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Proceedings of the Pacific Regional Peer Review on a Revised Operating Model for Sablefish in British Columbia in 2022

November 15-16, 2022
Virtual Meeting

Chairperson: Steve Schut
Editor: Yvonne Muirhead-Vert

Fisheries and Oceans Canada
Pacific Biological Station
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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 November 15-16, 2022 via the online meeting platform Zoom. The working paper presented for peer review is to provide a revised Sablefish Operating Model (OM) for 2022 that includes updated stock and fishery monitoring data, any new hypotheses about Sablefish stock and fishery dynamics, and estimates of key management parameters.

Due to the COVID-19 pandemic, in-person gatherings have been restricted and a virtual format for this meeting was adopted. Participation included DFO Science and regional Fisheries Management staff and external participants from the International Pacific Halibut Commission, Landmark Fisheries Research, Interface Consulting, Deep Sea Trawlers Association of BC, Pacific Halibut Management Association, Canadian Groundfish Research and Conservation Society, and the United States National Oceanic and Atmospheric Administration (NOAA).

The meeting participants agreed the working paper met the Terms of Reference objectives and was accepted. The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) providing advice to DFO Fisheries Management to inform fisheries managers on stock status and the performance of Sablefish management procedures (MPs) that are used to provide harvest advice relative to established objectives for the Sablefish fishery (DFO 2020). In addition, this work will meet *Fisheries Act* legal obligations and support ongoing implementation of DFO's Fishery Decision-Making Framework Incorporating the Precautionary Approach (DFO 2009) for Sablefish. The Science Advisory Report and 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 was held on November 15-16, 2022 via the online meeting platform Zoom to review the working paper entitled A Revised Operating Model for Sablefish in British Columbia in 2022.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Fisheries Management Branch. Invitations to the science review and conditions for participation were sent to DFO Science (Pacific and Gulf Regions) and Fisheries Management staff, and external participants from First Nations, National Oceanic and Atmospheric Administration (NOAA), the commercial and recreational fishing sectors, environmental non-governmental organizations, and consultants.

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

Cox, S.P., Johnson, S.D.N., Holt, K., Lacko, L.C., Kronlund, A.R., and Rooper, C.N. A Revised Operating Model for Sablefish in British Columbia. 2022. CSAP Working Paper 2021GRF03.

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

The Chair reviewed the Agenda and the Terms of Reference for the meeting, highlighting the objectives and identifying Yvonne Muirhead-Vert as the Rapporteur for the review. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. 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, 24 people participated in the Regional Peer Review (Appendix E).

Prior to the meeting, François Turcotte (DFO Science – Gulf) and Allan Hicks (International Pacific Halibut Commission) 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 provided to inform fisheries managers on stock status and the performance of Sablefish management procedures (MPs) that are used to provide harvest advice relative to established objectives for the Sablefish fishery (DFO 2020). In addition, this work will meet *Fisheries Act* legal obligations and support ongoing implementation of DFO's Fishery Decision-Making Framework Incorporating the Precautionary Approach (DFO 2009) for Sablefish. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

GENERAL DISCUSSION

Following a presentation by the authors, the two reviewers, François Turcotte (DFO Science – Gulf) and Allan Hicks (International Pacific Halibut Commission), 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. The proceedings document summarizes the discussions that took place by topic, including points of clarification by the authors; questions and comments raised by the reviewers and participants are captured within the appropriate topics. The formal reviews by the reviewers are located in Appendix C.

TERMS OF REFERENCE OBJECTIVE ONE

Objective 1: *Review a revised operating model (OM) for Sablefish, considering: estimates of catch from all sources including landings and discards, indices used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.), estimates of selectivity, annual fishing mortality, recruitment, stock biomass (both total and spawning stock), and retrospective analyses to examine model fit, and estimates of fishery reference points.*

Integration of ensemble: A reviewer requested that more explanation of the integration of OMs into an ensemble should be included in the paper since it was not clear how the uncertainty for composite metrics calculated from the ensemble was done. It was noted that the methods used could affect results for some of the metrics. The authors agreed to add more text to the methods section of the paper to describe how composite metrics are calculated when using the ensemble approach. They also clarified for meeting participants that weighted averages of the values from each of the five individual OM scenarios were used to calculate composite metrics, while the visualised simulation envelopes were created by sampling from the five posterior distributions in proportion to their weighting for visualisation purposes only (i.e., no metrics are calculated from the sampled OM). Fifty percent weighting was used for the base operating model scenario (baseOM) and average weighting was applied across the other four model scenarios.

Recruitment: It was stated that when simulating recruitment as part of forward projections, it is important to predict large recruitment events as well as times of low to no recruitment events over time. In the past, autocorrelated models were used to assess recruitment. The stock recruitment relationship is based on R_0 and the recruitment variance has been calculated to be ~0.85. The authors used process error with a bias correction to compensate for small changes in stock recruitment. It was suggested that the authors could expand on this section within the paper since there is still uncertainty on what is driving recruitment. It is also an important research topic to pursue in the future.

The *loRelCV* operating model scenario: A reviewer noted that when reviewing the OM senarios, the ***loRelCV*** scenario seems to have a better fit to the release data, stratified random survey (StRS) biomass index, and age composition data than the ***baseOM*** scenario. The authors responded by noting that while the ***loRelCV*** does fit better to release, age, and index data based on standardized residual error, the magnitude of predicted recent recruitments from the ***loRelCV*** scenario are very large, with three successive year classes bigger than have previously been seen (on the magnitude of 33 million fish). Recruitment of this magnitude was thought to be unrealistic. The chosen ***baseOM*** scenario seems to have a better fit to the data since it down weights the high recruitment events. A participant suggested that more details on the lack of fit to the ***baseOM*** scenario could be included in the results and uncertainty sections of the paper.

Projected recruitment: The participant then asked how the recruitment values were being generated in forward projections. They also expressed concerns that the recent recruitment event could be increasing the perceived productivity of the stock. The authors explained that they drew a posterior sample starting in 2018 and calculated the deterministic recruitment of the stock recruitment curve. Then the process error and bias correction were added. The projections of the median value now line up with equilibria. The authors also noted that they had previously considered OM scenarios that excluded the high 2015/2016 recruitment events when evaluating MPs during a 2019 Science Response (DFO 2020), and found that the current MP was relatively robust to this scenario.

In the current OM update, more years of data have now been added to the model and there is higher confidence that these year classes are substantially above average levels.

A question was then asked about how the stock recruitment parameters have changed. The authors indicated that estimated stock recruitment steepness (0.61 to 0.74), which had decreased with the last major OM update in 2016, was slightly higher than 2016 and 2019 estimates. Some of the difference could be from a slight increase in productivity and process error.

Initial population: The initial population is assumed to be in an unfished state in 1965. This assumption may be unrealistic given that there is known catch prior to this; however, the authors noted that catches were relatively small before 1965, and therefore may not have led to much stock depletion. A reviewer noted that it was unlikely that the population would be at an equilibrium age structure in 1965, and that due to the long lifespan of Sablefish, the assumed starting population age structure in 1965 will have an influence on the observations into the 2000s. The authors responded that the stock is now four generations past 1965, so these assumptions are unlikely to have too much of an effect on current model estimates.

Retrospective model fits: Retrospective analyses of subsequent model fits to data with each additional year of data showed that estimates of unfished biomass have increased slightly over time. The value for R_0 increases over time then B_0 increases due to the stock recruitment relationship.

Estimate of natural mortality (*M*): A participant asked why there was a different estimate of natural mortality (*M*) for males and females. The authors responded that the same diffuse prior is used for each stock, such that information on *M* is coming from data. They also suggested that females may be more mobile than males, and thus their estimates of *M* may be more confounded with out-migration. It is also possible that due to sexually dimorphic growth, the fishing mortality could be different between sexes, which may be confounded with *M*.

Another participant suggested that the tagging models could be reviewed to see if the fish are leaving British Columbia (BC). The authors agreed to add in structural uncertainty explanations in the paper, and look at the coefficient of variation as well. A question was also raised on whether the maximum modelled age class should be increased to deal with the large accumulation of males in the plus age class. A reviewer provided a recent paper by Burch et al. (2023) as a reference (in References Cited below).

Modelling of at-sea releases: It was noted that the current OM formulation assumes that sub-legal fish are caught in proportion to their abundance and fleet-specific quotas; however, this is not expected to be the case for trawl and to some extent non-directed longline hook sectors, which intercept sub-legal Sablefish as non-directed catch. Mis-specification of these release dynamics may account for observed poor fits to at-sea release data in recent years. It was suggested that future OMs consider alternative ways of accounting for at-sea releases, such as time-varying selectivity or additional fleet structure to capture the true process more accurately.

Catch per unit effort (CPUE) analysis: A reviewer asked why the zeros were removed from the trap fishery CPUE analysis data since zero catch is still a data point. While the authors noted in the paper that they had previously found negligible difference in the estimated CPUE index when zero values were included vs. when they were removed, the reviewer noted that this may not always be the case, and that there could be a potential risk in future years if not routinely checked. The authors responded that it is a legacy method and has been used for a long time, but noted that since the CPUE series is no longer updated (and hasn't been since 2009) there is no risk of failing to include zeros going forward. However, the authors also noted that the CPUE analysis methods could be updated in the future by considering more complex models. They agreed this work could be included as a recommendation for future work.

An observation was made that both the trap fishery CPUE index and the standardized survey index showed peaks in 2003. It was suggested that the higher index from both series could be taken to indicate that the trap index is reasonably representative of underlying biomass. The authors have discontinued the use of standardized CPUE and the standardized survey series in 2009 since the indices did not improve fishery performance. Since 2010, the only biomass index used has been the stratified random survey (StRS) index.

Growth data and maturity: It was asked if growth and maturity relationships had been inspected for potential trends over time. The authors showed a plot of patterns in Sablefish length-at-age over time. The figure showed that while there has been a reduction in average length-at-age over time, it is minor for males and slightly more significant for females. The authors noted they did not look at maturity over time.

Age composition: A participant suggested that it may be worthwhile to update data and analyses in the appendices that are used to develop the ageing error matrix for Sablefish. The authors agreed.

Plus group: A participant asked if it is worthwhile to look at the plus group which primarily consists of large and old male fish in the composition data. Building age compositions with more age groups could potentially get rid of the plus group.

Biological samples: It was recommended that biological sampling from longline fisheries should be increased in the future, and that a sampling program for trawl fisheries under electronic monitoring (EM) be developed since the at-sea-observer program was stopped during COVID.

It was noted that the commercial fishery voluntarily completes a lot of biological sampling at the end of their trips but the samples may not be an accurate reflection of the fishing trip (i.e., primarily fished in the north but collected the biological samples in the south).

Data weighting: There was a question on how the data were weighted for each of the annual age compositions. The authors indicated that a logistic normal was used based on the residual data from year to year. The authors agreed to improve the description of the weighting of age composition data in the paper.

TERMS OF REFERENCE OBJECTIVE TWO

Objective 2: *Compare estimates of key model parameters and their statistical properties between the previous OM implementation and revised 2022 OM implementation.*

Operating model (OM): Within this assessment, the OM was implemented in a new model fitting software. The transition analyses showed that the implementations were similar in both platforms. The new platform, Template Model Builder (TMB) offered better model diagnostics performance than the former model, AD Model Builder (ADMB). While better support for TMB within the fisheries science community was a primary reason for making this change, TMB is also better suited to modelling spatial structure, which may be of interest for Sablefish OM development in the future.

100 simulations: A reviewer asked if 100 simulations were enough to stabilize quartiles for the individual models and the integration of the ensemble. It was suggested that more simulations may be needed to calculate the metrics. The authors responded that they had created plots looking at the relationship between the number of simulation replicates and the distribution of performance metrics, and results indicated that 100 simulations were enough to achieve stabilized results.

Another participant asked if there were enough simulations to calculate the performance metric for objective two since it focusses on a shorter 10-year time period and only uses two data points (a start year and an end year). The authors clarified how they calculated the performance metric for objective 2. Specifically, they described how they first determined where the stock was relative to B_{MSY}, and then calculated the acceptable probability of decline to use when calculating the metric based on current status (i.e., the values used are conditional on the start year for projections). It was suggested that the authors should clarify in the paper that objective 2 is met because in nearly all simulations the stock is estimated to be above B_{MSY} at present; thus the objective is currently not applicable. It was also suggested that the authors could better describe the calculation of this performance metric in the paper and may want to consider revisiting the wording of the objective to clarify that the acceptable probability of decline is based on stock status at the beginning of the projection period.

TERMS OF REFERENCE OBJECTIVE THREE

Objective 3: *Review alternative OM hypotheses, considering sensitivity of model estimates to major axes of uncertainty that represent plausible scenarios of Sablefish population and fishery dynamics.*

Transboundary movement: The current Sablefish OM does not account for the transboundary movement of Sablefish between British Columbia (BC) and the United States (US). Based on tagging data it is known that fish move from Alaska, BC, and Washington State. Transboundary movements may have important effects on the Sablefish stock dynamics in BC that are not currently being captured by the OM. The current OM assumes that Sablefish is a closed population and a single stock.

A participant suggested that fish migrating in and out of BC could be playing a role in the variability. A good incremental step would be for scientists on both sides of the border to compare residual data and look for patterns in both regions (US and Canada) and negative data compositions.

Another participant suggested that the input data could be changed to age data since in some years there are some pop up populations (i.e., a high number of age 4 fish in the data) that were not there before. A time block on the discard rate and some data weighting for some of the indices could be added. It was suggested to conduct a formal ‘Francis tuning’ on the data or have a run where the data is removed in the future (Francis 2011).

It was agreed that the authors should make a clear recommendation about how transboundary movement scenarios could be developed in the future. For example, an alternative OM could be developed that allowed age-specific process error, which could represent age-based migration.

Slinky pots: A participant mentioned that slinky pots are being used in Alaska which could affect catchability. The pots are more efficient and economical than traditional fishing gear (i.e., trap fishery, longline hook and trawl). They noted it could be a future pressure and to keep an eye on this type of gear being used. An author responded that while slinky pots have not yet been widely adopted in BC (only one vessel used them for the first time this past year), it was something they would keep an eye on.

TERMS OF REFERENCE OBJECTIVE FOUR

Objective 4: *Compare the performance of the revised Sablefish MP to the previous MP implementation (DFO 2020) and the current Sablefish MP with alternative versions tuned to updated estimates of productivity and other key management parameters*.

Management procedure (MP): The current MP uses a maximum target harvest rate of 5.5% when calculating a catch limit; however, increased productivity estimates from the revised 2022 OM suggested that a higher maximum target harvest rate may still be able to achieve conservation objectives. As a result, the working paper examined management performance relative to objectives for a range of alternative MPs that differed in the maximum target harvest rate used, with rates ranging from 6% to 7.5% in increments of 0.1%.

It was noted that the minimum viable total allowable catch (TAC) used for the fourth objective (which was a socio-economic objective) was based on previously articulated industry perspectives that the fishery was only profitable when the TAC was above 1,992 tonnes.

The authors selected three MPs to show detailed results in the working paper: the current MP, and two alternatives with maximum target harvest rates of 6% and 6.4%. The authors elected not to show detailed results from MPs with maximum target harvest rates above 6.5% because these MPs gave average annual catch values close to 4,000 tonnes in the short-term (10 years), which were similar to the catch levels associated with large declines in biomass in the 1980s and 90s.

Under the current model, all management procedures (MPs) evaluated resulted in at least a 95% probability of being above the limit reference point (LRP) and a high probability that the biomass is above B_{MSY}. All conservation and target biomass objectives were met in this assessment.

Harvest rate (HR): A reviewer noted that the maximum target harvest rate (HR) had changed almost annually since 2011, and asked if the maximum HR change would continue to change every year if the fixed 5.5% maximum target harvest rate was applied consistently for the next 3 to 5 yrs. The authors noted for the period from 2017-2021 the HR was lowered from ~9.5% to 5.5% in annual increments, which was part of the MP design and had been simulation tested. Going forward, the maximum target harvest rate is expected to remain constant until the next cycle of OM updates and MP evaluations in 3 to 5 years. The authors agreed to clarify this in the working paper, and to clarify that while projections assumed a constant maximum target HR for the entire simulation period, in reality, the rate is expected to change with intermittent OM / MP updates.

Estimation model: The group was shown a plot of the estimated biomass from the state-space surplus production model (SSPM) used within the MP, which is different from the OM. The authors explained the SSMP provides an estimate of biomass to put in the harvest control rule.

The purpose of the estimation model is to set the TAC between OM updates. It was noted however that SSPM biomass estimates of legal biomass were known to be biased, and that annual estimates were slow to respond to increases or decreases in biomass indices. The authors suggested that future research could include tuning of the SSPM model to decrease bias, e.g., a Pella Tomlinson version of a production model could be considered or a model structure that allowed a random-walk in process errors. Such adjustments may provide a slightly better fit to the model so it may provide a better yield.

Operational control points: A participant asked how the operational control points used in the harvest control rule were derived, noting that it is important for these points to remain separate from the biological reference points used to characterize stock status. The authors responded that the operational control points were determined by tuning the management procedure to achieve desired performance. The operational control points are unique to the Sablefish management strategy evaluation (MSE) that is being used since the points are set in order to achieve operational objectives for the Sablefish fishery.

TERMS OF REFERENCE OBJECTIVE FIVE

Objective 5: *Characterize the status of the BC Sablefish stock relative to limit and target reference points.*

Reference points: The default DFO limit reference point (LRP) of $0.4B_{MSY}$ and the upper stock reference (USR) of $0.8B_{MSY}$, as recommended by the DFO Precautionary Approach policy, were used for this assessment. Five OM scenarios were run and 4/5 of the scenarios had a 100% probability of being above the USR while one scenario had a 92% probability of being over the USR. For the LRP, all five OM scenarios had a 100% probability of being above $0.4B_{MSY}$.

The estimated harvest rate (U) of legal-sized Sablefish in 2021 was estimated to be below the harvest rate at MSY (U_{MSY}), with a weighted-average estimate of a 94% probability (median value of 0.72 times U_{MSY}).

TERMS OF REFERENCE OBJECTIVE SIX

Objective 6: *Identify EVs based on previously published studies that may affect BC Sablefish population dynamics, present data-based explorations of links between EVs and BC Sablefish population dynamics, make recommendations about future research directions, and assess the utility of incorporating hypotheses that consider environmentally-driven change into the Sablefish MSE process.*

Environmental variables: None of the eight environmental variables considered (i.e., Aleutian Low pressure system, offshore productivity, inshore productivity, copepod abundance, sea surface temperature, Ekman Spring, Ekman Summer, and CPUE (biomass from DFO's StRS trap survey) were strongly correlated to BC Sablefish recruitment. While several variables were shown to be correlated to a body condition index, the extent to which the observed variation in body condition would affect Sablefish population dynamics (e,g., natural mortality, reproductive potential) is unknown at this time. A reviewer recommended that future investigations of environmental variables take a more 'regime' time period approach to environmental interactions. For example, this could include linking average recruitment over a period to average environmental variables. The authors agreed to include this as a research recommendation.

A member of the group asked if the authors had looked at the potential impact of predators and potential changing of mortality based on them. The authors noted that they did not look at predators.

Climate change: The authors mentioned that the long-term impacts to Sablefish are unknown at this time; however, a recent study in BC suggested that the species is less likely than other groundfish species to experience population declines with increases in temperatures due to expected increases in suitable habitat with increasing temperature.

REVISIONS TO THE WORKING PAPER

A table of revisions for the working paper was presented. It was reviewed in detail with participants to ensure that everyone was in agreement and where the authors agreed to make the requested revisions.

CONCLUSIONS

Meeting participants agreed the working paper satisfied all Terms of Reference objectives. The working paper was accepted with minor revisions.

RECOMMENDATIONS AND ADVICE

DRAFTING OF THE SCIENCE ADVISORY REPORT

One of the authors agreed to track changes on the draft Science Advisory Report (SAR) while it was being discussed with participants during the meeting. The SAR was discussed at length and participants had the opportunity to contribute to key sections. 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 PRO to all participants for final review and input.

ACKNOWLEDGEMENTS

The Centre for Science Advice Pacific (CSAP) congratulates the authors on a successful paper and appreciates the contribution from all participants. We thank the formal reviewers, François Turcotte (DFO Science - Gulf) and Allan Hicks (International Pacific Halibut Commission) for their time and expertise for providing their formal reviews of the working paper. We would also like to thank Steve Schut for his support throughout the process and as Chair of the meeting.

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APPENDIX A: TERMS OF REFERENCE

A REVISED OPERATING MODEL FOR SABLEFISH IN BRITISH COLUMBIA IN 2022

Regional Peer Review – Pacific Region

November 15-16, 2022
Virtual Meeting

Chairperson: Steve Schut

Context

Management of Sablefish (*Anoplopoma fimbria*) in Pacific Region is guided by a Management Strategy Evaluation (MSE) process. The MSE process uses operating models (OMs) to generate simulated data that represent alternative hypotheses for uncertain stock and fishery dynamics. The performance of candidate fishery management procedures (MPs) against each alternative OM scenario is evaluated against measurable objectives that represent conservation and socio-economic goals. Annual total allowable catches (TACs) have been set using simulation-tested MPs since 2011 (Cox et al. 2019, DFO 2020).

Sablefish OMs are revised at 3-to-5-year intervals, at which times status relative to biomass and fishing mortality reference points is characterized. Current and future performance demands for the MSE simulations require migrating the Sablefish OM and MP to a new software framework for 2022 and beyond. Thus, a comparison of updated OM and MP results to those obtained using the previous software (DFO 2020) is needed. Given updated estimates of Sablefish stock status and productivity, additional simulation-evaluation is required to determine whether the current MP, or versions that reflect current OM characteristics, can meet constraints imposed by conservation objectives.

Fisheries and Oceans Canada (DFO) Fisheries Management has requested that Science Branch provide a revised Sablefish OM for 2022 that includes updated stock and fishery monitoring data, any new hypotheses about Sablefish stock and fishery dynamics, and estimates of key management parameters. Sablefish have recently been prescribed as a major fish stock in Regulations under Canada's revised *Fisheries Act*, making them subject to the Fish Stock provisions. Under the Fish Stock provisions, there is a legal requirement to maintain major fish stocks at levels necessary to promote sustainability, and to develop and implement rebuilding plans for stocks that have declined below their Limit Reference Points.

DFO is developing a national framework for ecosystem approaches to fisheries management through a recently established 'National Working Group on Ecosystem Approaches to Fisheries Management'. The framework includes considering the integration of environmental variables (EVs) into stock assessments and fisheries science advice. In addition, the revised *Fisheries Act* states that the Minister shall consider the biology of the fish and the environmental conditions affecting the stock when implementing management measures. Consequently, a summary and analysis of links between Sablefish population dynamics and EVs is also requested to identify those relevant to BC Sablefish. Analyses will be data-based and guided by known, or presumed, mechanistic linkages between important Sablefish life history processes (e.g., recruitment and growth dynamics) and the ecosystem (e.g., ocean temperature). Modelled analyses that consider the possible effects of linkages between Sablefish population dynamics and EVs on harvest advice for BC Sablefish are out of scope for this review.

The assessment, and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR), will be used to inform fisheries managers on stock status and the performance of Sablefish MPs that are used to provide harvest advice relative to established objectives for the Sablefish fishery (DFO 2020). In addition, this work will meet *Fisheries Act* legal obligations and support ongoing implementation of DFO's Fishery Decision-Making Framework Incorporating the Precautionary Approach (DFO 2009) for Sablefish.

Objectives

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

Cox, S.P., S. Johnson, K. Holt, L. Lacko, A.R., Kronlund. A Revised Operating Model for Sablefish in British Columbia. 2022. CSAP Working Paper 2021GRF03.

The specific objectives of this RPR are to:

1. Review a revised OM for Sablefish, considering:
    - Estimates of catch from all sources including landings and discards,
    - Indices used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.),
    - Estimates of selectivity, annual fishing mortality, recruitment, stock biomass (both total and spawning stock), and retrospective analyses to examine model fit, and
    - Estimates of fishery reference points.
2. Compare estimates of key model parameters and their statistical properties between the previous OM implementation and revised 2022 OM implementation.
3. Review alternative OM hypotheses, considering sensitivity of model estimates to major axes of uncertainty that represent plausible scenarios of Sablefish population and fishery dynamics.
4. Compare the performance of
    - the revised Sablefish MP to the previous MP implementation (DFO 2020).
    - the current Sablefish MP with alternative versions tuned to updated estimates of productivity and other key management parameters.
5. Characterize the status of the BC Sablefish stock relative to limit and target reference points.
6. Identify EVs based on previously published studies that may affect BC Sablefish population dynamics, present data-based explorations of links between EVs and BC Sablefish population dynamics, make recommendations about future research directions, and assess the utility of incorporating hypotheses that consider environmentally-driven change into the Sablefish MSE process.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Fisheries and Oceans Canada (Ecosystems and Oceans Science, and Fisheries Management sectors)
- Provincial/Territorial jurisdictions (e.g. Province of BC)
- Academia or Academics (e.g., Simon Fraser University)
- Indigenous communities/organizations
- Industry (e.g., fishing industry)
- Non-government organizations (e.g. Oceana, David Suzuki Foundation)

References

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APPENDIX B: ABSTRACT OF WORKING PAPER

The British Columbia Sablefish fishery has been managed using a simulation tested harvest strategy since 2011, and he current operating model used for simulation tests of the Sablefish management procedure is due for an update of the data used to condition the model. We use this paper to detail the migration of the Sablefish operating model (SAB-OM) from the unsupported AD model builder (ADMB) language to the leading edge Template Model Builder (TMB) language. We detail a rigorous transition and bridging analysis between 2018 and 2021 data and hypotheses, as well as testing against several sensitivities, including at-sea release model assumptions, age composition likelihood weightings, and leading parameter prior distributions. At the same time, we also transition the Schaefer production model used to estimate biomass and operational control points within the Sablefish management procedure from ADMB to TMB, and re-evaluate it against operational fishery objectives. Sablefish biomass, productivity, and stock status for 2021/22, estimated over an ensemble of five SAB-OM ‘reference set’ hypotheses, indicate that the stock is currently not overfished and not experiencing overfishing, and spawning biomass at the start of 2022 is approximately 132% of optimal biomass B_{MSY} , and the 2021 harvest rate is about 71% of U_{MSY} , with recent dynamics driven by three large incoming year classes. Estimates of recruitment deviations from the base SAB-OM hypothesis are compared to environmental indices, but no significant relationships are evident, indicating that a more in-depth research project may be required to determine if a link exists. Finally, all tested sablefish MPs, including the status-quo MP with a 5.5% harvest rate, meet the biomass conservation and target objectives across the reference set of operating models, indicating the Sablefish harvest strategy is sustainable and precautionary.

APPENDIX C: WORKING PAPER REVIEWS

Canadian Science Advisory Secretariat (CSAS)

Regional Peer Review Process - Pacific

Written Review

Date: November 4th 2022

Reviewer: François Turcotte

Working Paper Title: Stock status and management procedure performance for the BC Sablefish (*Anoplopoma fimbria*) fishery for 2022/23

GENERAL COMMENT:

This document clearly describes the data, methods and results used to assess the BC Sablefish stock status. The amount of work described in the document is substantial and is appropriate to support the conclusions. The author's interpretation of the results are thorough and reasonable. The authors are transparent about the strengths and weaknesses of the assessment.

Two main elements of the assessment could be offered more consideration when discussing the analysis results:

1. The loRelCV OM seem to offer a better fit to the release, and StRS biomass and age composition data (by "forcing" a better fit to the release data). While this results in a bad fit to trawl catch data, it seem to answer questions about the lack of fit to some data sources in the baseOM. I would be interested in seeing more details given about the potential effects of this on the assessment results, considering this OM only has a small weight in the model ensemble average.
2. The recent recruitment event is estimated to be much higher than any recruitment event ever recorded in the assessment time period, and no ecosystem driver could be identified to evaluate to likelihood of such an event to occur in the near or distant future. Hence, including this productivity component in population projections might show a stock that is less productive than expected if such a recruitment event was to never happen again, and MPs expected to meet objectives might fail.

Given these uncertainties, should more caution be recommend against raising maximum harvest levels until more data years are included in the model to help resolve the scale of the recent recruitment event, and more research is performed to evaluate the probability of future high recruitment events? Could a scenario where such a high recruitment event does not happen again in the future be developed and MPs tested against it?

There is many moving parts in an MSE and the authors produced a great amount of work. I am looking forward to the meeting to be able to discuss the details of the assumptions that were tested by the authors. I included more specific comments below and edits in the pdf document.

REVIEW:

Is the purpose of the paper clearly stated:

The purpose of the working paper is clearly stated in section 1.2, and more specifically in lines 169-191. All specific objectives from the terms of reference have been met, and the work related the each objective has been properly described in the document.

Are the data and methods adequate to support the conclusions?

Appendix B.1

Why were the zero catch records removed from the CPUE analysis? Zeros are as valuable data points as the non-zero data points. Even if the difference was minor, it could become important and left undetected if not routinely checked, it seems like an unnecessary risk.

2003 CPUE index higher observation: Hard to fix since there is two reasonable explanations from different processes (recruitment vs bias in month of effort), was predictive modeling with month as covariate attempted? The standardized trap survey index seems to also peak in 2003 so that's a good sign that the increase in the 2003 commercial trap index is real and not just due to the month bias. Or was the sampling also month-biased in this survey for that year?

Appendix B.2

Differences in index computation methods yielded minor differences. Should have no effect on assessment results.

Appendix B.3

The trends in the three indices seem to match for the time they overlap, which is good considering only one index is maintained until the terminal year.

Section 2.1.1

Was there any attempt to see if growth could have changed directionally through time? Same question for maturity, any signal of a directional change through time in the data?

Section 2.1.4

Is there bounds on the surveys time-varying catchability?

Figure 2 shows age composition data for the stratified random survey up to 2021, text says 2003-2014 (line 307). What was used?

Section 2.1.5

Cohort tracking is good in StRS age composition data.

Improper prior penalizing the magnitude of unfished biomass with a weighting scalar = 100. Please provide more detail about how this method was established in previous assessments and why it is used.

- What is meant by improper, uninformative? Or improper as in deliberately set far from (lower than) the expected value to force the estimation down?
- By reducing the scalar, less weight is given to this prior in the objective function and the result is an increasing value of the estimate of B0. Hence, the intent here is to keep the B0 estimation low. Why is this done and are the unweighted-prior estimates deemed unreasonable? If this is the case, why is the model estimating higher than expected B0 values?

Section 3.1.1

Lack of fit to commercial trap fishery age composition in the 1980s seem to repeat in recent years. The models over-estimates the plus group and underestimates younger ages abundances. Model too restrictive in recruitment variations? Less over-estimation of plus group in indices. Selectivity specifications issue? I agree with the interpretation given by the authors.

The very high recruitment events in 2016 to 2018 would explain the under estimation of the StRS index by the model for years 2017-2019 if it is too restrictive on recruitment deviations. OMs should provide more information about this possibility (loRelCV increased recent recruitments when trawl releases CV was forced down). As mentioned in Appendix C, the incoming large year class could influence the selectivity parameters. The interpretation of under-estimated releases in the baseOM seem to point to underestimation of recent recruitment.

General comment about the baseOM fit to age composition: the authors identified potential issues and detailed the potential causes. More details could be provided about the expected effects of these lack of fit on the MPs performance.

Section 3.1.2

Figure 11: describe dashed lines

Appendix C

No major concerns about the transition and bridging analyses. The authors described the differences and provided reasonable interpretations.

Section 3.1.4

Table 7 M values are not reported.

No issue with the retrospective analysis.

Section 3.1.5

The loRelCV OM has the highest NLL of all OMs, highest NLL for the biomass index data, worst for catch data (all from trawl data: how reliable is the total trawl catch data?), best fit for release data (by force) and for age composition data. I find it insightful that this model seem to resolve the lack of fit to the age composition and trawl release lack of fit identified in other models, especially by offering a better fit to the age composition and biomass index from the StRS Survey data, which is the survey offering information on the scale of the recent recruitment event.

If this interpretation is correct, what is the best way to deal with this and the low weight this model is given in the model ensemble.

Section 3.1.7

I agree that the main uncertainty of the assessment is residing in the size of the recent recruitment event.

Section 3.2

Productivity increased because of a single recruitment event on a scale that has not occurred in the history of the stock assessment. Average productivity increased because of that event but it is not necessarily warrant of future productivity. The performance assessment of MPs with increased max harvest could change when more years of data are included in the model and the size of the cohort is known with more certainty. What explains this high recruitment event, is it likely to occur again within the timeframe of the objectives? If it doesn't occur again, the MPs expected to meet the objectives might fail to meet them because an average higher productivity have been estimate because of this high recruitment event.

The conservative reference points generated by the SSPM are a safety net for a stock that is driven by large infrequent recruitment events such as this one, for which it could take years of additional data to resolve the "true" scale. By being slowly responsive to such events, this model potentially balances out the uncertainty about the scale of the recruitment event by being precautionary in its nature.

Section 3.3

It would be important to elucidate the drivers of this recruitment event to evaluate the likelihood of it occurring again, and thus managing expectations about future productivity of the stock.

Appendix D

The prior on B0 has the biggest effect on estimates. More details could be given on the implications for the results of the assessment.

Appendix F

It seems like Sablefish recruitment is a complex process and its success is dependent on the alignment of multiple factors occurring across all development stages leading to recruitment. Based on this conclusion and the history of recruitment dynamics of the stock, how likely is the high recruitment event to occur in the future and how does this affect the perceived average productivity of the stock. Do the OMs used in the assessment cover this uncertainty? I agree with the research recommendation emerging from the analysis.

Figure 4: why is the HCR USR at 0.6Bmsy instead of the PA suggested 0.8Bmsy?

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

Yes, a great amount of work has been conducted for this assessment and a lot of details have been provided by the author, greatly aiding in the evaluation of the conclusions.

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?

The recommendations are provided in useable form for both short term decisions and long term expectations, while presenting uncertainties and being explicit about the range of outcomes covered by the various OMs and their underlying uncertainties. More emphasis could be put on the potential effects of the identified lack of fits to the data on the results and on the risk associated with the uncertainty of the scale of the recent high recruitment event. This would provide managers a better understanding of the overall expected outcomes when choosing a MP.

Canadian Science Advisory Secretariat (CSAS)

Regional Peer Review Process - Pacific

Written Review

Date: 4 November 2022

Reviewer: Allan Hicks (International Pacific Halibut Commission)

Working Paper Title: Stock status and management procedure performance for the BC Sablefish (*Anoplopoma fimbria*) fishery for 2022/23

OVERALL

This working paper is thorough and provides a detailed description of the updated operating model (OM) for Sablefish, stock status and parameter estimates for the Sablefish stock, objectives used for evaluation of management procedures (MP), simulation results examining the current and alternative MPs, and a preliminary analysis of the correlation of environmental variables with different Sablefish attributes. The working paper satisfies all six objectives of this Regional Peer Review (RPR), which are clearly stated in Section 1.2 of the working paper. The Terms of Reference for this RPR state that this working paper "will be used to inform fisheries managers on stock status and the performance of Sablefish MPs that are used to provide harvest advice relative to established objectives for the Sablefish fishery." The working paper is informative for fisheries management in that it clearly presents stock status estimates with uncertainty, along with results of simulations examining the current MP and other potential MPs.

Comments are provided below in two categories: 1) Priority comments that should be considered at this RPR, and 2) secondary comments that should be considered by the authors for improvement in the future but may be discussed at this RPR. Minor comments and editorial suggestions were distributed to the authors. The comments are referenced to a line or section in the working paper when appropriate. Embedded within these comments are research items that may be useful to consider to improve the assessment and management of Sablefish.

Overall, the science and methods presented in this working paper are sound and useful for the management of Sablefish fisheries.

PRIORITY COMMENTS

1. There are many sources of uncertainty included, such as hypotheses forming an ensemble for the OM. The included uncertainties are more than adequate for a stock assessment. However, I wonder if some important uncertainties are not captured in the forward simulations. For example:

    1.1. Changes in size-at-age. This was not examined in the model, but the analysis of environmental variables suggested that body condition possibly changes with the environment.

    1.2. Changing harvest rate. MPs tested here do not seem to capture the potential for variability in the harvest. This has been seen in the past where the harvest rate has not been constant across years (Table A2), and the harvest rate seems to be adjusted when the OM is reconsidered. Assuming a fixed target (also called max) harvest rate is a short-term management procedure, whereas the long-term harvest strategy is the process with possibly changing target harvest rates. Can this potential for changing harvest rates be codified.

1.3. Periods of low or high recruitment. It was unclear how the projections simulated incoming recruits.

2. Assuming that the initial population is at an unfished equilibrium state may be unrealistic, although it may be moot if there enough time to "burn-in" the population to where this historical period has little effect on the recent estimates. However, there seem to be informative data early in the time-period that may be influenced by this assumption of initial conditions. It is likely that even without fishing the population would not be at an equilibrium age structure because of the tendency for large year classes of Sablefish. With Sablefish living at least 35 years, the starting population in 1965 will have influence on the observations throughout the 70's and 80's, and the large proportion of fish in the plus group in more recent years suggests that the initial population may have an influence for even longer (a 35 year old fish in 2000 was born in 1965). Relatedly, age/length-compositions from the 1980's will have some information on the age-structure in 1965. It may be worthwhile to estimate initial recruitment deviations for most of the age-classes, at least to incorporate that variability (see Figure 10 showing first estimated recruitment deviations are in 1974). Looking at line 1078, stating that an equilibrium age structure is necessary, may not be true if you simply allow recruitment deviations to be estimated with a prior (i.e. sigmaR).

3. I am curious to learn more about the M prior and the effect on estimation. This prior (line 427) seems informative [N(0.1,0.01)] and different than that used for US west coast sablefish (Kapur et al 2021 Figure 41), not that it has to be the same. However, this prior has 2.5th and 97.5th percentiles near 0.08 and 0.12, respectively, and estimates of natural mortality for US west coast Sablefish are less than 0.08. Furthermore, the estimate of natural mortality for males is 0.052 for the baseOM (Table 5) which has very little probability according to the prior. Therefore, the data must be extremely informative (unlikely for fisheries data) or the prior is different for males.

4. The use of the trawl release standard error (SE) is an interesting way to account for structural uncertainty (size of recent recruitments). The estimated releases in recent years are always below the observed releases but isn't the case in earlier years (Figure 15). Furthermore, could a similar trend be found by changing the recruitment variance instead of the trawl release SE? Finally, is it possible to account for this uncertainty using a more direct method or meaningful hypothesis? For example, a change in selectivity, the process of how trawl releases are modelled, alternative discard mortality rate, or the option for extreme recruitment events.

5. A clear description of how the parameter estimates and performance metrics are calculated for the ensemble is necessary. It is unclear if these are calculated for each scenario and then averaged, if they are calculated for each sample of the posterior and then averaged across each sample (for which order of the samples would matter), or some other method. The details are important as the values can be different depending on the method (e.g. the ratio of medians is different than the median of the ratios). Additionally, when averaging individual parameters from each model, inconsistencies may arise (e.g. the average of status may suggest overfished/critical, but the average of TAC would be greater than zero and allow fishing). There is more work to do to determine best practices for combining models, but a clear explanation of the methods here would be helpful. This would include the paragraphs starting on line 557 and line 604. I note that the caption in Figure 20 has a brief mention of how composite OM is built, which is not mentioned in the text.

6. Are 100 simulations enough to properly characterize the uncertainty and stabilize the statistics? This is particularly important when calculating metrics such as the probability of

being above a threshold. Your model does not contain some of the uncertainty that other MSE simulations include (e.g. size-at-age) and thus 100 samples may be enough, but my experience has found that samples of 100 for projections of fisheries models is subject to considerable Monte Carlo error. Perhaps a plot of running quantiles would provide some insight. Furthermore, it seems that a large number of simulations would be necessary to calculate a performance statistic for objective 2 since the population is not always in the range of interest (see comment 9 below).

7. It is not common for assessment models to allow the average of recruitment to depart from R0 (there may be more parameters estimated than are years to estimate them; i.e. degrees of freedom). You provide a good explanation of some reasons for this, but one that may be missing is that R0 is not estimated accurately in the equilibrium population or the population in 1965 was above equilibrium and an R0 greater than average is needed for the initial age-structure. Allowing the recruitment deviations to not sum to zero brings up some additional questions:

    7.1. What is done in the projections with regard to average recruitment. Do the projections account for these reasons that average recruitment may differ from R0, or is R0 used and the population would equilibrate to the equilibrium estimated in 1965?

    7.2. What do reference points mean (B0, Bmsy, etc) mean if recruitment has not been average? Does this imply productivity has changed since 1965? The stock recruitment curve uses R0 and B0, and not the average observed recruitment.

    7.3. Is this indicative of a regime change that has affected average recruitment? I note that in Figure 10 (middle plot) the recruitment has rarely been above average between 1980 and 2013, which may align with a hypothesized regime change north of BC starting around 1977.

8. None of the objectives in Section 2.2.1. are directly related to yield volatility, so I wonder how the trade-off decision is between yield and yield volatility (line 940). I believe you mentioned that there was a trade-off between falling below 1,992 t (although there was a small probability of falling below) and maximising the yield (Table 8). I realise that yield volatility is useful to consider, and if it is part of the Sablefish decision-making process, perhaps it can added as a sixth objective to consider when other objectives are met.

9. I believe that objective 2 is to limit the probability of decline when the biomass is between 0.4Bmsy and 0.8Bmsy which has a linear tolerance between these values (line 537). It seems that to be able to calculate this statistic, the simulated population would need to traverse this range. However, the projections suggest a very small probability of falling below 0.8Bmsy (Figure 20) and the equation for the statistic (Table 4) is simple how often is 2031 biomass less than the 2022 biomass. It seems that 1) it is nearly impossible to calculate this statistic with these projections give the starting point, and 2) if the population starting point was at a very high point (say near B0) it would be highly likely that the population 10 years later would be less simply due to fishing but would remain above Bmsy. Therefore, how is it being determined from these simulations that this objective is met with this harvest policy (see Line 1027)? If it is met because the population is not simulated to fall between 0.4Bmsy and 0.8Bmsy in the next ten years, then that should be stated.

10. I did not understand the statement on line 1044 stating “annual adjustments to the harvest rate in response to the SSPM”. I realize that the harvest rate is adjusted when between the LCP and UPC, but Figure 4 suggests that it is static otherwise. I also notice that the maxHR has been adjusted in almost every year since 2011, but it is not clear why it changed in every year (Table A.2) where lines 578-580 state that the stock status is the only way it

would change. It seems that the MPs specify a target harvest rate for evaluation, with a recommended harvest rate (e.g. 5.5%), but I don't see a mechanism for future changes of the target harvest rate other than during the 3-5 year process of updating the OM and re-evaluating MPs. In the paragraph below line 584, it states that the maxHR has undergone a gradual reduction; does this imply that the maxHR going forward from here would remain constant? A clear process for the future would be useful.

11. Potential additional research recommendations:

    11.1. Investigating and then possibly modelling and projecting time-varying size-at-age to include that uncertainty.

    11.2. Examine the influence of outside areas (i.e. west coast and AK) on biomass, productivity, and recruitment, and determine if it is possible to include that uncertainty in the OM.

    11.3. Investigate the usefulness of time-varying selectivity or blocks of selectivity in response to past (a possibly future) management changes.

    11.4. (Re)-Establish a program to collect biological observations from at-sea discards.

SECONDARY COMMENTS

12. It may be helpful to clearly identify which parameters are estimated and which are fixed (and at what values). Tables 1 and 2 provide some of that information, but it doesn't seem to be complete and comprehensive. Additionally, clearly identify which numbers are which gear type. See other comments.

13. Early in the paper I was struggling to determine what is a sensitivity analysis, what is a scenario, what is a hypothesis, and what is part of the ensemble. It may be worth describing/defining these concepts early on.

14. Line 201 states that trawl fishery length compositions are available for 1970-2019, but Figure 1 shows trawl length compositions for only 4 years. Additionally, Figures G.3 and G.4 show four male length compositions and 3 female. What happened in 1981 and is there a difference in the fishery compared to recent years that would suggest not including those data or modelling selectivity in a different way? 1981 sample are for only males and very few over 57 inches? Are there 1981 female observations?

15. The paragraph on line 232 describes the growth parameters and how the K parameter is not estimated while others are estimated. Is there any concern about correlations (I realize this alternative parameterization may reduce those correlations). Furthermore, perhaps a range of values of K from the literature could be included to characterize uncertainty.

16. Paragraph starting with line 249: I am confused why the lack of age-composition data means that age-based selectivity cannot be estimated. Length-based selectivity is estimated and age-based selectivity is calculated from this and size-at-age. There are length compositions available for the trawl which may be informative for selectivity (but see comment #14). Maybe a bit more explanation would help.

17. I find it difficult to support dropping data because they do not fit. Perhaps there are some other reasons for excluding these data? Cox et al (In press) suggests that these ages may not have been random. It isn't that I suggest including them in the model, but perhaps more reasoning why they should not be included, or how would the model differ to include them. Also, it seems inconsistent that you include the CPUE (reluctantly) because it is the earliest observations, but exclude the age comps? You model time-varying catchability, thus maybe

time-varying selectivity would be useful. Furthermore, these are the earliest observations of cohorts (although there is weak tracking anyways) and it may inform your equilibrium age structure (see Priority comment #2 above).

18. In paragraph 316, I noticed that as an additional observation there is a large proportion of male Sablefish in the accumulator age of the age compositions (Figure 2 bottom row). Is there an explanation for this such as size selection and dimorphic growth? Should the accumulator age be increased?
19. In the description of ageing error (paragraph on line 332) it would be helpful to describe the range of assigned ages for a few true ages. Or plot the result. This would provide insight into what the variability is and how important is it.
20. I am wondering if assuming the plus group has no ageing error results in a disconnect in age assignment, especially with large proportions in the accumulator age group. For example, a true age 34 fish could be aged at 30 or in the plus group, but an age 35 fish is always in the plus group.
21. Line 382: I am not clear as to exactly how the 0.02 threshold and accumulation of nearby bins is performed. Does occur only at the tails of the composition (young and old ages), or could this apply for intermediate ages with large proportions on either side (and if so, how it the accumulator bin determined)?
22. Line 498: It may be worth justifying why RelCV=0.1 and m_h=0.67 are highly probable and each individually over the 5 scenarios gets 75% of the weight.
23. When stating the objectives that are calculated over “two Sablefish generations”, it may be helpful to state over the “**next** two Sablefish generations” to make it clear that this is including the near-term, is influenced by the starting conditions of the projections (thus will change in future iterations), and does not imply equilibrium. Furthermore, it would make it clear that none of these objectives are specifically a long-term, equilibrium harvest strategy, which I do not believe is a requirement of the DFO Precautionary Approach Framework (DFO 2006).
24. Line 568: It may be useful to depart from the assumption that the OM and estimation model equations are the same to determine how robust the MP is to uncertainty, variability, and alternative error in the OM that is not accounted for in the estimation model. I realize that there are general population dynamics, but alternative assumptions of how observation data are generated may be informative, for example.
25. The terms “exploitable biomass” and “legal biomass” are used throughout. It would be helpful to have a clear definition of these and whether they are the same.
26. Line 772-773: I am confused what is meant about support or lack of support. The survey age composition likelihoods are less for hiRelCV (Table 6) and maybe rewording this to make it clear that the age compositions support hiRelCV over the baseOM would help.
27. Maybe something to note in the analysis of yield lost due to discard mortality is that yield is a common and useful measure, but with price differentials between size classes, economics is useful to consider as well (see Sjoberg 2015).
28. Paragraph starting on line 819: In this paragraph, would it be useful to summarize the ensemble results as well?
29. Line 832: it is difficult to tell if the distributions are narrower. To me, they look similar. Maybe compare the standard error?
30. Line 896: There is no Figure 22. Do you mean Figure 21 middle row?

31. Target harvest rate is used to describe a multiplier on a biomass from the SSPM that is not the true exploitable biomass. Therefore, is harvest rate the proper term? It can get confusing because you report realised harvest rates being much less than the target harvest rate, and although you explain why, some may wonder why the target is not being achieved.
32. Line 1036: Does the wording here imply that you are striving to meet the target or you are trying to remain above the target at least 50% of the time. It is a subtle difference, but can make a difference on the choice of an MP. Perhaps alternative wording would be “remain above the target in 2052 with at least a 50% probability”.
33. Line 1051: It may be useful to also state that the MP (i.e. max harvest rate) is evaluated at this interval as well?
34. Line 1060: It may be useful to clarify that catch monitoring still occurred via EM.
35. Line 1070: However, this risk is not enumerated in the OM since immigration/emigration are not considered.
36. Line 1111: I think that also mentioning that this may also bring the reference points into closer alignment with the OM would be beneficial.
37. Line 1115: It would be helpful to list some of the benefits of including the tagging data.
38. Table 2: The logF are noted as estimated parameters, but in actuality logF_{t0} and delta_t are the estimated parameters (random walk).
39. Table 2 OM.2: What is D() on the left hand side. Is it referring to a cumulative density function or discards? It is confusing since D is used in F.6.
40. Table 2: The notation could be improved in this table by considering the subscripts and superscripts. Also, ‘lambda’ appears in many equations but is not defined.
41. The likelihoods table could be improved, possibly in the following ways.

    41.1. The numbers associated with gears could be described somewhere. I’m especially interested why gear 5 does not have a q in NLL.2 (I assume q is known which I think NLL.4 implies, although that q has a hat).

    41.2. Make sure notation is correct, such as hats, superscripts, and subscripts. For example, the tau in NLL.5. Relatedly, if NLL.4 feeds into NLL.5, wouldn’t the first n_g cancel?

    41.3. A little more background on concentrated negative log-likelihoods would be useful. In this working paper Bard (1974) is referenced, but in Cox et al (In Press) Bard (1978) is referenced. Would a paragraph describing how variance of observations is simply the deviation from assumed value and that externally calculated variances are not used.

    41.4. Pr.4 is for recruitment, I believe, and equation N.1 specifies a sigma_R but I do not see sigma_R in the prior. Does that imply sigma_R is 1.0? Similar concept for F deviations (delta). Does this imply the sigma is 1.0?

42. Table 9: A 4-5 year MSE/assessment cycle is specified, but the text mentions a 3-5 year cycle.
43. Table 9: Defining the SSPM as the assessment method may be confusing with the OM and estimation of status. Would “estimation model” be a better term for the SSPM?
44. Table 9: The UCP and LCP from the SSPM are known to be biased estimates of X%Bmsy. Is it necessary to call these 0.4Bmsy and 0.6Bmsy, or would it be sufficient to simply call them tuned LCP and UCP? Theoretically, they could be tuned as part of the process.

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APPENDIX D: AGENDA

DAY 1 – TUESDAY, NOVEMBER 15, 2022

Time	Subject	Presenter
0900	Introductions/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	Presentation of Working Paper cont'd	Authors
1115	Overview Written Reviews	Chair + Reviewers & Authors
12:00	**Lunch Break**	
1300	Identification of Key Issues for Group Discussion	RPR Participants
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 - WEDNESDAY, NOVEMBER 16, 2022

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**	

Time	Subject	Presenter
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
1500	Other Business arising from the review	Chair & Participants
1600	**Adjourn meeting**	

APPENDIX E: PARTICIPANTS

Last Name	First Name	Affiliation
Acheson	Chris	Canadian Sablefish Association
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