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Proceedings of the Pacific regional peer review on Bocaccio (*Sebastes paucispinis*) stock assessment for British Columbia in 2019, including guidance for rebuilding plans

December 17-18, 2019
Nanaimo, British Columbia

Chairperson: Greg Workman
Editors: Jill Campbell and Rowan Haigh

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July 2021

Foreword

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

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting of December 17-18, 2019 at the Pacific Biological Station in Nanaimo, B.C. A working paper presenting an updated Bocaccio stock assessment, including an evaluation of a 2016 recruitment event, 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 and recreational fishing sectors, and environmental non-governmental organizations.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report providing advice to the Groundfish Management Unit to inform the multi-species fishery planning. A revised working paper, providing details of the stock assessment, including data used, model equations and conclusions, will be published as a DFO CSAS Research Document.

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

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on December 17-18, 2019 at the Pacific Biological Station in Nanaimo to review the recent stock assessment for Bocaccio (*Sebastes paucispinis*).

The Terms of Reference (ToR) for the science review (Appendix A) were developed in response to a request for advice from the Groundfish Management Unit. 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.

A working paper (WP) was prepared and made available to meeting participants prior to the meeting:

Paul J. Starr and Rowan Haigh. 2019. Bocaccio (*Sebastes paucispinis*) stock assessment for British Columbia in 2019, including guidance for rebuilding plans. CSAP Working Paper 2018GRF03.

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

The Chair reviewed the Agenda (Appendix D) and theToR (Appendix A) for the meeting, highlighting the objectives and identifying the Rapporteur for the review. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. The room was equipped with microphones to allow remote participation by web-based attendees, and in-person attendees were reminded to address comments and questions so they could be heard by those online.

Members were reminded that everyone at the meeting had equal standing as participants and that they were expected to contribute to the review process if they had information or questions relevant to the paper being discussed. In total, 33 people participated in the RPR, including several scientists from the National Oceanic and Atmospheric Administration (NOAA) (Appendix E). Jill Campbell was identified as the Rapporteur for the meeting.

Participants were informed that Jaclyn Cleary and Kelly Andrews had been asked before the meeting to provide detailed written reviews (Appendix C) for the working paper to assist everyone attending the peer-review meeting. Participants were provided with copies of the written reviews.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to Fisheries and Aquaculture management to inform Bocaccio stock assessment and the multi-species fishery planning. A revised WP, providing details of the stock assessment, including data used, model equations and conclusions, will be published as a DFO CSAS Research Document. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

REVIEW

Working Paper: Bocaccio (*Sebastes paucispinis*) stock assessment for British Columbia in 2019, including guidance for rebuilding plans. 2018GRF03

Rapporteur: Jill Campbell

Presenter(s): Paul Starr and Rowan Haigh

PRESENTATION OF WORKING PAPER

WORKING PAPER PRESENTATION

The presentation of the working paper was given by Paul Starr and Rowan Haigh. The working paper abstract appears in Appendix B.

Surveys in 2018 and 2019 captured a large number of two- and three-year-old Bocaccio over a wide spatial distribution indicating a strong 2016-year class. These observations confirmed reports from a range of fisheries, both commercial and recreational, that young Bocaccio were ubiquitous throughout the coast. This apparent increase in Bocaccio abundance prompted a management request for science advice and an expedited stock assessment. The authors chose to adopt a Bayesian catch-at-age model in contrast with previous surplus models developed by Stanley et al. (2009, 2012) to evaluate stock status. The decision to move to an age-structured model was dictated by the fact that a surplus production model has no age information available to it but it was clear from the onset that the primary requirement for this stock assessment was to evaluate the nature of the recruiting 2016 cohort. The model developed here used data from six fishery-independent surveys, a single commercial catch-per-unit-effort (CPUE) series based on the bycatch of Bocaccio in the bottom trawl fishery, 12 years of commercial age data and 31 years of survey age data. The CPUE data from 2013 onward were dropped due to a determination that active avoidance of Bocaccio by industry participants would make this part of the series unrepresentative of Bocaccio abundance.

There were no significant differences in estimated growth over a range of investigated regions, leading to the conclusion that it would be appropriate to assume a single coastwide stock. However, growth differed between the sexes, requiring a two-sex model. The choice to model a single coastwide stock of Bocaccio was consistent with the previous stock assessments by Stanley et al. (2009, 2012).

Difficulties in ageing fish (due to significant ageing error) and relatively sparse samples resulted in a lack of contrast in the data, which prevented model convergence while estimating natural mortality (M); therefore, three fixed M values were used in the assessment: 0.07, 0.08, and 0.09, covering the range of plausible values for this parameter. Values less than 0.07 resulted in low estimates of spawning biomass but inflated stock status; values larger than 0.09 resulted in equilibrium spawning biomass as large as those estimated for more abundant BC rockfish species. The posterior distributions from the Markov chain Monte Carlo (MCMC) analyses for each of the three component model runs were combined into a composite base case model. Each component model run fit the abundance data well but failed to fit the high 2019 index point in the Queen Charlotte Sound synoptic survey. Residual patterns for fits to the age composition data were generally poor, likely due to an apparent lack of older ages in the latter years when the 2016 cohort dominated the samples and the large amount of ageing error in these samples. Projections using this composite model indicated a rapid rise in spawning biomass beginning in 2021 due to the recruitment of the large 2016 cohort into the spawning population. By 2022, when this large cohort reaches age 6, stock status was projected to move out from the DFO

Critical zone and into the Cautious zone (P(B_{2022}>0.4B_{MSY}) = 0.87, P(B_{2022}>0.8B_{MSY}) = 0.48), assuming a constant catch of 200 tonnes/year.

Nine sensitivity runs were conducted using the central model run (M=0.08) from the composite base case. The sensitivity run that dropped the CPUE series resulted in non-convergence and massive autocorrelation in the MCMC analysis and was disqualified as a credible sensitivity; the run that dropped early surveys (Goose Island Gully [GIG] Historical, National Marine Fisheries Service [NMFS] Triennial) had poor MCMC diagnostics but showed similarities with the other seven. Of the eight credible MCMC sensitivities, the trajectories of median depletion (B_t/B_0) converged in the final year (2020) to ~3-5% of B_0. The lack of major differences in the sensitivity runs provided confidence in the composite stock model.

An additional projection sensitivity run was prepared by the authors and presented at the RPR meeting, but was not included the working paper due to time constraints. This run repeated the projections using only the lowest 5% of the MCMC posterior distribution for R_{2017} from the composite base case. Even when using this lowest segment of the estimated size of the 2016 cohort, stock rebuilding time was extended by only two years under a constant catch scenario of 200 tonnes/year. This relatively small extension in projected rebuilding time, even when using the lowest 5% of the posterior distribution for R_{2017}, demonstrated the substantial strength of the 2016 cohort. These projections predicted that even when catch levels were increased to 500 tonnes/year, the spawning stock would move out of the Critical zone in 4-6 years.

Projections based on constant exploitation rates also indicated that the stock would move out of the Critical zone in 4 to 6 years under exploitation regimes up to 0.08/year.

PRESENTATION OF WRITTEN REVIEWS

JACLYN CLEARY

- Following discussion with the reviewer, the authors will provide clarification on how the M values were chosen. Higher M values are used in the literature for the California population of Bocaccio, but higher M values for the longer-lived BC population resulted in a lack of model convergence and high estimates of equilibrium unfished spawning biomass, which are unlikely due to Bocaccio’s low productivity.
- Clarification on the definition of maximum sustainable yield (MSY)-based reference points should be provided in the tables and paper (especially in section 9.2, page 21), as this will adjust the interpretation of Sustainable Fisheries Framework (SFF) values. It was noted that the recommendations would not be altered by a clarification of MSY definition.
- It was suggested that the authors conduct a sensitivity run using the historic average R_0 values (290 tonnes/year) from before the 2016 recruitment event. Due to software limitations, the authors were not able to do this run with the current model. However, the authors agreed to look into the feasibility of excluding specific recruitment years in the next full assessment of Bocaccio rockfish (BOR). Removing specific high-recruitment years from the calculation of average recruitment may make the 30- and 80-year projections more cautious, but will not alter the short-term advice. Note that the estimate of B_0 in this model is based on average recruitment, which includes the 2016 cohort; consequently it is not clear whether long-term projections based on a reduced average recruitment should be evaluated against reference points that reflect the reduction in average recruitment. Future levels of recruitment are difficult to predict, particularly for species known to rely on episodic large recruitment events. The short-term harvest recommendations (5 to 10 years) are not likely to

change, regardless of the average recruitment assumption. The authors will clearly indicate that average recruitment and the associated B_0 include the 2016 cohort.

- More qualifications will be provided around the reason for the large long-term projection uncertainty. A figure will be added to the text demonstrating the uncertainty in the recruitment projections.
- The reviewer suggested that the authors use simulated data in their models. The authors pointed out their model is not set up to use simulated data. They noted that the ToR only requested guidance for rebuilding plans, which occurs as a set of decision table for the next three generations.
- To address the concerns of a possibly overestimated recruitment event in 2016, the authors presented a projection sensitivity run using only the MCMC posteriors that had the lowest R_{2017} values (<0.05 quantile). The low-recruitment subset (150 samples out of 3000) was used to reconstruct the spawning biomass trajectory (1935-2020) and repeated the projections (2021-2080) across a range of constant catch scenarios. Rebuilding the spawning population to levels above the lower reference point (LRP) and upper stock reference (USR) was delayed only two years due to the estimated size of the 2016 cohort, even in the low-recruitment subset.
- The wording in the first ToR objective regarding reference point determination could be interpreted that the authors should provide analyses that supported the reference points used. Instead, the authors used the provisional reference points provided by DFO without developing alternative reference points. The authors suggested that such analyses were beyond the scope of this project and will reword the text in the working paper to be more in line with this ToR objective.

KELLY ANDREWS

- The reviewer expressed concern over the lack of large, older individuals in the commercial trawl data and wondered if this contributed to the lack of stability in the sensitivity run with the CPUE data removed. The authors thought that the lack of older individuals was primarily due to sampling, given that population levels were low giving rise to only a few encounters of these age classes. The authors pointed out that each of the four synoptic surveys were directed to sample every Bocaccio captured, with some survey years having less than 10 fish sampled. Older fish were more prevalent in the commercial age data. Although fewer old females were observed than old males, it was not possible to estimate M in this model and so this parameter was fixed at the same value for each sex. It was also noted by an author and some participants that older fish may not be fully selected to the surveys (for instance, they may hide in caves or be otherwise unavailable to the gear). This may imply a descending right-hand selectivity for older individuals, leading to estimates of cryptic biomass.
- Since *Sebastes* tend to have episodic recruitment, the reviewer inquired if this life history characteristic could be captured by the models. Since the previous notable recruitment event (which was not very large) was in 1969, the authors suggested that there were no data to inform such a model. The reviewer asked about using environmental covariates as indicators of recruitment, but the authors pointed out that rare episodic recruitment events are difficult to correlate with environmental factors.
- Clarification to the caption of Figure 39 was requested. The caption stated the 2016 cohort will not contribute to the spawning biomass until 2022, as they need to be four years old to

spawn. The caption was changed to include ‘Year 2022 is the second year that the 2016 cohort is assumed to contribute to the spawning population’.

- It was noted that there was a single tow in the historical Goose Island Gully survey in 1976 that captured a lot of Bocaccio (Figure B5). He suggested that this level of abundance was unable to sustain the population and wondered if the 2016 cohort would also fail to recruit. The authors compared Figure B5 with Figure B31 (Queen Charlotte Sound 2019 survey) to demonstrate the difference between these observations, with the latter figure showing a much broader distribution of observations, both spatially and in size of capture, compared to the 1976 observation of a single large tow. The authors also noted that the 2016 cohort was observed in other surveys and in the commercial fishery over several years. Consequently, the authors are confident that the 2016 cohort will successfully recruit to the spawning stock.

GENERAL DISCUSSION

POINTS OF CLARIFICATION

- Wording related to species classification in terms of Committee on the Status of Endangered Wildlife in Canada/*Species at Risk Act* (COSEWIC/SARA) policy was incorrect throughout the document. A participant with understanding of these policies offered to help the authors clarify this language. As well, it was noted that the requirements set out in the ToR (number of mature females) and the information needed by COSEWIC (e.g., number of mature males and females) were not the same.
- A participant expressed concern that the wording in the last sentence of the abstract indicated TAC would increase and that providing management advice in the Research Document was not within the scope of Science. The authors and other participants indicated that the authors could recommend changes to management and that the current total allowable catch (TAC) is already so low that it can only increase. Industry partners noted that the catch is currently over the TAC under complete avoidance measures. It was agreed that the sentence in the abstract be modified to remove indications of changes to the TAC.
- A participant asked to see a table showing the Francis (2011) weights (based on mean-age) used for each composition data set in the model. This would clarify the relative importance of each data set.
- Given the importance of the recent Fisheries Act changes surrounding rebuilding plans, a participant asked the authors to be more explicit in the wording surrounding the rebuilding plan guidelines and COSEWIC requirements.
- The meeting requested wording to more clearly distinguish that 69 tonnes/year (past five-year average) is not a catch limit (it is simply the observed average catch from 2015–2019) compared to projection scenarios at 200 tonnes/year which were used to show projected biomass in several figures and in the final paragraph on page 21 of the working paper.
- Some participants were unsure how the lowest 5th percentile of recruitment compared to the historical average that was calculated. It was confirmed that the historical average does include the 2016 cohort.
- A participant noted that the lower 5th percentile sensitivity run resulted in changes to the historical biomass estimates and that by selecting the samples with lower recruitment values, the limit reference point changed by up to 50%. The authors explained that under a Bayesian analysis each sample consists of a set of parameters that provide a full representation of the data. It is helpful to think of each run as a separate stock assessment.

The samples with low recruitment are also likely to be representations that will be at the lower end of productivity because the parameters will be consistently applied over the complete reconstruction of the stock history.

DATA UNCERTAINTIES AND ALTERNATE SOURCES

- A participant from the Sclerochronology laboratory spoke about the challenges in ageing the 2016 cohort. Inconsistencies in ageing may be due to recent staffing changes, loss of ageing expertise, and the lengthy time needed to bring new employees up to speed. Also, the laboratory has had little experience with such young *Sebastes*, given that they rarely show up in large numbers in the ageing samples. Bocaccio are difficult to age due to their rapid growth at young ages and their continued growth over the winter which results in the smearing of age rings. The lab did re-age the specimens and obtained similar results to their previous readings. They will send the otoliths to the University of British Columbia for isotopic analysis to confirm the results. It was noted by the authors that the Ageing Lab did considerable work in a short period of time and that their results added a great deal to the assessment.
- Other surveys were discussed in terms of their potential to provide data/information for future assessments.
  - Central coast dive surveys have been conducted by the Indigenous Resource Alliance since 2013. This group encountered 1700 8-cm fish in 2016. In 2017 this cohort was between 25-35 cm, in 2018 were 30-40 cm, and in 2019 were 40-50cm. This cohort is still a strong presence in their surveys although abundances decreased after 2016. Surveys are on-going and they should be able to see how this cohort progresses. More young-of-year were reported in 2019.
  - The 2016-year class was observed in the shrimp trawl surveys, which can be seen in Figure D26 of the working paper. The authors noted that the shrimp surveys have been omitted from rockfish stock assessments since 2015 because of their lack of appropriate spatial and depth range coverage for rockfish.
  - Parks Canada may have some data in their Clayoquot and Barkley Sound eelgrass surveys.
  - The surface salmon surveys have reported BOR catch. These surface surveys tend to catch larval fish which are difficult to relate to rockfish recruitment.
  - Recreational fishers from Winter Harbour to Prince Rupert were reporting strong catches of juvenile BOR and were some of the first people to detect the strong 2016 cohort.
  - US midwater trawl surveys off the central coast of California in 2015 and 2016 reported BOR among the top ten species caught. These data would apply to the southern population of Bocaccio.
  - NOAA has species abundance data from power plant intakes which captured the 2016 cohort. These data are publicly available from the Northwest Fisheries Science Center but would apply to the southern population (off California) of Bocaccio.
  - BOR may be caught in the hard-bottom long line survey which cover untrawlable habitat. However, it was noted that the large hook size and stationary bait would not select well for BOR and exclude juveniles. Vertical hook and line surveys may have better catchability but are not available.

PARAMETER UNCERTAINTY

- A participant from the US noted that they have difficulty ageing BOR in the south due to a lack of seasonality but have used lengths to determine cohorts. By including length data in the age-structured model, the historic length-only data could be used. The authors have reservations about using both age and length in the same model for technical reasons, but would consider it in the future. The 2016 BOR cohort was easy to track since it was isolated from other BOR age classes as it grew. The authors noted that since the link between age and length is so strong for this cohort, including both in the model may be using the same data twice but agreed to add this suggestion to future research recommendations.
- It was noted that the size of the 2016 recruitment event increases the value of B_0 which is then used in developing the management targets. It was suggested by a participant that a retrospective analysis be conducted to see how other parameter values, including average recruitment, are altered by this episodic event. The authors agreed to add this to future research recommendations.
- A participant suggested that the surveys could be evaluated using a statistical model similar to that used to estimate CPUE in the commercial fishery, rather than using the design-based (swept-area) indices presented in Appendix B of the working paper. The authors agreed to add this to future research recommendations.
- A participant submitted a paper from the literature that evaluated size-dependent fecundity in *Sebastes* (Dick et al. 2017). This paper suggests that fecundity may increase as a power of four rather than by weight, which is cubic and is the underlying assumption used in this stock assessment. The authors agreed to add this suggestion to future research recommendations. There was also some discussion that large older females may have eggs that tend to have higher survival. This may be the source of the higher productivity associated with large females that is discounted by assuming fecundity increases only with increased weight. It was suggested that closed areas such as marine reserves could improve female longevity, and consequently fecundity, which will aid in stock rebuilding.

SELECTIVITY UNCERTAINTY

- It was noted by some participants that when abundance was high, the habitat occupied by BOR shifts, with young BOR dispersed over sandy bottoms (rather than over high-relief ones). This observation may result in the prediction that the commercial trawl fishery selectivity may change as abundances increase due to the recruitment of the 2016 cohort. The authors noted that they used constant selectivity values because there was no evidence in the data that selectivity had changed. They noted that since 2013, the CPUE data had been removed due to fleet avoidance, reducing the availability of commercial data after 2012. Changes to the selectivity function could be included in the future research recommendations as the 2016 cohort recruits to the spawning population. A participant recommended removing the post 2013 commercial age data entirely to see if it alters the model outputs, which may indicate if there is a selectivity bias.
- A participant noted the low values for q (survey catchability) and wondered if this was due to the life history of the species or generated by the large recruitment event. The authors indicated that the q values were low because the biomass was estimated to be very low. At times the surveys caught only a few individuals then in 2016 over 1000 were caught. As well, because this is treated as a single stock off the BC coast, the survey area covered is smaller than the area occupied by the stock. Another participant mentioned that the synoptic bottom trawls are not a good indicator of semi-pelagic species such as BOR and its

surprising that the data on the 2016 cohort appears to be so good. The point was raised that, since so much of the BC coast is not presently fished with the trawl surveys due to MPA's and de-facto refugia from groundfish management plans, much of the 2016 cohort may never encounter fishing gear. They wondered how future stock trajectories will differ from historical exploitation. Since the assessment is coast wide, the authors had to estimate exploitation on a coastwide basis. The authors noted the lack of recruitment, not over fishing, has been driving the historic biomass decline. The synoptic surveys appear to capture this species reasonably well and completely removing the CUPE data was not possible, given the sensitivity run. It was also noted that the environment has more bearing on spawning stock than the fishery does and that the changes in harvest areas will not alter the population dynamics of BOR.

- A participant noted these large recruitment events are typically overestimated at first. In this case selectivity is higher for the smaller fish in the surveys as compared to the fishery and this might be affecting the selectivity function parameter estimates. They wanted to know if this impacted the recruitment estimates for previous years. The authors commented that they have ample age data for both the surveys and commercial trawls as seen in Figs. D.13 and D.14 of the working paper. They tried model runs with fixed selectivities, but these runs did not converge or gave implausible results. The model runs presented in the working paper appear to fit the 2016-year class acceptably well.
- There was concern about the log recruitment deviation vector being summed to zero across all years given the large recruitment variation. The authors commented that this assumption is needed in these models to give a recruitment assumption that is consistent with historical catches, the survey and age composition data.
- A participant commented on the lack of older females relative to males and suggested that either *M* is different between the sexes or that selectivity is different. These factors could have affected the estimates of recruitments. The authors said they did try estimating a different *M* value in the models for older females vs immature females but did not see a strong difference in model output. As well, differentiating between senescence and dome selectivity would be difficult, especially given the small amount of available age frequency data particularly at older ages. Female *M* values were ~0.015 higher than those for males when this parameter was estimated, but these model runs were unreliable. While the authors did the best they could, patterns remain in the recruitment residuals, likely due to the limited age data, ageing error and the strong influence of the 2016 cohort. Investigating the reasons for the difference in apparent abundance between older males and females should be added as a future research recommendation.

CONCLUSIONS

The RPR participants agreed that the working paper met the ToR objectives and was accepted with minor revisions. The following conclusions also appear in the Science Advisory Report.

In common with other BC rockfish stock assessments, this stock assessment depicts a slow-growing, low productivity stock. However, what is unusual about this stock assessment is that this stock appears to be even less productive than would be expected for the apparent rate of natural mortality suggested by the available ageing information. The low exploitation rates estimated by the model, which reach their highest point at around 0.06, a level much lower than that seen in other recent rockfish stock assessments, should result in catches below replacement levels, allowing the population to increase. But such increases have not been observed. Additionally, the number of good recruitment events appear to be few for Bocaccio, which has steadily declined over the period 1935–2020, in spite of the low exploitation rates stemming from management that has reduced recent removals to 100 t or less per year. These results corroborate the findings in previous stock assessments of BOR, with the 2020 spawning biomass in the Critical zone. However, what distinguishes this stock assessment from the previous ones is the signal of new recruitment in the form of the strong 2016 year class, which is estimated by the composite base model to be 44 times (median estimate; 5-95 range: 30–58) the long-term average recruitment, which will quickly move the spawning biomass out of the Critical zone starting in 2021.

RECOMMENDATIONS & ADVICE

The following recommendations and advice also appear in the Science Advisory Report.

Scheduling the next stock assessment depends completely on the actual strength of the recruiting 2016-year class, as it develops in the coming years. If it continues to show a strength consistent with the evaluation in this stock assessment, coastal BOR should rebuild to levels above upper USR in 3–5 years. The existing synoptic trawl surveys, particularly the Queen Charlotte Sound (QCS) and west coast Vancouver Island (WCVI) surveys, should provide adequate monitoring of this year class in the coming years. The next full stock assessment should be scheduled in 2025 (or possibly later), such that there will be at least two new indices from both the QCS and WCVI synoptic surveys. Regardless of when a new stock assessment is to be initiated, at least 6-12 months lead time is required before the new stock assessment starts to allow for the reading of new ageing structures that will be needed for the interpretation of the population trajectory. Advice for interim years is explicitly included in the decision tables and managers can select another line on the table if stock abundance appears to have changed or if greater certainty of staying above the reference point is desired.

Advice to management is provided in the form of decision tables. These tables assume the composite base case model is valid and there will be no management interventions if stock status reduces below accepted reference points at any level of constant catch.

FUTURE RESEARCH RECOMMENDATIONS

- Investigate including length and age as separate data sets in models to better understand year-class composition and to incorporate length only data sets. This may also reduce the impact of ageing error.
- Think about how to deal with survey and commercial fishery selectivity. A suggestion is to remove the post-2013 commercial trawl age data to see if these data have influence on the model outputs. Selectivity may also be changing as abundance increases.
- Explore differences in M values between sexes. Rather than estimating sex differences independently, there is a possibility of estimating one from the other. More data from the 2016 cohort may make the mortality difference more evident. Another possibility is to estimate a domed selectivity function to account for the lack of old females being caught.
- Investigate using model-based indices of survey abundance rather than using the design-based indices, as per NOAA's methods.
- Conduct a retrospective analysis using historic recruitment values in the model to see how other parameter values are altered by this episodic event.
- Investigate including the recommendations made by Dick et al. (2017) (*Sebastes* hyper-allometry). This research indicates that fecundity is based on an exponential rate to the power of four rather than the cubed power typically used in stock assessment models.

- Investigate including abiotic oceanographic data to the stock assessment, such as the work done by Schroeder et al. 2019, which linked the source of surface water to increased rockfish recruitment events in 2009, 2010, and 2013. This may also help give advice on how a changing climate will affect *Sebastes* stocks.

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APPENDIX A: TERMS OF REFERENCE

BOCACCIO (*SEBASTES PAUCISPINIS*) STOCK ASSESSMENT FOR BRITISH COLUMBIA IN 2019, INCLUDING GUIDANCE FOR REBUILDING PLANS

Regional Peer Review – Pacific Region

December 17-18, 2019
Nanaimo, BC

Chairperson: Greg Workman

Context

Bocaccio has been the subject of two detailed data reviews (Stanley et al. 2001; Stanley et al. 2004) and was formally assessed by Fisheries and Oceans Canada (DFO) in 2008 (Stanley et al. 2009). This assessment was updated in 2012 (Stanley et al. 2012). Bocaccio was assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Threatened in 2002 and re-assessed as Endangered in 2013. In 2011, a decision was made to not list Bocaccio under Schedule 1 of the *Species At Risk Act* (SARA). While DFO will continue to manage this species under the *Fisheries Act*, actions to address conservation concerns were outlined in the order not to list (SI/2011-56 July 6, 2011). In 2016, the Commissioner of the Environment and Sustainable Development found that for 12 of the 15 major fish stocks in Canada requiring rebuilding plans, DFO had neither plans nor timelines for developing them. DFO accepted the Commissioner's recommendation to set out priorities, targets, and timelines for putting in place rebuilding plans and will include any relevant measures respecting rebuilding fish stocks that will be established under a revised *Fisheries Act*.

Bocaccio (*Sebastes paucispinis*) is ubiquitous along the British Columbia (BC) coast and most catches are taken close to the bottom over depths of 60-200 m near the slope break of the continental shelf as well as gully edges in Queen Charlotte Sound and Hecate Strait (Stanley et al. 2009). These authors noted that because Bocaccio is semi-pelagic and schooling, the adults likely do not occupy specific sites other than preferring high-relief boulder fields and rocks (Love et al. 2002). The species appears to be a relatively short-lived compared to other *Sebastes* species such as Pacific Ocean Perch (*S. alutus*) or Rougheye Rockfish (*S. aleutianus*), a characteristic shared with other pelagic *Sebastes* species (e.g., Widow Rockfish, *S. entomelas*). This species generally only reaches maximum ages of 40-50 years; however, our records indicate one specimen reaching age 70. Genetic studies have shown no strong evidence for stock differences between the west coast of Vancouver Island and central California, but suggested that a Hecate Strait sample might have differed from those to the south (Matala et al. 2004).

The most recent stock assessment of Bocaccio placed this species in the DFO Critical Zone (Stanley et al. 2012) and Total Allowable Catches (TACs) were set at minimum acceptable harm levels in order for the multispecies trawl fishery to be able to continue operating (most other rockfish are well clear of the Critical Zone, with most in the Healthy Zone) while still allowing rebuilding. The history of trawl TACs since the 2012 stock assessment update are: 2013-14 = 150 t, 2015 = 110 t, and 2016-19 = 80 t (DFO IFMPs).

Data for Bocaccio appear to be sufficient (index series and age structures) to conduct a statistical catch-at-age analysis using a model variant of Coleraine called 'Awatea'. This model has been used successfully to assess various stocks in BC – Pacific Ocean Perch, Yellowmouth Rockfish (*S. reedi*), Silvergray Rockfish (*S. brevispinis*), Yellowtail Rockfish (*S. flavidus*), Rock

Sole (*Lepidopsetta bilineatus*), Redstripe Rockfish (*S. proriger*), and Widow Rockfish. The model used for both the 2008 and the 2012 Bocaccio assessments was a Bayesian surplus production model, which relied entirely on abundance indices and was only able to include information on population composition (age or length data) through the use of an informed prior on *r* (the productivity parameter in the model). The current authors hope to rectify this by using a catch-at-age model, or failing this, a delay-difference model (the latter has limited predictive capability compared to the former). Composition data should give estimates of recruitment events, which will improve the determination of the probability of success for rebuilding the stock. As well, the authors will review the assumptions made in the previous stock assessments for early historical levels of catch, expecting to bring them more in line with more recent rockfish stock assessments.

In the absence of updated science advice, there is uncertainty about the risks posed to the BC Bocaccio stock by current levels of catch. DFO Fisheries Management has requested that DFO Science Branch provide advice regarding the assessment of this stock relative to reference points that are consistent with the DFO's *Fishery Decision-Making Framework Incorporating the Precautionary Approach* (DFO 2009), including the implications of various harvest strategies on expected stock status. The advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will be used to inform fisheries management decisions to establish catch levels for the species. This work will also inform and supplement decisions external to DFO, specifically COSEWIC.

Objective

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

> *Paul J. Starr and Rowan Haigh. 2019. Bocaccio (Sebastes paucispinis) stock assessment for British Columbia in 2019, including guidance for rebuilding plans. CSAP Working Paper 2018GRF03*

The specific objectives of this review are to:

1. Recommend reference points consistent with the DFO Precautionary Approach (PA), including the biological considerations and rationale used to make such a determination. These might include the provisional DFO limit reference point (LRP) of $0.4B_{MSY}$ and the upper stock reference (USR) of $0.8B_{MSY}$, or historical reference points (e.g., B_{min}). The choice of reference points is often determined by the complexity of the population model, which, in turn, depends on the quality of the input data.
2. Assess the current status of Bocaccio in BC waters relative to the reference points recommended above. If necessary, provide evidence to support the separation of this species into spatially distinct stocks, and if required, provide advice on the status of these stocks.
3. Using probabilistic decision tables, evaluate the consequences of a range of harvest policies on projected biomass (and exploitation rate) relative to the reference points and provide additional stock metrics. If the data are insufficient to quantitatively evaluate BC Bocaccio in terms of PA reference points and decision tables, summarise what is known about the status of this species, and discuss the implications for harvest advice.
4. Provide guidance to be used by a management rebuilding plan under the PA framework for Bocaccio to satisfy recent legislation (Fisheries Act). Specifically, provide probabilistic decision tables that demonstrate a high probability of the stock growing out of the Critical Zone (i.e., above the LRP) within a reasonable timeframe (usually 1.5-2 generations).

5. Provide probabilistic decision tables to inform a COSEWIC assessment or a subsequent DFO Recovery Potential Assessment. This includes projections up to 1.5-2 generations to address COSEWIC's assessment criteria (assessment indicators A1 and A2) using probability tables of future population status (with respect to the reference criteria) at various catch levels, as well as estimates of the time taken to attain them (with different levels of confidence).
6. Describe sources of uncertainty related to the model (e.g. model parameter estimates, assumptions regarding catch, productivity, carrying capacity, and population status).
7. Recommend an appropriate interval between formal stock assessments (i.e. this should occur every 4 years, as per the order not to list), indicators used to characterize stock status in the intervening years, and/or triggers of an earlier than scheduled assessment. Provide a rationale if indicators and triggers cannot be identified.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Fisheries and Oceans Canada (DFO) (Science and Fisheries Management)
- Commercial and Recreational Fishing Representatives
- Environmental Non-government Organizations
- First Nations
- Province of BC
- USA Government Agencies (NOAA, Alaska Fish & Game)

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Matala, A.P., Gray, A.K. and Gharrett, A.J. 2004. Microsatellite variation indicates population structure of bocaccio. N. Amer. Jour. Fish. Manage. 24: 1189-1202.

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Stanley, R.D., McAllister, M., Starr, P. and Olsen, N. 2009. Stock assessment for bocaccio (*Sebastes paucispinis*) in British Columbia waters. DFO Can. Sci. Advis. Sec. Res. Doc . 2009/055. xiv + 200 p.

Stanley, R.D., K. Rutherford and N. Olsen. 2001. Preliminary status report on bocaccio (*Sebastes paucispinis*). Canadian Stock Assessment Secretariat Research Document 2001/148.

APPENDIX B: WORKING PAPER ABSTRACT

Bocaccio Rockfish (*Sebastes paucispinis*, BOR) is ubiquitous along the British Columbia (BC) coast (at ~60-300 m depth), occurring in low densities along the west coast of Vancouver Island (WCVI), across Goose Island and Mitchell gullies in Queen Charlotte Sound and into the lower parts of Hecate Strait.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2002 recommended a “Threatened” designation for the British Columbia (BC) population of Bocaccio Rockfish (BOR). In November 2013, BOR was reassessed by COSEWIC as “Endangered”. Under SARA (Species At Risk Act), an endangered species is defined as one that is facing imminent extirpation or extinction. BOR has been assessed twice (in 2009 and then in 2012) using a Bayesian surplus production model which evaluated this species to be in the DFO Critical Zone and led to setting TACs at the minimum acceptable levels of harm while still allowing the multispecies trawl fishery, which takes BOR in conjunction with other trawl species, to continue operating while still rebuilding. Beginning in 2017, there has been mounting evidence of a strong BOR recruitment event in BC waters, leading to difficulty in 2018 and 2019 for commercial operators to stay within the existing low catch limits that were set to encourage rebuilding in the BC BOR population. The purpose of this stock assessment is to evaluate the current BOR stock status and to assess the potential impact of this new recruitment on the status of BOR in the future.

This stock assessment evaluates a single BC coastwide population harvested by multiple fisheries. Analyses of biology and distribution did not support separate regional stocks for BOR. A single coastwide stock was also assumed for the two previous BOR stock assessments.

We use an annual catch-at-age model tuned to six fishery-independent trawl survey series, a truncated bottom trawl CPUE series, annual estimates of commercial catch since 1935, and age composition data from survey series (31 years of data from four surveys) and the commercial fishery (12 years of data). The model starts from an assumed equilibrium state in 1935, and the survey data cover the period 1967 to 2019 (although not all years are represented). Two fisheries are modelled: one a combined bottom and midwater trawl fishery and an ‘other’ capture methods fishery, which combines halibut longline, sablefish trap and rockfish longline fisheries. The second fishery is a compromise that acknowledges other methods capturing this species while keeping the complexity to a minimum, given the lack of good information from these additional fisheries.

Three base runs using a two-sex model were implemented in a Bayesian framework (using the Markov Chain Monte Carlo procedure) under a scenario that fixed natural mortality to three levels (0.07, 0.08, 0.09) while estimating steepness of the stock-recruit function, catchability for the surveys and CPUE, and selectivity for four of the six surveys and the commercial trawl fleet. These three runs were combined into a composite base case which explored the major axis of parameter uncertainty in this stock assessment. Nine sensitivity analyses were performed to test the effect of alternative model assumptions.

The composite base case suggests that the BOR spawning population lies entirely (with a probability of 1.0) in the Critical Zone, as do the three component runs. This is in spite of the stock being moderately productive and exploitation rates being uniformly low. For instance, the median exploitation by the trawl fishery, which accounts for 95% of the catch, in the final year is estimated to be 0.025 (0.012-0.044) even at the extremely low biomass levels. An extremely strong cohort, estimated at 44 times the long term average recruitment (range: 30-58), was born in 2016 and is projected to bring this stock out of the Critical Zone by the beginning of 2023 and will have a better than 50% probability of being in the Healthy Zone in that same year.

These predictions are entirely dependent on the assessed size of the 2016 year class, which is highly uncertain. However, there is evidence, beginning in 2017, that this cohort is large and dominates the available data. Three of the synoptic surveys, particularly the Queen Charlotte Sound survey in 2019, show strong quantitative increases in abundance and in distribution. This cohort dominates the age and length frequencies in the commercial trawl, beginning in 2018. Similar strong recruitment (in 2010 and 2013) in the US BOR population, located south of Monterey, has lifted that stock out of an ‘overfished’ designation and was assessed in 2017 to be approaching 0.5B0. We suggest that the proven capacity of the four active synoptic surveys plus the high quality monitoring of the trawl fishery catches and discards will allow managers some comfort that the progress of this strong cohort can be monitored as it recruits to the fishery and that adjustments to the TAC can be made if the cohort fails to return at anticipated levels.

APPENDIX C: WORKING PAPER REVIEWS

REVIEWER: JACLYN CLEARY, QUANTITATIVE ASSESSMENT METHODS SECTION, PACIFIC BIOLOGICAL STATION, DFO

This working paper is thorough and well written. Decisions relating to data and model choice are well explained and the authors have put a lot of effort in producing model outputs and exploring sensitivity runs. Data choices and rationales are well documented and have clearly benefitted from discussions within the BOR Technical Working Group.

The stock assessment evaluates a single BC coastwide population of Bocaccio harvested by multiple fisheries. The authors implement a two-sex statistical catch-at-age model fitted to 6 survey time series, an index of CPUE, commercial catch, and age frequency data (from survey series and commercial fisheries). Model fitting and parameter estimations are conducted in a Bayesian framework. A total of nine sensitivity runs were conducted, and results are explored relative to a composite base case. Two key uncertainties are discussed in detail: choice of fixed *M* value and influence of the 2016 cohort.

Biomass estimates and stock status in 2019 are presented relative to B_{MSY} and B_0-based reference points. Harvest advice is presented as probabilistic decision tables.

Below are comments for discussion and consideration at the RPR process, responding to different sections of the document. Major topics/action items in **bold**.

1. Section 2: This section describes two commercial fishery categories and past methods for reconciling historical catches.

   *Pls include start years for the two time series of catch data (currently only appears in the Appendix)

2. Section 6.1: “This lack of age frequency (AF) data required fixing the selectivities using the prior parameter values.” (similar sentence for lack of biological data from WCVI Triennial/ GIG historical surveys)

   *Where did these priors originate?

3. **Section 6.6: Natural mortality** The authors indicate they were unable to estimate *M* within the model. *M*-values from 0.05 to 0.10 are explored and the authors choose 3 fixed estimates of *M* (*M*=0.7, 0.8, 0.9) based on MCMC diagnostics.

   *Provide clarification in the WP that choice of fixed *M* values used in the model runs is based on MCMC diagnostics (*due to issues of model convergence*) and that the uncertainty explored is limited to the lower end of recommendations/ values provided of 0.077-0.136 provided by Hoenig 1983; Then et al. 2015; Hamel 2015. I’m assuming that if the model had converged with fixed *M* values at the upper range (e.g., 0.1-0.136), then the base runs and composite would reflect this. Higher *M* values in the composite base case would likely result in longer duration for rebuilding out of the critical zone. I think this is worth mentioning in the context of the conclusions, not just that choice of fixed *M* is a key uncertainty but that the authors were limited/restricted in their ability to explore fully published ranges due to lack of convergence.

4. Section 8.1.1: “Two notable exceptions to this generalisation was the lack of fit to the very large 1980 Triennial index and the failure to match the large uptick in the 2019 QCS index.”

   *1983 (Triennial) and 2018 WCVI Synoptic also show poor fits.

5. **Section 9.2: In para 4, pg 21, the authors define U_{MSY} as a target exploitation rate. The Sustainable Fisheries Framework (SFF) defines the removal reference as maximum, not a target**.

   The Removal reference is the maximum acceptable removal rate for the stock. It is normally expressed in terms of fishing mortality (F) or harvest rate. It could be described in ways other than F or harvest rate but it always must be described in terms of fishery-related pressure that affects the overall stock. The Removal reference includes all mortality from all types of fishing. To comply with the United Nations Fisheries Agreement (UNFA), the Removal reference must be less than or equal to the removal rate associated with maximum sustainable yield.

   Thus SFF compliance requires F_{MSY} be stated as a maximum (not target).

6. **2016 cohort: sensitivity of management advice (decision tables) to strength of 2016 cohort**

   Evidence of the 2016 cohort as a very strong year class is evidenced by all sources of survey and fishery data. The 2016 cohort is described 44 times larger than the long-term recruitment and from the recruitment time series (1935-2019) we can see this is a 1 in 80 year event.

   The authors are careful to explain the projections and decision tables as "dependent on the strength of the recruiting 2016 year class" and that if the stock "continues to show a strength consistent with what is seen so far, that coastal BOR should rebuild above the USR in 4-5 years".

   The authors recommend the next full stock assessment occur after 2025 such that there are two new indices from the QCS and WCVI synoptic surveys.

   I am concerned that the magnitude of influence of the 2016 cohort and uncertainty in strength of this year class is not sufficiently explored in the projections (and decision tables). *How does the rebuilding timeframe change if the 2016 cohort turns out to be less strong than is suggested by the current assessment?* I suggest the paper and advice to managers would benefit from further exploration of the magnitude of influence of the 2016 cohort on timeframe for rebuilding and stock projections. Please consider the following questions and suggestions:

   i. Show influence of the 2016 cohort on the estimated long-term average recruitment.

      - Long-term average recruitment presented in Figure F.21 (pg 205) is not "typical recruitment". The 2016 cohort bumps up the estimate of R_0 and hence average recruitment is increased for the duration of the projections.
      - Present Figure F.37 (pg 225) and estimated average recruitment with and without the 2016 cohort (ie, sensitivity run "typical average recruitment"). Include estimates of R_0 for both runs.

   ii. Show influence of the 2016 cohort on historical and projected recruitment, and compare with sensitivity run "typical average recruitment".

      - Present time series of estimated and projected recruitment under several constant catch strategies under base and sensitivity run "typical average recruitment" – e.g., see Fig 13, Yellowmouth assessment (2012/095. iv + 188 p.). Another option is comparison with runs where history ends in 2016 (start projections in 2017).

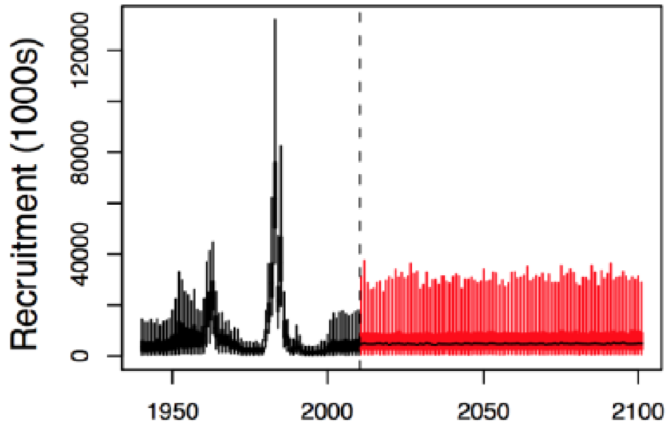

Figure 1. Fig 13 from Yellowmouth assessment (2012/095. iv + 188 p.)

iii. Reduce the influence of 2016 cohort in the projections: conduct sensitivity run(s) using percentiles of estimated average recruitment (e.g., 33rd, 15th, 5th) in the projections.

- Alternative to (ii)

iv. Explore uncertainty in the strength of 2016 cohort within the decision tables.

- The 2016 cohort is highly influential in the decision tables in the short term, due to increasing biomass from the 2016 cohort, and over all projection years due to higher R_0 continuing to bump up all future projected recruitments to levels way above typical recruitment observed in all years except for 2016 and somewhat 1969. I suggest this can be explored by presenting comparisons (base and average recruitment sensitivity run) for Figure 4 and typical decision table.

v. **Simulated data**: Comparison of model runs using simulated data (with different cohort strengths for 2016) could also be used to quantify the magnitude of influence of this cohort on timeframe for rebuilding and stock trajectory. This approach was used as a robustness test for Sablefish[1]

7. **Section 9.1 Reference points**

The terms of reference state: Recommend reference points consistent with the DFO Precautionary Approach (PA), including the biological considerations and rationale used to make such a determination. These might include the provisional DFO limit reference point (LRP) of $0.4B_{MSY}$ and the upper stock reference (USR) of $0.8B_{MSY}$, or historical reference points (e.g., Bmin). The choice of reference points is often determined by the complexity of the population model, which, in turn, depends on the quality of the input data.

On page 20 authors acknowledge limitations of the chosen reference points: "Note that no modelling has been carried out to determine the suitability of these reference points for the stock, nor have acceptable levels of risk been specified." However this is not fully addressing the objected stated in the ToR.

Do the authors feel this is a necessary step, if yes- add this to Future Research and Data Requirements. If no, explain in this section choice of reference points (B_{MSY} and B_0-based).

Other minor edits

- Table 1: specify 3000 MCMC samples in caption
- Page 15: "… stock biomass will rebuild to above the USR…" – define USR or direct reader where this is described.
- Figure 4: define LRP and USR as is done in Fig 5
- Page 19: "Consequently, the results from this run have not been reported." – it's unclear why S04 results are reported in Tables F61 and F62
- Page 25: typo: SFF (not SSF)

Responses to the five general questions

1. Is the purpose of the working paper clearly stated?

   Yes

2. Are the data and methods adequate to support the conclusions?

   Yes, with the exception of comments made above.

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

   Yes

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

   Yes, with the exception of comments made above (suggestions for additional sensitivity runs).

5. Can you suggest additional areas of research that are needed to improve our assessment abilities?

   Yes, see comment #7

References

DFO. 2020. Evaluating the robustness of candidate management procedures in the BC Sablefsh (*Anoplopoma fbria*) fishery for 2019-2020. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/025.

REVIEWER: KELLY ANDREWS, NORTHWEST FISHERIES SCIENCE CENTER, NOAA FISHERIES, USA

Dear authors and reviewers, I found this assessment to be clearly written and appears to use current standard-practice assessment models that are suitable to characterize the status of this population of Bocaccio. I found the data and methods easy to read and support for the use of important parameters were discussed.

I will preface this review with the fact that I am not a stock assessment biologist, my expertise is definitely on the ecological side of fisheries and ecosystems, so my thoughts, questions and comments below may reflect this, but I hope they are relevant to the review process!

General comments

I really have only three main concerns for the authors and then will leave the appropriateness of various parameter settings and model specifications for discussion with the rest of the review panel.

1. The authors suggest that setting M is one of the major assumptions of this assessment. I like the framework of using a mixture of the three chosen values used here (0.07, 0.08 and 0.09). The text describes the exploration of estimates lower than these values (<0.7) and described how those values didn't work or were not appropriate, but I did not see any description of using values greater than 0.1. The southern CA Bocaccio assessment uses 0.17 for M, so I wonder how a range of values on this order of magnitude would change the results?

   Related to this question, there is a statement on page 28 in the General Comments section, "However, Figure 7 indicates that the choice of M has little impact on the estimate of stock status, with all the component runs comprising the composite base case sitting well in the DFO Critical Zone." If you used a larger range of estimates for M (e.g. ~0.17), how would this change the predicted Spawning Biomass estimates seen in Figure 7?

2. The authors state that the average recruitment assumption is a very important assumption and I agree. From work on the southern CA stock, "good" recruitment events only occurred about 13% of the time (1959-1997 data; Tolimieri and Levin 2005). Cooler ocean temperatures during the period spanning egg production to the end of the larval stage correlated with higher recruits per spawner both before and after the regime shift. Prior to the 1976 shift, high log R/S values were more likely when upwelling was low during the settlement period, but there was no relationship after the shift. In the absence of fishing a "good" recruitment year needs to occur 15% of the time to achieve a nonnegative population growth rate of (X > 1.0), similar to the observed frequency of good recruitment events. Good recruitment years needed to occur >90% of the time under historic levels of fishing mortality to achieve a population growth rate >=1.0. And the data from BC suggest that "good" recruitment events for Bocaccio may be even less frequent (Fig., F.21).

   Based on these pieces of information, and the statements in the text that suggest this 2016 event is likely to rebuild this stock and that this rebuilding has also been observed in the southern CA stock as well, I'd like to point out one major difference between these cases. Thus far, there has only been one "good" recruitment event for the BC stock since the late 1970's, while there were several "good" years of recruitment observed in the southern California stock in 1999, 2010 and 2013, along with, what appear to be other "good-to-decent" recruitment years in 2014 and 2017 (see figure below from He and Field 2017).

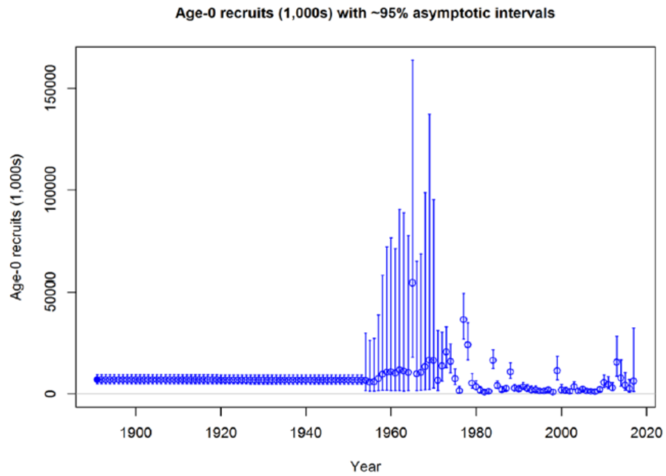

Figure 2. Figure 5 from He and Field 2017. Estimated annual recruits with 95% asympototic intervals.

Thus, I would caveat any statement in the text (example from pg. 29…"Therefore, it seems reasonable to accept the conclusion by this stock assessment that the size of the 2016 year class is considerably larger than the long term mean recruitment and that it is likely to be large enough to rapidly move this stock out of the Critical Zone and into the Healthy Zone.") with something like "…if more above average recruitment events are observed over the next few years." Or something that at least provides this contextual difference between these two case studies.

3. Based on the ideas presented in #2, I am finding it difficult to believe that the main result, shown in Figure 4, is a likely scenario. I admittedly don't know all the mechanisms within the stock assessment model that could cause this rapid change and increase in spawning biomass, but it seems unlikely, particularly if other "good" recruitment events do not occur – I hope there are other stock assessment reviewers that can comment on specific parameters or settings that could possibly be mis-specified to cause this type of model behavior? I think the authors are correct that the 2016 year class appears to be vastly greater than anything observed ever, but I am hesitant that this age class has been fully accounted for and/or that it could completely rebuild this stock by itself.

   One specific question related to the model output: The caption of Figure F.39 states that "Year 2022 is the first year that the 2016 cohort is assumed to contribute to the spawning population." If that is the case, then what age classes contribute to the initial large spike in spawning biomass from 2020 to 2022, as shown in Figure 4 (see my annotations in the figure below)? Was this a typo in Figure F.39's caption?

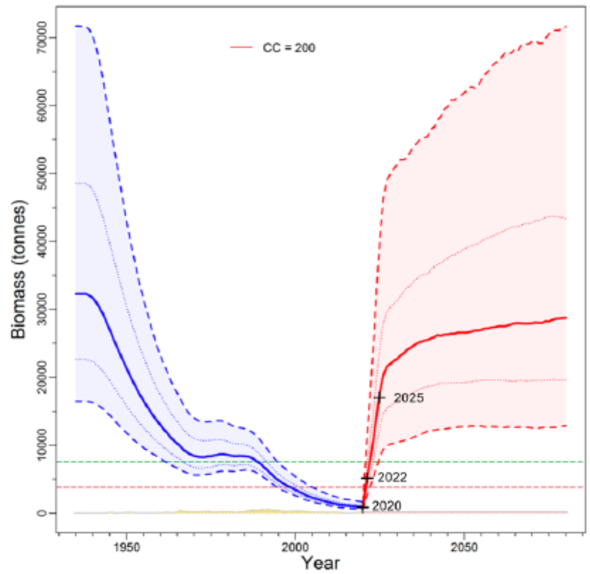

Figure 3. Figure 4 from working paper: Estimates of spawning biomass Bt (tonnes) for the composite base case. The median biomass trajectory appears as a solid curve surrounded by a 90% credibility envelope (quantiles: 0.05-0.95) in light blue and delimited by dashed lines for years t=1935-2020; projected biomass appears in light red for years t=2021-2080. Also delimited is the 50% credibility interval (quantiles: 0.25-0.75) delimited by dotted lines. The horizontal dashed lines show the median LRP and USR. Catch and assumed catch policy (200 t/y) are represented as bars along the bottom axis. Question: If the 2018 cohort doesn't contribute to spawning biomass until 2022 (Fig. F.39), where does the increase in spawning biomass from 2020-2022 come from?

Finally, on this note, the levels of spawning biomass that the model shows in ~2030 are at levels seen in the 1930's which was considered an unfished state. Can the number of recently maturing fish (with less eggs/spawner) from this one age-class really support this level of rebuilding, particularly considering the infrequency of "good" recruitment events for Bocaccio that are likely to come in future years?

Future research and data requirements comments

1. For item #3, I strongly agree, but would also add "explore the incorporation of ecosystem variables and their ability to decrease the uncertainty around estimates of recruitment"…or something like that.
2. Have you thought about whether spatial movement of adults could be a source of error in these models based on when surveys occur? Are there any seasonal components of movement that could alter your model results?
3. The immediate thought that comes to mind when thinking about the huge 2016 recruitment event is whether the warm Sea Surface Temperature (SST) values (the "Blob") could be responsible. Larval rockfish were in high abundances in other US West Coast surveys in 2016 and seems to be a coastwide recruitment event for rockfish. Would incorporating SST anomalies into the assessment framework help with recruitment estimates of the past?

References

Nick Tolimieri, and Phillip S. Levin. "The Roles of Fishing and Climate in the Population Dynamics of Bocaccio Rockfish." *Ecological Applications*, vol. 15, no. 2, 2005, pp. 458–468. *JSToR*.

He, X., and J.C. Field. 2017. Stock Assessment Update: Status of Bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2017. Pacific Fishery Management Council, Portland, Oregon.

APPENDIX D: AGENDA

Canadian Science Advisory Secretariat

Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Bocaccio stock assessment for British Columbia in 2019, including guidance for rebuilding plans

December 17-18, 2019
Nanaimo, BC

Chair: Greg Workman

DAY 1 – Tuesday, December 17, 2019

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***	
1045	Overview Written Reviews	Chair + Reviewers & Authors
12:00	***Lunch Break***	
1300	Identification of Key Issues for Group Discussion	Group
1330	Discussion & Resolution of Technical Issues	RPR Participants
1445	***Break***	
1500	Discussion & Resolution of Results & Conclusions	RPR Participants
1630	Develop Consensus on Paper Acceptability & Agreed-upon Revisions (ToR objectives)	RPR Participants
1700	Adjourn for the Day	

DAY 2 - Wednesday, December 18, 2019

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1 (*As Necessary*)	Chair
0915	Carry forward outstanding issues from Day 1	RPR Participants
1030	***Break***	
1045	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Summary bullets • Sources of Uncertainty • Results & Conclusions • Figures/Tables • Additional advice to Management (as warranted)	RPR Participants
1200	***Lunch Break***	
1300	*Science Advisory Report (SAR) cont'd*	RPR Participants
1445	***Break***	
1500	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair
1545	Other Business arising from the review	Chair & Participants
1600	***Adjourn meeting***	

APPENDIX E: PARTICIPANTS

Last Name	First Name	Affiliation
Anderson	Sean	DFO Science, Groundfish Section
Andrews	Kelly	National Oceanic & Atmospheric Administration
Archibald	Devon	Oceana
Boyes	Dave	Commercial Industry Caucus (CIC)
Campbell	Jill	DFO Science, Groundfish Section
Chaves	Lais	Council of Haida Nations
Christensen	Lisa	DFO Science, Centre for Science Advice Pacific
Cleary	Jaclyn	DFO Science, Quantitative Assessment
Cornthwaite	Maria	DFO Science, Fishery + Assessment Data
Dunabeitia	Ramon	BC Groundfish Conservation Society
Field	John	National Oceanic & Atmospheric Administration
Frid	Alejandro	Central Coast Indigenous Resource Alliance
Govender	Rhona	DFO, Resource Management, SARA
Grandin	Chris	DFO Science, Groundfish Section
Greene	Joe	Groundfish Technical Advisory Committee (GTAC)
Haggarty	Dana	DFO Science, Groundfish Section
Haigh	Rowan	DFO Science, Groundfish Section
Keppel	Elise	DFO Science, Groundfish Section
Kiezer	Adam	DFO Resource Management, Groundfish
Kronlund	Rob	DFO Science, National Headquarters
Lacko	Lisa	DFO Science, Groundfish Section
Lane	Jim	Nuu-chah-nulth Tribal Council
Mose	Brian	Groundfish Technical Advisory Committee (GTAC)
Olsen	Norm	DFO Science, Groundfish Section
Romanin	Kevin	Province of BC
Sporer	Chris	Pacific Halibut Management Association
Starr	Paul	Canadian Groundfish Conservation Society
Tadey	Rob	DFO Resource Management, Groundfish
Turris	Bruce	BC Groundfish Conservation Society
Wallace	Scott	David Suzuki Foundation
Wetzel	Chantel	National Oceanic & Atmospheric Administration
Wischniowski	Stephen	DFO Science
Workman	Greg	DFO Science, Groundfish Section