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Proceedings of the Pacific regional peer review on the assessment of British Columbia Pacific Cod for Areas 3CD and 5ABCD in 2018

October 10-11, 2018
Nanaimo, British Columbia

Chairperson: Greg Workman
Editor: Linnea Flostrand

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Foreword

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

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SUMMARY

These proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting of October 10-11, 2018 at the Pacific Biological Station in Nanaimo, British Columbia (BC). Science advice was based on objectives identified in a Terms of Reference developed and circulated prior to the meeting along with the meeting agenda. In-person and web-based participation included Fisheries and Oceans Canada (DFO) Science and Fisheries Management Sectors staff; and external participants from the International Pacific Halibut Association, BC commercial fishing industry, Canadian Groundfish and Research Conservation Society, and First Nations.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) providing advice to Management. 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 October 10-11, 2018 at the Pacific Biological Station in Nanaimo to review the stock status of Pacific Cod.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Fisheries Management. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from First Nations, commercial fishing sectors and non-government organizations.

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

Forrest, R., Grandin C., Anderson, S., and Starr, P. 2018. Assessment of Pacific Cod (*Gadus macrocephalus*) for Hecate Strait and Queen Charlotte Sound (Area 5ABCD), and West Coast Vancouver Island (Area 3CD) in 2018. CSAP Working Paper 2014GRF06.

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.

The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting, highlighting the meeting objectives. 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, 23 people participated in the RPR (Appendix D). Linnea Flostrand was identified as the Rapporteur for the meeting. Participants were informed that Daniel Ricard (DFO Science) and Ian Stewart (International Pacific Halibut Commission) had been asked before the meeting to provide written reviews for the working paper to assist everyone attending the peer-review meeting. Participants were provided copies of the written reviews prior to 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 inform fishery planning for the above-noted stocks. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

REVIEW

Working Paper: Forrest, R., Grandin C., Anderson, S., and Starr, P. 2018. Assessment of Pacific Cod (*Gadus macrocephalus*) for Hecate Strait and Queen Charlotte Sound (Area 5ABCD), and West Coast Vancouver Island (Area 3CD) in 2018. CSAP Working Paper 2014GRF06.

Rapporteur: Linnea Flostrand

Presenters: Robyn Forrest, Sean Anderson, Chris Grandin

PRESENTATION OF WORKING PAPER

A summary of the methods and findings reported in the WP was presented by the authors. Topics included in their presentations are briefly summarized below:

Applied data sets, observations and relationships pertaining to:

- Commercial fishery catches by stock region over time
- Research surveys and survey indices representing stock area groupings 5ABCD and 3CD
- Commercial fishery CPUE (catch-per-unit-effort) indices representing stock regions
- Commercial and survey fish length and data by sex
- Ageing uncertainty, length at age and length-weight relationships. Challenges with ageing Pacific Cod were explained. Observations from otoliths and dorsal fin ray samples are difficult to discern annuli from growth checks. Otoliths observations were said to likely have more uncertainty than those from dorsal fin rays.
- To address the appropriateness of using age-2 or age-3 knife edge fishery recruitment in the assessment model, an age-length key was developed using age and length information from 2007-2011 synoptic surveys. The key was applied to length data from commercial catch samples and the results indicate a high proportion of age-2 fish in the commercial fishery.
- A CSAS review meeting is planned for Nov 22 to 23, 2018 to review data limited synopsis reporting of Groundfish species.

COMMERCIAL FISHERY CPUE INDEX STANDARDIZATION METHODS AND RESULTS

To try to account for changes in fishery behavior and fishing patterns over time effects a Tweedie GLMM (general linear multiplicative model) standardization model was used to integrate random effects of several variables (e.g. month, locality and depth) to predict average levels with more realistic and explicit estimates of uncertainty/ variance. Plots were shown to compare trends between when random effects are and are not accounted for (showing that there is considerably less variance/ uncertainty when effects are not accounted for).

BAYESIAN DELAY DIFFERENCE MODEL

Separate assessments for 5ABCD and 3CD were conducted using a Bayesian delay difference model. Each model was fitted to survey indices, commercial CPUE and mean weight data to track effects of recruitment survival and growth on biomass. Major modeling assumptions were explained related to: constant mortality at age; knife-edge selectivity at age; the use of a linear weight-age relationship; Beverton-Holt stock recruitment functions, and fixed variances for observed and process error. The choice to combine 5AB and 5CD into one assessment

grouping resulted after consultation with industry and fishery managers and was endorsed in part because of challenges associated with having an assessment for 5AB on its own. The last Pacific Cod assessment in 2013 was based only on 5CD. Authors confirmed that by using uniform distributions for depicting q, no prior information was applied and the paper should be revised to clarify that.

New information presented since drafting of working paper related to:

- Growth parameters from combining information for both sexes by stock area (estimates for female data only were reported in working paper). For 5ABCD this increased the scale of the biomass time series slightly and had negligible effect on 3CD biomass.
- Methods and results associated with 2018 fishery catch estimates (extrapolation versus based on previous years). Reference model examples for 5ABCD extrapolated 3-year average catch proportions by September 30 2018 to end of fishing year (March 30, 2019), and for 3CD an intermediate catch amount was applied based on 2017 catch. For both 5ABCD and 3CD the addition and choice of options for estimating 2018 catch had negligible effects to the 2019 projected biomass estimates.
- The application of length and age keys and commercial fishery length samples to evaluate and verify the applicability of age 2-knife edge selectivity.
- Sensitivity runs aiming to bracket the full extent of uncertainty in several model parameters were shown as per reviewer written suggestion (i.e. related to synoptic survey catchability priors).

Results associated with revising reference models to include 2-sex growth parameters and 2018 catch estimates were shown, including sensitivity runs from varying priors. Information was presented representing: MCMC diagnostics and comparisons between prior and posterior distributions; fixed standard deviation parameters; MCMC (Markov chain Monte Carlo) trace plots and autocorrelations; survey and CPUE index MPD (maximum posterior density) fits and fits to mean weight over time series. Three types of reference points were defined for each stock region: LRP (Limited reference points) defined as the lowest estimated biomass from which a stock recovered to above average biomass from), which the working paper reported as 1971 for 5ABCD and 1986 for 3CD; USR (upper stock reference) defined as the average estimated biomass across 1956-2004, and the LRR (limit removal rate) defined as the average estimated fishing mortality from 1956-2004. Trends over time of recruitment, recruitment deviations, fishing mortality and retrospective bias were also shown and explained.

Revised assessment model sensitivity runs and resulting biomass trends for 5ABCD and 3CD were presented relating to how the model is informed by: fishery CPUE information: synoptic survey q mean priors and SD (standard deviation); constant natural mortality (M) mean and SD; recruitment model steepness (h) mean and SD; mean growth parameters (female or combined sex) and age at recruitment (2y versus 3y knife edge); the fixed variance (sigma) values for observation error, recruitment and mean fish weight and removing historical mean weight data; and inflating historical catch.

As expected, varying synoptic survey catchability prior means and SD had the most effect on biomass scale for both stock areas. The assessment model for area 3CD was notably more sensitive to changing growth parameters to 2-sex from female values than 5ABCD, and was also notably more sensitive to the effect of changing knife edge recruitment between 2 to 3 years.

REFERENCE POINTS AND DECISION TABLES

Information on leading parameters, and the roles of reference points and catch decision tables was provided with the use of examples representing output from revised reference model runs and sensitivity runs. It was emphasized that although $0.2B_0$ and $0.4B_0$ are common reference points for use in decision tables for other stocks, the current assessment model is parametrized differently by treating R_0 and R_{AV} as equal, which is incomparable with assessment models that estimate R_0 associated with calculation of B_0 (e.g. Forrest et al. 2018). The current method of treating $R_0 = R_{AV}$ generates estimates of B_0 that are much lower (less precautionary) than would otherwise be calculated.

FISHERY CPUE AND SYNOPTIC SURVEY COMPARISONS

To investigate the question of whether the synoptic surveys are tracking stocks differently to trawl fishery observations, a presentation was provided the second day which showed time series comparisons of biomass estimates from biennial synoptic survey indices compared to annual fishery CPUE indices. The results show that CPUE and survey trends representing common fishing grounds are well correlated for the years when both survey and fishery indices are available.

REFERENCE TO PUBLICATION ON ALTERNATE HARVEST CONTROL RULES AND USE OF REFERENCE POINTS

Information on key findings reported in Forrest et al (2018) was presented to provide background and clarification on the relevance and differences between approaches and outcomes of that paper and the current assessments. The roles of fishery reference points as operational control points linked to harvest control rules were explained and demonstrated. The Forrest et al. (2018) paper evaluated the use and performance of different types of reference points (maximum sustainable yield, historical and B_0-based) and resulting tradeoffs between conservation and fishing outcomes using simulation feedback examples for Pacific Cod and Rock Sole stocks. As part of their findings, Forrest et al. (2018) reports that history-based and B0-based reference points scored the highest for protecting stocks from over-fishing. However, the author emphasized that B0-based estimation methods used in Forrest et al. 2018 were different to methods for the current cod stock assessments due to different representation of average and initial recruitment. This methodological discrepancy makes results related to B0 reference points in the paper incomparable to those of the Forrest et al. (2018) paper.

QUESTIONS, COMMENTS, AND POINTS OF CLARIFICATION ARISING DURING SCIENCE PRESENTATIONS

The authors appreciated the revisions suggested by the reviewers and will aim to include them in final revisions to improve background information and presentation of information.

There was an inquiry into whether and how information from catch logbook or dockside interviews were used to parse out information for CPUE random effects factors. It was specifically asked “was fisher logbook information prior to 1996 used?”. The author explained how the database was queried but wasn’t sure what the requirements were for reporting raw or rolled up observations by tow over the historical period. A database manager was invited to respond to this inquiry and explained that before logbooks became mandatory, initially port observers manually rolled up information from fisher interviews and logbooks. Logging of set information and coordinates became mandatory in 1991. Prior to 1991, the GFCatch database houses information as trip (rolled up), and each trip can represent 1 to many sets. From 1991 onwards port observers used set information in logbooks to generate rolled up reports with a

comparable data structure before 1991. From 1996 onwards the data structure in logbooks and the database were aligned to record raw set information.

It was asked if depth had been looked at separately from locality for the modern fishery commercial CPUE period. An author agreed it would be interesting to look into but had not been done because modeling is already computationally complex and depth is considered to be implied in locality effects.

Several comments were made about changes in fishery behavior over time. Concern was shown that the fishery CPUE index assumption of being proportional to abundance is questionable due to knowledge that many changes in fishery behavior occurred over time, such as some avoidance of Pacific Cod grounds in some areas and seasons, changes in trawl mesh size etc. The explanation of smaller mesh sizes in 3CD compared to 5ABCD was provided, leading to why there would be smaller fish in the catches from 3CD. It was suggested that for the approximate period of 1980-1995, domestic trawl fishery catches could have been inflated rather than under estimated as there were species limits and incentives to misreport species. Catch sampling data for historical periods do not show the same degree of smaller cod than the modern period, and is grounds for concern that smaller fish were being dumped or not included in biological samples.

PRESENTATION OF WRITTEN REVIEWS

Daniel Ricard (DFO Science) and Ian Stewart (International Pacific Halibut Commission) provided written reviews of the working paper in advance of the meeting. Both reviewers applauded the authors for an in-depth, organized well written paper. It was also acknowledged that the authors had addressed several of the reviewers' written points in their science presentation. Below is a summary of the main points made by these reviewers on the first day of the meeting.

DANIEL RICARD, DFO SCIENCE

The reviewer asked why the working paper did not address the Terms of Reference objective related to multi-year advice. An author explained that this was due to the data limited nature of the cod stocks and the lack of information to base future projections on. It was explained that the annual allowable catch for cod and other species is set by Fishery Managers in consideration of stock assessment information and catch decision tables in consultation with industry (there is no harvest control rule). Furthermore, no simulation work has been done to depict varying stock dynamics hypotheses and fishing scenarios for 3CD and 5ABCD.

The reviewer asked whether annual length or weight information is representative of within year seasonality. An author responded that special Hecate Strait surveys were undertaken on a set of Pacific Cod fishing grounds in the early 2000s over multiple seasons and information from those surveys demonstrates there were differences by season but the current assessment models relationships as annually constant.

The reviewer suggested random effects models could be applied for reader discrepancies of ageing structures. A response to this was that annuli and check patterns are highly uncertain whether multiple readers are involved or not. Furthermore, dorsal fin rays, believed to be better for ageing than otoliths, are much more labour intensive to process.

The reviewer sought more detail on the survey designs and protocols and suggested more information on the surveys be included in the paper. A brief description of the survey designs and ranges in time series was provided, such as seasonality (being between spring and fall

transitions); time of day (daylight hours); deployed vessels (DFO versus charter), and types of trawl gear.

A comment was made than unlike surveys, fishery behavior related to the CPUE index includes fishing at various times (night and day) with a diverse set of gear. Furthermore, information on fishing time of day may not have been recorded prior to 1996 to investigate time of day effect.

IAN STEWART, INTERNATIONAL PACIFIC HALIBUT COMMISSION

The reviewer explained that when there is a lack of information to scale biomass trends, the use of multiple models to try to capture the uncertainty is an acceptable approach (e.g. major influences of q and fishery CPUE index).

The reviewer commended the use of Tweedie distribution random effects modeling for the fishery CPUE index and noted that the work is worthy of publication as other analysts would benefit from learning of this approach.

The reviewer identified uncertainty in historical catches is a topic worthy of discussion.

The reviewer appreciated the additional information presented by authors investigating the rationale for using age-2 versus age-3 knife edge fishery recruitment. The reviewer commented that he was surprised at the effect that removing the historical mean weight had on the scale of the biomass time series as he had suspected that changing age-of-entry would improve fits to mean weight time series.

The reviewer reiterated concern of using q priors based on other species and promoted an approach that brackets a range of plausible extremes, such as q prior means ranging from 1 to 0.2.

The reviewer reiterated concern applying a general policy to identify years with historically low biomass for a species to choose a reference point when species are caught in multi-species fisheries. He suggests considering other information (such as fishery or biological information) related to determining if a stock was fished down to a functionally low level. An author explained that the relative higher scale of the historical lows is a robust feature and would be precautionary if the stock was in fact larger in the historical period than the modern period.

A future work suggestion to develop a geospatial model that patches individual survey indices into a larger one was provided as an alternative to fitting different survey indices.

The reviewer wondered whether historical biomass trends of notably high peaks followed by notable lows were real or artefacts of the model’s compensation of years with large catches.

He suggested the working paper be revised to also explicitly report on 2018 biomass (current status) in result summaries.

With regards to multi-year advice and future assessment schedules, he supported scheduling an assessment as soon as possible after the most recent synoptic survey information can be incorporated.

The reviewer inquired into the rationale for using the range in h priors (0.2, 0.8). An author explained it was chosen to envelope a realistic value but is hyper parameterized since the model is relatively insensitive to changes in the prior value and since MSY (Maximum Sustainable Yield) reference points are not used.

GENERAL DISCUSSION

TIME SERIES TREND INFORMATION

The topic of whether historical and modern biomass scales are comparable was discussed in terms of changes over time with trawl fishery management, trawl fishery behavior, on board observers starting in 1996, catch sampling protocols and the integration of other time series informing the assessment models. It is unknown to what degree the changes in biomass scale over time are due to the changes in fishery behavior and fishery management, versus true stock dynamics. Examples of questions that arose were: Was the historical low in 1971 really that low? Is the range in biomass for the modern period really that low?

Participants commended the authors for preparing comparisons between time series estimates of fishery CPUE and synoptic survey indices. There was agreement that these results showed well correlated trends for years when surveys occurred and that the information should be included in the research document.

Inquiries were made into whether catches in the longline fishery and halibut survey data show similar Pacific Cod trends to the assessment model indices. An author said longline fishery and halibut survey data were excluded from the assessment but they did take a look at this information and noted that there were some similar trends.

There was discussion over uncertainty with stock structure and seasonality within and between management areas, and with surrounding areas such as in waters of Alaska, Strait of Georgia and Washington state. Questions arose on the reliability of the sampling representation of the synoptic surveys since they are conducted in the summer on a biennial frequency. An author noted that information from special Hecate Strait seasonal surveys (early 2000s) suggests some abundance, spatial distribution, and age and size seasonality occurs, but the assessment doesn't account for potential variation. The potential for including observations or hypotheses on seasonality of stocks trends and genetic analyses into future assessment models was suggested as future work recommendations.

DELAY DIFFERENCE MODELS

Priors, synoptic survey catchability

There was discussion on what priors to use for modeling Pacific Cod catchability (q) in the synoptic trawl research surveys. Although concern was voiced of using q prior information related to other species, without information specific to Pacific Cod, the options to parameterize the scale of the survey estimates are limited. It was accepted that with data limited species, using information from other species is acceptable. Participants considered plausible and implausible ranges biomass scale resulting from effects of varying q prior information (mean and SD). Biomass scales resulting from having no prior on q were deemed to be implausibly high.

Sensitivity runs and model average ensemble

Parameter settings in model runs determined to have implausible results were rejected for informing the model average. There was consensus to exclude model runs which excluded the historical fishery CPUE index; runs which had no priors for synoptic survey catchability, and runs having the synoptic survey mean q values reported in the WP but with SD =1.

There was discussion over the sensitivity runs from increasing historical catches by 25 and 50%. Examples of several potential sources of error in reporting historical catch were mentioned, such as under reporting by the foreign fleet, by the domestic fleet, and potentially

over reporting in some years by the domestic fishing related to species limits. There was agreement to remove the run that increased historical catch by 50%. Concern was shown that the effect of increasing the catch by 25% may also represent unrealistically high catch levels but other participants thought it was reasonable to include since the set of runs are meant to try to bracket the range of uncertainties associated with model input.

REFERENCE POINTS

Concern was shown that the proposed history-based LRP for 5ABCD included in the working paper represents the historical period and there may be modeling uncertainty associated with inconsistencies in biomass scaling between historical and modern periods. It was explained that in 2005, the 1971 biomass was proposed and accepted as a reference point for 5CD (Hecate Strait, Sinclair and Starr 2005) at a time when there were conservation concerns with the Hecate Strait stock. The use of a historical low biomass as a LRP for 5AB and 3CD had not been previously established.

A request was made for the authors to show output relating to using $0.2B_0$ and $0.4B_0$ as candidate reference points in decision tables. For the second day of the meeting the authors presented these results which showed that the $0.2B_0$ and $0.4B_0$ values were considerably lower than estimates of the history-based LRPs reported in the working paper. Thus the interpretation of stock status with respect to $0.2B_0$ and $0.4B_0$ in terms of critical or cautious zones was much more optimistic compared to using a historical low LRP and mean biomass for 1956-2004 for an USR. For example, evaluating recent 5ABCD biomass against a 1971 history-based LRF, would suggest the stock has recently been in the critical zone for at least 10 years; whereas evaluating against $0.2B_0$ and $0.4B_0$ reference points would suggest the stock has not recently approached the cautious zone. It was pointed out that the intent of a LRP is to avoid a critical zone and management actions should be triggered prior to the stock being perceived at such low levels (such as through using harvest control rules). History-based LRPs have nominally demonstrated to be more effective than other types of candidate LRPs at protecting stocks from being fished to critical levels. It was noted that the current assessment methods of using $R_{Avg} = R_0$ confounds the estimation of B_0 from time series mean biomass estimates which prevents findings reported in Forrest et al. (2018) related to B0 LRP to be comparable with the current stock model results.

For Hecate Strait cod stocks, it was explained that after unconstrained historical fishing and high catches prior to 2000, around year 2000 there was concern that the stock levels were low and the stock was in poor condition by 2000. At this time, the fishery responded by reducing annual allowable catches (e.g. from ~1000t to 200-400t) and seasonal Pacific Cod surveys were initiated over three years in 5 cod fishing grounds to get more information on stock demographics and behavior. It was emphasized that there is a record that the stock was perceived as low and vulnerable in 2000, during a modern period when on board observers were present. Based on this, it was proposed that the biomass estimated for year 2000 be considered as a candidate LRP for Area 5ABCD.

Meeting participants did not support the view that the recent stock status of 5ABCD is below a critical level and is in serious harm based on a LRP of the 1971 historical low because the stock is perceived to have fluctuated over a relatively narrow range while fishing has occurred in that region in the last 20 years. It was suggested that year 2000 is a suitable year to be a history-based LRP and there was general agreement to incorporate year 2000 biomass as a LRP for the stock 5ABCD and include it in decision tables, and to call it “the lowest estimated biomass which is agreed to be an undesirable state to avoid.” It was also agreed that $0.2B_0$ and $0.4B_0$ be excluded as candidate reference points from decisions tables, since these were not found to be appropriately conservative.

There was agreement to keep the LRP for 3CD as the 1986 history-based low biomass, since low biomass levels pre-1996 are comparable to low biomass levels post 1996.

There was discussion about using the mean biomass of years 1956-2004 as an USR for the stock areas. It was recognized that there is uncertainty with the scale of estimates between the historical and modern assessment periods but using a mean biomass that crosses these periods has value as it includes information of the stock's upper biomass potential and a fixed time series helps prevent against ratcheting down of LRP's from using means across a changing and modern time series. There was agreement to present the USR as the mean biomass of years 1956-2004 in the catch decision tables.

There was agreement to include the estimated average fishing mortality during 1956-2004 as the limit removal rate and to include the associated metrics of this reference point in the decision tables. A suggestion was made by one of the reviewers to include Kobe plots in the assessment document to show correlated changes over time between estimated fishing rates and biomass levels.

There was general agreement that effective evaluation of reference points cannot be done without defined fishery and conservation objectives and feedback simulation modeling.

MULTI-YEAR ADVICE

Due to the high degree of stock assessment uncertainty and the data limited nature of these stocks, no specific recommendations were made on intervals between formal assessments and potential indicator triggers to expedite full assessment efforts. The following lists considerations made related to the scheduling of future Pacific Cod assessments:

- Delay difference models have no information on stock age structure to project into future years and there is no informative information for projecting beyond one year. Furthermore, the species is known to have relatively high variability in juvenile recruitment and natural mortality between years.
- Assessments for the two stock groupings (5ABCD and 3CD) could be done at different times to make use of the most recent synoptic survey information since the biennial synoptic surveys alternate between stock areas.
- Simulation work to explore conservation risks associated with potential management practices and hypotheses for stock dynamics would be helpful for considering multi-year advice. It should not be assumed that precautionary approach risks are the same for the different stock areas.
- Information from biennial synoptic surveys can be made available to fishery management outside of an assessment process. Work is planned to improve and standardize the presentation of information on data limited stocks (e.g. November 2018 CSAS review meeting on this topic, called Data Synopsis Report for BC Groundfish).
- There was no consensus on the frequency of when full assessment should be done in terms of feasibility of improving stock assessment advice and prioritizing work plans and resources to perform work.
- If variance in synoptic survey index increases or decreases by 50% between 2 year survey observations, this could warrant another assessment. This approach was advised in the 2015 5AB and 5CD assessments.

REVISIONS TO WORKING PAPER

There was consensus to accept the working paper but revision requirements were identified for updating assessment model runs (reference case and model average ensemble) and using a newly defined LRP for stock area 5ABCD. In addition, some suggestions to improve the working paper were identified.

UPDATING ASSESSMENT MODEL RUNS, OUTPUT AND INTERPRETATION

1. Reference model input parameters:
    a. Revise document to reflect the revised use of combined sex growth models instead of using female growth parameters
    b. Represent area 3CD 2018 catch as equal to 2017, represent 5ABCD 2018 catch as extrapolated value reported in working paper
2. The set of input models for the model average ensemble include:
    a. Log prior of survey q for HSSS (Hecate Strait synoptic survey) and QCSSS (Queen Charlotte Sound synoptic survey) have mean of 0.35 and 0.65 respectively (Area 5ABCD)
    b. Log prior of survey q for WCVISS (west coast Vancouver Island synoptic survey) has mean of 1 (Area 3CD)
    c. Log prior of survey q for HSSS and QCSSS have SD of 0.6 (Area 5ABCD)
    d. Log prior of survey q for WCVISS has SD of 0.6 (Area 3CD)
    e. Prior for M has mean 0.4 and SD of 0.1
    f. Knife-edge selectivity at age 3 and update Ford-Walford parameters
    g. Fix sigma O at 0.15
    h. Fix sigma W at 0.15
3. Reference points and metrics to include in catch decision tables:
    a. Define LRP for 5ABCD as B_{2000} (instead of B1971) as the lowest estimated biomass agreed to be an undesirable state to avoid.
    b. Keep LRP for 3CD same as working paper (1986) which is a level similar to a low estimated in modern period.
    c. Keep LRR and USR definitions same as working paper (average fishing mortality and biomass for 1956-2004, respectively).

SUGGESTED REVISIONS

- Provide additional background text describing: surveys; methods for how growth is captured in the delay difference model (von Bertalanffy growth model and parameters associated with Ford-Walford parameters).
- Include the fishery CPUE and synoptic survey index comparison plots and results (note synoptic surveys are biennial whereas CPUE is annual so joining points between years of survey observations skews trends).
- Include Kobe plots to show temporal progression and relationship of annual estimates of fishing rate and biomass.

- Update abstract to include information related to summarizing 2018 biomass (current status) and harvest advice related to decision tables.
- Update Table 9s and 15 summarizing median and 95% credibility intervals for a complete set of estimates describing stock status and reference point values, and their ratios where appropriate.
- Reviewers also provided additional editorial suggestions in their written reviews or by direct communication with authors.

FUTURE WORK SUGGESTIONS

- Consider and investigate possible mixing between stock areas within and outside of British Columbia. Examples of types of information: genetics synchrony in recruitment, genetics.
- Consider and investigate other sources of Pacific Cod information in terms of trends in relative abundance, seasonality and size and age demographics (e.g. fisheries and surveys related to long line, International Pacific Halibut Commission, Alaskan waters, etc).
- Compare effect of shortening time series to just modern era post fishery observers (>1995), what happens when using modern information of surveys and CPUE and biological sample data alone. A caveat to looking at a shorter more modern time series is that this would limit biomass scale whereas historically, large catches demonstrate that the stocks had larger biomass.
- Combine regions of coast for a Pacific Cod coast-wide geospatial model.
- Try to characterize changes over time related to synoptic survey catchability using a length-based model.
- Collect additional information from sampling and ageing cod stocks and explore methods to represent uncertainty with ageing data and age-size relationships.
- Apply feedback simulations to test candidate reference points with different stock hypotheses. Consider alternate candidate reference points to be evaluated (dynamic, fixed).
- Consider ecological relationships with Pacific Cod abundance, distribution and growth between year and within year seasonality.
- Compare assessment model index trends with information from Alaskan Pacific cod surveys and fisheries, BC longline and halibut fisheries and surveys.

SCIENCE ADVISORY REPORT

A draft Science Advisory Report (SAR) for areas 3CD and 5ABCD was circulated and there was discussion on required steps to develop and circulate the SAR. Several key points to be included in the document, and emphasized in the summary points, were noted by the group.

There was consensus that only results from the model average ensemble will be included. The authors were asked to re-run the assessment models with the final set of agreed upon input information and the use of a different LRP for area 5ABCD. Participants reviewed and agreed on the figures and tables that should be included in the SAR. It was agreed that the Chair would work with authors to prepare a revised draft SAR for circulation to participants for feedback.

The set of input models for the model average ensemble include:

1. Log prior of survey q for HSSS and QCSSS have mean of 0.35 and 0.65 respectively (Area 5ABCD)
2. Log prior of survey q for WCVISS has mean of 1 (Area 3CD)
3. Log prior of survey q for HSSS and QCSSS have SD of 0.6 (Area 5ABCD)
4. Log prior of survey q for WCVISS has SD of 0.6 (Area 3CD)
5. Prior for M has mean 0.4 and SD of 0.1
6. Knife-edge selectivity at age 3 and update Ford-Walford parameters
7. Fix sigma O at 0.15
8. Fix sigma W at 0.15

Reference points and metrics to include in catch decision tables:

1. Define LRP for 5ABCD as B_{2000} (instead of B1971) as the lowest estimated biomass agreed to be an undesirable state to avoid.
2. Keep LRP for 3CD same as working paper (1986) which is a level similar to a low estimated in modern period.
3. Keep LRR and USR definitions same as working paper (average fishing mortality and biomass for 1956-2004, respectively).

CONCLUSIONS AND ADVICE

The use of MSY-based and B_0-based reference points could not be supported for this stock. Alternative “historical” reference points were considered and endorsed. They are:

1. an Upper Stock Reference point based on the estimated average biomass for the period 1956 to 2004;
2. a Limit Reference Point defined as the lowest estimated biomass agreed to be an undesirable state to avoid. The biomass for year 2000 for area 5ABCD and the biomass for year 1986 for area 3CD.
3. a Limit Removal Rate calculated as the estimated average fishing mortality for the period 1956-2004.

Advice to managers is provided in a decision table that summarizes the probability of breaching the reference points at a range of fixed catches for a one-year projection. The table uses a model-averaging approach intended to integrate results from the use of alternative model assumptions.

Due to the high degree of stock assessment uncertainty and the data limited nature of these stocks, no specific recommendations were made on intervals between formal assessments and potential indicator triggers to expedite full assessment efforts.

Feedback simulation modelling is recommended to evaluate the performance of reference points and alternative management procedures for Pacific Cod under a range of structural uncertainties, including time-varying selectivity, alternative representations of stock structure and alternative drivers of productivity, such as environmental forcing.

SOURCES OF UNCERTAINTY

The working paper reported that uncertainty is under-represented in the assessment models. Examples of key sources of uncertainty identified and discussed at the meeting are listed below:

- The effects of the assumption of constant selectivity in the trawl fishery. There is a poor understanding of the relationship between commercial CPUE data and abundance and how it has changed over the course of the fishery. As for many assessments, it is a large contributor to the structural uncertainty in this assessment, particularly given the significant changes in management regime, market forces, fishing behaviour, and gear efficiencies that are known to have occurred, as well as being the only source of abundance information before 1984.
- The delay-difference model's assumption of time-invariant, knife-edged selectivity at age two years is very likely to be violated for this stock. For examples, a comparison of length-frequency data from the fishery with data from the surveys suggests that the survey selects younger fish than the fishery.
- The lack of reliable age composition data due to difficulties with ageing Pacific Cod;
- There are relatively short series of fishery-independent abundance indices, which do not have clear trends.
- The impact of uncertainty in stock structure in understanding patterns in abundance.
- The impact of uncertainty in the magnitude of historical discarding and foreign catches.
- The impact of change in onboard observer coverage and representativeness of length samples from the commercial catch.

REFERENCES CITED

Forrest, R.E., Holt, K.R., and Kronlund, R.A. 2018. Performance of alternative harvest control rules for two Pacific groundfish stocks with uncertain natural mortality: bias, robustness and trade-offs. Fisheries Research (206): 259-286.

Sinclair, A.F. and Starr, P.J. 2005. Assessment of Pacific Cod in Hecate Strait (5CD) and Queen Charlotte Sound (5AB), January 2005. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/026. iii + 91 p..

APPENDIX A: TERMS OF REFERENCE

ASSESSMENT OF BRITISH COLUMBIA PACIFIC COD FOR AREAS 3CD, AND 5ABCD IN 2018

Regional Peer Review Process – Pacific Region

October 10 - 11, 2018
Nanaimo, BC

Chairperson: Greg Workman

Context

Pacific Cod (*Gadus macrocephalus*) is a commercially important species of cod that occurs along the entire coast of British Columbia (BC), Canada, and is considered to be a short lived species (10-11 years; DFO 2015). The majority of catches are taken in Hecate Strait and Queen Charlotte Sound, where abundance is highest, although large catches have also been taken off the West Coast of Vancouver Island. Pacific Cod are caught by the groundfish trawl fishery and occasionally by hook and line fisheries. Four stocks of Pacific Cod are defined for management purposes in BC: Strait of Georgia (4B); West Coast Vancouver Island (3CD); Queen Charlotte Sound (5AB); and Hecate Strait (5CD). This request is for Areas 3CD, 5AB, and 5CD only.

The last assessment for Pacific Cod was conducted in 2013 for Areas 5AB, 5CD, and in 2001 for Area 3CD. There is a requirement to estimate stock status relative to reference points that are consistent with the DFO's Fishery Decision-Making Framework Incorporating the Precautionary Approach (DFO 2009). These reference points can include Limit Reference Points, Upper Stock Reference Points, and Target Reference Points. In 2013, reference points were calculated for Hecate Strait and Queen Charlotte Sound Pacific Cod stocks (DFO 2015).

Fisheries and Oceans Canada (DFO) Fisheries Management has requested that DFO Science provide advice regarding the assessment of Pacific Cod in Areas 3CD, 5AB, and 5CD, relative to reference points that are consistent with the DFO's Precautionary Approach (DFO 2009), and the implications of varying catches 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 help define catch levels for the species.

Objectives

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

Forrest, R., Grandin C., Anderson, S., and Starr, P. 2018. *Assessment of British Columbia Pacific Cod for Areas 3CD, and 5ABCD in 2018*. CSAP Working Paper 2014GRF06

The specific objectives of this review are to:

1. Recommend reference points consistent with the DFO Precautionary Approach and include the biological considerations and rationale used to make such a determination.
2. Assess the current status of Pacific Cod for Areas 3CD, and 5ABCD, relative to the recommended reference points.
3. Using probabilistic decision tables, evaluate the consequences of a range of constant catch harvest policies to projected biomass relative to the reference points and additional stock metrics including projected biomass relative to current biomass.

4. Describe the sources of uncertainty related to the model (e.g. model parameter estimates, assumptions regarding catch, productivity, carrying capacity and population status).
5. 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. 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 (e.g. NOAA, Alaska Fish & Game)

References

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

Forrest, R.E., Rutherford, K.L, Lacko, L., Kronlund, A.R., Starr, P.J., and McClelland, E.K. 2015. Assessment of Pacific Cod (*Gadus macrocephalus*) for Hecate Strait (5CD) and Queen Charlotte Sound (5AB) in 2013. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/052.

APPENDIX B: WORKING PAPER ABSTRACT

The status of two stocks of Pacific Cod (*Gadus macrocephalus*) in Hecate Strait/Queen Charlotte Sound (Area 5ABCD) and West Coast Vancouver Island (Area 3CD) was assessed using Bayesian delay-difference models. The models were fit to fishery-independent indices of abundance and new standardized commercial catch-per-unit-effort (CPUE) indices that were developed using Tweedie generalized linear mixed effect models (GLMMs). New analyses of growth and maturity were also done and incorporated into the models.

Reference points based on historical reconstruction of long-term average biomass and fishing mortality were accepted in 2013 for the Area 5CD Pacific Cod stock. "Historical" reference points were recommended because uncertainty in estimates of productivity parameters implied large uncertainty in reference points based on maximum sustainable yield (MSY). On the basis of the previous acceptance of historical reference points for Area 5CD Pacific Cod, the current assessment applies the same approach for the Areas 5ABCD and 3CD stocks. For both stocks an upper stock reference point (USR) is defined as estimated average biomass during the period 1956-2004. A limit reference point (LRP) is defined as the minimum biomass from which the stock is estimated to have recovered to above average (1971 in Area 5ABCD, and 1986 in Area 3CD). For both stocks, a limit removal rate (LRR) is defined as estimated average fishing mortality during the period 1956–2004.

Biomass in Area 5ABCD is estimated to have been on a declining trajectory since 2011, following declining trends in abundance indices, despite low estimated fishing mortality rates over the same period. Median posterior estimates of biomass are estimated to be below the median LRP for Area 5ABCD. Recruitment is estimated to have been below average for the past two decades.

Biomass in Area 3CD is estimated to have been on a declining trajectory since 2015 after following an increasing trend from a historical low level of biomass between 1998 and 2014. These trends are consistent with the available biomass indices, including a recent downturn in the WCVI synoptic survey and the CPUE series. Median posterior estimates of biomass are estimated to be above the median LRP but below the USR for Area 3CD.Recruitment is estimated to have been below average for most years in the past two decades, with above average peaks in 2009, 2013 and 2014.

Model estimates of biomass and stock status in both management areas were very sensitive to prior assumptions about natural mortality and survey scaling parameters, variance in the mean weight data, and the goodness of fit to the indices of abundance, particularly the commercial CPUE data. Harvest advice was produced in the form of decision tables that summarized the probability of breaching reference points in 2019 over a range of fixed 2018 catch levels. Due to model sensitivity to a number of assumptions, decision tables for both stocks were provided using: (i) only projections from the Reference Model; and (ii) a model-averaging approach using projections over five alternative model configurations.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat, Centre for Science Advice Pacific
Regional Peer Review Meeting (RPR)

Assessment of British Columbia Pacific Cod for Areas 3CD, and 5ABCD in 2018

October 10-11, 2018
Seminar Room, Pacific Biological Station
3190 Hammond Bay Road, Nanaimo BC

Chair: Greg Workman

DAY 1 – Wednesday, October 10

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Sean Anderson + Robyn Forrest
1030	***Break***	
1045	Written Reviews and Authors Response	Chair +Reviewers & Authors
12:00	***Lunch Break***	
1300	Identification of Key Issues for Group Discussion	RPR Participants
1330	Discussion & Resolution of Technical Issues	RPR Participants
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 - Thursday, October 11

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1 (*As Necessary*)	Chair
0915	Discussion & Resolution of Technical Issues (Continued from Day 1)	RPR Participants
1030	***Break***	
1045	Discussion and Resolution of Working Paper Conclusions	RPR Participants
11:30	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1200	***Lunch Break***	
13:00	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
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 D: MEETING PARTICIPANTS

Last Name	First Name	Affiliation
Anderson	Sean	DFO Science
Christensen	Lisa	DFO Science, Centre for Science Advice Pacific (CSAP)
Connors	Brendan	DFO Science
Edwards	Andrew	DFO Science
Flostrand	Linnea	DFO Science
Forrest	Robyn	DFO Science
Gagné	Marc	DFO Science
Grandin	Chris	DFO Science
Haggarty	Dana	DFO Science
Haigh	Rowan	DFO Science
Keppel	Elise	DFO Science
Kronlund	Rob	DFO Science
MacDougall	Lesley	DFO Science, CSAP
McCall-Thompson	Élyse	DFO Science
Mose	Brian	Commercial Industry Caucus - Trawl
Ricard	Daniel	DFO Science
Starr	Paul	Canadian Groundfish and Research Conservation Society
Stewart	Ian	International Pacific Halibut Commission (IPHC)
Tadey	Rob	DFO Resource Management
Thompson	Jason	Council of the Haida Nation
Turris	Bruce	Canadian Groundfish and Research Conservation Society
Wor	Catarina	DFO Science
Workman	Greg	DFO Science