Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Proceedings Series 2023/008

Pacific Region

Proceedings of the Pacific regional peer review on the development of biological reference points and retrospective evaluation of abundance trends in Fraser River Dungeness Crab (Management Areas I and J)

February 28 – March 1, 2022 and October 26, 2022
Virtual Meetings

Chairperson: John Candy
Editors: Jill Campbell and Yvonne Muirhead-Vert

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

February 2023

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.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1701-1280
ISBN 978-0-660-47215-7 Cat. No. Fs70-4/2023-008E-PDF

Correct citation for this publication:

DFO. 2023. Proceedings of the Pacific regional peer review on the development of biological reference points and retrospective evaluation of abundance trends in Fraser River Dungeness Crab (Management Areas I and J); February 28 – March 1 and October 26, 2022. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2023/008.

Aussi disponible en français :

MPO. 2023. Compte rendu de l'examen par les pairs de la région du Pacifique sur l'établissement de points de référence biologiques et l'évaluation rétrospective des tendances liées à l'abondance du crabe dormeur dans le fleuve Fraser (zones de gestion I et J) ; du 28 février au 1 mars et le 26 octobre 2022. Secr. can. des avis. sci. du MPO. Compte rendu 2023/008.

TABLE OF CONTENTS

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 February 28 to March 1, 2022 and October 26, 2022 via the online meeting platform Zoom. The working paper presented for peer review focused on developing biological reference points to help determine the stock status of the Fraser River Dungeness Crab Management Areas (I and J) relative to abundance trends.

Due to the COVID-19 pandemic, in-person gatherings have been restricted and a virtual format for this meeting was adopted. Participation included DFO Science and Fisheries and Resource Management staff, and external participants from First Nations organizations, Washington Department of Fish and Wildlife, the commercial and recreational fishing sector, consultants, and academia.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report providing advice to DFO Fisheries Management Branch to inform Dungeness Crab stock status, including the need for evaluating alternative harvest strategies.

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

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) was held on February 28 to March 1, 2022 and on October 26, 2022 via the online meeting platform Zoom to review the working paper on developing biological reference points to help determine the stock status of the Fraser River Dungeness Crab Management Areas (I and J) relative to abundance trends.

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, Alaska and Washington Departments of Fish and Wildlife, the commercial and recreational fishing sectors, consultants, and academia.

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

Aulthouse, B., Araujo, H.A., Burton, M., Zhang, Z., Obradovich, S., Fong, K., and Curtis, D. Development of biological reference points and retrospective evaluation of abundance trends in Crab Management Areas I and J. 2022. CSAP Working Paper 2016INV01.

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

The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting, highlighting the objectives and identifying the Rapporteur for the review. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. 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, 31 people (first meeting) and 27 (second meeting) participated in the RPR (Appendix D).

Participants were informed that Gordon Kruse (University of Alaska Fairbanks) and Adam Cook (DFO Science, Maritimes Region) had been asked before the meeting to provide detailed written reviews for the working paper to facilitate the peer-review process.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to DFO Fisheries Management Branch to inform Dungeness Crab stock status, including the need for evaluating alternative harvest strategies. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat website.

GENERAL DISCUSSION INITIAL MEETING (FEBRUARY 28 – MARCH 1, 2022)

Following a presentation by the authors, reviewer Gordon Kruse (University of Alaska Fairbanks) shared his comments and questions on the working paper. The authors were given time to respond to Dr. Kruse before the discussion was opened to all participants. The second reviewer, Adam Cook (DFO Science, Maritimes Region), chose to raise his comments during the group discussion. This proceedings document summarizes the discussions that took place by topic, where points of clarification presented by the authors in their presentations and questions and comments raised by the reviewers and participants are captured within the appropriate topics.

STANDARDIZATION MODEL REQUEST

Some participants requested the authors standardize the data and rerun the Limit Reference Point (LRP) calculations. They felt there were many aspects of the survey design and data management that introduced uncertainty in the LRP results that could be better captured. The authors indicated that the survey has changed little over the years. Past standardization exercises exploring depth, bait type, location, and soak time indicated negligible effects, and the standardization exercise undertaken in this WP (standardizing for soak time, depth, and Crab Management Area (CMA)) also indicated negligible effects. The authors also presented the 4-year moving average of the standardized catch per unit effort (CPUE) index which had similar trends to the nominal CPUE index. A Bayesian version of the negative binomial generalized linear model is currently being developed to account for more uncertainty in future assessments. A reviewer indicated that an advantage to a standardized CPUE index is that all of the data could be included (data from both Area I and J instead of just I), smoothing trends would not be necessary, and changes in population dynamics may be easier to detect through patterns in model residuals or diagnostics. The authors and some of the scientists were concerned that the methodology was no longer being evaluated, but rather the LRP values, which was not the focus of the RPR meeting. The basis for the acceptance of the defensibility and rigour of the science should not be dependent upon the LRP value.

The authors agreed to conduct a data standardization exercise likely using generalized linear mixed effect models to explore the effects of season, trap competition, trap separation, state of maturity, fishing pressure, bottom temperature, bait type, state of tides at moment of survey, and other environmental factors. Mixed effects could include year, site, depth, trap location in string, and the distribution of the response (to better handle the zeros in the data). The standardization and reanalysis of the data would be a significant amount of effort and thus a second meeting would have to be called.

GENERAL DISCUSSION/POINTS OF CLARIFICATION

Link between female CPUE and legal male LRP: One participant was unsure of the connection between using female CPUE to determine LRPs for legal male crabs. The authors indicated this correlation has been used by DFO and others for many years to develop management strategies. The size-sex-season harvest strategy has been in place since 1914 with relatively high success that protects the reproductive potential of female and sublegal size of male Dungeness Crabs. The minimum size limit for male crabs allows male crabs to reproduce at least once before recruiting to the fishery. As well, females can skip molt, thereby retaining sperm, which theoretically allows the population to be resilient to high exploitation rates. The authors will include a correlation plot for females and sublegal males. Future work looking at megalops abundance to predict legal male abundance may also be possible.

Definition of female crabs: In response to a comment from a reviewer, the authors will provide clarity whether the term 'female' refers to mature females only or all females. The authors indicated that all females are considered to be sexually mature. Females reach sexual maturity at 100 mm and less than 0.5% of females are below this width. The authors said that if they exclude females below this size in the analyses it would not likely influence the results.

Berried females: Female crabs with egg clutches are called 'berried females' and their catchability is very low at this stage as they bury in the sand. The data indicate the catches of females decline extremely rapidly in the fall, typically in mid-November. The fall crab survey wraps up in mid-October, one month prior to the average date of reduced female catchability. As a data preparation step, the authors chose November 15th as a data inclusion cut-off point to exclude any surveys conducted post November 15th. Some participants were concerned about the validity of using this date and preferred a more robust environmental factor be used instead, such as water temperature. The authors noted that survey catch data will need to be monitored to ensure the proportion of females with eggs does not change during the fall survey.

Fishery-independent data: In response to a reviewer comment, the authors clarified that while the data do not come from the commercial fishery and are therefore fishery-independent, the surveys do occur alongside the commercial fishery. It is not possible or desirable to have spatial or temporal independent sampling from the fishery. Efforts are made to ensure commercial fishery gear is 40m away from sample gear, but this cannot be guaranteed. However, the chance of commercial fishers interfering with DFO survey gear is unlikely, despite a participant suggesting this might be the case. The authors will add text to highlight that the fishery may be impacting the survey results. These concerns may be addressed in the CPUE standardization exercise.

Productivity phase: In response to a reviewer question, the authors will clarify that the entire time series is considered as the productive period, as there were no years with low catches to indicate the stock was in a low productivity phase. While there are anecdotal accounts of increased undocumented catch, the landings data indicate the current years are no less productive than previous time periods. The authors will conduct a sensitivity analysis to estimate B_{mean} (mean female CPUE over the fall survey time series) over different time periods to confirm the entire time series can be considered 'productive', as well as overlay trends in catch rates of females, sub-legal males, and legal males to ensure the different classes of crab are indicating the same productivity trends.

SURVEY METHODOLOGY

A few participants requested additional clarity on many aspects of the survey design to better understand the data that were used in this research, including information on what the survey was originally designed to measure. However, the numerous suggestions from a few participants to review and potentially change the survey methodology were out of the scope of this work.

Sampling locations: A few participants requested clarity on how sampling locations and depths have been standardized over time. They were concerned that the variability that exists between sampling locations and depths was not being properly accounted for if the authors averaged over all depths and sampling locations. The authors indicated that sampling location, gear type, bait type, soak times, and depths are standardized and this sampling design allows for data collection in a variety of habitats. This sampling design is suitable for the empirical analyses undertaken here. A standardization analysis was completed by Zhang and Dunham (2013) but the results did not change by very much. These concerns may be addressed in the CPUE standardization exercise.

Sampling timing: A participant was concerned with the timing of the survey and asked for the survey to be moved to November and for the spring survey to be moved to August to better monitor female crab abundance. They recognized that in each CMA the crabs have different timing for molting, mating, and migrating and that the commercial fishery should be a part of designing, scheduling, and planning surveys in each area. The participant was reminded that future changes to survey design are out of the scope of this work. The primary literature supports the timing of a fall survey, the authors will add more references to the Research Document.

Bait type: A participant noted that Dungeness Crab preference for bait changes throughout the fishery seasons and commercial fishers have learned to adapt to this. The authors acknowledge there may be better bait types to maximize catch, however, the survey uses a standard bait type throughout and this may be reducing catchability. The participant suggested the survey design be 'modernized' to account for this, however, the authors indicated it is not possible to alter bait type during the survey as it is difficult to standardize a variable that requires in-season expert knowledge. These concerns may be addressed in the CPUE standardization exercise.

METHODS

Exclusion of CMA J data: Data from CMA J was omitted from the analysis due to a lack of deeper (>20m) depth strata as this CMA is very shallow. Some participants were concerned that the results were being extrapolated to CMA J with little justification. The authors provided justification for why CMA I and J are considered as a single stock, and will ensure this justification is properly captured in the Research Document. The authors indicated the two areas are ecologically a single area in terms of proximity and habitat, genetics, larval dispersal, fishery dynamics, and survey CPUE indices. Fishery data from the United States portion of Boundary Bay cannot easily be included in the model as the same type of data are not collected. The authors feel there is sufficient justification for applying the results they derived from CMA I to CMA J, however some participants disagreed. They indicated that the fishery in the United States was not accounted for and commercial fishers have noticed differences in population migrations between CMA I and J. The data from CMA J were originally included in the analysis and the results with and without CMA J data were similar. These concerns may be addressed in the CPUE standardization exercise.

String vs trap as the unit of measurement: A reviewer asked why the data were treated at the string level rather than at the trap level. The authors indicated that this survey data have historically been treated in this manner as the traps on a single string are autocorrelated by location. Since the unit of measurement is the string, there are only three instances of strings with zero caught crab in the entire data set. Additionally, if the data are considered at the trap level, the data would need to be standardized by trap location as each trap may sample the population differently, especially the first and last traps in the string, which may move due to high currents or swell. The survey design accounts for this by requiring 50 pound anchors on each string end, with 10 meters of line from the anchor to either the first or last trap. The authors will add text to clarify why the unit of measurement is the string and not the trap and how this decision affected the treatment of zeros in the data set. These concerns may be addressed in the CPUE standardization exercise.

Leslie method assumptions: The Leslie method was used to estimate average exploitation rates in each fishing period and a few participants were concerned the assumptions of this method were not properly addressed. Sublegal male crabs can molt to legal size during the fishing season which represents a violation of the Leslie method which does not allow for changes to population size. The authors indicated that they assume any recruitment or immigration is balanced by natural mortality and emigration. As well, since the Leslie method

estimated exploitation rates from the fisheries are very high (>97%), the inclusion of other sources of mortality, such as handling mortality, will likely have little impact on the simulation results. However, the authors will explore including a variable for catchability of soft vs hard shelled crabs in the simulation method (proportion of soft shelled crabs in traps = proportion of soft shelled crabs in the population * relative catchability of soft shelled crabs). The authors reiterated the assumption checking they discussed in their paper, indicating that they were able to show the assumptions were met as defined by seminal work on the Leslie method. The authors also indicated that determining the proportion of soft shelled crabs in the population is challenging, as most legal crabs are fished in the first two to four weeks of the fishery opening.

Bayesian method to empirical reference point geometric means: In response to a participant question, the authors will provide clarity on how the Bayesian method was used to generate the geometric mean deterministic reference points.

Mean vs median annual CPUE estimates: The authors have calculated geometric 4-year running mean of the female CPUE index to determine the smoothed trend in the data. This method smooths the data, preventing extreme observations from having a large influence on the trends, however taking the mean of the time period means there will always be a lag for any declining trends and any extreme values will contribute to the trend for multiple years. A participant suggested using the median of the CPUE data instead as it removes the lowest and highest values, so there is a reduced lag in the trend and any extreme values have low to no impact on the trend. To allow for results in the most recent year, a Tukey end rule could be applied (a weighted average of the last data point and the two previous data points with more weighting on the recent year of data). Using the median results in a 2 year lag in determining the trend, using the mean results in a 3 year lag. For both methods, the data should be right-weighted, rather than centre or left-weighted. At the beginning of the second day of the meeting, the authors presented a figure exploring how the results differed when using the mean vs median and left, centre, and right-weighting. The trends between the two methods were similar, however there were some minor differences. The authors indicated that the method to calculate this index is not directly relevant to management decisions, so long as the smoothing is not extreme or that extreme values are allowed to drive the trends. The authors will conduct a sensitivity analysis to explore the effect of using median or means and 3, 4, and 5-year running averages. The method that is most robust, makes the most biological sense, and provides timely advice to managers will be chosen.

Running average time period: In response to reviewer and participant requests, the authors will run a sensitivity analysis exploring how using a 3, 4, or 5-year running average impacts the results, as well as how the time period impacts the speed at which management actions can be taken. It is important that managers have the information they need to act quickly if the LRP is breached, but not so quickly that they act unnecessarily if the abundance is higher in the subsequent year due to natural variation in Dungeness population dynamics. The authors will conduct a sensitivity analysis to explore the effect of using median or means and 3, 4, and 5-year running averages. The method that is most robust, makes the most biological sense, and provides timely advice to managers will be chosen.

Stock-Recruit (SR) model: A reviewer stated that the Beverton-Holt model used was reasonable, however they asked the authors for more clarity on how they extended the work of Myers et al. (1994) to estimate the Upper Stock Reference point.

Confidence intervals: In response to a participant question, the authors clarified that confidence intervals cannot be produced for the simulation model reference points as the simulation model is unable to characterize the uncertainties of those outputs. The authors will add confidence intervals on the figures for the empirically derived reference points.

RESULTS

Female CPUE variability: The female CPUE data trend varies considerably between 2002 and 2010 (see Figure 8). In response to participant questions about this variability, the authors indicated that some data were missing or excluded during this time frame, which, coupled with natural variation, may have contributed to the variability observed during this time frame. A participant asked the authors to include information on if and how the survey methodology, data preparation, and fishery dynamics have changed over time and how that may have influenced these results.

MANAGEMENT APPLICATION

'Provisional' LRP wording: A reviewer suggested dropping the 'provisional' LRP qualifier as all reference points are considered provisional as there is no fixed or final reference point. However, another participant was concerned that if these LRPs are included in Integrated Fisheries Management Plans (IFMP), there is a risk they may become static. They requested that at least the spirit of the 'provisional' qualifier be retained by indicating the LRPs need to be updated regularly. The reviewer agreed that this advice needs to be updated regularly, and that the LRPs should either all be labeled as 'provisional' or none should be labeled as 'provisional' and the intended spirit of updating the LRPs be made clear. Another participant preferred keeping the word provisional as this type of analysis has not been done on female Dungeness Crab before.

Implications of breaching the LRP: A few participants were unsure of what the implications might be when the LRP is breached. A rebuilding plan may be triggered, but a few participants wondered if the LRP would need to be breached for a certain number of years before a rebuilding plan would be required. Currently, the trend results lag one year behind the CPUE data which adds another layer of uncertainty. The authors indicated that these management decisions are out of the scope of this work.

Timeframe to update the LRP: The authors will make it clear in the Research Document that they do not recommend the LRP be updated annually, rather the LRP will be fixed until the next re-assessment.

Utility of this method to other CMAs: The authors indicated further work needs to be done to determine if these methods could be applied to other CMAs. Other CMAs may not have the same survey methodology or long term data. Additionally, more work is needed to determine how this methodology to develop LRPs would be applied under an IFMP or other management plan.

FUTURE WORK/RESEARCH QUESTIONS

Non-commercial fishery impacts: Some participants were concerned with the high levels of First Nations, recreational, and illegal fishery removals not being included in this analysis. The authors agreed that these removals are unknown due to lack of data and partly the reason developing reference points is of high importance. Better understanding the impact of these other fisheries is important future work.

Stock Recruit model: A reviewer mentioned that the SR relationship may be the result of autocorrelated environmental factors impacting recruitment more than population dynamics. The authors agreed that further exploration of this is valuable future work. One reason the authors did not recommend using the SR relationship to develop LRPs is because of this possibility.

Other areas of future research that were briefly discussed were:

- Conduct a coastwide connectivity study of Dungeness Crab to better identify the metapopulation structure along the west coast of North America.
- Develop fishery independent surveys in other CMAs to facilitate extension of this work to those CMAs.
- More fully investigate drivers of Dungeness Crab recruitment in British Columbia.
- Explore autocorrelation in the abundance time-series. Dungeness Crab periodicity and life history generates a time series of females and sublegal males that give the impression of a SR relationship when in reality, environment could be largely responsible.
- Consider whether Dungeness Crab in CMA I would lend themselves to the development of a size- or stage-based stock assessment model.

CONCLUSIONS

Participants had difficulty in reaching consensus on the working paper. A few participants felt the justification for applying the results from CMA I to CMA J were not sufficient and therefore the TOR objective to develop LRPs for both areas was not fully met, however the data standardization exercise may allow for the inclusion of CMA J data. Some participants with backgrounds in science and statistical methodology indicated that the data standardization was a minor revision and did not require another full peer review. Other participants felt the data standardization was a major revision and wanted the chance to review the new results prior to accepting the working paper. One participant felt the paper should be rejected. The Chair gave the participants three options:

1. Accept working paper with minor revisions. The standardization will be reviewed by the reviewers and a small group. The SAR will be drafted today. Standardization material will be added later and SAR will be circulated.
2. Accept working paper with major revisions. The standardization will be reviewed by the entire group in another meeting and SAR will be drafted then.
3. Not accept working paper.

Half the participants favoured option 1 and the other half of the participants favoured option 2. A few participants did not think the authors should be allowed to select an option, one author expressed concern of being excluded. Consensus in the meeting was to accept the paper with major revisions. No one expressed interest in option 3. The authors will conduct the data standardization exercise (with support from a small group of participants). Another CSAS meeting will be held with all participants in the fall of 2022 to discuss the results.

FOLLOW UP MEETING (OCTOBER 26, 2022)

OVERVIEW

On October 26, 2022, a virtual meeting was held to conclude the discussion on data standardization, and prepare summary bullets for the draft SAR. In the interest of efficiency, the Standardization of Data Appendix, Revision Table, and Agenda were distributed in advance of the meeting. 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.

GENERAL DISCUSSION

The authors presented a recap of the previous meeting, provided an overview of the Standardization of Survey CPUE, and discussed the results from the revisions of the working paper.

In the previous iteration of the data, the authors had excluded Area J since they were concerned that the shallow habitat depths in Area J would bias the data to shallow trap depths. Data from both Area I and J were then standardized to alleviate this issue and have included depth as a predictor in the model.

The authors have also standardized DFO survey CPUE data to account for survey methodology, environmental variables, survey conditions, and crab behavior. One of the reviewers had suggested to the authors in the previous meeting to use individual trap data to account for processes acting at the trap level that could affect catchability (i.e., type of bait or number of legal male crabs within the trap). The standardized CPUE was then used to estimate empirical reference points and the stock recruitment relationship instead of using raw unstandardized CPUE.

The methodology of the DFO Survey which started in 1988 has remained consistent over time but factors such as bait type, timing, location and soak duration have changed. Common bait used for this survey is Herring but Geoduck, squid, and fish frames have also been used. For the last 10 years, the survey timing has remained consistent with a survey in the spring (mid-May) and fall (mid-October). The survey uses a fixed station design and some stations have been added and removed over time. The authors noted that soak times have varied a little bit over time. The target soak time is 20 hrs but has varied due to weather. The variability noted above could confuse the relationship between the survey CPUE and population abundance. Therefore, the standardization of the data reduces potential bias in the abundance index time series.

At the time of the survey, data are recorded on the following parameters, bait type, soak time, depth, presence of legal males, trap location of the string, and date. The authors have included the following environmental variables such as tide data, weather data, wind direction, and depth (min and max) within the data standardization. River flow and air temperature were dropped due to the high correlation with day/month. The minimum and maximum depths are recorded but only the minimum depths are used since there is not much variability between the two depths as the traps are set along a contour. The standardized data also included variables -random effects that are inconsistent over time using the Pacific Fisheries Management Area (PFMA) and Sub areas. All DFO research sets included from both Areas I and J in this analyses. Some data observations were removed from the analyses due to missing parameter data (i.e., traps without soak times, non-standard usability codes). Overall 308 observations were removed for a total of 32,651 trap observations to be included in the data standardization process.

The authors used a negative binomial likelihood for the model structure. The Widely Applicable Information Criterion (WAIC) was used to determine the best fit standardization model for all datasets (female, sublegal male, legal male).

Questions After the Presentation

Data included and excluded: A participant was curious which depth was recorded, if it was for each trap or the entire string. The authors indicated that the depth is recorded when the string goes out and the minimum and maximum depths for the entire string are recorded. There are no data loggers on the traps.

The participant then asked why river flow and air temperature were excluded since the Fraser River flow peaks in June and declines afterwards while air temperature peaks in July-August and then declines. The authors originally stated that the river flow and air temperature were correlated to day and month. They indicated that using the word correlation may be wrong with Julian day. In the initial fitting model process, they looked at the Variance Inflation Factor and the values were above threshold so they dropped them to avoid variance inflation.

One participant asked if the time series contained weather data. The authors confirmed that it is a variable in the model.

Another participant mentioned that crab could be migrating north towards Area I and J and was wondering if this migration was considered within the model. The authors indicated that migration was not considered.

Bait: Within the analyses, bait is listed as a categorical predictor. The participant wanted to know how the authors assigned a value to each kind of bait and if bait was a significant predictor. The authors responded by letting them know a dummy variable was created for each bait type.

Trap type: A member of the group asked if any trap types were excluded from the models and if there is much variation with the traps. The authors noted that the DFO Dungeness Crab trap type is consistent and all DFO data were included in the models.

Trap age: It was asked if pot age was considered and if that type of data was recorded. It is noted by some from the fishing community that new pots are not as good as seasoned pots due to the electromagnetic field. The authors noted that these data are not recorded and the DFO traps are mix of old and new pots. In contrast, another participant indicated that new pots fish better with the zinc than older traps.

Results: It was suggested that a table of CPUE could be included in the final write-up for the full model to see if deeper traps lead to higher or lower CPUE. The authors agreed that they could include a table of the magnitude of effects and provide a statement on the significance in the result section.

Trap competition: A participant asked if the data considers the location of DFO sampling traps in close proximity to other baited traps for food, social and ceremonial (FSC) purposes while testing since First Nations are able to fish when the fishery is closed. Typically, the First Nations fisheries are fishing in the spring when DFO is conducting the spring survey. A participant provided an example of a time when the CCGS *Neocaligus* placed traps alongside small commercial traps that were using better bait (i.e., squid, tuna, cockles). It is hypothesized that traps with the better bait could be outcompeting the DFO traps being set with herring for a 24 hour soak. They wondered if there is a variable included in the model to factor in this type of competition. Commercial fisheries will use better bait in their traps when the market value of crab is high.

The participant noted that in Figures E.1 and E.2 that the abundance dropped near the critical zone in 2009 and 2010 when fishing was good in the area for legal males. During the fall survey for those two highly productive years, there would have been a lot of boats and gear in the water since there were many legal males in October. Typically, legal males are not found in the area during this time of year. They indicated that they were fishing hard with one day soaks during this time of high productivity and there was a lot of competition in the area.

A participant asked if there is a variable that is used in the modelling to consider this side-by-side competition. The participant believes that at times of high competition that these events could have a great impact on the results DFO are seeing. The authors indicated that there are

no DFO data recorded at this time with DFO gear being in close proximity to commercial or other traps. DFO could start to include the spatial temporal and random effects within the analyses to account for some of this variability. The results produced in this paper does not account for this variability.

The participant mentioned that prior to 2010, people were fishing at a higher effort before China started importing crab. Typically, in fall months, the price of crab is low. After 2010, China started to fish crab and the price has subsequently increased. The amount of competition has increased due to higher market values of crab.

It was suggested that DFO should give prior notice to all fishers so they would not fish in the area when sampling is taking place. It would provide better answers for the management of the fishery.

The authors noted that trap competition was a valid point but looking at 1000 datasets may not make too much of an impact. Depending on the skipper of the vessel they try to get a clean set when sampling but there have been times where they have been corked[1]. The participant indicated that the commercial fishers may be receptive to moving their gear when DFO is sampling. One of the authors deferred to the participant since they would have a better sense if the commercial fishers would be receptive to this kind of approach.

The participant wondered when there are sampling errors and if DFO reviews the fish slips and log books to compare fishing low and high numbers. Does DFO look at the broader picture than just the model? Would DFO consider doing another sampling event, if the results are erroneous and the model is not picking on the intense competition? Would the authors look at doing Willem's (service provider with Pacific Coast Fisheries Services) testing at the same time of year when competition is high due to high market prices? It was suggested for future work to start the conversation with the commercial fleet to remove their gear when DFO is conducting the survey.

A participant wanted to reiterate that they would like to see the commercial fishery data included in the model. They believe it could assist with future stock assessments. It was suggested that the authors look at the distance between commercial traps and DFO traps. In 2010, 2011 and 2012, there were close to 50 boats fishing in Area I and more recently it is down to 22 boats. The number of extra traps in the water based on the high number of boats in previous years would likely have an effect on the testing.

Stock assessment framework: Another participant commented on the potential variables (e.g., survey CPUE, catch composition) and asked if this was going into a stock assessment. The authors said that the results from this paper would be the initial input for one. Typically, a stock assessment framework would take into account these various sources of information from the fishery to determine the LRP. The standardization of the data is just the first step of the stock assessment and should not be the basis for assessing the stock as a whole. In the future, the development of a stock assessment framework from diverse sources of information including larval and commercial catch data would be beneficial.

Another participant mentioned that all fishery data are imperfect at this time and the driver of this paper is the policy to develop the limit reference points. What needs to be articulated is a tool to provide management advice and potential actions. They asked how the two indicators are integrated for stock status. They also asked what the management advice would be if the

[1] Getting "corked" is commercial fishing slang which means someone sets their gear in front/on top of yours and catches all the fish before they can get into your net/trap.

stock dips into the critical zone. The participant indicated there was more variability in the results since there is no smoothing of the curve that would normally happen within a stock assessment framework. The authors agreed with the participant that the data are imperfect. The results from the paper are a first step and further discussions will be needed to provide management advice with fisheries managers.

Boom and bust cycle: One participant mentioned that crab populations are cyclical in nature and that areas will go from boom to bust. They indicated it can be difficult to predict these cycles and researchers should be aware of the history of the area.

Standardization of the data: A participant was concerned with the small test site in Area J since traps in this area are located at more shallow depths than in Area I. They wondered why a different LRP is not used. The authors explained by standardizing the data for both Area I and J that the model would account for different trap depths.

The participant was concerned with the results from the original paper since it only used data from one area. The authors explained that data from both Area I and J were used in the standardization. They also mentioned that the results from this paper included both spring and fall survey data sets.

Another participant was concerned that there is no integration of commercial fishery and larval survey data in the model. The authors mentioned that larval sampling did begin this year. They agreed that the larval monitoring is a good source of information as well as data from the commercial fishery and that they should be incorporated into future assessments.

A reviewer noted the revised results provided a first step and provided practical advice and noted that potential rules will be needed to be generated to define the measures. These measures would need to be taken when females are healthy and the recruits are in the cautious zone. It would be helpful to have this conversation before there is an issue with the stock.

Survey timing: There was a question from a participant wondering if there is any difference with the spring and fall surveys to the timing of the commercial fishing. The authors mentioned that there is a noticeable effect in the data since there seems to be a higher proportion of females present in fall. The spring survey is outside the timing of the commercial fisheries whereas the fall survey is conducted when other fishing is occurring. The authors noted that these variables are time stamped within the time series.

DEVELOPMENT OF THE SCIENCE ADVISORY REPORT (SAR)

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

CONCLUSIONS

Meeting participants agreed the working paper has satisfied all Terms of Reference objectives and was accepted, with major revisions. Consequently, a follow up meeting was held on October 26, 2022 to discuss changes to the paper before development of the SAR. The draft SAR was discussed at length and participants had the opportunity to contribute and provide input to key sections. At the end of the follow up meeting, a revised draft SAR was complete. The Centre for Science Advice Pacific (CSAP) office will circulate the draft SAR and draft PRO 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 contribution from all participants. We thank the formal reviewers, Gordon Kruse (University of Alaska Fairbanks) and Adam Cook (DFO Science, Maritimes Region) for their time and expertise for providing their formal reviews of the working paper. We would also like to thank John Candy for his support throughout the process and as Chair of the meeting.

REFERENCES CITED

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

Myers, R., Rosenberg, A., Mace, P., Barrowman, N., and Restrepo, V. 1994. In search of thresholds for recruitment overfishing. ICES Journal of Marine Science 51(2): 191–205.

Zhang, Z., and Dunham, J.S. 2013. Construction of biological reference points for management of the Dungeness Crab, (*Cancer magister*), fishery in the Fraser River Delta, British Columbia, Canada. Fisheries research 139: 18–27.

APPENDIX A: TERMS OF REFERENCE

DEVELOPMENT OF BIOLOGICAL REFERENCE POINTS AND RETROSPECTIVE EVALUATION OF ABUNDANCE TRENDS IN FRASER RIVER DUNGENESS CRAB (MANAGEMENT AREAS I AND J)

Regional Peer Review – Pacific Region

February 28 – March 1, 2022
Virtual Meeting

Chairperson: John Candy

Context

Fisheries and Oceans Canada (DFO) manages the Dungeness Crab fishery, which consists of seven Crab Management Areas (CMAs; A, B, E, G, H, I, and J) in the Fraser River Delta, British Columbia (BC). Although some differences exist between the CMAs (Harbo and Wylie, 2006), within Canada, Dungeness Crab fisheries are primarily managed based on a '3 S' (size, sex, and season) management strategy. This management strategy is designed to allow sexually mature sublegal male crabs one to two breeding seasons prior to recruiting into the fishery, to protect female crabs, and to protect crabs during vulnerable softshell periods.

As is typical of the Dungeness Crab fisheries along the Pacific coast of North America, catch has fluctuated between and within CMAs on both annual and decadal scales. Although a similar management strategy has been in place since the early 1900s, recent declines in commercial catch for CMAs I and J, along with heightened awareness of the effects of changing environmental conditions, have elevated concerns regarding the long term sustainability of the fishery. In response to these concerns, as well as the need to be compliant with the fish stock provisions of the *Fisheries Act*, and DFO's Precautionary Approach (DFO 2009), DFO is taking the necessary steps to promote the sustainability of the stock.

Fisheries and Oceans Canada (DFO) Fisheries Management Branch has requested that DFO Science Branch develop biological reference points to help determine the stock status of the Fraser River Dungeness Crab Management Areas (I & J), relative to abundance trends.

The advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) process will be used to inform resource managers on stock status, including the need for evaluating alternative harvest strategies. The advice may also provide a framework for developing biological reference points and a method for assessing abundance trends in other CMAs. Crab Management Areas I and J currently have the most comprehensive DFO fishery independent survey data, making them a logical starting point for developing reference points coast-wide.

Objectives

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

Aulthouse B., Araujo, H. A., Obradovich, S., Burton M., Zhang, Z., Fong, K. and Curtis, D. Development of biological reference points and retrospective evaluation of abundance trends in Crab Management Areas I and J. 2022. CSAP Working Paper 2016INV01.

The specific objectives of this review are to:

1. Develop a biological limit reference point and recommend an upper stock reference for DFO Crab Management Areas I and J.

2. Compare long-term trends in abundance indices for (a) legal male, (b) female, and (c) sub-legal male Dungeness Crab in CMAs I and J, and where appropriate, compare these indices to the reference points in (1) to determine stock status.
3. Discuss sources of uncertainty, including the applicability of these methods to determine reference points in other CMAs.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Fisheries and Oceans Canada (Science, and Fisheries Management sectors)
- Academia (e.g. University of British Columbia)
- First Nations (e.g. Cowichan, Musqueam, Semiahmoo, Squamish, Tsawwassen and Tseil-Waututh)
- Commercial Industry
- Sport Fishing Advisory Board

References

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

Harbo, R.M. and Wylie, E.S. (eds.) 2006. Pacific commercial fishery updates for invertebrate resources (2000). Can. Manuscr. Rep. Fish. Aquat. Sci. 2735: viii +304 p.

APPENDIX B: WORKING PAPER ABSTRACT

This paper identifies two sets of reference points: an upper stock reference (USR = 0.456 female standardized CPUE) and a limit reference point (LRP = 0.228 female standardized CPUE), as described in A Fishery Decision-Making Framework Incorporating the Precautionary Approach (DFO 2009a) also known as DFO's Precautionary Approach (PA) policy. These reference points will inform the assessment of stock status of Dungeness Crab in Crab Management Areas (CMAs) I and J. Candidate reference points were estimated using three methodologies: a data-driven empirical method, a model-based method which estimates the stock-recruitment relationship, and a simulation model-based method. We recommend applying the empirically-based methodology for determining reference points for the Dungeness Crab in CMAs I and J as they are more interpretable than the simulation model-based reference points, and are more estimable than the stock-recruitment reference points. Subsequent research can use this framework to develop reference points for Dungeness Crab in other CMAs.

APPENDIX C: AGENDAS

INITIAL MEETING FEBRUARY 28 AND MARCH 1, 2022

DAY 1 - Monday, February 28

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Authors
1030	**Break**	
1045	Overview Written Reviews	Chair + Reviewers & Authors
12:00	**Lunch Break**	
1300	Identification of Key Issues for Group Discussion	Group
1330	Discussion & Resolution of Technical Issues	RPR Participants
1445	**Break**	
1500	Discussion & Resolution of Results & Conclusions	RPR Participants
1630	Develop Consensus on Paper Acceptability & Agreed-upon Revisions (Revisions Table + TOR objectives)	RPR Participants
1700	Adjourn for the Day	

DAY 2 - Tuesday, March 1

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

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

FOLLOW UP MEETING OCTOBER 26, 2022

DAY 1 - Wednesday, October 26

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 1130	Con't Discussions of Revisions *Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Summary bullets • Sources of Uncertainty • Results & Conclusions • Figures/Tables	RPR Participants
12:00	**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 D: PARTICIPANT LIST

INITIAL MEETING FEBRUARY 28 AND MARCH 1, 2022

Last Name	First Name	Affiliation
Araujo	Andres	DFO Science
Aulthouse	Brendan	DFO Science
Benson	Ashleen	Landmark Fisheries Research
Bosley	Katelyn	Washington Dept Fish and Wildlife
Buerk	Dillon	DFO Resource Management
Buitendyk	Willem	Pacific Coast Fisheries Services
Bureau	Dominique	DFO Science
Burton	Meghan	DFO Science
Campbell	Jill	DFO Centre for Science Advice Pacific
Campbell	Kelvin	Commercial Crab Area H Representative
Candy	John	DFO Science
Christensen	Lisa	DFO Centre for Science Advice Pacific
Cook	Adam	DFO Science, Maritimes Region
Curtis	Dan	DFO Science
Ellis	Chelsey	Area A Crab Harvester Association
Fong	Ken	DFO Science
Frederickson	Nicole	Island Marine Aquatic Working Group
Ganton	Amy	DFO Fisheries Management
Greenberg	Aaron	University of British Columbia
Hajas	Wayne	DFO Science
Hansen	Christine	DFO Science
Hawkshaw	Sarah	DFO Science
Kanno	Roger	DFO Resource Management
Kruse	Gordon	University of Alaska Fairbanks
Lochead	Janet	DFO Science
Mijacika	Lisa	DFO Resource Management
Nowosad	Damon	Q'ul-lhanumutsun Aquatic Resources Society
Obradovich	Shannon	DFO Science
Power	Sarah	DFO Science
Taylor	Justin	Commercial Crab Area I Representative
Tjhie	Hong	DFO Fisheries Management

FOLLOW UP MEETING OCTOBER 26, 2022

Last Name	First Name	Affiliation
Araujo	Andres	DFO Science
Aulthouse	Brendan	DFO Science
Benson	Ashleen	Landmark Fisheries Research
Buerk	Dillon	DFO Resource Management
Buitendyk	Willem	Pacific Coast Fisheries Services
Burton	Meghan	DFO Science
Campbell	Kelvin	Commercial Crab Area H Representative
Candy	John	DFO Science
Christensen	Lisa	DFO Centre for Science Advice Pacific
Cook	Adam	DFO Science, Maritimes Region
Curtis	Dan	DFO Science
Ellis	Chelsey	Area A Crab Harvester Association
Fong	Ken	DFO Science
Frederickson	Nicole	Island Marine Aquatic Working Group
Ganton	Amy	DFO Fisheries Management
Hajas	Wayne	DFO Science
Hawkshaw	Sarah	DFO Science
Kanno	Roger	DFO Resource Management
Kruse	Gordon	University of Alaska Fairbanks
Mijacika	Lisa	DFO Resource Management
Muirhead-Vert	Yvonne	DFO Centre for Science Advice Pacific
Nowosad	Damon	Q'ul-lhanumutsun Aquatic Resources Society
Obradovich	Shannon	DFO Science
Taylor	Justin	Commercial Crab Area I Representative