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Proceedings of the Pacific Regional Peer Review on Recommendations on the design of a Multispecies Benthic Marine Invertebrate Dive Survey Program for Stock Monitoring

July 13-14, 2022
Virtual Meeting

Chairperson: Mary Thiess
Editor: Yvonne Muirhead-Vert

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

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Foreword

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

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on July 13-14, 2022, via the online meeting platform Zoom. The working paper presented for peer review focused on recommendations on the design of a multispecies benthic marine invertebrate dive survey program for stock monitoring along the coast of British Columbia.

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 (Pacific Region, Maritimes Region, and NHQ), regional Fisheries Management staff; and external participants from the Underwater Harvesters Association, Pacific Urchin Harvesters Association, Kitasoo/Xai'xais First Nation, Pacific Sea Cucumber Harvesters Association, and a consulting statistician.

The meeting participants agreed the working paper met the Terms of Reference objectives and was accepted with revisions. The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) providing advice to DFO Science on the implementation and monitoring of key benthic marine invertebrate species that aligns Fisheries management with the legislated requirements of the *Fisheries Act* and the regulations pertaining to the Fish Stocks Provisions.

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

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on July 13-14, 2022, via the online meeting platform Zoom to review the working paper entitled, “Recommendations on the Design of a Multispecies Benthic Marine Invertebrate Dive Survey Program for Stock Monitoring”.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Science. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from DFO Science, Fisheries Management, First Nations, and commercial seafood harvesters associations.

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

Lochead, J., Schwarz, C., Rooper, C., and Bureau, D. Recommendations on the Design of a Multispecies Benthic Marine Invertebrate Dive Survey Program for Stock Monitoring. CSAP Working Paper 2019SCI08.

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

The Chair reviewed the agenda (Appendix D) and the Terms of Reference (Appendix A) for the meeting, highlighting the objectives and identifying Yvonne Muirhead-Vert as the Rapporteur for the meeting. Meghan Burton was identified to capture the agreed upon working paper revisions for the authors. 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, 27 people participated in the RPR (Appendix E).

Prior to the meeting, Mackenzie Mazur and Joanne Lessard were asked to provide detailed written reviews of the working paper to assist everyone attending the peer-review meeting. Participants were provided with copies of the written reviews ahead of the meeting. The authors also received a number of informal reviews from colleagues in advance of the meeting and had a chance to consider these comments. During the opening comments, the Chair thanked participants who had provided informal comments in advance and noted that participants would need to ensure their questions and concerns were discussed sufficiently over the course of the peer review meeting. As such, these informal reviews were not explicitly raised at this meeting but were captured throughout the discussions.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to inform the ongoing implementation and development of the multispecies benthic invertebrate monitoring program and to align management of the benthic invertebrate fisheries with the legislated requirements of the Fish Stocks Provisions. The Science Advisory

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

GENERAL DISCUSSION

Following a presentation on the recommendations for the design of a multispecies benthic invertebrate dive survey (MSBIDS) by the authors, the two reviewers, Mackenzie Mazur (DFO Science) and Joanne Lessard (DFO Science), shared their comments and questions on the working paper. The authors were given time to respond to the reviewers before the discussion was opened to all participants. The 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. Both reviewers agreed that the paper met the TOR's objectives, and their formal reviews are located in Appendix C.

TERMS OF REFERENCE OBJECTIVE ONE

Depth ranges: A reviewer asked how much habitat was being excluded from the survey since many species such as Sea Cucumber are found at depths greater than the maximum depth of the survey. The maximum depth of the survey is 12.2m (40 ft) chart datum, which translates to a maximum actual survey depth of 19.8m at high tide in locations with the highest tide amplitudes. In DFO diving regulations, shallow dives are restricted to 18.3m (~60 ft) or shallower to promote safety while maximizing bottom time. In comparison, the depth range for single-species Sea Cucumber surveys are from 0 to 60ft at the time of the survey and does not account for tide height. The authors have agreed to add the maximum depths used in single-species marine invertebrate dive surveys, for each species identified, in the paper for context.

Fetch: One reviewer sought clarification on how much of the shoreline would be excluded from the survey given the recommended fetch cut-offs. The authors mentioned the high fetch cutoff is based on the upper 95% of fetch for marine invertebrate survey dives (total number of dives = 24,657) conducted in British Columbia (BC) and that it excluded less than 5% of the coast. Approximately 20% of the coast is excluded by the low fetch cutoff. Overall, the authors have estimated that ~24% of coast is excluded by fetch cut-offs. It was noted that all species of interest in the survey are found at fetch values greater than 20,000m which is 4.3 on the log scale in Figure 12 of the working paper.

Size classes: A reviewer noted that it was not clear what size classes and life stages are being captured with this survey. There was some concern that some size classes were being missed due to the fetch and depth cut-offs used in the survey design. The authors have agreed to add the size distributions to the paper (i.e., shell length, split weight). From the pilot survey data, it was determined that a representative range of sizes of animals for each species are being observed under the proposed survey design.

Survey timing: A number of participants wondered why the survey is scheduled in the month of September. They were unclear if the decision was based on biological or logistical factors. The authors explained that the pilot surveys were conducted in the month of September due to logistical reasons. September has relatively good weather and visibility, and it is also a good time for the availability of divers since it does not conflict with other dive surveys. The reviewer asked if visibility is recorded on the dive sheets and the authors confirmed that it was.

Clarification on sampling: The authors will add some text regarding the fisheries and their opening dates to add some context to the paper. Red Sea Urchin fisheries opens on August 1, the Green Sea Urchin fishery opens on September 1, and both are open year-round. The quota for these stocks is usually achieved during winter months. The Sea Cucumber fishery starts on October 1, and it is a relatively short fishery since the quota is usually achieved within 4-6 weeks of the opening.

A participant asked how the animals are counted when they are positioned on the edge of the quadrat. The authors explained that if an animal is more than ½ way in the quadrat it would be included in the count.

Data usage: The data could be used for a variety of purposes. It is important not to limit the use of the data collected from the survey at this time. Geoduck data collected from the multispecies dive survey could be compared with the single species survey. There is a benefit to have more than one abundance index for a species. The authors agreed the data could be useful for many purposes beyond informing stock status of the species that are currently identified in the paper.

For example, the data could be used to assess the status of *Pycnopodia*. At this time, there is no formal need for it, but since *Pycnopodia* have been recently listed as critically endangered by the International Union for Conservation of Nature (IUCN), the data could be formally required in the future.

One reviewer suggested the data could be used in an ecosystem-based approach for stock assessment models and the producer/consumer risk could be revisited over time. It was also noted that reference points could change in the future and the data collected could be useful for those updates.

Species habitat: Relationship data are being used for habitat suitability indices and species distribution models and this work is ongoing. The authors confirmed that they will continue to share data and work with habitat suitability index and species distribution modelers.

Community Index: One participant asked if it was possible to develop a community species index for those species seen but not recorded on the survey. They believed the data collected could be used to build indices of community complexity and diversity to monitor the environmental conditions (i.e., change in temperature, hypoxia, acidification) due to climate change. The authors indicated that it would be possible to analyze the algae data from the survey. They mentioned that there are some studies to look at the abundance of kelp and sea level rise. The authors mentioned that this survey was not designed as a biodiversity survey for invertebrates. The habitat mapping survey looks at the presence and absence of a large number of invertebrate species and those data would be useful for biodiversity analyses. During development of this survey, the authors considered how many species to include and what would be manageable in terms of data collection. It was felt that finding enough qualified divers that can reliably identify of all the species would likely be a limiting factor to the survey.

Quadrat size: In the working paper, there was a reference to a “strip quadrat” and one participant sought clarification on what it referred to. The authors explained that the strip quadrat refers to sampling between marks along the transect line and across a bar perpendicular to the transect. Single-species Geoduck surveys use 1 x 5m strip quadrats and sea cucumber single-species surveys use 2 x 5m strip quadrats. For Geoduck and sea cucumber surveys, each of the two divers survey on opposite sides of the transect line, so that the total transect width for these surveys is 2m and 4m, respectively. For the multispecies survey, the two divers work together on the same 1 x 1m ($1m^2$) quadrat delineated by an aluminium square. Using a quadrat size greater than $1m^2$ for a multispecies survey would not be practical or logistically feasible. Consequently, a $1m^2$ quadrat size was chosen for multispecies dive surveys to be consistent with DFO urchin and abalone surveys. The authors confirmed that they will clarify the wording in the working paper.

TERMS OF REFERENCE OBJECTIVE TWO

Relative abundance indices: Geoduck data from this survey are not directly comparable to data from the single species surveys. The data collected on the abundance of Geoducks is not accurate during September because the percentage of the total number of Geoduck siphons that are visible on the substrate (the “show factor”) is low. Also, Geoduck surveys are typically conducted on beds, so the location is different than what is being proposed in this working paper. It is likely that not enough of the proposed randomly placed transects will be located on Geoduck beds. Similarly, Abalone data from this survey are not directly comparable to single species survey results. The Abalone index site survey uses a Breen method while the multispecies survey proposes to use random transects. However, data collected for both species will still provide valuable complementary indices of abundance/associated information.

Green Sea Urchin: A participant mentioned there has been a coast wide population explosion with Green Sea Urchin possibly due to the removal of the predator *Pycnopodia helianthoides* with seastar wasting disease in 2013-2014, and they do not believe that the Green Sea Urchin index sites are fully capturing the dynamic situation as the population changes. They believe that more data is needed to make better management decisions regarding the stock. For this reason, the participant is supportive of the re-randomized transect approach instead of just using index sites. A combination of both approaches would likely assist with the management of the fishery.

One participant requested further clarification on why the MSBIDS can’t be used to determine stock status for Green Sea Urchin and what would be required to be able to do so. The participant was concerned that the density estimates would be taken out of context and the stock could be considered overfished. The authors explained that the reference points for Green Sea Urchin are relatively new and were developed solely from two high density sites on the south coast. In the future, it is possible for the reference points to be updated as more coast wide data become available. The authors have agreed to remove Green Sea Urchin from Table 8 where it was compared against the limit reference point (LRP) and then add wording in other tables, so the density estimates are not taken out of context.

Juvenile sea cucumbers: It may be worthwhile to note how well the survey detects cryptic juvenile sea cucumbers as the LRP includes both adults and juveniles. It is noted that in recent surveys more juveniles have been seen than in previous years. One participant asked if it was possible to add juvenile detectability as an uncertainty in the paper. It may be beneficial to show the proportion of juveniles out of the total number of sea cucumbers observed, for context. The authors also agreed to add summaries of split weight data, as individual sea cucumber weights vary considerably across the BC coast. A participant requested that a caveat be added that seastar wasting disease began in 2013-2014 while the multispecies survey started in 2016, which could explain why more small sea cucumbers are being seen (i.e., a main predator of juvenile sea cucumbers, *Pycnopodia helianthoides*, has had significant reductions in abundance, which may be contributing to a reduction in cryptic behaviour of the juvenile sea cucumbers). The authors were cautious on this point since there are no data from both before and after the onset of seastar wasting disease. The single species sea cucumber survey, however, would have the data from both before and after and could be used for this purpose, but it is out of scope for this paper.

The adult size is not clearly defined within the paper and the authors noted that they use the length of a specific type of pencil (15cm bensia pencil) to distinguish between juvenile and adult animals in the field. The authors indicated that counts of both juvenile and adult sea cucumbers are recorded on the datasheets and entered in the database. The authors agreed to check the analyses to ensure the sum of adult and juvenile densities are included in Figure 26. The authors did note that for sea cucumber, the single species survey uses a 4m x 5m quadrat and for the multispecies survey, a 1m x 1m quadrat is used to determine the biomass density.

Stratification: Stratification needs to be considered since variability in species densities may change depending on the region being sampled. It was agreed that stratification based on fetch, Sea Otter presence, substrate, or depth does not improve the variability estimates at this time. One participant suggested adding a recommendation indicating a number of variables that could be good candidates for stratifying the analyses in the future.

Structure of paper: It was suggested that the authors consider re-structuring the paper into two parts and placing the survey protocol into an Appendix. At times, the terminology was confusing to the reviewer so restructuring as proposed would resolve the majority of the confusion. The reviewer noted that the paper could be separated into two sections: the multispecies survey, and then the considerations to change the protocol moving forward, with each consideration addressed separately so the language is clear. It was noted that over the course of the meeting that participants identified a possible third section discussing the required number of transects and suggestions for dividing the BC coast into regions of suitable size to be surveyed during each field season. The authors were open to restructuring the paper as per the reviewer's suggestion. The paper could have a methods/results section for each part and then and overall discussion that would bring everything together.

Recommendations section: Within the recommendations section, one reviewer commented that there should be no recommendations on management decisions since this is a Science request and not a management request.

The recommendations are sound for the RPR. The data collected could fit within other frameworks for stock assessments in the future, although it is unclear at this time how the stock assessments may evolve in the future. It may be worth comparing data from the single and multispecies surveys in the same region in the future. The assessment framework and how the survey is conducted will likely evolve over time. One author agreed with this statement and mentioned that in order to be directly comparable, the two surveys (i.e., single species and multispecies surveys) would need to be at the same time of year with similar variables tracked. An author mentioned the sea urchin data collected in 2017 from the single species survey could be compared to the multispecies pilot survey since there was some overlap on where both surveys took place.

Current single stock surveys versus MSBIDS index: The MSBIDS is intended to develop a coast wide, unbiased abundance index for assessing stock status of a variety of species. The MSBIDS does not currently fit into the Biomass Assessment Frameworks for the species of interest; however, some of the biomass assessment frameworks could be adapted to include the MSBIDS survey data (e.g., for Red Sea Urchin and sea cucumber, MSBIDS could provide more up-to-date Pacific Fisheries Management Areas (PFMAs) densities and biomass estimates, which could potentially be used for quota calculations, or use to identify PFMA densities that have changed significantly since they were surveyed by a single-species survey, thereby identifying priority areas to be re-surveyed with the single-species survey).

Acceptance sampling: One of the authors provided clarification on why acceptance sampling was used in this paper and answered a number of questions regarding its use. A participant asked how the double sampling could be put into practice and asked for clarification on why the number of transects for the initial sample would be 19 for Green Sea Urchin and Red Sea Urchin and 39 for Giant Red Sea Cucumber, coast wide. The initial sample size is small so that stocks that are obviously above the upper stock reference (USR) or obviously below the LRP are quickly identified and additional sampling is only done on the stocks that are closer to, or in between, the reference point thresholds.

Another question was how the producer/consumer risks change since the invertebrate densities are highly variable along the coast. The sampling does not change the producer/consumer risks. The authors noted that you need to be careful when the density is close to the LRP or between the LRP and USR, because you need enough data to decide whether or not the stock is below the LRP. You can have small sample sizes when you are well below the LRP or well above the USR (see further comments under the section Terms of Reference Objective 3, Number of Transects).

Data collection in harvested and unharvested areas: A participant asked how harvested and unharvested areas are considered when determining stock status. The single species surveys focus on harvested areas, or areas being considered for reopening to harvest. The multispecies survey transects are randomly placed along the BC coast, regardless of harvested or unharvested areas, and as such, harvest status (of a transect site) is not considered as a stratification variable. Overall, the stock status applies to the stock as a whole, regardless of whether or not the surveyed area is being harvested or not.

One participant wanted to highlight the need for transects to be identified whether they were in harvested or non-harvested areas in order to obtain accurate density estimates. Data on the harvest locations are collected by the harvesters and they are required to submit them as a condition of licence. The location data are archived as shapefiles in a database and available for geospatial analyses. There are many different ways to look at data. The Pacific Fisheries Management Ares (PFMAs) could be used to indicate whether a transect is in an area that is open or closed.

With reference to recommendations 4 and 5 in the working paper, the transects will be randomized. There are many ways to randomize the transects that will provide good coverage.

Harvest options: It was clear in the working paper that the MSBIDS data could not be used to provide harvest option recommendations at this time. However, the MSBIDS data could potentially be used for providing harvest option recommendations for urchins and sea cucumbers in the future once sufficient data are collected and if there was a request to update the assessment frameworks.

Converting densities from m^2 and meters of shoreline length: One participant asked if there is an issue with converting the densities used in the paper from spatial densities (the number of invertebrates per meter squared) to the linear density (the number of invertebrates per meter of shoreline length). The authors explained that there is a different way of doing each calculation. The authors were more focused on the spatial densities which are the units needed to compare against the reference points. The spatial densities are not affected by transect length. It was also noted that shoreline length is a fractal number (i.e., will increase with increasing precision of measurement), so it does not provide a fixed value. However, for sea cucumbers, fisheries managers use a static estimate of shoreline length, so it is not always changing.

Producer/consumer risk and the value of K: The authors explained that when the density estimate is between the LRP and the USR, a decision rule is needed to know when to stop collecting data. The value of K is between the LRP and the USR and is considered to be a buffer. The rule is: if the estimated density is less than K then stop collecting data. For the double sampling plan, the value of B would be the buffer around K. It may be beneficial to add more text in this section of the paper to clarify this point.

The recommended number of transects could change since reference points could change over time or if a double sampling plan is used to collect the data. The recommended number of transects is a guide for the amount of sampling needed if a density estimate is between the LRP and USR. The sample size presented in the paper indicates that a lot of effort is required to make a good decision for Giant Red Sea Cucumber when the density estimate is between the LRP and USR.

Data collection in lower density sites: One participant asked how data is being collected in lower density sites on the coast. The authors provided an example of having an area of low density representing 10% of the coast, then you could place more transects there, and then weight the density estimate by 10% to determine a coast wide estimate with stratification.

Monitoring sites: A participant wanted to know how the survey would be operationalized and how the coast would be divided to logistically collect data over as few years as possible. The authors suggested that one option would be to sample 80 transects per year and complete the survey in three years to cover the entire coast and meet the recommended 241 transect target, an option that is based on the current level of funding and resources. Another participant asked how the coast would be divided. The authors indicated that it is out of scope at this time.

One author noted that if you are interested in a particular area then you could do a preliminary survey of 10-20 transects to get an early indication of whether the stock is likely below the LRP or above the USR. If these early results are inconclusive, then more sampling would be required. It may be worthwhile to add some text regarding this in the paper. The authors noted that it is outside the scope of this paper.

Supplementary material: The format and storage of the supplementary information referenced in Appendix 2 of the working paper was discussed since the Appendix currently contains a link that connects to an html file on Dropbox, and it was unclear how this would be maintained going forward. There was some discussion on whether or not the supplementary materials would be published with the working paper. In the end, it was determined that the authors would create a static copy of the html file and the underlying data used to generate the file could be stored using a GitHub or GitLab account.

TERMS OF REFERENCE OBJECTIVE THREE

Survey area selection and rotation: On Day 2 of the meeting, the authors presented some additional slides to provide a visual example of how the survey area could be selected and how the survey rotation strategy could be configured.

One participant asked what happens when there are eight blocks to sample in the North and two blocks in the South. The authors stated that the vessel could potentially sample the two southern blocks either at the beginning or the end of the sampling trip since the vessel is usually based out of Nanaimo or Victoria.

Sampling design: Sampling generally takes place in a 21-day trip, which works out to approximately 16 days of diving. This could result in 120 transects per year and a 2-year rotation, based on the current ship time availability and level of resources. If less ship time is available, then a three-year rotation may be necessary.

Another participant suggested using the five regions sampled over a three-year period. The regions could be identified by PFMA. A participant mentioned that a design that involved large areas and lots of distance to cover between transects, for example three weeks of moving every night, would be hard on the divers since it affects their sleep. This type of sampling plan would gather finer resolution data at the regional level and could enable calculation of regional reference points rather than contributing to coast wide reference point calculations. One author mentioned that the regions are somewhat arbitrary. You would want to consider their relative size when determining the number of transects in each region, or you could weight the regional density estimates based on the size of the regions to come up with a coast wide estimate.

A participant mentioned that the West Vancouver Island region is a different ecosystem from the Strait of Georgia. From an ecological standpoint, the survey could summarize the abundance indices from a coast wide, region, PFMA or a habitat level.

The authors noted that the variability in the density estimates did not differ by region, but the mean densities did differ by region. If one of the goals in the future is for finer resolution in the density estimates, then this would require a lot of sampling. It is likely you will need to do this by modelling. The authors noted that the policy guidance for C-68 specifies one reference point for each stock and the stocks of interest have coastwide ranges so stock status will be estimated coastwide.

Rotation of sampling plan: It was suggested the sampling plan could rotate every three years and this suggestion could be placed in the uncertainties section. Participants agreed it would be beneficial to include the slides (presented on day 2) in the working paper. The authors agreed and will also flesh out other examples of plans.

Another participant asked how robust the survey design is and if the survey could switch from a 2-year rotation to a 3-year rotation. One of the authors noted that the actual number of years in the rotation does not matter but changing the rotation schedule would make survey logistics challenging.

Transect length: One participant was unclear how the distance of the transect was measured. The authors mentioned that the transect starts at the shallow end and goes out to a maximum length of 125m or maximum depth of 12m chart datum. These parameters are related to logistical (maximum transect length that can be completed on a single dive) or safe diving limits for divers (maximum depth). The participant indicated it would be helpful if this was noted in the paper and the authors agreed to add this clarification.

Number of transects: One participant asked for clarification regarding the possibility of the reference points changing in the future and how it would affect the number of transects that would be needed to be completed. The authors clarified that the number of transects to be sampled could change if there was a change in the reference points. There was some concern that only one region would be sampled in a year due to the large number of transects which would confound the density estimates with inter-annual variation. The authors acknowledged that reference points could change as more data is collected over time and the survey may need to occur over a few years to cover the entire BC coast.

The working paper does not make a recommendation on the exact rotation schedule since the level of resources could change over time (i.e., level of funding, ship time availability and availability of divers). The authors agreed that the 241 transects is currently worded more as a rule and should be reworded as a guideline. The authors noted that the paper presents a worst-case scenario (i.e., 241 transects would be needed assuming the density fell somewhere between the current LRP and USR for Giant Red Sea Cucumber and the stated consumer and producer risk tolerances at 5% each). The number of transects required for the other species are lower.

The authors pointed out that it is easier to have a consistent approach of 241 transects over the 3-year timeframe to gain ship time and resources year-to-year than to have a smaller number of transects and then try to scale up. It is proposed in the working paper that 80 transects could be reasonably sampled on an annual basis so it would take three years for the entire survey to be completed. During discussions the authors suggested that it might be possible to complete 120 transects in a year and therefore the entire survey could potentially be completed in two years.

Survey frequency: The annual survey is currently conducted in September and this time frame should continue. The rotation of the survey could be over 2 years or 3 years and is dependent on ship time and the availability of other resources. The ship time should be linked back to the scientific advice. It would be ideal if the entire coast could be surveyed in the shortest interval possible to potentially detect local/rapid events (disease outbreaks, rapid population change, etc.).

Distribution of survey effort: The transects should be randomly placed throughout the survey area. The benefit of re-randomizing transects outweigh the statistical improvement in survey precision from using index sites, plus there are additional logistical challenges with index sites (e.g., it is very difficult to repeat the exact location of a transect).

Survey area: It was noted that there were discussions with First Nations regarding areas of interest when determining the survey area. The authors mentioned that some transects were sampled within the areas of interest however the transect locations were still randomly selected.

Statistics: A participant mentioned that the variables are not clearly defined in the equations of the working paper. The calculation of the standard deviation-to-mean ratio of 1.27 needs to be clearly defined early on in the paper. It was mentioned that the standard deviation-to-mean ratio of 1.27 for each transect would be applied for the entire area. The sample size will change depending on this ratio. In the supplementary documentation, it is explained how the sample size would change if the standard deviation-to-mean ratio changes.

Acceptance sampling: One of the authors provided an overview on acceptance sampling to help the group understand the underlying statistics for the proposed sampling plan. When the density estimate is between the LRP and USR, then the sample size would need to increase to maintain the predetermined producer/consumer risk tolerances. If you are well over the USR or well below the LRP, then a smaller size is sufficient, assuming you have an unbiased sample. When surveying a small geographic region, then you would need to manage the sample size the same way as coast wide. Based on results from the pilot surveys, it is assumed that the common coast wide standard deviation-to-mean ratio is 1.27.

Stratification: It was suggested the authors include a recommendation to consider other stratification variables (or combinations of stratification variables) as they become available at sufficient resolution for the whole coast in the survey design or data analysis. It was noted that this analysis only considered effects of stratification variables in isolation rather than with possible interactions and this could have masked the effects of the variables. Species distribution models, habitat suitability models, harvest status, or protection status would be beneficial when reconsidering the variables already evaluated.

Type 1 and Type 2 Errors: One participant asked why Type 1 and Type 2 errors were not included within the paper. One of the authors explained that these types of errors can change depending on your perspective. Using traditional hypothesis testing and power analyses will give the same answer as acceptance sampling. The acceptance sampling terminology is preferred because it provides a comprehensive assessment that is meaningful regardless of one's perspective (of what would constitute a false negative or a false positive result).

TERMS OF REFERENCE OBJECTIVE FOUR

Sea Otter occupancy: One participant was curious about dynamic variables such as Sea Otter occupancy and how it will be monitored in the future. The authors agreed that it may be a beneficial variable to continue to look at in the future. One participant indicated that officers on the bridge of the Coast Guard ships do document Sea Otter sightings and log marine mammal sightings. The Sea Otter occupancy data was obtained from the marine mammal survey section. Sea Otter data is not currently collected during the MSBIDS.

Abalone: Abalone data from the MSBIDS are not directly comparable to data from the abalone index site survey. One participant believes that the data collected from the MSBIDS would be a benefit since index site surveys have their own limitations. Results based on data from both surveys would likely give a more accurate density estimate of abalone for the entire BC coast.

One participant noted that two minutes seems quick to complete data collection within a quadrat and asked how that search time compares with targeted abalone surveys. The authors mentioned the two minutes was an estimated completion time and an average has not been calculated yet for the multispecies survey.

For comparison, the single species abalone survey uses the same size of quadrat, and it is estimated that each quadrat takes approximately four minutes to complete. For the multispecies survey, each quadrat takes approximately two minutes and thus, roughly 45-60 min to complete the entire transect. One difference between the two survey methods is that the divers physically remove the algae on abalone surveys (to better expose the substrate), and that takes some time. The MSBIDS data provides a good estimate for most sizes of abalone but will likely be not as robust for the very small ones (<5mm in size). The authors believe it will be a complimentary source of data on the density and distribution of abalone over time. Data for *Pycnopodia*, a predator of abalone, is also collected on a quadrat-by-quadrat basis during both the single species abalone survey and the MSBIDS.

Cryptic abalone: One participant suggested that the divers should take advantage of the opportunity to record observations of cryptic abalone while they are in the field since it seems to be a relatively simple thing to do. It could provide some additional information about cryptic occurrence. By collecting the data, it may ease some of the concerns about not having actual cryptic quadrats in the sampling design. The authors noted that data collected on an opportunistic basis may not be of great value since it would not be collected consistently. If the recording of cryptic abalone is not feasible at this time, then it could be flagged as a potential need for future work.

If, over time, there is an increase in abalone abundance then cryptic quadrats could be added in the future. Divers may not be able to turn over every rock within the quadrat because some are too large, so it could potentially lead to biased sampling. It would be important to come up with an unbiased way of noting cryptic behavior in the future. It would be beneficial to add some text in the uncertainties section regarding this. Data collected from the multispecies survey will be shared with the abalone monitoring program.

One participant asked how the survey will avoid bias in the presence of Sea Otters. It is known that cryptic behavior changes in the presence of Sea Otters. One participant noted that abalone will go down into crevices when Sea Otters are present. Data collection for these animals would be substrate dependent since divers cannot move large boulders during the survey. However, an author mentioned that data on cryptic abalone will still be collected during the ongoing Abalone Index Sites Survey.

Another participant asked if a correction factor for cryptic abalone would be added to the multispecies survey. The authors mentioned that this was out scope of this paper. That said, a conversion factor with substrate data could be potentially developed. Another participant disagreed with the use of a conversion factor for the cryptic individuals since there is too much year-to-year variation to determine a reliable correction factor.

TERMS OF REFERENCE OBJECTIVE FIVE

In addition to the future work identified under the previous TOR objective headings, the group also highlighted the following future work needs:

Oceanographic data: Participants suggested the collection of oceanographic data such as temperature, salinity, pH, and oxygen concentration when conducting the survey. The data collected may assist with the calibration and/or validation of other oceanographic and ecosystem models. It may be possible to capture temperature/salinity/pH variables using sensors while the dive is taking place. This topic has been discussed in the past and the data could be useful, however the dive takes only an hour at each site. It may be helpful to use data loggers maintained by the Institute of Oceans Sciences (IOS) to collect the data. The dive team would need to work with people who are familiar with the sensors and their deployment to review potential options. One participant thought salinity would be an interesting parameter to measure since it could show incremental variability and may signal a change in the environment.

Camera technology: One participant asked if it could be possible to use systems such as drop cameras, stereo cameras, and/or remotely operated vehicle (ROVs) to collect data. It might be good to integrate this technology into the survey. There are a few studies in the literature that speak to this integration of technology in dive surveys. The use of the camera equipment would be dependent on algae abundance and substrate type. It was mentioned that small animals may be missed with the use of cameras. Cameras do not see as many animals as the divers. Invertebrates are able to hide under algae and smaller rocks that divers can move, compared to cameras which have a fixed field of view. The results will also depend on the experience of the video annotator.

ROV data has not yet been used in the recent invertebrate species distribution models developed by DFO in the Pacific Region. One participant noted that it takes lots of effort to annotate the data (2-3 hours for every hour of video). It was suggested by another participant that cameras would be better suited at depths where divers are unable to work which could generate estimates that better represent the entire spatial range of each species.

The authors mentioned divers currently work in swell and high current areas where it would be hard to use an ROV. These work sites are better suited for divers and a link was provided to a recent paper on this topic. A comparison of underwater photo, video, and visual diver survey methods to assess nearshore algae and invertebrate communities was also provided to the participants for their reference.

Double sampling plan: One reviewer really liked the idea of a double sampling plan but noted that the paper states that it may not be feasible. They believed that it was premature to make this statement within the working paper. It was suggested that the sentence should either be removed or changed. It could be a topic that is discussed under the future work section.

The group decided that the detailed double sampling plan should be moved to an Appendix within the working paper since it is not logistically feasible at this time and the paper should focus primarily on the simple sampling plan. In the future, the double sampling plan could cover a large part of the BC coast, if another dive team and vessel were utilized at the same time. Another option would be to achieve buy-in from partners to use their vessels to assist with sampling during the same timeframe. At this time, it may be possible to utilize the double sampling plan for smaller areas but not coast wide.

Reference points: The authors reminded participants that the reference points for sea cucumber and Red Sea Urchin are for the entire coast and not just a specific (high density) region like for Green Sea Urchin. It was also noted that it was not within the scope of this paper to review previously established reference points.

Integration with other survey types: It was suggested that the data collected from the multispecies survey could be compared with other surveys (i.e., visual surveys, trawl surveys, single species survey, etc.). Comparative studies with single species surveys that occur at the same time and within the same area could potentially contribute to the re-assessment of species' assessment frameworks.

Technological improvements: The use of underwater calipers and other tools to improve sampling efficiency should be documented over time as any change in the use of technology could impact the interpretation of relative abundance indices over time. Currently, the dive team is recording metadata into a trip table when conducting the survey. As the survey evolves, the survey team needs to track changes on how animals are counted over time. The authors will need to work with the data unit on the type of data that is collected. It is acknowledged that the survey is a snapshot in time and will evolve as new technology becomes available.

REVISIONS AND RECOMMENDATIONS TO THE WORKING PAPER

The group was shown the revision table with all the revisions agreed upon by the authors. The author of the table reviewed it in detail with participants to ensure that everyone was in agreement and that the authors understood the requested revisions.

Survey timing: Currently, the pilot survey has been conducted in the month of September. If the timing is based only on logistics, then it would be better to change the timing of the survey to an ideal time now rather than after several years of data collection. The authors agreed to remove September as the survey month and only note that the survey should be done at the same time of year each year. One participant suggested that it is better to be less prescriptive here and to link the recommendation back to the science advice. All participants agreed the working paper and SAR should include a recommendation that it would be optimal if the survey was completed over the shortest interval as possible.

The authors mentioned the timing of the survey does not necessarily matter to them, but they would like to develop a standardized survey to be completed at the same time of year to develop the index. A different month could improve the index of abundance for Geoduck. However, if the survey remains in September into the future, the Geoduck index could potentially account for the catchability of Geoduck by using a correction factor.

Survey protocol: One participant suggested that the detailed dive survey protocol could be published as a standalone manual and to remove it from the CSAS document. However, one of the objectives of the Terms of Reference was to describe the methods used in the pilot surveys, so the authors agreed that the dive survey protocol will be included as an appendix within the CSAS paper. This way the appendix could be extracted as a standalone manual.

Coast wide assessment and survey rotation: The authors clarified that the areas sampled during the 2016-2020 pilot surveys will not necessarily be the same areas sampled in the future for long term monitoring. The areas selected for pilot surveys between 2016-2020 were intended to provide data from a range of habitats and regions on the BC coast to inform the recommendations made in the research document. The slides presented on Day 2 of the meeting are an important part of this paper since they further detail methods of obtaining an unbiased index of the coast by detailing options for portions of the coast to survey each year. The group suggested it would be helpful for the authors to make a recommendation on the area selection methods that could be feasible. All methods from the slides are feasible except for the simple random sampling plan (i.e., n=80 simple random sampling plan along the coast). It is not clear if it is within the scope of the paper to make a specific recommendation on area selection, but a potential next step could be to add a recommendation that has flexible wording. Participants agreed that a one-year rotation may be too ambitious, but the two-year rotation seemed feasible.

Lastly, the authors noted that the survey sites for this September have already been selected and the dive team is finalizing the sampling plan. It is possible the dive team may divide the coast into north/south division and use a panel design for the survey in 2023.

CONCLUSIONS

Meeting participants agreed the working paper satisfied all Terms of Reference objectives. The working paper was accepted with revisions.

RECOMMENDATIONS AND ADVICE

DRAFTING OF THE SCIENCE ADVISORY REPORT

One of the authors agreed to track changes on the draft Science Advisory Report (SAR) while it was being discussed with participants during the meeting. The SAR was discussed at length and participants had the opportunity to contribute to key sections. At the end of the meeting, a draft SAR was completed. The meeting chair will work with the authors to finalize the draft SAR. Once completed, 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, Mackenzie Mazur (DFO Science) and Joanne Lessard (DFO Science) for their time and expertise for providing their formal reviews of the working paper. We would also like to thank Mary Thiess for her support throughout the process and as Chair of the meeting.

APPENDIX A: TERMS OF REFERENCE

RECOMMENDATIONS ON THE DESIGN OF A MULISPECIES BENTHIC MARINE INVERTEBRATE DIVE SURVEY PROGRAM FOR STOCK MONITORING

Regional Peer Review – Pacific Region

July 13-14, 2022
Virtual Meeting

Chairperson: Mary Thiess

Context

Stock assessment dive surveys for benthic marine invertebrates (Northern Abalone, Green and Red Sea Urchins, Giant Red Sea Cucumbers and Geoducks) in British Columbia (BC) have historically been conducted as single-species surveys that estimate density and/or biomass in different portions of the BC coast in different years. The data collected through these surveys have been used to set quotas for their respective commercial fisheries and are generally not suitable for stock status monitoring. Although the Northern Abalone fisheries were closed in 1990 and listed as an endangered species under the *Species At Risk Act* in 2009, population monitoring surveys are ongoing as part of their recovery strategy.

Since 2016, Fisheries and Oceans Canada (DFO) Science has been working to develop a multispecies monitoring program to determine stock status of benthic marine invertebrates to ensure dive fisheries are compliant with the Department's Precautionary Approach Policy (DFO 2009), including the legislated requirements of the amended *Fisheries Act* (RSC 1985, c. F-14), and specifically, the regulations pertaining to the Fish Stocks Provisions. This new multispecies monitoring program is intended to provide fishery-independent, quantitative monitoring of stock abundance over time, in fished and unfished regions of the BC coast. The multispecies dive survey program will monitor abundance of Red, Green and Purple Sea Urchins, Giant Red Sea Cucumber, Northern Abalone, Sunflower Star, and likely only presence/absence of Geoducks given that the timing of the multispecies survey (generally September) is not an optimal time for assessing Geoduck abundance. This new monitoring approach is intended to enable DFO Science to determine stock status in relation to reference points for key benthic marine invertebrate stocks. The data collected is also expected to facilitate the incorporation of ecosystem considerations in Fisheries Management decision making.

To support the design and implementation of the new monitoring program, multispecies benthic invertebrate pilot surveys have been conducted on north and southeastern Vancouver Island, the mainland North Coast, southeast Haida Gwaii and the west coast of Vancouver Island from 2016-2021. There is now sufficient data to inform optimal survey design to meet multispecies monitoring program objectives over the longer term.

DFO Science has requested that Science Branch review and provide recommendations on optimal survey design for the multispecies benthic invertebrate monitoring program to ensure the surveys collect the data necessary to meet program objectives. DFO Science will summarize invertebrate abundance estimates, including associated estimates of variability, by species and region. This process is not intended to formally assess stock status at this time. The advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will be used to inform the ongoing implementation and development of the multispecies benthic invertebrate monitoring program and to align management of the benthic invertebrate fisheries with the legislated requirements of the Fish Stocks Provisions.

Objectives

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

Lochead, J., Schwarz, C., Rooper, C., and D. Bureau. Recommendations on the design of a Multispecies Benthic Marine Invertebrate Dive Survey Program for Stock Monitoring. CSAP Working Paper 2019SCI08.

The specific objectives of this review are to:

1. Describe the methods used to collect multispecies benthic invertebrate dive data during the 2016-2021 pilot studies.
2. Summarize benthic marine invertebrate abundance and its variability by species and region for the 2016-2021 pilot surveys for Red, Green and Purple Sea Urchins, Giant Red Sea Cucumber, Geoduck, Northern Abalone, and Sunflower Star. Note any gaps or uncertainties arising from the design and/or implementation of the pilot studies.
3. Make recommendations on optimal survey design considerations such as survey effort (number of transects), survey frequency, distribution of survey effort (random, index sites, panel design), etc.
4. Make recommendations on types of environmental data that would inform relevant survey stratification and/or strengthen the interpretation of the species abundance results (e.g., Sea Otter, *Enhydra lutris,* presence/absence, occupancy time, fetch, etc.)
5. Identify knowledge gaps and key uncertainties that could be addressed to further improve the survey design.

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)
- Parks Canada
- First Nations
- Pacific Sea Cucumber Harvesters Association
- Pacific Urchin Harvesters Association
- Underwater Harvesters Association

References

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

APPENDIX B: WORKING PAPER ABSTRACT

A new multispecies benthic invertebrate monitoring program is being developed to quantitatively monitor stock abundance over time on the BC coast. This dive survey is designed to monitor abundance of Green (*Strongylocentrotus droebachiensis*), Red (*Mesocentrotus franciscanus*) and Purple (*Strongylocentrotus purpuratus*) Sea Urchin, Giant Red Sea Cucumber (*Apostichopus californicus*), Northern Abalone (*Haliotis kamtschatkana*), Sunflower Star (*Pycnopodia helianthoides*) and Pacific Geoduck (*Panopea generosa*) populations, and also collects detailed habitat information on substrate and algae. The survey protocol was developed in 2016 and is described in detail. Pilot surveys were conducted in different areas of the coast from 2016 to 2021. Data from these pilot surveys, along with data from single-species surveys (1978 to 2021), were analysed to make recommendations on optimal survey design for the new monitoring program. The methods included reviewing single species analyses that informed sampling intensity on transects, looking at historic maximum transect lengths, investigating stratification variables, and using an acceptance sampling method to determine the minimum required number of transects, given predefined risks and certainties associated with being above or below reference points. In addition, densities of the Giant Red Sea Cucumber and size and habitat subsets of Red Sea Urchin populations were estimated as an example of how these data could be used to assess stock status in the future. The recommendations on survey design were to: 1) continue dive survey protocol described in this document and with the quadrat skipping sampling scheme that is dependent on transect length with a maximum transect lengths of 125 m; 2) continue scheduling multispecies dive surveys in September to avoid introducing seasonal variability in the data; 3) select sections of shoreline with fetch values between 20,000 m and 2.52 million m for transect placement; 4) conduct at least 241 transects coast wide prior to conducting a coast wide stock assessment; and 5) re-randomize transects on each visit.

APPENDIX C: WORKING PAPER REVIEWS

Fisheries and Oceans Canada

Canadian Science Advisory Secretariat (CSAS)

Regional Peer Review Process - Pacific

Written Review

Date: 30-June-2022

Reviewer: Mackenzie Mazur

CSAP RSIA: **2019SCI08**

Working Paper Title: **Recommendations on the design of a Multispecies Benthic Marine Invertebrate Dive Survey Program for Stock Monitoring**

The questions in the template are addressed but to reduce redundancy, topics are referred to in bold throughout the template. Those topics are then elaborated on after the questions in the template.

Is the purpose of the working paper clearly stated? Does it meet the TOR objectives?

The paper does a great job of stating the purpose and meeting the TOR objectives. The purpose of the working paper is clearly stated: “to review the 2016-2021 pilot data and make recommendations on optimal survey design for the long-term, coast wide monitoring program”. The paper does meet TOR objectives, but additional clarification and discussion would be beneficial. The methods were described in detail. However, some clarification would be beneficial (**survey area, fetch, clarification on sampling, survey month**). Benthic marine invertebrate abundance and its variability were summarized, stratification was analyzed, and five recommendations were stated, but additional uncertainties can be discussed (**number of transects, size classes, data usage, survey area, stratification**).

Are the data and methods adequate to support the conclusions?

The analysis is sound, thorough, and supports the survey recommendations. The dive survey protocol is modified based on the previous dive surveys and justified with the analysis presented in the paper. The dive survey is recommended to be conducted in September to avoid seasonal variability. The survey is recommended to have fetch cut-offs due to dive safety, feasibility, and species abundance. The survey is recommended to have 241 transects spread over multiple years due to the required sample size from the analysis. Transects are recommended to be re-randomized each trip instead of index sites, and the analysis supports this conclusion.

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

The data and methods are explained in detail, but some parts could benefit from some clarification and discussion (**see all sections below**).

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

Recommendations are provided in a clear, useable form numbered 1-5. Although uncertainty around some of the conclusions are discussed, there are some topics that could be further addressed in the discussion section (**number of transects, size classes, data usage, survey area, stratification**).

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

There is always more research that can be done related to survey design and our resulting assessment abilities. Some additional areas of research include ecosystem-based approaches, distribution modeling, catchability/selectivity, stock assessment models, and consumer and producer risks (**ecosystem-based approach, survey area, catchability and selectivity study, stock assessment models, producer and consumer risks**).

Number of transects

The number of transects seems dependent on the sea cucumber reference points and how close the LRP and USR are to each other. A discussion on these reference points and if they may change would be useful. Are the reference points estimated with data from the previous survey appropriate if the previous survey was not suitable for informing stock status? Also, the number of transects requires that only one region be surveyed each year. Surveying different regions of the coast each year poses challenges when using the data for coast wide statuses. The survey may not capture annual variation that is occurring in one region but not others. Even if the species is long-lived, recruitment can be variable and local and not captured in a multi-year survey. Local high or low recruitment events may violate the assumption that averaging three years of data across three different regions produces a coast wide density for determining stock status. So, the survey design may not be robust to variability in recruitment events. Not detecting high or low recruitment events could be detrimental by resulting in a loss in catch and/or an overexploited stock. This poses the trade-off of precision vs. accuracy. Sampling more transects in a given region may be precise but biased due to potential regional effects. Sampling less transects per region but over a larger area provides accurate but less precise estimates. This discussion could be added to the paper.

Size classes

Plots on length compositions would be helpful to understand if all size classes/life stages are detected in the survey (i.e., the selectivity of the survey). It seems that small abalone might not be. What about the other species? Are some size classes missed by not surveying below a fetch of 20,000 m? It would be helpful to clarify the length compositions of each species found under fetches of 20,000 m. The same can be done with depth.

Fetch

Survey areas had minimum and maximum fetch values, which may limit the amount of habitat that is surveyed. Is some habitat missed by not surveying below a fetch of 20,000 m? Was there a species density threshold used to determine the low fetch cut-off? It would be helpful to clarify this or show the proportion of each species found under fetches of 20,000 m. One way to do this would include adding a line at a fetch of 20,000 m in Figure 12. Also, how was the 26 m buffer determined for fetch points?

Depth

Minimum and maximum depth were chosen based on past surveys and for dive safety reasons, but it would be helpful to understand if the species may be abundant outside of the survey depth range. Red sea urchin, sea cucumber, and geoduck may have habitat deeper than the transect according to Figure 21. Are these species found below 12.2 m in fisheries and/or trawl surveys? Are abalone found shallower than -2 m in fisheries? How often does the maximum transect length occur before the maximum depth is reached?

Stratification

I agree that the stratification variables explored would not benefit the results by pre- or post-stratification at this point. However, for future work on stratification a discussion around what variables would be the most feasible to stratify with would be helpful. It is also possible to stratify by more than one variable. Static variables that differ among transects and not along a transect seem to be the most feasible and useful for stratification. Dynamic variables such as sea otter occupancy would be more difficult, especially since the last year of observations seems to be in 2009. It seems like there was not much occupancy up until 2009. Sea otter occupancy varies overtime and may have changed since then. There are also areas covered by the multispecies survey that are not covered by the sea otter survey. Also, how were the fetch stratum cut-offs determined?

Survey month

The pilot surveys have been conducted in September. However, it is not clear why September is the best time to conduct the survey. Geoducks are not as visible in September. What about the behavior of the other species? How close is the fishing season to when the surveys are conducted? Does this vary by species?

Clarification on sampling

Some parts of the survey protocol were not entirely clear. The protocol for when sea cucumbers are at the edge of the quadrat is clear, but what about if geoducks, abalone, or *Pycnopodia* are on the edge of the quadrat? Or are these species not long enough for this to be an issue? Was visibility recorded on the data sheets? How are the regions surveyed determined each year? A description of the rotation of areas to be surveyed each year would be helpful.

Data usage

The survey informs stock status for only two species. This survey could also provide additional indices for stock status for the other species surveyed. The data from this survey could also be used to expand other survey areas or as an index of abundance. For example, although geoducks are not that visible in September, the geoduck density estimates from the multispecies survey could be used as an additional index along with the index from the geoduck survey to estimate stock status. The index from the multispecies survey would have a lower catchability than the index from the Geoduck surveys. Geoduck data from the multispecies survey can also inform where the geoduck survey may need to expand.

Also, if the LRPs and USRs that the densities are compared to are based on the previous surveys, which were not suitable for determining stock status, is it likely that the reference points are suitable for determining stock status? It seems that green sea urchin reference points are not suitable, but what is different about red sea urchin and sea cucumber reference points? More information on how these reference points can be used at the coast wide level would be useful.

Survey area

Additional clarification on the survey area would be beneficial. The survey areas were collaboratively identified through fishery footprints and engagement with First Nations. How were the areas of interest identified through engagement with First Nations different than the fishery footprint? The species may be in other areas at lower densities. Collecting data at those lower densities can improve our understanding of population dynamics and spatial variation of the species.

Data collected on surveys should be reviewed regularly to provide insight on whether the survey is capturing habitat for each species. The survey locations may not be capturing the whole habitat for each species. Without information on habitat variables and species-habitat relationships, it is difficult to determine species habitat. Further research on species habitat could inform the survey design moving forward as more data are collected and species habitat is better understood. The survey area may need to be expanded to cover more of the species habitat. Data from the multispecies survey but possibly also the trawl surveys (presence/absence) could be used in species habitat research. Species distribution may also change with climate change. I recommend including a description on the impacts of climate change regarding water temperatures and each of the focus species. After more data have been collected and species habitat is more understood, survey area could be revisited.

Ecosystem-based approach

The paper discusses that this survey will contribute towards an ecosystem-based approach to stock assessment and fishery management, but there is not a description on how the survey data can be used towards that effort. Future research can use the survey data to inform species-environment relationships for models that support an ecosystem-based approach.

Catchability and selectivity study

Future research could include more search time on quadrats to understand the catchability and selectivity with a shorter search time. For example, some quadrats can have more search time to find the small abalone and then the selectivity differences between search times can be compared. The same can be done with cryptic sampling for small boulder and/or cobble habitats. This can also provide insight on the differences in catchability among substrates. There may also be differences in catchability among survey areas and through time due to visibility.

Stock assessment models

These data collected through the survey can be compared to the reference points directly, but these data can also be used in stock assessment models. This comprehensive coast wide survey can be very informative for stock assessment models in the future.

Producer and consumer risks

Producer and consumer risks could be revisited for each species. There may be different risks for different species, and these risks may change overtime.

Fisheries and Oceans Canada

Canadian Science Advisory Secretariat (CSAS)

Regional Peer Review Process - Pacific

Written Review

Date: July 3, 2022

Reviewer: Joanne Lessard

CSAP RSIA: **2019SCI08**

Working Paper Title: **Recommendations on the design of a Multispecies Benthic Marine Invertebrate Dive Survey Program for Stock Monitoring**

1. Is the purpose of the working paper(s) clearly stated? Does it meet the TOR objectives?

The objectives of the paper are clearly stated. The purpose of the paper needs to be 'clarify' in the intro – there are several species as target for the Multispecies survey (MS), but only 2 are considered for stock status purpose: "The survey is designed to monitor abundance of Green, Purple and Red Sea Urchins, Giant Red Sea Cucumber, Northern Abalone, Sunflower Star and Geoducks. The survey will also collect detailed habitat information on substrate and algae. The multispecies survey is intended to enable DFO Science to determine stock status in relation to reference points for Giant Red Sea Cucumber and Red Sea Urchin." P11. While the reasons are throughout the document, these 2 sentences together really begs the question of why look for 7 species, but only use the survey for 2.

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

Yes, for just about everything except perhaps rotation cycle and regions surveyed (see below; in this case, the data and methods may be adequate but the conclusion is ambiguous).

I was surprised that none of the variable tested to stratified the methods improved the CV by much or if it was, (e.g.) the increase in precision didn't outweigh the increase logistics. However, post-stratification could still be considered for depth. Obviously this would differ for each species which is why it's not useful to setup a whole survey.

Higher cutoff for fetch should be considered given that the majority of transects from all dive surveys are in areas where fetch is >300,000. Not sure this is needed for this paper as Fig 12 show that it probably couldn't be used for pre-stratification. Perhaps something to explore in future work, especially for abalone, RSU and PSU.

I particularly like the idea of the double sampling plan. I know we can't do that just yet, but we are close! This is not something that I would have thought possible 10 years ago (or even further when we were copying underwater data onto keypunching sheets at night after a full day of diving). In the discussion, there is a statement that double sampling may never be feasible: "A further issue with a double sampling plan is that ideally the reduced sample would come from a very broad geographic area (i.e., covering the whole coast), not just one region, making it not logistically feasible." I think the analyses of how many transects are enough could be repeated for each region as variability is not the same for all region for all species or in this case, cuke which is the species that requires the most transects to achieve the precision needed to have low risks (at the moment a single sd:mean ration is used, the famous 1.27 value). More data from the MS protocol may be necessary to perform this analysis, so I'm not suggesting that it should be done now. Perhaps after the next rotation? Since cuke seems to be driving the number of samples required, the analysis could using cuke data only for each region. See future work section below.

There needs to be some clarification on the rotation and/or the number of regions surveyed. In the discussion: “the coast could be divided into three regions with at least 80 transects conducted in each region.” So what is it that you are suggesting? You surveyed 5 regions. A rotation of only 3 or rotation of 5 regions with stock status evaluated every 3 years? You would drop 2 regions? How is that coast wide then? This implies that an additional recommendation is needed that is explicit on how many regions are surveyed over how many years and on how many years are used to determine status.

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

In some areas there are too much details for a CSAS paper. In others, there needs to be a few more words to explain how the calculations are done and how to interpret some of the results. I think a restructuring of the paper would help with the too many and not enough as well as the confusion that comes from using similar terms in different contexts (e.g. sd:mean, SD vs SE vs variance which seemed to be interchanged through the document, but not really –can’t we have SE or SD and not both?). I suggest separating the survey protocol and putting all those details in an appendix. The protocol can be described briefly in the main body of the paper. Separation would also avoid some of the confusion of which results go with which survey methods (as ‘historical’ surveys were also used to inform some of the decisions about the MS protocol going forward). I suggest separating the paper in 2 parts:

1. MS survey history, protocol used and survey results
2. Considerations to change or keep the protocol moving forward

In the 2nd part, each considerations should be kept separate and whole – i.e. describe the methods used to look at that consideration and present the results or what was learned in the same section.

The initial protocol was based on some field testing (mostly to see if it was feasible), but it was really the result of discussions between experienced divers. One of the purpose of this paper is to assess if the design was successful and to seek improvements. Hence the 2nd part – which was done after the fact (I know some of it was explored in the last few years but still, after the fact – the protocol probably wasn’t changed on purpose so that we could compared regions).

There are some variables in equations that are not defined (see comments in doc).

In methods under ‘expected precision’, it is ‘stated’ that the sd:mean ratio of 1.27 will be used but it doesn’t match the text above. The value comes from section 3.1.3 in results. Some text needs to be added here to at least refer to where the value comes from (see comments in doc).

The equation in section 2.1.9 is missing after: “The gain in efficiency if all transects are replicated in each of two years, called the design effect, was calculated as follows:” or is this sentence not supposed to be there since DE is calculated a few equations later.

I can’t find Figures 26 & 27 in the results or how the densities from MS surveys are above USR or that there is no difference between closed and opened areas in Gwaii Haanas. These are interesting results as they show how the MS survey can be used and should be highlighted. These are in the discussion but those results are not presented.

The equations should be numbered so that sections that use the same equations can refer to an equation number. I think this will become necessary if the paper is restructure as suggested above.

The tables embedded in the text need titles. Some of the tables and figures at the end of the doc need more explicit titles (see comments in doc). I think they should be embedded within the text, especially considering that some tables are in the text (all without titles) and others are at the end. Ensure tables and figures are numbered in the order they appear in the text.

Consistency of region/location naming should be considered – trip 1-6 is confusing. In particular, which region trip 1-6 represent is not described in the title of the tables embedded in the text and most of the text & tables/figures at the end of the doc use a name (e.g. North Coast BC) or a year for a given survey. I don't particularly like the trip ID – and I know acronyms are not popular anymore, but to put some of the results in context (e.g. sea otter occupation), we need to know where the survey took place.

The discussion needs more flow – paragraphs don't always flow the previous paragraph. I think some headings would help with organizing ideas/discussion points together. I suggest a short discussion on the MS survey results – although it would be nice to know how they compare single-species survey densities (e.g. I was surprised at GDK densities from the MS surveys – I expected them to be much lower given that MS surveys are not necessarily targeting GDK habitats. Are they in fact high – discussions with authors indicate that they're not, which can lead to more support to continue single-species survey in some case.). Most of the discussion should focus on the considerations explored for design improvements – so heading should match the headings in part 2 (assuming the restructuring as suggested takes place).

Be careful how you use "small" and "large" scale – I suggest using fine and broad instead to avoid confusion (see comment in doc).

I have made suggestions throughout the document in Word. Please take my comments with humour, many are intended that way.

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

Well this was a Science request… It does not provide advice to management, but I think the CSAP process could. I think with the results presented in the paper, we can go further and recommend that this protocol can be used for stock assessment of RSU and RSC – i.e. not just stock status using LRP and USR. This would probably require further analyses and a different assessment framework. I also think that this protocol could be used for other species, notably abalone and green urchin after a comparison of the methods currently in use for these species is completed.

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

There is now a RSU SDM coast wide – stratifying using high, medium and low probability of occurrence should be explored.

I think that there is time to evaluate if the double sampling would be feasible for each region. The analysis at the moment is coast wide, but stock assessment (not stock status) requires region-based estimates. As 241 are necessary coast wide for cuke over 3 years which means 3 regions (although see comment above on regions/rotation conundrum) and that catastrophic events could be lost if only considering coast wide status, an evaluation of region variability and how many transect are necessary by region to have low risks should be completed. This may mean that some regions require more transects than others. It would be interesting to see a similar analysis using the single-species survey protocol and how this compares.

See comments above about fetch post-stratification for abalone, RSU & PSU as well as the comparison of densities from different survey protocols (e.g. abalone and GSU where index sites are used – for abalone, Campbell et al. 2000 [MS report 2528] and Campbell et al 1998 [CSAS res doc 1998/89] looks at random sites compared to historical index sites to see if index sites based harvesters advice were different than surrounding areas [the answer was no]; it would be interesting to see if variation on index sites was less than on random sites. The variation on either groups might have been too high to detect differences between groups. In theory, since index sites were selected to be all good fishing grounds, i.e. high habitat quality, the variation should be less than with random sites where presumably a range of habitat quality are found. In other words, the data from 1997 and 1998 could be reanalyzed using some of analyses used in this doc.).

APPENDIX D: AGENDA

Canadian Science Advisory Secretariat

Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Recommendations on the design of a Multispecies Benthic Marine Invertebrate Dive Survey Program for Stock Monitoring

July 13-14, 2022

Virtual

Chair: Mary Thiess

DAY 1 – Wednesday, July 13, 2022 (All times below in Pacific Standard Time)

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	Overview Written Reviews con't	Chair + Reviewers & Authors
1430	Identification of Key Issues for Group Discussion	Group
1445	***Break***	
1500	Discussion & Resolution of Technical Challenges, Results & Conclusions	RPR Participants
1530	Develop Consensus on Paper Acceptability & Agreed-upon Revisions (TOR objectives met; Revisions Table)	RPR Participants
1600	Adjourn for the Day	

DAY 2 - Thursday, July 14, 2022

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

APPENDIX E: LIST OF PARTICIPANTS

Last Name	First Name	Affiliation
Araujo	Andres	DFO Science
Armsworthy	Shelley	DFO Science, Maritimes
Atkins	Mike	Underwater Harvesters Association
Bureau	Dominique	DFO Science
Burton	Meghan	DFO Science
Campbell	Jill	DFO Science
Christensen	Lisa	DFO Centre for Science Advice Pacific
Colclough	Carley	DFO Centre for Science Advice Pacific
Featherstone	Mike	Pacific Urchin Harvesters Association
Fong	Ken	DFO Science
Ganton	Amy	DFO Fisheries Management, Sustainable Fisheries Framework
Hajas	Wayne	DFO Science
Hankewich	Sandie	Kitasoo/Xai'xais First Nation
Hansen	Christine	DFO Science
Howse	Victoria	DFO Science, Maritimes
Krause	Geoff	Pacific Sea Cucumber Harvesters Association
Lessard	Joanne	DFO Science
Lochead	Janet	DFO Science
Mazur	Mackenzie	DFO Science
Mijacika	Lisa	DFO Fisheries Management, Invertebrates
Muirhead-Vert	Yvonne	DFO Centre for Science Advice Pacific
Obradovich	Shannon	DFO Science
Ridings	Pauline	DFO Fisheries Management, Invertebrates
Rooper	Chris	DFO Science
Schwarz	Carl	Stat Math Consulting
Thiess	Mary	DFO Science, National Headquarters (NHQ)
Wylie	Erin	DFO Fisheries Management