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Proceedings of the Pacific regional peer review of Candidate Limit Reference Points for Pacific Herring in British Columbia using a Closed-loop Simulation Modelling Approach

May 27-28, 2015
Nanaimo, BC

Chairperson: Nicholas Duprey
Editor: Lesley MacDougall

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Science Branch
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Foreword

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

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SUMMARY

These Proceedings summarize relevant discussions and key conclusions that resulted from the Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) meeting of May 27-28, 2015, held in Nanaimo, British Columbia to review the working paper titled, "*Candidate Limit Reference Points for Pacific Herring in British Columbia using a Closed-loop Simulation Modelling Approach*".

In-person and web-based participants included current and retired Fisheries and Oceans Canada (DFO) Science and Fisheries Management staff, First Nations representatives, representatives from the Province of British Columbia, Alaska Department of Fish and Game, members of commercial and recreational fishing sectors, environmental non-government organizations, and academia.

The working paper presented the results of a closed – loop simulation modelling approach to evaluate the performance of a select group of management procedures relative to candidate limit reference points (LRPs). The current British Columbia (BC) Pacific Herring harvest strategy does not include a clear set of biological LRPs that reflect the conservation requirements as described in the "Fishery Decision Making Framework Incorporating the Precautionary Approach"; part of DFO's Sustainable Fisheries Framework. This closed – loop simulation model, and the selected management procedures, were presented as a proof of concept for the intended purpose of identifying and evaluating LRPs and informing the renewal of the management framework for BC Pacific Herring in accordance with Canada's Sustainable Fisheries Framework. Additional meeting objectives were to: describe operating model scenarios for each of the five major BC Pacific Herring stocks; assess the suitability of the modelling approach for simulating environmental forcing factors and exploring the performance of existing and alternative management procedures at avoiding candidate LRPs; and discuss considerations for the selection of biologically – based LRPs including providing advice on subsequent science initiatives required to advance renewal of the management framework for BC Pacific Herring. Note that advice was not expected, nor provided regarding the selection of one specific management procedure or LRP.

The conclusions and advice resulting from this RPR process will be provided in the form of a Science Advisory Report, and will be used to inform the ongoing renewal of the management framework (development of objectives, data collection, harvest control rules) for BC Pacific Herring. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) Website.

Compte rendu de l'examen par les pairs régional du Pacifique sur les Points de références limite possibles pour hareng du Pacifique en Colombie-Britannique en suivant l'approche du modèle de simulation en boucle fermée

SOMMAIRE

Les présents comptes rendus fournissent un sommaire des délibérations et des constatations issues de la réunion régionale d'examen par les pairs du Secrétariat canadien de consultation scientifique (SCCS), qui a eu lieu les 27 et 28 mai à Nanaimo, en Colombie-Britannique, afin d'évaluer le document de travail intitulé « Candidate Limit Reference Points for Pacific Herring in British Columbia using a Closed-loop Simulation Modelling Approach ».

Les participants en personne et en ligne comprenaient des employés actuels et retraités des secteurs des Sciences et de la Gestion des pêches de Pêches et Océans Canada (MPO), des représentants des Premières Nations, de la province de la Colombie-Britannique et du Alaska Department of Fish and Game, de même que des membres des secteurs de la pêche récréative et commerciale, d'organisations non gouvernementales de l'environnement et du milieu universitaire.

Ce document de travail présentait les résultats obtenus au moyen d'une méthode de modélisation fondée sur une simulation en boucle fermée, utilisée pour évaluer le rendement d'un groupe précis de procédures de gestion relativement aux points de référence limites éventuels. La stratégie de pêche du hareng du Pacifique actuellement en vigueur en Colombie-Britannique ne comprend pas de points de référence limites biologiques clairement indiqués qui tiennent compte des exigences en matière de conservation, conformément au Cadre décisionnel pour les pêches en conformité avec l'approche de précaution, qui fait partie du Cadre pour la pêche durable du MPO. Cette modélisation fondée sur une simulation en boucle fermée ainsi que les procédures de gestion retenues ont servi d'éléments de preuve valideurs pour identifier et évaluer les points de référence limites, et pour éclairer le renouvellement du cadre de gestion du hareng du Pacifique en Colombie-Britannique conformément au Cadre pour la pêche durable du Canada. La réunion visait également les objectifs suivants : décrire des scénarios opérationnels de modélisation pour chacun des cinq principaux stocks de hareng du Pacifique en Colombie-Britannique; évaluer la pertinence de l'approche de modélisation pour simuler les facteurs contributifs environnementaux et examiner le rendement des procédures de gestion existantes ou de rechange en ce qui concerne l'évitement des points de référence limites éventuels; et discuter des facteurs à prendre en considération lors de la sélection de points de référence limites biologiques, notamment la formulation de recommandations sur les initiatives scientifiques qui seront requises pour faire évoluer le renouvellement du cadre de gestion du hareng du Pacifique en Colombie-Britannique. Veuillez noter qu'aucune recommandation n'était attendue, et qu'aucune recommandation n'a été fournie sur la sélection d'une procédure de gestion ou d'un point de référence limite en particulier.

Les conclusions et l'avis découlant de ce processus régional d'examen par les pairs seront présentés sous la forme d'un avis scientifique, et serviront à guider le renouvellement du cadre de gestion (établissement d'objectifs, collecte de données, règles de contrôle des prises) du hareng du Pacifique en Colombie-Britannique. L'avis scientifique et le document de recherche à l'appui seront rendus publics sur le site Web du Secrétariat canadien de consultation scientifique.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on May 27-28, 2015 at the Coast Bastion Hotel in Nanaimo to review a closed-loop simulation model used to evaluate the performance of a select number of management procedures (the combination of data, frequency of data collection, and harvest control rule) against candidate limit reference points for British Columbia (BC) Pacific Herring.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Fisheries Management. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from DFO, First Nations, commercial and recreational fishing sectors, environmental non-governmental organizations and academia.

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

> Benson, A., Cox, S., Cleary, J., and Taylor, N. Candidate Limit Reference Points for Pacific Herring in British Columbia using a Closed-loop Simulation Modelling Approach. CSAP Working Paper 2013PEL01

The meeting Chair, Nicholas Duprey, welcomed participants, reviewed the role of CSAS in the provision of peer-reviewed advice, and gave a general overview of the CSAS process. The Chair discussed the role of participants, the purpose of the various RPR publications (Science Advisory Report, Proceedings and Research Document), and the definition and process around achieving consensus decisions and advice. Everyone was invited to participate fully in the discussion and to contribute knowledge to the process, with the goal of delivering scientifically defensible conclusions and advice. It was confirmed with participants that all had received copies of the Terms of Reference and working paper prior to the meeting.

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

Members were reminded that everyone at the meeting had equal standing as participants and they were expected to contribute to the review process if they had information or questions relevant to the paper being discussed. In total, 31 people participated in person the RPR and 10 participated via webinar (Appendix D). Lesley MacDougall was identified as the Rapporteur at the meeting.

Participants were informed that Dr. Trevor Branch and Dr. Sherri Dressel had been asked before the meeting to provide detailed written reviews for the working paper to provide a starting point for discussions at the peer-review meeting. Participants were provided with copies of the written reviews in advance of the meeting (Appendix E).

The conclusions and advice resulting from this review will be used to inform the renewal of the management framework for BC Pacific Herring in accordance with Canada’s Sustainable Fisheries Framework. The Science Advisory Report and supporting Research Document will be made publicly available on the CSAS website.

PRESENTATION OF WORKING PAPER

Working Paper: Candidate Limit Reference Points for Pacific Herring in British Columbia using a Closed-loop Simulation Modelling Approach. CSAP Working Paper 2013PEL001

Rapporteur: Lesley A. MacDougall

Presenters: Ms. Jaclyn Cleary, Dr. Sean P. Cox, and Dr. Ashleen Benson

Ms. Cleary presented the background for a herring management renewal approach. It was identified that it is potentially a three year process to gather information and combine with data already available, modify the operating model to evaluate objectives, and explore the performance of different operating models. The renewal process will be a joint DFO Science-Management collaboration, in consultation with First Nations, user groups, and others, to develop conservation objectives, economic objectives, and stock biomass reference points.

Dr. Cox presented the working paper. A structured approach was needed to develop objectives, define working hypotheses, and evaluate consequences. To be complete, the process will require more than DFO Science input – the stock assessment model is only one of the important elements. The Management Strategy Evaluation approach (MSE) is being proposed as an alternative to the current stock assessment approach in the management of BC Pacific Herring. The work presented here is one of the first steps towards a MSE approach. This working paper uses a simulation approach, which is being reviewed here, to evaluate alternative hypotheses in the future without requiring the review of the simulation tool each time.

MSE is a structured approach to designing a fishery management system that is likely to meet stakeholder and manager objectives. It involves the following steps:

- Identify objectives
- Define alternative Management Procedures (MP). Simulated MPs consist of:
    - Data (time series of total catch, exploitable biomass indices, proportions-at-age)
    - Stock Assessment Model (historical biomass estimates, recruitment, natural mortality, selectivity, stock-recruit parameters, and operational control points derived from these parameters)
    - Harvest Control Rules (for computing a catch limit based on stock assessment)
- Choose an operating model – this is where the simulation exercise fits in
- Define working hypotheses for population dynamics
- Explore implications and tradeoffs of alternative target and limit objectives

This analysis explored best practices for limit reference points (LRPs) in fisheries – based on a literature review of LRPs used for other pelagic fisheries around the world, and introduced a simulation approach to explore the sensitivity of different management procedures to candidate quantitative LRPs.

Simulated management procedures (MPs) consist of three components: (1) a fishery data set involving time-series ($t = 1, 2, \ldots, T$) of total catch, a time-series of exploitable biomass indices, and proportions-at-age in the fishery catch and survey; (2) a stock assessment model that estimates historical biomass, recruitment, natural mortality, selectivity, and stock-recruitment parameters up to time step t (AM.1) as well as operational control points derived from these parameters as required by harvest control rules (Cox et al. 2013); and (3) a harvest control rule for computing a catch limit based on stock assessment results.

The authors used four generalized operating model scenarios to represent uncertain future dynamics in Pacific Herring natural mortality and growth rates. The limited suite of scenarios was not intended to be exhaustive, but instead to demonstrate challenges in developing management procedures in the presence of non-stationary population dynamics and in judging performance with respect to LRPs. The scenarios represent combinations of future (1) natural mortality (M): Constant M = constant average at 2013 values or Increasing M = a 1.5-fold increase in average natural mortality over the projection period and (2) growth rate: Constant Growth = constant average at 2013 values or Historical Growth = a trend toward historical growth rates given by the average over the first five years of observations (i.e., 1951-1955). Each of the management procedures was simulated for four scenarios: Natural mortality (M) remains constant; M increases; Growth (G) remains constant at 2006 levels; G returns to historic levels. All four scenarios were simulated for all four management procedures, in each of the five major BC Pacific Herring Management Areas (Prince Rupert District [PRD], West Coast Vancouver Island [WCVI], Strait of Georgia [SOG], Haida Gwaii [HG] and Central Coast [CC]).

The expansion factor q was set to q=1, rather than using a model-generated estimate of q. This decision was made by the authors to allow for the review and evaluation of the results without the added confounding uncertainty attributed to estimating q.

Results from the simulation exercise confirmed that LRP's are useful to determine the conservation performance of management procedures. Results also indicated that sensitivity to LRP's varies among herring stocks, primarily due to differences in current M relative to historical equilibrium values of M.

PRESENTATION OF WRITTEN REVIEWS

Dr. Sherri Dressel, Alaska Department of Fish and Game, and Dr. Trevor Branch, Washington Department of Fish and Game, provided written reviews of the working paper (Appendix E). Both reviewers noted that the paper was well written and well organized, allowing for clear navigation through the material.

SIMULATION METHOD

Both reviewers noted that the Working Paper effectively described the candidate biologically based LRPs, data and assessment methods, operating model scenarios, and evaluation of the performance of existing and candidate LRPs. Thus, the simulation framework and its associated evaluation were well thought out, appropriate, and clearly described.

LIMIT-REFERENCE POINTS

There were suggestions from both authors to improve the treatment of candidate LRPs, including listing the candidate LRPs in the Methods section to provide clarity, and providing more detail to support the conclusion that LRPs that track the dynamics of natural mortality and growth (NSB_0), reference the lowest level of biomass from which the stock has recovered (Historical B), or reference equilibrium-based F_{MSY} are not worth pursuing in the future. There was also a suggestion to explore alternate LRPs based on no-fishing scenarios.

There was some concern regarding the high estimates for fishing mortality calculated in this study, compared with approximate exploitation rates cited in Schweigert et al. (2007) and Zheng et al. (1993).

HARVEST CONTROL RULES

In addition to the model-based harvest control rules explored in this simulation method, empirical harvest control rules could also be tested. For example, time-varying directional trends in mean growth and natural mortality affect harvest control rule performance and the estimation and avoidance of limit reference points. The consequences of these time-varying directional trends (non-stationarity) in fish stock productivity on performance of management procedures for single species fisheries management have presently not been explored in detail in either the scientific literature or for Pacific Herring fishery management. Exploring alternative scenarios for future changes is intended to improve the understanding of the harvest control rule performance against conservation objectives as defined by limit reference points (LRPs). Emphasis was placed on exercising caution when interpreting the results from the working paper.

GENERAL DISCUSSION

The general discussion of the WP focused on a few key themes which will be summarized below. These included parameters of the model, differences in fishery impacts, additional sensitivity analysis, uncertainties, and advice. There was also lengthy discussion regarding how this work fits in to the larger efforts required to achieve management renewal for BC Pacific Herring. It was recognized that the simulation tool had been applied narrowly, reflecting an estimation of the current management procedures as well as an alternate, for illustrative purposes only. It was widely stressed that the renewal of BC Pacific Herring management would require a much broader scope; further research, collaboration and consultation would be necessary to ensure the appropriate objectives are identified and the appropriate information, including traditional knowledge, is collected and included in future assessment frameworks.

MODEL PARAMETERS AND ASSUMPTIONS

Differences in Fishery Impacts

Catch was a parameter used in the model, and catch is treated as an instantaneous removal. In the case of Pacific Herring fisheries, there are two main types; a Roe fishery and Spawn-On-Kelp fishery. The Spawn-On-Kelp fishery harvests eggs and the Roe fishery harvests fish, resulting in potentially different impacts to Pacific Herring stock biomass and productivity, as well as the potential for one fishery to have impacts on the other. One study was identified that indicates harvest of eggs will have different implications for LRP's than harvest of adults (Shelton et al. 2014). Additionally, the BC Pacific Herring fishery has a sequential catch history, not an instantaneous one. It was recommended that the Working Paper identify that the framework allows for separate treatment of separate fleets, and sequential fisheries, with the understanding that the way the fisheries is managed is a management issue.

Setting q=1

The current assessment model used in previous years for Pacific Herring does not have q fixed as equal to 1. The authors noted that the purpose for setting the expansion factor, or catchability quotient, q equal to 1 in the simulation model was to reduce the noise to the outputs. Setting q as a constant allows the simulation model to run without crashing, and results in a better illustration of the potential consequences of management procedures, which was the focus for this work. There was recognition that setting q as a constant within the simulation tool when it is not constant in the formal assessments introduces an uncertainty in the simulation that should be considered if it's used to estimate how well the HCR is performing. Reviewers wanted further elaboration, within the paper's discussion section, regarding what effects fixing q may have on how well the model simulates the current decision making environment. On Day 2, Dr. Cox provided an update with simulation runs where q=1 and where q is treated as per the assessment framework; in general, the results indicated that assuming q prior =1 maintains a lower probability of the biomass falling below LRP at the expense of some catch. It was suggested that expanded discussion regarding the uncertainties associated with the use of a fixed q would be useful in the Working Paper. Authors agreed that they could describe this in the Working Paper as an illustration of how the model can help to answer questions regarding trade-offs for a particular question NOT as a recommendation of specific values for q. The use of priors increases the probability that biomass will fall below LRP. The SAR should note that there is evidence that the assumptions of q may have implications on the estimates. There is value of understanding the weight of belief in what q is to the outcomes of the simulation.

Suggested future work included estimating q in future simulation structures, with the suggestion that the effect of using a prior may not have the same effect in each of the populations around the coast.

SPATIAL RESOLUTION, SPATIAL STRUCTURE OF POPULATIONS

There was some discussion identifying that the current operating model and stock assessment model do not take into account finer spatial structure information, such as the potential for genetically distinct populations that are currently lumped into B_0. This could have the result of possibly overestimating B_0 and over harvesting small local populations. It was suggested that other empirical rules than the one illustrated in the Working Paper, namely the lowest stock biomass from which the stock had recovered, may be more useful for finer scale management. Authors agreed to include a Central Coast example harvest control rule to input into the simulation model as proof of concept that alternate HCRs can be tested, but stressed that their inclusion should not be considered endorsement of any particular rule. It was recommended that the SAR include acknowledgement that this tool is flexible and can be used to explore alternative rules in this way.

FACTORS INFLUENCING NATURAL MORTALITY, M

The authors noted that environmental and/or climate change impacts have not been explicitly identified in the simulation tool, but the natural mortality values are intended to include the environmental/climate change effects. A number of potential environmental forcing factors were identified that may warrant future consideration. Unidirectional climate change is likely occurring, which may have impacts on herring at the southern edge of their range. Additionally, it is possible that that the standing stock was larger due to the environment being more amenable to a larger stock in the past. Setting reference points and goals based on a previous state may also have the result of setting reference points that are no longer attainable given the current state. This may need to be considered regarding discussions of operating models.

Similarly, the potential impacts of increased predation by marine mammals was not described specifically in the simulation, but would be included as part of the natural mortality and the questions regarding what may happen if M increases. There may also be a spatial component to this question, which may link to the discussion above regarding the spatial scale at which the simulation modelling should occur. There has been some recent work on from the Scotian shelf that suggests an increase in predators may result in redistribution of prey fish species over very large scales.

Conversely, it was also noted that the results of the simulation model, in particular the high frequency with which the current operating model and the other selected examples fell below the candidate LRPs may be an artefact of the existing assumptions of M increasing in the model. It was noted that it would be useful to know if a lower M could be used, and if so, what might be the implications of a lower M.

UNCERTAINTIES

Additional uncertainties that were not included in this Working Paper included exploring the impact that long-term declines in body size may be having on the performance of management procedures; rare or extreme events outside of historically observed values; changes in management actions and their impact on results; or the impact of applying management procedures at smaller spatial scales than the current DFO Management Areas. It was observed that the MSE approach has the flexibility to include scenarios to explore and evaluate these uncertainties, and recommendations were made to identify this as potential future work, as described in the Recommendations and Advice section below.

SUMMARY OF REQUIRED REVISIONS

A list of revisions to be undertaken was provided to the authors following the regional peer review meeting. Note these were in addition to items raised by the formal reviewers.

CONCLUSIONS

The Working Paper was accepted with revisions as identified during the meeting. A draft SAR was developed with the input of participants and was circulated to participants for further edits and comments.

There was consensus that the methodology used in the paper was sound. It was determined that the simulation exercise demonstrated the utility of conducting case-specific closed-loop simulations to evaluate harvest management procedures. The analytical framework has flexibility to explore a broad set of management procedures, ecological hypotheses and objectives proposed by First Nations, industry, and other stakeholders.

It was agreed that the suite of operating models examined was not exhaustive with respect to potential future productivity, growth, assessment, fishing, and mortality scenarios. However, they provide a reasonable diversity of scenarios to support the general findings. Based on the limited scope and assumptions used for these simulations, LRP's based on F_{msy}, NSB_0, and those based on lowest biomass from which the stock has recovered appear to be less capable of assessing the relative risks and performance of management procedures compared with LRPs based on fixed (equilibrium) objectives.

The approximation of the current DFO management procedure that was tested and analyzed appears to maintain stocks above the candidate LRPs only over a narrow range of conditions. Increases in natural mortality, similar to those estimated over the past several decades, revealed potential conservation and fishery risks in 4 of 5 stocks areas. Specifically:

- Simulated spawning biomass for Strait of Georgia (SOG) herring was maintained above the $0.25B_0$ LRP 95% of the time under the DFO1 and DFO2 management procedures, which is consistent with the original evaluation performed for the stock in 1988
- The simulations for Prince Rupert District (PRD), the Central Coast (CC) and Haida Gwaii (HG) stocks suggest that both the DFO and the Lenfest management procedures could result in Spawning Stock Biomass (SSB) frequently dropping below the LRPs used in this simulation exercise
- The LRP that was allowed to change with natural mortality and growth rates (NSB_0) often failed to indicate risk in situations where risks could actually be significant. This was also

true for the empirical LRP that reflected the ‘worst-case’ scenario (Historical B), which was lowest historical biomass from which the stock has recovered.

RECOMMENDATIONS AND ADVICE

It was recommended that accurate representations of current management procedures be developed for evaluation with this tool; for example, modelling multiple fleets and/or sequential fisheries, inclusion of trends in size-at-age, and addressing uncertainty in the spawn survey scaling parameter (q).

Additional recommendations included using the MSE approach to explore changes in management actions and potential impacts on results, as well as evaluating the performance of management procedures applied to spatial scales finer than current DFO Management Areas.

ACKNOWLEDGEMENTS

The Chair thanks the authors of the Research Document, Ms. Jaclyn Cleary, Dr. Sean Cox, and Dr. Ashleen Benson, for producing a high quality document in a timely fashion; the reviewers, Dr. Sherri Dressel and Dr. Trevor Branch for their expertise and valuable evaluations; and the meeting participants for thoughtful and constructive input. Lesley MacDougall is also appreciated for her work as rapporteur resulting in these proceedings, and finally Ann Mariscak and the CSAS office for assistance coordinating the meeting and producing final reports.

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APPENDIX A: TERMS OF REFERENCE

Candidate Limit Reference Points for Pacific Herring in British Columbia using a Closed-loop Simulation Modelling Approach

Regional Peer Review Process – Pacific Region

May 27-28, 2015
Nanaimo, British Columbia

Chairperson: Nicholas Duprey

Context

British Columbia's Pacific Herring fisheries are managed based on a harvest strategy initially designed in 1986, and further refined in 1996. The harvest control rule element of the strategy prescribes a target exploitation rate of 20% when herring stock biomass is predicted in the following year to be above an operational cut-off level of 25% of the estimated unfished biomass and an exploitation rate of 0% when the predicted biomass is below the cut-off level. Closed-loop simulation tests indicated that this rule would only cause herring stock biomass to drop below the cut-off level in 5% of years (Hall et al. 1988).

Since adopting the strategy in 1986, two major herring stocks - Strait of Georgia (SOG) and Prince Rupert District (PRD) have remained above the cut-off level. However, the major stocks in West Coast Vancouver Island (WCVI), Central Coast (CC), and Haida Gwaii (HG) have been below cutoff in 32%, 21%, and 46% of years (1986-2013), respectively, which far exceeds expectations indicated by the original simulations. Long term declines in body size (weight at age) have been observed for all BC herring stocks from the early-1980s to 2010, as well as variability in estimated natural mortality rates since 1951 (DFO, 2014). Their relative contributions to stocks falling below cut-offs are currently not well understood.

One of the challenges of establishing harvest control rules and biological limit reference points for herring stocks are time-varying changes in growth and natural mortality, referred to as non-stationarity. Non-stationarity, or time-varying changes in productivity affects harvest control rule performance and the estimation and avoidance of limit references points. For Pacific herring stocks, changes in growth have been observed, and current stock assessments indicate time-varying changes in natural morality. The consequences of non-stationarity in fish stock productivity have not been explored in detail within the scientific literature nor have they been evaluated for Pacific Herring fishery management. Exploring alternative scenarios for future changes could lead to a better understanding of whether harvest control rules and biological reference points need to be adapted to improve the long-term sustainability of herring fisheries.

The existing Pacific Herring harvest strategy lacks a clearly defined set of biological limit reference points (LRPs) that reflect conservation requirements under DFO's Sustainable Fisheries Framework. Biological LRPs are used in harvest strategies as quantitative conservation benchmarks from which the probability that a management procedure (MP) that will lead to unacceptable conservation outcomes for each non-stationary productivity scenario can be computed. LRPs are, therefore, critically important because they ultimately guide the entire harvest management system and the expected conservation, economic, and social outcomes.

In this closed-loop simulation approach to exploring candidate LRPs, the operating model is nested within a simulation framework and is designed to allow testing of proposed management procedures (the combination of data, assessment model, and harvest control rule) against multiple objectives while considering alternative theories of herring stock productivity and dynamics, and the consequences of different assessment methods and data frequency scenarios (annual, biennial surveys). This approach is an extension to models published by Cox and Kronlund (2008), Cleary et al. (2010) and Cox et al. (2013).

This Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) will review the simulation model developed for BC Pacific Herring, and describe the performance of alternative management procedures relative to candidate LRPs. The advice arising from this CSAS RPR will be used to inform the renewal of the management framework for BC Pacific herring in accordance with Canada's Sustainable Fisheries Framework.

Objectives

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

Benson, Cox, Cleary, Taylor. Candidate Limit Reference Points for Pacific Herring in British Columbia using a Closed-loop Simulation Modelling Approach. CSAP Working Paper 2013PEL001

The specific objectives of this review are to:

1. Identify candidate biologically-based limit reference points (LRPs) for Pacific Herring based on literature review of LRPs for pelagic species (if available), along with the data and assessment methods required to assess these for Pacific Herring.
2. Describe operating model scenarios developed for each of the five major herring stocks. Assess suitability of the modelling approach for the development of simulations that incorporate decadal scale environmental forcing (e.g. climate, tropic interactions, predator communities, etc.) through changes in natural mortality and growth, and a clear representation of uncertainty.
3. Using the modelling framework described in #2, explore the performance of existing and alternative management procedures (the combination of data, frequency of data collection, and harvest control rule) at avoiding candidate LRPs. Present outcomes using a set of performance statistics that measure yield, variability in yield, and the probability of avoiding limits for each stock area.
4. Discuss considerations for the selection of biologically-based limit reference points (LRPs) for Pacific Herring stocks and provide advice on subsequent science initiatives required to advance renewal of the management framework for BC Pacific Herring.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Participation

- Fisheries and Oceans Canada (DFO) (Ecosystems and Fisheries Management)
- Academia or Academics
- Aboriginal communities/organizations
- Industry (fishing industry, processors)
- Other invited experts (environmental non-government organizations)

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APPENDIX B: ABSTRACT OF WORKING PAPER

British Columbia's (B.C.) Pacific Herring (*Clupea pallasi*) fisheries are managed using a harvest strategy that was initially designed in 1986. Since adopting the strategy, two of five major herring stocks have remained above the cut-off level each year and continue to support fisheries, while three stocks have at times dropped below cut-off for up to eight consecutive years. Significant increases in estimated natural mortality (M) and decreases in body size have been observed for some stocks over the same period of time. The relative contributions of these factors to stocks falling below cut-offs are currently not well understood.

This paper represents the first step in a management strategy evaluation (MSE) process that develops the analytical framework for future analyses and explores the suitability of candidate conservation objectives (limit reference points) for the 5 Pacific Herring stocks. The key components of the framework are: (1) operating models that reflect a range of potential future changes in growth and natural mortality, (2) management procedures (MP) comprised of data, stock assessment, and harvest control rules (HCR) including the current DFO rule and alternatives recommended for forage fish, and (3) biological limit reference points (LRP) that are used in determining the expected conservation performance of alternative management procedures. The LRP include (i) equilibrium reference points that remain fixed over time (ii) a dynamic reference point that tracks changes in productivity, (iii) a historical reference point that defines LRP in terms of lowest observed biomass, and (iv) DFO policy values of $0.4B_{MSY}$ and F_{MSY}.

This study suggests that future work to identify LRPs for BC herring fisheries should focus on fixed (equilibrium) objectives related to biomass. Fishing mortality-based LRPs were not generally useful for distinguishing between candidate MPs on the basis of conservation performance. Furthermore, our analysis indicates that the current DFO MP performs well only over a narrow range of conditions for particular stocks. Increases in M similar to those estimated over the past several decades revealed relatively poor conservation performance in 4 of 5 stock areas. We therefore recommend exploring alternative MP that can provide good performance across a range of future states of nature.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat

Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Candidate limit reference points for Pacific Herring in British Columbia using a closed-loop simulation modelling approach

May 27-28, 2015

Coast Bastion Hotel
11 Bastion Street, Nanaimo, BC

Chair: Nicholas Duprey

DAY 1 - Wednesday, May 27th 2015

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Authors
1030	***Break***	
1045	Overview Written Review – Sherri Dressel	Chair + Reviewer & Authors
1130	***Lunch Break***	
1230	Overview Written Review – Trevor Branch	Chair + Reviewer & Authors
1315	Identification of Key Issues for Group Discussion	RPR Participants
1330	Discussion & Resolution of Technical Issues	RPR Participants
1400	***Break***	
1420	Discussion & Resolution of Technical Issues (Continued)	RPR Participants
1700	Adjourn for the Day	

DAY 2 - Thursday, May 28th 2015

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1	Chair
0915	Discussion & Resolution of Results & Conclusions	RPR Participants
1000	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1030	***Break***	
1050	Science Advisory Report (SAR) Develop consensus on the following for inclusion: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1200	***Lunch Break***	
1300	Science Advisory Report (SAR) • Continued	RPR Participants
1500	***Break***	
1520	Science Advisory Report (SAR) • Continued	RPR Participants
1630	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments	Chair
1645	Other Business arising from the review	Chair & Participants
1700	***Adjourn meeting***	

APPENDIX D: PARTICIPANTS

Last Name	First Name	Affiliation
Ashcroft	Chuck	Sport Fishing Advisory Board
Benson	Ashleen	Landmark Fisheries Consultant
Branch	Trevor	University of Washington
Brown	Laura	DFO Science
Brown	Gus	Gladstone Reconciliation Team (HTC)
Chalmers	Dennis	Province of BC
Cleary	Jaclyn	DFO Science
Cox	Sean	SFU
Dorner	Brigitte	Hakaii Network
Dressel	Sharon	Alaska Department of Fish and Game
Duprey	Nicholas	DFO Science / Chair
Frid	Alejandro	Central Coast Indigenous Resource Alliance
Fu	Caihong	DFO Science
Gladstone	Keith	Gladstone Reconciliation Team (HTC)
Goruk	Andrea	DFO Fisheries Management
Hall	Peter	DFO Fisheries Management
Hall	Don	Nuu-chah-nulth Tribal Council
Hay	Doug	DFO Scientist Emeritus
Holmes	John	DFO Science
Humchitt	Carrie	Gladstone Reconciliation Team
Jackson	Corey	DFO Fisheries Management
Jones	Russ	Council of Haida Nation - Haida Fisheries Program
Kanno	Roger	DFO Fisheries Management
Kulchyski	Tim	Cowichan Tribes
Laliberte	Bernette	IMAWG
MacDougall	Lesley	DFO Science
Moody	Reg	Heiltsuk First Nation
Newman	Earl	Heiltsuk First Nation
Okamoto	Dan	SFU
Olson	Andy	Tseshaht First Nation
Ormond	Chad	Q'ul-lhanumutsun Aquatic Resources Society
Rusch	Bryan	DFO Fisheries Management
Rusel	Christa	Atlegay Fisheries Society
Schweigert	Jake	DFO Scientist Emeritus
Spence	Brenda	DFO Fisheries Management
Starr	Paul	Herring Conservation and Research Society (HCRS)
Surma	Szymon	UBC
Tanasichuk	Ron	Heiltsuk Tribal Council Representative
Taylor	Nathan	DFO Science
Thomas	Greg	HCRS & Chair of the Herring Industry Advisory Bd
White	Penny	Central Coast Indigenous Resource Alliance

APPENDIX E: WORKING PAPER REVIEWS

Date: 5/25/15

Reviewer: Sherri Dressel, Alaska Department of Fish and Game

CSAS Working Paper: 2013PEL01

Working Paper Title: Candidate Limit Reference Points as a Basis for Choosing among Alternative Harvest Control Rules for Pacific Herring (*Clupea pallasi*) in British Columbia

Candidate Limit Reference Points as a Basis for Choosing among Alternative Harvest Control Rules for Pacific Herring (Clupea pallasi) in British Columbia is an extremely well written paper. The issues addressed in the paper are extremely pertinent and imminently important. The background is explained and the notation is well delineated. The authors do a particularly nice job of describing the assumptions and limitations of the models and lining out the implications of these assumptions. They make a strong use of examples to help explain concepts or clarify sentences that are particularly difficult to conceptualize. The paragraph and sentence structure make the writing flow and made the paper a joy to read.

The paper effectively described candidate biologically-based limit reference points based on literature review of LRPs and described the data and assessment methods required to estimate these for Pacific herring. The methods are well explained, particularly for such a difficult topic. At the end of the review I will suggest a few areas where additional explanation would be helpful. Compared to the other sections, the results section was difficult to follow. This is due, in part, to the immense amount of information that needed to be conveyed. Combining the stocks into three general types based on the natural mortality trend was very helpful in this regard. Another thing that would help would be to include an orienting paragraph at the beginning of the results to tell the reader how the results section will flow, what scenarios will be described in detail and why, and whether conclusions from these scenarios can be applied to scenarios discussed in less detail.

The paper described the operating model scenarios for each of the five major herring stocks. Authors presented a modelling approach for looking at potential results of increases in growth to historical levels and continued increases in natural mortality beyond what existed historically. They clearly explained that these were not a comprehensive set of possible future conditions. It seemed a bit incomplete, however, to choose scenarios where growth and mortality extended beyond the historical range in one direction and not the other (i.e. scenarios were not shown where growth continued to decrease beyond the level seen in 2013 or where natural mortality decreased beyond that which existed early in the time series). While developing more scenarios than those that were presented in the current paper would likely make the paper unwieldy, a discussion of whether the results from these additional scenarios might change the final paper recommendations would be particularly valuable.

When discussing operating model scenarios, the paper does not specifically mention or address decadal scale environmental forcing, as suggested in the Terms of Reference. The scenarios examined, however, clearly showed population changes that might occur in response environmental changes. While the trends in natural mortality and growth mentioned by the authors appear to be more linear than oscillating decadally, the scenarios chosen are likely helpful for finding management procedures that will be effective in both cases. It would be helpful if the authors might discuss, to the extent practicable, how oscillating changes in growth and natural mortality would affect populations similarly or dissimilarly. If conclusions cannot be made, recommendations for further study would be helpful.

Authors explored the performance of existing and alternative management procedures at avoiding candidate LRPs and present outcomes using a set of performance statistics that measure yield, variability in yield, and the probability of avoiding limits for each stock area. The authors provided helpful insight in the discussion regarding the reasons why situations in which stocks did not fall below certain LRPs did not necessarily indicate healthy stocks or helpful LRPs (e.g. lowest historical biomass LRP). Introducing this concept in the methods by describing how to interpret the probability of avoiding limits as a measure of performance would be helpful.

The authors discussed considerations for the selection of LRPs and provided advice on subsequent science initiatives that should be addressed next with the goal of advancing the renewal of the management framework for BC herring. One conclusion of the paper is that LRPs that track the dynamics of natural mortality and growth (NSB0), reference the lowest level of biomass from which the stock has recovered (Historical B), or reference equilibrium-based F_{MSY} are not worth pursuing in the future. Additional discussion, description, and justification would have been helpful for me as a reader. Graphs might also help to provide an image for why Historical B or NSB0 will not be useful.

The authors described the uncertainty in the data, analysis and process well. I particularly appreciated the cases where the authors described uncertainty that was not incorporated into the simulations and where authors were able to discern how that would affect the results.

The authors recommend using DFO rather than Lenfest rules because the Lenfest harvest rate is too high and because Lenfest rules are based on F_{MSY}, which is difficult to estimate. The authors make a strong case why basing rules on F_{MSY} is a drawback (considerable error in estimation), but it may also be worth mentioning whether there are benefits to basing a rule on F_{MSY} and then explain why the drawbacks outweigh the benefits. Also, if the harvest rate resulting from Lenfest rules was lower (say, 0.25 F_{MSY}), would DFO rules still be recommended as more beneficial because of the error in estimating F_{MSY}? In other words, is it possible to distinguish between poor performance because of the high harvest rate and poor performance because the uncertainty in estimation of the harvest rate was high?

The fishing mortality rates calculated in the study seem surprisingly high. I did a rough comparison of approximate exploitation rates in this study with those cited in Schweigert et al. (2007) and Zheng et al. 1993). For instance, the exploitation rate at MSY for five BC stocks ranged from 0.24 to 0.36 (Schweigert et al. 2007), for Prince William Sound ranged from 0.34 to 0.42 (Zheng et al. 1993), and for Eastern Bering Sea was 0.36, which roughly suggests that harvest rates under Lenfest rules of 0.5 F_{MSY} might be approximately 10-20%. However, exploitation rates in this study under Lenfest rules might be approximately 1.5 to 2 times that of the DFO rules (according to Figure 2 for CAA, DFO fishery mortality at 20% exploitation rate is F=0.225 and Lenfest fishery mortality (0.5 F_{MSY}) ranges from approximately F=0.3 to F=0.45, suggesting that the exploitation rate at MSY in this study might be approximately 30-40%. A discussion of why the exploitation rate at MSY would be approximately twice that of these other studies, and whether that might result from assumptions in the models, would be helpful.

The Lenfest study suggests that fishing mortality should not exceed F=0.5 F_{MSY} or F=0.5M. In this study 0.5 F_{MSY} and 0.5M are considerably different. It may be worthwhile to include this in the consideration of the Lenfest rules (inclusion in the discussion).

Schweigert and Ware (1995) suggest that serial correlations in the recruitment process need to be incorporated into simulations models that are used to evaluate harvest rate policies rather than simply random variation, since serial correlations can make a population less resilient to exploitation. It would be helpful if the authors touched on this in the discussion and suggest what impact serial correlations might have on the results of this paper, recommend or not recommend it as an important avenue for further research, and explain why it is or is not necessary to examine before implementing an alternative management policy.

Suggestion of topics for additional explanation or clarity:

- When listing the candidate limit reference points (LRPs) in the first full paragraph on page 3, making the link (maybe putting in parentheses) to exact scenarios that are compared in tables (e.g. Tables 7-11) and figures would help orient the reader.
- Additional explanation regarding what equilibrium values were (I see in the Table 2 legend that they were computed using M1951 and His G, but it would be helpful to include this in the text if it isn't), how they were selected (why were M1951 and His G selected and what difference would it have made if values at other time periods were chosen?), and how they were rescaled to non-equilibrium values from the 2013 stock assessment (the rescaling was mentioned but difficult to understand exactly what it meant or how it was done).
- Similarly, how were age-compositions estimated at equilibrium values and then how were they modified/scaled?
- The information provided on the different construction of the assessment and operating models were extremely helpful (referring to the three main differences that were listed on page 6). Why were these differences implemented and what, if any, impact do you expect these differences had on the results?
- The information on informative priors and the effect on the variability of MSY and F_{MSY} were valuable. How did you select the informative prior on initial M and is there any way to say approximately how influential do you think it was on the results (how optimistic)?

Literature Cited

Schweigert, J. F., C. Fu, C.C. Wood, and T.W. Therriault. 2007. A risk assessment framework for Pacific herring stocks in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/047. 78 p.

Schweigert, J. and D. Ware. 1995. Review of the biological basis for B.C. herring stock harvest rates and conservation levels. Department of Fisheries and Oceans, revised PSARC H95:2.

Zheng, J., F. C. Funk, G. H. Kruse, and R. Fagen. 1993. Threshold management strategies for Pacific herring in Alaska. Pages 141-165 in G. H. Kruse, D. M. Eggers, R. J. Marasco, C. Pautzke, and T. J. Quinn, II, editors. Proceedings of the international symposium on management strategies for explored fish populations. University of Alaska Sea Grant College Program Report

Date: 25 May 2015

Reviewer: Trevor A. Branch, School of Aquatic and Fishery Sciences, University of Washington

CSAS Working Paper: 2013PEL01

Working Paper Title: Candidate limit reference points as a basis for choosing among alternative harvest control rules for Pacific herring (*Clupea pallasi*) in British Columbia

Overall comments

The working paper examines the performance of four harvest controls rules (DFO1, DFO2, Lenfest1, Lenfest2) when applied to five herring populations. Performance is assessed against a variety of limit reference points (LRPs) to help make informed choices as to which LRP should be adopted. The closed loop simulation approach is the right way to do this, and the methods seem sound, and well thought through. My comments below mainly are my attempt to think outside the box to a limited amount, and are based on past experience with management strategy evaluations, plus a re-read of Punt et al. (2015).

The most interesting results are that even if maximum fishing rates are half of F_{MSY}, some herring populations will still decline to well below any of the LRPs considered. To some extent this is a function of the very high values estimated for F_{MSY}. In addition, herring are well known to exhibit fluctuations in abundance that may last for several to many years, which will lead to populations falling below any LRP and remaining at low levels regardless of the operating model or reference fishing mortality used.

Given this, it seems unlikely that any harvest control rule would be able to avoid biomass falling below an LRP more than 5% of the time, which is the stated goal. Instead, consideration should be given to an LRP that is based on probabilities if there was no fishing at all. For example in Table 7, column $0.4B_0$, increasingM-Historical Growth, the DFO1 harvest control rule has a 15% greater probability of falling below $0.4B_0$ than the NoFish policy (0.24 vs. 0.09). The LRP could be “no rule should result in the population falling below $0.4B_0$ more than 5/10/20 percentage points often than the no-fishing rule”. In de Moor et al. (2011), for instance, the performance statistic is defined based on risk with the control rule compared to risk under zero fishing.

A major type of harvest control rule not explored by the model is an empirical control rule: treat the survey as an absolute index, and allow fishing only when this is above a certain value, at 25% of the survey index. This avoids the cases where the assessment model gets the biomass estimate wrong. Both the DFO1 and Lenfest rules could easily be adapted to be empirical rules. This is worth serious consideration as an alternative to the current model-based rule (where an assessment model is fit to all the data and catch is a function of model-estimated parameters).

Major points

1. In Figures 3-8 only one realization of the full set is plotted. It would be helpful to have 3-5 realizations plotted for the future so that the behavior of operating models can be compared for a range of outcomes.

2. In the operating model, abundance estimates are assumed to be unbiased and absolute estimates. Experience suggests, however, that abundance estimates are more often from the tails of the distribution than expected (“black swan” events). Some consideration might be given to a sensitivity test where the abundance estimates periodically are drawn from the tails of the distribution.

3. There is little discussion in the manuscript about the differences between DFO1 and DFO2 in terms of setting harvest levels. In practice they perform nearly identically but the latter

costs are halved since surveys are conducted only every second year. This suggests serious consideration be given to only conducting surveys every second year, to reduce management costs.

4. The simulation study seems set up to explore a variety of “floor-rate” harvest control rules, where floor is the biomass below which there is no fishing, and rate is fishing mortality above the floor. It would be very interesting in future work to see the trade-offs between stock status and mean catch for a variety of alternatives for floor and rate.
5. In Figure 9 and Figure A3, Lenfest1 is clearly better than DFO1 when the probability of falling below the LRP is high. Some examination of the conditions under which this is true would be useful to include in the manuscript.
6. A summary figure is needed that compares the harvest control rules for all aspects of their behavior: mean biomass (or risk of being below LRP), mean catch, average annual variation in catch (AAV), and net present value of the future catch. It is hard at present to judge the trade-off between these different objectives, under each control rule.
7. There are currently no limits on the allowed annual percent increase in catch, or percent decrease in catch. Most management procedures have these built in to reduce AAV. Additionally, if the control rule sets catch to within say 10% of last year’s catch, many control rules just set the new allowable catch equal to that in the previous year. Again, this reduces AAV and assists in having a more orderly industry.
8. The review of management strategy evaluations (Punt et al. 2015) has many useful suggestions. Among them: deciding on a set of sensitivity tests to ensure that the rule works under different scenarios, and a set of less plausible robustness tests; setting up “exceptional circumstances” under which managers would be able to avoid following the harvest control rule; having participants in the fishery proposal alternative control rules that might perform better; producing trade-off plots to see how much more catch you would get with greater risk to the biomass; and showing a series of future catch trajectories so that participants better understand what catch variability looks like under each rule.

Minor points

1. A distinction is drawn between operational control points (OCPs) and biological reference limit points (LRPs) in the first paragraph of section 1.1. It is unclear whether any of the paper deals with OCPs though, and they are not mentioned again.
2. Section 1.1 “and B_{MSY} (approximately 0.35 B_0)” needs a little more justification. Is this B_{MSY} for herring populations only? A recent paper (Thorson et al. 2012) concludes that B_{MSY} for spawning biomass is on average at 0.40 B_0 for a large number of stock assessments, for example.
3. The definition of steepness is attributed to Mangel et al. (2010). The reference is missing from the reference list, and in any case this formulation long pre-dates 2010 and is normally attributed to Mace and Doonan (1988).
4. The Walford parameters alpha and rho are missing from the list of model parameters.
5. Lines 7-10 of 2.2.2. says the assessment model uses all available information, and then says that it only fits to fishery age composition data. Which of these two is true.
6. In 2.2.2. end first para, the wording makes it sound as if the Lenfest HCRs are deliberately disadvantaged.
7. In places in the document, the cumulative burden of acronyms makes it very difficult to understand the text, e.g. the top paragraph on page 11 has 23 acronyms and 16 model

parameters. Writing out the place names, management procedure, etc. would make the text more readable.

8. The text needs a definition of “depletion” D, e.g. in Table 8. Is this spawning biomass relative to B_{MSY}, total biomass relative to unfished biomass? I personally don’t like this use since this statement “depletion is 10%” is ambiguous: it is 10% less than B_0 or at 10% of B_0?

References

de Moor, C. L., D. S. Butterworth, and J. A. A. De Oliveira. 2011. Is the management procedure approach equipped to handle short-lived pelagic species with their boom and bust dynamics? The case of the South African fishery for sardine and anchovy. ICES Journal of Marine Science 68:2075-2085.

Mace, P. M. and I. J. Doonan. 1988. A generalised bioeconomic simulation model for fish population dynamics. New Zealand Fisheries Assessment Research Document 88/4. Fisheries Research Centre, MAFFish, POB 297, Wellington, NZ.

Punt, A. E., D. S. Butterworth, C. L. de Moor, J. A. A. De Oliveira, and M. Haddon. 2015. Management strategy evaluation: best practices. Fish and Fisheries doi:10.1111/faf.12104.

Thorson, J. T., J. M. Cope, T. A. Branch, and O. P. Jensen. 2012. Spawning biomass reference points for exploited marine fishes, incorporating taxonomic and body size information. Canadian Journal of Fisheries and Aquatic Sciences 69:1556-1568.

APPENDIX F: SUGGESTED WORKING PAPER REVISIONS

The participants agreed that the following were the key revisions required in the working paper, as discussed during the peer review:

- Address major points identified in both formal reviews (included in Appendix E)
- Clarification of some terms, model equations in the paper
- Inclusion of estimate q re-runs
- Inclusion regarding using data-based management procedure (as introduced by Dr. Tanasichuk)
- Some discussion about considerations in developing a spatial-structured simulation framework including data gaps, spatial objectives, alternative hypotheses about movement and stock structured dynamics
- Clarification about the specific dynamics of the single fishery used in the simulations
- Some discussion about the reason for the difference in Fmsy estimates between the working paper and those in the literature
- Expanded discussion of non-stationary Bo considerations
- Expanded discussion of how capturing different operating models and operational control roles could be used to deal with multiple fisheries