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Proceedings of the Pacific Regional Peer Review on A Management Procedure Framework for British Columbia Groundfish

June 8-9, 2020
Virtual Meeting

Chairperson: Andrew Edwards
Editor: Linnea Flostrand

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

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Foreword

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

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat Regional Peer Review meeting of June 8-9, 2020 at the Pacific Biological Station, in Nanaimo, British Columbia. A working paper focusing on 'A Management Procedure Framework for British Columbia Groundfish' was presented for peer review.

The meeting was held virtually due to restrictions related to coronavirus disease 2019 (COVID-19). Virtual participation included a total of 54 participants from DFO (Science, Fisheries Management, and Ecosystem Management Branches) and external participants representing the United States National Oceanic and Atmospheric Administration, First Nations, Washington Department of Fish and Wildlife, the commercial and recreational fishing sectors, academia, non-government organizations, and consultants.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report providing advice to the DFO Fisheries Management Branch to inform them on harvest strategies for data-limited groundfish stocks.

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

INTRODUCTION

These proceedings summarize the relevant discussions and key conclusions that resulted from the Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting of June 8-9, 2020. Science discussions and advice were based on objectives identified in a Terms of Reference (Appendix A), followed an agenda (Appendix B), and were associated with a working paper (summarized in Appendix C) titled:

Anderson, S.C., Forrest, R.E., Huynh, Q.C. and Keppel, E.A. A Management Procedure Framework for British Columbia Groundfish. CSAP Working Paper 2014GRF07c.

The meeting was originally planned to be at the Pacific Biological Station, Nanaimo, British Columbia (BC) in April 2020 but due to the pandemic of the coronavirus disease 2019 (COVID-19) it was rescheduled for June and held virtually using Zoom video conferencing. In an effort to streamline the meeting and since the working paper (working paper) was prepared for the April review date, it was decided that the review process could benefit from incorporating the written reviews from the two reviewers (Carrie Holt and Meaghan Bryan) in advance, having the authors respond to the written reviews in writing, and then circulating the responses (Appendix D) and the revised working paper to all participants before the rescheduled meeting. Zoom poll results concluded that 90% of participants agreed that this approach benefitted the process.

Virtual participation included a total of 54 individuals from DFO (Science, Fisheries Management, and Ecosystem Management Branches) and external participants representing the United States National Oceanic and Atmospheric Administration (NOAA), First Nations, Washington Department of Fish and Wildlife, the commercial and recreational fishing sectors, academia, non-government organizations and consultants (Appendix E). The Chairperson was Andrew Edwards and the rapporteur was Linnea Flostrand.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) to the DFO Fisheries Management Branch. The SAR and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat website.

PRESENTATION OF WORKING PAPER

Working paper: *A Management Procedure Framework for British Columbia Groundfish. CSAP Working Paper 2014GRF07c*

Presenters: Sean C. Anderson and Robyn E. Forrest

A summary of the methods and findings reported in the working paper was presented by the authors. Presented topics (in brief) are listed below.

Management Procedure (MP) framework (with data limited species):

- Definition and examples of data-limited groundfish species and accounting for uncertainty in stock assessments;
- Fish Stocks provisions in the *Fisheries Act* (section 6.1);
- MP components and applications, description and role of closed loop simulation, and MP best practices steps and importance of engagement;
- Tiered approached to stock assessments based on data availability and richness;
- Roles and components of closed-loop simulation;
- The BC groundfish data synopsis and standardized data (Anderson et al., 2019);
- Overview of the MP framework: 1) defining the decision context, 2) selecting objectives and defining performance metrics (PMs), 3) selecting uncertainties and specifying of operating models (reference and robustness sets), 4) identifying candidate management procedures, 5) simulating the application of MPs, 6) presenting results and selecting MPs;
- Open-source Data Limited Methods Toolkit (DLMtool) R package, which is transparent and reproducible. DLMtool operating model (OM) development and MSEtool (another R package) implementation of stock reduction analysis (SRA) conditioning to observed data. Further R packages were developed/extended for this project (gfdlm, csasdown).

West Coast of Vancouver Island (WCVI) Rex Sole (*Glyptocephalus zachirus*) case study:

- Illustrating application of framework, not intended to provide science advice;
- Datasets representing bottom trawl catch per unit effort (CPUE) time series data from standardized synoptic survey and commercial catch records, and associated biological data (e.g. length and weight);
- Based on decision context of seeking an MP to determine catch limits for an interim period (e.g. until subsequent assessment cycle), with six provisional probability-based performance metrics, and six reference and two robustness OM scenarios for varying uncertainties;
- Estimated depletion and fishing mortality time series trajectories for each OM;
- SRA model fits to the trawl survey and commercial CPUE indexes for each OM;
- Simulated application of the MPs to evaluate performance, based on convergence and probability criteria;
- Average and minimum probability performance of PMs by MP across reference set of OMs;
- Probability results by PM in different types of figures. For the reference-set OMs, results were shown in colour-coded probability tables, demonstrating trade-offs between short-term catch and conservation metrics. Trade-offs between multiple PMs were shown in radar-

plots. For the robustness-set OMs, results were shown in colour-coded tables and performance-tradeoff plots (short term catch versus LRP metrics);

- Biomass, fishing mortality and catch trajectory results for satisficed MPs showed that the robustness OM that did not include the commercial catch CPUE index (and assigned the 1995 initial catch equilibrium level to be 50% of post 1995) to have the most effect on time series results.

Discussion topics on the applications of MP framework efforts:

- Implicit versus explicit reference points. Key differences identified between MP framework and conventional stock assessment are that in the MP framework: (1) reference points and stock status are not explicitly reported, or at least not emphasized; 2) objectives related to the probability of breaching reference points must be agreed on at the beginning of the process;
- Can test alternative assessment intervals and applications of MPs, whether actual performance of an MP departs from predicted behavior under the set of OMs, and to re-evaluate OMs, MPs, or both;
- Can advise on rebuilding plans and recovery potential assessments;
- Can account for uncertainty in changing environmental conditions;
- Can assess the value and effects of different types of information;
- Can evaluate the performance of data moderate and data rich MPs;
- The MP framework advice is limited to the range of uncertainty depicted in OMs and the quality of data used and requires considerable engagement, starting at early stages (i.e. with fishery managers, First nations, stakeholders and other groups).

There were no points of clarification from participants to the authors during the presentation.

PRESENTATION OF REVIEWS

Drs. Meaghan Bryan (NOAA) and Carrie Holt (DFO) provided written reviews of the working paper in advance of the meeting (Appendix D). Both reviewers commended the authors on a thorough, organized and well written working paper. It was also acknowledged that the authors had addressed most of the reviewers' written points in the authors' response to reviews (Appendix D), and in the revised working paper that was circulated to all participants prior to the meeting. Below is a brief summary of the topics brought up by reviewers during their presentations on the first day of the meeting.

MEAGHAN BRYAN

The reviewer noted that her comments were all adequately addressed in the authors' responses but she reiterated some comments for discussion purposes only.

As per comment 9 of the written review, the reviewer emphasized that for cases when stock status is already perceived to be below a healthy level, such as when developing rebuilding plans, it would be beneficial to evaluate short term performance of candidate MPs. Or model short-term MPs and the possible phasing-in of alternate MPs if conservation requirements are met. The authors agreed that this is a good idea and an MP framework should be tailored to such objectives on a case-specific basis, and simulation of short term performance could be tested by specified MPs as done in the Inside Yelloweye Rockfish (*Sebastes ruberrimus*)

working paper (presented in a companion CSAS Regional Peer Review meeting held June 10-11, 2020, that directly followed this one).

As per comment 11 of the written review, the reviewer noted that for the Rex Sole case study, in contrast to assigning the same selectivity and maturity ogive to both the commercial fishery and synoptic survey, future work could explore additional uncertainty where the fishery and survey selectivities differ. This is especially relevant because commercial fleet dynamics may vary from the survey by gear, area, and targeting or avoiding species. The authors responded that selectivity was identified as a key uncertainty and that alternative selectivities could be modelled in OMs, as was done in the Inside Yelloweye Rockfish working paper.

CARRIE HOLT

The reviewer noted the rigorous work of the working paper sets precedence that aligns well with the DFO precautionary approach framework for data-poor, data-moderate and data-rich species.

With respect to working paper section 3.2, the reviewer noted in the *Fisheries Act* provisions that short- versus long-term performance is context-specific, and argued that the entire simulation period should be of interest, with long-term rebuilding plans only part of the evaluation criteria. Authors noted that for groundfish, conservation metrics are usually evaluated over the long term and so the working paper methods reflect that. The authors agreed that performance metrics should be stock-specific, and they addressed this point in their written response and in working paper revisions.

The reviewer asked if it is worth discussing possible preferences and alternatives to the performance metrics that are calculated across all replicates and years simultaneously. The authors responded by providing several examples of how different performance metrics can be calculated for different objectives and risk tolerances in section 3.2 and emphasized that performance metrics are context specific and need to be identified and determined to fit objectives.

The reviewer asked if the authors can recommend some best practices for choosing the reference and robustness sets of OMs (beyond the suggestion to look at natural mortality, steepness of the stock-recruitment curve, and initial depletion) and to explore interactions among uncertainties. The authors provided a written response to this comment and revised the working paper to address this topic, where they cite several references. In brief, there do not yet seem to be many established protocols. For the working paper, the authors took an iterative approach to selecting robustness set results, suggesting that robustness set OMs should provide contrast to reference set results. The reviewer stated the authors' response was a valuable addition.

In comment 8c, the reviewer asked to what extent interactions among uncertainties should be considered with reference sets of OMs. She noted that, depending on context, there may be some interactions that should be investigated, but recognizes the challenge of testing interactions and that it is impossible to test all combinations. How the SRA includes covariance among estimated parameters in the conditioned OM was explained in terms of options that could be coded to tailor to a specific MP framework process, such as to explore covariance. But currently, by default, manually specified OM parameters are either fixed or drawn from a uniform distribution.

The reviewer stated the authors did a good job of addressing the limitations of MP framework efforts in the revised working paper discussion but commented that some data limited stocks

have so many uncertainties that there will be cases where it would be difficult to effectively rank MPs and OMs.

The limitation of single-species assessment work in mixed-stock fisheries was questioned and the topic of how the MP framework could be expanded to a multi-species framework was brought up as a suggested topic of discussion. It was noted that multi-species approaches are outside of the scope of the current TOR and that the review was focused on the Fish Stocks provisions of the *Fisheries Act*, which require reference points and stock status to be expressed on a single-species basis.

The authors and the reviewer agreed that it should be emphasized that to be compliant with the DFO Precautionary Approach framework and Fish Stock provisions, explicit LRPs need not be defined. The Sustainable Fisheries Framework (SFF) and the Fish Stocks provisions of the *Fisheries Act* require that fish stocks be maintained at sustainable levels, particularly above the LRP. Providing LRPs is implicit in the evaluation of MPs – they are consistent with the intent of the policies**.** This was identified as a discussion topic for the meeting. An author emphasized that within the MP framework, the set of OMs can be seen as a stock assessment that provides information on reference points and stock status, but it is unclear how that would be incorporated into the advisory and management decision process. It was also noted that people may want to reference the distribution of LRPs implicit within an OM. Uncertainty is across the OMs so if an individual OM gets selected to direct management decisions based on favourable MP results, this would result in biased use of an OM.

The reviewer noted that for other species groups such as salmon, engagement and decision-making processes can be quite different and work differently under different timelines compared with groundfish, especially with diverse sets of stakeholders and interested parties.

GENERAL DISCUSSION

ROLE OF MP APPROACHES IN SCIENCE ADVICE

The intention and application of an MP approach and the current working paper were discussed. It was emphasized that stock status advice was not being provided as part of the review and the Rex Sole case study was to demonstrate an application of the framework. The current review proposes and communicates an adaptable process for future applications for data-poor, data-moderate, and data-rich stocks while separating the framework process from an actual assessment. Development of the MP framework working paper for Pacific groundfish enabled authors, other analysts, and colleagues, to develop, prepare, and communicate tools for future work. It is expected that there will be more efficiency in the process once people are more familiar with the framework.

Application of an MP approach as a modern best practice available to DFO Science and Pacific fish stocks was explained in terms of the decision context, which can be the same for data-poor or data-rich species, where data richness is a continuum between extremes. The framework provides flexibility within each of the best-practice steps to address the decision context. In decision contexts concerning allocating resources to evaluate the value of information, an MP approach is the only effective way to evaluate information pertaining to statistical power of sampling designs, filling information gaps, weighting of evidence, etc.

For many data-limited stocks it will not be possible to reliably estimate biological reference points or estimate stock status. MP approaches may be especially important for these stocks because the Sustainable Fisheries Framework and the Fish Stocks provisions of the *Fisheries Act* require that fish stocks be maintained at sustainable levels, and particularly above the LRP.

The MP framework implicitly preserves the intent of these policies, despite the fact that reference points and stock status are not explicitly provided.

Effectively following the best practice steps outlined for the MP framework can be an enormous amount of work that needs to be case-specific to align to stock, decision context, and objectives. One participant cautioned that there are no generic approaches or recommendations to suit all MP framework applications. For example, summary probability statistics as PMs for some applications may not be appropriate where the magnitude of an outcome (e.g. breaching a reference point) can be an important metric that should be evaluated. Authors agreed, and emphasized that approaches need to be considered on a case-specific basis and that their work showcased the use of an agreed upon DFO PM for an LRP. A section in the paper also discussed that depending on objectives and jurisdiction, in addition to the magnitude and frequency of the outcomes, the defined time period of a PM statistic should also be considered.

It was also agreed that MP framework recommendations and efforts should not just be focused on the use of indices of abundances in MPs as there are other data sets and ecological signals that may be relevant. It was recognized that there are challenges with using and simulating noisy data, such as fish-length compositions, and although DLMtool has some capacity to simulate noisy data, additional exploration could be done, which could be extended to modelling maturity and selectivity.

The MP framework is also applicable to addressing Species At Rick Act (SARA) and Committee on the Status of Endangered Wildlife in Canada (COSEWIC) objectives and projection periods as described in section 3.2 of the working paper, which the Inshore Yelloweye Rockfish working paper applies.

Several examples were given of past stock assessments on data-limited groundfish species that were perceived as having unsatisfactory outcomes because of the lack of an agreed upon process to deal with the high level of uncertainty. These were for skates (DFO 2014), the outside stock of Yelloweye Rockfish (DFO 2015a), Redbanded Rockfish (DFO 2015b) and a simultaneous assessment of five rockfish species (DFO 2015c). In particular, the latter two examples were unable to provide advice to managers.

DIFFERENCES BETWEEN MP APPROACHES AND STOCK ASSESSMENTS

Several advantages of an MP approach over a standard stock assessment were identified.

Examples are (not in order of priority):

- MP approaches include considerations of different OMs and MPs, such that participants are not locked into providing advice from only one MP;
- When an MP approach is framed in an effective decision context it provides the best way to mitigate risks, which is often not done as part of stock assessments. Stock assessments generally do not provide information on how an MP is expected to perform;
- When there is no trustworthy model to pass a review, the only way to test MPs is through an MP approach;
- An MP approach removes the ambiguity of interpreting an MP for use in stock assessment and catch advice;
- Through an MP approach, it should be possible to exclude unsatisfactory MPs (such as to reduce chances of bad choices, oversimplification of uncertainty, or false robustness claims);

- An MP approach can inform on frequency of assessments and re-evaluation of an applied MP;
- An MP approach can be used to identify the value of different types of information (for cost-benefit purposes) and be used to plan efforts to reduce data poverty.

It was suggested that the differences between an MP approach and a stock assessment could be emphasized more in the Introduction of the paper. Whether or not the application of the MP framework will make stock assessment advice more efficient was questioned since stock assessment and MP-approach efforts can both require substantial work.

A suggestion was made by a participant for review participants to draft guidelines for when an MP framework application versus a stock assessment would be appropriate, but authors or other reviewers were not supportive of this suggestion. An author explained that the driver of the decision context for whether to plan the MP framework versus a stock assessment is beyond the scope of DFO Science and does not follow a prescriptive nature.

PROVISIONAL REFERENCE POINTS IN OPERATING MODELS

Whether the provisional reference points derived within OM scenarios should be considered in the future as part of providing stock assessment advice was discussed. There was general understanding and agreement that information from OM provisional reference points could be considered for stock assessment purposes. The working paper cautions against risks (and biases) associated with the OMs with more favourable PM results being selected for management decisions, and these types of risks need to be emphasized in the review advice.

It was argued that the degree to which results from individual OMs should be explored, versus aggregating OMs into a reference set, needs to be carefully considered on a case-specific basis incorporating weight-of-evidence and expertise approaches. For a data-limited species (like Rex Sole), the uncertainty is across the range of OMs and it can be argued that the step of aggregating OMs into reference or robustness sets may give less meaningful information.

Examples were discussed of stocks where OM output is applied to current or recent execution of MPs and decisions. Associated with BC Sablefish, which is a data-rich stock that has gone through management strategy evaluation (MSE) analyses, PMs are provided for MPs for one reference OM that has evolved over time. With Albacore Tuna, OMs are weighted across an aggregate set of MPs. The International Whaling Commission applies a suite of OM in the context of a gradient of case scenarios and contingency plans.

EVALUATING MANAGEMENT PROCEDURES AFTER IMPLEMENTATION

In association with evaluating assessments and triggering re-assessments, a participant pointed out it is in the first two MP framework steps that the adaptability of changing an implemented MP should be considered (to lend itself to a best practices ‘step 7’), to assess whether a selected MP is working for short- and long-term objectives. If too much gets changed too frequently then long-term objectives and views become difficult to realistically follow.

SPATIAL CONSIDERATOIN OF STOCK DYNAMICS

The adaptability of DLMtool to model spatial considerations of stock dynamics and MPs was discussed. DLMtool can be used to develop OMs that model stock movement dynamics (e.g. immigration and/or emigration) and model MPs that reflect area and seasonal closures. With data limited species, there is a lot of uncertainty, especially with regards to effects of year and of fish age. There is interest to apply such modelling to reflect effects of rockfish closures on species such as Yelloweye Rockfish.

Another spatial consideration that can be explored is how indices from different stock areas can be used, as they can be considered separately or stitched together for greater spatial representation for testing OMs and MPs.

MULTI-SPECIES FISHERIES

Whether and how MP framework efforts can be applied to multi-species fisheries and/or species complexes was discussed. Current and recent Fish Stock Provisions are single species-based so that is what the current work focused on, but DLMtool does have multispecies modelling features that could be explored for BC groundfish. However, modeling spatial and/or multi-species dynamics does make analytical approaches much more complex with increased dimensions that may be difficult to represent. Different approaches to conditioning OMs may also be required. Options include representing a suite of species as a complex or trying to model and track multiple species individually. Different considerations would be needed to model MPs that set TACs across a collective of species or by individual species (e.g. nearshore complexes versus offshore) and modelling multiple fleets would be even more challenging (e.g. bottom trawl, hook and line, trap, etc.). A participant noted that work on these topics underway in the U.S. is related to nearshore species complexes and that DFO staff and colleagues may want to monitor that progress.

It was noted that with the multi-species nature of groundfish fisheries, fleet behavior is often influenced by the desire to either catch or avoid a small subset of species. OMs reflecting different fleet behaviour could be developed with multi-species objectives to test different MPs. Use of historical TACs and catch data can be used to inform modelling. It was pointed out that most species that have TACs are relatively data rich.

BAYESIAN METHODS FOR DATA-MODERATE AND DATA-RICH CASES

For possible future analytical exploration, the idea of incorporating Bayesian modelling for data-moderate to data-rich cases into an MP framework was mentioned. Since there can be challenges with maximum likelihood estimation (with multiple minima occurring) it was asked whether it may be feasible to explore OMs that have been tested by Bayesian methods first. It was pointed out that if data and model complexity of simulations cannot be completed efficiently, that may restrict exploring some models. Some suggestions to get around this were made (e.g. Markov chain Monte Carlo in SRA conditioning, coding the iSCAM model to become an OM, or using surplus production models).

VISUALIZATIONS OF PERFORMANCE METRICS

There was discussion on visualization of results and working paper figures 5-13 as to their utility and clarity. Overall, there seemed to be understanding and appreciation of the value and interpretation of the figures along with information provided in the captions. Summarizing and colour coding PM metrics was seen as an adaptable and useful communication tool. Participants found seeing performance of MPs across OM scenarios useful and the flexibility afforded by evaluating bivariate trade-offs was recognized.

The radar (radial) plot was discussed in terms of its advantage of being able to show tradeoffs of all MPs, and its disadvantages of being confusing and/or misleading when there are many MPs and PMs (e.g. Inside Yelloweye Rockfish working paper). There was agreement that figures that show historical and projected B/B_{MSY}, F/F_{MSY} (biomass and fishing mortality rate relative to those at maximum sustainable yield), and catch trends by multiple MPs and OMs are important and that these plots show envelopes of uncertainty, which can be very wide. A participant noted that with large amounts of uncertainty across OMs it may still be hard to

evaluate if and whether an MP is working. The value of showing projected results as quantiles in Kobe and phase plots relative to reference points was identified and emphasized in the context of the Sustainable Fisheries Framework and Fish Stock Provisions policies. There was general agreement and understanding that figures presented in the working paper are effective for demonstrating application to a single-species groundfish stock, and that other types of figures may be more relevant on a case-specific basis.

The topic of whether and how the upper stock reference (provisionally $0.8B_{MSY}$) will continue to be regarded as a desired prospective DFO reference point on a national level was brought up. It was explained that there may be a transition to instead consider a target reference point.

ACCEPTANCE OF WORKING PAPER

There was consensus to accept the working paper. Some minor suggested revisions were made during the review (and some sent separately to authors), which authors agreed to consider.

SCIENCE ADVISORY REPORT

A draft of the Science Advisory Report (SAR) was circulated the morning of the second day of the meeting and the chair reviewed the format and intent of the SAR and facilitated discussion on information to include in the various sections. Participants briefly reviewed and discussed information for inclusion in the Context, Summary, Analysis (including Sources of Uncertainty), Other Considerations (Implicit versus explicit knowledge of reference points, Tuning MPs, Reassessment frequency and triggers, Extensions of framework) and Conclusions and Advice sections of the SAR. It was decided that the content of the SAR would include the working paper Figure 5 of the flow chart showing the steps of the MSE process adapted from Carruthers and Hordyk (2018) as well as the collection of generic figures demonstrating how results of MPs can be shown to compare tradeoffs between MPs (working paper Figures 5-13). It was decided to exclude the extensive details of the Rex Sole case study in order to keep the focus on the MP framework process and not on a case study and its associated results (as well as to keep the SAR brief). The chair was tasked with editing and developing sections of the SAR in more detail prior to circulating a revised draft of the SAR to participants after the meeting.

CONCLUSIONS

There was consensus to include several points in the SAR reflective of the advice of the review process and consistent with information in the working paper, pertaining to:

- MP framework processes are endorsed for the provision of DFO Science advice as they represent modern and internationally accepted methods of providing advice on fish stocks with several expected benefits;
- The importance and roles of the six best-practice steps associated with planning and implementing a successful MP framework;
- A recommendation that the MP framework be used to evaluate MPs after implementation.

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APPENDIX A: TERMS OF REFERENCE

A Management Procedure Framework for British Columbia Groundfish

Regional Peer Review – Pacific Region

June 8-9, 2020
Virtual meeting

Chairperson: Andrew Edwards

Context

The Fisheries and Oceans Canada (DFO) Sustainable Fisheries Framework (DFO 2009) lays the foundation for an ecosystem-based and precautionary approach to fisheries management that enables continued productivity of Canada's fisheries.

The Pacific Region Groundfish Integrated Fisheries Management Plan includes over 200 groundfish species (DFO 2019) of which approximately 100 are regularly caught in British Columbia (BC). Individual Transferable Quotas are used to manage fisheries, where quotas are ideally set using stock assessment information. However, in recent decades, DFO groundfish stock assessments have focused on data-rich species, resulting in a subset of stocks with full stock assessments, while many stocks with less informative data remain unassessed. Consequently, quotas assigned to rarely assessed or unassessed stocks may result in catch rates that are too high, may restrict harvesting opportunities to catch target species, or may result in failure for fisheries to meet seafood certification standards. This project aims to address this gap by developing a framework that can provide sound and timely scientific advice for data-limited groundfish stocks (defined here as stocks with insufficient data for a full age-structured stock assessment or lacking existing assessment models).

DFO Fisheries Management has requested that Science Branch develop a framework for applying a management-procedure approach to data-limited groundfish stocks in British Columbia. DFO Science has undertaken a two-phase approach to exploring assessment methodologies for data-limited groundfish stocks that are robust to a range of data quality, information, and uncertainty. The first phase, a groundfish data synopsis (Anderson et al. 2019), provided a visual snapshot of long-term and recent survey trends, fishing trends, growth and maturity characteristics, and data availability for over 100 BC groundfish stocks. The second phase, and the focus of this peer review, is to develop a framework for testing the performance of a suite of data-limited management procedures against conservation and fishery objectives. This will be done using an existing closed-loop simulation framework that includes building appropriate operating models, testing suites of management procedures, and determining management procedures that best meet conservation and fishery objectives for one or more case-study stocks. The framework will use the open source R package DLMtool (Carruthers and Hordyk 2018), developed at the University of British Columbia, in partial partnership with DFO.

The advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will be used to inform DFO Fisheries Management on harvest strategies for data-limited groundfish stocks, and may be used to inform other processes, including COSEWIC and Marine Stewardship Council for conservation and/or certification purposes.

Objectives

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

Anderson, S.C., Forrest, R.E., Grandin, C.J., Huynh, Q.C. and Keppel, E.A. A Management Procedure Framework for British Columbia Groundfish. CSAP Working Paper 2014GRF07c.

The specific objective of this review is to:

Develop a framework to test the performance of data-limited management procedures for BC groundfish fisheries. Steps include:

1. Recommend provisional conservation and fishery objectives based on Sustainable Fisheries Framework policies and associated performance metrics (e.g., probability of maintaining biomass above a limit reference point, probability of short-term yield remaining above a threshold) for use in future assessments.
2. Screen available data-limited management procedures for potential suitability in future assessments. Candidate management procedures may include fixed total allowable catch levels, empirical procedures, and simple models paired with harvest control rules.
3. Develop one or more operating models for one or more case-study species using the R package DLMtool (Carruthers and Hordyk 2018) and data extracted using the data synopsis tools (Anderson et al. 2019).
4. Apply closed-loop simulation using DLMtool to evaluate the performance of select management procedures against the objectives in step 1.
5. Establish provisional visualizations of performance metric trade-offs.
6. Identify the benefits of the framework to support timely harvest advice for data limited species. Identify limitations of the framework and recommend next steps.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Fisheries and Oceans Canada (DFO)
- Academia
- Indigenous communities/organizations
- Fishing industry
- Nongovernmental organizations

References

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APPENDIX B: AGENDA

Canadian Science Advisory Secretariat
Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Management Procedure Framework for British Columbia Groundfish

June 8-9, 2020 Virtual Platform on Zoom
Chair: Andrew Edwards
Rapporteur: Linnea Flostrand

DAY 1 – Monday, June 8, 2020

Time	Subject	Presenter
0900	Introductions and overview of virtual platform Review Agenda CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Authors
1030	***Break***	
1045	Overview of Written Reviews	Chair + Reviewers & Authors
12:00	***Lunch Break***	
1300	Identification of Key Issues for Group Discussion	Group
1330	Discussion & Resolution of Technical Issues	RPR Participants
1430	***Break***	
1445	Discussion & Resolution of Results & Conclusions	RPR Participants
1530	Develop Consensus on Paper Acceptability & Agreed-upon Revisions (TOR objectives)	RPR Participants
1600	Adjourn for the Day	

DAY 2 - Tuesday, June 9, 2020

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1 (*As Necessary*)	Chair
0915	Carry forward outstanding issues from Day 1	RPR Participants
1030	***Break***	
1045	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Summary bullets • Sources of Uncertainty • Results & Conclusions • Figures/Tables • Additional advice to Management (as warranted)	RPR Participants
1200	***Lunch Break***	
1300	*Science Advisory Report (SAR) cont'd*	RPR Participants
1430	***Break***	
1445	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair
1530	Other follow up commitments (as necessary)	Chair + Participants
1600	***Adjourn meeting***	

APPENDIX C: WORKING PAPER ABSTRACT

The Pacific Region Groundfish Integrated Fisheries Management Plan lists approximately 80 species-area fish stocks for which annual total allowable catches are required, most of which are applied as individual transferable quotas within the British Columbia (BC) integrated groundfish fishery. The majority of fish stocks encountered by the integrated groundfish fishery are considered data-limited, where data-limited stocks are defined as those with insufficient data to reliably estimate stock status or estimate abundance or productivity with conventional stock assessment methods such as statistical catch-at-age models. In recent decades, Department of Fisheries and Oceans (DFO) groundfish stock assessments have focused on data-rich stocks, resulting in a subset of stocks with full stock assessments, while many stocks with less informative data remain unassessed.

The DFO Sustainable Fisheries Framework, legislated via the Fish Stocks provisions in the *Fisheries Act*, requires that fish stocks be managed at sustainable levels—specifically at biomass levels above the Limit Reference Point (LRP). For data limited stocks, data are often insufficient to adequately account for uncertainty in the assessment of stock status relative to biological reference points in traditional stock assessments. Instead of focusing on the explicit knowledge of current stock status, we propose a management-oriented approach that emphasizes selecting management procedures (MPs) that have a high likelihood of maintaining fish stocks above implicitly known reference points across multiple plausible states of nature, regardless of the quality and quantity of available data.

Worldwide there has been a movement towards MP (or management strategy evaluation [MSE]) approaches to providing science advice on fish stocks via closed-loop simulation. Closed-loop simulation differs from conventional stock assessment because it simulates feedback between the implementation of MPs and a simulated system representing the fish stock and its environment, described by one or more operating models (OMs). This document presents a methodology for developing appropriate OMs, testing suites of MPs, and identifying MPs that best meet the objectives of fisheries management and stakeholders. We outline six best-practice steps for MP approaches: (1) defining the decision context, (2) setting objectives and performance metrics, (3) specifying OMs, (4) selecting candidate MPs, (5) conducting closed-loop simulations, and (6) presenting results to evaluate trade-offs. We then describe our proposed approach (the “MP framework”) and how it aims to accomplish each of these best-practice steps. Included in our framework are provisional conservation and fishery objectives and performance metrics based on Sustainable Fisheries Framework policies, a provisional library of data-limited MPs that are appropriate for BC groundfish stocks, and provisional visualizations to help decision-makers evaluate performance of MPs and trade-offs amongst MPs.

We undertake a case study of the Rex Sole (*Glyptocephalus zachirus*) stock in the West Coast Vancouver Island groundfish management area (Area 3CD) to demonstrate an application of the MP framework. The case study develops six reference-set OMs and two robustness-set OMs. The case study reveals a set of survey-index-based MPs, constant catch, and surplus production- based MPs that achieve > 0.9 probability (9 times out of 10 chance) of maintaining biomass above the LRP in the long term (35–50-years in the future) while maintaining a > 0.8 probability (4 times out of 5 chance) of maintaining catches at or above recent (5-year) average levels in the near future (1–10 years) in the reference-set OMs. We also present performance metrics related to the long-term probability of biomass remaining above the Upper Stock Reference, the long-term probability of fishing below F_{MSY} (fishing mortality at maximum sustainable yield), the long-term probability of maintaining catches above recent average levels, and the probability of catch variability remaining below historical levels. Four of the MPs

achieved only slightly lower performance metrics in the robustness OMs, compared to the reference-set OMs, while other MPs were more sensitive to these OM robustness scenarios.

We highlight issues regarding reference points, MP tuning, assessment frequency and triggers, the inclusion of environmental effects, assessing the value of information, and use of this framework as part of stock rebuilding plans. Throughout, our framework emphasizes transparency and reproducibility and to that end we develop an associated package for the statistical software R that facilitates applications of the framework. Overall, we intend this framework to improve the capacity for Pacific DFO Science to provide evidence-based catch advice for more groundfish stocks—regardless of data limitations—in a standardized and transparent manner consistent with the DFO Sustainable Fisheries Framework, the Fish Stocks provisions in the *Fisheries Act*, and international best practices.

APPENDIX D: REVIEWER COMMENTS AND AUTHOR RESPONSES

Note that authors' responses (AR) are presented in indented, italicized text for both reviews.

REVIEW 1: CARRIE HOLT, FISHERIES AND OCEANS CANADA

This working document clearly outlines a framework for evaluating management procedures for data-limited groundfish that is aligned with best practices in the scientific literature and other jurisdictions. It provides a robust basis for providing catch advice for these stocks in a way that is consistent with the intent of the PA Framework and the *Fisheries Act*. I commend the authors on this working paper, and hope that it creates a precedent for similar frameworks in other fisheries.

General comments related to the Terms of Reference

The Terms of Reference states that the objective of the CSAS review is "to develop a framework to test the performance of data-limited management procedures for BC groundfish fisheries." However, the title suggests the framework applies to all groundfish, including data-rich stocks. What additional considerations would need to be considered when applying to data-rich stocks (e.g., fuller range of MPs)? Should the title be changed to reflect the focus on data-limited? Although the concepts may apply equally, the details and recommendations in this paper relate specifically to data-limited cases.

AR: An earlier version of the working paper did include "data-limited" and at one point included "data-limited and data-moderate" in the title. However, these terms have many definitions in the literature and we see no reason why the framework could not be applied to any groundfish stock if desired, with the types of modifications mentioned. We now include a sentence in Section 1.5, which suggests the framework could be extended to data-moderate and data-rich species. We have also added a new section on data-moderate and data-rich stocks at the end of the discussion (Section 5.7).

The Terms of Reference identifies 6 steps in the development of the MP Framework. I have aligned my general comments with these steps.

This made responding to the comments easier, thank you.

1. Recommend provisional conservation and fishery objectives based on Sustainable Fisheries Framework policies and associated performance metrics (e.g., probability of maintaining biomass above a limit reference point, probability of short-term yield remaining above a threshold) for use in future assessments.

    - The text proposes 5 provisional tactical conservation and fisheries objectives (section 3.2). Are these proposed for BC groundfish in general (data-limited stock, or including data-rich)? If more general, to what extent were they vetted by Fisheries Management, First Nations, or stakeholders?

    AR: We have added a note that these objectives were refined after discussions with our technical advisory group. We had already noted that objectives and performance metrics should be refined on a stock-by-stock basis in two places in Section 3.2.

    - Why are the probability of B > LRP and USR evaluated over the long-term in the provisional set of PMs? For *Fisheries Act* considerations, the entire simulation period may be more relevant. The long-term would be specifically relevant to rebuilding plans where the long-term window would match the time-frame by which the stock must be rebuilt (generally 1.5-2 generations).

AR: In our experience with groundfish, conservation metrics are usually evaluated over the longer term reflecting sustainability objectives, while catch metrics are often evaluated over both short and long-terms. Cox and Kronlund (2008) noted that trade-offs change over time, hence selection of different periods. In the Inside Yelloweye Rockfish rebuilding plan (Haggarty et al. in review), both short and long-term P(B>LRP) were of interest to ensure that rebuilding occurred over both short and long terms. Therefore the time frame over which to calculate performance metrics may be somewhat stock-specific, depending on the trade-offs to evaluate. We added some text to note this.

- Section 3.2 "For example, we recommend calculating the FMSY performance metric across all replicates and years simultaneously". So, a single value over all years and replicates is calculated. An alternative is the proportion of years where F < FMSY with CIs identified from the replicates. Why choose the first over the second? What are advantages/disadvantages of each?

AR: We have added text in the last paragraphs of Section 3.2. We also changed "we recommend calculating" to "we calculated".

- Can authors provide advice on how to change aspirational objectives into tactical objectives, in collaboration with stakeholders, First Nations, and managers, or point to literature that can aid this process? Defining rigorous objectives can limit progress in evaluating MPs, or halt progress entirely. In addition, can authors provide guidance on identifying cultural objectives (Section 3.2)? Is there any precedence in other jurisdictions that DFO can draw lessons from?

AR: We have added a bullet in Section 2.1 to emphasize the importance of determining how the process will be governed. We have also added text to Section 2.2 to more clearly describe the inherent conflict in fishery objectives and the need to develop a well-governed process to develop the final list of objectives. We have also included references to approaches and needs for incorporating social and cultural objectives.

- To what extent do the authors think this framework can capture questions related to allocation? Performance metrics on fishery-specific catches may be more relevant to stakeholders than total catch, which would require additional assumptions about allocation.

AR: At this stage we have not considered allocation. In applications of the framework, stakeholders may indeed be interested in allocation. In general, we do not consider allocation the role of Science. However, in some cases where there are large differences in selectivity among fleets, Science may be able to support appropriately framed allocation decisions (e.g., long-term conservation impacts of allocating more catch to a fleet that catches smaller fish). We have indicated in several places that the framework is flexible to extensions, and it can accommodate multiple fishing fleets with different selectivity (see the Inside Yelloweye Rockfish application of the framework (Haggarty et al. 2020)).

2. Screen available data-limited management procedures for potential suitability in future assessments. Candidate management procedures may include fixed total allowable catch levels, empirical procedures, and simple models paired with harvest control rules.

    - "In general, identification of available MPs is the role of Science." (Section 2.4). There may be a role for Fisheries Management identifying MPs, who could provide input about acceptability or feasibility of various MPs due to, e.g., management inertia (Armitage et al. 2019) in the initial screening.

AR: Immediately after the statement "In general, identification of available MPs is the role of Science", the working paper goes on to say "Managers, stakeholders and First Nations may be involved in determining desirable performance metrics and may also provide input on feasibility of implementing some MPs." There was a typo here where "performance metrics" should have read "MPs". We have updated this paragraph and added the Armitage reference.

3. Develop one or more operating models for one or more case-study species using the R package DLMtool (Carruthers and Hordyk 2018) and data extracted using the data synopsis tools (Anderson et al. 2019).

    - Is there any way to make the identification of uncertainties in reference and robustness sets, and the distinction between reference and robustness sets less subjective, i.e., defining "major impact" and "wider range of uncertainties".

    AR: See comments below

        - Can the important dimensions of uncertainty identified in the reference and robustness sets be assessed for each case study quantitatively through preliminary sensitivity analyses? (or multivariate or global sensitivity to explore interactions among uncertainties).
        - If not, can you recommend some best practices for choosing the reference and robustness sets (beyond the suggestion to look at *M*, *h*, and initial depletion)?

    AR: We have not found examples in the literature where there has been a formal or objective means of identifying reference and robustness sets. This approach has mainly been taken in South African MSEs (we have added references to two Rademeyer and Butterworth (2006a and b) reports, but otherwise we think there are relatively few established protocols. These authors took an iterative approach to selecting robustness set results, suggesting that robustness set OMs should provide contrast to reference set results. Punt et al (2016) suggest a means of starting and provide a list of the main sources of uncertainty as well as recommendations for the minimum sources of uncertainty to consider. We have updated Section 2.3 with more information from the literature. We also added a recommendation in Section 3.3 that, for stocks with available stock assessments, these should be consulted to identify major sources of uncertainty. We have also added a note to Section 2.3 about weighting of OMs.

        - Categorical uncertainties lend themselves to inclusion through reference and robustness sets (e.g., structural uncertainties related to model form), but continuous uncertainties (e.g., level of *M*) could be accounted for through relatively wide distributions within OM slots instead. This approach integrates over all intermediate values of the continuous variable, whereas identifying distinct reference sets for a continuous variable bounds the uncertainty and treats the low and high values as equally plausible in the "average" OM results. Can you provide some recommendations on which approach to take when?

    AR: We had already recommended in Section 3.3 that specific sources of uncertainty should be isolated through development of alternative OMs. We added a citation to Punt et al 2016. We have noted in several places that the approach to developing OMs should be evaluated iteratively in light of providing contrast in results.

        - When identifying reference sets, to what extent should interactions among uncertainties be considered? One variable may only have an impact at certain levels of another variable. (e.g., *Ceq* 50% and no CPUE in the Rex Sole example).

8c. Some MSE processes do take interactions among uncertainties into account but in many cases it is not computationally possible. In this case, it may be necessary to do some exploratory analysis at the start to determine which combinations produce the largest differences in results. Punt et al (2016) suggest it is more common to select 'base' levels for each factor and then develop alternative OMs which vary one (or more than one) factor in turn. We have added text and references in Section 2.3.

- "Development of OMs is principally the responsibility of Science". This may depend on the fishery. For those fisheries where First Nations and stakeholders are deeply imbedded in advisory process and management, these could be co-developed.

AR: We think we have already addressed this. The whole sentence reads "Development of OMs is principally the responsibility of Science, although input from stakeholders, First Nations and other parties is desirable, especially with respect to identifying key uncertainties and ensuring plausibility of the OMs." The exact role of non-Science parties will be nuanced and depend upon the particular case and we expect that this will be defined in Step 1.

- The OM conditioning section would benefit from further explanation. For example,
  - The parameter distributions inputted into OM slots are only minimally updated through the calibration process by removing a small number of replicates where the SRA model did not converge or produced unrealistic F values. I'm not clear on how one chooses which parameters are estimated at this stage (*D*, *R0*, *AC* for Rex Sole) vs. assumed based on external data/expert opinion in the prior step and updated only with removal of replicates that don't converge, etc.? Are you recommending that these three parameters are estimated in the SRA for all data-limited BC groundfish?

AR: We have added a list of the parameters updated by the SRA in the preliminary section of Appendix A. Yes, those three parameters will be updated by the SRA. We note that some other parameters are updated depending on data and refer to details in Appendix B.

  - How are interactions among parameters included in the conditioning, if at all? Are parameter sets chosen such that they account for covariance among parameters (or individually)?

AR: Covariance among estimated parameters in the SRA is automatically included in the conditioned OM.

Whether or not there is covariance amongst the manually specified parameters depends on how the OM is specified. For example, covariance in growth and maturity parameters for Rex Sole is accounted for by drawing from their posterior probability distributions (Appendix F). By default, however, manually-specified OM parameters are either at fixed values or usually drawn from a uniform distribution (i.e., without covariance between parameters).

We added notes to explain this at the end of the preliminary section of Appendix A.

  - Section 3.3 "Where there is no index of abundance, we recommend developing a wide range of uncalibrated OMs conditioned on available catch data, which differ in terms of major uncertainties, especially related to stock productivity and current depletion level." Can you clarify the difference between calibrating the OM with observed data and conditioning it?

AR: Calibration and conditioning were used synonymously throughout the document, and have been reworded for consistency.

- For approximately what proportion of BC groundfish would this be the case? Is the uncertainty ever so large such that the outputs from the simulation are not meaningful i.e., cannot rank the MPs on conservation or biomass objectives?

AR: We have not attempted to quantify the proportion of groundfish stocks without an index of abundance since, technically, we have survey data for all of them (albeit many will be uninformative). The groundfish synopsis report would be a place to start this exercise but we think this is outside the scope of this working paper. This statement was meant to acknowledge that the framework can still work in theory for stocks with very little information. Our technical advisory group advised us to start with stocks where we can customize operating models and condition them on observed data, to build familiarity with the framework. In time we will come to the very data-limited or data-less stocks but this would need to be after the framework has been tested with more familiar stocks.

4. Apply closed-loop simulation using DLMtool to evaluate the performance of select management procedures against the objectives in step 1.
    - No comments
5. Establish provisional visualizations of performance metric trade-offs.
    - To what extent have these visualizations been vetted with Fisheries Management, First Nations and stakeholders? There may be a learning curve when applying these visualizations (especially Fig. 8, radar plot) such that it takes several meetings to gain comfort with the plots. If the same stakeholders are involved in various assessments, it might be valuable to apply the same arrangement of axes in Figs. 7 and 8 across assessments, to the extent possible.

    AR: There has been no vetting process as such, but the visualizations were refined over a year as the authors and technical advisory group gained familiarity and provided feedback (see acknowledgements for list of participants in the technical advisory group). The technical advisory group, which included fishery managers, Science colleagues, an academic party, and one industry representative, provided extensive feedback on a very early draft of the working paper. We did seek broader input from the groundfish industry but there were many competing priorities. Therefore the familiarity-building process for these visualizations largely begins with this CSAS meeting. We did characterize the visualisations as provisional in the working paper. We have added a note that we expect some or all of the visualizations to be refined over time (beginning of Section 3.6.2).
6. Identify the benefits of the framework to support timely harvest advice for data limited species. Identify limitations of the framework and recommend next steps.
    - The benefits are well articulated in section 1.6. In that section, I would add that this approach can be used to inform recovery potential assessments and rebuilding plans, evaluate impacts of the environment (as required in the fish stock provisions), and assess the value of collecting more information. Also, in the bullet “provide evidence-based catch advice for more stocks”, I suggest emphasizing that this approach allows DFO to provide advice for stocks for which advice was not previously available (i.e., it can fill large gaps in management advice).

    AR: We have added the reviewers’ suggestions to Section 1.6.

    - Limitations are not specified. What are they? Beyond BC groundfish, they could include applications to fish stocks that are not well specified with any available OM, dynamics that are so uncertain that MPs rank equally on conservation or biomass PMs, fisheries with large numbers of diverse stakeholders and First Nations that lengthens

implementation period of the framework beyond available time frame, and/or fish stocks driven in part by management levers outside of DFO control.

AR: This was an oversight. We have added a Limitations section at the end of the discussion.

- For species where there is no directed fishery, but there is a quota because of harvest in mixed-stock fisheries, how valuable is a single-species MP framework? Do the authors anticipate expanding this to a multi-species framework?

AR: Currently most groundfish species are managed by single species TACs. The Fish Stocks provisions also require reference points and stock status to be expressed on a single species basis (although they also speak to the need to account for environmental considerations, which could include multispecies considerations). This version of the framework is designed to address the need to provide advice for single species. We have an initiative in place that will use these tools to touch on multispecies questions (funded by the Fisheries Science Ecosystem Research Program), but this work is in the very preliminary stages. To some extent, multispecies considerations are managed by the industry itself through choices of where and when to fish to achieve desirable species compositions. In general, we feel it is better to start with a simple framework and learn from it.

- One specific recommendation that could be articulated in the SAR is that explicit LRPs need not be defined to be compliant with the PA Framework and Fish Stock provisions as long as LRPs are implicit in the evaluation of MPs.

  > "Although the MP Framework does not emphasize explicit knowledge of fish-stock reference points, it emphasizes selecting management approaches that have a high likelihood of maintaining fish stocks above implicitly known reference points across multiple plausible states of nature…. The Sustainable Fisheries Framework and the Fish Stocks provisions of the *Fisheries Act* require that fish stocks be maintained at sustainable levels, and particularly above the LRP (Section 1.2). This framework implicitly preserves the intent of these policies, despite the fact that reference points and stock status are not explicitly provided." (Section 5)

AR: We agree with the reviewer.

- Policy analyst/managers may want to use the distribution of LRPs implicit within the OM for reporting purposes to demonstrate that an LRP (or distribution of LRPs) has been identified. I suggest adding text about whether this is appropriate or not in Section 5.1.

AR: We agree with the reviewer that this is important but do not feel we can comment further without guidance from the regional peer review (RPR) committee. We hope this can be discussed in the RPR meeting.

Minor comments

Section 1.2

- You could point out that the USR and the “healthy” zone boundary are not clearly defined in the Precautionary Approach Framework, making it difficult to identify objectives that align with them, asides from the suggested provisional value of 0.8 B_{MSY}. Note, 0.8 B_{MSY} is a provisional value that can be used, and is not necessarily a recommended USR.

AR: We agree this is an important topic, but we could not find an appropriate space in the working paper to include a discussion of this complex issue without distracting from the description of the framework. We have referred readers to two upcoming research documents (Marentette et al. 2020a and b) for discussion of current thinking on the roles of reference points in Section 3.2.

Section 1.6

- Consider mentioning the apparent inconsistency between being compliant with Fish stock provisions and yet not explicitly defining LRPs for data-limited stocks here.

  AR: We have added some text at the end of Section 1.6.

Sections 2 and 3

- In general, I'm not sure the distinction between Sections 2 and 3 is large enough to warrant two separate sections. I had many questions on reading the steps in Section 2 that were answered in Section 3. You could consider combining them.

  AR: The intent of Section 2 is to provide an overview of the steps to orient the reader before getting into the details of the framework, although this does lead to some repetition. We have added a note just before Section 2.1 to say that details can be found in Section 3.

Section 2.2

- I suggest mentioning that these steps can be iterative. Defining rigorous objectives can limit progress or halt progress entirely. Instead, preliminary objectives can updated after simulations, as would presumably be done if this Rex Sole case study was fully implemented.

  AR: We agree and have noted that all steps in the process will be iterative at the beginning of Section 2.

- Figure 3. The placement of "Step 1: Define the Decision context" is a bit awkward. I assume it is placed at the top to infer that it is done first, though the remaining steps are not ranked top to bottom. Step 1 overlaps more with identifying candidate MPs and performance metrics, than the "Data, assessment, expert judgement" bubble at the top. The Decision context is more of an underlying box within which the entire flowchart is placed.

  AR: We agree and have revised the positioning of Step 1 in the figure (now at the top of the figure). We have also adjusted the position of Step 6 and modified the boxes at the bottom of the figure.

Section 2.3

- For stocks where there is no clear support for one SR relationship over another, then this structural uncertainty listed in section 2.3 (paragraph 3) as part of the robustness set might be assigned to the reference set.

  AR: See response to Comment 8 for general approach to assigning OMs to robustness or reference sets.

Section 2.4

- Why not consider a model-based MP that uses the SRA?

AR: A model-based SRA MP would be possible (or any of the other age-structured MPs available in MSEtool), assuming the availability of some ageing data going into the future. We did not consider evaluating an age-structured MP as we are not confident yet of simulating sufficiently realistic (i.e., messy) age composition data for stocks with patchy sampling or availability of aged otoliths. We have noted in the Discussion that the framework could be used to assess the value of collecting age composition data and we think this would be the appropriate process for testing the performance of age-structured vs data-limited methods. Note that DLMtool does have options for delay-difference model-based MPs. We investigated these MPs early in the process but decided against using them because they are conditioned on the correct value of natural mortality and therefore may over-perform in simulation. In future applications we will certainly explore performance of more data-moderate and data-rich MPs, compared with the data-limited MPs presented in this working paper.

Section 3.2

- Marentette and Kronlund (2019) review definitions of "sustainability" in fisheries across jurisdictions, and an upcoming National CSAS process (May 26-27 2020, "Science Advice for Precautionary Approach Harvest Strategies under the Fish Stocks Provisions") will further explore a definition of "sustainability" relevant to DFO.

  AR: We have added references to both Marentette papers.

- Paragraph 5. The PA Framework states that the target can either be at the USR *or higher* than it.

  *AR: We have modified the text to read "while the probability of reaching a target biomass (e.g., the threshold to the Healthy Zone **or some pre-defined target above the USR)** can be lower at around 50%".*

Section 3.4

- Within the framework, the authors "in some cases, excluded MPs that were difficult to understand and communicate. A library of provisional MPs included in this framework are described in Appendix D". This assumes that the performance of complicated MPs would be similar to those included, so the loss from not including them is less than the cost from having to communicate a complicated MP.

  We have clarified in Section 3.4 that we excluded one family of MPs (with reference) that we found difficult to communicate but which did not appreciably give different results. We feel that engagement throughout the process is important, as noted elsewhere (e.g., the end of Section 2.4).

Section 3.4.1

- "Index-slope MPs fit a regression to population index data". I might add "regression of population index data over time".

  AR: We have revised the text accordingly.

Section 3.5

- "In our experience, the number of required replicates is likely to be at least 100". I might add "In our experience *with BC Groundfish*, the number of required…".

  AR: We have revised the text accordingly.

Section 3.6.2

- It might be more effective if the Figures were consistent with each other. Fig 5 suggests that only MP-15 is satisficed (for the two PMs where the thresholds for satisficing were highlighted, LT LRP and LTC), but Fig. 6 which only includes MPs that were satisficed has 4 MPs listed, including those that were not satisficed in Fig. 5.

  AR: We agree and will revise Fig. 5 and 6 for consistency after the review meeting.

- It was not clear at first read what “true” and “false” reference meant in the legend to Fig. 6. I suggest explaining in the caption.

  We have updated the caption for Figure 6.

- Fig. 10. The shading is a bit too faint. This Figure would be more realistic if all the satisficed MPs were included. The plot gets confusing with many lines, but I think this is what is recommended (and shown in the Rex Sole example).

  AR: We prefer to keep the illustrative plots simple. We have added notes to Figure captions for Figures 9 and 10 to indicate that in applications of the framework, there would be separate panels for each MP.

  We will make the shading in Fig. 10 less faint after the review meeting.

- Fig. 10 legend (and elsewhere). I think it would be clearer to always specify "OM scenario", instead of just "scenario" as in the legend. In other MSE applications, the combination of OM and MP could be considered a scenario.

- We now use “OM scenario” instead of just “scenario” throughout the text. We will change this in any legends after the review meeting.

  AR: We have edited text throughout to specify “OM scenario” where appropriate.

- Fig. 11 caption,
  - “The thin black lines represent replicates…” The lines are all the same thickness.
  - “… represents the 95% quantile”. I would add “of the simulated index values”.
  - “The vertical dashed line represents the last historical year of the closed-loop simulation”. I would change this to “… the last historical year of the observed data”.
- Fig. 12. Define dashed lines in the caption.

  We have made all these changes.

Appendix A

- “Set parameter values and ranges in the OM”, based on independent data, meta-analyses, and expert opinion? Some guidance here would be helpful

  AR: We have added examples of sources for OM parameters and referred to Appendix E and Haggarty et al 2020 for examples.

Appendix A.5

- “reference points recommended in Canada’s Precautionary Approach Framework” should be “reference points suggested in …”

  AR: We have made this change.

Appendix A.6

- This paragraph might be expanded to mention that the implication of declining MSY values is improved status and vice versa. Also, I suggest that this question of appropriate baseline be resolved in collaboration with fisheries management, stakeholders, and First Nations, and decisions be made in a transparent manner.

  AR: We have updated Appendix A.6 accordingly.

Appendix C.4

- The implementation slots are for variability in total allowable effort, and size and age, but Appendix A, Eqn. A.37 and A.38 describes TAC implementation uncertainty. Where is this specified (or is this calculated)? Also, section C.4 states that implementation slots are by default = 0. Does this mean the implementation uncertainty is assumed zero for BC groundfish (i.e., TACs are achieved exactly)?

  AR: That was an error—we meant to consider TAC rather than TAE in the implementation error (we are only including MP's for which TACs are provided). This has been revised in the Default Implementation slots section (C.4) in the working paper. And yes, it is assumed that with 100% observer coverage under-reporting error is negligible (e.g., uncertainty is zero or very small). For non-target species the TACs may not be fully used; however, we expect underages would be less biologically precautionary.

Appendix D

- D.3.2 section is confusing and Fig. D.5 needs more explanation. Switching between nomenclature (Itarget vs δ at the top of the Figure D$ and D5) is confusing. It might be clearer if the parameter combinations at the bottom of section D.3.2 were more clearly mapped on to the Figure D5. On the right y=axis, I would replace "TAC=.." with x=…" to more clearly map them, and then possibly add TAC in parentheses.

  AR: We have re-written the description of the MP to make it clearer. We have updated Figures D4 and D5 as suggested and improved the captions.

Appendix E.3

- If there is no directed fishery on this species, does variability in catch matter?

  AR: Variability in catch probably matters less for incidental species, but may still be a concern in multispecies fisheries, where large fluctuations in low quota species can affect the ability of the fleet to realise TACs on target species. We have added some text to this effect in Section 3.2.

- Mention here that reference catch is last 5 years in this case

  AR: Added in.

Appendix E.4

- What is *Ceq* for OM Scenarios 3, 4, 5 and 8? I assume *Ceq* = 200% > for these OM scenarios.

  AR: Ceq was set at 200% in all scenarios unless otherwise specified. We have clarified this in the caption of Table E.1 and in Section E.4.1.1.

Appendix E.4.1

- Why was *Ceq* capped at 250% of 1996. 200-250% seems like a narrow range to consider.

  AR: We did some preliminary runs with Ceq > 250%. The estimated stock size increases with increasing Ceq so the higher Ceq scenarios did not yield any contrast in ranking of MPs or trade-offs. We have added a note in Section E.4.1.1

Appendix E.4.2

- "We do not necessarily expect this to become a default robustness OM in applications of the framework". Are the other reference and robustness sets recommended then as defaults? A clear statement about whether they are not is warranted, and if yes, then further justification on the choice of those uncertainties for all other BC groundfish.

  AR: No, there are no reference and robustness sets recommended as defaults. We have deleted the sentence.

Appendix E.4.3

- I suggest moving the criteria for discarding replicates into the main text.

  AR: We have included some text describing the SRA process in Section 3.3.

- Add the number of replicates in this section. I assume it's the same as for the DLM tool in Step 5, 250?

  AR: We have added this information.

- Fig. E7. Why do the histograms and hence parameter estimates in the first row (OM scenario 1) differ from those in the last row (OM scenario 8), if both have *Ceq* = 200% (TBC), and increasing *M* in the last scenario only impacts the forward simulation, not the historical period? The same for Figs. E9 and E10, panels 1 and 9.

  AR: This is because M is held at a fixed value in the historical period for the OM Scenario 8, whereas it is drawn from a distribution for OM Scenario 1.

- Does DLM tool use only the replicates and parameter estimates from the SRA (Figs. E.7 and E.8), and ignore the original OM slots.

  AR: The DLMtool OM is updated with key parameter estimates from the SRA. All other OM parameters are unchanged. We have improved the description of which parameters are updated in Appendix A. See also response to Comment 10.

Appendix E.7

- Fig. E.16 caption "Dot-and-line plot of performance metrics across scenarios". This plot shows performance metrics across MPs, not scenarios. Which OM scenario is this plot for? Same for Figs. E17 and E18. I assume these are supposed to be repeated for each OM scenario in the reference set.

  AR: This plot indeed does show performance metrics across OM scenarios. The dot is the mean and the line segment is the range across OM scenarios. We have revised of the caption to make this clearer.

- I find the panels in Figs. E.26 small and bit fuzzy because of the grey dots (maybe I need reading glasses!). I wonder if a version of this plot without the grey dots might make the location of colour shapes relative to BMSY and FMSY more obvious.

AR: We think it is important to show the raw data as well as the contour lines; however, we will turn the grey dots into much smaller and lighter grey dots that we think detract less from the contours after the review meeting.

REVIEW 2: MEAGHAN D. BRYAN, ALASKA FISHERIES SCIENCE CENTER, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Summary

A management procedure framework was presented for data-limited groundfish species in British Columbia. Management advice is not currently provided for many of these groundfish species. The goal of this framework is to identify management procedures that are robust to key uncertainties and provide catch advice. I found the presentation of the proposed management procedure framework to be well organized, thorough, and overall solid framework. The authors provided a concise review of the current best practices for conducting management strategy evaluations used to identify procedures for providing management advice. They also effectively demonstrated how published best practices were used in the proposed management procedure framework. I also appreciate that the authors identified the main responsibility of each participant group within each step of the framework, which will help to set expectations for input.

This framework could be implemented using a variety of software, but the current implementation relies on the DLMtool (Carruthers and Hordyk 2015) and the MSEtool (Huynh et al. 2019). They are both freely available R packages (R Core Team 2019). The advantage of using the DLMtool is that it was developed specifically to create OMs to test data-limited management procedures (MPs) and contains a large library of data-limited MPs that have been published in the literature.

A case study was also presented to demonstrate how the framework would be implemented.

The topics for discussion below are organized following the headings in the report and are intended to provide feedback about the suggestions and decisions the authors made throughout their document.

1. **Define the decision context**:

   In some management systems, the catch advice from an MP may not be produced annually. Therefore, the catch advice in one year is applied for a few to several years before being updated. I assume that in BC the catch advice from the MP would be updated annually. This should be clearly specified within this step of the procedure as it would either influence how the MP is applied during the projection years or whether implementation error should be included in the OM.

   AR: We have included a bullet in Section 2.1: "How often will the decision be evaluated and updated?" and a note in Section 2.4 about the importance of considering the period of time for which MPs will be left in place.

2. **Selection of objective and performance metrics**:

   The authors suggest using a suite of provisional performance metrics that address conservation and economic objectives. The conservation performance measures are appropriately guided by the objectives of the *Fisheries Act*. The suggested economic objectives are standard to many MSEs and address concerns about catch variability over time and reflect short-term and long-term objectives. The list of proposed performance metrics is an adequate starting to point to base discussions for other potential metrics, but as the authors note participation by industry, fisheries managers, science, and NGOs is crucial to ensure a comprehensive suite of performance metrics is developed.

AR: Please also see our responses to Reviewer 1 Comment 5.

Performance metrics represent specific objectives and are partially defined by the time period in which they cover (i.e., short- and long-term) and is relative to the total length of the simulation. The total length of the simulation should be based on the generation time of the species or some time frame that reflects a point in which the projected stock size reaches a point of relative stability or equilibrium. The suggested definition for long-term appropriately uses generation time and specifically states that long-term is a “minimum of 1.5-2 generation times or 50 years”. I am not in disagreement with these definitions, but justification for this suggestion is lacking in the document. Did preliminary simulations indicate that relative stability in the projections was most often achieved at 50 years when 1.5-2 generations was less than 50 or was this based on the experience of other published data-limited MSEs?

AR: We added text to Section 3.2. We added two references (DFO 2009 and 2013) to justify choice of 1.5 to 2 GT. We also noted that we chose 50 years as a period that should result in stable performance for shorter lived stocks and added references to the case study and three published studies. We added the example of Inside Yelloweye Rockfish for a longer period used for a longer lived stock. We suggested that preliminary simulation testing may be needed to evaluate stability in projections.

Short-term performance metrics were defined for economic objectives, but not conservation objectives. This is not uncommon; however, short-term conservation metrics can be important and informative for stocks that are assumed to be severely depleted. The authors indicate that performance metrics are customizable and can be defined for such objectives. Including some discussion about why and when short- or mid-term conservation metrics should be used would be beneficial for report completeness.

AR: We have added a note about this and an example in Section 3.2.

Equations for the performance metrics calculated over replicates and over time were not provided, but were described. An example equation, would be beneficial to clarify the description.

AR: We have provided an example equation for LT LRP and also an equation for AADC. We have provided several updates to Section 3.2 to improve clarity and address comments by both reviewers.

3. **Uncertainty and operating model specification**:

The outlined considerations for operating model(s) specification is thorough. Examples of key uncertainties are put forth and the reasoning behind why and how different uncertainties would be split between a reference set and robustness set of OMs is clear.

The OMs within the DLMtool will be used as part of the MSE. Uncertainties related to population dynamics, fishery dynamics, observation dynamics, and management implementation can be accounted in the DLMtool. One aspect of the DLMtool that was not specifically addressed in the document is that the uniform distribution is the default distribution describing parameter uncertainty in the OMs (Appendix B, Carruthers and Hordyk 2018). Drawing from a series of uniform distributions without correlation structure between parameters could lead to unrealistic parameter combinations and over-estimate uncertainty. Although this could be viewed as a conservative approach that may lead to a greater number of MPs being eliminated leaving the most robust for consideration. However, when evaluating the trajectories of individual replicates if these outliers are numerous they may overshadow the performance of the MP. Have the authors considered the implications of this default model assumption and whether there is a need to modify these assumptions?

AR: Please see our response to Reviewer 1 Comment 11. Covariance among parameters is included in some cases, and is also included when parameters are updated by the SRA. For parameters where there is a large amount of uncertainty, the default assumption of uniform distribution makes the most sense. For parameters to that results are sensitive, alternative OM Scenarios should be developed. Please also see our responses to Reviewer 1 Comment 8.

The authors suggest using stock reduction analysis (SRA) to condition the operating model on observed data. This step is often not possible for many data-limited situations. SRA has been used to assess data-limited species and has also been used as a complement to more traditional, complex stock assessments methods (Walters et al. 2011). As such, using SRA to condition the OM for BC groundfish species is an improvement upon using an unconditioned OM and is appropriate for this group of species.

Identifying candidate management procedures:

A sensible approach to choosing an initial set of MPs was suggested. BC groundfish are managed by quotas; therefore, the authors chose MPs that provide catch advice. Data availability/requirements and the knowledge to support MP assumptions were also factored into the decision making process. They therefore concentrated on index based and constant catch empirical MPs and surplus production model based MPs.

Many of the empirical MPs that were chosen have default parameterizations that were intended for severely depleted stocks and must be tuned to reflect the perceived status of the type of species being evaluated. The authors correctly suggested that the empirical MPs be tuned to reflect the perceived status of BC groundfish stocks.

The authors also suggested to include reference MPs to demonstrate maximum rebuilding rates under a no fishing scenario, a perfect information scenarios fishing at Fmsy, and status quo scenarios to understand how a default management strategy would performed compared to the other chosen MPs. I agree that reference MPs should be included and follows current best practices for MSE.

The authors provide reasons for not including length based metrics even though there is a substantial amount of length data from the fishery-independent survey. Length-based MPs are often used when there is a lack of survey data. In addition to the issues with simulating messy composition data, studies have shown that index based MPs generally meet conservation metrics with higher probability than length based metrics (e.g., Sagarese et al. 2018). Hence, I agree with the decision to not include them for consideration.

AR: Thank you. We have added a citation to Sagarese et al 2018 to Section 3.4.

4. **Simulation of the application of management procedures**:

A key aspect of the simulation procedure of any MSE is knowing how many replicates to run. In some situations, run time is the main determinant. The DLMtool is an efficient platform and runtime is generally not an issue and convergence can be examined by comparing the consistency of the individual performance metrics as the number of replicates increase. This is a reasonable approach.

The time-series visualization (Figure 9), which plots the historical and projected biomass, fishing mortality, and catch may also be used as a diagnostic check. If many of the individual trajectories are wildly different this could reflect issues with the sampled parameter space.

AR: We have added some text to Section 3.6.2 in the reference to these figures.

Another important aspect of MSE is the decision making process. The authors suggest using an iterative satisficing approach, where performance metric targets are used as criteria for eliminating MPs from consideration. This is a sensible step to streamline the decision making process to identify the best performing MP.

5. Presentation of results and selection of management procedure:

There is a fine line between presenting too little or too much information when trying to identify a single, best performing MP that will be used to provide management advice. Overall I found that the provisional visualizations achieved their intended goal. Figure 5 is a concise summarization of information crucial to the decision making process. The conditional color formatting of the probabilities and suggested sorting clearly shows the trade-offs among the performance metrics, but more importantly helps to visually rank and identify the top performing MPs that should be seriously considered for implementation. Figure 6 was the least helpful visualization to me, but it does show the range of achieved probabilities across scenarios which is informative.

Regarding visualizing the performance trade-offs, I prefer Figure 8. Figure 8provides a full comparison among all performance metrics. Would this plot be created for each scenario as is suggested in Figure 7 or is would average metric used when creating the radar plots? The bivariate plot in Figure 7 is useful and helps to identify the trade-off between two variables. I can envision that the bivariate plots could become overwhelming and less informative if many comparisons between performance metrics are made. Is the intention to use the bivariate plots to compare the trade-offs between the most important conservation objective with the most important economic objective? If more than 3 performance metrics are used, I suggest using the bivariate plots to highlight the top two or three most critical performance metric to evaluate their trade-offs and to facilitate the final decision making process.

AR: In the Rex Sole case study and also the Inside Yelloweye Rockfish application (Haggarty et al. 2020), we averaged across OM scenarios for the visualisations presented in Figs 6–8 for the reference set, and showed individual OM scenarios for the robustness set. However, in other applications of the framework, there may be a desire to also see individual plots for the reference set, depending on the contrast among OMs. We agree that the trade-off plots should be between a subset of performance metrics of primary interest, perhaps representing the most important trade-offs. In the Rex Sole case study we show the trade off between the primary conservation metric and short term catch, the two metrics used in the satisficing screening steps.

While radar plots (Figure 8) are sometimes a compelling means of presenting multiple performance metrics at once, we had also cited studies outlining some of their shortcomings in Section 3.6.2. The Inside Yelloweye Rockfish Rebuilding Plan (Haggarty et al 2020) shows particularly challenging realisations of radar plots. For these reasons we also presented the dot and line and two-way trade-off plots. The framework is completely open to inclusion of new visualizations that better present this multi-dimensional information.

I agree with the reasoning for producing Figures 9 and 10. They clearly demonstrate how the underlying OM assumptions can lead to a range of performance for each MP. I particularly think they are useful for determining whether other short-term performance metrics are needed, as the authors state in the document. Figures 12 and 13 are useful for understanding the trade-off between B/Bmsy and F/Fmsy. Plotting the trajectory over time in the Kobe plot in Figure 13 also highlights how often the stock falls with the critical, cautious, or healthy zone for each MP. The long-term probability of being in the healthy zone may meet the criteria of long term conservation metrics, but if early in the time series the stock is

in the unhealthy zone another MP may be preferred in the short term and a phased in approach to MP may be needed. This comparison would help facilitate this decision.

AR: This is a good point and we have added text in Section 3.6.2 highlighting that this plot presents another diagnostic check that may lead to the addition of new performance metrics (e.g., shorter term conservation metrics). We think it is an interesting idea to phase in a new MP as the projection period progresses but suggest that it would need to be treated as a new "double MP" and be simulation-tested like any other MP. We have not added this suggestion to the working paper, but think it is a worthwhile discussion point for the review meeting.

6. Rex sole case study

This case study was presented to demonstrate the implementation of the MP framework. It was not intended to provide management advice. Therefore, the steps taken to conduct this MSE were not done in collaboration with the identified participant groups in section 3. Regardless, the steps taken to complete the MSE followed the guidance provided in section 3.

AR: Please see our response to Reviewer 1 Comment 13.

The reference set of OMs included a number of reasonable key uncertainties that should be considered. It is assumed that the commercial fishery and the survey have the same selectivity and it was assumed that this matched the maturity ogive. The lack of length data from the fishery seems to make this assumption a necessity; however, is this assumption justified? Do they fish in similar areas with similar gear? Would the targeting behavior of the commercial fleet for other species result in different selectivity patterns for the survey and fishery. In the future, it may be worthwhile to consider and include an OM scenario where the fishery and survey selectivity differ.

AR: We agree that selectivity is a key uncertainty, both in our Rex Sole case study and for data-limited species in general. While we did include an alternative representation of selectivity in one OM scenario, we did not consider a scenario with separate selectivities for commercial and survey fleets, which we could have done, perhaps informed by relative length compositions in each fleet.

We did consider alternative selectivities for survey, commercial and recreational fleets for the Inside Yelloweye Rockfish application (Haggarty et al 2020), and considered survey selectivity to be a major source of uncertainty. We note that even with information about different hook sizes in the two longline surveys used for this species, it was not possible to resolve differences in selectivity between the two survey fleets, highlighting the challenge of providing plausible selectivity estimates for data-limited species.

The robustness set includes two OMs to evaluate the effect of assumed equilibrium catch and the other has time-varying natural mortality to represent the impact of climate change on the stock. Both are important uncertainties to consider. Developing an OM that considers greater uncertainty in the catch may also be worthwhile. On-board and dockside observer coverage has been 100% since 1996 for this fishery. There is no indication that this program would change in the future, but an interesting robustness OM would be to apply implementation error to the catch in future years. This would demonstrate the value of catch information. In addition, it would find an MP most robust to an unexpected change (e.g., reduced coverage due to health safety concerns over time) in this important source of information.

AR: We agree that implementation uncertainty is an important dimension of uncertainty to consider. In general, post-1996 catch data from BC groundfish fisheries is considered reliable, as is longline catch data post-2006 (when 100% at-sea electronic monitoring (EM) was introduced). However, observer coverage may change, or be interrupted at times: the COVID-19 pandemic has presented an example of this, where some of the trawl fleet is trialling EM in the absence of at-sea observers due to safety concerns. For some species that are important recreationally or to First Nations, there may be other uncertainties associated with catch data.

AR: We appreciate the recommendation and think that implementation error scenarios concerning catch reporting should be developed in collaboration with fishery managers, including First Nations managers, and the commercial or recreational industry, as appropriate to the stock.

We have added a note about this in Section 3.3.

The identified candidate procedures consisted of a reasonable list of constant catch, index-based, and surplus production MPs. Several tuning options for the Itarget, Islope, and GB slope MPs were presented. The target index (Itarget) MP performed quite well, whereas Islope and GB slope were eliminated because they did not meet the threshold probabilities set forth by the satisficing rules. Would Islope and GB slope performed better with additional tuning? Was the difference in performance because how these MPs scale recent catch through tuning or is it because recent catch is not defined in the same way across the MPs? This would be a worthwhile discussion when identifying the shortcomings of individual MPs.

AR: It is quite possible that performance of several MPs could have been improved with more tuning but instead we illustrated these MPs over a range of tuning parameters. In applications of the framework we suggested fine-tuning MPs to achieve desired performance in the Discussion (Section 5.2). We have added a citation to Sagarese et al. (2018) in Section 5.2.

The convergence statistics for the increasing M robustness OM are missing for STC and AADC in Figure E.12. Were the values less than what is shown on the scale of the y-axis (0.4-1)?

AR: We assume the reviewer is referring to LTC not STC. Indeed, the values are off the y-axis scale in this case. We have added the following text to the caption:

"Note that in the 'M increasing' OM scenario the LTC and AADC metrics do not appear because they are below the lower y-axis limit (or perfectly at 1 in the case of AADC and NFref)"

The presentation of the results utilized all of the provisional visualizations. The authors suggest that Figures E.13 and E.14 provide the basis for decision making and present the average and minimum performance metrics, respectively, across OMs. I agree that these figures provide the best overview of the key trade-offs among the performance metrics and the ranking of the MPs. These same tables for the robustness OMs should also be considered during the decision making process. Without considering the robustness OMs, the constant catch MPs seemed to perform quite well; however, when assuming the stock was lightly fished or experiencing increasing natural mortality, the performance of the constant catch degrades. Performance with respect to LT LRP and LT USR of the constant catch MPs may be an overestimate. The constant catch MPs rely on historical catch data to derive the catch advice which is not updated based on feedback from the system. The time series plots show that catch remains high as biomass declines. When the catch advice is greater than stock biomass the DLMtool code prevents the stock from going extinct. This

would not happen in practice; therefore, consideration of constant catch MPs should be done with caution. When implementing this framework to provide management advice, as the authors state in other sections, the discussion should also consider these time series plot in addition to the probability tables.

AR: We agree that robustness set results are an important component of the decision-making process. For Rex Sole, the tables are provided in Figure E.28.

The reviewer makes a good point that these plots are also important for indicating MPs, such as constant catch MPs, that would cause extinction of the stock, even though the behaviour would be masked by long-term average metrics. We have added some text to Section 3.6.2.

Reassessment frequency and triggers

I was glad to see that the issue of reassessment frequency was addressed in the discussion. I agree with the authors that the MSE framework can be used to evaluate the frequency of re-assessment or can rely on an informal evaluation process. This management procedure approach is meant to increase the efficiency of providing management advice for non-target species. Efficiency gains could be lost if reassessment frequency is left open ended or designated as an informal process due to the time it takes to prepare the logistics for these meetings. Therefore, identifying an optimal reassessment frequency through simulation with the intention of retaining efficiency of the data-limited assessment system is recommended.

Assessing the value of information

Understanding the value of information is incredibly important for justifying current data collection programs and the need for potential data improvements. I agree with the authors that the proposed MP framework can be used to conduct this type of evaluation. Additional performance metrics measuring the relative cost of collecting data and processing data and benefit of gains in catch will be important to consider.

AR: This is a good point. We have added some text at the end of Section 5.5.

Rebuilding plans

Determining when a rebuilding plan should be triggered using a data-limited framework is indeed a challenge. The suggested decision rule, “if calibrated OMs overwhelmingly place a fish stock in the Critical Zone across a range of plausible OM assumptions, this could be grounds for triggering a rebuilding plan” is seemingly reasonable. A probability assigned to “overwhelming” should be determined while developing performance metrics and will be dependent on the risk tolerance of the group.

AR: This is a good point. We have removed the term “overwhelming” and replaced it with “high probability” as well as a reference to new guidance on rebuilding plans in light of recent legislative changes regarding rebuilding plans. We stop short of recommending a particular probability as rebuilding guidance is still being developed. Instead we suggest that results can contribute to a “weight of evidence” approach to deciding whether a rebuilding plan should be triggered.

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APPENDIX E: MEETING PARTICIPANTS

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