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Proceedings of the Pacific regional peer review of the Shortspine Thornyhead (*Sebastolobus alascanus*) Stock Assessment for the Pacific Coast of Canada in 2015

December 10, 11, and 18, 2015
Nanaimo, BC

Chairperson and editor: Maria Surry

Fisheries and Oceans Canada
Science Branch
3190 Hammond Bay Road
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October 2016

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 discussions and key conclusions that resulted from the Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting of December 10, 11, and 18, 2015 at the Pacific Biological Station in Nanaimo, B.C. One working paper focusing on a stock assessment of Shortspine Thornyhead for the Pacific coast of Canada was presented for peer review.

Shortspine Thornyhead (*Sebastolobus alascanus*) has been captured in the British Columbia commercial trawl fishery in appreciable amounts since the late 1980s. Although there is some directed fishing on this species, it is largely caught along with other groundfish species in the commercial trawl fishery.

The Fisheries and Aquaculture Management Branch of DFO requested an updated assessment to determine whether current harvest levels are sustainable and compliant with policies of the Sustainable Fisheries Framework (SFF), in particular the Fishery Decision-making Framework Incorporating the Precautionary Approach (PA Framework). The assessment process included a review of available stock and fishery monitoring data, and analyses of those data to produce inputs to a quantitative population dynamics model. A delay difference model fit to six survey and CPUE abundance indices assuming a coast-wide stock was used to quantify stock status and forecast biomass subject to a range of fixed annual catches. The estimated status of Shortspine Thornyhead relative to candidate reference points consistent with the PA Framework was reported.

In-person and web-based participation included Fisheries and Oceans Canada (DFO) staff from the Science and Fisheries and Aquatic Management Branches; and external participants from the Canadian Groundfish Research and Conservation Society, the Deep-sea Trawlers Association, and the National Institute of Water and Atmospheric Research (New Zealand).

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report providing advice from Science to fishery managers and other clients. The Science Advisory Report (SAR) 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'Évaluation du stock du sébastolobe à courtes épines (*Sebastolobus alascanus*) dans la côte du Pacifique du Canada en 2015

SOMMAIRE

Le présent compte rendu résume les discussions et les principales conclusions de la réunion régionale d’examen par des pairs de Pêches et Océans Canada (MPO) et du Secrétariat canadien de consultation scientifique (SCCS) qui a eu lieu les 10, 11 et 18 décembre 2015 à la Station biologique du Pacifique de Nanaimo, en Colombie-Britannique. Un document de travail sur l'évaluation des stocks de sébastolobe à courtes épines de la côte du Pacifique du Canada a été déposé aux fins d'examen par les pairs.

Des sébastolobes à courtes épines (*Sebastolobus alascanus*) sont capturés en quantité appréciable dans le cadre de la pêche commerciale au chalut de la Colombie-Britannique depuis la fin des années 1980. Bien qu'il y ait une certaine pêche dirigée de cette espèce, celle-ci est principalement capturée avec d'autres espèces de poissons de fond dans le cadre de la pêche commerciale au chalut.

La Direction générale de la gestion des pêches et de l'aquaculture du MPO a demandé une nouvelle évaluation afin de déterminer si les niveaux de prises actuels sont durables et conformes aux politiques du Cadre pour la pêche durable (CPD), en particulier le Cadre décisionnel pour les pêches intégrant l’approche de précaution (cadre de l'AP). Le processus d’évaluation comprenait un examen des données disponibles sur le stock et la surveillance des pêches ainsi que l'analyse de ces données afin de produire des intrants pour un modèle quantitatif de dynamique des populations. Un modèle de type différence-délai adapté à six relevés et aux indices d'abondance des captures par unité d'effort (CPUE) partant de l'hypothèse d'un stock présent sur l'ensemble de la côte a été utilisé afin de quantifier le stock et de prévoir la biomasse en fonction de divers niveaux de prise annuels constants. L'estimation de l'état du sébastolobe à courtes épines par rapport aux points de référence proposés, conforme au cadre de l'AP, a été présentée.

Le personnel du Secteur des sciences et des directions générales de la gestion des pêches et des ressources aquatiques de Pêches et Océans Canada (MPO), des participants externes de la Canadian Groundfish Research and Conservation Society, de l'Association des chalutiers en eaux profondes et du National Institute of Water and Atmospheric Research (Nouvelle-Zélande) ont participé aux réunions en personne et aux séances Web.

Les conclusions et les avis qui découlent de cet examen seront présentés sous forme d'un avis scientifique présentant les opinions du Secteur des sciences aux gestionnaires et à d'autres clients. L'avis scientifique et le document de recherche à l'appui seront rendus publics sur le site Web du Secrétariat canadien de consultation scientifique.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) meeting was held on December 10, 11, and 18, 2015 at the Pacific Biological Station in Nanaimo to review the stock assessment of Shortspine Thornyhead (SST, *Sebastolobus alascanus*) off the Pacific coast of Canada.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from the Fisheries and Aquaculture Management Branch of DFO. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from First Nations, commercial and recreational fishing sectors, and environmental non-governmental organizations. In total, 20 people participated in the RPR (Appendix B).

The meeting Chair, Maria Surry, welcomed participants and invited them to introduce themselves and give their affiliation. Kathryn Temple was identified as the Rapporteur for the meeting. The Chair 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, reminding participants that the meeting was a science review and not a consultation. The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting (Appendix A), highlighting the objectives. It was confirmed with participants that all had received copies of the Terms of Reference, Agenda, and working paper.

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

> Stock Assessment of the coastwide population of Shortspine Thornyhead (*Sebastolobus alascanus*) for British Columbia, Canada in 2015, by Paul J. Starr and Rowan Haigh. (CSAS Working Paper 2014GRF04)

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, including the development of the Science Advisory Report (SAR). 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.

A written review of the working paper was provided by Charles Edwards (National Institute of Water and Atmospheric Research – New Zealand, Appendix E). The goal of soliciting the review was to inform, but not limit, discussion by participants attending the review.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) to inform fishery management decisions for the coastwide Shortspine Thornyhead stock. Along with these Proceedings, the SAR and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

REVIEW

Working Paper: Stock Assessment of the coastwide population of Shortspine Thornyhead (*Sebastolobus alascanus*) for British Columbia, Canada in 2015 (CSAP WP2014GRF04)

Authors: Paul J. Starr and Rowan Haigh

Reviewer: Charles T. T. Edwards, National Institute of Water and Atmospheric Research (NIWA) Ltd., Wellington, New Zealand

Chairperson: Maria Surry (Groundfish Section, Marine Ecosystems and Aquaculture Division (MEAD), Pacific Biological Station (PBS), DFO)

Rapporteur: Kathryn Temple (Groundfish Section, MEAD, PBS, DFO)

Presenters: Paul Starr (Canadian Groundfish Research and Conservation Society)
Rowan Haigh (Groundfish Section, MEAD, PBS, DFO)

Meeting: Dec. 10,11 and 18, 2015, Seminar Room, Pacific Biological Station, Nanaimo BC

PRESENTATION OF WORKING PAPER

The authors provided a summary presentation of the working paper. Background information on the biology of SST, its range and distribution, and catch history was included. The authors described the data inputs required for the assessment, including five fishery-independent surveys used to index abundance – US National Marine Fisheries Service (NMFS) Triennial, West Coast Vancouver Island (WCVI) Synoptic, Queen Charlottes Sound (QCS) Synoptic, Hecate Strait (HS) Synoptic, West Coast Haida Gwaii (WCHG) Synoptic – and an analysis of commercial catch and effort data which was used to create a sixth abundance index series. Four additional surveys were evaluated for use in the model but were not included as inputs to the stock assessment model. The authors noted that the data from the NMFS Triennial survey were determined to be marginally acceptable for use in the assessment, because of the relatively small areal coverage of Canadian waters (the lower half of Vancouver Island's west coast). It was retained in the assessment because of the scarcity of early information (1980 – 2001) and because the area covered included areas where SST were later taken by commercial fisheries. The authors clarified that tows from the NMFS survey used in this assessment were restricted to those that occurred within Canadian waters.

The delay difference population dynamics model used for the assessment was described, including key model assumptions and the fixed and estimated model parameters. A proposed reference case and a summary of 20 additional sensitivity runs were presented.

The reference case model was assumed to start at equilibrium from B_0 in 1980, where B_0 is the estimated biomass of SST in 1980 before the start of the fishery and is also the biomass required to maintain the average level of recruitment estimated over the stock reconstruction. The stock assessment results were evaluated against provisional reference points from Fisheries and Oceans Canada's Fishery Decision-making Framework incorporating the Precautionary Approach (PA, DFO 2009), including a limit reference point (LRP) of $0.4B_{\text{MSY}}$, an upper stock reference (USR) of $0.8B_{\text{MSY}}$, and a reference harvest rate of u_{MSY}, where B_{MSY} is the estimated long-term equilibrium biomass when the stock is fished at the exploitation rate (u_{MSY})

that results in maximum sustainable yield (MSY). Stocks are considered to be in the “critical” zone when $B_t < 0.4B_{MSY}$, in the “cautious” zone when $0.4B_{MSY} < B_t < 0.8B_{MSY}$, and in the “healthy” zone when $B_t > 0.8B_{MSY}$, where B_t is the predicted biomass at time t.

The authors pointed out that there was uncertainty in the ageing information available for SST assessment due to the small number of age observations for this difficult-to-age species. They noted that there were discrepancies between the age data and estimates of natural mortality (M) and growth used for this assessment with those found in the literature. Most SST in the available age sample for this assessment were less than 50 years old, leading to an estimate of M=0.08; however, ages greater than 50 are common in US stock assessments for this species, leading to estimates of M that range between M=0.03 and 0.06. In addition, the available DFO ages resulted in an estimated growth function with faster growth rates than the growth function used in a stock assessment of the same species off the western coast of the lower 48 states in the US (Taylor & Stephens 2013). In response to requests by participants, the authors completed additional model scenarios which were based on the US estimates of growth and used lower estimates of M to bracket the life history parameter estimates that occur in the literature but were not included in the original suite of sensitivity cases. These results were presented to participants when the meeting reconvened on December 18, 2015.

WRITTEN REVIEW

Charles Edwards, NIWA Ltd., Wellington, New Zealand

The reviewer provided a written review prior to the meeting (Appendix E), and presented summary slides at the meeting by teleconference. The main points of the review were as follows:

1. Biological input assumptions are well justified.
2. There appear to be conflicts in the input data which prevent a good model fit, namely predicated values for the commercial CPUE prior to 2003 do not match trends in the observations. The model attempts to match the mean weight changes, but cannot reproduce the overall increase in mean weight that has occurred since 2000.
3. Life-history sensitivities have been extensively explored but do not appear to improve model fit.
4. Management advice based on the assessment results and sensitivities is well described and presented, however these conclusions should retain an appropriate caveat given the poor model fits.

The reviewer endorsed the authors’ choice of using a delay difference model for the assessment.

The reviewer noted that the delay difference model tracks the recruited component of the biomass which is assumed to be fully selected and mature. He felt that in general, estimates of somatic growth and age at recruitment (maturity), which are required as auxiliary data in the model, were largely well justified. However, the reviewer suggested that the estimate of natural mortality used in the model was based on an unreliable estimator, and that, given the available data on growth and maturity; alternative estimates would be better justified.

The reviewer pointed out that the model did not produce a good fit to mean weight data, and discussed why this might have occurred, making the following two points:

1. Absolute stock size will determine the influence of catches on the dynamics; therefore, if stock size is too high, the model will rely on recruitment deviations to fit the data.

2. The current abundance indices do not appear to respond to the catch (particularly unresponsive in the early years) which will force the model to estimate high stock size and/or large recruitments; however the model can't rely on large recruitments because of conflicting signals in abundance indices and annual mean weight data (1995 – 2000 & 2010 - 2015) and therefore attempts a "compromise" fit.

The reviewer asked the following questions to which the authors responded (italics):

Were the 1998 mean weight data reliable? The estimated mean weight for 1998 was very high, followed by a large decrease in annual mean weight until 2000, after which there was a steady increase in annual mean weight. The reviewer suggested that the authors delete the 1998 estimate to evaluate model sensitivity to the outlier.

The authors responded that the 1998 data point was considered to be reliable as it was based on a large sample size of lengths distributed over many tows. They reported that a model fit had already been attempted that excluded the 1998 point with no significant change to the fit. The authors noted that they had excluded a 1997 data point due to a small sample size of only 120 lengths from a single tow.

How do estimates of the recruitment parameters, R_t, enter the likelihood for years 1980 to 1995, since equation E26 cannot be used to predict recruits for these years?

The authors clarified how recruitment was estimated in the early part of the reconstruction. The first 15 years use the estimate of unfished recruitment, R_0, until the knife-edge age of recruitment (k) to the fishery is reached at k=16 years.

Do the areas covered by surveys represent the areas where fisheries operate, i.e., do surveys represent the fishery both geographically and by depth strata?

The authors clarified that the surveys represent the areas where the trawl fishery operates. The authors referred to the figures in the Working Paper which show commercial CPUE (Figure 1) and the survey areas (Appendix B).

Should abundance indices take into account the relative importance of each survey? For example, should the WCHG survey be weighted more heavily than other surveys?

The authors responded that they did not have any basis for changing the relative weighting among the surveys. This could be done through manipulation of survey coefficients of variation (CVs, e.g. by adding "process error") but was not done, allowing the relative weightings implied by the unadjusted CVs to remain.

Discussion of the reviewer's question on the utility of the surveys, and his concern that the NMFS survey may have an unduly large influence on the estimate of unfished biomass, B_0, was deferred to general discussion.

**Note: further discussion on weight and survey data is captured under "General Discussion"

GENERAL DISCUSSION

Unless otherwise specified, text in non-italic font reflects questions and comments from the participants. Italicized text reflects the responses to those questions and contributions from the authors. The Shortspine Thornyhead meeting participants (Appendix B) are collectively called "participants" herein.

After the Reviewer's presentation, the meeting was opened to all participants for general discussion. The following issues were discussed:

- Mean weights;

- Survey indices and CPUE;
- Uncertainty in the ageing data;
- Trawl footprint;
- Reference points;
- Decision tables;
- Smaller spatial scales;
- Ecosystem considerations.

The discussion corresponding to each of the issues is summarized below.

MEAN WEIGHTS

The reviewer noted that the model did not produce a good fit to annual mean weight data and demonstrated that there were conflicting signals between abundance (surveys and commercial CPUE) and the mean weight data. Participants asked whether

1. area, depth, and other effects had been considered when calculating the annual mean weights;
2. the increase in mean weights over time could have been due to a coincident shift in the fishery northward (e.g., SST weight might increase with increasing latitude);
3. the increase in mean weights represented changes in recruitment to the fishery.

An industry representative confirmed that the fishery directed at SST moved northward over time due to changing market demands; for example, in 1998-2000, market demand shifted to favour larger fish, resulting in the fishery moving north. From 2005 onwards there was no further movement of the fishery northward. A participant also noted that fishing depth had changed and suggested that the effect of changes in depth/location on mean weights should be examined more closely.

The authors responded that they had attempted to account for latitude and depth effects in the General Linear Model (GLM) used for weight analysis. They noted that they had additionally calculated approximate mean weights (using landing data graded into weight bins) from two recent SST-targeted trips in the north, and found the results were consistent with the mean weights used in the model. They acknowledged that the GLM analysis may not have been completely successful in removing latitude and depth effects. For instance, the observed increase in annual mean weights may result from a change in selectivity or there could be an interaction between the year effects with the northward movement of the fishery which was not included in the analysis.

Participants recommended that the authors look for a spatial-temporal pattern in the mean weight series, and determine whether it can it be correlated with movement of the fishing effort over time.

The authors generated plots illustrating mean weight trends over time for three areas of the coast (3CD: west coast of Vancouver Island; 5ABC: Queen Charlotte Sound and southern Hecate Strait; 5DE: northern Hecate Strait, Dixon Entrance, and the west coast of Haida Gwaii). The figure showed that there was no trend in mean weights in area 5AB (which had much less data), but there were increasing trends in mean weight in both 3CD and 5DE, indicating that the increase in mean weight is not entirely due to a northward shift in the fishery. The authors also plotted the distribution of lengths that were used to calculate mean weight. They noted that *there were very few fish > 40 cm, and even fewer > 50 cm. They plotted length by depth class in 3CD, 5ABC, and 5DE, and noted that in 3CD the majority of the catch was < 40 cm, and that the effect of mean length changing with depth was not strong in either 3CD or 5DE.*

Participants were satisfied that questions regarding the model fit to the mean weight data had been explored sufficiently within the scope of this assessment. Participants and authors agreed that the SAR could capture the contradiction between mean weights and biomass indices in the section on Sources of Uncertainty. Participants agreed that the changes in fishery behaviour over the history of the fishery could be included in the Research Document.

SURVEY INDICES AND CPUE

The reviewer noted that fits to the abundance indices (survey indices and commercial catch per unit effort, CPUE) were poor, and questioned the utility of the indices. He further asked if there was concern that the NMFS survey may have an unduly large influence on the biomass estimates because it was the only survey available during the period from 1980 to 2001. He suggested that the authors consider model runs with only commercial CPUE data used to index abundance, and consider a composite index derived from combining survey indices of abundance.

A participant noted that there may be utility in selecting tows used to generate survey indices. The commercial CPUE data clearly showed catch from deep strata, and the Hecate Strait survey showed most catches coming from those same deep strata. Furthermore, the CPUE from the commercial fishery increased with increasing depth. Another participant pointed out that the CPUE standardization procedure removes the depth, area, and other confounding effects.

The authors did not see utility in selecting tows from strata rather than using a single survey index as designed. They argued that the random stratified survey design already accounts for differences between depth strata. They commented that while an index based on single stratum could be developed, it is likely to show a similar trend to the existing index using all the survey data.

Participants agreed that additional sensitivity runs were required to address the questions on how the survey and CPUE index series were included in the model.

The authors presented two new sensitivity cases. One case excluded the NMFS survey from the model fit, and a second case excluded all survey indices and used only commercial CPUE as an abundance index. The authors did not agree with the reviewer's suggestion of generating a composite index, as it was unclear how to weight the suite of surveys to produce a composite index. Removing the NFMS survey from the model fit did not change the model results. The "CPUE-only" case fit the CPUE data reasonably well, while estimating a lower level of stock status than other cases presented so far. The authors noted that although CPUE would be affected by changes in the fishery as was discussed for weight data, latitude, depth, and timing were all accounted for in the CPUE standardization.

Participants were satisfied that these additional sensitivity runs addressed the questions raised by the reviewer and some of the participants in how the survey indices and CPUE affected the model results, and noted that the SAR should include these scenarios in the discussion.

AGE DATA

Ageing Methods

Shortspine Thornyhead is a challenging species to age. The analysis of bias between otolith burnt-section and thin-section ageing methods contained in the Working Paper was judged to have low power given the small sample size of n=60. Some participants disagreed with the authors' interpretation that the bias was small.

The Program Head of the Sclerochronology Lab at PBS commented that the age sample used for the assessment was an initial attempt at ageing SST, and the Sclerochronology Lab at PBS has not developed a standardized protocol for ageing this species. He concluded that there was low confidence among age readers in the accuracy and bias properties of the age interpretations, and that ageing of SST was an active topic of research. He noted that there was no information which could be used to provide an error estimate for the ageing data.

A participant noted that researchers in the United States have validated ages for SST (Kline 1996, Cailliet et al. 2001). The Program Head of the Sclerochronology Lab clarified that while the general method is validated, and the longevity of SST is confirmed, the specific instructions on how to distinguish annular rings from other patterns on the otolith still need to be developed.

There was discussion as to whether the analysis of bias between the otolith burnt-section and thin-section ages should be excluded from the Research Document given the current low confidence in SST ageing; it was agreed that the analysis should be retained provided revisions reflected the clarification provided by the discussion.

Age Sample

Participants noted that growth curves and estimates of natural mortality for SST in BC reported in the Working Paper implied faster growth rates than those reported in US assessments. Estimates of natural mortality in the US range from 0.03 – 0.06, while the estimate of M reported in the Working Paper is 0.08 for SST sampled from BC waters. They observed that while there were few SST > 50 cm in the age sample from BC used in the current assessment, there appeared to be substantially more SST > 50 cm reported from US waters.

The authors noted that they had used the age data available to them for BC SST. The authors agreed that the BC growth curve differed from the US growth curve, but argued that they had no objective way of adjusting the parameters of the BC growth curve given the available data. They also noted that the US assessments used the Hoenig estimator (Hoenig 1983) for natural mortality, which is known to have some biases. The authors re-iterated that there were few fish in the BC age sample > 50 cm. The authors had compared the distribution of lengths in the otolith sample to the overall distribution of available length data, and found no evidence that the age sample was unrepresentative of the fishery. The authors conceded that the available age sample may not represent the population due to selectivity and/or sampling bias.

Participants noted that research surveys in BC do encounter larger specimens of SST than were included in the age sample. However, an industry representative noted that the BC bottom trawl fishery does not see many fish > 22 inches (55 cm).

There was some discussion on possible reasons for the fishery and research samples not encountering larger/older fish, as well as possible reasons why the Canadian and US fisheries might encounter larger/older fish. Possible factors included the depths fished, selectivity of the fishery, and the relative timing of the Canadian and US fisheries. The head of the Sclerochronology Lab reminded participants that larger fish are not necessarily older.

Participants agreed that it was not possible to answer these questions, and this would remain a source of uncertainty.

A participant clarified that the issue was not whether the age sample was representative of the fishery, but rather whether the sample included a representative distribution of size-at-age for the youngest and oldest fish in the population.

Additional Sensitivity Cases

Participants agreed that there was an unexplained discrepancy between SST length data observed in the BC fishery and that observed in the US. This discrepancy could not be attributed to ageing bias, differences between the fishery in BC and the US, or other causes. Due to the uncertainty and potential bias in the age data used in this assessment, and associated effects on the estimation of growth, natural mortality, and knife-edge selectivity (k), the participants requested additional work be completed.

The authors were asked for additional sensitivity cases to illustrate the effects of using an alternative growth curve, range of natural mortality and age at knife-edged recruitment to the fishery. The authors reported that they initially attempted to use parameters from Jacobson's (1991) growth curve along with the length-weight relationship from the BC samples. However, results indicated that this choice introduced a mismatch in length data between BC and the US and convergence of the assessment model could not be achieved. Instead, they replaced the BC growth data with a growth curve developed by Hamel (2005) and used by Taylor and Stephens (2013) in their recent assessment of SST for the US west coast. Specifically, the following sensitivity cases were requested:

Table 1. Twelve scenario options for comparison. DFO growth: L_∞=47.257cm, K=0.0385, t0=-8.456; NMFS growth: L_∞= 84.99cm, K= 0.0178, t0=-2.88.

Scenario	Growth	*M*	*k*-len (cm)	*k*-age (y)
1	DFO	0.03	29	16
2	DFO	0.06	29	16
3	DFO	0.08	29	16
4	NMFS	0.03	29	21
5	NMFS	0.03	24	16
6	NMFS	0.03	21	13
7	NMFS	0.06	29	21
8	NMFS	0.06	24	16
9	NMFS	0.06	21	13
10	NMFS	0.08	29	21
11	NMFS	0.08	24	16
12	NMFS	0.08	21	13

The meeting adjourned on December 11, 2015 to allow the authors time to produce the additional sensitivity cases. When the meeting reconvened on December 18, 2015, results for the new sensitivity cases were presented by the authors, who discussed the assumptions associated with each case.

The authors stated their views that:

1. a knife edged recruitment corresponding to a length of 29 cm may be too large due to the number of fish that would be excluded from the recruited biomass;
2. a knife-edged recruitment corresponding to a length of 24 cm is consistent with the distribution of observed lengths for SST captured in the fishery; and

3. a knife-edged recruitment corresponding to a length of 21 cm implies that fish are recruiting to the fishery at a weight of only 100 g, which is unrealistically small.

The authors further noted that M = 0.03 may be too low, given the implied large value for equilibrium mean weight (i.e. ~2 kg) and the lack of large Shortspine Thornyhead collected from the fishery in BC, even in samples obtained early in the history of the fishery. They suggested that M = 0.06 is a more appropriate choice, and similar to the value of 0.05 estimated by Hamel (2005). They noted that the model is very sensitive to small differences in assumed values.

The authors noted that while the DFO and NMFS growth curves were dissimilar, the estimated Walford parameters appeared to be similar. However, small changes in Walford slopes had large impacts on sizes-at age. For example, the growth curves intersect at approximately age 26 years, with much larger fish above this age in the NMFS growth model compared to the DFO growth model, and significantly smaller NMFS fish below this intersection. The authors acknowledged that the DFO growth curve is likely biased (e.g., L_∞ too low), but the NMFS growth curve produced large and unrealistic equilibrium mean weights, in the order of 2kg which are not consistent with BC observations.

The authors showed a slide comparing the median expected values of B/B_0, the probability (P) of exceeding $0.8B_{MSY}$, and the probability of exceeding $0.4B_{MSY}$ for the DFO growth curve with the range of M values (0.03, 0.06, 0.08) at $k_{[length]}$ = 29 cm and the NMFS growth curve with the range of M values (0.03, 0.06, 0.08) at each value of $k_{[length]}$ (29 cm, 24 cm, 21 cm). They noted that the values of B/B_0 were in line with other assessments that have been deemed acceptable, and all probabilities of staying above the USR were close to 1.0 except for those that used the NMFS growth curve with $k_{[length]}$ = 29 cm. The authors noted that all investigated models predicted a decline in biomass between 2016 and 2019, at the current levels of fishing.

The authors noted that selecting a single reference case was not a realistic option. Based on the sensitivity runs, there was no obvious reason that one run should selected over another as a reference case. Of the sensitivity cases discussed, only the case where an age at knife-edged recruitment corresponding to a length of 29 cm combined with the NMFS growth function caused the stock to enter into the “cautious” zone” in the late 1990s and early 2000s. This scenario recovered to around 50 – 60% B_0 by the end of the reconstruction in 2015, but predicted a rapid decline at current levels of removals.

Participants noted that the research document and SAR should capture the uncertainty in selecting one run over the other as a reference case. Participants also noted that the lack of confidence in the available age data, and the unexplained discrepancy between SST length data observed in the BC fishery and that observed in the US were key sources of uncertainty that should be included in the SAR.

TRAWL FOOTPRINT

Participants discussed the potential effects on the conservation of SST from the establishment of the restricted trawl footprint in 2012, and whether the excluded areas represented potential refugia for SST. It was noted that the establishment of the restricted trawl footprint is an example of mitigating risk through closures. A participant suggested that this information be included in the SAR.

An industry representative suggested that closures which occurred off Haida Gwaii in 2000 – 2001 and in other areas (e.g., off Triangle Island) during the exploratory expansion of the Longspine Thornyhead fishery created large refugia for both Longspine Thornyhead and Shortspine Thornyhead.

The authors commented that they had not compared the historical spatial locations of SST catches to the area encompassed by the trawl footprint.

Participants suggested that the authors include a figure illustrating the spatial distribution of Shortspine Thornyhead catches before and after the establishment of the trawl footprint from 1996 forward.

The authors presented a figure showing the number of tows catching SST and the SST total catch before and after the trawl footprint was implemented in 2012. These data suggested that about 10% of the SST catch before 2012 had been taken in the area now excluded from the restricted trawl footprint.

Participants agreed that the information on the trawl footprint should be included in the SAR.

REFERENCE POINTS

There was general agreement that the proposed reference points were acceptable in the absence of alternative species-specific reference points. Participants agreed that there was no basis for selecting a single model run as the reference case on which to base specific values for the reference points. Participants requested that the SAR include a discussion on the uncertainties with respect to the model estimated reference points (given the short time series and data-limited nature of the assessment).

Participants agreed that the DFO Precautionary Approach (PA) reference points of $0.4B_{MSY}$ as a limit reference point (LRP), $0.8B_{MSY}$ as an upper stock reference (USR), and u_{MSY} as a reference removal rate should be included in the final decision tables for advice to managers.

DECISION TABLES

Participants suggested that, given the wide range of plausible productivity scenarios without a preferred scenario, the twelve scenarios presented in Table 1 could be averaged to produce a decision table that showed the status of the stock relative to the selected reference points over a range of fixed annual catches. No one sensitivity case emerged as a reference case, given the uncertainties in the fixed inputs to the model, the short-time series of abundance index data and the conflicting signals between annual mean weights and abundance indices.

Sensitivity cases to be averaged for the calculation of the decision tables should include the 12 cases presented in Table 1: the three DFO-growth references cases and nine additional sensitivity runs using NMFS growth requested by participants. These cases would cover the range of fixed input values for M and age at knife-edge selectivity. Current (2016) and forecast (2019) stock status relative to $0.4B_{MSY}$,$0.8B_{MSY}$, and u_{MSY} would be summarized over a range of annual catches from 0 to 1000 t. It was suggested that a table be included that lists the uncertainties associated with each sensitivity. Participants agreed that boxplots summarizing performance statistic outcomes for the model-averaged results should be included in the SAR.

SMALLER SPATIAL SCALES

No information was provided upon which to base the advice at smaller spatial scales than coastwide. A representative from the DFO Groundfish Management Unit noted that assessment at a smaller spatial scale would be included in future requests for advice.

The authors cautioned that data support for assessment at a spatial scale smaller than coast-wide would be low, and therefore separate assessments for smaller areas might not be feasible.

A participant noted that while the assessment of population status could remain at a coast-wide scale, a management procedure could distribute effort at smaller spatial scales to avoid problems such as spatial depletion.

ECOSYSTEM CONSIDERATIONS

No information was provided with respect to how climate/ecosystem state could potentially affect SST distribution and abundance. However, participants suggested that discussion of the coincident species captured in the multi-species fishery along with SST could be noted under Ecosystem Considerations in the SAR.

CONCLUSIONS

CONSENSUS ON PAPER ACCEPTABILITY

The working paper was accepted subject to revisions outlined in the following sections.

CONSENSUS ON SHORTSPINE THORNYHEAD ASSESSMENT

The objectives of the terms of reference were achieved.

The following issues were identified which may affect the reliability of the SST assessment results:

1. The available data were limited (e.g., no catch-at-age time series or long-term fishery independent abundance indices), which necessitated the adoption of a simple model framework requiring strong assumptions.
2. There was uncertainty and potential bias in the age data used in this assessment. As a result, there was uncertainty in estimation of growth, natural mortality, and knife-edge selectivity, as demonstrated by the differences between the DFO and NMFS growth functions.
3. Contradictory signals existed between the time series of abundance indices and annual mean weights (both among the abundance indices and in comparison to the mean weights).

These issues were explored using 35 model scenarios which bracketed a range of plausible values that were considered to encompass low and high extremes for the fixed inputs for M and k, as well as exploring two different growth functions. Twelve of these scenarios were averaged to provide precautionary advice to managers using the DFO Precautionary Approach (PA) reference points of $0.04B_{MSY,}$ 0.08_{BMSY}, and u_{MSY}.

An assumption of the analysis was that SST is a single coastwide stock. Therefore, harvest advice on a smaller scale was not provided. Advice at a smaller spatial scale would require definition of spatially specific objectives for the stock and fishery and may not be feasible, given the limited quantity of available data.

INSTRUCTIONS TO AUTHORS

The following revisions to the Research Document are requested:

- Add results corresponding to the additional sensitivity cases produced during the meeting;
    - Include a summary table describing the 12 sensitivity cases used for model averaging, including a column indicating the case-specific uncertainties.

- Produce decision tables that summarize model-averaged states for stock status and harvest rate.
  - Update the abstract of the research document.

- Include the information on mean lengths by area and by depth that was presented during the meeting in the biology section
- Explain that observed lengths at age were used to infer selectivity; emphasize that length proportions are a function of selectivity not sufficient alone to define selectivity (Taylor et al. 2005).
- Include a discussion on how the trawl footprint restriction has affected the exploitation of SST, with an evaluation of the impact on conservation objectives.
- Include a discussion on how the fishery has evolved over time as a background against which the changes in annual mean weight and CPUE can be evaluated.
- Discuss the uncertainty with respect to the estimated reference points.
- Include a figure comparing the predicted equilibrium mean weights.

RECOMMENDATIONS AND ADVICE

The advice from this assessment will be provided based on the average of 12 model scenarios. A single decision table will be provided in the SAR and will include the DFO PA reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$ along with u_{MSY}, for a range of annual harvest levels from 0 – 1000 tonnes, with a projection for B_{2019} only.

The following research recommendations arose from the meeting:

1. Reassess the growth curve for BC SST when reliable ages become available.
2. Develop protocols for production ageing of SST using thin-sectioning (underway).
3. Collect length-stratified biological samples from the commercial fishery and from research surveys to ensure that age structures represent the full size range of SST in BC.

ACKNOWLEDGEMENTS

The chair thanks the reviewer, Charles T. T. Edwards (NIWA, New Zealand), for his valuable review of the working paper, all the meeting participants for their involvement, and Kathryn Temple for being an excellent rapporteur. Rob Kronlund provided an extensive and helpful review of these proceedings. Lesley MacDougall's participation and support during the meeting, as well as Ann Mariscak's logistical support is greatly appreciated.

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APPENDIX A: TERMS OF REFERENCE

Shortspine Thornyhead *(Sebastolobus alascanus)* Stock Assessment for the Pacific Coast of Canada in 2015

Regional Peer Review Process – Pacific Region

December 10-11, & 18, 2015
Nanaimo, British Columbia

Chair: Maria Surry

Context

Shortspine Thornyhead (*Sebastolobus alascanus*) has increasingly been caught by the commercial trawl fishery since the mid-1980s. A coastwide total allowable catch (TAC) limit was first set in 1997 (748 t) and is currently 771 t. Although there is some directed fishing effort on this species, it is largely caught along with other groundfish species in the commercial trawl fishery. Minor catch amounts are taken by the hook and line fisheries. The geographic range of Shortspine Thornyhead is extensive (Love et al. 2002), occurring from the Sea of Japan, through the Aleutian Islands and down along the west coast of North America to Baja California. The depth range for this species varies widely (down to 1500 m) but it is found most often in commercial catches between 150 and 450 m depth, with spawning aggregations in the oxygen minimum zone (600-1000 m) (Jacobson and Vetter 1996). Shortspine Thornyhead larvae and juveniles spend 12-14 months in the pelagic zone before settling onto the shelf at 100 m depth. As this species gets older and larger, it migrates into deeper water. This is may be an adaptation to reduce the risk of predation. The most recent stock assessment to review this species occurred in 1999 (Schnute et al. 1999). A quantitative population model has not previously been used to assess this species. Fisheries and Oceans Canada (DFO) Fisheries Management has requested that the Shortspine Thornyhead coastwide stock be assessed relative to reference points that are consistent with the DFO Precautionary Approach (DFO 2009), and that probabilistic decision tables be produced that forecast the impacts of varying harvest levels on stock status.

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 following working paper to provide the basis for discussion and advice on the specific objectives outline below:

Paul J. Starr and Rowan Haigh. Shortspine Thornyhead (Sebastolobus alascanus) Stock Assessment for the Pacific Coast of Canada in 2015. CSAS Working Paper 2014GRF04

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

1. Review and evaluate stock and fishery monitoring data available for assessment of stock status and harvest projections of *Sebastolobus alascanus*.

2. Test the ability of the available data to support quantitative assessment model determinations of stock status.

3. Suggest candidate reference points (either biomass-based or fishing mortality-based) consistent with the DFO Precautionary Approach, including alternatives to models-based reference points.

4. If possible, provide forecasts of the predicted status of Shortspine Thornyhead Rockfish relative to candidate reference points across a range of management actions.

5. If possible, provide science advice appropriate for management of Shortspine Thornyhead at smaller spatial scales; or, provide rationale why this is not possible.

Expected Publications

- CSAS Science Advisory Report (1)
- CSAS Research Documents (1)
- CSAS Proceedings (1)

Participation

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

References

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APPENDIX B: PARTICIPANTS

Last Name	First Name	Affiliation
Ackerman	Barry	DFO Fisheries Management Groundfish
Edwards	Andrew	DFO Science, Groundfish Section
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APPENDIX C: AGENDA

Canadian Science Advisory Secretariat
Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Shortspine Thornyhead (*Sebastolobus alascanus*) Stock Assessment for the Pacific Coast of Canada in 2015

December 10, 11, 18, 2015
Pacific Biological Station, Nanaimo, BC

Chair: Maria Surry

DAY 1 – Thursday December 10, 2015

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Authors
1030	***Break***	
1050	Overview Written Review	Chair + Reviewer & Authors
1130	Identification of Key Issues for Group Discussion	Group
1200	***Lunch Break***	
1300	Discussion & Resolution of Technical Issues	RPR Participants
1430	***Break***	
1450	Discussion & Resolution of Technical Issues	RPR Participants
1645	Check in on progress and confirmation of topics for discussion on Day 2	RPR Participants
1700	Adjourn for the Day	

DAY 2 – Friday December 11, 2015

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1	Chair
0915	Discussion & Resolution of Technical Issues (Continued from Day 1)	RPR Participants
1030	***Break***	
1045	Discussion and Resolution of Working Paper Conclusions	
1130	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1200	***Lunch Break***	
1300	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1430	***Break***	
1445	*Science Advisory Report (SAR) (*Continued)	RPR Participants
1630	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair
1645	Other Business arising from the review	Chair & Participants
1700	***Adjourn meeting***	

DAY 3 – Friday December 18, 2015

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Terms of Reference and Status of Day 1 & 2	Chair
0915	Presentation of New Results	Authors
0945	Discussion & Resolution of Technical Issues (continued from days 1 & 2)	RPR Participants
1015	***Break****	
1030	Discussion and Resolution of Working Paper Conclusions	RPR Participants
1100	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1130	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1230	Next Steps –SAR review/approval process and timelines, Research Document & Proceedings timelines	Chair
1245	***Adjourn meeting***	

APPENDIX D: ABSTRACT OF RESEARCH DOCUMENT

A new stock assessment is presented for coastwide (PMFC areas 3 and 5 combined) Shortspine Thornyhead (SST) based on a delay-difference production model fit to five fishery-independent surveys, a CPUE series derived from commercial catch rates, and an annual mean weight series derived from unsorted commercial catch samples. Growth rates, natural mortality and selectivity were assumed externally from the model. The stock assessment was characterised by considerable uncertainty associated with conflicting growth models and a range of plausible natural mortality estimates and sizes for full recruitment. In addition, there was conflict in the fitted index series, with the biomass indices generally showing little contrast while the mean weight at age series showed increases after a sharp initial drop. The stock assessment was conducted in a Bayesian framework, where the best fit to the data was used as the starting point for a search across the joint posterior parameter distributions using the Monte Carlo Markov Chain (MCMC) procedure. A composite reference scenario (model average) was selected to represent this stock, consisting of 12 model runs which spanned plausible hypotheses with respect to growth, either based on age-length pairs from the Department of Fisheries and Oceans (DFO) biological database or based on a published growth model from the US National Marine Fisheries Service (NMFS). The composite reference scenario also included three values for instantaneous natural mortality M (0.03, 0.06, 0.08) as well as a range of lengths at which knife-edge recruitment (k) to the fishery occurred (k = 29, 24, 21 cm). Three of the 12 runs assumed the DFO growth model in conjunction with three M values and k=29 cm. The remaining nine runs were based on the NMFS growth model and included three values of M and three values for knife-edge recruitment (k=29, 24, 21 cm). An MCMC posterior for the composite scenario was constructed by pooling 1000 MCMC samples from each of the selected runs to give a posterior of 12,000 samples, thus giving equal weight to each run. The composite reference scenario was evaluated against two B_{MSY}-based reference points consistent with the DFO Precautionary Approach policy and the exploitation rate at B_{MSY} (u_{MSY}). The model-average median estimates of current stock status (B_{2016}/ B_0) ranged from 40% to 141% B_0 with a median estimate of 79%, indicating that current biomass is well above all reference points. Three-year projections at the level of current removals resulted in a biomass decline which remained above reference levels. The stock assessment provides a decision table which evaluates the probability of the model average case staying above three reference points across a range of 11 constant catches. However, because the six abundance index series show little contrast, the stock assessment is unable to resolve productivity uncertainties, with similar fits to the data across the investigated range of natural mortality and age-at-knife-edge recruitment parameters. Therefore, this assessment was unable to provide advice on the absolute size of the stock and the level of equilibrium yield.

APPENDIX E: WRITTEN REVIEW

Date: December 7, 2015

Reviewer: Charles T. T. Edwards
National Institute of Water and Atmospheric Research (NIWA) Ltd., Wellington, New Zealand

CSAS Working Paper: 2014GRF04

Working Paper Title: Stock assessment of the coastwide population of Shortspine Thornyhead (*Sebastolobus alascanus*) in 2015 off the British Columbia coast

General comments

The authors apply a delay-difference model to assess the status of shortspine thornyhead and use the model results to provide advice on how the stock will likely respond to alternative future catches. This class of models is capable of utilising a wide variety of data, is more tractable and easily analysed than cohort-structured models, and yet provides a more realistic representation of the biological processes when compared to simpler surplus production models. In particular, they allow the dynamic components of growth and recruitment to be represented explicitly. For this assessment a wide variety of biological information is available, as well as abundance and catch data. This makes a delay-difference modelling approach appropriate.

Delay-difference models track the recruited component of the population biomass, i.e. that which is fully selected by the fishery. Inter-annual dynamics are predicted by somatic growth and mortality of recruited biomass, and new recruitment. All catches are applied to the recruited biomass component, which is also assumed to be tracked by whatever commercial or fishery-independent abundance indices are available. In addition, if recruitment is a function of the recruited biomass, then this implies that the recruited biomass is mature. This simplistic representation of both selectivity and maturity is one of the primary advantages of a delay-difference modelling approach, although it makes the appropriateness of these assumptions a critical part of the model evaluation.

Model input assumptions based on life history data

One of the first steps in model development is to identify an appropriate knife-edge age at recruitment to the commercial fishery. This was done using length-frequency data from the commercial fishery and an estimated length-age relationship.

The length at recruitment was selected as the median length-frequency observed in the commercial samples. Assuming selectivity is described by a logistic cumulative density function the median is an estimate of the length at which 50% of the lengths are selected. The length-age relationship was obtained by fitting a von Bertalanffy growth model to otolith data. The authors had some difficulty fitting female length-age observations when commercial data were included. To resolve this problem the authors: 1) used “research-only” observations; 2) “gave equal weighting to each age class”; and 3) dropped three “influential observations”. The influential observations were those from female ages >= 55 years, which when included resulted in clearly unrealistic estimates of the Linf growth parameter (Table D5). Although it does not appear to be explained explicitly, the reviewer has assumed that “research-only” refers to the survey observations and that (as per step 3 above) the data were aggregated as mean values so as to yield only one point per age. Without seeing the fits it is not obvious how these steps are justified, but the final fit shown in Figure D4 is nevertheless very good. The sex-specific growth curves are “interpolated” to yield a combined sex growth curve, although this interpolation is not explained.

Using the length at 50% selection and the combined sex growth curve the authors calculate an age at recruitment of 16 years. With reference to the modelling assumption that the recruited component of the biomass is mature, the authors estimate the maturity ogives for both males and females and demonstrate that the age at 50% maturity is 8-9 years, and that by age 16 all fish are mature. This is a useful validation.

The delay difference model requires an estimate of the average weight increment of recruited biomass per year, which is usually obtained by fitting a von Bertalanffy growth model to weight at age data. This procedure is not fully described in the report and is therefore difficult to review.

Finally, the model requires an input value of natural mortality. This is obtained using the exponential model popularised by Quinn II and Deriso (1999):

$$M = \frac{-\ln(p)}{t_m}$$

where p is a proportion of the recruits that survive to ages greater than the maximum observed age (tm), and is usually assumed to be between 0.01 and 0.05 (Hewitt and Hoenig, 2005). There are a number of problems with this estimator (summarised by Kenchington, 2014), in particular pertaining to the estimate of tm, which is heavily dependent on the sample size and an assumption that the stock is unexploited at the time. Assuming that p = 0.01 and using the maximum age of 95 years recorded in the DFO database, the authors estimate M = 0.048. The authors acknowledge that their maximum age is consistent with the maximum ages reported elsewhere, and that the associated M value is consistent with assumptions made in US assessments of shortspine thornyhead. However instead of using this for the reference case, the authors propose it to be a lower bound and instead select a reference case value of M = 0.08. This does not appear to be well justified from an objective view of the biological data, but is revisited when discussing performance of the model estimator in section F3.

Input data for model parameterisation

To parameterise the delay-difference requires an equilibrium recruitment R0 and annual estimates of fishing mortality and recruitment. The R0 parameter, combined with the steepness h and weight at recruitment allows initialisation of the recruited numbers and biomass. Given additional somatic growth parameters as input values, the model then keeps track of the recruited numbers and biomass over time. The estimated parameters required to describe the dynamics are therefore R0, fishing mortalities Ft and recruitments Rt (or the analogous log-normal deviate term ωt). The Ft values are selected so as to predict the catches exactly, presumably using a local minimisation. The catch time series appears to be well justified and the delay-difference model is initialised at unfished equilibrium at the start of the catch series in 1980. If it is uncertain whether or not fishing has occurred before this time then it may have been more appropriate to initialise the model at an equilibrium fishing mortality greater than zero. However this choice of initialisations is revisited and further justified in section F3.

Recruitments are treated as random-effects with prior values predicted by the Beverton-Holt recruitment relationship, which makes use of the estimated parameter h and biomass values predicted by the model dynamics. Information on recruitment is provided by mean weight input data, since large recruitment events predict smaller mean weight and vice versa. Weight data were obtained from the commercial fishery, standardised using a General Linear Model and provided as a model input.

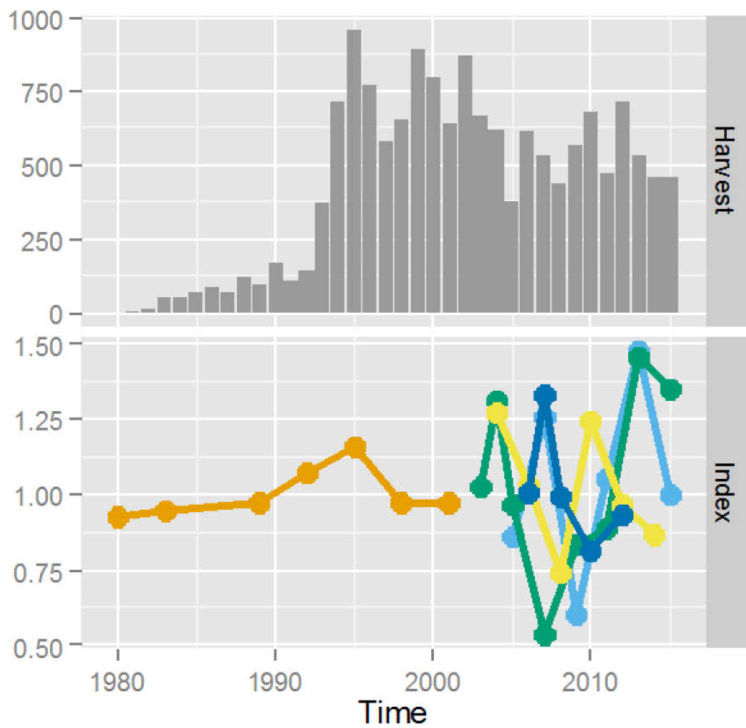
Recruitment fluctuations and stock size relative to the catches will determine fluctuations in the biomass over time. Abundance indices that track such changes can therefore inform both of these model components. However since the model represents recruited biomass only, it is important that the abundance indices represent this same biomass component.

The commercial catch per unit effort data, given that the age at recruitment was also derived from commercial data, most likely reflects changes in the recruited biomass. However this cannot be assumed for the survey data. In the absence of survey derived estimates of selectivity, which might be shown to match those for the commercial fishery, the relevance of survey abundance indices should be assessed from spatial overlap with the commercial fishery. Given the apparent ontogenetic distribution of age with depth it could be supposed that surveys operating in the same locations as commercial fishing might yield similar age classes. Using this argument it seems that the Hecate strait and NMFS surveys, both of which operate in depths shallower than the commercial fishery, are less useful, since they do not track the abundance of the age classes being fished.

Model fit

The model fit appears to be poor. Predicted values for the NMFS and Hecate surveys, and for the commercial CPUE prior to 2003 do not match trends in the observations. Fits to the WCVI, QCS and WCHG surveys are slightly better, as for the CPUE post-2003. The model attempts to match the mean weight changes, but cannot reproduce the overall increase in mean weight that has occurred since 2000. This result invites some speculation as to why the model is performing poorly.

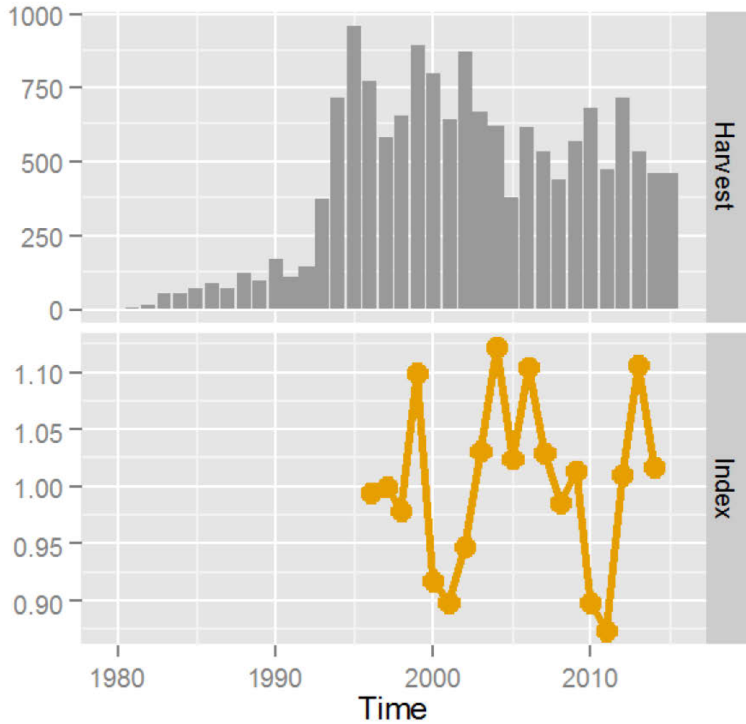
The harvest and survey indices are reproduced below, with each index scaled to a geometric mean of one. The indices are given equal weight by the model fitting procedure, and it is instructive to view changes relative to the catches.



First, the model assumes that catch and abundance reflect the same recruited biomass components of the population. Therefore a change in catch should lead to a change in the abundance index. If it does not, then either biomass changes have been negated by recruitment fluctuations, or the catches are too small to have any noticeable effect. From the above figure, it can be seen that there is a large increase in the catches between 1980 and 1995. The NMFS index, the only index that covers that time period, does not respond as it would if catch has a noticeable effect on the dynamics. Furthermore, from Figure F2, no large recruitment fluctuations are reported in this period. This suggests that the model has solved the inconsistency between catch and abundance by predicting a high absolute stock biomass – so that the effects of catch on the dynamics are small.

Large recruitment fluctuations appear in 1999 and 2000, corresponding with an apparent drop in the mean weight. Predicted recruitment then declines and stays low until 2010, which matches a period of increasing mean weight. During this period, between 2000 and 2010, there appears to be conflicting or inconsistent information in the survey data, which, as already mentioned, the model does not fit very well.

A similar plot for the commercial CPUE is given below.



In 2000 and 2001, there is clear drop in the CPUE, which opposes the large recruitment fluctuations required to match the decline in mean weight. Between 2005 and 2015 the model fits the CPUE data reasonably well, approximately matching the decline and then increase. Following our supposition that the model is relying mostly on recruitment fluctuations to reproduce the dynamics, we can see another obvious conflict in the data at this point. Between 2005 and 2010 the CPUE is going down and the mean weight continues up. This would suggest low recruitment, which is predicted by the model (Figure F2). However from 2010 onwards the CPUE goes up (as does the QCS survey) and the mean weight goes up, the former suggesting high recruitment the latter suggesting low recruitment. Unsurprisingly, the model struggles to fit both sets of data, and in this case does not match the increase in mean weight from 2010 onwards.

In summary, it appears that the model is attempting to match both abundance and mean weight observations via recruitment fluctuations, rather than through a response to the catches. This might be appropriate, if it is indeed a recruitment driven fishery, but conflicts in the data prevent recruitment fluctuations from fitting these data well. Catches themselves could be being rendered obsolete by another data conflict, in this case between catch and abundance in the early period of the fishery, which can be negated by estimating a high absolute stock biomass.

Sensitivity runs

The authors explore a broad diversity are sensitivities, most importantly adjusting the biological input assumptions to the model and evaluating differences in the output. Notably, and with reference to comments made above, alternative values for M (specifically less than the base case of M = 0.08), and attempts to initialise the model at a depleted starting population, yielded poor estimation performance (i.e. convergence of the estimation algorithm was either difficult or not successful). Another important sensitivity that was tested was the assumed age at recruitment, which was varied from 12 to 20.

In summary, the range of sensitivities tested, which also included varied assumptions regarding the data and error distributions, where more than adequate. However they did not yield any noticeable improvements to the model fit.

Management advice

Management advice based on the assessment results and sensitivities is well described and presented. However these conclusions should retain an appropriate caveat given the poor model fits.

Omissions, clarifications and corrections

For ease of interpretation table E1 could be modified to distinguish between estimated (i.e. R0 and h) and derived model parameters (i.e. κ, a, b, etc.).

Additional details should be given on how the somatic growth parameters (α and ρ) are estimated.

How is the “interpolated” von Bertalanffy growth curve generated?

How are Ft values chosen so as to correctly predict the catches?

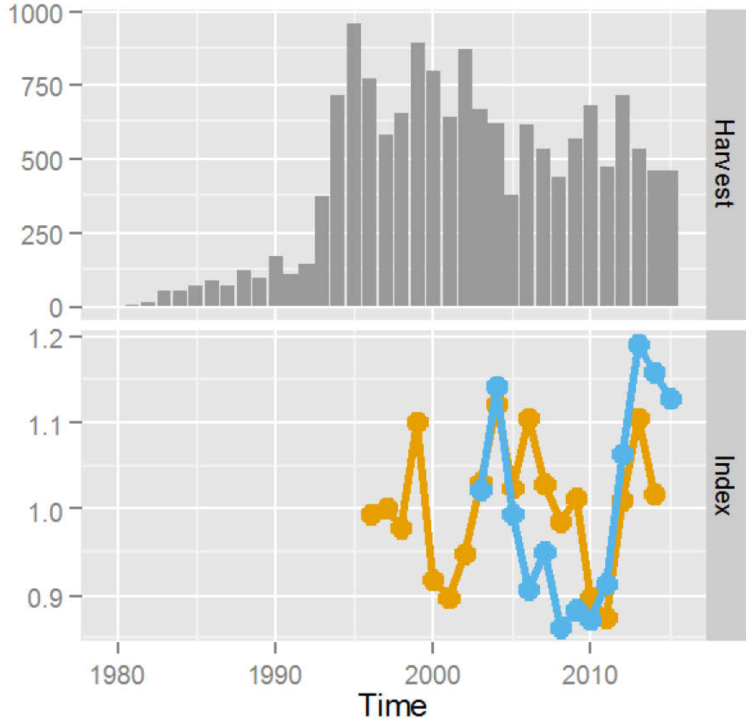
In section F.2: the prior on R0 is not reported; the prior on q is incorrectly specified (inconsistent with Figure F3); and a beta prior on h as reported will give prior weight to steepness values of h < 0.2, which is inconsistent with the Beverton-Holt recruitment relationship - the prior on h should be bounded at h = (0.2, 1) to avoid negative recruitment values.

It is not clear how recruitment estimates Rt enter the likelihood for years 1980 to 1995, since equation E26 cannot be used to predict recruits for these years.

How are recruitment values generated during the projections?

Reviewer’s suggestions for future work

In an attempt to resolve conflicts between the abundance indices and changes in the catch, these indices could be re-evaluated. In particular, the utility of the NMFS survey, which is the only survey to cover the early period of the fishery and yet does not match the commercial fishery spatially, should be questioned. Similarly the remaining surveys should be weighted based on their relevance to the commercial fishery. One approach would be to construct a mean weighted survey index with the weights provided by the mean biomass estimates from each survey. As an example, with the NMFS survey removed, and the commercial CPUE plotted alongside the composite survey index, a revised dataset is shown below.



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