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Pacific Region

Proceedings of the Pacific regional peer review on the identification of candidate reference points and harvest rate options for the commercial Red Sea Urchin (*Mesocentrotus franciscanus*) fishery in British Columbia

February 13, 2019
Nanaimo, British Columbia

Chairperson: Lyanne Curtis
Editor: Janet Lochhead

Fisheries and Oceans Canada
Science Branch
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

May 2021

Canada

Foreword

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

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Aussi disponible en français :

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SUMMARY

These Proceedings summarize the key discussions and conclusions that resulted from Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on February 13, 2019 at the Pacific Biological Station in Nanaimo, BC. A research paper evaluating the provisional Limit Reference Point (LRP) and Upper Stock Reference (USR) as well as various harvest rate options for the Red Sea Urchin (RSU) fishery were presented for peer review.

The committee consisted of DFO Science and Fisheries Management (FM) staff as well as invited representatives from Parks Canada, Pacific Sea Urchin Harvesters Association, Washington Department of Fish and Wildlife and the Council of the Haida Nation. The conclusions and advice resulting from this review will be provided in the form of a Research Document and a Science Advisory Report providing advice to FM on the RSU harvest rate options using new simulation models and the provisional reference points.

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

INTRODUCTION

On February 13th, 2019, a Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) meeting was held at the Pacific Biological Station in Nanaimo to review a Research Document evaluating the provisional Limit Reference Point (LRP) and Upper Stock Reference (USR) and various harvest rate options of the Red Sea Urchin (RSU) fishery using new simulation models (Appendix A).

The Terms of Reference (ToR) for the science advice (Appendix B) were developed in response to a request for advice from DFO Fisheries Management (FM) branch. Notifications of the science review and conditions for participation were sent to various representatives with relevant expertise in the subject area, including internal (DFO Science, FM) and external (Parks Canada, commercial fishing sectors and collaborators, the Council of the Haida Nation) representatives (Appendix C).

The following working paper was prepared and made available to meeting participants prior to the meeting:

> Lochead, J., Zhang, Z., and Leus, D. 2019. The identification of provisional reference points and harvest rate options for the commercial Red Sea Urchin (*Mesocentrotus franciscanus*) fishery in British Columbia. CSAP Working Paper 2016INV02.

The meeting Chair, Lyanne Curtis, 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 purpose of the various RPR publications [Science Advisory Report (SAR), Proceedings, and Research Document], and the definition and process around achieving consensus decisions and advice. The Chair reviewed the Agenda (Appendix A) and the ToR (Appendix C) for the meeting, highlighting the objectives and identifying the Rapporteur (Christine Hansen). The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. 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. They were reminded that everyone was expected to contribute to the review process if they had information or questions relevant to the paper being discussed. The Chair and CSAP staff ensured that all participants had received all the necessary documents for the review.

The Chair explained that the review of the research document would begin with a presentation on the work given by the authors followed by the presentation and discussion of the written reviews of the paper. The reviews were written by Henry Carson, Ph.D., (Washington Dept. of Fisheries and Wildlife) and Rénald Belley, Ph.D., (DFO Science), and provided to participants beforehand to assist with the peer-review meeting process. The chair continued and explained that a general discussion of the research paper would follow the presentation and written reviews, and that any relevant discussion points would tabled and recorded for later discussions. The conclusions and advice resulting from this review will be provided in the form of a Research Document and a SAR providing advice to FM on provincial reference points and a range of harvest rate options based on the outcome of new simulation models for RSU dive fishery. The Research Document and supporting SAR will be made publicly available on the CSAS Science Advisory Schedule.

REVIEW

Working Paper:

Lochead, J, Zhang, Z., and D. Leus. The identification of candidate reference points and harvest rate options for the commercial Red Sea Urchin (*Mesocentrotus franciscanus*) fishery in British Columbia. CSAP Working Paper 2016INV02.

Rapporteur: Christine Hansen

Presenter: Janet Lochead and Zane Zhang (Authors)

PRESENTATION OF WORKING PAPER

Janet Lochead gave a presentation on the background and major topics of the working paper. Zane Zhang explained the development and application of the mathematical simulation models in the working paper.

Points of clarification

After Janet Lochead finished the presentation, the Committee had some points of clarification that were addressed by the authors.

An annual harvest rate of 2%, derived from a modified Gulland surplus production model and applied to estimated current exploitable biomass, has been used for most of the BC coast since 1994. A consistent harvest rate of 2% was assumed in the models. . Concerns were brought up regarding varying harvest rates and histories of the fishery along the coast. The authors and some committee members confirmed that the harvest rates pre-1994 were much different than they are today and that they varied among areas of the coast. Along the South Coast, harvest rates were much higher in the 1970s and the fishery began along the North Coast in the 1980s. However, variation around the 2% harvest rate would have been relatively small for the years of data that were included in the modelling (1994-2016).

The size of RSU at maturity and available to the fishery were confirmed to be 50 mm and greater than 90mm test diameter (TD), respectively. A relationship between RSU age and test diameter is not known, but one between jaw length and age is known, and it estimates that RSU can live over 100 years if not more (Ebert 2008). This jaw-age relationship cannot be converted directly to the test diameter at age. Age-at-length relationships used in traditional fishery exploitation models were not possible for RSU, the authors used a different relationship to model growth: the annul size increment versus the diameter of the previous year. This relationship was based on previous tagging work done on RSU that >20mm TD (Zhang et al. 2008).

Two points were tabled for a later discussion.

WRITTEN REVIEW AND COMMITTEE DISCUSSIONS

Written reviews

Written reviews were requested from Henry Carson, Ph.D. (Washington Dept. of Fisheries and Wildlife) and Rénald Belley, Ph.D. (DFO Science), who are both knowledgeable in the area of invertebrate stock assessment science. Their reviews were provided before the meeting and distributed to the participants before the CSAS review. Both reviewers expressed that the work was scientifically sound and well written; Appendix D (below) for their full reviews. The authors agreed to incorporate the minor editorial comments from both.

One of the reviewers brought up the effect of Sea Otter abundance on RSU populations and whether it should be incorporated into the models. The authors clarified that the fishery generally does not operate in areas where Sea Otters occur. They also suggested that predicting the recolonization rates would be helpful for FM and it was confirmed that this science advice has been requested from FM in the past. Adding a statement about the importance of conducting further work on Sea Otter impacts into the future work section of the document was suggested and the committee agreed.

Conversely, the RSU within urchin barrens were brought up with a suggestion to apply different exploitation rates to those areas. The authors clarified their advice, stating that it provides a broad range of harvest rates that will allow managers to be flexible in their decision making.

A reviewer noticed that the growth models for the North Coast and Haida Gwaii were not used in the simulation models and suggested clarification around those decisions was needed in the paper. The authors clarified that the growth models came from previous mark-recapture studies. The growth model fit to the survey length frequency data was good for the South Coast, but not for the North Coast or Haida Gwaii. They speculated that the mark-recapture data came from one location each, within the North Coast and Haida Gwaii, and likely did not represent those entire regions, whereas the survey length frequency data came from many locations within each of the regions. They further clarified that that South Coast growth model fit the three regions well and was therefore used for all the regions. The authors agreed to add more text into the research document to clarify their decision making process around this issue.

The effect of water depth on RSU densities was brought up in one review and briefly discussed. The authors stated that investigating this effect is of interest, but that ultimately it was beyond the scope of the work and they did not believe incorporating this effect would impact the final advice.

Of concern to one reviewer was the issue of sink-source population dynamics, especially in RSU populations within areas with Sea Otters. The reviewer questioned whether such sink populations were self-sustaining. The reviewer suggested stronger language in section “3.3 Reference Points” in regards to the linkage between the use of information on low density RSU populations within Sea Otter areas and the justification for the LRP. The authors clarified that the source-sink dynamics of RSU populations in British Columbia are unknown, but that populations of RSU with low abundances exist and persist within Sea Otter areas. They stated that within Sea Otter inhabited areas lower abundance populations of RSU tend to be cryptically located in cracks and crevices and are also found in areas where Sea Otters do not commonly go to forage They speculated that these pockets of higher density populations are likely to contribute to fertilization efficiency and post-dispersal recruitment success.

The persistence of RSU populations within Sea Otter areas led them to believe that successful spawning and fertilization events are happening in these areas of low abundance and that they could be used as a source of information to inform the LRP. The reviewer stated that an argument could be made that these low-abundance RSU populations within otter-inhabited areas may depend on the non-otter RSU populations. The authors stated that they believed they described this lack of knowledge about the RSU population source-sink dynamics in the uncertainties section of the paper, but agreed to include stronger language around the connection between these low abundance Sea Otter-inhabited RSU populations and the development of the provisional LRP.

The development of the USR based on doubling the LRP was discussed initially in the context of applying it to RSU populations within Sea Otter-inhabited areas, but the authors clarified that they based this doubling on previous work done with the Green Sea Urchin (GSU). They explained that unlike RSU, GSU data were available to develop biologically based reference

points. These data sets reflected boom and bust cycles in the populations and that the USR for GSU was close to the doubling range of the RSU LRP. Based on the outcomes of the GSU work and the lack of data on RSU, the authors believe that doubling the RSU LRP to create the USR was justified. They did acknowledge that this decision-making process needed to be better described in the text and agreed to do so.

The reasoning behind the interpolation of quadrats that were not sampled in section “3.4 Stock Status” was questioned and the authors clarified that this interpolation is only necessary when the quadrat spacing was not consistent. This happens in the field and using such data would give more weight to certain areas of the transect. The reviewer suggested discussing this in the paper and the authors agreed.

The differences in the RSU populations and outcomes of the models among areas was brought up as a curiosity and was discussed, specifically how different the South Coast was from all the other regions. Differences including harvest history and environment were brought up by the authors and the authors agreed to discuss reasons why the South Coast results may be different from the other areas in the paper.

One reviewer wondered if the authors attempted to simulate pulse recruitment in addition to the random generation of annual recruitment densities that was used in the paper. The reviewer noted that in Washington State, researchers have found evidence in the data of significant pulse recruitment with many years of near-zero recruitment in between, suggesting that pulse recruitment happened. The authors agreed with the reviewer, but stated that the autocorrelation of the recruitment needed to be investigated first and that was not possible for this work. The authors suggested putting this into the future work section of the research document and the committee agreed.

Concern over the interpretation of the model probabilities tables and their wording was brought up by one reviewer. The committee discussed the differences in how harvest rates are applied and developed among countries and clarified that DFO Science provides advice, but does not set the rates. The authors discussed the language around using the tables as the advice and provided ideas for the text to ensure that the reader was aware of the uncertainties and that the probabilities in the tables should not be taken literally and that they are advice on a range of harvest rate options.

The Natural Mortality (NM) rates used in the models were discussed, and a reviewer wondered why a size-dependent NM was not used. The authors stated that given the data they had, this would be difficult to estimate. They took a simplified approach in which the model seemed to fit the data well. They did, however, acknowledge that this simplification does not reflect exactly what is happening in the wild. The authors suggested adding this issue to the uncertainties section of the research paper.

Discussion

Assumption that the population is at equilibrium

A committee member brought up an assumption in the simulation models, that the RSU population is at equilibrium. This assumption was discussed in the context of it being a common assumption of fishery exploitation models and that it may need more explanation in the text, especially in terms of why it may be violated. The authors agreed to add more text about this issue, what it is, and the reason it may be violated into the uncertainties section of the research document.

Spatial scale of stock status assessment and harvest rate work

The issue of spatial scale was discussed in two contexts: (1) whether there was a bias in the spatial scale of the work and, (2) the appropriate spatial scale at which to assess RSU stock status using the provisional reference points developed. The authors explained the work on harvest rates was separated into three separate regions due to their geographic separation, which was explained in the research document. This was also done in order to provide advice that was relevant to these distinct geographic areas. They further explained that the objective of the LRP and USR work was to develop provisional points, not the spatial scale at which to determine stock status using these reference points. The data that these reference points were developed from came from fishery-independent data within geographic boundaries that were developed for salmon harvest planning, and are not biologically relevant to broadcast spawners such as RSU. These data were collected to inform fisheries management decision making to set quotas, not to biologically assess the population. The authors applied the provisional reference points to the three large geographic areas, reasoning that the RSU larval duration is long with the potential to spread great distances and that these data came from these specific areas, not the entire coast.

A discussion about how to describe the geographic areas in this work and the application of the provisional LRP and USR for stock status and harvest rate work ensued. Some committee members felt it was important that this work be applied to, and explained as, Sea-Otter free areas. Others felt that this limited the application of the provisional reference points, making it irrelevant if otters move into these areas. A committee member clarified that Sea Otters are already within these three, larger geographic areas. The chair separated the discussion into two relevant points: (1) the relevant description of the geographic areas should be applied to; and (2) how to deal with Sea Otter-inhabited and otter-free areas and whether including this information was relevant. The chair read the TOR to the committee to clarify that harvest rates were requested for Haida Gwaii, Mainland North Coast and South Coast Inside waters and that one LRP and one USR were requested for the fishery. The TOR was reviewed to see whether a direct connection to Sea Otters was in them and whether this was part of the requested science advice; no direct connection was found in the TOR. A discussion about how the fishery is managed, the relevance of Sea Otter presence and how to apply the reference points occurred. The authors clarified again that the objective of the work was to develop provisional reference points, the LRP and USR, not determine the spatial scale at which to assess stock status. The authors noted that the goal was to create single reference points for the fishery, not to assess stock status for the entire BC coast or create multiple reference points. A committee member agreed with the authors and believed one set of references points should be used for the entire fishery. The committee appeared to be at a standstill, but putting this issue of spatial scale and assessing stock status into a recommendation was suggested. A consensus was reached and the committee agreed that this issue should be added as future work.

Model fitting

Concern of over-parameterizing the models was brought up. The authors explained that the models were developed to answer specific questions and they believed the models they constructed did that well. They further explained that the model doesn't actually have a lot of parameters, but does have considerable data. They did acknowledge that they did estimate a few parameters, but they didn't feel it was over-parameterized. In terms of the model reflecting reality, the authors explained that the model estimates reality based on the information that is published. They explained that this was done with limited resources and time, and that models can always be changed, approached differently or modelled differently, but that their value is in whether they answered the questions at hand. The authors felt that the models did this well, and no further comments were made on the issue of over-parameterization of the models.

A committee member brought up two concerns regarding the model: (1) the model and (2) the implementation of the model. They further explained that they believed that the grid method for estimating parameter values was a very uncommon method, which has to be done manually, does not have parameter uncertainty and that there are may be correlations issues among parameter values. They suggested a Bayesian approach to estimate these parameters. They mentioned that getting large urchins in these models is persistent problem, that changing the mortality rate did not solve this and made them uncomfortable.

The authors justified the method used citing that it was used by Hilborn and Waters, very famous fisheries scientists. The authors went on to explain that what really matters is adjusting mortality rates for large RSU in the South Coast and that the growth models were a non-issue. They explained that if they used the original growth model parameters the same results would be produced. They agreed that a Bayesian approach was an option but that it takes lot of time and effort, but they believed they solved the problem with a practical approach that saved time. The chair summarized the authors rebuttal and asked if the committee if there were any objections to the model. Another committee member wondered if putting the model in a Bayesian framework could be a future goal. A discussion about whether this was worth the effort to resolve a small issue that occurred. The chair asked the committee if they thought a Bayesian model to select mortality rate was necessary. The committee member clarified he meant applying Bayesian methods to the implementation of the model. The authors asked if they meant changing the entire process of creating the model. The committee member explained they weren't sure about how to implement the model and suggested a Bayesian platform.

The authors explained that the estimated model parameters are based on length frequency data, which is a standard design for growth models and that they were not certain a Bayesian platform would provide a solid foundation to estimate mortality rates using these data. The chair asked if this issue was discussed as part of the technical working group involved in this work, and the authors responded that it was. The chair asked the committee if they believed this was a point of contention, if the work presented was scientifically defensible and unless there was any major point of contention on this that the committee should move forward with other discussions. The committee member understood and was satisfied their concerns were discussed. The authors confirmed the chair's statement was correct and that the technical working group, of which many committee members were a part of, chose this method based on resources and time constraints. Further, it was agreed to ahead of time. The chair asked if there were any objections of the method being defensible and agreeing that a discussion about its defensibility took place. No objections were brought up.

Underestimation of serious harm given non-marketable RSU are included in the modelling and subsequent probabilities

The authors explained that they believed the LRP should be based on spawning biomass below which there would be serious harm; the LRP should be biologically based. This is why they chose to examine various harvest rates on the entire spawning biomass. A discussion took place around the harvest rate probabilities, the size classes applied and the possibility of growth overfishing over time. A committee member pointed out that this may not be an issue, it depends on the question at hand. If the sustainability of the stock is of concern than this isn't an issue, but if the concern is sustainability of the fishery it may be a concern because over time (100+ years) the population might be dominated by 50-90-mm TD RSU. This could lead to size related fecundity issues, i.e. larger individuals are more fecund. Another committee member pointed out that parts of the model are randomly generated from past recruitment events, and that this isn't a concern. This member believed, the member that was concerned was looking for probabilities of the size range in the population. The discussion stalled and the chair asked the

committee if this was a contentious issue that needs to be dealt with. The committee did not object to moving forward to another discussion point.

Tanaka versus Logisitic growth models

A committee member brought up the different results in these two models for smaller RSU and wondered if this needed to be explained more in the text. They also wondered if the authors could help the managers decide between the results of the two models. The authors explained that the recruitment test diameter ranges were pretty consistent for the North Coast and Haida Gwaii, but not in the South Coast. In the South Coast the data there were larger proportions of very small and large RSU, but both models behaved the same way when RSU are > 30-mm TD. They further explained they did not know which model to recommend, because we don't have data for small urchins. Several committee members agreed with the authors approach to include both models in the research paper. The original concern was clarified, in that the committee member thought there should be more text in the paper explaining the differences. Another committee member suggested including a sentence regarding the probability of breaching the reference points relative to the two models. The authors agreed to do this in the document and consensus was reached on this issue.

Multi-species survey and its relevance to the research document

A committee member sought clarification as to why the multi-species survey was discussed in the paper with a referral to the RSU fishery. The authors explained that the survey is intended to address multiple species and that it was included in this work as a potential solution to address the issues around the lack of time-series data. It was also important to mention as the department moves towards precautionary compliance of the RSU fishery. A suggestion was made to reduce the text around this topic. Another committee member discussed how the department will be legally mandated through bill C-68 to monitor stock status and that currently that isn't possible for the stock status of the invertebrate dive fisheries. They went on to explain that assessing stock status of the dive fisheries is something that management has requested from Science and that Science believes this multi-species approach is a way to get there. A committee member explained that the content of the manuscript does not amount to working orders that management must comply to, and to clarify the concerns about why this shouldn't be placed in the manuscript. The concern mentioned was that it has not gone the CSAS process. A suggestion was made to include some text stating that the multi-species survey is the next step for monitoring stock status against the reference points. The authors believed this was captured in the document already, but other members suggested that the original recommendation was very broad and needed to be more focused. Another member suggested adding "develop a monitoring program" in recommendations #4. Three consensus decisions were made: (1) change some of the wording in paragraph 2 of pg. 21, (2) split paragraph 4 on pg. 19 into two paragraphs, (3) add specific language regarding the development of a monitoring program.

CONCLUSIONS

The committee concluded that the presented paper provides the appropriate development of provisional Lower Reference and Upper Stock Reference points for the Red Sea Urchin dive fishery, as well as, a suite of potential harvest rates with probabilities of breaching these references points based on the paper, the reviews and the proceeding discussions. The chair and rapporteur agreed to summarize the decisions made about paper revisions and to circulate it for any objections due to time constraints; none were subsequently made. The committee agreed that the paper did not need to be circulated to the entire committee again after the revisions were made. The research paper, its conclusions and scientific advice, were conditionally accepted pending inclusions of these recommended changes:

- Include Sea Otter abundance and recolonization rate models into the future work section
- Include explanation regarding why the RSU growth models didn't correspond well using the Haida Gwaii data and how it did not fit with the region's mark-recapture experiment when compared the other areas.
- Clarify the linkage between developing the LRP to sea otter-inhabited areas as a source of information of low population size/density.
- Explain how the GSU reference point work was used to justify of doubling the LRP to create the USR given the lack of similar data for RSU.
- Explain the rationale behind interpolating quadrat data and why it was a rare thing.
- Speculate why the South Coast results may be different from the other areas.? Add text on the potential reasons for the difference.
- Add text in the uncertainties section regarding the choice of a knife-edge change in the mortality rate as opposed to a gradual one.
- Discuss the differences between the Tanaka and Logistic model, especially at the smaller size ranges of RSU and among regions. Add a sentence around the probability of breaching the LRP and USR relative to the two models.
- Change some wording on para 2. Of p. 21: “multispecies survey” to “monitoring program”, split up paragraph 4 on page 19.
- Incorporate all other minor editorial changes in the both written reviews that were not discussed at the meeting
- Add investigating how these models might change if pulse recruitment was used instead of those randomly selected from the data distribution into the future work section.
- Recommendations:
    1. Set the coast wide LRP at 0.3 mature (≥ 50 mm TD) RSU/m_2 on RSU habitat.
    2. Set the coast wide USR at 0.6 mature (≥ 50 mm TD) RSU/m_2 on RSU habitat.

       Committee recommendation: Change (1) and (2) to “Recommend setting LRP and USR at 0.3 and 0.6 mature (>50mm TD) RSU/m/2, respectively, within RSU habitat”
    3. Consider probabilities of breaching Reference Points outlined in Decision Tables 12-23 to set regional RSU harvest rates

       Committee recommendation: change the wording and refer to the specific geographic areas in this work, not the entire coast: “Recommend consideration of the probabilities of breaching Reference Points outlined in Decision Tables 12-23 of the research document to set regional RSU harvest rates within Haida Gwaii, Mainland North Coast and South Coast Inside Waters regions”
    4. Develop a survey design and monitoring program for RSU that allow the collection of time-series abundance and size data, in representative areas of the coast, for use in population monitoring and stock status assessment.

       Committee recommendation: change wording to “Develop a survey design and monitoring program for RSU that allows the collection of time-series abundance and size data in representative areas of the coast for use in population monitoring and stock status assessments.”

RECOMMENDATIONS

RSU stock status is above the recommended USR of 0.6 mature RSU/m^2 (on urchin habitat) for all three regions combined (1.44 ± 0.07 RSU/m^2) and for each region individually:

1. Recommend setting the LRP and USR at 0.3 and 0.6 mature (>50mm Test Diameter) RSU/m^2, respectively, within RSU habitat.
2. Recommend consideration of the probabilities of breaching Reference Points outlined in Decision Tables 12-23 of the research document to set regional RSU harvest rates within Haida Gwaii, Mainland North Coast and South Coast Inside Waters regions.
3. Develop a survey design and monitoring program for RSU that allows the collection of time-series abundance and size data in representative areas of the coast for use in population monitoring and stock status assessments.

SOURCES OF UNCERTAINTY

In this identification of provisional Reference Points and harvest options for BC's RSU dive fishery, the sources of uncertainty that were not quantitatively incorporated include:

- The potential harvest rate analyses assume that:
    - the distribution of recruitment densities observed in the survey data reflects the year-to-year distribution of recruitment densities, for each region examined;
    - the population of RSU is in equilibrium. That is, the size frequency distribution and densities of the RSU populations are constant and do not change over time for each region of the coast; and,
    - the mortality rates applied to two different size classes and fitted to these models represents those of the RSU populations in the regions of interest and that these mortality rates are constant and do not change over space (within regions) and time.
- RSU along the BC coast form a meta-population. A stock-recruitment relationship cannot be defined for RSU in the traditional sense because planktonic larval duration is long, and recruitment to one location is unlikely to be linked to the reproductive capacity at that location. Without the ability to model larval movement, recruitment and settlement, it is not possible to determine which populations act as sources of larvae to other populations along the coast (Allen et al. 2018).
- Broadcast spawners such as RSU may be subject to both pre- and post-dispersal Allee effects (Allee 1931, Quinn et al. 1993). Low densities of adult RSU may cause the pre-dispersal effect of reduced fertilization efficiency (Levitan et al. 1992) (the model does not incorporate this).
- The data used to assess stock status were derived from the RSU survey program (Campbell et al. 1999; Leus et al. 2014), which was designed to estimate biomass at the PFM Area or Subarea level for the purpose of providing quota options, and not to provide representative data for the assessment of stock status. These data may not represent the entire metapopulation along the BC coast, because non-fished areas are not represented.

APPENDIX A: AGENDA

Canadian Science Advisory Secretariat (CSAS) Regional Peer Review Meeting (RPR)

The identification of candidate reference points and harvest rate options for the commercial Red Sea Urchin (*Mesocentrotus franciscanus*) fishery in BC

February 13, 2019
Nanaimo, British Columbia

Chair: Lyanne Curtis

DAY 1 - Wednesday

Time	Subject	Presenter
9:00	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
9:15	Review Terms of Reference	Chair
9:30	Presentation of Working Paper	Authors
10:30	***Break***	
10:45	Overview Written Reviews	Chair + Reviewers & Authors
12:15	***Lunch Break***	
12:45	Identification of Key Issues for Group Discussion	Group
13:00	Discussion & Resolution of Technical Issues, Results & Conclusions	RPR Participants
14:00	***Break***	
14:15	Develop Consensus on Paper Acceptability & Agreed-upon Revisions (TOR objectives)	RPR Participants
15:00	*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
16:30	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair
17:00	Adjourn for the Day	

APPENDIX B: LIST OF MEETING ATTENDEES

Last Name	First Name	Affiliation
Barton	Leslie	DFO Science
Belley	Rénald	DFO Science
Bureau	Dominique	DFO Science
Candy	John	DFO Centre for Science Advice Pacific
Carson	Henry	Washington Department of Fish and Wildlife
Christensen	Lisa	DFO Centre for Science Advice Pacific
Curtis	Lyanne	DFO Science
Fong	Ken	DFO Science
Frierson	Taylor	Washington Department of Fish and Wildlife
Hajas	Wayne	DFO Science
Hansen	Christine	DFO Science
Jones	Russ	Council of the Haida Nations
Krause	Geoff	Pacific Urchin Harvesters Association
Lee	Lynn	Parks Canada
Lochead	Janet	DFO Science
Obradovich	Shannon	DFO Science
Ridings	Pauline	DFO Fisheries Management
Thompson	Susan	DFO Science
Wylie	Erin	DFO Fisheries Management
Yakgujaanas	Jaasaljuus	Council of the Haida Nations
Zhang	Zane	DFO Science

APPENDIX C: TERMS OF REFERENCE

The identification of candidate reference points and harvest rate options for the commercial Red Sea Urchin (*Mesocentrotus franciscanus*) fishery in British Columbia

Regional Peer Review Process – Pacific Region

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Chairperson: Lyanne Curtis

Context

The Red Sea Urchin fishery in British Columbia (BC) is managed using an annual harvest rate of 2% (Leus et al. 2014). This harvest rate was derived using a modified Gulland surplus production model; a model used when a stock is data limited and in the early stages of exploitation. The model is simple and precautionary, however it carries an inherent uncertainty because it multiplies the estimated instantaneous natural mortality rate by an arbitrary correction factor of 0.2. The Red Sea Urchin fishery is not in the early stages of exploitation, rather commercial harvesting has been occurring for over 40 years and there has been almost 25 years of density and size data gathered on fishery independent surveys. Data from these surveys have been used to estimate growth and mortality rates for Red Sea Urchins in BC (Zhang et al. 2008, Zhang et al. 2011). The availability of a substantial amount of biological information warrants a re-evaluation of the 2% harvest rate derived from the modified Gulland model.

The existing Red Sea Urchin harvest strategy lacks a clearly defined set of biological reference points that reflect conservation thresholds under DFO's Sustainable Fisheries Framework (DFO 2009). Biological reference points are used in harvest strategies as quantitative conservation benchmarks from which management actions can be taken.

Fisheries and Oceans Canada (DFO) Fisheries Management requested DFO Science Branch to provide advice on the application of a range of harvest rates for the Red Sea Urchin commercial fishery. This Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will develop a new model that will simulate the response of Red Sea Urchin populations to a range of harvest rates for the following regions of the coast: the Inside Waters between Vancouver Island and the Mainland, Mainland North Coast and Haida Gwaii.

In addition, to assess whether harvest rates are sustainable and compliant with the DFO Precautionary Approach the concept of serious harm will be considered in identifying a Limit Reference Point (LRP) and an Upper Stock Reference (USR) for the Red Sea Urchin fishery. Density-based reference points will be recommended and the rationale for this approach will be reviewed.

The assessment and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will be used to update the British Columbia Red Sea Urchin fishery management framework. More specifically, advice will be used to establish reference points and update the Red Sea Urchin harvest rates implemented in British Columbia.

Objectives

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

Lochead, J, Zhang, Z., and D. Leus. The identification of candidate reference points and harvest rate options for the commercial Red Sea Urchin (Mesocentrotus franciscanus) fishery in British Columbia. CSAP Working Paper. 2016INV02

Guided by the DFO Sustainable Fisheries Framework, the following objectives for this assessment have been established:

1. Develop a new model that will simulate the response of British Columbia Red Sea Urchin populations to a range of harvest rates for the following regions of the coast: the Inside Waters between Vancouver Island and the Mainland, Mainland North Coast and Haida Gwaii.
2. Recommend a candidate Limit Reference Point and Upper Stock Reference consistent with the DFO Precautionary Approach for the Red Sea Urchin fishery.
3. Provide decision tables specifying the estimated probability of breaching the LRP and USR across a range of harvest rates, for the following regions of the coast: the Inside Waters between Vancouver Island and the Mainland, Mainland North Coast and Haida Gwaii.
4. Where possible, assess the current status of Red Sea Urchin populations relative to the candidate reference points for the following regions of the coast: the Inside Waters between Vancouver Island and the Mainland, Mainland North Coast and Haida Gwaii.
5. Examine and identify uncertainties in the data and methods.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document

Expected Participation

- Fisheries and Oceans Canada (DFO) (Ecosystems and Oceans Science, and Ecosystems and Fisheries Management sectors)
- First Nations
- Pacific Urchin Harvesters Association

References

DFO 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach. (Accessed December 19, 2018)

Leus, D., Campbell, A., Merner, E., Hajas, W.C., and L.L. Barton. 2014. Framework for estimating quota options for the Red Sea Urchin (*Strongylocentrotus franciscanus*) fishery in British Columbia using shoreline length and linear density estimates. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/094. vi + 68 p.

Zhang, Z., Campbell A. and D. Bureau. 2008. Growth and nautral mortality rates of Red Sea Urchin (*Strongylocentrotus Franciscanus*) in British Columbia. Journal of Shellfish Research 27(5): 1291-1299.

Zhang, Z., Campbell, A., Leus, D. and D. Bureau. 2011. Recruitment patterns and juvenile–adult associations of red sea urchins in three areas of British Columbia. Fisheries Research 109: 276–284.

APPENDIX D: WRITTEN REVIEWS

REVIEWER 1 - RÉNALD BELLEY, FISHERIES AND OCEANS CANADA

General comments:

- The purpose of the working paper is clearly stated.
- The data and methods are adequate to support the conclusions.
- The data and methods are explained in sufficient detail to properly evaluate the conclusions.
- The recommendations are provided in a useable form, and the advice reflect the uncertainty in the data, analysis, and process.
- The authors suggest additional areas of research at the end of the report. If these suggestions are implemented, they should allow to improve the assessment abilities in the future. In addition, adding a model of Sea Otters abundance for each region would be beneficial for long term predictions.

Methodology:

The new models proposed rely on data from 22 RSU fishery-independent SCUBA dive surveys (from 1994 to 2016), which is a considerable amount of time to follow the RSU population trends in each regions. Tanaka and Logistic growth models are adequate and natural mortality estimates are as precise as possible. The incorporation of the large RSU density on recruitment density is an excellent addition to the overall model which helps refine the estimates, precision, and predictions. Therefore, the model predictions under different harvest rate scenarios are reliable under the current conditions.

The reference points suggested are based on previous studies and on mature RSU (≥ 50 mm TD) which is more conservative. Moreover, they follow the Precautionary Approach and therefore seems appropriate for this species in each regions.

Interpretations:

The interpretations are factual and highlight clearly the most important points of the model predictions.

Recommendations:

Recommendations are reasonable and based on 22 RSU surveys and good models.

Additional comments:

- P. 9, point 7: Should probably define "*E*" here (harvest rate)
- P. 10, point 6: Replace "matrixes" by "matrices"
- Table 2: Replace "Large **SRU**-recruitment" by "Large **RSU**-recruitment"

REVIEWER 2 - HENRY CARSON, WASHINGTON DEPARTMENT OF FISHERIES AND WILDLIFE

Is the purpose of the working paper clearly stated? Yes. The title does a pretty good job right away.

Are the data and methods adequate to support the conclusions? In general, yes. I have attached some clarifying questions to the manuscript to assure the conclusions are fully supported. These include:

1. More information is needed to explain why growth models in two of the three regions were not supported by model fitting.
2. More information is needed to explain the proposed relationship between densities of RSU in Sea Otter areas and fishery reference points.
3. I'd like to discuss the choice to suddenly change the natural mortality rates 4 – 10 fold for urchins that have grown past the minimum legal size

Are the data and methods explained in sufficient detail to properly evaluate the conclusions? In most cases, Yes. I have added clarifying questions to the manuscript where they are not.

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

Yes. Tables 6 – 24 clearly show the predicted density and probability of breach for all three regions, both growth models, and multiple time spans. Decision-makers may request a recommendation from which growth model to manage, and also may interpret some tables to mean that a 24% harvest rate is sustainable – which may not be the intent of the authors. The discussion seems to address uncertainty adequately.

Can you suggest additional areas of research that are needed to improve our assessment abilities? I'm not sure what "is needed", but I can sure suggest additional areas of research

1. Investigate an Allee Threshold to use as a reference point instead of a proxy
2. Investigate changes in vital rates by depth
3. Why does the SC seem to behave differently than the other two regions? Is it simply its harvest history?
4. Experiment with forcing a pulse recruitment model instead of random selections from a distribution

Specific comments

Pg. 3, paragraph 3, line 1-4

I don't quite understand why spacing was different and where it was different

Pg. 5, paragraph 2 (below equations), lines 6-8

"However, uses of the growth models for the Price Island and Louise Island resulted in substantially poorer model fits to length frequency data (Section 3.3)."

I think more explanation might be needed here as to why the growth models didn't correspond well to their own region's mark-recapture experiment, and why the SCIW model did. Perhaps this is discussed in Zhang et al. 2008 already?

Pg. 6, section 3.2.3

However, uses of the growth models for the Price Island and Louise Island resulted in substantially poorer model fits to length frequency data (Section 3.3).

Pg. 6, equation 4, $DL_y<DL_o$

When population under harvest is less than the current population? I got lost here.

Pg. 6, 3.2.4

“We assumed that the TD distribution of the pooled data represents the distribution at the equilibrium state realized under the assumed harvest rate of 2% of the existing abundance for the region.”

Equilibrium assumption - could be discussed further here, or perhaps existing language in discussion section is sufficient.

Pg. 8, section 3.2.5

“We calculated densities of RSU within the recruitment TD range in each PFM Subarea and each survey year, using the survey data

Could remind of the year span again for clarity - 1996 - 2016?

Pg. 9, paragraph 1

“….pseudo RSU population in an area of 20,000 m2 (quadrats) to represent the current population in each region.”

There is no discussion of changes in TD by depth. We see dramatic ones in WA. I understand that biomass is calculated by linear m of shoreline, but some discussion of depth might be warranted.

Pg. 12, paragraph 2

“DFO’s Fishery Decision-Making Framework Incorporating the Precautionary Approach (DFO 2009), the LRP is defined as the stock status below which serious harm is occurring to the stock. The LRP is therefore meant to be biologically based. The framework notes that below the LRP, there may also be resultant impacts to the ecosystem, associated species and a long-term loss of fishing opportunities. Defining a LRP for the RSU stock in BC is challenging because current RSU abundance is believed to be unnaturally inflated. Historically, RSU populations were limited by Sea Otter (*Enhydra lutris*) predation. Sea Otters abundance declined due to the fur trade so that they were rare and probably ecologically extinct from BC waters by about 1850; with the last confirmed sighting in BC in 1929 (Cowan and Guiguet 1960). Following the extirpation of Sea Otters from BC, the abundance of RSU would have increased substantially (Riedman and Estes 1990) and a coast wide fishery developed. Current RSU populations are considered to be at historically high levels where Sea Otters are absent.”

I'm not understanding the connection between the density of urchins in otter areas and LRP or URP. You'd ideally base those points on Allee thresholds (which I get we don't know) or something similar. Perhaps you can spell out the logic a bit more. If it is the fact that RSU populations appear viable/persistent in otter areas, it might be argued that they wouldn't be if not for non-otter areas.

Pg. 13, paragraph 2

“The research studies presented in Table 5 spanned almost 50 years, from 1967 to 2014.

We could add data from our Neah Bay area (otter impacted) surveys, although the current lit review seems more than adequate without.

Pg. 14, paragraph 3

“Where RSU are not sampled in a quadrat, linear interpolation is used to estimate TD and density.”

Why was this necessary, as opposed to simply limiting analysis to the quadrats sampled?

Pg. 15, paragraph 5

“With a 24% harvest rate, both the Tanaka and Logistic growth models produce a 97% and 55% chance of the mature RSU density falling below the USR and LRP, respectively, in 100 years.”

I'm curious if another aspect of the SC makes it different than the other two regions, other than lower densities (and I assume a more widespread harvest history).

Pg. 16, section 4.3.1

There is evidence of significant pulse recruitment with many years of near-zero in between. Instead of random selections from the distribution, was any attempt made to simulate pulse recruitment?

Pg. 18, section 4.3.6

“RSU population trajectories in areas that Sea Otters recolonize is expected to differ from RSU population projections presented in this paper.”

Just curious - what would you recommend for harvest rate / management changes if you could predict the future and knew otters were going to colonize a new area soon.

Pg. 21, Recommendation 3

“Consider probabilities of breaching Reference Points outlined in Decision Tables 12-23 to set regional RSU harvest rates.”

I understand the need for transparency, but I would urge caution in language here. One interpretation of tables 12 - 15 is that you could harvest at 24% and be 97% confident of not breaching USR. We'll talk next week about what that result says about the whole exercise, I guess.

Pg. 29, Table 2

SC(Logistic)

The lack of consistency for SC under the two models really jumps out compared to the other two regions. Let's make sure this is adequately covered in the discussion.

Pg. 29, Table 2

Natural mortality rate.

I get that reducing M for sublegal sizes gave a better model fit, but I'd like to further discuss the implications of a 4 - 10 fold jump in this parameter at the legal threshold, rather than some more gradual adjustment with size.

References

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