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Proceedings of the Pacific regional peer review on a revised operating model for Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada

January 20, 2016
Nanaimo, British Columbia

Co-chairs and editors: Julia Bradshaw and John Holmes

Fisheries and Oceans Canada
Science Branch
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Canada

Foreword

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

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SUMMARY

Fisheries and Oceans Canada (DFO) and the British Columbia (BC) Sablefish (*Anoplopoma fimbria*) fishing industry are collaborating on a management strategy evaluation (MSE) process intended to develop and implement a transparent and sustainable harvest strategy. Variations of age-structured models have been used in simulation testing candidate management procedures and represent the cornerstone of the MSE process.

The existing Sablefish harvest strategy is defined by four components:

1. Operational fishery objectives used to assess the acceptability of alternative management procedures;
2. A management procedure (MP) that consists of data - total landed catch and three abundance indices, an assessment method – a tuned Schaefer state-space production model, and a harvest control rule defined using estimated biomass at maximum sustainable yield (B_{MSY}) and fishing mortality at maximum sustainable yield (F_{MSY}) values;
3. A simulation-based evaluation of the management procedure against alternative operating models representing selected hypotheses about Sablefish stock dynamics; and
4. Application and monitoring of the MP in practice. The issues of potential structural mis-specification in the operating model and the lack of fit to key historical data were recognized in 2010 peer reviews.

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 of January 20, 2016 at the Pacific Biological Station in Nanaimo, BC. A working paper describing and testing a revised operating model for Sablefish in British Columbia intended to address the issues identified in 2010 was presented for peer review.

In-person and web-based participation included Fisheries and Oceans Canada (DFO) Science and Fisheries and Aquatic Management Sectors staff; and external participants from First Nations organizations, the commercial fishing sector, and academia.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) providing advice to Management to inform a simulation-based evaluation of the performance of alternative management procedures against agreed upon objectives for the Sablefish stock and fishery. The MSE approach is an iterative process for decision-making and analysis that is ongoing for the Sablefish fishery.

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

Compte rendu de l'examen par les pairs de la région du Pacifique sur l'Élaboration du modèle d'exploitation de la morue charbonnière (*Anoplopoma fimbria*) en Colombie-Britannique, au Canada

SOMMAIRE

Pêches et Océans Canada (MPO) et l'industrie de la pêche de la morue charbonnière (*Anoplopoma fimbria*) de la Colombie-Britannique (C.-B.) collaborent à un processus d'évaluation des stratégies de gestion (ESG) visant à élaborer et à mettre en œuvre une stratégie de pêche transparente et durable. Les variations des modèles fondés sur la structure d'âge ont été utilisées dans les procédures de gestion proposées faisant l'objet de simulations, et représentent la pierre angulaire du processus d'ESG.

La stratégie de pêche à la morue charbonnière existante est définie par quatre composantes :

1. Des objectifs opérationnels des pêches utilisés pour évaluer l'acceptabilité des autres procédures de gestion.
2. Une procédure de gestion qui comprend des données (prises débarquées totales et trois indices liés à l'abondance), une méthode d'évaluation (modèle de production réglé Shaefer de type état-espace) et une règle de contrôle des prises définie à l'aide d'une estimation de la biomasse au rendement maximal soutenu (B_{RMS}) et de la mortalité par pêche au rendement maximal soutenu (F_{RMS});
3. Une évaluation fondée sur la simulation concernant la procédure de gestion par rapport à d'autres modèles d'exploitation représentant les hypothèses retenues quant à la dynamique des stocks de morue charbonnière;
4. L'application et la surveillance de la procédure de gestion utilisée. Le problème des mauvaises spécifications structurelles potentielles dans le modèle d'exploitation et le manque de cohésion des principales données historiques ont été reconnus lors d'examens par les pairs en 2010.

Le présent compte rendu résume les discussions pertinentes et les principales conclusions de la réunion régionale d'examen par des pairs du Secrétariat canadien de consultation scientifique (SCCS) de Pêches et Océans Canada (MPO), qui a eu lieu le 20 janvier 2016 à la station biologique du Pacifique de Nanaimo, en C.-B. Un document de travail décrivant et mettant à l'essai un modèle d'exploitation révisé pour la morue charbonnière en Colombie-Britannique, et visant à aborder les enjeux cernés en 2010, a été soumis aux fins d'examen par les pairs.

Au nombre des participants en personne ou par conférence Web, il y avait des employés des secteurs des Sciences et de la Gestion des pêches et de l'aquaculture du MPO, des participants externes provenant d'organisations des Premières Nations, du secteur de la pêche commerciale et des universités.

Les conclusions et avis découlant de cet examen seront présentés sous la forme d'un avis scientifique fournissant des conseils à l'intention de la direction, afin d'orienter une évaluation fondée sur la simulation du rendement des autres procédures de gestion par rapport aux objectifs convenus pour le stock et la pêche de la morue charbonnière. L'approche de l'ESG est un processus itératif pour la prise de décisions et les analyses en cours concernant la pêche de la morue charbonnière.

L'avis scientifique et le document de recherche seront disponibles sur le site du Secrétariat canadien de consultation scientifique (SCCS).

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) meeting was held on January 20, 2016 at the Pacific Biological Station in Nanaimo to review a revised operating model for the Sablefish (*Anoplopoma fimbria*) Management Strategy Evaluation (MSE), including several improvements to the model formulation and the data input to the model.

These proceedings report on the main points developed during the presentations, review and discussions as part of the evaluation of the revised operating model. The regional peer review process is open to all participants who have appropriate technical expertise, experience and interest in the topic to engage in a robust peer review of the data inputs and model performance. The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Fisheries Management. In total, 21 participants with relevant expertise within DFO Science, Fisheries Management, First Nations, the Government of British Columbia, the commercial fishing sector, non-governmental organizations, and academia participated in the RPR in person or via webinar (Appendix B).

The meeting co-chairs, John Holmes and Julia Bradshaw, welcomed participants, reviewed the role of CSAS in the provision of peer-reviewed advice, and gave a general overview of the CSAS process. The co-chairs discussed the role of participants, the purpose of the various CSAS publications (Science Advisory Report, Proceedings and Research Document), the definition of consensus used by CSAS and the process for achieving consensus. The co-chairs noted that the purpose of the meeting was a science review and not a consultation, and then reviewed the Terms of Reference for the meeting, highlighting the objectives to be achieved. Although the meeting was scheduled for two days, participants agreed that the review could be accomplished in one day and a revised Agenda (Appendix C) was developed and approved. The co-chairs confirmed that copies of the Terms of Reference, working paper, and a meeting agenda were distributed to participants prior to the meeting. Lisa Lacko was identified as the rapporteur for the meeting.

All participants were reminded that they had equal standing and were invited to participate fully in the discussion and to contribute their knowledge to the review process, with the goal of delivering scientifically defensible conclusions and advice. The majority of participants attended the meeting in person, others attended by webinar.

The following working paper (WP) was prepared and made available to meeting participants prior to the meeting (see summary in Appendix D):

> A Revised Operating Model for Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada by S.P. Cox, A.R. Kronlund, and L. Lacko (CSAP Working Paper 2014GRF03)

Participants were informed that Dr. William Clark (International Pacific Halibut Commission, retired) was asked before the meeting to provide a written review of the working paper to inform, but not limit, discussion by participants attending the meeting. His review can be found in Appendix E. Participants were provided with copies of the written review prior to the meeting.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) to Fisheries Management to inform Sablefish fishery planning (DFO 2016). The SAR and supporting research document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

PRESENTATION OF WORKING PAPER

Working Paper: A revised operating model for Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada. CSAP Working Paper 2014GRF03.

Rapporteur: Lisa Lacko

Presenter(s): Sean Cox and Michelle Jones

Sean Cox began his presentation of the working paper by providing a background description of the MSE process applied to Sablefish in British Columbia. He described the revisions to the 2011 operating model implemented for the working paper. These revisions include a two-sex/age-structured model to account for differences in growth, mortality, and maturation of male and female Sablefish, adjusted model age-proportions via an ageing error matrix, and a modified multivariate-logistic age composition likelihood formulation to reduce model sensitivity to small age proportions. The presentation included a discussion of the significance of various data inputs to the model on the determination of model states such as biomass and harvest rates. Finally, a presentation of the selectivity function analysis based on tag release-recovery data was given by PhD student, Michelle Jones.

Operating Model Revisions

The management procedure (MP) for 2016-17 uses a state-space production model in conjunction with a harvest control rule to estimate the total allowable catch (TAC). The TAC has been reduced from approximately 4,600 t in the 2005/06 fishing year, to 2,300 t when the MP was introduced for the 2011-12 fishing year, to the current TAC of 1,992 t for the 2016/17 fishing year. These reductions were implemented due to concerns over declining BC Sablefish abundance and beginning in 2011-12, to increase the likelihood that conservation objectives would be met. Reducing TAC is just one control measure that can be implemented to reduce fishing mortality. However, a broader goal of this paper was to investigate other mechanisms to achieve stock rebuilding without additional TAC reductions. For example, a reduction in at-sea releases of sub-legal sized Sablefish (<55 cm), which incur post-release mortality, could mitigate the need for catch reductions. Integration of the groundfish fisheries in 2006 and the reductions in TAC have resulted in hook and line gear accounting for a larger proportion of the total catch, which can now exceed 50% of landings.

The 2011 operating model fit releases from the trap fishery, and the hook and line fishery data well with the exception of a large outlier in the hook and line data for 2006. However, the fit to the trawl release data was poor, underestimating the observed releases by hundreds of tonnes in some years.

An ageing error model developed for Alaska Sablefish by Hanselman et al. (2012) was implemented in the revised operating model for BC Sablefish in 2014. Hanselman et al. (2012) assumed that ageing error is asymmetric about a given age (i.e., an age 3 fish can be 2-7 years of age) and that younger ages tend to be underestimated. The Working Paper authors noted this addition to the operating model improved the resolution of cohort strength estimates and produced a more plausible pattern of recruitments than the overly-smooth recruitment series estimated by the Cox et al. (2011) model. The effect of the ageing error correction was to reduce smearing of cohorts into adjacent year classes which tends to compress between year variability.

Mortality rates and harvest rates on legal size Sablefish (>55 cm) estimated by the revised operating model are similar to those estimated by the Cox et al. (2011) model, but sub-legal harvest rates estimated by the 2014 model (7-8%) are higher than the estimates from the 2011 model. This change may help to explain why stock rebuilding is slower than expected despite large reductions in catches since 2006, and help to identify management measures that could be implemented to mitigate mortality of sub-legal Sablefish.

There are currently two fishery-independent data sources, the stratified random trap survey (StRS) and Standarized survey (Std). The longline trap fishery is used as a source of proportion-at-age times-series data for BC Sablefish as are the StRS and Std survey age proportions.

Proportions-at-age estimated from samples collected by the StRS show coherence of strong cohorts from the 2000 and 2008 year classes. The model fits to these data are considered reasonable by the authors. The results demonstrate the value of a directed fishery-independent survey that follows a statistical survey design.

The Std survey, now discontinued, was originally intended to sample nine localities deemed to be productive Sablefish grounds and spaced along offshore waters such that the survey could be completed in about 30 days. Model fits to the proportion-at-age data for this survey show a lack of fit to the plus group and cohort patterns that are less clear than those evident in the StRS survey data. This result is likely less a function of ageing error than a survey scheme that focused on commercial fishing grounds rather than sampling the distribution of offshore Sablefish, i.e., a non-representative survey design.

The longline trap fishery is the only source of commercial fishery age-composition data in the BC Sablefish assessment process. The data series begins in 1982, however, there are issues with unrepresentative sampling and low sample sizes in some early years. Inspection of the observed data shows no clear cohort patterns. Based on recruitment patterns from Alaska and the west coast of the United States, a very large 1977 year class should be evident in the recruitment data, with additional large year classes in the 1980s, 1999-2000 and most recently in 2008.

Scenarios (D1-D7) in the working paper were designed to allow for varying combinations of data and data weighting to overcome some of the data and index issues that were identified in the 2010 review. The D1 data scenario represents the age- and sex-structured alternative to the previous age-structured operating model used for BC Sablefish (e.g., Cox et al. 2011). The remaining models, D2 through D7, represent alternative operating model scenarios for stock size and productivity, all of which employ the age-correction matrix. Scenario D2 was designated as the base model for the evaluations and is the same as D1 with the addition of an ageing error matrix. The D3 model scenario is identical to D2 but with a shorter estimated recruitment time series (1990-2015). The authors recommend further exploration of D3 as an alternative base operating model because it may reduce errors that occur due to poor information content in the early part of the historical period. The remaining data scenarios (D4-D7) attempt to address how the model responds to different inputs by varying the weights of data inputs (which are multipliers on the likelihood) or using an alternate data series time frame. Scenario D7 is essentially what the model would look like if data collection began in 2003. The results for D7 illustrate the exaggeration of residual error in the model when a small data set is used. The residual error variances are used to compare data set fits. Estimates of biomass from each of the scenarios (D1-D7) produce qualitatively similar patterns over time (Figure 21; Cox et al. 2014 WP).

Table 5 of the WP presents estimates of legal biomass and legal harvest rates produced using the different data scenarios. Both scenarios D1 and D2 produce estimates of female spawning biomass between 8,000 and 9,000 tonnes in 2015, which would be amongst the lowest estimated spawning biomass values for the BC stock. The revised model estimates that mortality of sub-legal fish (< 55 cm) is approximately 7-8% compared to an estimate of 1-2% in the 2011 model. These higher sub-legal mortality estimates may be part of the explanation for why the BC Sablefish stock does not seem to be rebuilding as quickly as expected.

Fishery Selectivity Analysis

Fishery selectivity at length was estimated based on tag release-recovery data. Despite the practice in many stock assessments, the assumption of fixed selectivity over several decades is implausible. The analysis of the tag release-recovery data included consideration of alternative shapes for gear selectivity (i.e., combinations of logistic, Normal and Gamma functions with asymptotic and dome-shaped formulations), and evaluated whether the data would support estimation of time-varying selectivity.

The authors analyzed data obtained from tags released on Sablefish trap surveys and recovered by commercial longline trap, longline hook, and trawl gear fisheries. They compared the relative performance of logistic, normal, and gamma selectivity functions based on stationary and time-varying parameterizations. The first length class (450-500 mm) in commercial trawl recoveries was excluded from the analysis because of small sample sizes or zero observations in some years that prevented all time-varying models from converging. The authors tried asymptotic and dome-shaped functions to describe the selectivity curve. For the asymptotic fits, the logistic function was used and for dome-shaped relationships, the double normal function was used. Models were compared using Akaike's Information Criterion (AIC). Recoveries were restricted to fish recaptured in the first year after release to increase the likelihood that individual fish remain within their release length class in the year following release. Time-varying parameterizations provided a better model fit than alternative models for the estimation of longline hook and trap survey selectivity. The longline hook and trap fisheries are more selective for larger size classes of Sablefish, whereas the trawl fishery is more selective for smaller size classes. Over time, there is a trend for trawl gear to select larger fish. Possible explanations for this result include that larger Sablefish occur deeper than the depths predominately fished by trawl gears, large Sablefish are reported less frequently, or they may migrate out of BC waters.

WRITTEN REVIEWS AND DISCUSSION

Review by Dr. William (Bill) Clark

- The reviewer provided his general comments to the meeting participants. He considered the new model features to be appropriate and consistent with best practices in stock assessment science. He was also in agreement with the ideas proposed by the authors for future development of the model. The review (Appendix E) outlined several questions and comments that were addressed by the authors as summarized below.
- The reviewer asked how set locations were placed within the randomized trap survey strata because he wanted to know whether different spatial or depth distributions could explain the relative paucity of plus group fish in fishery catches relative to survey catches. The authors explained how the randomized stratified trap survey is designed and how fishing operations are conducted. Commercial fishery sets are are more common in shallower depths than the middle depth stratum and the deep depth stratum. The randomized trap survey is intended to encompass the depth range of offshore Sablefish whereas the commercial fishery targets higher productivity areas in the shallow depth band.
- It was noted that the growth parameters estimated from BC trap survey size-at-age data are higher than the values adopted in the model. The von Bertalanffy growth equation parameters used as fixed inputs to the operating model were chosen based on review of the

Sablefish literature. The reviewer suggested that since the growth parameter, *k* values, which expresses the rate at which the asymptotic length is approached, used in the operating model are similar for males and females, there can't be a great difference in calculated length at age of either sex. The reviewer wondered whether this lack of difference was realistic. The authors agreed to provide an improved explanation of how the growth parameters used in the operating model were selected. Estimates of k for males and females obtained using trap survey size-at-age data are at the high end of the range reported in the literature for both Canadian and U.S. populations and therefore the authors chose to use lower growth rate estimates in the operating model.

- The size of the plus group is notably large for male Sablefish sampled by the standardized trap survey. Both the female and male plus group appear to be quite large relative to the preceding age groups in stratified trap survey catches, but neither are numerous in commercial trap catches. The standardized trap survey data show large positive residuals of plus group fish in model fits. What are the estimated total mortality rates, e.g., ages 25-35+ fish in the model fits? The authors noted that there was no difference between male and female natural mortality in these data.
- What was the difficulty in fitting releases in 2010? Trap and longline hook fisheries were adequately fitted to the model, but trawl releases were not captured because of high releases in the early portion of the time series.
- Formula and term definitions will be clarified in the paper (i.e., OM.18).
- The multivariate logistic (MVL) distribution of sample age proportions assumes that all the sample proportions have the same coefficient of variation (CV), which doesn't sound realistic. In multinomial sampling the smaller age groups have much larger CVs than the larger ones. Even if the multinomial model is not correct because of heterogeneity, the smaller proportions are expected to have much larger CVs than the bigger ones. Could this be the reason that there was trouble fitting the young/middle-aged groups early in the time series? Alternatives to the MVL distribution could be a vector of standard deviations, or Fournier's ELEFAN scheme with an estimated variance scalar. The authors noted that they tried the Multifan likelihood scheme in the model (e.g., Fournier et al. 1990), but ultimately decided on the multivariate logistic model. The authors agreed to reconsider the Multifan approach in future, and agreed that working out the sampling variance of the composition data by bootstrapping was a viable approach.

GENERAL DISCUSSION

Model Fit

- The model continues to show lack of fit to trawl releases during the 1996 to 1999 period. Fishing for Longspine Thornyhead (*Sebastolobus altivelus*) that occurred during this period required longer trawl tows due to the deeper fishing depths and lower catch rates. Thus, bottom trawl selectivity for Sablefish may have been different during the late 1990s than at present, resulting in more Sablefish releases.
- There was a request to include the 32 x 32 ageing error matrix developed from Hanselman et al. (2012) in an appendix because it demonstrates the application to a stock model with a large plus group (accumulator age class). The authors agreed to include this additional information about the ageing error matrix.

- An ageing error matrix should be developed in the future that is specific to BC Sablefish. The Sclerochronology Lab at PBS provides a range of ages and information on agreement and confidence and a matrix might be developed based on inter-reader agreement. Hanselman et al. (2012) found that Alaska Sablefish ages tend to be underestimated at older ages and overestimated at younger ages.
- A proposal is recommended, to submit to CARE (Committee of Age Reading Experts, a joint Canada and United States expert group originating from the Western Groundfish Conference), to develop ageing error matrices for Alaska, BC, and the US west coast stocks.
- The 35+ group does not appear in the commercial fishery, which tends to be concentrated spatially, but it does show up in the stratified random trap survey data, which is more spatially diffuse. Therefore, there is value in contrasting the depth distribution of the catches between surveys, and commercial fisheries to determine if spatial and depth related differences might explain the paucity of fish in the plus group for commercial trap data.
- Potential explanations for the model not capturing the plus group (35+) in commercial catches were discussed and include the hypothesis that older fish could be less catchable by commercial fisheries which concentrate their efforts between 250 and 400 feet, i.e., these older fish move into deeper waters outside of fishing areas, or are more desirable because of their size and associated value and therefore unrecorded.

Commercial Sampling Program

- Revise the commercial catch sampling program to improve the proportion at age data for trap, hook and line, and trawl gears. Suggestions for changes to the commercial sampling program will go into the SAR.
- Discussion of current sampling protocols noted that hyper-aggregation of ages might be an issue due to changes in the fishery and it was recommended that sampling protocols be redesigned in conjunction with industry.
- Tasking observers with additional sampling was discussed and it was noted that this may create workload issues.

Tagging Selectivity

- Approximately 8,000-10,000 Sablefish are tagged and released during the annual fishery-independent trap survey. The goal of the program is to estimate fishery selectivity for each gear type and to gather information on Sablefish movement. Approximately 315,000 tags have been released and 22,000 tags have been recovered since the inception of this program.
- Participants discussed whether other types of tags could be applied to Sablefish to improve annual recovery rates, such as PIT or RFID tags inserted in the head of fish, such that only the head would be retained at the cost of forfeiting length, sex and maturity data. It was suggested that fish sex could be determined through genetic testing.
- It was noted that there is an experiment underway for Pacific Bluefin Tuna where close-kin mark-recapture techniques are being applied to derive fishery-independent estimates of stock abundance, mortality and other population parameters using genetic markers of parentage.

CONCLUSIONS

- The WP was accepted with minor revisions (Appendix F).
- There was consensus that the new features in the revised operating model (two-sex structure, ageing error matrix) are appropriate and follow best practices in fisheries science. These structural changes resulted in recruitment estimates with reduced auto-correlation, improved fits to the age-35+ group and the temporal pattern of at-sea releases in the trawl fishery from 2000 until present. The revised operating model is considered an improvement relative to the 2010 operating model and is recommended for use in future BC Sablefish management system simulations.
- The lack of fit to some at-sea releases in the trawl fishery (1996 to 1999) and in the trap fishery (2006 and 2007) remains an area for improvement.
- Six of the seven data scenarios (D2-D7) represent plausible operating model scenarios for stock size and productivity and are recommended for future evaluations of Sablefish management procedures. Scenario D2, which is a two two-sex model with an ageing error matrix applied to model ages, was adopted as the base operating model in the WP, so designated because of the improvements imparted by the ageing error correction. It is recommended that the D3 scenario, which is identical to D2 but with a shorter estimated recruitment time series (1990-2015), be explored as an alternative base operating model because it may reduce poor model behaviour that occurs due to low information content in in the early part of the historical period. Scenario D1 represents the sex-structured alternative to the previous age-structured 2010 operating model used for BC Sablefish (Cox et al. 2011), but it lacks the ageing error correction matrix and so is not considered further.
- It is recommended that future model development explore ways to more fully integrate tagging data into the sex- and age-structured operating model to address issues related to correlations among estimates of unfished biomass (B_0), the steepness of the stock-recruitment relationship (h), and length-based selectivity.
- Inconsistent sampling of age composition data in commercial catches (only Trap fishery age composition data are currently available) has contributed to model issues that have been consistently identified during BC Sablefish harvest strategy evaluations. The commercial catch sampling program should be reviewed to improve the sampling protocol in light of changes to the fishery since integration occurred and the sampling protocol was first designed.
- Management strategy evaluation is an iterative process of change and improvement in response to revised objectives, new data, and new understanding of system dynamics. It is recommended that BC Sablefish operating models be reevaluated for suitability at 5-year intervals or when required due to significant changes in the understanding of the stock and fishery.

ACKNOWLEDGEMENTS

Dr. William Clark (Seattle, Washington) provided a thorough written review of the Working Paper. His effort in providing feedback to the authors and committee is much appreciated. The co-chairs thank Lisa Lacko for rapporteuring during the meeting.

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APPENDIX A: TERMS OF REFERENCE

A revised operating model for Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada

Regional Peer Review – Pacific Region

January 20, 2016
Nanaimo, British Columbia

Co-chairs: John Holmes and Julia Bradshaw

Context

Fisheries and Oceans Canada (DFO) and the British Columbia (BC) Sablefish fishing industry collaborate on a management strategy evaluation (MSE) process intended to develop and implement a transparent and sustainable harvest strategy. Sustainability of harvest strategies is determined by simulation testing alternative management procedures against operating models that represent a range of hypotheses about uncertain Sablefish stock dynamics. Performance of management procedures used in these tests is measured against pre-agreed conservation and catch objectives for the stock and fishery (Cox et al. 2011, DFO 2014).

The existing Sablefish fishery operating models were developed to represent alternative hypotheses about natural mortality rates, at-sea release mortality rates, individual growth rate, and recruitment autocorrelation. These processes are all fundamental to fish population dynamics, yet are typically the most difficult parameters to estimate reliably from fisheries data. The models are structured by age and also by growth groups; the latter dimension is added as part of an evaluation of size-based discarding, selective grading of fish at sea, and potential regulatory changes aimed at reducing these activities. Operating models were fitted to available data for the BC Sablefish fishery to estimate model parameters conditional on each hypothesis for subsequent simulation testing of alternative management procedures.

The Fisheries Management Branch of Fisheries and Oceans Canada requested advice from Science Branch to continue development of the Sablefish operating model to improve model structure and ability to represent uncertain biological and fishery processes prior to a full collaborative MSE process planned for 2016/17.

Objectives

Guided by the DFO Sustainable Fisheries Framework, particularly the Fishery Decision-making Framework Incorporating the Precautionary Approach (DFO 2009), meeting participants will review the working paper:

A revised operating model for Sablefish in British Columbia, Canada. S.P. Cox, A.R. Kronlund, L. Lacko, and M. Jones. CSAP Working Paper 2014GRF03.

The working paper will be used to provide advice with respect to the following objectives:

1. Review a revised Sablefish operating model and assess suitability for simulating realistic data that represent stock and fishery process such as natural mortality rates, sexually dimorphic growth, fishery selectivity, at-sea release mortality rates, recruitment dynamics, and changes in future division of catch among gear types.
2. Propose candidate operating model hypotheses to be used for subsequent evaluation of management procedures for the collaborative MSE process planned for 2016/17.

Expected Publications

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

Expected Participation

- DFO (Science, Fisheries Management)
- Aboriginal communities
- Province of British Columbia
- External reviewers
- Industry
- Non-governmental organizations and other scientists and stakeholders.

References

Cox, S.P., Kronlund, A.R., Lacko, L. 2011. Management procedures for the multi-gear Sablefish (*Anoplopoma fimbria*) fishery in British Columbia, Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/063. viii + 45 p.

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APPENDIX B: MEETING PARTICIPANTS

Last Name	First Name	Affiliation
Acheson	Schon	DFO Science, Groundfish Section
Acheson	Chris	Canadian Sablefish Association
Bradshaw	Julia	DFO Science
Clark	Bill	International Pacific Halibut Commission (retired)
Cox	Sean	SFU
Dorner	Brigette	Heiltsuk First Nation
Edwards	Andrew	DFO Science, Groundfish Section
Frank	Ron	Maa Nulth Fisheries Committee
Haigh	Rowan	DFO Science, Groundfish Section
Hargreaves	Marilyn	DFO Science, Centre for Science Advice Pacific
Holmes	John	DFO Science
Jones	Michelle	SFU
Keizer	Adam	DFO Fisheries Management, Groundfish
Lacko	Lisa	DFO Science, Groundfish Section
Laliberte	Bernette	Cowichan First Nation
MacDougall	Lesley	DFO Science, Centre for Science Advice Pacific
Rutherford	Kate	DFO Science, Groundfish Section
Temple	Kathryn	DFO Science, Groundfish Section
Williams	Daniel	DFO Science, Groundfish Section
Workman	Greg	Science, Groundfish Section
Wyeth	Malcolm	DFO Science, Groundfish Section

APPENDIX C: REVISED AGENDA

A revised operating model for Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada

January 20, 2016

Pacific Biological Station, Nanaimo, BC
Chairs: John Holmes/Julia Bradshaw

DAY 1 – Wednesday January 20, 2016

Time	Subject	Presenter
09:00	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
09:15	Review Terms of Reference	Chair
09:30	Presentation of Working Paper	Authors
10:30	***Break***	
10:50	Written Review	Chair + Reviewer & Authors
11:30	Identification of Key Issues for Group Discussion	RPR Participants
12:00	***Lunch Break***	
13:00	Discussion & Resolution of Technical Issues	RPR Participants
14:30	***Break***	
14:45	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
15:00	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
16:30	Next Steps • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Co-Chairs
17:00	Adjourn for the Day	

APPENDIX D: WORKING PAPER SUMMARY

Fisheries and Oceans Canada (DFO) and the British Columbia (BC) Sablefish (*Anoplopoma fimbria*) fishing industry collaborate on a management strategy evaluation (MSE) process intended to develop and implement a transparent and sustainable harvest strategy. Variations of age-structured models have been used in simulation testing candidate management procedures and therefore represent the cornerstone of the MSE process. In this paper, we revise the Sablefish operating model to account for potential structural model mis-specification and lack-of fit to key observations recognized in previous models. Specific modifications include:

i. changing from an age-/growth-group operating model to a two-sex/age-structured model to account for differences in growth, mortality, and maturation of male and female Sablefish,

ii. adjusting model age-proportions via an ageing error matrix,

iii. testing time-varying selectivity models, and

iv. revising the multivariate-logistic age composition likelihood to reduce model sensitivity to small age proportions. Structural revisions to the operating model improved fits to age-composition and at-sea release data that were not well-fit by the previous operating model. Accounting for ageing errors improved the time-series estimates of age-1 Sablefish recruitment by reducing the unrealistic auto-correlation present in the previous model results. The resulting estimates clearly indicate strong year classes of Sablefish that are similar in timing and magnitude to estimates for the Gulf of Alaska.

Two unanticipated results were that:

i. time varying selectivity parameters were not estimable (or necessarily helpful) despite informative prior information from tagging; and

ii. improved recruitment estimates helped to explain the scale and temporal pattern of at-sea release in the trawl fishery. The latter finding represents a major improvement in our ability to assess regulations and incentives aimed at reducing at-sea releases in all fisheries. Estimates of Sablefish stock status, productivity, and trends over the past several years are consistent with previous harvest strategy simulations. Estimated exploitation rates for years 2011-2015 varied across seven data scenarios (~ 8-10%), but are consistent with exploitation rates projected for the current U60-40+Floor management procedure under the former operating model.

APPENDIX E: WORKING PAPER REVIEW – BILL CLARK

Date: Jan. 13, 2016

Reviewer: William G. Clark, International Pacific Halibut Commision (IPHC) (retired)

Summary

The British Columbia sablefish fishery is assessed and managed under a harvest policy that includes

i. clear management objectives,

ii. a simple management procedure (MP) based on a fitted Schaefer model and a harvest control rule, and

iii. an ongoing management strategy evaluation (MSE) in which the performance of the management procedure is tested on data generated by a suite of operating models, which in everyday parlance are alternative plausible age-structured assessment models fitted to fishery and survey data. This sort of management system is widely regarded as ideal, but each of the elements is challenging in practice. The B.C. sablefish management system is a model for others because it has successfully developed and implemented all three elements.

The present review concerns a routine update of the suite of operating models based on practical experience and some recommendations from an earlier review. New features are:

i. a split-sex model,

ii. an aging error matrix,

iii. priors on fishery selectivity based on tag recoveries, and

iv. updated data on at-sea releases by the trawl and longline fisheries.

Review

The new features are entirely appropriate. The first two are standard practice in most assessments nowadays, and the third is a notable successful application of mark-recapture analysis to a real stock assessment. It often happens in other assessments that the form of fishery selectivity is uncertain from model fitting alone, which raises questions about stock abundance and harvest policy. In the case of B.C. sablefish the tagging data supply the needed information. I presume this work will be published elsewhere.

Apart from the new features, I have a few questions and comments about other features of the operating models that may be outside the scope of the present review but that I include for the authors' consideration going forward. None of these is a new technical concern. The main issues are: (i) the large plus group in some but not all age compositions, and (ii) the appropriateness of the multivariate logistic distribution for fitting age compositions. For ease of reference I will list my questions and comments according to where the subject material appears in the documents, beginning with the appendices where the data are described.

Appendix C

p. 12 (Fig. C-8). How were stations placed within strata in the stratified random trap survey? How does the distribution of survey stations compare with the distribution of commercial sets? (The question here is whether different spatial or depth distributions could explain the relative paucity of plus group fish in fishery catches relative to survey catches.)

Appendix D

pp. 4-5. Growth. The growth parameters estimated from B.C. trap survey data are Linf=70.4 and k=0.39 for females, and Linf=60.4 and k=0.29 for males. The adopted values are Linf=72 and k=0.25 for females, and Linf=68 and k=0.29 for males. It is stated that these values were chosen to "approximate the range of U.S. values", but none of the cited estimates has Linf so close for females and males. The adopted k values are also close, so there can't be a great difference in calculated length at age of females and males. Is that realistic?

pp. 10-15. Plus group. Plus group fish are not numerous in commercial trap catches. They are numerous in standardized trap survey catches (esp. males) and in stratified trap survey catches, where both the female and male plus group catches appear to be quite large relative to the preceding age groups. But it is only the standardized trap survey that shows large positive residuals of plus group fish in model fits (main paper pp. 50-54). What are the estimated total mortality rates for e.g., ages 25-35+ fish in the model fits?

Main paper

p. 16. Released fish. What data on size composition of released fish are available for estimating trawl and longline selectivity? What was the difficulty in fitting releases in 2010?

p.18. Plus group in the aging error matrix. Good job that you gave some thought to the proper treatment of the plus group in the aging error matrix and added some extra age classes to accomplish that. You need to do that, and not everybody does.

p. 18. Calculation of q. Observation formulas L.1-L.3 (p. 38) don't look quite right in view of how the numerator and denominator of the rhs of L.1 are defined on p. 34.

p. 19. MVL. The multivariate logistic (MVL) distribution of sample age proportions is obtained by adding zero-mean normal deviates to the logs of the true proportions and then normalizing the antilogs. In the cited Schnute papers and apparently in these models, there is only a single standard deviation of the normal log deviates for all age groups. (Is that true? I'm unsure because the little n term in L.6 on p. 34 is undefined, as are some other little n terms.) If so, then the assumption is that all the sample proportions have the same coefficient of variation (CV), which doesn't sound realistic. In multinomial sampling the smaller age groups have much larger CVs than the larger ones. Even if the multinomial model doesn't hold because of heterogeneity, I would still expect the smaller proportions to have much larger CVs than the bigger ones. Could this be the reason that you had trouble fitting the young/middle-aged groups early on? As an alternative to the simplest MVL distribution you could consider one with a vector of standard deviations, or Fournier's ELEFAN scheme with an estimated variance scalar. (I had good luck with that approach in my day.) Yet another idea is to work out the purely sampling variance of the composition data by bootstrapping and scale that.

The proper modeling and weighting of composition data is a very live issue at present with no one right answer (and maybe no right answer at all). In U.S. Pacific coast assessments the most popular treatment seems to be to use a multinomial density with the arithmetic mean input sample size tuned to the harmonic mean of output sample size, but that requires iterating which you quite reasonably want to avoid in your numerous model fits.

p. 24. Geometric distribution of aging error. The Hanselman et al. paper reports that sablefish age readings in Alaska have a geometric distribution but that in some trials a naïve normal distribution (based e.g. just on percent agreement assuming no bias) performed as well or better than the geometric in practice because if the geometric wasn't spot on it would miss a lot of the true distribution. Given the uncertainty involved in carrying the Alaska results over to B.C., you might do as well or better with a simple normal model.

APPENDIX F: WORKING PAPER REVISIONS

The following revisions were recommended for the working paper and future iterations of the Sablefish operating model.

Considerations for next iteration:

- Look at the likelihood function
- Eliminate data before 1990, after which reporting was improved, to avoid "poor data" issues. Could be accomplished with an operating model scenario fitted to reduced data.
- Generating a BC ageing error correction matrix should be considered
- Develop a consistent sampling design across all fishery sectors reporting Sablefish;
- Clarify the K parameter, include scenarios with different sets of growth parameters,
- Try out MULTIFAN again, try to sample variance by boot strapping.

Revisions for current paper:

- Explain in the methods why the authors assumed a multivariate logistic likelihood formulation for age proportions.
- Add an ageing error matrix appendix with the specifications and include the values for the 32 x 32 matrix of age classes.
- Correct error in the OM.12 equation, the fishing mortality term, subscript should be a *g*.
- Not all terms are defined in the paper, make sure all are included, i.e., the *n* term in L.6 and other *n* terms.
- Clarify L.6 term to indicate the sample size is the number of age classes.
- L.21 delta term should match OM.12
- Table 5. Change subscript D_{2011} to D_{2015}.
- Figure 3. Clarify caption (left and right models or top and bottom?).
- Figure 21. Remove the right axis and revise the caption.
- Figure A-1 clarify caption, open circles?
- Change base model to D2, exclude D1 because it is simply a 2 sex alternative to the 2010 model (i.e, it lacks ageing error correction).