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Proceedings of the Pacific Regional Peer Review on the Arrowtooth Flounder (*Atheresthes stomias*) Stock Assessment for British Columbia in 2021

October 19–20 and December 5, 2022
Virtual Meeting

Chairperson: Shannon Obradovich
Editor: Yvonne Muirhead-Vert

Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

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Canada

Foreword

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

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on October 19–20, 2022 and December 5, 2022. The working paper presented for peer review is to update management advice for the coastwide Arrowtooth Flounder stock in British Columbia as requested by the Pacific Groundfish Management Unit (GMU).

Due to the COVID-19 pandemic, in-person gatherings were restricted and a virtual format for this meeting was chosen. Participation included DFO Science regional Fisheries Management staff and external participants from the National Oceanic and Atmospheric Administration (NOAA), Interface Fisheries Consulting, Mariner Seafoods, Commercial Industry Caucus-Trawl, Pacific Halibut Management Association, and the Canadian Groundfish Research and Conservation Society.

The meeting participants agreed the working paper met the Terms of Reference objectives and was accepted with major revisions. The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) providing advice to DFO Fisheries Management on the coastwide assessment of this stock relative to the 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 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) virtual Regional Peer Review (RPR) meeting was held on October 19–20, 2022 and December 5, 2022 to review the working paper entitled Arrowtooth Flounder (*Atheresthes stomias*) Stock Assessment for British Columbia in 2021.

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

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

Grandin, C.J., Anderson, S.C. and English, P.A. Arrowtooth Flounder (*Atheresthes stomias*) Stock Assessment for British Columbia in 2021. CSAS Working Paper 2019GRF03.

The meeting Chair, Shannon Obradovich, 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, the working paper, written reviews (Appendix C), and a summary of corrections to the code and model.

The Chair reviewed the Agenda (Appendix D) and the Terms of Reference (Appendix A) for the meeting, highlighting the objectives and identifying Yvonne Muirhead-Vert as the Rapporteur for the review. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. Participants were reminded that everyone at the meeting had equal standing 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, 20 people (first meeting) and 18 (second meeting) participated in the RPR (Appendix E).

Prior to the meeting, Mackenzie Mazur (DFO Science) and James (Jim) Ianelli (NOAA) were asked to provide detailed written reviews of the working paper to assist everyone attending the peer-review meeting. Participants were provided with copies of their written reviews ahead of the meeting.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to Fisheries Management to provide a coastwide assessment on Arrowtooth Flounder relative to the 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 the expected stock status. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

INITIAL MEETING (OCTOBER 19–20, 2022)

GENERAL DISCUSSION

Following a presentation by the authors, the two reviewers, Mackenzie Mazur (DFO Science) and James (Jim) Ianelli (NOAA), shared their comments and questions on the working paper. The authors were given time to respond to the reviewers before the discussion was opened to all participants. This Proceedings document summarizes the discussions that took place by topic, including points of clarification by the authors. Questions and comments raised by the reviewers and participants are captured within the appropriate topics. The formal reviews by the reviewers are located in Appendix C. One of the reviewers had questions regarding the analyses and requested additional analyses. The updated analyses were provided to the participants to review in advance of the meeting.

TERMS OF REFERENCE OBJECTIVE ONE

Recommend reference points consistent with the DFO Precautionary Approach (PA), including the biological considerations and rationale used to make such a determination. These reference points will include the reference removal rate (F_{MSY}), the limit reference point (LRP) and the upper stock reference (USR).

Reference points: The provisional DFO limit reference point (LRP) of $0.4B_{\text{MSY}}$ and the upper stock reference (USR) of $0.8B_{\text{MSY}}$, as described in the DFO Precautionary Approach policy, were not used in this assessment and there was discussion about alternative reference points to satisfy this objective.

It was suggested by a participant that $0.4B_0$ is more aligned with a target reference point than a USR. A reviewer suggested that a dynamic reference point could be an alternative to a static reference point given recent low recruitment compared to the average.

A participant asked what the expected value of B_0 was when B_{MSY} reference points are 0.4 and 0.8. They also asked what the calculated proportion of B_{MSY} was when B_0 is 0.4 and 0.8. They also asked what B_0 was when B_{MSY} is 31.2 kt. The authors indicated that it would be approximately 31 kt/180 kt = 0.16 kt using the median of the posterior, but that the full calculation would involve performing that calculation on each Markov chain Monte Carlo (MCMC) draw. The participant indicated that it would be helpful to plot this.

Upper Stock Reference (USR): A participant asked why a value of $0.4B_0$ was chosen for the USR. The authors responded that the previous assessment for Arrowtooth in 2015 used the same reference points. They noted that they were unable to use B_{MSY} as it was influenced by the relationship between the estimates of maturity and commercial age selectivity, resulting in a large portion of the mature biomass being invulnerable to the fishery. Similar B_0-based reference points are used for the Hake fishery stock assessments and in many NOAA assessments. A participant asked if B_0 is the same as B_{MSY} and the authors indicated that B_0 and B_{MSY} are not the same.

Another participant commented that the USR is unique to Canada. Australia uses maximum economic yield (MEY), which assesses economic benefit. A participant shared that in New Zealand, $0.4B_0$ is often used as a target reference point, and that for short-lived, more productive species, a lower target of $0.35B_0$ may be used. A participant provided the paper *Best Practice Reference Points for Australian Fisheries* (Sainsbury 2008) to provide information on how Australia treats reference points.

It was suggested that the authors should look at Alaska and Washington state stocks and their stock assessment approaches. The authors indicated that the reference point for Hake is calculated using 0.4 spawning potential ratio (SPR) of F_{40} which is a harvest rate target rather than a biomass target like $0.4B_0$.

After a lengthy discussion, there was some agreement that $0.4B_0$ could be a candidate target reference point or the proposed USR. The authors agreed to add $0.35B_0$ in the decision table and the SAR as an alternative USR.

Removal reference: It was noted that the estimates of F_{MSY} seemed to be too high to be credible. A participant asked if there were suggestions for an alternative. The authors agreed to investigate alternatives. The authors ultimately proposed finding the fishing rate and catch that would take the stock to $0.4B_0$ in the long term (defined as 50 years in the future) given recent (last decade) average recruitment.

TERMS OF REFERENCE OBJECTIVE TWO

Assess the current status of coastwide Arrowtooth Flounder in BC waters relative to the reference points.

Stock status was primarily discussed in the follow up meeting on December 5, 2022.

Stock structure: The Strait of Georgia was not included in this assessment and one of the reviewers was wondering why. They suggested that a genetic study should be conducted to see if it is a separate stock from the one in outside waters or the same. At the time of this assessment, it was assumed to be a separate stock.

TERMS OF REFERENCE OBJECTIVE THREE

Using probabilistic decision tables, evaluate the consequences of a range of harvest policies on projected biomass relative to the reference points.

Relative spawning biomass plots: The authors explained that B_0 is the initial equilibrium biomass associated with R_0 and has no year associated with it. Looking at the projections, the relative spawning biomass is a fraction of B_0 from 1997 onwards. The authors explained that the equation section within the paper shows how B_0 is calculated.

The authors agreed to include total allowable catch (TAC) by increments of 1,000 t (instead of 2,000 t) and to include probabilities of projected biomass being above/below reference points in the decision table.

Retrospective analyses: A reviewer explained that retrospective patterns are an expression of model instability, so it’s important that they are quantified. Mohn’s rho is used to measure the magnitude of retrospective patterns, and a value higher than 0.2 or lower than -0.15 indicates considerable retrospective patterns for long-lived species. Retrospective pattern Mohn’s rho value of 0.099 seems fine to the authors. They were willing to show output that shows the Mohn’s rho value.

Estimations of *F*: A participant expressed concern that the vulnerable biomass was not being calculated correctly over time. They felt that the authors were not plotting with the correct value of fishing mortality (F). Reviewing Equation G36, a participant commented that the plot should be e^{γ} instead of gamma. Another participant suggested that the authors could pair it with the estimated biomass to make sure the numbers look correct. The authors indicated that they were plotting e^{γ} and it was peaking at 0.3 in the plot. The authors have agreed to review the data and check the calculation of F.

Decision table: The authors provided only one year of projections in the decision table as the uncertainty would get larger as the number of projection years increased. They surmised that it was likely that there would be another stock assessment for Arrowtooth Flounder within the next couple of years, once more data have been collected for each area of the coast. Given the one-year projection, a participant asked if anything else could be added to provide some direction for decision making. A participant reminded the group that GMU would like a couple of years of projections in the decision table.

Projections: A reviewer asked how the projections were run and how uncertainty was incorporated. It was agreed that the authors would rerun the base model using 10 million samples to generate the final decision table with 3-year projections.

TERMS OF REFERENCE OBJECTIVE FOUR

Describe sources of uncertainty related to the model (e.g., model parameter estimates, assumptions regarding catch, productivity, carrying capacity, and population status).

Catches: A participant asked the authors if they would be able to create a plot comparing estimated catches with actual catches. The authors confirmed that they were nearly identical but agreed to generate this plot. There was a discussion on how iSCAM estimates *F*.

Geostatistical survey indices: The authors used two versions of the geostatistical indices:

1. using single surveys (in the WP as a sensitivity analysis), and
2. using a stitched coastwide index across the four surveys.

The coastwide index was shown to be similar to the discard catch per unit effort (CPUE).

One of the reviewers asked about the geostatistical models and sought clarification on which one of the four was used for the model. The authors explained that they used the delta-gamma model (binomial likelihood for encounter vs. non-encounter and a gamma likelihood for positive catch rate if encountered) using a depth smoother.

Survey area: It was noted that the area of the synoptic trawl surveys covers more than the fishing grounds. The authors agreed that a map of the trawl footprint could be added.

Maturity: A participant mentioned that the maturity data from the surveys was not ideal since the fish spawn in winter and are in a resting state in summer (at the time of the surveys). They felt that the estimate of maturity was not accurate due to the timing of the survey. The participant suggested that sampling should be undertaken in the winter instead of summer to provide better estimates of the maturity for this species.

It was indicated that a major source of uncertainty in the model was maturity. A change in maturity changes the vulnerable biomass. If the maturity is wrong, then decision making could be wrong. The authors have agreed to add an additional sensitivity test excluding developing or resting state fish from the maturity ogive in the working paper.

A participant asked why it appears that the surveys are selecting older fish. A participant suggested it could be the way that the selectivities were estimated. Another participant asked if the B_{MSY} estimate was used only for females or both sexes. The authors indicated that spawning biomass (B) was calculated using both sexes in the model.

Modelling platforms: A participant expressed concern about the iSCAM model since several errors had been identified and corrected. The participant suggested that the authors could do the modelling on two different platforms and compare the results. Another member of the group asked the authors to provide them with the rationale for using iSCAM. They indicated that this model was used in the 2015 Arrowtooth Flounder stock assessment as well as in several other groundfish assessments for over a decade, is used in the Pacific Herring assessment, and they wanted to be consistent with the previous assessment. The authors agreed to present additional comparisons with Stock Synthesis 3 (SS3).

TERMS OF REFERENCE OBJECTIVE FIVE

Provide information on environmental conditions that may impact the stock, including climate change impacts if possible.

Body conditioning modelling: There were questions regarding the timing of the surveys and if they occurred at the same time of year. The surveys are within a couple of months of each other, with the Queen Charlotte Sound (QCS) synoptic occurring later in the season.

A participant asked if the condition factor was in the assessment model. The authors explained that it was a separate analysis. Concern was also raised with the fit of the age composition data. There was an error in the code when the working paper was initially distributed, and after revisions, the concern disappeared. One of the reviewers noted that the model is appropriate with the data that was currently available.

A participant asked if there is stock mixing at international boundaries. There is uncertainty about whether the stock migrates north and south. It was suggested that this would be good to examine in future.

TERMS OF REFERENCE OBJECTIVE SIX

Recommend an appropriate interval between formal stock assessments, indicators used to characterize stock status in the intervening years, and/or triggers of an earlier than scheduled assessment (DFO 2016). Provide a rationale if indicators and triggers cannot be identified.

It was noted that the DFO Precautionary Approach (PA) policy looks at the status and trajectory of the stock status. The risk tolerance changes when stock status changes. The participant was not confident about the decision table and suggested some feedback simulation work for this stock. Another participant asked if the model could be run again to include this year’s (2022) survey data as well as the commercial data to calculate 3-year projections. The authors noted that this was out of scope for this paper. Another participant noted that the assessment was to provide advice up to 2021, which was agreed upon with the TOR Steering Committee for the development of this working paper.

Alternatively, another participant wanted the data from another year to be included due to the timing of the science advice. The Integrated Fisheries Management Plan (IFMP) consultation process is in December, and it would be helpful to have this advice in advance of the meeting.

It was suggested that major revisions could be distributed later to all participants and be included into a Science Response (SR) that would also incorporate another year of data. It was noted that no age data would be available for the year so it would increase the uncertainty. The only updated data would be from the West Coast Vancouver Island (WCVI) synoptic survey since data from the other surveys had not been entered yet.

Given the stock was estimated to be below $0.4B_0$ with declining survey indices in the base model, declining estimated spawning biomass and low estimated recruitment, it was suggested that another assessment should be completed in two years when the entire coast of BC has been surveyed again. The next stock assessment would be in 2024.

ADDITIONAL DISCUSSION TOPICS

Commercial data: There was a question about why the commercial maturity data were not used. For this assessment, the authors only used survey data for the maturity ogives. The authors have agreed to add the new plots containing only commercial maturity data for comparison.

Survey data: There was a discussion regarding what age of fish are caught within the surveys. It was noted that the surveys target a mixed age of fish including juveniles, extending into shallower water. Another participant asked if the survey covers all fishery grounds for age and composition. It was suggested that it would be helpful to have a survey map included.

A participant reviewed age-at-maturity in Alaska and in Washington state. It appears that age seven is the 50th percentile for maturity in Alaska. There seemed to be some difference from what is happening south of the British Columbia (BC) border. They were curious to know why the synoptic surveys appear to be selecting older fish.

Zero tows (binomial CPUE): A participant asked for clarification on whether the 100% discard rule in the discard CPUE time series means the entire tow is discarded or 100% Arrowtooth is discarded. The authors clarified that it is the entire tow. The authors presented a plot of proportion of commercial tows catching no Arrowtooth. The group suggested the figure and the numbers could be added.

CPUE by year graph: There was a discussion about a CPUE by year graph provided by the authors. The group discussed whether zero-catch tows were included. The authors shared that Halibut shows a similar distribution, although the Queen Charlotte Sound (QCS) data have a different distribution. The year-round trawl closure area (800-line) in QCS may decrease the CPUE, but only after 2019. It was noted that there was also an increasing absence in locations where Arrowtooth was historically caught.

Maturity: The authors showed new maturity plots on Day 2 containing just fish sampled from the commercial data. Resting stage fish (stage 7) were removed from these plots which appeared to increase the age of maturity. The spatial plots of maturity based on samples for just females were then shown. There was a spatial Gaussian Markov random field. The maturity was a function of length, and length at 50% maturity was 42 cm for females. The authors noted that the surveys are conducted at different times of the year so that would introduce some variability. Reviewing QCS, it looks like the fish are younger and there is a smaller sample size. One of the authors wanted to remove the QCS samples from the maturity plot. Others expressed that the fish are not commercially abundant in the summer since the fish migrate to shallow water. The West Coast Haida Gwaii survey occurs later in the year and at deeper depths than the other surveys. It was noted that Arrowtooth Flounder do not frequently occur on the west side of Haida Gwaii. The synoptic survey there is conducted in summer in deeper water. Another participant indicated that the fish’s maturity is considered to be resting so samples are not representing maturity accurately.

A participant questioned why a geostatistical model, varying in time and space, was not applied to maturity. They suggested that graphs of maturity at length for Arrowtooth Flounder surveys and the Arrowtooth Flounder maturity model presented in the meeting could be improved. A participant showed examples of relative frequency plots of maturity versus month for another fish species in the major BC survey areas. It was noted that Alaska does not use Stock Synthesis 3 (SS3) for Arrowtooth Flounder but a different model. The Alaskans also use lengths instead of empirical maturity and then adjust to determine a mean age, so it is a pseudo-age. The authors indicated that the data being collected on maturity from the surveys in BC that happen in the summer are not ideal to estimate maturity because the fish spawn in the winter.

Ageing error: It was noted that in Figure 20 of the working paper there could be an issue with year classes. They noted that there could be an ageing error that should be addressed as it could bias commercial and survey data, affecting recruitment variability, and changing productivity. Another participant suggested a different model could be used to include the ageing error. They stated that the authors could move from iSCAM and use SS3. Another person supported using the model one knows best. The authors have agreed to include a recommendation in the future research section on sensitivities run with ageing error.

Discard CPUE: A participant commented that the CPUE is the main driver within this assessment and noted that all surveys except QCS are consistent with the CPUE series. The authors showed the RPR participants a plot of the QCS index fit in a single sex model and it showed similar trends to the other plots when the discard CPUE was removed. A participant asked why the shoreside CPUE selectivity was not used as the discard fishery instead of fixing age-at-50%-harvest at 9 y and the authors said it was an oversight. The difference between the use of 8.67 y and 9 y would likely increase uncertainty in the model. It was recommended that in the future, shoreside CPUE selectivity should be used as the discard fishery selectivity instead of using a fixed value for the discard fishery.

It was suggested that the projections should resample estimated recruitment from the last 10 years and not use average recruitment. The authors indicated that recruitment would not affect the projections. The authors have agreed to additional sensitivity runs for the discard CPUE index using selectivity estimated from the shoreside fleet before the December meeting.

It was noted that in Figure 10 of the working paper, the value of F is low in 2019 for only males in the plots. The authors suggest that they could create dynamic B_0 plots where the fishing mortality is held at zero (no fishing) to evaluate the relative contribution of fishing and recruitment to the biomass trend.

Queen Charlotte Sound (QCS) synoptic survey selectivity: A participant asked why the model does not follow the QCS survey index. There was speculation that QCS could host a nursery population since it appears that younger fish are located there. At the time of the 2022 assessment, the model did not track the abundance index as well as indices in other areas. The participant asked if the fit QCS index series was better when the discard CPUE was removed from the model. The authors explained that they did not take the discard index out of the base model, but looked at the bridging model (a set of transitional models were used to compare the single-sex, single-fleet 2015 assessment model to the split-sex, two-fleet model used in this assessment). The authors offered to do a quick run that removed the discard index. A reviewer noted that the survey could be picking up an important signal that we do not understand at this time and noted it is important that future research looks into this.

It was suggested that the survey seems to be targeting younger fish since it is not catching many over the age of 10. A participant commented that fish are not being caught at the optimal depths for this stock and could explain why older fish are not showing up in the survey.

Research recommendations: A participant made a research recommendation to have trained personnel look at Arrowtooth Flounder during the winter fishery when the stock is spawning instead of during the summer. The fish are frequently in a resting state during the summer survey sampling.

Clarification of language: There was a suggestion that some pieces of the front section should be removed. The authors agreed to identify instances of the following words: “absolute”, “vulnerability”, and “selectivity” to ensure that the terms are used consistently. It was also mentioned that the last paragraph before the acknowledgements on the timing of updating assessments should be revised or a new rationale should be discussed.

Appendix equations (iSCAM code) clarification: The authors showed equations and confirmed that the iSCAM variable “phib” in the code was “phiE”, as in the documentation. The authors noted that the model was correct, and the documentation/manual will be corrected.

Prior to the meeting, the authors reviewed the code based on a reviewer's comment about poor age composition fits. Additional corrections to the code, and the resulting plots and tables, were provided to participants. The authors provided an explanation of code changes and answered participant questions about corrections to age composition fits, proportion of females within the model, and male/female maturity curves in the selectivity plots. The authors also agreed to review whether spawners had been included in B_0 in equation G.26. Additional analyses were requested by participants and provided by the authors on the following morning.

CONCLUSIONS

The participants accepted the paper with major revisions and a follow-up meeting was scheduled to discuss the updated working paper. The SAR was developed during the follow-up meeting using the new information. The authors agreed to update the paper based on the corrections and suggested revisions discussed at the meeting.

FOLLOW UP MEETING (DECEMBER 5, 2022)

OVERVIEW

On December 5, 2022, an virtual meeting was held to review the major revisions completed by the authors and to prepare summary bullets for the Science Advisory Report (see Appendix D: Agenda for the follow-up meeting). The revised Arrowtooth Flounder working paper, a revisions table, and agenda were distributed in advance of the meeting. The authors noted that they had addressed the major revisions and agreed to complete the minor revisions before submitting the final version for publication as a Research Document. The meeting began with an overview of the previous meeting, a review of the Policy on the Principle of Consensus (CSAS 2010), and the purpose of the Science Advisory Report. These proceedings summarize the discussions that took place by topic, including points of clarification by the authors; questions and comments raised by attendees are captured within the appropriate topics.

GENERAL DISCUSSION

The authors went over the revisions requested by the group: (1) additional figures (catch data and length-at-age for commercial samples); (2) sensitivity runs; (3) additional calculations (i.e., dynamic B_0, reference removal rate); (4) stock projections out to four years for management; and (5) additional references about USRs. The authors and RPR participants discussed the revised results.

Additional figures: The authors presented additional figures on catch data and length-at-age for commercial samples to the group. The figure for predicted catch showed a good fit to the data and will be included in the Research Document.

Sensitivity runs: The new sensitivity models were run using 10 million MCMC samples to generate four years of projections and the decision table. In some of the runs, the plots showed high uncertainty, and the tail of the projection showed a large increase in relative spawning biomass at the end which did not make sense. For the relative spawning biomass, the removal of the discard CPUE did not have much effect on the model results. Additional sensitivity runs were completed, and it was found that most runs did not show any meaningful change compared to the base model results, except for one run based on the assumption of higher recruitment variance. The run with greater assumed recruitment variance placed the stock closer to the LRP. The authors noted they could not rule out this sensitivity run as implausible.

Maturity ogives: Alternative maturity ogive fits were shown with the removal of maturing, resting, and developing stage codes. These three codes were shown individually in new figures. There was a good fit to the proportion mature-at-age data when the developing and resting codes were plotted together and when the maturity ogive for only females was plotted on its own.A participant commented that it would be beneficial to collect biological samples in the winter when the fish are spawning. The current maturity estimates may be biased, and authors have agreed to add a recommendation in the future work section to collect samples in the winter.

Reference points: The provisional DFO LRP of $0.4B_{MSY}$ and USR of $0.8B_{MSY}$ in the PA policy were not used in this assessment. Estimated F_{MSY} was found to be unrealistic and the calculated U_{MSY} values were close to the upper limit of 1, suggesting that all vulnerable fish could be harvested without repercussions to the stock.

Alternative sets of reference points were reviewed for this assessment, and the use of B_0 was recommended. For the last Arrowtooth Flounder assessment, the LRP was chosen to be $0.2B_0$ and the USR was $0.4B_0$. The authors suggested maintaining these same reference points. Four years of projections were calculated and presented in the decision table including projections of an additional reference point of $0.35B_0$. The results from the 2021 assessment determined that, based on the proposed USR of $0.4B_0$, the stock is in the Cautious zone based on the PA policy.

B_0 USR: The reference points for B_0 were reviewed and compared across several jurisdictions. It was noted that values near $0.4B_0$ are both frequently a target and a control point below which fishing mortality should be decreased. In Australia, Maximum Economic Yield (MEY) is used with an assumed value of $0.48B_0$ below which the value of F is ramped down whereas in the United States of America (USA), $0.4B_0$ is used for groundfish as the operational control point (OCP) where the value for F is ramped down.

A participant mentioned that New Zealand was not reviewed and presented by the authors. The authors pointed out that 20% B_0 in New Zealand is approximately equivalent to the LRP in Canada and there is no direct equivalent to the USR in New Zealand, which is why they did not include it in their international review. Another participant noted that MEY and MSY are not the same and this point was acknowledged by the authors. The authors questioned whether it is consistent with the precautionary approach (PA) to lower reference points in times of low recruitment and when spawning biomass is in decline and approaching a reference point. The authors cautioned about the possibility of shifting baselines. They mentioned that based on the PA policy and recent national guidance, alternative reference points, including those based on B_0, can be used and it is not ideal for reference points to change from assessment to assessment.

Dynamic B_0: A dynamic B_0 was calculated in R using the mean parameter values and expanded to include the two-fleet, two-sex catch-at-age model. The fishing mortality was set to zero and all mean parameter estimates were included. The time series for this dynamic B_0 was presented. The authors agreed that it would be included in the Research Document.

Reference removal rate: The reference removal rate was calculated to be 4.406 kilotonnes/year (kt), or 10.5% of the vulnerable population. This rate was found by projecting the stock over a 50-year time period to find the catch that would place the stock at $0.4B_0$. Several assumptions were made for this calculation such as that low average recruitment will continue and that natural mortality, growth, and maturity-at-age will all remain the same. The removal of catch in 1 kt increments was provided in the decision table.

SS3: The authors noted they completed additional testing by recreating the model in Stock Synthesis 3 (SS3) to confirm that the results were in agreement. There are some fundamental differences between the two models including treatment of B_0, bias correction on recruitment deviations, spawning stock biomass being for females only, and the treatment of split-sex selectivity curves. Reviewing the results from both assessment models, it was found that fishing mortality, recruitment dynamics, and dynamic B_0 were comparable. The status in the last year (2022) for B/B_0 and the future projections also showed similar trends.

DEVELOPMENT OF THE SCIENCE ADVISORY REPORT (SAR)

Participants were provided with a draft Science Advisory Report (SAR) that was prepared beforehand, and they had an opportunity to review it during the morning break. One of the authors tracked the changes on the draft SAR while it was being discussed with participants during the meeting.

Stock status: It was assumed that Arrowtooth Flounder comprised a single stock along the coast of BC. All areas of the coast were included in this assessment except for Area 4B (lying between Vancouver Island and the BC mainland). The stock status for Arrowtooth Flounder was determined to be in the Cautious zone relative to the proposed USR of $0.4B_0$ ($P(B_{2022} < 0.4B_0) = 0.66$).

Structural uncertainty: Nine different types of sensitivity runs to explore structural uncertainty were completed, and most runs did not differ greatly from the base model results. The authors agreed to highlight the broad sensitivity results, highlight any runs that were notably different from the main run, and to note the relative plausibility of the runs, where possible.

Stock trends and assessment frequency: Currently, the stock is estimated to be below $0.4B_0$ and has declining survey indices, declining estimated spawning biomass, and low estimated recruitment. It is suggested that another assessment be completed in two years when the entire coast of BC has been surveyed again (i.e., there will be four new data points for inclusion in the model).

B_0: The estimate of B_0 is dependent on the unfished recruitment and the spawning biomass per recruit. The model began from a non-equilibrium state in 1996 as described by the iSCAM process equations with estimated initial numbers at age and an initial recruitment deviation. Alternative assumptions and approaches for calculating B_0 are also plausible but were not considered in this assessment although a comparison to SS3 was presented.

QCS survey: The model did not fit the QCS survey index as well as it did for the other surveys. There appeared to be smaller and/or younger fish observed in the QCS survey compared with the other surveys.

Stock-recruitment curve: This stock has poor recruitment, which could potentially be due to environmental variables and/or stock sizes. The relationship between maturity and fishery selectivity curves affects vulnerable biomass and is a source of uncertainty.

Figures and tables: A participant asked if the catch versus relative spawning biomass figures for each projected year could be added to the SAR as a panel figure instead as four individual figures. The attendees agreed on the following figures:

- commercial catch by fleet;
- selectivity curves by sex for the base model;
- relative spawning biomass for the base model with projections and reference points into the future; recruitment from the base model;
- the decision table; and

- reference rate figures in the SAR.

A trace plot (i.e., a phase or Kobe plot) could also be included in the SAR to see how stock status relative to fishing mortality was tracked over time. This figure could be added to the SAR to assist GMU with determining the harvest rates using the B_0 reference points. The authors agreed to generate one if time permitted.

FUTURE RESEARCH

Biological data: It was recommended that the commercial fisheries and the synoptic surveys collect biological data including maturity, age, and fish lengths to reduce the data gap for age structure. A participant suggested that data should also be collected during the winter when the fish are spawning. More ship time would be required to collect data in the winter to resolve this data gap.

iSCAM model: A participant asked if the authors will continue to use the iSCAM platform in future. The authors noted they may consider other modelling platforms for future assessments, including SS3, the Woods Hole Assessment Model (WHAM), or the new in-development model at NOAA, Fisheries Integrated Modeling System (FIMS). A participant noted the importance of a debugging protocol in whichever model platform was chosen.

Closed-loop simulation: It was recommended that a closed-loop simulation model approach (MP Framework) or Management Strategy Evaluation (MSE) be used to capture the uncertainties in the system as well as environmental variables related to climate change.

Sensitivities: It was recommended to have a more detailed review of recruitment variance and initial biomass assumptions in the next stock assessment.

Dynamic B_0: It was recommended that the inclusion of dynamic B_0 be considered in future assessments.

CONCLUSIONS

Meeting participants agreed that the working paper had satisfied all Terms of Reference objectives and was accepted. The draft SAR was discussed, and participants could contribute and revise key sections. At the close of the follow-up meeting, a revised draft SAR was produced. The meeting Chair will work with the authors to finalize the draft SAR. Once complete, the Centre for Science Advice Pacific (CSAP) office will circulate the draft SAR and draft proceedings to all participants for final review and input.

ACKNOWLEDGEMENTS

The Centre for Science Advice Pacific (CSAP) congratulates the authors on a successful paper and appreciates the contributions from all participants. We thank the formal reviewers, Mackenzie Mazur (DFO Science) and James (Jim) Ianelli (NOAA) for providing their time and expertise to formally review the working paper. We would also like to thank Shannon Obradovich as Chair of the meeting.

REFERENCES CITED

CSAS. 2010. Policy on the Principle of Consensus.

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

Sainsbury, K. 2008. Best Practice Reference Points for Australian Fisheries. Australian Fisheries Management Authority Report R2001/0999.

APPENDIX A: TERMS OF REFERENCE

Arrowtooth Flounder (*Atheresthes stomias*) Stock Assessment for British Columbia in 2021

Regional Peer Review – Pacific Region

October 19–20, 2022
Virtual Meeting

Chairperson: Shannon Obradovich

Context

Arrowtooth Flounder (*Atheresthes stomias*) is a significant species within the groundfish trawl fishery. Arrowtooth Flounder are also a minor component of the groundfish hook and line fisheries. The last stock assessment of Arrowtooth Flounder was conducted in 2015 (Grandin and Forrest 2017) with an age-structured assessment model. Since 2006, the fishery has been subject to coastwide Total Allowable Catches (TACs) of 15,000 - 18,000 mt for the Groundfish Trawl fishery with a reduction to 5,000 mt in 2020 and a closure of key fishing grounds. This reduction in TAC was in response to a declining trend in the Hecate Strait and West Coast Vancouver Island Synoptic bottom trawl surveys since the last assessment. The survey index declines also triggered the need for a new assessment.

Updated stock status and harvest advice would assist in determining whether current harvest levels are sustainable and compliant with the Sustainable Fisheries Framework (SFF). The SFF policy, *A Fishery Decision-making Framework Incorporating the Precautionary Approach* (PA Framework; DFO 2009), outlines the methods for applying the Precautionary Approach (PA) in the management of Canadian fisheries. Application of the PA usually implies estimation of fishery reference points and evaluation of current stock status relative to those reference points. Estimation of these quantities requires development of quantitative models conditioned on available fishery, survey, and biological data.

Since 1996, 100% observer coverage in the commercial groundfish trawl fishery has provided reliable reporting of catch and discards for the largest source of fishery mortality. Prior to 1996, however, landings of Arrowtooth Flounder were unreliable and characterised by high proportions of discards due to low market demand, low value, and the known rapid deterioration of product due to the presence of the same parasites prevalent in Pacific Hake (*Merluccius productus*). In many cases, the entire Arrowtooth Flounder catch in a trawl tow would be discarded, and the discards not properly recorded in fishing logbooks. As a result of this inconsistent record keeping, trends in catch statistics prior to 1996 are unreliable and it is impossible to reconstruct historical catches prior to 1996. A model-based approach to the assessment of stock status, conditioned on estimates of historical catches before 1996 is therefore unlikely to be successful and has been dropped as a possible approach to the stock assessment of this species. An alternative approach, which initiates the model from a non-equilibrium starting point and which is based on reliable catch and discard time series beginning in 1996, will be used, as was used in the 2015 assessment.

Fisheries and Oceans Canada (DFO) Fisheries Management Branch has requested DFO Science Branch provide advice regarding the coastwide 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 assessment, and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR), will be used to inform fisheries managers on stock status and to provide harvest management advice.

Objectives

Guided by the DFO Sustainable Fisheries Framework, meeting participants will review the following working paper to provide the basis for discussion and advice on the specific objectives outlined below.

Grandin, C., and Anderson, S.C. Assessment of Arrowtooth Flounder (*Atheresthes stomias*) for British Columbia in 2021. CSAP Working Paper 2019GRF03.

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 reference points will include the reference removal rate (F_{MSY}), the limit reference point (LRP) and the upper stock reference (USR).
2. Assess the current status of coastwide Arrowtooth Flounder in BC waters relative to the reference points.
3. Using probabilistic decision tables, evaluate the consequences of a range of harvest policies on projected biomass relative to the reference points.
4. Describe sources of uncertainty related to the model (e.g., model parameter estimates, assumptions regarding catch, productivity, carrying capacity, and population status).
5. Provide information on environmental conditions that may impact the stock, including climate change impacts if possible.
6. Recommend an appropriate interval between formal stock assessments, indicators used to characterize stock status in the intervening years, and/or triggers of an earlier than scheduled assessment (DFO 2016). Provide a rationale if indicators and triggers cannot be identified.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Fisheries and Oceans Canada (Science and Fisheries Management sectors)
- Province of British Columbia
- Indigenous communities/organizations
- Fishing Industry
- Environmental Non-Government Organizations

References

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

DFO. 2016. Guidelines for providing interim-year updates and science advice for multi-year assessments. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/020.

Grandin, C., Forrest, R. 2017. Arrowtooth Flounder (*Atheresthes stomias*) Stock Assessment for the West Coast of British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/025. v + 87 p.

APPENDIX B: ABSTRACT OF WORKING PAPER

Arrowtooth Flounder (*Atheresthes stomias*, Turbot) are an important component of the bottom trawl fishery in British Columbia. They are managed as a coastwide stock, with a current TAC of 5,000 t and catch of 3,051 t in 2021. Prior to the introduction of freezer trawlers in the mid-2000s, most of the historical catch of Arrowtooth Flounder is understood to have been discarded at sea. This was largely due to proteolysis, which occurs in the muscle tissue of this species a short time after it is caught, making the flesh unpalatable. In the past decade, markets have been established for fillets that have been frozen at sea, and the freezer trawl fleet has taken an increasing proportion of the coastwide catch.

This assessment fits a two-sex two-fleet Bayesian age-structured model to catch, survey, and age-composition data from the years 1996–2021 for management areas 3CD (West Coast Vancouver Island), 5AB (Queen Charlotte Sound), 5CD (Hecate Strait), and 5E (West Coast Haida Gwaii) combined. Catch data prior to the introduction of at-sea observers in 1996 were considered too unreliable for inclusion in the assessment due to unknown quantities of discarding at sea.

The base model presented in this assessment estimates the 2022 median spawning biomass to be 59,493 tonnes and to have been on a decreasing trajectory since approximately 2012. Reference points based on maximum sustainable yield (MSY) were strongly impacted by estimates of selectivity in the trawl fisheries. Reference points based on fractions of B_0 (unfished spawning biomass) were chosen instead, as was done in the last assessment. The median 2022 spawning biomass was projected to be below the USR (Upper Stock Reference) $0.4B_0$ and above the LRP (Limit Reference Point) $0.2B_0$. There was a 0.15 probability the spawning biomass was below the LRP $0.2B_0$ in 2022. Sensitivity analyses were done to test the effects of fixed parameters, prior probability distributions, and input data treatment on model outcomes. In several sensitivity models, there were poor MCMC (Markov chain Monte Carlo) diagnostics or unreasonable estimates of selectivity and/or catchability. A series of retrospective model runs back eight years indicated a distinct breakpoint when 2019 data onwards were added. Since 2019, the data cause declines in estimated spawning biomass over the last decade.

Management advice is provided in the form of decision tables that forecast the impacts of a range of 2022 catch levels on Arrowtooth Flounder stock status relative to these reference points. The base-model decision table suggests that a 2022 catch equal to 4,000 t (1,000 t less than the 2022 TAC), would result in a 2023 biomass being below the USR of $0.4B_0$ with a probability >0.99. The same catch would give a ∼0.15 probability (about 3 times out of 20) of the 2023 biomass falling below the LRP of $0.2B_0$. A 2022 catch equal to 6,000 t would result in a 2023 biomass with a ∼0.22 probability (about 1 time out of 5) of being below the $0.2B_0$ LRP.

The magnitude of catch and discards prior to 1996 as well as a lack of earlier fisheries independent surveys is a major source of uncertainty in this assessment that makes it challenging to assess the scale and productivity of the stock. The use of a stitched geostatistical survey to replace the separate synoptic survey indices could help resolve some issues fitting the Queen Charlotte Sound Synoptic survey index, which has a lower rate of decline than the other survey indices. After evaluating ecosystem considerations and known biology of the stock, there are no clear indications that current environmental conditions should modify the catch advice in this assessment. Given the proximity of spawning biomass to the LRP under the base model and most sensitivity analyses, as well as the declining survey indices, it is suggested that this stock assessment be updated with new data in approximately two years when one additional survey has been run in each area of the coast.

APPENDIX C: WORKING PAPER REVIEWS

Date: October 11, 2022

Reviewer: Mackenzie Mazur

Working Paper Title: Arrowtooth Flounder (*Atheresthes stomias*) Stock Assessment for BC in 2021

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

The purpose of the working paper is clearly stated in section 1.1 Purpose of Document.

Are the data and methods adequate to support the conclusions?

Data and methods are adequate to support the conclusions, and the Arrowtooth Flounder stock assessment report is thorough and sound. The authors put a lot of work into this assessment. The model and assumptions seems appropriate for the data available and the biology of the species.

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

Some parts of the data and methods are explained in great detail, such as the fishery data history. The appendices are excellent at providing the details to understand the stock assessment model. There are detailed explanations and visualizations of the bridge models as well. I appreciate the many different visualizations of the retrospective patterns. However clarification on other parts of the data and methods would be helpful:

Stock structure

Clarification on the stock structure/boundaries would be helpful. Why is the Strait of Georgia not included in the stock assessment? The paper states that stock structure is poorly understand and then explains the approaches that allow for better understanding of stock structure. However, has any genetic, morphological, or life history parameter study been done to understand Arrowtooth Flounder stock structure? Do we have an understanding of spatial variability of the stock? I feel this is important to elaborate on since complex stock structures have large variation.

Data

Clarification on the data used would be helpful. Were data extracted using the gfdata or gfplot package or both? How were outliers dealt within the CPUE data (commercial and survey)?

Questions specific to fishery data:

It seems that the hook and line fishery data were not included. I am assuming this is because it makes up a small amount of the catch, but it would be great if that could be elaborated on in the text. Also, why are there discards in the freezer trawler fleet? Isn't this fleet targeting Arrowtooth Flounder? Have spatial closures taken place in response to halibut bycatch? In the length data figures, why are commercial lengths aggregated and not separated by sex?

Questions specific to survey data:

What are the depth strata for the West Coast Haida Gwaii Synoptic Survey? Are ages from the surveys randomly sampled? Do the surveys capture different size/age compositions? Do the surveys cover all of the fishing grounds? Additional clarification on key Arrowtooth Flounder fishing grounds would be beneficial. How is it known where the key Arrowtooth Flounder fishing grounds are? Is this knowledge from the literature or personal communication?

CPUE

The arithmetic mean seems to be used for survey abundance indices and the geometric mean seems to be used for the discard CPUE. Why not use the geometric mean for calculating survey abundance indices? More discussion on this would be helpful.

Also, the authors state they did not use a standardized commercial CPUE index, because there is a bias towards high CPUE in the fishery. However, if the bias is consistent, there should not be an issue with using the index in the stock assessment. Is hyperstability what may be occurring? If so, I recommended stating that clearly in the paper.

Parameters

How come only survey data are used to estimate biological parameters?

The paper states that only steepness was sensitive to prior probability distributions, but then it states that catchability was sensitive to priors.

Projections

Some clarification on the projections would be beneficial. Why is 2021 recruitment projected if it is estimated as well? How were the catch increments decided? How was uncertainty incorporated? How was the normal distribution of log recruitment anomalies for projections decided? Recruitment seems to be declining overtime (Fig. 9). Perhaps the recruitment distribution drawn from in the projections should be recruitment from only recent years.

Sensitivity analyses

In sensitivity analysis 4, the SD increases in the second scenario, although it states that the SD is decreasing. In sensitivity analysis 9, the mean increased, although it states that the mean is decreased.

There is a sensitivity analysis with time-varying selectivity for the Queen Charlotte Sound Synoptic survey. What evidence is there that the selectivity of the survey changed overtime? The poor selectivity fit can also be due to other factors such as time-varying catchability. Environmental conditions may have resulted in a change in catchability for the Queen Charlotte Sound Synoptic Survey. Can time-varying catchability be evaluated with ISCAM? Since it was mentioned in the paper but not discussed, does the age/size composition of the Queen Charlotte Sound Synoptic Survey suggest that the Queen Charlotte Sound represents a nursery ground?

Terminology

The term ‘absolute’ may refer to a true value that is not estimated. I do not think that is what ‘absolute biomass’ is in this document. What about using just ‘biomass’?

Using ‘vulnerability’ and ‘selectivity’ interchangeably is a bit confusing. Perhaps use one term throughout the document?

Industry advisors

Who were the industry advisors?

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?

Recommendations are provided in a useable form as decision tables, and uncertainty is reflected. However, I suggest quantifying the uncertainty in retrospective patterns. Mohn’s Rho values for retrospective patterns would help quantify the degree of retrospective bias. Retrospective patterns are an expression of model instability, so it’s important that they are quantified. Mohn’s rho (Mohn, 1999) is used to measure the magnitude of retrospective patterns, and a value higher than 0.2 or lower than -0.15 indicates considerable retrospective patterns for long-lived species (Hurtado-Ferro et al., 2015).

Additionally, the paper mentions that the LRR could be FMSY, but then states that FMSY is unrealistically high. Is there an alternative LRR then?

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

The authors suggest areas of research throughout the text which I agree with. Additional areas of research that would improve our assessment abilities for Arrowtooth Flounder would be stock mixing between US and Canadian stocks and thermal tolerance of Arrowtooth Flounder.

Date: Oct 12, 2022

Reviewer: James Ianelli

Working Paper Title: Arrowtooth Flounder (ATF, *Atheresthes stomias*) Stock Assessment for BC in 2021

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 reference points will include the reference removal rate (FMSY), the limit reference point (LRP) and the upper stock reference (USR).*
2. *Assess the current status of coastwide Arrowtooth Flounder in BC waters relative to the reference points.*
3. *Using probabilistic decision tables, evaluate the consequences of a range of harvest policies on projected biomass relative to the reference points.*
4. *Describe sources of uncertainty related to the model (e.g., model parameter estimates, assumptions regarding catch, productivity, carrying capacity, and population status).*
5. *Provide information on environmental conditions that may impact the stock, including climate change impacts if possible.*
6. *Recommend an appropriate interval between formal stock assessments, indicators used to characterize stock status in the intervening years, and/or triggers of an earlier than scheduled assessment (DFO 2016). Provide a rationale if indicators and triggers cannot be identified.*

Consequently, this review is structured around reading/commenting on main document, then addressing these objectives in the conclusion.

ASSESSMENT OVERVIEW

Organization-wise, I found this document exceptionally well written and put together. The elements appear to all be in order, and issues related to data availability and assessment uncertainty are well noted and handled. The software package is well tested and elegant, and easily accessible on github for testing and evaluating. I agree that the switch to split-sex, 2 fisheries is appropriate and that this is a better representation of the biological conditions of the stock in this region. The application of gfdata repository is admirable and the abiity to access data in a transparent reproducible way is great.

The results fall flat in my opinion. The analysts write that the fit to the age composition are reasonable but they are extremely poor and unacceptable (e.g., Figs 13-23). The boxplot residuals hide the horrible patterns (I don't buy that balancing over the time series is appropriate). **The worry here is that the DM fitting is simply ignoring the age composition data.** I couldn't find what the effective sample size was with the converged estimate from the Dirichlet multinomial specification. This is important because the selectivity estimates will be impacted. The selectivities should also be considered separately by sex, and allow for dome-shapedness and some time-varying selectivity (within reason). These all interact with the problem of F_{MSY} estimates etc (which the analysts note, but mainly just point to asymptotic selectivity being much greater than maturity).

Regarding selectivities for the indices, there shouldn't be too many males older than age 10 given M ~ 0.35 so I worry that there's an interaction among the indices and "qS_a" terms that is interacting in odd ways with the actual sex ratio data. This raises a concern. Normally, the processes affecting the sex ratio would be in the model and this doesn't seem to be the case. Perhaps it is an efficiency to do the estimation and assume it's fixed (0.79 females) but this is a bit unusual. For data that are available, it'd seem preferable to fit sex and age combined as part of the composition data (DM or multinomial).

Conversely, the index data are clearly over-fit, especially the discard CPUE. Incidentally, it would have been nice to actually plot the posterior-predictive distributions in Figure 11 since all the pieces are already there.

From a technical standpoint, the MCMC methods should be replaced with the adnuts R package. This provides robustness in bounded parameters and is MUCH faster and more efficient at providing diagnostics.

Despite recommendations from technical and industry advisors, I would like to have a summary of what the ballpark of removals were prior to 1996. Sure, the catch estimates will be inaccurate, but since it's a noted source of uncertainty, and DOES affect interpretation of B_0 having some idea is important. What would F have to be to go from B_0 to 48% of that value by 1996? Does that "F" make sense as a bycatch species? So how much has effort changed before and after 1996 for groundfish targets? A consideration of actual effort could help, especially since it's being used in one of the indices (CPUE for discards).

I have a number of concerns with the reference point calculations. Generally, I'm opposed to imagining there's enough contrast and information to estimate stock-recruit relationship and hence stock productivity. This is a data set that spans slightly more than half of my career in fisheries (first job, 1977!) and is relatively long-lived and probably isn't a full unit-stock (US N and S boundary spillover/exchange). In the assessment they report B_{MSY} but use a proxy for LRP and "USR" for decision table purposes. I have no issue with 0.4 and 0.2 for those values, but disagree that in this case, B_0 should be treated as a reliable reference point. An alternative would be to evaluate the relative impact that fishing has had on the stock (even if it's just since 1996). That is, as one step replay the assessment forward with the recruitment estimates BUT without any fishing mortality. This would show what the impact of fishing has been on the stock and provide a somewhat more empirical dynamic B_0 reference point. This of course assuming one wishes to focus on managing the ATF stock (as opposed to other issues related to shore-based fisheries).

Regarding the risk table, the statements are too strong and misguided in my opinion. The reference to some fractions of B_0 and probabilities from a management perspective might better be stated as something actually estimated to have occurred. For example, given a catch projection, what is the probability that the catch rate will be below the lowest observed and separately, above the highest observed (where "observed" might be the discard CPUE predictions?). The B_0 reference points are very highly confounded with estimates of steepness, and if a strong year-class arrives then the estimate (by definition) will drop precipitously (as steepness will increase given "low" SSB). It's simply not a robust approach to reference point management.

I think DFO / (the authors?) reconsider using the term "freezer trawlers" as the name for one of the fleets. Especially since the "shoreside" fleet is also using trawl gear (not to mention, this name to me invokes warmth, like "fireside"). In the modern day of pronouns, and for the sake of plain scientific differentiation, it seems a descriptive and unbiased naming convention could be adopted. "Trawlers delivering to shore-based processors" and "trawlers processing at-sea". Or shore-based and at-sea? Or maybe there's a simpler categorization. I know it sounds petty, but it does read (to me) as good (shoreside) vs evil (freezer trawler) and the writeup reflects this in numerous places. Where and how fish are caught is a policy decision and reflecting this in a scientific stock assessment document should be discouraged. For example, the two paragraphs starting on line 185 do not belong in this document as they have no specific consequence on management implications relevant to the assessment.

Furthermore, the paragraphs starting on line 212 read like it was a mistake that a fishery developed that avoided discarding and found a way to process and market ATF. I do worry that there seems to be an adversarial flavor to the different fleets identified in the assessment. It doesn't belong.

Minor edits

Line 539 "..jurisdictions"

REVIEW OBJECTIVES

1. *Recommend reference points consistent with the DFO Precautionary Approach (PA), including the biological considerations and rationale used to make such a determination. These reference points will include the reference removal rate (FMSY), the limit reference point (LRP) and the upper stock reference (USR).*

I disagree with the choice here and think there are better alternatives. That said, it is *very* conservative.

2. *Assess the current status of coastwide Arrowtooth Flounder in BC waters relative to the reference points.*

The stock is well above B_{MSY} estimates, but below .4 B_0

3. *Using probabilistic decision tables, evaluate the consequences of a range of harvest policies on projected biomass relative to the reference points.*

See comments above on decision table, I think the consequences should be re-evaluated based on past estimates of biomass/CPUEs

4. *Describe sources of uncertainty related to the model (e.g., model parameter estimates, assumptions regarding catch, productivity, carrying capacity, and population status).*

As noted by analysts, pre 1996 catches are ignored. This affects the fact that there's rationale to say the stock in 1996 was less than 50% of "unfished" when prior to that time ATF were only discarded and not targeted.

5. *Provide information on environmental conditions that may impact the stock, including climate change impacts if possible.*

Agree with the authors conclusion that at this time no action need be taken relative to climate change effects.

6. *Recommend an appropriate interval between formal stock assessments, indicators used to characterize stock status in the intervening years, and/or triggers of an earlier than scheduled assessment (DFO 2016). Provide a rationale if indicators and triggers cannot be identified.*

Also agree with authors to conduct one in a few years when new survey data become available and refinements to model can be made.

APPENDIX D: AGENDA

DAY 1 – Wednesday, October 19, 2022

Time	Subject	Presenter
0900	Introductions/Overview of virtual platform Review Agenda CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Authors
1030	***Break***	
1045	Presentation of Working Paper cont'd	Authors
1115	Overview Written Reviews	Chair + Reviewers & Authors
1200	***Lunch Break***	
1300	Identification of Key Issues for Group Discussion	RPR Participants
1330	Discussion & Resolution of Technical Issues	RPR Participants
1430	***Break***	
1445	Discussion & Resolution of Results & Conclusions	RPR Participants
1530	Develop Consensus on Paper Acceptability & Agreed-upon Revisions (TOR objectives)	RPR Participants
1600	Adjourn for the Day	

DAY 2 – Thursday, October 20, 2022

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1 (*As Necessary*)	Chair
0915	Carry forward outstanding issues from Day 1	RPR Participants
1030	***Break***	

Time	Subject	Presenter
1045	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Summary bullets • Sources of Uncertainty • Results & Conclusions • Figures/Tables • Additional advice to Management (as warranted)	RPR Participants
1200	***Lunch Break***	
1300	*Science Advisory Report (SAR) cont'd*	RPR Participants
1430	***Break***	
1445	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair
1500	Other Business arising from the review	Chair & Participants
1600	***Adjourn meeting***	

DECEMBER 5, 2022 – PART 2

DAY 1 – Monday, December 5

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review and revisions of working paper Discussion of Revisions	Authors RPR Participants
1030	***Break***	
1045	Con't Discussions of Revisions	
1130	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Summary bullets • Sources of Uncertainty • Results & Conclusions • Figures/Tables	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	RPR Participants
1600	***Adjourn meeting***	

APPENDIX E: PARTICIPANT LIST

INITIAL MEETING OCTOBER 19–20, 2022

Last Name	First Name	Affiliation
Anderson	Erika	DFO Centre for Science Advice Pacific
Anderson	Sean	DFO Science
Christensen	Lisa	DFO Centre for Science Advice Pacific
English	Philina	DFO Science
Finn	Deirdre	DFO Fisheries Management
Grandin	Chris	DFO Science
Haggarty	Dana	DFO Science
Ianelli	James (Jim)	National Oceanic and Atmospheric Administration
Kronlund	Rob	Interface Fisheries Consulting
Mann	Shannon	Mariner Seafoods
Mason	Gwyn	DFO Fisheries Management
Mazur	Mackenzie	DFO Science
Mose	Brian	Commercial Industry Caucus – Trawl
Muirhead-Vert	Yvonne	DFO Centre for Science Advice Pacific
Obradovich	Shannon	DFO Science
Starr	Paul	Canadian Groundfish Research and Conservation Society
Tadey	Rob	DFO Fisheries Management
Turris	Bruce	Canadian Groundfish Research and Conservation Society
Haigh	Rowan	DFO Science
Olsen	Norm	DFO Science
Nielsen	Erika	DFO Science

FOLLOW UP MEETING DECEMBER 5, 2022

Last Name	First Name	Affiliation
Anderson	Erika	DFO Centre for Science Advice Pacific
Anderson	Sean	DFO Science
English	Philina	DFO Science
Finn	Deirdre	DFO Fisheries Management
Grandin	Chris	DFO Science
Haggarty	Dana	DFO Science
Haigh	Rowan	DFO Science
Kronlund	Rob	Interface Fisheries Consulting
Mann	Shannon	Mariner Seafoods
Mason	Gwyn	DFO Fisheries Management
Mazur	Mackenzie	DFO Science
Mose	Brian	Commercial Industry Caucus – Trawl
Muirhead-Vert	Yvonne	DFO Centre for Science Advice Pacific
Obradovich	Shannon	DFO Science
Sporer	Chris	Pacific Halibut Management Association
Starr	Paul	Canadian Groundfish Research and Conservation Society
Tadey	Rob	DFO Fisheries Management
Turris	Bruce	Canadian Groundfish Research and Conservation Society