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Proceedings of the Pacific Regional Peer Review on the Application of the Management Procedure Framework for Outside Quillback Rockfish in British Columbia in 2021

May 29-30, 2023
Virtual Meeting

Chairperson: Ben Davis
Editors: Yvonne Muirhead-Vert and Olivia Gemmell

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Foreword

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

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on May 29-30, 2023 via the online meeting platform Zoom. The working paper presented for the peer review was written to provide scientific advice to support management of Outside Quillback Rockfish (*Sebastes maliger*), and applied the Management Procedure (MP) Framework (Anderson et al. 2021) to evaluate the performance of index-based and constant catch MPs to meet policy and fishery objectives.

Participation included DFO Science, Fisheries Management, and external participants from Blue Matter Science Ltd., Landmark Fisheries Research, Maa-nulth First Nations, Ha'oom Fisheries Society, Interface Fisheries, Nuu-chah-nulth Tribal Council (NTC), Washington Department of Fish and Wildlife (WDFW), Pacific Halibut Management Association, and Central Coast Indigenous Resource Alliance (CCIRA).

The meeting participants agreed the working paper met all of the Terms of Reference objectives and the paper was accepted with minor revisions. The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) providing advice to the Groundfish Management Unit (GMU) to inform harvest advice for the Outside Quillback Rockfish fishery in accordance with the DFO Precautionary Approach (DFO 2009), and the legislated Fish Stock Provisions of the *Fisheries Act*. The advice will also inform the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reassessment of Quillback Rockfish status. The Science Advisory Report and the supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) meeting entitled *Application of the Management Procedure Framework for Outside Quillback Rockfish in British Columbia in 2021* was held on May 29-30, 2023 via the online meeting platform Zoom. The working paper (listed below) was reviewed during the RPR meeting.

The [Terms of Reference (TOR)](#) (Appendix A) for the science review were developed in response to a request for advice from DFO's Fisheries Management Branch. Invitations to the science review and conditions for participation were sent to representatives with relevant expertise from DFO Science and Fisheries Management staff as well as from the Washington Department of Fish and Wildlife (WDFW), First Nations, the commercial and recreational fishing sectors, environmental non-governmental organizations, and consultants.

The following working paper was prepared and made available to meeting participants prior to the meeting (the working paper abstract is provided in Appendix B). The paper will be developed into a Research Document and posted on the CSAS website.

Huynh, Q., Siegle, M.R., and Haggarty, D.R. Application of the Management Procedure Framework for Outside Quillback Rockfish (*Sebastes maliger*) in British Columbia in 2021. 2023. CSAP Working Paper 2016GRF02b.

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

The Chair reviewed the agenda and the [Terms of Reference](#) for the meeting, highlighting the objectives and identifying Olivia Gemmell as the Technical Rapporteur for the meeting and Yvonne Muirhead-Vert identified as the Rapporteur for the revisions table. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. The virtual meeting was held on the meeting platform Zoom, where audio and text conversations were conducted and recorded. Members were reminded that everyone at the meeting had equal standing as participants and that they were expected to contribute to the review process if they had information or questions relevant to the paper being discussed. In total, 25 people participated in the RPR (Appendix D) over the two-day meeting.

Prior to the meeting, Kathryn Meyer (WDWF) and Divya Varkey (DFO Science) were asked to provide detailed written reviews of the working paper to assist everyone attending the peer review meeting. Participants were provided with copies of their written reviews ahead of the meeting.

The conclusions and advice resulting from this review will be used to inform fisheries managers on harvest advice for the Outside Quillback Rockfish fishery in accordance with the DFO Precautionary Approach (PA; DFO 2009), and the legislated Fish Stock Provisions of the *Fisheries Act*. The Outside Quillback Rockfish assessment will be used in conjunction with the Inside Quillback Rockfish assessment to inform the Committee on the Status of Endangered

Wildlife in Canada (COSEWIC) reassessment of Quillback Rockfish status. The Science Advisory Report and supporting Research Documents will be made publicly available on the Canadian Science Advisory Secretariat website.

GENERAL DISCUSSION

Following a presentation by the authors, the two reviewers, Kathryn Meyer (WDFW) and Divya Varkey (DFO Science), shared their comments and questions on the working paper. The authors were given time to respond to the reviewers before the discussion was opened to all participants. This proceedings document summarizes the discussions that took place by topic, with points of clarification presented by the authors in their presentations, and questions and comments raised by the reviewers and participants captured within the appropriate topics. Both reviewers' formal submissions are located in Appendix C.

TERMS OF REFERENCE OBJECTIVE ONE

Based on the discussion on high level strategic objectives identified at the 2021 workshop (Haggarty et al. 2022), develop quantitative objectives to be evaluated with performance metrics.

Quantitative objectives: A point of clarification was raised to refine the following statement, '*Maintain the stock above the LRP/USR during two generations with at least 75/50% probability of success*' since there is some room for interpretation. The reviewer suggested that the wording could be altered by stating whether the objective is to achieve the respective minimum probability that the stock *never* falls below the limit reference point (LRP) or upper stock reference (USR) over two generations, or that the mean over the projected time series is above the LRP or USR with at least the minimum probability. The authors have agreed to add some text to provide clarity to the reader that the latter definition was used.

TERMS OF REFERENCE OBJECTIVE TWO

Develop and assess a suite of operating models (OMs) and describe the uncertainties the OMs are meant to address.

Operating Models (OMs): The authors presented five operating models that were developed for Outside Quillback Rockfish. The reference set included mean natural mortality scenarios (M=0.056 and 0.046), a low recreational catch scenario, and two robustness sets including a lower steepness scenario, and a lower than average recruitment scenario.

Robustness OM: A reviewer suggested that the authors develop another robustness OM to monitor changes in population dynamic parameters over time and to explain how these data would alert fishery managers, if the assumptions in the model were not met. The authors noted that this was implicitly done, i.e., the stock-recruitment relationship had been already implicitly modeled to be less productive in the projection compared to the historical conditioning for OM (B).

Model diagnostics from the conditioning step: A negative retrospective pattern was observed in OM(1) indicating that the estimated stock would become larger as more data is added to the model. However, the extent of the pattern was not large enough to warrant a concern. The authors were not surprised by this pattern since it could be related to a data quantity issue (i.e., there are only two years of Hecate Strait (HS) age structure data). More research is needed on how to treat the model diagnostics for a data limited stock.

When M is freely estimated it goes towards 0.09, potentially informed by a better fit within the plus group. An alternative fit with age varying *M*, descending with age, was explored but did not significantly alter biomass estimates. The authors noted that the most appropriate pattern between *M* and age may be U-shaped.

Spatiotemporal modeling of hard bottom longline (HBLL): Spatiotemporal modelling of HBLL data provides a coastwide index for abundance (i.e., the north and south regions are stitched together). The model can take into account the spatial irregularities in the sample design and habitat variables for the abundance index.

A participant indicated that they do not fully support the approach of stitching north and south regions together and prefer to use the original indices and to keep north and south separate. They recommended using a robustness set may be a better approach instead of stitching. An author replied that the north and south survey areas do not align with the northern and southern areas in the operating model and that stitching the surveys together addresses this spatial mismatch.

Synoptic Hecate Strait (HS) trawl survey: the HS trawl survey appears to be catching younger fish compared to the bottom trawl fishery. A participant asked if the fishery selectivity is age or length based. The authors indicated all the fisheries and surveys are age based, with the exception of the trawl survey, which is length based. The trawl survey is picking up smaller fish in shallower water that are not yet vulnerable to hooks on the longline surveys.

Internet Recreational Effort and Catch (iREC): The authors noted the catch rates were higher between the iREC reporting program compared to the creel survey for Quillback. The conditioned Operating Model, OM(3)(low iREC) is 50% lower than what is estimated for the true recreational catch.

The authors indicated that this discrepancy did not have a huge impact on the results in this assessment since recreational catch is much smaller than commercial catch. The authors have agreed to report the recreation catch in tonnes, in addition to pieces, to easily compare with the commercial catch.

Stock Synthesis Model: A reviewer requested the inclusion of the SS3 control file, data files, and a table of equations in Appendix D or as a hyperlink. The reviewer wanted the ability to reproduce the model while other members of the group preferred schematics to use as a visual guide on how the model functions instead of having to review the code. A discussion occurred on the possibility of having the control and data files on either GitHub or Zenodo. In the end, the authors agreed to include a table of equations, and schematics for SS3 and OpenMSE in the working paper.

Some participants wanted more detail on parametrization choices and sensitivity and diagnostic tests. Another participant requested that a summary table of the SS3 parameters be included in the working paper to provide clarity on which parameters in the model are fixed and which are estimated. It was also suggested that the table would include the OM input parameter distributions with their source (i.e., estimated from data). The authors have agreed to include this table.

MSEtool: Some questions were asked regarding the clarification on how the 200 management strategy evaluation (MSE) samples were brought into the MSEtool. The authors explained that the multi-OM feature (with multiple populations and fleets) of MSEtool was used. The two areas were imported to be distinct populations with identical dynamics to what was modeled in SS3. A question was raised on how the data from multiple fleets can be transformed into a single fleet. The authors explained that they used F at age to get the effective selectivity and kept the selectivity constant in the projections. It was recommended that the authors generate a figure showing this configuration.

SS3 residual bubble plot: The authors generated a SS3 residual bubble plot in the evening of the first day to satisfy questions raised by the reviewers. A reviewer wanted to look for systematic patterns in the cohorts and age classes using colour. The group agreed that a coloured heatmap of the plotted age data residuals would be included in the working paper. Other members of the group suggested that a quantile plot or figures of the fisheries could be helpful to visualize the age data.

Data: A participant asked why this assessment is for 2021 since the advice is two years old and may not be relevant at this time. The authors explained that this assessment began in the middle of 2021 and they had to make a decision on where to cut off the data for the analysis. Some human resource challenges also contributed to the delay in completing this analysis. The authors offered to make an edit in the Research Document to provide a stock status update to the beginning of 2022. This edit would not change the overall outcome of the working paper.

Limited aging data resulted in unrealistic trends in the stock history when the values for h and M were estimated. Therefore, the authors decided to fix the values for h and M to produce more realistic results in the OMs. Concern was raised that if the fixed parameters were inappropriate, then the model and its projections are incorrect. The participant wanted to address some of the fundamental data issues before addressing the environmental correlations.

Data limited versus data rich species: A discussion occurred on the differences between a data limited species versus a data rich species. Few species in groundfish are truly data limited (in comparison to some taxonomic groups) but there are major data gaps in ages and the time series for fisheries independent surveys. The time series is relatively short for a long-lived species such as Quillback, and does not include the period of high exploitation that occurred in the 1980s and early 1990s.

Data weighting: The question was raised on why the authors used the McAllister and Ianelli (1997) method over the Francis method (2011, 2017) when down weighting the age composition data relative to the indices. In this assessment, the harmonic mean instead of the arithmetic mean was used, which provides similar weighting factors to the Francis method. To generate a good fit to the survey age data, the authors down weighted the hook and line mean weight data by 0.01 and for the Fishery-Independent Setline Survey of the International Pacific Halibut Commission (IPHC FISS) data. Sample size and age were also down weighted. The authors have agreed to add more explanation and include figures with residuals to the working paper. Future work could include looking at the high estimate of *M* as robustness.

200 simulations: The question was raised regarding the uncertainty around the B_{MSY} estimates for each OM. The authors explained that 200 simulations were run and Table 3 in the working paper provides the estimates for maximum sustainable yield (MSY). The authors have agreed to add the estimated LRP and USR and their ratios relative to B_0 to Table 3.

Markov Chain Monte Carlo (MCMC): The parameters in the MCMC plots were the only ones freely estimated. A participant noted that it would be beneficial to include this information in future reviews.

Comparison of design-based versus geospatial index: The authors presented a figure comparing the design-based versus the geospatial index showing the habitat variables, which excluded the hook competition since it flattened out the trend. The benefit of using the geospatial index is that variables can be included in the standardization.

The figure presented to the group showed the residuals of the geospatial index, although the models could not be compared using Akaike information criterion (AIC) between models with and without hook competition. The authors noted that there were no issues in the residuals.

Implementation error: It has been estimated that food social and ceremonial (FSC) catch from dual fishing trips makes up 1–5% of the total commercial catch (see Table C.10 FSC catch [t] of Outside Quillback Rockfish as a proportion of total commercial catch). A reviewer expressed concern that total catch was underestimated due to unreported FSC catch, wondered how much was occurring outside of the dual fishing trips, and asked whether perfect implementation of the catch advice in the simulations of the management procedures was appropriate. The authors agreed to provide more of an explanation for perfect implementation in the model with FSC in the working paper. They felt that the magnitude of unreported FSC catch was likely to be low given the available data and did not model catch implementation error. A participant suggested that it may be possible to obtain Quillback data from the Maa-nulth First Nations' database. A recommendation will be added to the future work section of the Research Document to explore other sources of FSC catch data in collaboration with Indigenous organizations.

Sources of uncertainties: The sources of uncertainty for this assessment included the age samples, survey index, FSC catch, the effects of environmental conditions on the OMs, and historical catch. Although a reconstruction algorithm for historical catch is followed, it remains a major source of uncertainty.

TERMS OF REFERENCE OBJECTIVE THREE

Consider environmental conditions that may affect the stock as presented in the Guidelines for Implementing the Fish Stocks Provisions in the Fisheries Act.

Fish Stock Provisions: This analysis estimated a 99% probability that the stock in 2021 is above the limit reference point (LRP) of 0.4 B_{MSY} and above the upper stock reference (USR) of 0.8 B_{MSY} across the three reference OMs. In Table 1, the authors have agreed to add ratios of the LRP and USR relative to B_0 to show the comparison between alternative reference points.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC): In this assessment, there is a high probability that the stock has declined by 30% in the last 81 years when the three reference OMs are averaged. The findings from this Research Document may be used to inform COSEWIC's next assessment in conjunction with the recent Inside Quillback assessment.

Ecosystem Considerations: The reviewers suggested that the discussion on climate change could be expanded and, where possible, trends in the biology could be drawn from large ecosystem models. The authors agreed to include more discussion on environmental conditions that cause changes to natural mortality in the overall population, and the potential impacts of predation on juveniles through the robustness OM. They will include the following studies: English et al. 2021, Schroeder et al. 2019, Perryman et al. 2021 and Howell et al. 2021 to strengthen this section of the working paper. An author noted that the groundfish (GF) Synopsis document will be used to monitor changes in life history parameters and survey indices over time. It was suggested that future work consider non-stationarity parameters in the MP framework since these parameters are likely to change in the future.

TERMS OF REFERENCE OBJECTIVE FOUR

Recommend candidate reference points including a limit reference point (LRP) and upper stock reference point (USR) consistent with the DFO Precautionary Approach. Additionally, *characterize the stock status relative to the LRP, USR, and if possible, B_{MSY} and B_0 for each OM and aggregated across OMs.*

Reference points: The provisional DFO limit reference point (LRP) of 0.4 B_{MSY} and the upper stock reference (USR) of 0.8 B_{MSY}, as recommended by the DFO Precautionary Approach policy, were used for this assessment (DFO 2009). The authors mentioned that they wanted to capture some of the discussion points that were raised with the technical working group on reference points in the working paper. They also noted that the technical working group did not cover all the issues that were covered in this CSAS meeting.

A reviewer asked the authors to add a table of depletion levels that correspond to the LRP estimates in all OMs besides the base OM to provide insight on how M, recruitment steepness, and growth affect the LRP with regards to unfished stock levels. The authors agreed to add this table to the working paper. The reviewer also suggested the authors could generate another OM to show the change of the LRP on unfished stock levels but the authors noted that this was explored during the technical working group and not further considered.

The authors were asked to describe the Quillback population dynamics that allow this slow growing species to have a high resilience to depletion (i.e., why 0.4 B_{MSY} = 0.12 B_0). The authors indicated that fishery selectivity of some immature fish contributed to the skew in the yield curve, as described in Section 4.3.4.

Lastly, a participant asked for a more in-depth description of how recruits were assigned to each of the two areas and their decision-making process. The authors agreed to add text to the working paper and will provide insight on how these assumptions influence the models.

Target reference point (TRP): A reviewer asked if a TRP is used to support the management of the stock. The authors indicated that it was beyond the scope of this science advice request but a TRP will be determined in the next phase of the process led by GMU.

TERMS OF REFERENCE OBJECTIVE FIVE

Propose a set of candidate management procedures (MPs) and test the candidate MPs across the suite of OMs using a closed-loop simulation.

Quantitative objectives and performance metrics: A suggestion was made to include a short-term growth performance metric in the MP to evaluate the relative growth of the stock. Projections from this metric would determine if the stock is increasing, staying the same, or decreasing in the short-term. These projections would complement long-term performance metrics within the MP. The authors indicated that short-term biomass performance metric was initially explored but was not included in the analysis. Growth is well-estimated in the working paper and was not part of the axis of uncertainty. The other nine metrics were included in the MP instead. The authors agreed to add the short-term metric in a summary table and some text in the discussion.

Another suggestion was to incorporate the mean age of the population as a metric to show changes in the population age-structure. This metric could be used as a warning signal to complement other signals of population decline. However, mean age can also decline due to strong recruitment events so may not always be indicative of population decline.

A reviewer suggested the authors look at mean length-at-age over time. The authors indicated that no directional change was readily apparent in mean length-at-age, but also noted that they do not regularly have the age data near the origin to estimate T_0.

MPs: The authors presented a suite of constant catch MPs, index-based MPs, and reference MPs (no fishing removals and F_{MSY} reference) were developed and explored in this assessment.

All candidate MPs except one met the three conservation objectives under the OM reference set scenarios. It was suggested that a couple of the figures from Appendix F on the closed loop projections would useful to be included in the main body of the document as well as in the SAR.

The robustness set MPs that performed poorly were the fixed catch MP and RecentCatch MP since they did not meet the F_{MSY} criterion and thus one of the PA policy criteria. The authors explained that robustness tests demonstrate how the MPs will behave in a given scenario. The test provides information on the behaviour of the MP rather than a forecast of what will occur in the future.

A reviewer requested a brief description on the preferred MP that will be selected. The authors indicated that this request is out of scope for this assessment. GMU will select the preferred MP based on the findings from the Research Document and the guidance provided in the Science Advisory Report (SAR).

Fits to the indices: There was a lengthy discussion around the fits to the indices. A question was raised on how the HBLL was weighted. Data from the HBLL should be weighted higher since it was designed to index the abundance compared to the design of the Hecate Strait (HS) survey. The authors agreed to include the improved fit to the HBLL data in the Research Document with a discussion of the additional fits. They will also include the new figure with model results when the HS survey was excluded. They noted that the use of IPHC survey for updating index-based MPs was dismissed since it is not very good for Quillback.

A member of the group noted the fit to the indices in Figure 5 showing the maximum posterior density is not good and asked how it could be improved. The author agreed to re-run the data after day one of the meeting and present new figures the next day.

A suggestion was made for Figures F.11 and F.12 to start with the historic catch value at 2021 so all the figures start from the same point rather than using the first year of projection.

A reviewer asked if the fit-to-age and length data could be presented as ratios of predicted proportions instead of proportions in the data since the higher age classes are difficult to evaluate. The authors preferred to present residuals with color plots instead of bubble plots for better visualization. The authors have also agreed to add residual plots for the fisheries in addition to the surveys.

A reviewer requested that a new version of Figure 18 be included in the working paper that shows four horizontal lines representing the LRP, USR, 0.2 B_0 and 0.4 $B_{0,}$ the main metrics the MP projections are evaluated against. The authors have agreed to update this figure with the suggested revision.

Jackknife index series: A summary table of the jackknife index series was presented to the group showing the upweighting factor of HBLL, which produced a better fit for HBLL north but did not improve the HS survey fit. The authors have agreed to include the analysis in the Appendix and add a paragraph in the future research section of the working paper.

F_{MSY}: A reviewer suggested the inclusion of a figure on long-term fishing mortality rates and the estimated value of F_{MSY}. They wanted see the impact of fishing on current F levels compared to F_{MSY}. The authors indicated that Figures 21-23 already capture these comparisons but have agreed to include a panel figure in the main section of the working paper that is similar to the Figure 7 in the Inside Yelloweye Rockfish rebuilding plan (DFO 2020) in the SAR, to show F/ $F_{MSY,}$ B_{MSY}, and catch.

Growth parameters: A reviewer asked how growth was estimated and if mean length-at-age estimations were included in the OMs. The authors explained that growth was estimated separately from SS3. The authors agreed to provide new input tables for the SS3 and openMSE parameters along with a schematic to provide clarity to the reader.

A reviewer suggested presenting the parameter covariance plots for growth parameter estimates in addition to Figure A.6, and a figure similar to A.5, colour faceted by year, to confirm there are no long-term trends in mean length-at-age.

The authors mentioned that the while the residual variance in mean length-at-age is high (coefficient of variation (CV)=0.09), the standard errors in parameter estimates are quite small resulting in a 95% confidence interval. While the authors felt figures with facets over the years could be difficult to interpret due to survey effects and selectivity issues, they agreed to include that figure. It was suggested that future work could include the regular aging of young fish and inclusion of growth parameters in the modelling and uncertainty.

A reviewer asked if it would be useful to compare an additional OM that uses a different trajectory for the growth estimates. The authors believe that growth estimates are quite precise and this section in the working paper is well-described so they did not explore alternative estimates. However, they did agree to provide annual growth estimates from 2006 to 2023 from the HBLL survey.

TERMS OF REFERENCE OBJECTIVE SIX

Review the simulation results and demonstrate potential trade-offs between achieving different objectives under different MPs, including constant catch and index-based MPs.

Index-based MPs: The question was asked if the indices for the North and South HBLL were averaged before being used in the MP. The authors explained that each management procedure provided catch advice separately by area, based on the trend in the corresponding index.

The GF Synopsis report could be used as a formal annual check about index trends for the North and South populations.

Catch curve analysis: Catch curve analysis was used to estimate total mortality (*Z*) from age-structured data. The reviewers asked the authors to provide more context and insight on the change in the shape of the age distribution in the HBLL survey.

The question was raised on how the robustness OM for low recruitment was implemented. The authors explained the mean recruitment deviation is 0.7 instead of 1.0 in the projection. Implicitly, the projected stock recruitment alpha is 70% of the historical alpha. Figure A.10 visualizes the age structure data by showing maturity frequencies by month and summarizing macroscopic classifications of rockfish gonad samples. A link to openMSE will be added to the text to provide details of the stock-recruitment relationship.

Natural mortality (*M*) and steepness (*h*): An estimate for natural mortality could be obtained from a tagging program or a catch curve from an unfished population. A Brownie model can be used to calculate *F* and *M*. However, tag reporting and release mortality, e.g., from barotrauma, may make tagging programs unfeasible for Quillback Rockfish.

Stock-recruit steepness may not be estimated well from a noisy stock-recruitment plot.

Figure 17 shows a summary of uncertainty within and among OMs. A participant requested to see a robust set to see the fit to different data. The authors agreed to generate a plot of M and h for this.

Generation time (GT): The GT for Outside Quillback Rockfish in this assessment was calculated to be 27 years, which is slightly less compared to the 2011 assessment of 32 years.

The GT is based on the natural mortality value of 0.067 and 50% maturity at 8.7 years. The projections were generated over two generations (54 years) for Outside Quillback Rockfish.

Probability tables: A participant asked if it was possible to include a colour bar for scale in the colour-coded probability tables. The authors agreed to this revision.

Tradeoff plots: It was suggested that the trade-off plot captions include axis descriptions, since the plotted variable definitions are complex and only mentioned at the beginning of the document. The authors agreed to this suggestion.

TERMS OF REFERENCE OBJECTIVE SEVEN

Recommend an appropriate assessment frequency and any conditions for exceptional circumstances that warrant re-evaluating the OMs.

Assessment frequency: The authors recommended the OMs be re-evaluated in five to six years through the CSAS Regional Peer Review process, and every two years for the index-based MPs to include new survey data. A reviewer recommended adding more specific examples, especially those that relate to climate change, to the exceptional circumstances section. The authors agreed to add more examples into the working paper. Depending on the chosen MPs from this assessment, more discussions on timelines and process will occur with GMU.

The question was asked why seven years was chosen to assess the fishery since it was not clear in the working paper. A member of the group indicated that participants from the 2021 workshop felt a shorter timescale of seven years would capture the Quillback population turnover rather than using GT (27 years). The authors have agreed to add more text on this shorter timescale in the working paper.

Identification of exceptional circumstances: A reviewer recommended adding more specific examples, especially those that relate to climate change, to the exceptional circumstances section. The group identified the following triggers that could cause a re-assessment: the OMs are not performing as expected, or a visual comparison of projected data versus observed data indicates large discrepancies between the two datasets. Visual comparisons would use the GF Synopsis report’s index as a tool to monitor the changes in age structure, and other life history parameters. Age samples will be collected and submitted to the aging lab on an annual basis. The authors agreed to add more examples into the working paper.

Future Research

Performance metrics: Currently, the MP framework follows different approaches depending on the species. A participant noted that since the MP framework is a relatively new tool, there are some inconsistencies in how the performance metrics are calculated between species. It would be helpful for scientists and/or Fisheries Management to create some commonalities with all *Sebastes* species using the MP framework.

Rockfish Conservation Areas (RCAs): It was recommended that data from the Remotely Operated Vehicle (ROV) survey in 2018 and collected through RCA monitoring be incorporated into stock assessments and OMs. It was noted that only 34 of the 162 RCAs are in outside waters.

Collaborators: It was recommended that DFO continues to work with commercial fishers, recreational fishers, and First Nations to collect catch and biological data.

Other strategic objectives: It was recommended that other strategic objectives that were not directly incorporated in this assessment (i.e., depletion versus MSY reference points) are included in future work.

CONCLUSIONS

The group was shown the revision table and all revisions were agreed upon by the authors. Meeting participants agreed the working paper satisfied all Terms of Reference objectives and the paper was accepted with minor revisions.

RECOMMENDATIONS AND ADVICE

DRAFTING OF THE SCIENCE ADVISORY REPORT

Participants were provided with a draft Science Advisory Report (SAR) that was prepared in advance of the meeting. During the meeting, one of the authors used track changes on the draft SAR to document changes during discussions. The SAR was discussed and participants had the opportunity to contribute to key sections and identify the included tables and figures. At the end of the meeting, a draft SAR was completed. The meeting Chair will work with the authors to finalize the draft SAR. Once completed, the Centre for Science Advice Pacific (CSAP) office will circulate the draft SAR and draft Proceedings (PRO) to all participants for final review and input.

ACKNOWLEDGEMENTS

The Centre for Science Advice Pacific congratulates the authors on the successful paper and appreciates the contribution from all participants. We thank the formal reviewers, Kathryn Meyer (WDFW) and Divya Varkey (DFO Science) for their time, expertise, and providing their formal reviews of the working paper. We would also like to thank Ben Davis for his support throughout the process and as Chair of the meeting.

REFERENCES CITED

Anderson, S.C., Forrest, R.E., Huynh, Q.C., and Keppel, E.A. 2021. A management procedure framework for groundfish in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/007. vi + 139 p.

DFO. 2009. A fishery decision-making framework incorporating the precautionary approach.

DFO. 2020. Evaluation of Management Procedures for the Inside Population of Yelloweye Rockfish Rebuilding Plan in British Columbia. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/056.

English, P. A., Ward, E. J., Rooper, C. N., Forrest, R. E., Rogers, L. A., Hunter, K. L., Edwards, A. M., Connors, B. M., and Anderson, S. C. 2021. Contrasting climate velocity impacts in warm and cool locations show that effects of marine warming are worse in already warmer temperate waters. Fish and Fisheries, 23, 239–255.

Francis, C. 2011. Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: pp. 1124-1138.

Francis, C. 2017. Revisiting data weighting in fisheries stock assessment models. Fisheries Research. 192: pp. 5-15

Haggarty, D.R., Siegle, M.R., Litt, M.A., and Huynh, Q. 2022. Quillback Rockfish Fishery and Conservation Objectives Workshop Summary Report. Can. Tech. Rep. Fish. Aquat. Sci. 3488: viii + 56 p.

Howell, D., Schueller, A.M., Bentley, J.W., Buchheister, A., Chagaris, D., Cieri, M., Drew, K., Lundy, M.G., Pedreschi, D., Reid, D.G. and Townsend, H. 2021. Combining Ecosystem and Single-Species Modeling to Provide Ecosystem-Based Fisheries Management Advice Within Current Management Systems. Front. Mar. Sci. 7:607831.

McAllister, M.K., and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and 1214 the sampling/importance resampling algorithm. Can. J. Fish. Aquat. Sci. 54: 284–300.

Perryman, H.A., Hansen, C., Howell, D., and Olsen, E. 2021. A review of applications evaluating fisheries management scenarios through marine ecosystem models. Reviews in Fisheries Science & Aquaculture, 29:4, 800-835.

Schroeder, I.D., Santora, J.A., Bograd, S.J., Hazen, E.L., Sakuma, K.M., Moore, A.M., Edwards, C.A., Wells, B.K., and Field. J.C. 2019. Source water variability as a driver of rockfish recruitment in the California Current Ecosystem: implications for climate change and fisheries management. Can. J. Fish. Aquat. Sci. 76: 950–960.

APPENDIX A: TERMS OF REFERENCE

Application of the Management Procedure Framework for Outside Quillback Rockfish in British Columbia in 2021

Regional Peer Review – Pacific Region

May 29-30, 2023
Virtual Meeting

Chairperson: Ben Davis

Context

Quillback Rockfish (*Sebastes maliger*) are a wide-spread marine fish that occur in British Columbia's (BC's) coastal waters. Quillback Rockfish are targeted in hook and line commercial fisheries, Food, Social and Ceremonial fisheries, and recreational fisheries.

Fisheries and Oceans (DFO) manages two Quillback stocks: an inside stock that occupies the waters in Queen Charlotte Strait, the Broughton Archipelago and the Salish Sea, and an outside stock that corresponds to all other waters in BC. In 2009, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed Quillback Rockfish as one coast-wide stock, comprised of both inside and outside stocks, and designated as threatened. While a decision by Governor in Council to list this species under the *Species at Risk Act* (SARA) is still pending, COSEWIC is still required to review the classification of each species at risk every 10 years (s.24 of SARA). In order to support implementation of SARA, updated scientific information and advice on the current status of these two stocks is required.

DFO Fisheries Management (Groundfish Management Unit; GMU) requested that Science Branch review existing fishery, biological and survey data to recommend candidate reference points for outside Quillback Rockfish, and, if possible, to provide guidance and rationale on alternative reference points to the provisional maximum sustainable yield (MSY)-based reference points. The analysis and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR), will be used by GMU to inform harvest advice for the Outside Quillback Rockfish fishery in accordance with the DFO Precautionary Approach (DFO 2009), and the legislated Fish Stock Provisions of the *Fisheries Act*. Quillback Rockfish are currently being considered as a major stock within the Sustainable Fisheries Framework. The Outside Quillback Rockfish assessment, together with the previously CSAS peer reviewed Inside Quillback Rockfish assessment[1], may inform the COSEWIC reassessment of Quillback Rockfish status.

DFO Science will be following the Management Procedure (MP) Framework to provide advice to fishery managers. The MP Framework uses closed-loop simulation to evaluate the robustness of management procedures to achieve fishery and conservation objectives across plausible states of nature (Anderson et al. 2021). This approach is particularly well-suited for stocks with major uncertainties in stock dynamics, such as outside Quillback Rockfish. As part of the MP Framework, strategic fishery and conservation objectives and performance measures were previously identified in a workshop series in March 2021 (Haggarty et al. 2022) with DFO

[1] Quang Huynh, Matthew R. Siegle, Dana R. Haggarty. In prep. Management Procedure Framework for Inside Quillback Rockfish (*Sebastes maliger*) in British Columbia in 2021. DFO Can. Sci. Advis. Sec. Res. Doc. Meeting December 6-7, 2022.

scientists and managers, Indigenous representatives and knowledge-holders, commercial and public fishing representatives, non-governmental organizations, and scientists.

Objectives

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

Quang Huynh, Matthew R. Siegle, Dana R. Haggarty. Application of the Management Procedure Framework for Outside Quillback Rockfish (*Sebastes maliger*) in British Columbia in 2021. 2023. CSAP Working Paper 2016GRF02b

The specific objectives of this review are to:

1. Based on the discussion on high level strategic objectives identified at the 2021 workshop (Haggarty et al. 2022), develop quantitative objectives to be evaluated with performance metrics.
2. Develop and assess a suite of operating models (OMs) and describe the uncertainties the OMs are meant to address.
3. Consider environmental conditions that may affect the stock as presented in the Guidelines for Implementing the Fish Stocks Provisions in the *Fisheries Act*.
4. Recommend candidate reference points including a limit reference point (LRP) and upper stock reference point (USR) consistent with the DFO Precautionary Approach. Additionally, characterize the stock status relative to the LRP, USR, and if possible, B_{MSY} and B_0 for each OM and aggregated across OMs.
5. Propose a set of candidate management procedures (MPs) and test the candidate MPs across the suite of OMs using a closed-loop simulation.
6. Review the simulation results and demonstrate potential trade-offs between achieving different objectives under different MPs, including constant catch and index-based MPs.
7. Recommend an appropriate assessment frequency and any conditions for exceptional circumstances that warrant re-evaluating the OMs.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Fisheries and Oceans Canada (DFO) (Ecosystems and Oceans Science, Fisheries Management)
- Indigenous Organizations (Central Coast Indigenous Resource Alliance, Council of the Haida Nation, Ha’oom Fisheries Society, Maa-nulth First Nations, Nuu-chah-nulth Tribal Council)
- Industry (Commercial Industry Caucus, Groundfish Hook and Line Subcommittee, Pacific Halibut Management Association, Sport Fishing Advisory Board)
- Environmental non-government organizations (David Suzuki Foundation, Oceana)
- Consultants (Interface Fisheries, Landmark Fisheries Research)

- Other governmental organizations (Washington Department of Fish and Wildlife)

References

Anderson, S.C., Forrest, R.E., Huynh, Q.C., and Keppel, E.A. 2021. A management procedure framework for groundfish in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/007. vi + 139 p.

DFO 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach.

Haggarty, D.R., Siegle, M.R., Litt, M.A., and Huynh, Q. 2022. Quillback Rockfish Fishery and Conservation Objectives Workshop Summary Report. Can. Tech. Rep. Fish. Aquat. Sci. 3488: viii + 56 p.

APPENDIX B: WORKING PAPER ABSTRACT

The purpose of this project is to provide scientific advice to support management of Outside Quillback Rockfish (*Sebastes maliger*). The stock is expected to be prescribed as a major fish stock, at which time its sustainable management will be legislated under the Fish Stocks Provisions of the Fisheries Act. This analysis applied the Management Procedure (MP) Framework, recently developed for BC groundfishes, to evaluate the performance of index-based and constant catch MPs, with respect to meeting policy and fishery objectives.

To account for uncertainty in underlying population dynamics and data sources, we developed five alternative operating model (OM) scenarios, which differed with respect to specific model and data assumptions. Operating models were conditioned on historical catches, indices of abundance, and age composition. Three reference OMs varied on either the assumption of the natural mortality value or historical recreational catch for Outside Quillback Rockfish. Two additional robustness OMs were developed, with evaluating a lower stock-recruit steepness value, and another that modeled lower than average recruitment in the projection. The reference OMs indicated the stock was above the LRP (0.4 B_{MSY}) with very high probability in 2021.

Three fixed-catch MPs and eight index-based MPs that adjust the catch based on the recent trend in the index of abundance from the outside hard-bottom longline (HBLL) survey were tested in the closed-loop simulations. In the reference set, almost all MPs, except for the fixed catch at 125 percent of recent catch, passed the proposed satisficing criteria with the stock: (1) exceeding the LRP with at least 75% probability, (2) exceeding the USR of 0.8 B_{MSY} with at least 50% probability, and (3) less than the removal reference of F_{MSY} with at least 50% probability, during the projections of two generations (54 years) duration. All index-based MPs also met the satisficing criteria in the two robustness operating models.

Visualizations present trade-offs in tabular and graphical formats to support the process of selecting the final MP. Among satisficed MPs, there is a trade-off between biomass and fishery catch levels after two generations. We propose operating models to be identified in the reference set when used to identify stock status. We also provide future research recommendations regarding commercial fishery biological sampling and Food, Social, and Ceremonial (FSC) catch. We make recommendations to use the HBLL index of abundance to identify triggers for future reassessment.

APPENDIX C: WORKING PAPER REVIEWS

WRITTEN REVIEW

Date: May 19, 2023

Reviewer: Divya Varkey, Fisheries and Oceans Canada

CSAS Working Paper #: 2016GRF06b

Working Paper Title: Application of the management procedure framework for Outside Quillback Rockfish (*Sebastes maliger*) in British Columbia in 2021

Overall, it is obvious that an incredible amount of work has gone into the development of the operating models, and testing of the management procedures. Kudos to the team for the hard work that has gone into the operating model development and conditioning and also extensive documentation. The approach adopted (i.e. to develop operating models and test management procedures) is the most progressive approach available in the current fisheries science paradigm.

For each of the five questions listed, I am providing summary responses. In the section below, I respond with specific questions to each of the items in the ToR. I have some recommendations for additional sensitivity analyses and considerations for the research team and CSAS meeting.

Caveat: It is possible that I have requested discussion or clarification in the review for items that the authors had already covered and I likely missed in reading through the different sections of the working paper. Please excuse and advise accordingly.

The following five questions provide general guidance for your review:

1. Is the purpose of the working paper(s) clearly stated?

   Yes. The organization of the working paper is excellent. Key findings are summarized in the main section with considerable detail provided in supporting appendices. I highly appreciate this format for documentation of the work.

2. Has the working paper fulfilled the ToR objectives?

   Yes, the working paper addresses objectives of the ToR. Extensive operating model development and simulation analyses is presented to evaluate different management procedures to support the management of the stock.

3. Are the data and methods adequate to support the conclusions, and explained in sufficient detail?

   Yes, to a large extent. I believe all the datatypes used in the analyses have been presented in the working paper. The analysis is also presented in detail. I have requested some additional figures and suggested one more reference OM. These comments are in the section below itemised by topics in ToR.

4. If the document presents advice to decision-makers, are the recommendations provided in a useable form, and does the advice reflect the uncertainty in the data, analysis or process?

   Yes. Uncertainty is incorporated in the operating model formulation and the projections. The performance metrics presented to the decision-makers (especially figures 30 to 33) present the uncertainty associated with the simulations. It allows the decision maker to consider different levels of risk tolerance to different levels of projected stock trajectory. Some comments on this below: itemised by topics in ToR.

5. Can you suggest additional areas of research that are needed to improve the working paper?

   Yes. Two generation time projections means that the projections run for a much longer than 50 years. It is important to consider the impact of possible environmental effects and how conditions could be different from what the operating model is conditioned on. For example, a natural mortality scenario, where the M in the OM conditioning phase remains the same, but could change in future due to environmental changes. Or, that the OM is conditioned on current steepness levels, but steepness could change in the projection period. Also for further research is required on the ratio of Bmsy to B0 and what aspects of the population dynamics and fisheries have the largest impact on this ratio and how good are the data sources to inform and correctly identify these parameters.

Comments by items in ToR

1. Quantitative objectives and performance metrics

   The working paper presents several biomass and catch based performance metrics to address the objectives. Suggested considerations:

- The authors have included several performance metrics that evaluate the status of the stock with respect to LRP, USR, and two depletion levels. I think all these PMs are very useful for management to evaluate the performance of all the management procedures tested.
- The incorporation of mean age of the population is a very useful metric that can show changes to population age-structure over time of this long lived species. This performance metric will likely provide a warning signal about decline in stock health before the other PMs are able to show the same.
- There are short term objectives (Short term catch) to present the impacts of the MP on fishing levels in the short-term. However, looking at short term impact on MPs on population size in the short term is not done here. It is possible to follow the probabilities from the two metrics (LRP2GT and USR 2GT) and evaluate years where the biomass was below the LRP or USR. It would be beneficial to introduce a performance metric that examines short-term growth of the stock compared to current levels. This metric would assess whether the stock is projected to increase, remain stable, or decline in the short term. Such an evaluation would complement the assessment of long-term performance metrics in determining the effectiveness of the MP.
- Is there interest in using a TRP to support the management of the stock. All the biomass based PMs presented in the working paper evaluate probabilities against the LRP and USR? Does this stock have any recommendations for TRP?

2. Suite of operating models and uncertainties explored

   As mentioned previously, the documentation for the work is excellent. Some considerations for additional material to incorporate:

- The stock synthesis model that is used to develop is a very complex modelling approach, with I believe different approaches available to model and condition the different data types. The authors have provided information on the stock synthesis control file (Appendix D2). However, if possible, it will be helpful if all the equations used to specify the operating model could be presented in this Appendix. Also the authors discuss the reweighting factors for the indices; it would be useful to include the rationale/approach for the reweighting factors and how this affects the influence of the different data sources towards the population trends and age structure in the operating model.

- Model fits and summary plots
  - Figures 5 to 12 present the model fits and overall the fits seem to follow the major trends in the data. As noted by the authors, the model seems to suggest a stronger presence of larger/older fish in the population than perhaps suggested in the data. It would be helpful to provide additional context in this regard, for example related to the biology/ecology of larger and older individuals or related to specifics of the surveys.
  - It is difficult to evaluate the fits to the higher age classes due to the scale of the figures and low proportions at these ages. A suggestion is to also present the fits to the age and length compositions as ratios of predicted proportions versus proportions in data.
  - Please include a version of figure 18 (perhaps with only the coastwide trend) of the spawning biomass trend that includes 4 horizontal lines each to represent the LRP, USR, 0.2B0 and 0.4B0 which are 4 main metrics against which the MP projections are evaluated. I understand that figures 19 and 20 try to present similar information but it is difficult to understand model comparisons when the presented separately as in figures 19 and 20.
  - What is uncertainty around the Bmsy estimates for each OM?
  - Although not a model fit figure, it will be useful to add a figure of long term fishing mortality rates and estimated Fmsy to summarize the impact of fishing on the historical stock trajectory and to understand how current F levels compare to the Fmsy for the stock.
- Growth parameters:
  - The growth model with full detail is presented in Appendix A. However from Appendix D (likely due to my limited familiarity with SS3 model), it is unclear if mean length-at-age were used in the OM conditioning or if the uncertainty in the length-at-age estimations was included in the OM?
  - It will be informative to present the parameter covariance plots for the growth parameter estimates in addition to figure A.6. It will also be interesting to see figure A.5 as a facet over years to confirm that data do not suggest any long-term trends in mean length-at-age.
  - Given the uncertainty in the length-at-age distributions and that the OM is conditioned of age and length composition data from surveys and fisheries, it would be worthwhile to compare an additional operating model that uses a different (but highly probable) growth trajectory based on a combination of Linf and k chosen from the parameter covariance plots. Similar to the evaluation of a lower M reference OM, it will be useful to evaluate a lower 'growth' reference OM.

3. Environmental conditions that may affect the stock

- The authors consider the impacts of greater predation on juveniles through the robustness OM (B) that incorporates low recruitment.
- It might be worthwhile to add some discussion on expected impacts to the resilience of the stock to climate change – for example, changes to natural mortality rates in the overall population and how these might influence the performance of the management procedures.

4. Reference points

- The authors provide an excellent discussion on limit reference point in section 4.3.4 and in section 7.7. In the base OM, the LRP of 0.4Bmsy is equivalent to 0.12B0. It will also be useful to see a table of depletion levels that correspond to the LRP estimates in all the other OMs. This will perhaps improve understanding on how changing the M and recruitment steepness, and growth (*if the additional OM could be implemented*) affects the LRP with respect to unfished stock levels.

- When an LRP is defined using B0 as a metric, LRP tends to range from 0.2 to 0.3 B0 depending on stock productivity. In this context, the USR determined for the Outside Quillback in the working paper is around 0.24 B0. It will be useful to comment more on what are the aspects of the Quillback population dynamics and fisheries that allow this fairly slow growing species to have fairly high resilience to depletion.

5. Candidate Management Procedure testing and review of simulation results

- The MP framework used for the purpose is excellent. A total of more than 10 MPs that include reference point based, constant catch, and index based MPs are tested. Constant catch based MPs provide valuable information on the long term impacts of status quo fishing levels. The trajectory of the projections especially figures from appendix F are very useful to understand the performance of an MP.
- For the index-based MPs, are the indices for the 'North' and 'South' HBLL averaged before use in the MP? Figure E1 is very helpful, but what is the step in MP implementation after an alpha value each is determined based on each simulated index series.
- Figures F11 and F12: It is unclear why in these figures the starting points are different between MPs.
- My suggestion here is to include some figures from Appendix F in the main section of the document as I think these would be very useful for the decision makers. The figures of the performance metrics (figures 30 to 33) are very useful but it is important to view the stock trajectory in addition to verifying the probability values in the performance metrics figures. For example, certain probabilities can remain high through a phase of stock decline.

6. Assessment frequency and exceptional circumstances

- Section 7.6 clearly describes when exceptional circumstances will be triggered. However, it is not stated if there is a recommended (default) assessment frequency for this stock.

7. Some additional minor clarifications

- Catch curve analysis in Appendix G.
    - Z estimates showed a decline between 2006 to 2010 and post 2010, and the document suggests that the mean age showed a decline from 30 years to 20 years. It will be good to add some more context on the reason for the change in the age distribution.
    - Figure A10: what are the authors trying to show in this figure and what is the relevance to the maturity curve used in the operating model?
    - How is the robustness OM for low recruitment implemented – is mean recruitment set to 0.7 of mean recruitment from the stock recruit curve?

Overall, I would like to reiterate that this is an extensive body of work with thorough documentation and this work sets high standards for evaluation of stock status and designing feasible management procedures.

WRITTEN REVIEW

Date: May 17, 2023

Reviewer: Kathryn Meyer, Washington Department of Fish and Wildlife

CSAS Working Paper #: 2016GRF06b

Working Paper Title: Application of the management procedure framework for Outside Quillback Rockfish (*Sebastes maliger*) in British Columbia in 2021

First and foremost, I would like to commend the authors for their efforts in developing this working paper and in their application of the management procedure framework to this relatively data-limited fish stock. As a framework overall, it appears to provide fishery managers with the information needed to make thoughtful, risk averse decisions while best utilizing the information available for a particular stock. This application of the management procedure framework meets the objectives outlined in the Terms of Reference document and provides a clear pathway towards meeting both policy and strategic objectives identified for this species. Below, I provide responses and additional comments to the reviewer questions followed by responses to the Terms of Reference objectives. The following comments and suggestions are intended to be constructive in nature, with the goal of providing the best possible science advice to decision-makers.

The following five questions provide general guidance for your review:

1. Is the purpose of the working paper(s) clearly stated?

Yes, the purpose of this working paper was clearly stated. The document outlined the policy context well and described the overarching goal of providing science advice for the outside stock of Quillback Rockfish to fishery managers, in compliance with the provisions in Canada's Fisheries Act. The specific policy and strategic objectives of the paper were also clearly identified, noting the underpinnings in either the Precautionary Approach Framework outlined in the Fish Stocks Provisions of the Fisheries Act, or in the 2021 fishery and conservation objectives workshop for Quillback rockfish.

As a minor request, an additional brief description of the process through which the preferred management procedure will be selected and subsequently adopted would be helpful for clarification and context.

2. Has the working paper fulfilled the ToR objectives?

Yes, the working paper has fulfilled the objectives outlined in the ToR with some additional requests for consideration outlined below under the responses to each particular ToR objective.

3. Are the data and methods adequate to support the conclusions, and explained in sufficient detail?

Overall, yes – the data and methods were described well and included helpful detail in the Appendices. Appendix A, B, and C were quite well described and sufficiently detailed, including the description of the HBLL survey model fitting procedure and selection which was excellent. However, there are a few areas specifically that would benefit from additional information such that some of the technical aspects of the methods could be better evaluated. Suggestions are as follows:

- Evaluating the stock synthesis model fit to historical data as part of the conditioning step was explained well at a high level but did not contain sufficient detail to allow for a thorough technical review. SS is a generalized implementation of a fully integrated statistical catch-at-age model, which allows for a wide range of discretion at the hands of the modeler that can significantly influence the outcome. When evaluating such a model for adoption in a direct management context, it's typical to see multiple model runs with sensitivity tests, likelihood profiles for key parameters, and other diagnostics to evaluate model stability, sensitivity, and convergence. In this case, since the model isn't being used to directly inform management but to 'condition' OM parameters, it isn't extremely clear how much influence the SS model fit has on OM projections and subsequent testing of alternative MPs. However, figure D4 and table D1 indicate that some model parameters which were estimated in SS had very different posterior distributions. It also appears that the only free parameters in SS were those related to recruitment and the ascending limb of the selectivity curves for the fisheries and surveys, so again it's difficult to say without further detail whether alternative specifications would influence the OM and if so, to what magnitude.

- The authors referenced attempts to estimate additional parameters, such as natural mortality and steepness, which were said to have produced an unrealistically high estimate of M and an implausible stock status. Based on the information included it isn't possible to ascertain what may be driving the model towards a high M, but one possible explanation is that the SS model was attempting to explain a lack of expected larger/older individuals in the data. Allowing estimation of additional selectivity parameters such that selectivity is not forced to be asymptotic for at least some of the fisheries may help resolve this issue. It seems plausible, given that the authors note larger individuals in certain fisheries over others (e.g. higher mean weight in the trawl fishery) and could potentially have a large impact on the estimated timeseries of recruitment. I would recommend conducting alternative runs of the SS model to evaluate sensitivity of key input parameters into the OM, or if this has done to include a summary of these results.
- For transparency and reproducibility, it would be helpful to either include the SS control and data files as additional Appendices or include them through a hyperlink as additional materials.
- Finally, a table of all OM input parameter distributions with their source (i.e. 'estimated in SS' or 'estimated from data' or 'derived from the literature') would be a helpful reference and would aid future reviewers.

4. If the document presents advice to decision-makers, are the recommendations provided in a useable form, and does the advice reflect the uncertainty in the data, analysis or process?

Yes, the alternative MPs are clearly presented in text and in figures 30-34 and Appendices E and F. The authors did an excellent job outlining the alternative MP's in the context of policy objectives and presented the trade-offs of each very clearly such that decision makers have the information needed to determine how best to meet strategic objectives.

I do have some concern that uncertainty may be underestimated, however. There is no error or bias in the simulated catch, nor is there any implementation error associated with the simulated TAC. I'm not sure I follow the rationale that these are assumed to be negligible because of the historical model fitting procedure, so I am requesting further clarification in the text to support this decision. Additionally, I think it necessary to justify the lack of TAC implementation error in light of the catch accounting challenges in the FSC sector, which is noted to be under-reported.

5. Can you suggest additional areas of research that are needed to improve the working paper?

Again, the working paper overall provides a well documented and sophisticated approach to meeting Canadian policy and strategic objectives for responsible fisheries management. It clearly demonstrates a large body of work and a deep level of understanding of both the policy governing fisheries and the technical aspects of the management procedure framework used to meet these goals. However, there are a few areas that could be further developed.

The management procedure framework provides an opportunity to evaluate tradeoffs in the performance of management alternatives and implicitly incorporates uncertainty in the population dynamics, data observation, and management implementation processes in a way that is not possible through stock assessment-based management frameworks. A main assumption of this approach, however, is that future conditions will remain constant and as we move further into an era of non-stationarity in climate and ocean conditions, this assumption is very likely to be violated.

As the authors point out, the mechanistic linkages between ocean/environmental conditions and population dynamics processes are not well described and further, future conditions may be outside of the range of empirical observations. Drawing from large-scale climate and ecosystem models where possible, however, could be very useful for approximating how the population and ecosystem may function in the future (see Perryman et al 2021[2]). If not feasible, some informed speculation based on observed trends in the biology of similar species could be informative, such as examining long-term trends in life history parameters observed in numerous groundfish species along the west coast of north America.

The two robustness OMs are intended to capture the dynamics of either a stock with lower productivity (OM A) or reduced recruitment (OM B), which is a reasonable approach to capturing different states of nature presumably resulting from a less favorable ecosystem. However, these two OMs may not capture other aspects of the future stock that may significantly impact long-term MP performance, such as earlier maturity and a smaller terminal size, among others. My recommendations are as follows:

- Bolster the discussion on potential impacts to this species and the ecosystem due to changing climate conditions, drawing from the available literature on the subject and observed trends in other species.
- Develop another robustness OM based on changing population dynamics parameters over time, and if not feasible under the current timeline, clearly explain in the text how the data being monitored will alert fishery managers to departures from expected MP performance or biological assumptions used to develop the OM. This was done to some extent but could be expanded upon to include elements such as noting apparent changes in life history parameters based on available/expected monitoring, in addition to monitoring average size and index values.
- Monitoring trends in average size could be misinterpreted since reduced recruitment would lead to an increase in mean size until larger/older year classes are reduced by the fishery. I suggest developing a metric that also monitors new recruits to the fishery in addition to overall mean size/age, following-up with what specific actions would be taken if departures from expectations occur.

Other general comments/suggestions:

[2] Perryman, H.A., Hansen, C., Howell, D., and E. Olsen. 2021. A review of applications evaluating fisheries management scenarios through marine ecosystem models. Reviews in Fisheries Science and Aquaculture. 29 (4)

- More detail on how and why weights were applied to the composition data in SS, and a justification for applying the McAllister and Ianelli (1997) method as opposed to the more recent method developed by Francis (2011[3], 2017[4]).
- A more in-depth description of how recruits were assigned proportionally to each of the two areas, and what information was used to guide that decision. Any thoughts on how these assumptions may influence the model results would also be helpful.

Responses to each specific objective described the Terms of Reference document:

1. *Based on the discussion on high level strategic objectives identified at the 2021 workshop (Haggarty et al. 2022), develop quantitative objectives to be evaluated with performance metrics.*

The working paper clearly quantifies three policy objectives and one strategic objective to be evaluated with 9 performance metrics. The policy objectives include an explicitly defined the Limit Reference Point (LRP), Upper Stock Reference (USR), and fishing mortality limit in terms of MSY, but includes depletion-based reference points as well. For objectives one and two, maintaining the stock above the LRP and USR, respectively, was defined in terms of a specific time duration of two generations, which they define as a 54-year period and includes a minimum probability of success for achieving each which reflects a previously agreed-upon level of acceptable risk.

A point which could be clarified further, however, is more explicitly defining what is intended when stating 'Maintain the stock above the LRP/USR during two generations with at least 75/50% probability of success.' There is some room for interpretation in this statement, which could be clarified by stating whether the objective is to achieve the respective minimum probability that the stock *never* falls below the LSR or USR over two generations, or that the mean over the projected time series is above the LSR or USR with at least the minimum probability.

2. *Develop and assess a suite of operating models (OMs) and describe the uncertainties the OMs are meant to address.*

The working paper meets this objective by clearly describing the development of and thought process leading to a suite of operating models (OMs) used to capture specific areas of uncertainty not fully represented in any one OM. The authors presented three reference OMs which were subsequently integrated as an ensemble model and two robustness OMs to explore the potential consequences of different states of nature.

The reference models were described as addressing uncertainty in the stock dynamics with respect to natural mortality (M) and included an OM with the preferred value and an OM with a lower value to capture additional uncertainty in this highly influential parameter. They provided literature support for values of M in this range and calculated the value of M using the Then et al (2015) method, which appears reasonable given the difficulties in estimating M directly. Please see comments related to M estimation under question 3 above.

The third reference OM captures the uncertainty in the historical recreational catch timeseries, which potentially overestimates catch from this fishery sector. This OM was conditioned with the

[3] Francis, C. 2011. Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: pp. 1124-1138.

[4] Francis, C. 2017. Revisiting data weighting in fisheries stock assessment models. Fisheries Research. 192: pp. 5-15.

historical catch timeseries reduced by 50% to incorporate potential consequences of overestimating historical catch in the simulations. Together, these OMs integrate across the three primary areas of uncertainty using an ensemble approach.

Additionally, two robustness OMs were developed to test the performance of management procedures under lower stock productivity through reducing the steepness parameter (OM A) and low recruitment through reducing the mean of the recruitment deviations (OM B). OM A evaluates the consequences of unforeseen circumstances leading to a reduction of stock productivity. Please see comments related to capturing changing future conditions under question 5 above.

3. *Consider environmental conditions that may affect the stock as presented in the Guidelines for Implementing the Fish Stocks Provisions in the* Fisheries Act*.*

This area could use some additional, more specific, consideration. Although, as the authors point out, there is very little empirical evidence of mechanistic linkages of between environmental variables and changes in recruitment and/or natural mortality. However, we do have information on ecosystem-level projections which predict some degree of non-stationarity (through trend or increases invariability). It's realistic to assume that the conditions in 2070 will be quite different than they are today, and consequently that the population dynamics of Quillback Rockfish and the ecosystem on which they depend will also be different. The assumption is that this will increase mortality at some life history stage, likely during the early life history portion leading to recruitment success or failure.

A key question is whether the HBLL index and mean age information used to assess departures from the simulated population trajectory will capture these changes within a reasonable timeframe, such that management can alter course as needed. Once concern is that mean age alone is unlikely to pick up recruitment failures in a timely fashion and consequently it may make sense to explicitly include an additional metric which tracks recruitment explicitly. Additionally, trends towards faster growth, smaller size at maturity, and smaller terminal size are being observed in fish populations along the west coast – presumably in response to changing environmental conditions. Capturing and mitigating responses to future climate scenarios is extremely difficult and a struggle for fishery managers everywhere. Ultimately, the authors did a very good job at attempting to account for low productivity scenarios and I've included a few suggestions for their consideration under question 5 above.

The fourth strategic objective is defined as maintaining access and catches in both the short and long-term, to be used as a tradeoff with the three previous policy objectives. This objective is quantified as performance metrics 4-6. Which examine the average catch over projection years 1-7 (4), catch at year 54 (5), and catch stability defined as the average inter-annual variability in catch over the projection period. These performance metrics fully quantify strategic objective #4, but do not specify a target probability so that they may be used when evaluating tradeoffs among alternative MP's, which seems logical and well justified.

4. *Recommend candidate reference points including a limit reference point (LRP) and upper stock reference point (USR) consistent with the DFO Precautionary Approach. Additionally, characterize the stock status relative to the LRP, USR, and if possible,* B_{MSY} *and* B_0 *for each OM and aggregated across OMs.*

Yes, the paper outlined candidate reference points (LFP and USR) extremely clearly and characterized stock status and reference points in terms of both BMSY and B0.

5. *Propose a set of candidate management procedures (MPs) and test the candidate MPs across the suite of OMs using a closed-loop simulation.*

Yes, the paper did an excellent job of describing candidate MPs in the text and throughout Appendix E. The methods for each MP were clearly stated and justified in their selection based on the available information for this stock. I appreciated the inclusion of the zero fishing MP and the FMSY reference MP, which helped bound expectations for alternative MP performance. I have no additional comments as this aspect of the working paper was quite well developed.

6. *Review the simulation results and demonstrate potential trade-offs between achieving different objectives under different MPs, including constant catch and index-based MPs.*

Yes, the working paper met this object fully. The results for each simulated MP were clearly communicated through the figures in Appendix F and in the body of the document. The color-coded tables of probabilities and catch values were helpful in displaying the relatively complex results clearly, as were the tradeoff plots. I appreciated subsetting those MPs which met the 'satisficing' criteria within the tradeoff plots and certain tables. I only have two relatively minor comments:

- If possible, I think it would be helpful to make the text a bit clearer in terms of which MPs are 'on the table' for fishery managers to consider based on whether they achieve the policy goals with the defined level of probability.
- In the color-coded probability tables, please include a color bar for scale
- In the tradeoff plot captions, I think it would be helpful to refer readers back to the description of what each of the axes represents since the definitions are somewhat complex and described only at the beginning of the document

7. *Recommend an appropriate assessment frequency and any conditions for exceptional circumstances that warrant re-evaluating the OMs.*

Yes, an assessment frequency of 2 years was recommended as were the conditions for exceptional circumstances that warrant re-evaluating OM performance. However, as noted above under ToR object 3, I believe that the guidance for identifying exceptional circumstances would benefit from additional, more specific, examples and perhaps lacks a few key areas where change may occur.

APPENDIX D: PARTICIPANTS

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Gemmell	Olivia	DFO Science
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Haigh	Rowan	DFO Science
Huynh	Quang	Blue Matter Science Ltd.
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Lane	Jim	Nuu-chah-nulth Tribal Council
Meyer	Kathryn	Washington Department of Fish and Wildlife
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Siegle	Matthew	DFO Science
Sporer	Chris	Pacific Halibut Management Association
Tadey	Rob	DFO Fisheries Management
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