appendix C). Linnea Flostrand (DFO Science) was identified as the rapporteur for this meeting.

Written reviews of the working paper by Drs. Mike Bradford and Steven McAdam were submitted and distributed before the meeting (Appendix D). The goal of soliciting the formal written reviews was to inform, but not limit, discussion by participants attending the review meeting.

Sean MacConnachie (DFO Science) gave a brief presentation on the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) process that re-assessed the Upper Fraser White Sturgeon DU and how this links to the Canadian Species at Risk (SARA) process. Briefly, in their latest White Sturgeon assessment, COSEWIC combined three White Sturgeon Nationally Significant Populations (NSPs) into a new Upper Fraser Designatable Unit (DU). In 2006, the Upper Fraser and Nechako River populations were listed as Endangered under SARA legislation whereas the Mid-Fraser population was not listed at that time. In anticipation of the Upper Fraser River DU being considered for listing under SARA given COSEWIC's latest re-assessment of White Sturgeon, DFO Science was asked to undertake an updated Recovery Potential Assessment (RPA), based on the National RPA Guidance, to support decision making with respect to SARA requirements. The science advice generated via this process will update and/or consolidate existing advice regarding White Sturgeon in the Upper Fraser DU. It was acknowledged that a DU with populations having different existing SARA listings is novel to the RPA and science advice process and information was provided at both the DU and sub-DU scales where available.

REVIEW OF THE RECOVERY POTENTIAL ASSESSMENT

Working Paper:	Recovery potential assessment for White Sturgeon (*Acipenser transmontanus*) Upper Fraser Designatable Unit *WP2014SAR02.*
Presenters:	Todd Hatfield and Eric Smyth
Formal reviewers:	Mike Bradford and Steven McAdam
Rapporteur:	Linnea Flostrand
Outcome:	Working paper accepted subject to revisions.

PRESENTATION OF WORKING PAPER

Todd Hatfield began by giving a brief overview of the SARA and COSEWIC processes and history with respect to the Upper Fraser White Sturgeon DU (a metapopulation that includes the Mid-Fraser, Upper Fraser, and Nechako sub-DUs) and the current RPA. The presentation included information on the species' biology, past and current abundance estimates of adults (≥165 cm) for the Mid-Fraser (749), Upper Fraser (185) and Nechako (630) populations, as well as maps characterizing population distributions, and important habitat sites (based on confirmed and suspected habitat usage related to known habitat requirements). Seven abiotic and five biotic threats were identified in the working paper.

Eric Smyth presented information on the adult population abundance recovery targets and the metapopulation model used in the working paper. He identified modeling uncertainty associated with applied parameter values (populations versus DU), inter-population (i.e., intra-DU) exchange rates, the metapopulation model applied, Nechako River hatchery stocking rates and assumed stocking duration. Results from 100 year projections were shown using information depicting current assumed age structure and abundance. Plots showed associated variability between the two different sets of life history parameters for each population and assumptions associated with high stocking rates and recruitment in the Nechako. Additional plots were shown to depict effects from varying exchange rates, having a metapopulation model with trilateral exchange at equal rates, and limiting stocking to 20 years. Due to initial population structures, modeled results depicted the Mid- and Upper Fraser populations to remain relatively stable whereas the Nechako population was depicted as crashing without stocking inputs. In general, trajectories for each population resulting from different sets of life history parameter values were similar. The greatest differences occurred in model scenarios with high Nechako stocking rates (leading to population projections that appeared to greatly exceed carrying capacity) and potentially high exchange rates between populations that overwhelmed the metapopulation and altered stock structure.

Points of Clarification

It was asked why the Upper Fraser had a 100 year equilibrium population trajectory with little variability (i.e. ranging from ~183 to 186 fish) and why aren't results in integers (i.e. why do plots show fractions of fish?). The response was that this is to be expected for modeling a long lived species at equilibrium, especially when modeling was not accounting for random outside influences. Output demonstrates relative stability over time because of this. Binomial distributions were not used in the modeling (unlike what was done in Wood et al. (2007)) and so means of the current RPA equilibrium trajectories were not limited to integers.

The authors were asked what they based their Nechako stocking rates on. Authors stated they wanted to demonstrate effects from a high level of ongoing stocking (including overwhelming the metapopulation) and they recognize that other scenarios (e.g., reduced stocking, different stocking regime) may be more applicable and invited feedback from participants to revise if required.

Clarity was sought on why annual survival of hatchery releases was modeled as 0.93 when Wood et al. (2007) used 0.2. Since Wood et al. (2007) was published additional information from Kootenay and Columbia River hatchery-stocking enhancement efforts suggest that juvenile survival of cultured fish is considerably higher than 0.2, and may be as high at 0.93 if released at a larger sizes. Although there is considerable uncertainty with the survival estimate of Nechako hatchery releases, the primary purpose was to demonstrate the effect, especially exchange, of high stocking rates.

Concern was expressed that the high stocking rates in the Nechako could result in a swamping of local and downstream wild populations with hatchery fish. It was stated that enhancement objectives are to start with high stocking rates aimed to mitigate year class gaps from recruitment failure but that stocking rates are expected to decline over time as adults are lost from the population and/or habitat improves to a level that can support all White Sturgeon life stages in the Nechako River. Stocking rates and their duration over time were identified as topics requiring further discussion by participants and a potential change in the metapopulation model used.

Clarity was sought on potential numbers of pre-adults by population. It was noted that for the Nechako there is evidence that recent recruitment has been negligible due to a lack of observed sturgeon less than 165 cm. For the Mid-Fraser, sampling plans have been outlined to investigate the population structure, juveniles have been observed but this is still believed to be an information gap. In contrast, there is some information for the Upper Fraser suggesting reasonable recruitment. A revision suggestion was made to have the RPA include information on what is known about population structure and include additional references.

REVIEWER - MIKE BRADFORD

The reviewer's feedback focused mostly on the modeling methods. He reiterated similarities and differences between methods used in the working paper and those used in Wood et al. (2007). He proposed that since the current paper's model results focus on the mean of the model runs, rather than a measure of the probabilities associated with performance measures, that another way to go would be to turn off random variability assigned to parameters and generate deterministic output. It was pointed out that no performance measures have been identified to evaluate projection output against. The topics of recovery objectives (targets) and ideas for communicating advice were identified as areas for further discussion by participants.

The reviewer stated that the modeling in the working paper shows a huge and unrealistic hatchery effect with no density dependence. If the current and future hatchery management of Nechako stocking is not being realistically modeled, nor the associated probability of swamping wild populations, then other scenarios should be adopted. In the model applied by Wood et al. (2007), where a fish was born was used as an indicator of fitness, whereas in this working paper no methods have been applied to model or track genetic effects. The objectives and strategies of Nechako River hatchery stocking efforts and how modeling could be reconsidered were identified as topics for further discussion by participants.

The question was raised why an exchange rate of 5% should be modeled when there is no evidence to support such a high rate among sub-DUs. The reviewer noted that genetic studies suggest that interbreeding between the three populations appears small (as there is evidence for distinct populations) and clear differences in age and size structure between populations exist, also suggesting low levels of exchange. He added that fish movement observations do not confirm that genetic exchange is occurring, only that adult fish can move within the DU. The authors agreed and said they wanted to model a relatively high upper range but 5% appears to be too high. Modeling exchange rates was identified as a topic for discussion by participants.

The reviewer stated than an equilibrium state would be expected to need longer than 100 years given the long lifespan of sturgeon and different population equilibrium levels would be expected for different levels of human induced mortality (HM). Model results demonstrate response trends but are missing information to assist with interpretation (i.e., what a change of HM means in the context of an actual mortality event). It was noted the goal was to demonstrate scenarios where changes in HM (and Hab_t) could be contrasted.

REVIEWER - STEVEN MCADAM

The second reviewer began by saying that the RPA process is largely driven by concerns with the low Nechako River population abundance and its observed recruitment failure whereas the other two populations appear relatively stable. Further, it was noted that a large amount of work is underway to restore Nechako River sturgeon habitat with the goal of improving recruitment success and the reviewer recommended that this information be described in the paper, such as associated with uncertainty in future productivity.

There was agreement with the other reviewer that a 5% exchange rate between populations is an unrealistically high bookend for modeling. He also suggested that the paper include text clarifying what exactly is being modeled by metapopulation exchange rates, since there are different types of movement (temporary occurrence in another population's geographic range with or without reproduction, permanent movement with or without reproduction, etc.). There is considerable uncertainty associated with movement behaviour and modeling does not track specific changes due to immigration and emigration (i.e., individuals are not tracked in the model so any fish that moves assumes the characteristics of the fish in the receiving population).

The reviewer stated that current levels of HM are known to be above 0 and questioned why modeling would depict it to be 0 for the three populations. He recognized that estimates of annual HM are not readily available for all populations but there are known sources of HM, such as from catch and release fishing, poaching etc. A point of clarification was made to explain that modeled annual survival rates of wild populations included both natural and human induced sources (i.e. 0.96%). Modeled trajectories are tuned at equilibrium with this, which confounds representation that initial HM=0. A suggestion was made to partition these modeling parameters to reflect current understanding of available information. The topic of representing current degrees of HM, possibly separate from natural mortality, by population was identified as needing further discussion.

The reviewer noted that COSEWIC has a method for representing generation time and other options include the average age of mature fish in a population, where estimated generation time is greater than average age at maturity (and stated that for these sturgeon populations that would 30-40 years). It was noted that other variables, such as males maturing at smaller sizes and ages than females, may be considered.

Modeling of high stocking rates and high survival of hatchery fish in the RPA was said to be misleading since planned monitoring and management of hatchery releases is in place to monitor survival and abundance over time (as described further below).

DISCUSSION

Summary information by discussion topic is presented below.

Nechako River Hatchery Stocking Effects

Experts involved in the Nechako River White Sturgeon hatchery and stocking program provided background information on juvenile fish culture efforts and release strategies. After recognizing that there has been recruitment failure occurring in this population over decades and that the wild population structure appeared to be mainly $\geq$ 45 years old, the provincial government embarked on hatchery enhancement to increase younger year classes with the long term goal of realizing a self-sustaining population following interim stocking efforts. Stocking strategies include breeding plans, ongoing monitoring and adaptive management (the evaluation of which was beyond the scope of this assessment). A proposed one generation stocking period was described (20-30 years), associated with expected availability of wild brood stock (i.e., adults would be dead after this time). Monitoring the effectiveness of the hatchery program includes the use of juvenile indexing (mark and recapture with fin clipping, pit or radio tags), estimating survival of hatchery fish to use in population projections, and addressing risks learned from salmon enhancement. During 2006-2008 feasibility studies related to Nechako River stocking occurred, including comparing spring versus fall releases, and trials indicated spring releases had better overall survival. Enhancement considerations are aimed at protecting wild genetic structure by augmenting with wild larval capture, reared, and released into the Nechako River. Additional information related to this discussion point is available in Williamson et al (2004) and the Nechako White Sturgeon Recovery Initiative (2005).

There was general agreement that modeling Nechako stocking for 100 years at consistently high stocking and survival rates is neither logistically feasible nor consistent with stocking objectives. It was suggested that the RPA may not need to model swamping of populations with hatchery fish if adaptive management is in place (but the success of this depends on the ability to detect and respond to undesirable changes which has some uncertainty). For this process participants agreed that modeling hatchery releases for a shorter term, such as 20 years was valid and consistent with recovery objectives/plans, recognizing other scenarios are possible but beyond the scope of the current process. The use of a carrying capacity (for adults and/ or juveniles) in modeled scenarios that limits the impacts of stocking inputs was suggested as one way to limit unrealistic population growth but again, this was not possible to incorporate in the current process. Also, it was noted that time lags could be modeled to represent time delays of a slower than anticipated management response (i.e., population trajectories allowed to "over-shoot" for some time) such that hatchery cohort releases could be modeled as a pulse or a series of pulses into the population. It was mentioned that there are limitations related to projections being tuned by equilibrium modeling and feedback from the Hab_t and HM parameters and that there may be too many assumptions to effectively model hatchery inputs, especially since adaptive management will be in place (and assumed responsive). Participants agreed that it was useful to see model outputs for scenarios with relatively high levels of hatchery inputs to demonstrate linkages within the metapopulation but that inter-population exchange rates should not overwhelm the metapopulation. Consensus was reached to remove the scenario of 100 years of annual stocking of 12,000 juveniles with an annual survival parameter of 0.96 and rather to run the model with stocking for 20 years with exchange "capped" to prevent Nechako hatchery-generated fish from overwhelming the Upper Fraser DU metapopulation. However, should adaptive management fail, the metapopulation model presented shows that swamping of other sub-DUs with hatchery fish could occur. Further, potential consequences of hatchery fish on native juvenile sturgeon were not modelled.

Recovery Targets

There was discussion on the proposed recovery targets for abundance of adult White Sturgeon (≥165cm) used in the RPA for the three populations, recognizing juvenile White Sturgeon are important but their abundances are not included in the identification of recovery targets. The Upper Fraser target of 185 fish was based on the current abundance estimates, and is believed to be relatively stable based on abundance and population structure information (i.e. juvenile and adult fish) and is likely at its current carrying capacity (albeit a low one). The Mid-Fraser target of 749 is also an estimate of current abundance and this population is also believed to be at its carrying capacity. Better information on abundance and population structure for both the Mid- and Upper Fraser sub-DUs would be valuable for future efforts given many uncertainties. The Nechako target of 1,628 was based on a hind cast estimate for the year 1967, but the COSEWIC target of 1,000 required to support a viable population could also be considered. The intent of recovery targets as representing a population size that supports survival or recovery of the DU was emphasized. It was pointed out that whether the recovery target for Nechako is 1,000 or 1,628 the modeled contour would look the same. Allowable harm can be considered in terms of whether population projections are greater or less than recovery targets. There was consensus on the use of the proposed recovery targets for mature adults (185 Upper Fraser, 749 Mid Fraser and 1,000 Nechako).

Qualifications around the hindcast estimate of a carrying capacity of adult Nechako sturgeon of 1,628 for the year 1967 in modeling work were given. It is believed that the Nechako carrying capacity used to be higher but that habitat and food supply (i.e., abundant salmon populations) have declined considerably from historical levels. Also, relatively high levels of fishing and other impacts affecting survival are known to have occurred for decades prior to 1967 such that this point in time likely represents a population already under stress. There was concern that the estimate of 1,628 adults may be misinterpreted as a true carrying capacity of the system, especially after habitat restoration and survival of hatchery releases are in effect. Participants agreed that for the immediate purposes of RPA modeling and considering allowable harm, the 1,628 hindcast estimate of the Nechako carrying capacity is the best available information, but it must be recognized that there is a high level of uncertainty associated with it and reduced carrying capacity could result in increased exchange.

Population Exchange Rates and Movement

There was consensus that the 5% modeled exchange rate among populations was unrealistically high and could be removed from contour plot scenarios but that 0 and 0.1% rates should be sufficient to cover the potential true range rates. A revision to the text should include that a 5% exchange rate was modeled but the extent of trends was unrealistic so modeling was excluded from the document.

Actual exchange rates are unknown but believed to be low (based on genetics and differences in demographics). An average of 1-2 fish a year having reproductive exchange between populations would likely result in observed genetic differences and was thought to be consistent with an upper estimate of 0.1% exchange between populations. It was acknowledged there is uncertainty around hatchery juvenile sturgeon behavior that could result in greater movement from the Nechako.

The metapopulation model reported in the working paper only depicted indirect movement between the Nechako and Mid-Fraser populations but direct movement between the Nechako and Mid-Fraser was deemed more realistic given radio telemetry data supporting direct movements. Thus, this will be revised in the working paper. Furthermore, modeling shows it may have a notable effect on their projections, especially related to reducing Hab_t and increasing HM.

Direct exchange also likely occurs between the Lower Fraser DU and the Mid-Fraser population of the Upper Fraser DU but the extent of which is highly uncertain. Research is currently underway to investigate movement patterns and exchange rates between populations using fin ray chemistry, hatchery marked fish, development of genetic baselines by population, radio tagging etc. Modeling inter-DU exchange was not undertaken in this process.

It was suggested that a revision to the working paper include information on research efforts underway to try to resolve some of these uncertainties associated with exchange rates and movements. One of the reviewers agreed to assist in the development of such a revision, including the provision of applicable references.

Another source of uncertainty identified was how the demographic structure of each population may affect exchange rates since different movement patterns and habitat use would be expected between juvenile and adult sturgeon. There is evidence from other enhancement projects that juvenile movements appear greater than adults and a population with a large number of juveniles (such as from stocking) may have more emigration. Although the modeling is framed in terms of adult exchange and may be off in scale and time lags, the current equilibrium modeling does demonstrate directional trends between populations from varying exchange rates. Revised text to the working paper should discuss uncertainty of demographic effects affecting exchange rates and distinguish between movement patterns that do provide a genetic exchange versus movement patterns whereby habitat is temporarily used.

Model Parameters

Participants reviewed the information presented in Table 4 of the working paper. In addition to several editorial points (summarized below). The authors described the role and interpretation of the Hab_t and HM multipliers in the modeling and recognized that additional explanation in the text was required to assist with clarity, (i.e. Hab_t=1 habitat productivity is approximately equal to current carrying capacity). Suggestions to improve the interpretation of contour plots were made, such as marking spots on counter plots representing initial model conditions (i.e., assumed current values for Hab_t and HM) as well as marking recovery target thresholds over trajectory periods. Text to describe how the Hab_t parameter effectively varies the production of modeled juveniles was also requested to be included with the revisions.

Participants determined that the annual survival rate used for equilibrium modeling should be partitioned into an annual natural survival rate and a human induced mortality rate to clarify the population models. There was consensus that initial human induced mortality rates should not be 0 since there is evidence that HM has occurred/is occurring for all three populations. A subset of participants was tasked with compiling available data (related to permitted catch and release fishing, poaching, etc.) to estimate parameter values of initial human induced mortality (HM) for use in revisions of modeling scenarios. Since information based on observations won't be available during the review meeting, default values for the three populations were identified (best available information) as an interim measure to proceed with review discussion and advice (Upper Fraser 0.003, Mid-Fraser 0.006, Nechako 0.005). There was concensus that a HM range of 0.3-0.6% for modeling purposes was appropriate but that both the working paper and the SAR should reflect that there is a high degree of uncertainty, especially for the Nechako group.

Important Habitat

There was discussion on the information presented in the working paper related to Figures 2 and 3 and the distinction between advising on previously identified critical habitat due to a prior SARA listing (relevant for Upper Fraser and Nechako populations) and information on confirmed and suspected important habitat sites not designated as critical habitat. There was consensus that sites known or suspected to represent high value habitat should be documented in the RPA, including new information not previously reported, so that information will be available to inform management and listing decisions and recovery planning. The paper should reflect this conclusion and also clarify any wording in the text and figures which may not clearly distinguish legally defined critical habitat under SARA and known or suspected to important habitats (Section 3). A manager offered to help authors revise wording in Section 3 to meet that purpose.

Allowable Harm

Participants agreed that for assessing and modeling allowable harm the authors of the RPA should not be expected to determine how this should be done and that participants needed to provide direction for this. It was acknowledged that allowable harm on a population or DU should not exceed population growth for a population to remain stable or to increase.

With respect to the Nechako hatchery enhancement, obtaining brood stock was said to be difficult already. An example was given that if brood stock handling introduced some level of mortality to adults (such as an average of 2 fish/year for 20 years), that an undesirably high loss of individuals would result. The point was made that if the DU does get SARA listed, then allowable harm could be set to 0, thereby potentially impeding Nechako brood stock collection.

There was discussion on how to assess available information and frame advice in the context of allowable harm. Questions that came up were: How can recovery targets be considered? What about other recovery goals affecting population survival, such as population structure and adequate habitat for spawning and juvenile survival? Should performance metrics be used with probability distributions? A population with 50 mature individuals has been referenced as an extinction threshold, is this something worth considering? It was acknowledge that the models used in the RPA working paper were not designed to model and statistically evaluate population responses (associated with age structure, etc.) to assess management scenarios such as varying allowable harm.

Modeling increases in HM from assumed initial conditions was identified as a good place to start for framing advice. This would allow one to visualize across a range of HM values the point where reaching a recovery target becomes problematic. Most RPAs are conducted for populations that are already below recovery targets but for the Upper Fraser DU, two of the three groups are at recommended recovery targets already. For those two groups, current HM levels may be a reasonable level of allowable harm (although not specifically characterized and quantified). The small adult population size of the Upper Fraser (185) is believed to be due to a low carrying capacity but the small population would also be expected to be more sensitive to effects of allowable harm. The Mid-Fraser has been subject to catch and release activity and appears relatively stable, whereas the Nechako is below the recommended recovery target because of recruitment failure so an increase in adult abundance is required. Based on the current estimate of 630 adult fish in the Nechako, and a population structure lacking juveniles, participants suggested no allowable harm except in support of conservation objectives until there is evidence of improved population structure and an adult abundance above the recovery target of 1,000 fish.

OVERVIEW OF RPA OBJECTIVES AND ELEMENTS

As a guide to verifying and identifying whether and how the working paper addressed each of the objectives and elements listed in the terms of reference, participants reviewed a summary table that was drafted as a checklist and method of summarizing where in the working paper the information can be found (including the paper's referencing of other information sources). Managers indicated that since RPA process is designed mainly to advise on the DU listing process and allowable harm, if there is justification to provide information by population and not by DU that should be communicated. Notes by sets of elements are provided below.

Elements 1-3 (Biology etc.): Adequate information provided in the working paper.

Elements 4-7 (Habitat etc.): This information said to be mainly for informing critical habitat. The working paper does identify habitat sites believed to be important in supporting recovery targets. Participants agreed that it doesn't make sense from a management perspective to roll up information for a DU to try to fit the COSEWIC grouping. There are information gaps related to the spatial extent and configuration of habitat and distribution that current and future research can address. Participants agreed that advice should be framed in terms of the DU having three populations and any loss of one population would be a failure of the DU recovery or survival.

Elements 8-10 (Threats etc.): Information presented in Table 2 of the working paper by population was deemed appropriate. Information in this table is based on results of an assessment presented in DFO (2014) and is listed by population and not summarized by DU. Participants agreed that this is the most informative method of documenting the threats for providing advice. Information gaps related to recent HM impacting the populations and DU level have been identified and this uncertainty to be presented in the working paper and SAR. Wording in the RPA should qualify that although aquaculture/hatchery enhancement activities were assigned a moderate risk, that adaptive management will be in place to minimize threats from these activities. Someone asked whether railway spills should also be included, since there is an active railway along vast sections of the main stem Fraser and Nechako Rivers. Participants agreed that a spill could be a serious threat if a harmful substance entered the riverine ecosystem, but it was noted that these risks are generally not included in RPAs due to their perceived low probability and restricted impact in space and time relative to the larger-scale ones considered in the RPA. Threat related to railway spills was not added to the threat list of Table 2.

Element 11 (Ecological impacts, abatement of threats, monitoring efforts): The aims of this multi -step element were regarded as beyond the scope of this review and the RPA document. The intent of the components of this element is believed to inform how monitoring programs can be applied. It was suggested to note that the working paper partially addressed this element but that it is unrealistic expectation for an RPA to inform on all the monitoring that has occurred in the ecosystem affecting sturgeon. The RPA provides qualitative predictions through scaling across ranges of HM and Hab_t, which conceptually addresses how the populations benefit or are compromised from varying threats. A suggestion was made to have text added to the RPA that speaks to ecological impacts, such as stating that by addressing threats affecting sturgeon, most associated species (prey base etc) would also benefit.

Element 12 (Abundance and distribution targets): Participants reiterated that advice should be framed in terms of the DU having three populations and any loss of one population would be a failure of the DU recovery or survival. Proposed recovery targets (related to abundance, population structure and important habitat) should be at the population scale, if rolled up to DU then caveats of population components also needs to be included. For example, a definition of achieving recovery at a DU scale was given: if each of the 3 populations had 1000 or more mature individuals and each population demonstrated successful natural reproduction and population sustainability.

Elements 13-15 (Projections given current conditions): There was agreement that the working paper addresses this and information at a population scale rather a DU scale most reasonable.

Element 16-19 (Mitigation etc): Table 3 of the working paper (from DFO 2014) is good for this purpose. Some revisions to text in Section 5 of draft RPA were identified to improve descriptions related to: restoration and enhancement efforts, degree of functional habitat in each population, limitations from habitat and prey availability and socioeconomic wording.

Elements 20-21 (Projections from varying HM and Hab_t): Agreement that the working paper addresses this by modeling at a population scale but some modeling revisions are required (listed below).

Element 22 (Allowable Harm): The RPA to provide a rationale for thinking of changes to HM and Hab_t in both directions and describe how mitigation from changing HM or improving habitat productivity to be interpreted in contour plots. Concern was expressed that many habitat changes are irreversible with no true mitigation, whereas HM may be seen as more reversible through hatchery inputs or enforcement efforts etc. Perceived compensation between HM and Habt ranges may be unrealistic due to complicated processes within and between populations. For the Nechako, current Hab_t is assumed to be approximately 0 due to lack of habitat supporting recruitment but we don't know what would happen if other habitat loss occurred (i.e.

it could get worse than it already is). Participants reiterated that advice should be framed in terms of the DU having three populations (based on genetic differences, demographics etc) and loss of one population would be a failure to the recovery of the DU.

REVISIONS

The paper was accepted subject to some substantial revisions, including re-running revised models as identified by the authors and the meeting participants, in addition to several editorial revisions. Following the revisions to the modeling work and editorial changes, updated information is to be included in the SAR and the final Research Document. Appendix F outlines the expected revisions identified by the participants at the meeting.

DEVELOPMENT OF SCIENCE ADVISORY REPORT

The intent of the SAR and the relevant sections were explained. Direction was given to participants to focus on developing summary points, including the main mitigation measures and identifying uncertainties associated with population survival or recovery.

Summary Points

- The Upper Fraser White Sturgeon Designatable Unit (DU) now encompasses the Mid-Fraser, Upper Fraser and Nechako Nationally Significant Populations (NSPs). Due to differences, including putative genetic ones, among these three populations management should continue at the sub-DU scale. This requires setting and managing objectives for each and failure to achieve the population abundance target of any sub-DU results in failure at the DU scale.
- White Sturgeon is the largest, longest-lived freshwater fish species in North America. It is a slow-growing, late maturing species.
- The Upper Fraser White Sturgeon DU extends from Hell's Gate upstream through the Mid- and Upper Fraser River (upstream of Prince George) and Nechako River systems.
- Important rearing habitat has been identified for adult and sub-adult sturgeon in each of the three sub-DU areas but important habitat for spawning and larval and juvenile sturgeon remains an uncertainty. No spawning sites have been confirmed for the Mid- and Upper Fraser sub-DUs and only one spawning site is known for the Nechako sub-DU.
- Current estimates of adult sturgeon abundance within the DU are 185 in the Upper Fraser, 749 in the Mid-Fraser, and 630 in the Nechako. Recruitment likely is occurring in the Fraser River mainstem sub-DUs as juvenile sturgeon are present in both the Mid- and Upper Fraser River. However, in the Nechako, ongoing failures of natural recruitment means that very few wild juvenile sturgeon exist and most of these are of hatchery origin. Juvenile sturgeon abundance is unknown for the entire DU.
- The federal recovery strategy for White Sturgeon has identified threats for the survival or recovery of Upper Fraser White Sturgeon. Both habitat quality and quantity have declined in some areas impacting survival and recruitment and overall carrying capacity. This is especially true in the Nechako where spawning habitat has been lost and/or is no longer functional. Even when habitat and food resources have not declined, there are significant risks to long-term viability when populations are small, as is the case here.
- Recommended population abundance targets have been identified for each of the sub-DUs: 185 adults for the Upper Fraser, 749 adults for the Mid-Fraser, and 1,000 adults for the Nechako.

- Current adult estimates are at the population abundance targets for both the Mid- and Upper Fraser sub-DUs but below the target for the Nechako sub-DU where recruitment failure persists. Given that White Sturgeon is a very long-lived and late-maturing species the changes in juvenile recruitment may not be reflected in adult abundance for decades, as noted in the Nechako.
- Currently, hatchery production is the primary source of juvenile sturgeon in the Nechako system. There appears to be limited exchange among the three sub-DUs within the Upper Fraser. Adaptive management of Nechako River hatchery operations should ensure hatchery-produced sturgeon do not overwhelm the other sub-DUs in this metapopulation.
- Modeling that includes both habitat productivity (Habt) and human induced mortality (HM) allows visualizations of potential trade-offs should changes to either occur. There is very little scope for improved habitat productivity for the Mid- and Upper Fraser sub-DUs. However habitat improvement is essential in the Nechako sub-DU where spawning habitat restoration efforts are required to restore naturally sustained recruitment.
- Since human induced mortality was considered low for all three sub-DUs there is limited scope to reduce it further, except perhaps the Mid-Fraser where there is more uncertainty.
- The Nechako sub-DU is well below its recovery target of 1,000 adult fish, so there is limited scope for additional allowable harm to this sub-DU and any should be in support of conservation objectives.
- Potential allowable harm for Mid- and Upper Fraser sub-DUs was evaluated by modeling changes in HM while maintaining current Habt values. If HM increased 2× for the Mid-Fraser sub-DU or 3× for the Upper Fraser sub-DU over current HM levels, it would have substantial negative effects on the abundance of White Sturgeon.

REFERENCES CITED

DFO (Fisheries and Oceans Canada). 2014. Recovery strategy for White Sturgeon *(Acipenser transmontanus*) in Canada [Final]. In Species at Risk Act Recovery Strategy Series. 80 Ottawa: Fisheries and Oceans Canada. 252 pp. (Accessed July 12, 2016)

Nechako White Sturgeon Recovery Initiative. 2005. Breeding Plan for Nechako White Sturgeon. Prepared by Susan M. Pollard, BC Ministry of Environment. 35 pp.

Williamson, C., S. McAdam and D. Cadden. 2004. Assessment of hazards and risks associated with the recovery of Nechako white sturgeon. Nechako White Sturgeon Recovery Initiative Report.. 20 pp.

Wood, C., D. Sneep, S. McAdam, J. Korman, and T. Hatfield. 2007. Recovery potential assessment for white sturgeon populations listed under the Species at Risk Act. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/003. (Accessed July 12, 2016)

APPENDIX A: AGENDA

Regional Peer Review (RPR), Centre for Science Advice Pacific

Recovery Potential Assessment - White Sturgeon, Upper Fraser Designatable Unit

March 30 - April 1, 2016
Coast Inn of the North, Prince George, BC

Chairperson: Dr. Thomas Therriault

Day 1 - Wednesday March 30, 2016

Time	**Subject**	**Presenter**
9:00	Welcome, Introductions, Review Agenda & Housekeeping, CSAS Overview & Meeting Procedures	Tom Therriault
9:30	DU vs Population	Sean MacConnachie
9:45	Presentation of Working Paper	Todd Hatfield
10:45	***Break***	
11:00	Reviewer Presentations & Author Response	Todd Hatfield
12:15	***Lunch Break***	
1:30	Group Discussion to review working paper	RPR Participants
3:30	***Break***	
3: 50	Group Discussion to identify Issues and Topics needing further discussion	RPR Participants
4:30	***Adjournment***	

Day 2 – Thursday March 31, 2016

Time	**Subject**	**Presenter**
9:00	Welcome, Introductions, & Housekeeping	Tom Therriault
9:15	Review of Day 1 discussion	Tom Therriault
9:30	Review of Science Advice Report	RPR Participants
10:45	***Break***	
11:05	Review of Science Advice Report	RPR Participants
12:15	***Lunch Break***	
1:15	Review of Science Advice Report	RPR Participants
2:30	***Break***	
2:45	Review of Science Advice Report	RPR Participants
4:30	***Adjournment***	

Day 3 – Friday April 1, 2016

Time	Subject	Presenter
9:00	Welcome, Introductions, & Housekeeping	Tom Therriault
9:15	Review of Day 2 discussion	Tom Therriault
9:30	Compilation of advice and revision of SAR	RPR Participants
10:45	***Break***	
11:05	Compilation of advice and revision of SAR	RPR Participants
12:15	***Lunch Break***	
1:15	Review of Science Advice Report	RPR Participants
2:30	Finalization of SAR Content and Next Steps and Timelines	Tom Therriault
3:30	***Adjournment***	

APPENDIX B: TERMS OF REFERENCE

Recovery Potential Assessment – White Sturgeon, Upper Fraser Designatable Unit

Regional Peer Review Meeting – Pacific Region

March 30 - April 1, 2016
Prince George, British Columbia

Chairperson: Dr. Thomas Therriault

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.

Within Canada, White Sturgeon occur only in British Columbia. In 2003 they were divided into six populations, based on geography and genetics: the lower, middle and upper Fraser River; Nechako River; Columbia River; and, Kootenay River. All populations were designated as endangered by COSEWIC, but only the latter four are legally listed under SARA. Following their listing a RPA (Wood et al. 2007) was undertaken followed by advice on the identification of critical habitat (Hatfield et al. 2013). A Recovery Strategy for White Sturgeon in Canada has also been developed (DFO, 2014).

In 2013, COSEWIC re-assessed White Sturgeon and found there to be four populations, or designatable units (DU); Lower Fraser, Upper Fraser, Upper Columbia, and Upper Kootenay White Sturgeon (COSEWIC 2012).

In support of listing recommendations for Upper Fraser White Sturgeon by the Minister, DFO Science has been asked to undertake an RPA, based on 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 SARA. The advice in the RPA may also be used to prepare for the reporting requirements of SARA s. 46 and s.55. The advice generated via this process will update and/or consolidate any existing advice regarding Upper Fraser White Sturgeon.

The new Upper Fraser DU is now comprised of an amalgamation of the former Mid-Fraser, Upper Fraser and the Nechako DUs. Significant recovery activities have taken place and it is expected that management activities will continue to be directed at this sub-DU scale. As a result, this RPA will inform recovery and listing at not only the DU scale, but where appropriate, provide advice for ongoing activities at the sub-DU level.

Objectives

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

Biology, Abundance, Distribution and Life History Parameters

Element 1: Summarize the biology of Upper Fraser White Sturgeon.

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 Upper Fraser White Sturgeon.

Habitat and Residence Requirements

Element 4: Describe the habitat properties that Upper Fraser White Sturgeon needs 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 in Upper Fraser White Sturgeon's distribution 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 Upper Fraser White Sturgeon

Element 8: Assess and prioritize the threats to the survival and recovery of the Upper Fraser White Sturgeon.

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 Upper Fraser White Sturgeon.

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 Upper Fraser White Sturgeon 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

- CSAS Science Advisory Report
- CSAS Proceedings
- CSAS Research Document

Expected Participation

- Fisheries and Oceans Canada (Science, Fisheries Management, Fisheries Protection Program, and Species at Risk)
- Province of British Columbia
- First Nations
- Industry
- Other invited experts (environmental non-government organizations)

References

COSEWIC. 2012. COSEWIC assessment and status report on the White Sturgeon *Acipenser transmontanus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxvii + 75 pp.

DFO. 2007a. Revised Protocol for Conducting Recovery Potential Assessments. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/039.

DFO. 2007b. Documenting habitat use of species at risk and quantifying habitat quality. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/038.

Fisheries and Oceans Canada. 2014. Recovery strategy for White Sturgeon *(Acipenser transmontanus*) in Canada [Final]. In Species at Risk Act Recovery Strategy Series. 80 Ottawa: Fisheries and Oceans Canada. 252 pp.

Hatfield, T., Coopper, T. and McAdam, S. 2013. Scientific Information in Support of Identifying Critical Habitat for SARA-listed White Sturgeon Populations in Canada: Nechako, Columbia, Kootenay and Upper Fraser (2009). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/153. viii + 103 p.

Wood, C., D. Sneep, S. McAdam, J. Korman, and T. Hatfield. 2007. Recovery potential assessment for white sturgeon populations listed under the *Species at Risk Act*. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/003

APPENDIX C: PARTICIPANTS

Last Name	First Name	Affiliation
Bradford	Mike	DFO Science
Coopper	Tola	DFO Ecosystems Management Branch
Flostrand	Linnea	DFO Science
Hatfield	Todd	Ecofish Research
MacConnachie	Sean	DFO Science
MacDougall	Lesley	DFO Centre for Science Advice
Magnusson	Gisele	DFO Policy
McAdam	Steve	Province of BC
Nantel	Martin	DFO Ecosystems Management Branch
Norgard	Tammy	DFO Science
Rosenau	Marvin	BCIT
Sary	Zsolt	Province of BC
Smyth	Eric	Ecofish Research
Taylor	Phillip	DFO Science
Therriault	Tom	DFO Science
Toth	Brian	Lheidli Tenneh
Watkinson	Doug	DFO Winnipeg
Williamson	Cory	Freshwater Fisheries Society of BC
Williston	Lee	Province of BC

APPENDIX D: WRITTEN REVIEWS

REVIEWER: MIKE BRADFORD, DFO SCIENCE

To conduct this review I read the working paper, and consulted the following documents:

COSEWIC. 2012. COSEWIC assessment and status report on the White Sturgeon *Acipenser transmontanus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

DFO (Fisheries and Oceans Canada). 2007. Revised Protocol for Conducting Recovery Potential Assessments. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/039.

DFO, 2007. Proceedings of the PSARC meeting on white sturgeon populations listed under the Species at Risk Act. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2007/013.

DFO (Fisheries and Oceans Canada). 2014. Recovery strategy for White Sturgeon (*Acipenser transmontanus*) in Canada. Species at Risk Act Recovery Strategy Series. Ottawa: Fisheries and Oceans Canada. 252 pp.

Korman et al. 2007. Simulation model to explore recovery potential of endangered white sturgeon populations. Appendix 2 to Wood et al. 2007.

Schrier, et al. 2012. Hierarchical patterns of population structure in the endangered Fraser River white sturgeon and implications for conservation. CJFAS 69:1969-1980.

Wood, C., D. Sneep, S. McAdam, J. Korman, and T. Hatfield. 2007. Recovery potential assessment for white sturgeon populations listed under the Species at Risk Act. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/003.

SUMMARY OF RESPONSES TO STANDARD CSAS QUESTIONS

1. Is the purpose of the working paper clearly stated and aligned to the Terms of Reference for this CSAS Review?

   The TOR has clearly identified 22 elements that are based on DFO (2007). The paper does not list the elements explicitly in the purpose statement.

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

   The key analysis (and conclusions) of the RPA relate to the population modelling and analysis of changes in harm or habitat. A previously published model was employed with some modifications and parameter changes. The model and approach should be adequate as it was used for an earlier RPA for this species.

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

   There are key elements in the Korman model that should be explained in the current document to assist the reader in interpreting the result. These include the assumption of strong density dependence in the egg-age-1 stage that is the limiting life stage for the population, that the habitat modifier Hab_t applies to the juvenile stage only, and density-dependent parameters are “tuned” so that the equilibrium population size is the proposed recovery target. A stronger justification for the use of the metapopulation approach and more information about the hatchery program is needed.

4. Is the working paper aligned to the objectives in Terms of Reference?

   The structure of the paper does not match the elements of the TOR, particularly in the latter sections. Adherence to the TOR would ensure the completeness of the document.

5. Does the advice reflect the uncertainty in the data, analysis or process?

   The original model is a stochastic model that includes recruitment variation and binomial-based variation in survival and other demographic parameters. This allows for probabilistic statements about recovery or survival under different modelled scenarios (See Wood et al. 2007). Such variation was ignored in the current analysis. Some sensitivity analyses were used to evaluate the management actions but no analysis of other parameters was conducted. The most important differences between the 2007 and current version are the metapopulation and hatchery element but these have the least support or justification. That uncertainty is not reflected in the paper.

6. Are there additional areas of research that are needed to improve the quality of or the ability to provide advice and recommendations related to the stated objectives?

   Under the movement scenarios (and without, for the Nechako) the assumed survival rates of hatchery fish result in them becoming a dominant part of the population. Additional metrics, including the proportion of hatchery and wild fish in the adult population and potentially some of the hatchery metrics like PNI (Proportionate Natural Influence) should be employed to track hatchery affects. My understanding is that hatchery fish are not normally included in COSEWIC status or trend assessments, so the status of the wild population could be masked by hatchery fish. Hatchery fish also pose a risk to the recovery goal of a self-sustaining population.

OVERALL COMMENTS

An RPA for all BC white sturgeon populations was previously conducted by Wood et al. (2007) and reviewed and approved (DFO 2007). In that analysis probabilistic advice regarding the effects of harm on meeting various population targets was provided, based on results from a simulation model. Allowable harm was assessed by evaluation of population trajectories relative to recovery objectives set out in a draft Recovery Strategy.

Smyth et al. used the same model, but updated the analyses with some new parameters and a metapopulation exchange component. They also developed their own recovery targets despite the finalization of the Recovery Strategy. Unfortunately the results are not summarized in a similar manner (particularly with respect to uncertainty) as in Wood et al. and are difficult to evaluate.

My suggestion is that the template set out by Wood et al should be followed in this update, with greater emphasis on justification of the movement model, and a more thorough analysis of the risks and benefits of the hatchery program. Closer adherence to the TOR will assist the presentation.

COMMENTS ON SPECIFIC SECTIONS

6.1 Abundance

It should be noted that the Reed et al (2003) citation is a compilation of modelling studies used to estimate risks of extinction and is not based on empirical observations.

The RPA should address the probability that the population can achieve the recovery targets and be consistent with the recovery goal. The authors have suggested the targets should be current population size. However, there are also targets in the Recovery Strategy, in particular, there is a 50 year interim target of 1000 adults (200 for the Upper Fraser). It seems the analysis should use the published values in the Recovery Strategy rather than potentially creating confusion by having another set of targets.

7.1 Model Structure

The authors use the Korman et al. 2007 model, with some modifications in parameters, and in model structure. Although they don't need to reproduce a complete description of the model in the current document, more detail on key elements are important to be able to understand model results. I found I had to rely on Korman et al. extensively to be able to interpret the results.

The Korman model uses a density-dependent Beverton-Holt model to describe early life history and population regulation in the larval or juvenile stage. As the parameters of the BH function are not known a proxy for α is chosen from the literature and β is found by "tuning" such that the long-term equilibrium population size (assumed to be current population size) is reached. Log-normal recruitment variation is assumed, although this may underestimate variation if there are large catastrophic events that cause recruitment failures.

There is little information presented to rationalize the metapopulation model. A modest amount of genetic differentiation among populations would imply that the annual rate of exchange between populations would be extremely small given the generation time. The high rate of exchange in some model runs (5%/annum) is significant enough that there should be radio tagging observations that can support it. Unfortunately without knowledge of the population of origin of tagged fish and observations of spawning these observations are difficult to use for parameterization of the model, as they may represent foraging. Information such as that in Schreier et al. should be used to justify the model.

The observation of Mid-Fraser to Nechako movement noted in COSEWIC (2012) contradicts the assumption made in the model that no exchange occurs between these two populations (very bottom of page 30 of working paper; but this is inconsistent with model results in Figure 7).

Two key differences in the current model relative and the 2007 analysis is the number of hatchery fish being released (now set at 12000/year all 100 years of simulation) and hatchery fish survival, increased from 0.2 to 0.93. This latter value is a "pers. comm" and no other information is provided. At a minimum the survival rate and release strategies should be subject to sensitivity analysis, and evaluated against goals that hopefully have been set by the Nechako program. The results suggest the parameters of the hatchery components could have large negative impacts on the achievement of the recovery goal of the other populations.

A few key values can be derived from the fitting process that can assist in understanding the model. The Beverton Holt model describes the production of juveniles in relation to spawner abundance. From the model the asymptotic age-1 production, which is the estimated capacity of the juvenile habitat, and the spawning population size that achieves a significant fraction of the maximum (80 or 90%) can be derived (Fig 1). I think these would reveal that the average number of age-1 fish recruiting to the adult population per year is relatively low, and would provide some idea of the spawner abundances that would result in meaningful reductions in recruitment.

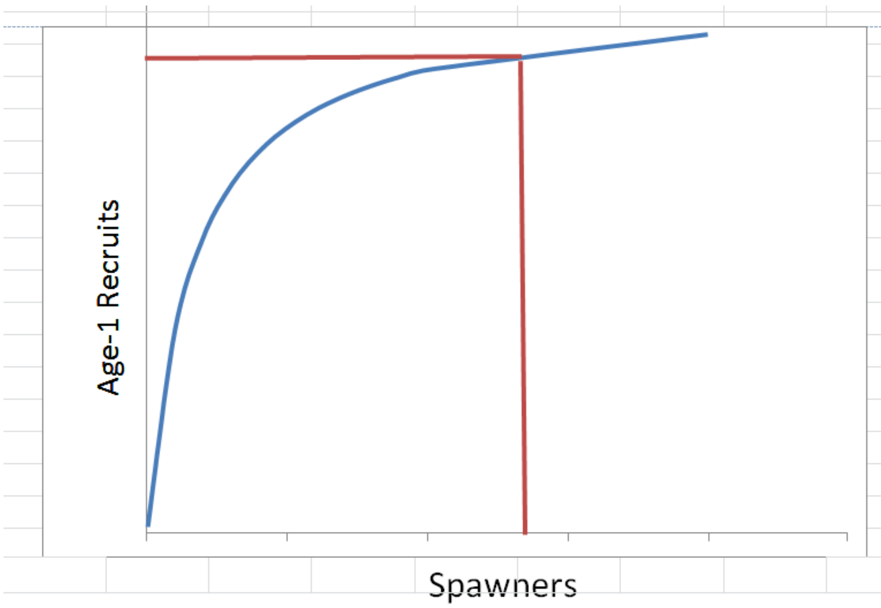

Figure 1- a generic BH curve showing the spawner abundance that results in a large fraction of the age-1 production.

Some addition details that would be nice to have on hand are:

1. How is adult (last line of Table 4) defined? What is the age of maturity for females?
2. What was assumed for hatchery survival in Korman (I think it was 0.2)
3. What are the α, β parameters (or equivalents) that emerge from the fitting?
4. What is assumed about reproduction (particularly spawning frequency?).
5. It should be emphasized that Hab_t parameter is for larval/juvenile habitat only and HM is mortality on older fish (the vulnerability profile is for net and hook and line fishing).

7.5 Model results

Median (not mean) results be presented, representing the "typical" scenario. However, results should be presented in a stochastic/risk-based framework (i.e., probability of achieving a target, see Wood et al.).

This section suggests "the habitat supply is sufficient to reach the target". However, this is solely an outcome of the model fitting procedure (juvenile production parameters are tuned to the target). This is not a result. The tuning also means the final population size will be sensitive to adult mortality (HM scenarios) as there is no compensation (or density effects) in the adult stages.

The results in Figure 7 show the effects of the parameter choices for the hatchery releases- The age-1 to age 20 survival of hatchery fish is about 40% meaning nearly 5000 fish will recruit into the adult population for the Nechako. This will swamp natural production in the other populations under the migration scenarios.

7.5.1.1

Isn't the difference between LHS1 and LHS2 for the Nechako mainly due to the dramatically different survival rates for hatchery fish?

7.5.2 Allowable harm assessment

The process by which the AHA is being evaluated (as per Element 22 of the TOR) should be outlined in the methods. In particular, a more nuanced approach to evaluating allowable harm may be more useful.

As with section 7.5 it appears the model is fit so that the equilibrium population size is the recovery target. It is inevitable that any change in survival or juvenile habitat capacity will cause the population to fall below equilibrium. Implicit in the model is that ongoing "take" from incidental or deliberate human actions is imbedded in either the mortality rate estimates, or is factored into the tuning phase. The HM parameter is mortality over the current baseline.

The habitat parameter Hab_t is a scalar on the juvenile habitat and simulates modifications to those habitats used by the egg-age 1 stages. There is no linkage in the model between habitat and age 2 and older fish. Reference should be made to "juvenile" habitat whenever referring to Habt.

The task, as identified in Element 22 is to evaluate mortality or habitat change that will not jeopardize survival (persistence) or recovery. Since all populations will decline and may stabilize at levels below carrying capacity under additional mortality, it may be more appropriate to determine the levels of mortality that will result in some percentile of the carrying capacity.

One potential approach is to use the recruitment curve (see figure above) to set some lower bounds on the spawning stock size.

The use of the 30% decline in 3 generations can be debated. For COSEWIC it is not the sole indicator of status as the size of the adult population (and other metrics) will come into play. Given the structure of the model it is likely the population will stabilize over a very long time and the trend in the first 100 years may not be true indicator of population persistence (in the model at least). Statements such as "would result in substantial risk" (see bottom of page 43 and 44, the same paragraph appears to have been pasted in twice without revision) are not useful.

The model was used to make risk-based assessments of impacts of mortality or habitat change. That is, the results can be expressed as the probability of exceeding some threshold value, given stochasticity in the model. It appears that the results presented are based on some central tendency (mean?) which implies there is a 50% probability of that event.

Some explicit consideration of the risks of hatchery production to the Nechako population, and to other populations if migration does indeed occur should be included. It is unclear whether there is a target in terms of adult fish from the hatchery program; presumably it exists to maintain the population at an appropriate level so that if successful natural reproduction does occur a robust population self-sustaining population will be maintained. The proportion of hatchery fish in both the Nechako, and the other populations under different movement patterns is an important parameter to track. See Wood et al. (2007) use of the proportion wild indicator.

The contour diagrams are difficult to interpret as the vertical axis labels are hidden and in many cases there are few or no isoclines or labels.

Finally, the model results should be used to inform the Allowable Harm analysis, not replace it. It would be useful to have the results interpreted in a more useable format for managers. For example, can the HAbt changes be translated into likely threats to juvenile rearing areas? How many fish per year can be taken before the persistence of the population is reduced by x?

REVIEWER: STEVEN MCADAM, BC MINISTRY OF ENVIRONMENT

1. Is the purpose of the working paper clearly stated and aligned to the Terms of Reference for this CSAS Review?

All elements are addressed within the document. However, concordance between the working paper and the TOR would benefit from more explicitly identifying the 22 elements within the document. I have provided detailed comments indicated by page (P) and paragraph (p) for some of these elements.

With specific regard to allowable harm (element 22) the analysis suggests that the middle and upper Fraser groups are stable if current conditions are maintained and no exchange is assumed. Allowable harm under scenarios the include exchange are affected by uncertainty regarding actual exchange rates and future stocking. As a result, allowable harm until those scenarios still has substantial uncertainty.

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

I have some concerns that are noted below. In particular assumptions regarding exchange rates and Nechako stocking rates have a very dominant effect on results. There is substantial uncertainty regarding suitable exchange rates. The high scenario of 5% certainly appears too high based on current results. Similarly results clearly suggest that the assumed stocking rate would lead to unintended consequences. I would expect stocking rates to decline if the predicted results were observed. Therefore the assumption of a stable (and high) stocking rate over the modelling period appears unrealistic. Given the uncertainty in these two key assumptions further scenarios would need to be considered in order to make results most useful for supporting management decisions.

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

The data and methods are explained, although I found a few locations where the description of results was unclear (see detailed comments). Also, given the dominant effect of hatchery inputs and my expectation that these will change (i.e. decline), the absence of other scenarios makes evaluation of some conclusions somewhat moot (i.e. scenarios affected by hatchery inputs).

4. Is the working paper aligned to the objectives in Terms of Reference?

In a general sense yes, but I did find a number of locations where the material did not appear to be as up to date as it could be. I have detailed these concerns in my comments below. Most specifically this regards the presentation of the causes of recruitment failure, for which the inclusion of other information could have focussed attention on changes to spawning and early rearing habitat, and the current habitat restoration efforts.

5. Does the advice reflect the uncertainty in the data, analysis or process?

Sources of uncertainty are indicated in the report. Consideration of the two life history settings does address the effects of uncertainty in most parameter settings. However, future changes in stocking rate are not addressed, but should be. Additional means to evaluate reasonable levels of exchange would also be valuable. For example, demographic differences between the Nechako (long term recruitment failure) and the middle/upper Fraser indicate that exchange into the Nechako of juveniles must be very low or absent. Genetic differences might also provide some indication of the level of exchange, although reproductive exchange can be achieved without demographic exchange.

6. Are there additional areas of research that are needed to improve the quality of or the ability to provide advice and recommendations related to the stated objectives?

Additional areas of research largely flow from the comments above. Evaluation of different stocking rates and methods to evaluate exchange rates are two areas that would be particularly beneficial.

GENERAL COMMENTS

1. The report indicates that upper and middle Fraser populations will meet abundance targets if current conditions are maintained, and even with small changes to Habt and HM. This finding is largely a result of model assumptions. To strengthen this assertion some evaluation of possible current trends would be valuable, though I appreciate the data limitations in doing so.
2. The Nechako population is undergoing recruitment failure and responses for that population are dominated by the effects of supplementation. This dominant effect of one assumption (stocking at 12,000/year) is addressed further below.
3. Exchange rates – These also have a strong effect on results, so it is imperative that further consideration is given to whether they are reasonable assumptions. This is also addressed below. What level of exchange is compatible with current population differences? Genetic differences may be challenging to evaluate, but demographic differences may be more amenable to analysis. For example, the demographic differences suggest that there is near zero exchange into the Nechako.

STOCKING RATES

The report shows that results for the Nechako are dominated by hatchery inputs. This dominant effect of hatchery inputs affects the Upper Fraser groups at 0.1% and 5% exchange, and the Middle Fraser group at 5% exchange. The strong effect of stocking in the Nechako creates some challenges. In particular I expect that stocking rates will likely decrease over time. I expect this decrease will occur for two reasons. First, if the results predicted in this analysis are observed then I expect stocking rates would be reduced. Monitoring is currently in place to evaluate movements of white sturgeon out of the Nechako, so even considering the model assumption that exchange is limited to adults (this assumption is addressed below) I would expect that the maximum period for high stocking rates would be ~25 years. However, monitoring regarding juvenile abundance and survival would support changes much earlier than that, and I would predict changes could occur within 5 years. Secondly, habitat restoration efforts in the Nechako are being pursued, and at some point should supplant hatchery stocking. While we can't set a date for this, I expect this will occur within 10 years and definitely within 50 years. So my overall concern is that the assumed continuation of stocking for 100 years leads to modelled results that are unrealistic. This assumption primarily affects the Nechako group, with effects on the other two groups depending on the assumed exchange rates.

EXCHANGE RATES

Three exchange rates were considered (0, 0.1% and 5%). My understanding is that the 5% exchange rate was intended to provide a high assumption. While I believe it achieved that goal, the results appear unreasonable and therefore may be uninformative. The two lower scenarios appear more informative, however, even the low level exchange leads to substantial effects under current stocking assumptions. Further evaluation of exchange assumptions against other indicators would be beneficial. For example, can we estimate exchange rates from movement data, genetic data or demographic data? As noted above demographic differences suggest no exchange into the Nechako River for fish under 40-50 years old. One could evaluate the maximum exchange rate that could occur while still observing the present demographic differences. Also I believe the model assumes the same level of exchange between two groups, but the basis for this is unclear.

Additionally the logic of demographic exchange is somewhat unclear. The model assumes that exchange occurs for adults. While very low exchange rates would be hard to detect for any population how well does this assumption match observations for other sturgeon? The genetic differences identified in other studies (Smith et al., Schreier et al.) appear to influence the assumed pattern of exchange (i.e. no direct exchange from Nechako to Middle Fraser), however, reproductive exchange and demographic exchange are distinct. So the logic of this assumed exchange pattern is unclear.

SPECIFIC COMMENTS (P=PAGE, P=PARAGRAPH)

P2p2 You might mention their presence in tributaries. Presence has been confirmed for the Seton (fish found on Seton trash rack) and the Thompson (capture in Kamloops Lake). Available evidence suggests use of these areas may be occasional (except the Seton fish was trapped upstream by the dam – this statement is based on my analysis of the fish's fin ray chemistry).

P4 – 2.3.4 "At the onset of the feeding larval period…"

P5 p1 The Semakula and Larkin (1968) reference is for the lower Fraser. While they may provide a general indication for the species this range may be less relevant to the Upper Fraser DU.

P5p5 The reference to spawning in side channels is for the lower Fraser. Seems unlikely to be as relevant in this DU due to a) the more limited abundance of side channels (e.g. middle Fraser is largely canyonized), b) lower volumes so side channels smaller c) loss of side channels in the Nechako (see ref in McAdam et al. 2005) and d) confirmed mainstem spawning in the Nechako.

P5p6 I don't think the prevalence of repeat spawning is the best wording. I'd say there is certainty that it occurs, but uncertainty about the interspawning interval.

P5p7 White sturgeon are iteroparous (i.e. omit "may also"). Additionally, I would not use Semakula and Larkin in this manner. It refers to the lower Fraser. These sorts of intervals appear to be longer than estimates from other sources (e.g. actual repeat spawners in the Kootenay and Nechako). Also, the methods underlying the estimates by Semakula and Larkin are spawning checks. I've never seen any other reference to spawning checks in sturgeon, so I question the validity of their estimates.

P6p2 The last sentence makes statements about movement. Some substantiation should be provided. For example, in this DU what evidence is there of dams altering movement patterns? The only example I can think of is a fish trapped in Seton Reservoir, but a single example doesn't seem to warrant this sort of general statement.

P8p2 The middle Fraser is also distinct as it is canyonized through much of its length. This is somewhat unique (some other canyon populations in the Snake River, but that river is highly regulated).

P12p2 Seton and Thompson River examples are mentioned above and could be mentioned in this paragraph.

P13p4 It would be good to indicate the basis of the last sentence indicating the molluscs are likely prevalent in the diet?

P13p5 Spawning has been initiated at lower temperatures. I believe the lowest was between 11 and 12C. This occurred subsequent to Sykes's work and should be included in the spawning reports. Cory Williamson or Brian Toth should have a better idea here.

P14p2 The reference to the lack of use in Kamloops Lake is out of date.

P14p5. In general the material referring to recruitment failure causation appears somewhat dated. For example the reference to Korman an Walters (2001).

P15p4 Again, I'm concerned that the reference to Korman and Walters (2001) is dated, though the statement here is generally correct. Since that time the Nechako TWG has done a lot of work considering different hypotheses. Largely this culminated in McAdam et al. (2005), however, it is important that this study did not consider all hypotheses in a structured manner. That sort of approach was used in McAdam (2015), and again substrate change appears to be the causal mechanism in the Columbia River. A similar analysis is not available for the Kootenay though Paragamian et al. (xxxx) and McDonald et al. (xxxx) (see refs in McAdam 2015) also indicate substrate change is the likely cause in the Kootenay. Therefore, multiple studies in multiple rivers indicate a substrate mediated effect. While this is certainly not proof it provides stronger evidence than is implied in the current text. The importance of this is the potential for spawning habitat remediation, which we are actively working on. If successful (and I do expect we will have some success soon) then assumptions regarding hatchery stocking rates will vary. Given the dominant effect of hatchery stocking rate and survival assumptions, anything that may affect those stocking rates over the short and medium term deserves particular attention.

P15 4.1.1 I think the report should specifically mention changes to spawning habitat. There is good evidence that early survival is critical to recruitment, that spawning habitat is a particularly vulnerable habitat type, and that changes to spawning habitat have occurred.

P16p2. The lack of proof regarding causes of recruitment failure is important to acknowledge. However, there is increasing evidence of a substrate mediated cause (noted above). Given this I think uncertainty is over emphasized in this document.

P17p3. While the magnitude of illegal harvest is not known I believe there is evidence that it is not zero. This doesn't appear to have been captured in the current analysis (though might have little effect on the current analysis).

P18 p3 The use of habitat enrichment during early rearing may also yield some benefit with regard to adverse hatchery effects.

P20p3 Smelters doesn't seem appropriate for this DU.

P21p2 There are some terminology edits needed. Line 3 should be white vs. juvenile (sturgeon). Line 5 should refer to larval vs juvenile survival. The second half of this paragraph deserves some attention as there has been a substantial amount of work regard this particular impact. Lab studies are in McAdam (2011). These were extended to small scale field studies in McAdam (2012). This in turn led to larger scale field scale restoration experiments consisting of creating two spawning 'pads' in 2011. There are a number other reports on the fluvial geomorphology of the reach that might be of interest that further build upon this impact mechanism (see NWSRI website).

P24p1 What is the assumed generation time? I often use 40 years. If so 100 years doesn't capture 3 generations.

P24p4 The timing of recruitment failure appears incorrect. Best estimate is 1967, which is 49 years ago. That said the number of adults wouldn't have declined by 1976 so effects on adult abundance may be nil or minimal.

P25p4 From a modelling perspective I understand why you might only allow adults to move, but I'm not sure it is biologically realistic. There appears to be a discord between what we understand of their behaviour and the model assumptions. Adult behavioural studies often indicate specific and repeated use of particular habitats. Some studies (Nelson and McAdam 2012) show highly resident groups. Other studies (Beardsall and McAdam 2016) show a split between resident and non-resident movement types in the lower Fraser. Assuming the latter there is a possibility of genetic exchange without demographic exchange. However, this model assumes both co-occur. There may be a need for some analysis to see how likely this is given our current understanding of demographic and genetic differences between these groups. This may inform the likelihood of each of the exchange scenarios.

P42p2+3 – There appear to be inconsistencies in the text with regard to the 0% exchange scenario. Paragraph 2 indicates that the 0% scenario doesn't achieve 100% of target abundance. Paragraph 3 indicates that the 0% exchange achieves the target abundance. I assume the paragraph 3 version is correct. The paragraph 2 statement may refer to the 0.1% exchange, but the reader shouldn't need to figure this out.

P44p1+2 Same issue as above but for the upper Fraser group.

P50p3 typo 1999; pers comm is Cory Williamson

APPENDIX E: SUMMARY OF WORKING PAPER

The recovery potential for the Upper Fraser White Sturgeon DU was assessed by examining the current population status, potential threats, and possible results of management strategies. Within the Upper Fraser DU, there are three distinct groups (also referred to as populations) for the Middle Fraser, the Upper Fraser, and the Nechako River.

Prior to 1995, information about the abundance of White Sturgeon stocks in the Upper Fraser DU was very limited, with previous monitoring focused on the Nechako River group. Recent estimates of abundance estimates of mature (>160 cm) White Sturgeon in the Upper Fraser DU was 1,177 fish. The most recent estimate of mature White Sturgeon in the mid Fraser group was 749 fish and the abundance was believed to be within the historic range, suggesting that the population is currently at equilibrium. Similar trends have been observed for the upper Fraser group and the best estimates for the mature (>160 cm) White Sturgeon was an estimated 185 fish. For the Nechako River group, the best estimated adult population size was 630 fish; however, the declining trend in abundance for the Nechako River group reflects recruitment failure.

Twelve threats to White Sturgeon in the Fraser River have been identified and are discussed in detail regarding their potential impact to the local White Sturgeon population. Abiotic threats include loss of habitat, habitat fragmentation, altered hydrograph, pollution, reduced turbidity, fishing effects, and altered thermal regime. Biotic threats include small population size effects, hatchery and aquaculture, reduced or altered food supply, change in ecological community, and disease.

Metapopulation models were designed to evaluate the effect of changes to mortality or habitat productivity on the abundance of the three groups while considering uncertainty regarding the life history parameters and exchange. The results from the modelling exercise show that relatively small changes to human-induced mortality or habitat productivity can have substantial effects on the abundance of sturgeon in the mid and upper Fraser, given the parameter and modeling assumptions. This loss of sturgeon may be mitigated by the introduction of individuals from the Nechako group given the model structure and exchange rates. The effects of varying human-induced mortality or habitat productivity has little effect on the Nechako group relative to its ability to achieve the Nechako target; however, this is dependent on the large number of fish annually stocked into the Nechako and their relatively high survival rate.

APPENDIX F: IDENTIFIED REVISIONS

Projection modeling scenarios and modeling parameters:

- Use of means as statistic in contour plots endorsed
- Only population-specific life history contour plots need to be presented (LHS2).
- Uncertainty associated with Life History Scenarios- mention in text
- Partition annual survival (i.e. 0.96) to represent natural survival and human induced mortality.
- Initial HM and Hab model parameters by population listed below. Estimates of human induced mortality (HM_0) by population may change if task group finds evidence to update values in time to be applied for modeling revisions.
- Mid Fraser: Hab_0 =1.0; HM_0 = 0.006 (0.6%)
- Upper Fraser: Hab_0 = 1.0; HM_0 = 0.003 (0.3%)
- Nechako:
    - Current modeled population carrying capacity should be 1628 (typo Table 4 has 0).
    - Hab_0 = 0.0; HM_0 = 0.005 (0.5%)
    - Visual markers needed on contour plots to show conditions.
    - Show results with stocking and without stocking.
    - Stocking structure to be controlled by use of carrying capacity (and concept of reducing swamping effects through adaptive management)
    - Annual stocking based on deficit between observed juv-1 fish and number of juv-1 fish based on stable age distribution assuming adult pop of 1,600 adults
    - Remove use of a survival rate on released hatchery fish – assume net input with maxing stocking releases of 12,000 age-1 fish/ year
    - Have stocking inputs into for 20 yrs only

Modeling inter-population exchange:

- Metapopulation model to assume equal connection populations
- Show 0% and 0.1% results for all populations
- Text stating 5% exchange rates tested and extent of responses but not determined be unrealistic
- Demonstrate minor issue
- Adult exchange only being modelled
- Modeling doesn't represent any effects of exchange of genetics – qualify this in this
- Discuss uncertainty in known and modelled movement exchange behaviour
- Exchange is being explored in monitoring

Allowable harm

- Text to recommend no allowable harm for Nechako, already below target and not necessary to model changes in HM from current

- Some allowable harm for science/ broodstock (current conditions?)
    - Refer to text (Wood et al.) for Upper Fraser recommendation
    - Show results for Mid Fraser and Upper Fraser (if possible)
        - Consider multiple HM values ranging from HM 1x,1.5x,2x,3x, or some other upper number but with Habt = 1.0
        - Show 500 iteration pathways for a longer timeframe (500 yrs), can be placed in appendix
- Show results as a cumulative/exceedance plot

Additional identified/ suggested revisions

- Figures with axis variables not shown (Hab and HM axes needed),
- Consistent use of recovery “target”, in the context of trajectories etc
- Additional explanation of modeling and role and interpretation of Hab and HM in text.
- Information on important habitat: wording and figures need distinguish between legally defined critical habitat and sites identified as important habitat based on known or suspected importance.
- Wording related to threats should qualify that although hatchery enhancement activities are assigned a moderate risk, adaptive management is in place to minimize related threats
- A suggestion was made to have text in RPA state that by addressing threats affecting the sturgeon populations, most associated species (prey base etc) would also benefit.
- Section 5 (mitigation) revisions identified related to improving descriptions of: habitat restoration and enhancement activities; degree of functional habitat in each population; limitations from habitat and prey availability, and wording related to socioeconomics.