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Proceedings of the Pacific regional peer review of Glass sponge reefs in the Strait of Georgia and Howe Sound: status assessment and monitoring advice

March 1-2, 2017
Nanaimo, BC

Chairperson: Mary Thiess
Editors: Katie Gale and Josephine Iacarella

Fisheries and Oceans Canada
Science Branch
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Canada

FOREWORD

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

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting that took place March 1-2, 2017 at the Pacific Biological Station in Nanaimo, B.C. A working paper focusing on the development and implementation of methodology to characterize the status of nine glass sponge reefs currently protected through fishing closures in the Strait of Georgia and Howe Sound, along with advice for the development of a future monitoring plan, were presented for peer review.

In-person and web-based participation included staff from Fisheries and Oceans Canada (DFO) Science, Oceans, and Fisheries and Aquaculture Management sectors; and external participants from Natural Resources Canada, the commercial and recreational fishing sectors, environmental non-governmental organizations, and academia.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report providing advice to DFO Fisheries Management to inform future monitoring of glass sponge reef status and assessment of the effectiveness of current fishing closures.

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

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on March 1-2, 2017 at the Pacific Biological Station in Nanaimo to review the Strait of Georgia and Howe Sound Glass Sponge Reefs: Status assessment and ecological monitoring advice.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from Fisheries and Aquaculture Management. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from within DFO, as well as Natural Resources Canada, commercial and recreational fishing sectors, environmental non-governmental organizations, and academia.

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

> *Dunham A., Mossman J., Archer S., Davies S., Pegg J., Archer, E. Glass sponge reefs in the Strait of Georgia and Howe Sound: Status assessment and ecological monitoring advice. CSAP Working Paper 2014SFF02*.

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, working paper, formal reviewers' comments, and draft SAR.

The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting, highlighting the objectives of the review process. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. The room was equipped with microphones to allow remote participation by web-based attendees, and in-person attendees were reminded to address comments and questions into their microphones so they could be heard by those online.

Members were reminded that everyone at the meeting had equal standing as participants and were expected to contribute to the review process if they had information or questions relevant to the paper being discussed. In total, 33 people participated in the RPR (Appendix D). Katie Gale and Josephine Iacarella were identified as Rapporteurs for the meeting.

Participants were informed that Ellen Kenchington and Sally Leys had been asked before the meeting to provide detailed written reviews of the working paper to serve as a starting point for discussions at the meeting (Appendix E). Participants were provided with copies of the written reviews in advance of the meeting. Canadian Parks and Wilderness Society also provided written comments in response to the Working Paper prior to the meeting (Appendix F).

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to Fisheries and Aquaculture management to inform a preliminary characterization of reef status and advice for future monitoring plan development of the nine glass sponge reefs currently protected by fishing closures in the Strait of Georgia and Howe Sound. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat website as they become available.

PRESENTATION OF WORKING PAPER

Co-authors Anya Dunham and Stephanie Archer provided an overview of the working paper and some additional clarification in partial response to the formal reviewers' comments.

Points of clarification: A participant questioned why the 'substrate type' tool in VideoMiner was not used. The authors acknowledged that the habitat category method is more comprehensive and will be recommended over the bin method for future work. They further clarified that there was poor agreement on substrate classification among video annotators and it was used as one of several components of the matrix for habitat category assignment, rather than on its own, as a result.

PRESENTATION OF WRITTEN REVIEWS

DR. ELLEN KENCHINGTON

Dr. Kenchington presented a series of slides to summarize her review (detailed comments are provided in Appendix E). Overall, she indicated it was a very good dataset and good baseline analysis. She recommended that the authors think a bit more about how to re-analyze things more appropriately for future assessments. Drs. Dunham and Archer then outlined their responses to Dr. Kenchington's review, indicating where they agreed to make changes to the working paper in response to her comments (Appendix G).

There were no points of clarification from participants.

Dr. Kenchington provided a mark-up of the working paper with minor editorial comments directly to the authors for their consideration.

DR. SALLY LEYS

Dr. Leys presented her review and general discussion was encouraged following each major point (detailed comments are provided in Appendix E). Overall, Dr. Leys noted that "Dr. Dunham and colleagues have produced an extremely useful document on a complex and challenging topic… This is the first attempt, in the world, to develop methods for assessing the status of a sponge reef. Necessarily it raises discussion points, but this working paper provides an excellent framework for building a solid mechanism for assessment and a future monitoring program for the sponge reefs in the Strait of Georgia and elsewhere."

There were no specific points of clarification from participants.

Dr. Leys also provided a mark-up copy of the working paper with minor editorial comments directly to the authors for their consideration.

GENERAL DISCUSSION

Note: The general discussion from the meeting has been grouped and synthesized by broad topics, rather than in the order it occurred.

ENVIRONMENTAL CONTEXT

- There were questions from participants about whether the environmental conditions at the reefs reflect the expected oceanographic conditions given context/circulation models. It was suggested that the authors use existing oceanographic time series (e.g. Nanoose station) to provide additional long-term environmental context. The Science Advisory Report will note a need for continuing long-term oceanographic time series, and suggest reef-specific

variables of interest are added (i.e. measures of nutrients, bacteria, and silicate) in the "Ecosystem Considerations" section.

STATUS INDICES AND ABILITY TO DETECT CHANGE

- A recurring point raised during the meeting was whether the sponge-based status indices developed by the authors—which provide an indicator of relative status among the reefs assessed—are useful for monitoring, and how they relate to reef biology.
- A recurrent discussion point was that it is difficult to determine if the indices are useful without having conservation objectives (COs) for the fishing closures. Since there are currently no COs in place, the authors focused on using suites of quantitative metrics to characterize the reefs. There is a knowledge gap regarding how the different indices relate to ecosystem function (e.g., how indicative are they of habitat creation? Or of water filtration capacity?).
- The proposed composite index was found to be problematic and will be removed from the working paper prior to publication. For example, similar index values can result for reefs with very different characteristics (e.g., live, dead, mixed, broken). Other indicators/indices were suggested to be able to detect change in the ecosystem. A comprehensive review of possible indicators was identified as an area for future research.
- A recurrent discussion point was the ability to detect change, given the different sources of variability in the system (within and among reefs). One reviewer noted the importance of inter- and intra-observer training to reduce observation variation and observer error. Given that there are no estimates of current variation, there were concerns that any future change in the system would not be detectable. A reviewer noted that even if you go back to the same spot in a reef twice, you don't get the same results (i.e. images). The reefs are dynamic, and images will also be influenced by environmental conditions (e.g., water quality, etc.).
- There were requests to compare the two years of transects, but the authors stated that the randomized transects were placed in each year in such a way that they could not be compared (i.e., not overlapping) and that the survey design was not designed to be a time series.
- A reviewer endorsed the working paper's recommendation to use index sites/index transects as repeated monitoring sites for future surveys. This will enable estimation of observation error/variance to include in future calculations.
- A reviewer described how long-term experiments really are needed to understand change, and to assess whether management measures are effective. Due to multiple stressors, recovery might not occur because there are other factors involved (e.g., climate change). It was noted that any observed change may be a result of the fishing closure, or due to extrinsic factors (e.g., climate change), or other factors not yet understood. The authors pointed out that given the reef complexes were observed to be in poor or declining condition prior to the fishing closure, an observation of "no change" could indicate the fishing closures are working. A participant noted that since the reefs are only closed to fishing, that observed changes could be informative about other impacts on the reefs.
- A participant noted an important distinction: this paper is not focused on indicators of management effectiveness (due to lack of COs), but rather on indicators of ecosystem state.

INDICATOR SPECIES

- There was discussion about the utility of indicator species. Participants noted the importance of distinguishing between “indicator species analysis”, which highlights species that have high fidelity and specificity to a certain habitat type, and “monitoring indicators”, which are used to track changes in ecosystem state over time.
- A reviewer raised the point that monitoring indicators should have characteristics of sensitivity, responsiveness, and specificity to be useful in a monitoring context. Participants noted that it would be interesting to know how the indicators change in response to stressors, and that considering multiple or cumulative stressors is important. It was suggested to do the indicator species analysis within each reef complex, given that there is substantial variation among reef complexes. The authors agreed to put this in the paper.

REEF STATUS

- There was substantial discussion about whether there is sufficient understanding of the variation among and within reef complexes to call this assessment a “baseline” for reef status. Given that parts of the reef are already damaged, that it is not presently known what a “healthy” reef looks like, and that considerable variation exists within and between reefs (as well as observer variation), many participants were uncomfortable with explicitly calling this work “establishing a baseline”. It was recommended to clarify in the working paper that even if this is not technically a “baseline”, it is the start of reef monitoring in its current state, based on the best available existing knowledge. It was recommended that the authors try to state which reef complexes were sufficiently sampled to indicate (to managers) that there is a good understanding of their status (as not all reefs have been sufficiently well sampled to date). It was emphasized that defining “status” and explicitly setting the context for this work is important.
- There was significant discussion around whether there is enough information to understand what a “healthy” reef looks like. Right now there is not enough information to know what a “healthy” or “pristine” reef looks like, and it is likely that each complex has a different optimal state. The term “health” was replaced with “character” or “characteristics” to emphasize that the paper is describing the reefs, but cannot really comment on how relatively healthy each is. This was identified as a key area for additional research.
- The reviewers and participants were in agreement that the paper represents a huge amount of work, considering the field work and analyses that went into it.
- For future research purposes, it was suggested to come up with a best/worst set of images to illustrate what a “healthy” vs. “unhealthy” reef looks like.
- With reference to the “% broken” indicator, a reviewer noted the importance of distinguishing between dead reef, really old dead reefs, and white reefs. The reviewer also noted that not all broken sponges are caused by anthropogenic disturbance – sponges die naturally, and are also preyed on by nudibranchs, so use of this indicator needs to be better specified to ensure it actually indicates for what is intended.
- There was discussion around the focus of the paper, and that it should focus on assessing reef status and evidence of impacts to the reefs, but not assess the stressors directly (i.e., this is not a full ecological risk assessment). A participant explained that it is difficult to track how impacts of stressors have changed over long time frames as core samples from the reefs are uninformative (i.e. they do not exhibit the same growth/sedimentation/expansion rings that coring of other structures can provide).

REEF BOUNDARIES

- The authors used several methods to calculate percent cover of both live and dead sponge. There was discussion regarding further clarification of how the different methods relate to each other and which was most appropriate in particular circumstances. In particular, the authors noted that the video annotators did not always agree on whether to record a sponge as a substrate or as a species, and that in general, substrate classification was poorly agreed upon.
- Participants noted that fishing effort is currently focused around the edges of the reef, where there is currently little survey data (i.e., survey transects run perpendicular to the edge of the reef/fishery closure boundary). There was an interest in surveying around the circumference of the reefs to better understand the margin/edge of the reef complex since that may be where largest human impacts/changes occur. Further, the boundaries of the reef may change over time due to natural processes, so periodic re-assessment of the boundaries may be necessary. This was out of scope for this meeting, but is of interest in the future.
- There was substantial discussion on how reef boundaries are geologically defined versus biologically defined. A participant noted that in some cases, high densities of live sponge can be found outside of the geologically-defined reef polygon (and even outside of the fishing closure). This relates to the geological definition of a reef (built up substrate of previous generations of substrate and accumulations of substrate) vs. areas which may be functioning as reef due to its structure but do not show up through remote sensing analyses. It was noted that the multibeam data may need to be re-analyzed at some point in the future.

LINKAGES WITH OTHER PROCESSES

- Participants noted that the work of "status assessment" is complementary to other DFO processes, such as the Ecological Risk Assessment Framework (ERAF). There was discussion and questions about how the present work fits in with DFO's larger vision for oceans and fisheries management. Other components include ecologically and biologically significant areas (EBSAs), VMEs (vulnerable marine ecosystems), *Policy for Managing the Impact of Fishing on Sensitive Benthic Areas* ("SBA Policy"), which is of interest for fisheries, aquaculture, oceans management, and habitat. All this work is related to the larger concepts, such as how do characteristics like biodiversity and resilience change over time, and in relation to what stressors?
- Fishing closures specifically relate to the SBA Policy via OEABCM (other effective area-based conservation measures; also called OECMs, other effective conservation measures).
- Links between this work and marine protected areas (MPA) and EBSA management work was noted.

FUTURE WORK

- It was suggested by a reviewer and supported by the participants that a species inventory should be put together to document the sponge reef assemblage. There was discussion on the most appropriate format for this document. There is precedent in DFO for publishing photo-documented species inventories as technical reports, but some participants preferred a more dynamic (updatable) format such as an online source. While DFO IT and networks might prevent this from being done in-house, this might be a good opportunity to work with partners. It was agreed that a static report, such as a technical report, would be a good start. This report could also include photos showing what is presently considered to be "healthy",

"broken", or "dead" sponge, and to represent what each end of the spectrum for each of the indices looks like. This inventory will also help provide consistency for future assessments and allow annotators to cross-reference their species identifications with past efforts.

- There was interest in looking at anthropogenic and climate stressors over time and space, particularly to link the changes in indicators to those stressors.
- A participant noted that trash and debris (e.g., fishing gear) will not just disappear from the reefs now that they are closed to fishing. Future assessments that include anthropogenic objects sightings will need account for this.
- The video analysis protocol outlined in the research document is being amended to improve analyses in the future. For example, the use of the ten second bin protocol is replaced with continuous recording of observations (i.e. every observation is assigned its own timestamp). This approach enables more efficient video annotation quality control and allows for a broader range of data analyses. If needed, datasets resulting from this approach can still be directly compared to those created via the ten second bin protocol by combining observations occurring within each ten second interval.
- It was suggested to prepare and recommend a protocol for future users analyzing the videos or planning a monitoring plan. It is important to plan and track how multiple video reviewers are analyzing the data.

OTHER NOTES

- There was some confusion with the naming conventions for each reef complex, as the fishery closure names do not always reflect the common names used for the reefs in the literature. Where possible, the authors will refer to both in the WP. The authors chose to align the reef complex names with those found in the DFO Fishery Notice pertaining to the reef closures (FN0415).
- There were some questions about the recovery potential of the sponge reefs. The authors and a reviewer explained there is variation in ability to recover, and depends on the impact and the type of damage. For example, when the reef is cleanly sliced (e.g., by a hydro cable), re-colonization and growth have been observed. In instances of crushing though (e.g. by trawling), re-colonization is not readily apparent. Sedimentation is also a major threat (and there are differences observed among species in response to sedimentation). A reviewer noted that death can be natural in the reefs, and that as a sponge grows, the base of the sponge may die as the flow regime changes around the reef.

CONCLUSIONS & ADVICE

- The working paper was accepted with minor revisions as noted in Appendix G.
- The information presented in this review to characterize the nine glass sponge reef complexes in the Strait of Georgia and Howe Sound can be viewed as the best available reference for reef status prior to the bottom-contact fishing closures implementation. Through the maps and descriptions provided, this work demonstrates that the reefs have unique characteristics and reef-specific community structure, and further research is needed to better understand the drivers of these differences.
- Based on the best available knowledge at present, the grid method is recommended for estimating percent live sponge cover and the oscula count method is recommended for assessing effective filtration capacity of the glass sponge reefs being assessed.

- The metrics included in this assessment are a subset of potential metrics available to characterize and monitor glass sponge reefs. Future assessments may need to incorporate different metrics, based on new knowledge and improved understanding of reef biology and ecology, as it becomes available. There is a need for a comprehensive evaluation of potential indices to determine their relative utility, based on their theoretical rationale, sensitivity, specificity, and cost-effectiveness. These elements cannot be assessed until there are explicit conservation objectives in place for the reef complexes.
- This process provides general advice to guide the development of an ecological monitoring program for the Strait of Georgia and Howe Sound glass sponge reefs. Specific recommendations to operationalize a monitoring plan cannot be made until explicit conservation objectives are developed. That is, the concept of what constitutes an "effective fishery closure" needs to be defined quantitatively before a suitable metric, or suite of metrics, can be recommended. As an example, good indicators of management effectiveness will not necessarily be the same as good indicators for assessing or monitoring the state of the ecosystem over time.
- Due to distinct differences in reef characteristics, it is recommended that the northern and southern reefs of the Outer Gulf Islands reef complex are treated as separate sub-complexes for future monitoring purposes.
- If assessing human impacts in the buffer zones around the reef (currently extending 150m beyond the reef footprints determined using multibeam swath bathymetry imagery collected between 2002 and 2010) is determined to be a management objective, then additional metrics and sampling protocols to evaluate this will need to be developed. For example, if encroachment of fishing activity into the reef buffer zones is a concern, then explicit components to address this will need to be added to the monitoring plan.
- It is recommended that the monitoring program be adaptive: if effects of stressors are detected or suspected, more frequent and/or intensive monitoring can be initiated to track recovery or decline and to determine the likely causes of the changes observed.
- Ongoing monitoring requires mechanisms to ensure repeatability and consistency in assessment over time. Visual species identification is one source of variability that can easily be addressed by way of a species inventory or image catalogue that can be used as a reference by annotators. This catalogue could be produced as a technical report and/ or provide an opportunity to partner with academic and non-government organizations (*e.g.* Vancouver Aquarium, Ocean Networks Canada, Marine Life Sanctuaries Society, universities, BC Museum) to produce a common online repository for this information.
- As the first attempt at a comprehensive quantitative characterization of the Strait of Georgia and Howe Sound glass sponge reefs, this work highlights a number of future research opportunities. For example, there is a need to link additional oceanographic, ecological, and geological information together to provide a more comprehensive understanding of the variability observed within and among sponge reef complexes. This work may also lead to broader application in other areas (e.g., EBSAs and implementation of the SBA Policy).
- Additional scientific research is needed to fill knowledge gaps, to iteratively improve existing monitoring methods, and to explore novel monitoring approaches and techniques. As more data becomes available, proposed indices could be refined and new ones incorporated, while consistent, comprehensive, and well-resolved time series datasets are maintained.
- This work focused on the nine sponge reefs protected by the fishing closures in the Strait of Georgia and Howe Sound, but could be adapted for application to glass sponge reefs in

other areas (*e.g.*, Hecate Strait, Chatham Sound). Reefs in Hecate Strait are known to include a third reef-building glass sponge species, *Farrea occa* (Conway 1999), and may thus require modified suites of indices to adequately assess and monitor them.

- The advice for development of an ongoing monitoring program provided here addresses indices and metrics related to the significant ecosystem components (SECs) of the ERAF. It does not comprehensively address stressor-specific indicators. This work can be incorporated into an ecological risk assessment(s) conducted at a later date.
- To put reef-scale changes in context over time, there is a need to monitor broader ecosystem indicators (*e.g.*, oceanographic time series data collected at Nanoose station, Ocean Network Canada cabled observatory). Further, it is recommended that sponge-specific oceanographic measures (nutrients, bacteria, silicate) be included in the suite of properties measured at this station.

SUMMARY AND CLOSING

The Chair concluded the RPR by thanking everyone for attending and outlining the revision and publication timelines for the science advisory report, research document, and proceedings.

ACKNOWLEDGEMENTS

Special thanks to the authors for producing a valuable research document under challenging timelines; reviewers Ellen Kenchington and Sally Leys for taking the time to travel to the meeting and for providing their conscientious written reviews; the peer review participants for their constructive input and discussions during and following the review; Katie Gale and Josie Iacarella for their attentive and thorough work as rapporteurs, both at the meeting and to produce these proceedings; and finally, the CSAS office (Lesley MacDougall, Lisa Christensen and Brittany Myhal) for their assistance with coordinating meeting logistics and publishing the meeting documents.

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APPENDIX A: TERMS OF REFERENCE

GLASS SPONGE REEFS IN THE STRAIT OF GEORGIA AND HOWE SOUND: STATUS ASSESSMENT AND ECOLOGICAL MONITORING ADVICE

Regional Peer Review Process – Pacific Region

March 1-2, 2017
Nanaimo, British Columbia

Chairperson: Mary Thiess

Context

Glass sponge reefs are unique habitats found along the Pacific coast of Canada and the United States. They are built by dictyonine glass sponges with spicules of nearly pure glass that form reefs through the attachment of larvae to exposed skeletons of dead sponges and by trapping sediments entrained in bottom currents. The reefs gradually grow to reach heights of up to 21 meters and widths of up to several kilometers. The bulk of each reef consists of dead sponges buried by sediments, with only the most recent generation of sponges growing 1-2 meters above the ocean floor.

Glass sponge reefs have intrinsic, ecological, and economic value. They provide a link between benthic and pelagic environments, play an important role in carbon and nitrogen processing, and act as a silica sink. While a full understanding of their ecological role is yet to be realized, diverse communities of invertebrates and fish, including those of economic importance, have been documented in association with the reefs (Cook et al. 2008, Marliave et al. 2009, Chu and Leys 2010).

Over the past 14 years, nine glass sponge reef complexes have been mapped by the Canadian Hydrographic Service in the Strait of Georgia and Howe Sound using remote sensing, multibeam sonars (Conway et al. 2004; Conway et al. 2005; Conway et al. 2007; K. Conway, pers. comm.). However, remote sensing techniques cannot differentiate between live, dead, and dead and buried patches of glass sponges within a reef; therefore, while these techniques assist in locating and delineating glass sponge reef structure, they cannot provide information on reef status or health. In the past, some of the reefs were surveyed for live glass sponge abundance and distribution using Remotely Operated Vehicles (ROVs) (Cook et al. 2008; Chu and Leys 2010), while others remained unassessed. Furthermore, no standard quantitative metrics for sponge health or sponge reef status have been developed to date.

In 2012 and 2013, the nine glass sponge reefs in the Strait of Georgia and Howe Sound—previously delineated with remote sensing techniques—were surveyed by DFO Science using an ROV and a standardized survey design to document live glass sponges and megafaunal communities associated with them. These surveys confirmed the presence of live reef-building glass sponges in all nine reefs. In 2014, DFO requested that fishers using bottom-contact gear (prawn trap, crab trap, shrimp trawl, groundfish trawl and hook-and-line) voluntarily avoid these nine glass sponge reef areas while DFO consulted on formal protection measures. After reviewing important input from the consultation process with First Nations, commercial and recreational fishers and conservation organizations, DFO proceeded with formal fishery closures to protect the nine glass sponge reef complexes in the Strait of Georgia and Howe Sound, effective June 12, 2015. Beginning April 1, 2016, the closures also apply to First Nations Food, Social, and Ceremonial fisheries.

The protection of sponge reefs is a key component to a number of international commitments made by Canada through the United Nations Convention on Biological Diversity and the United Nations Food and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries. During the consultation process, multiple stakeholders inquired about DFO's plans to monitor effectiveness of glass sponge reef closures. DFO Fisheries Management has requested Science Branch to provide an evaluation of the current health status of the nine reef complexes, along with science advice for how reefs could be monitored on an ongoing basis. Therefore, the primary goals of this work are to: (1) assess the status of the nine glass sponge reefs in the Strait of Georgia and Howe Sound prior to bottom fishery closures being put in place (monitoring baseline); and (2) provide recommendations for future monitoring initiatives. This work focuses on the nine glass sponge reef complexes included in the current fishery closure process; other sponge reefs that may be found in the area and sponge formations (such as sponge gardens) are out of scope.

The assessment and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will be used to inform management decisions regarding adaptive management and future monitoring of the sponge reefs in the Strait of Georgia and Howe Sound and to respond to stakeholder requests for scientific information on the sponge reefs. It will support the Department's implementation of the Policy to Manage the Impacts of Fishing on Sensitive Benthic Areas and the Ecological Risk Assessment Framework (ERAF)for Coldwater Corals and Sponge Dominated Communities in the Pacific Region.

Objectives

The following working paper will be reviewed and provide the basis for discussion and advice:

Dunham A, Mossman J, Archer S, Pegg J, Davies S. Glass sponge reefs in the Strait of Georgia and Howe Sound: status assessment and ecological monitoring advice. CSAP Working Paper 2014SFF02.

The objectives are to:

1. Describe and map the presence of live reef-building glass sponges in nine sponge reefs complexes in the Strait of Georgia and Howe Sound protected by DFO's bottom-contact fishery closure initiative.
2. Characterize the range of environmental conditions encountered by glass sponge reefs in the Strait of Georgia and Howe Sound.
3. Characterize megafaunal communities associated with glass sponge reefs.
4. Develop glass sponge reef condition and/or recovery potential metric(s) to enable objective quantitative comparisons over time and space.
5. Characterize condition of each of the nine reef complexes prior to commencement of bottom-contact fishery closures for use as the monitoring baseline.
6. Explore correlation between reef condition and associated megafaunal community structure.
7. Provide recommendations for monitoring strategy, methods, and protocol development.
8. Examine and identify uncertainties in the data and methods.
9. Provide recommendations on future research needs.

Expected Publications

- Science Advisory Report

- Proceedings
- Research Document

Expected Participation

- DFO: Science, Fisheries and Aquaculture Management, Oceans, Fisheries Protection Program.
- First Nations
- Academia
- Fishing industry (recreational and commercial: prawn trap, crab trap, shrimp trawl, groundfish trawl, and hook-and-line)
- Environmental non-government organizations: Canadian Parks and Wilderness Society (CPAWS), Marine Life Sanctuaries Society, Vancouver Aquarium, Sunshine Coast Conservation Society.

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APPENDIX B: WORKING PAPER ABSTRACT

Glass sponge reefs are structured biogenic habitats unique to the North East Pacific that serve as biogeochemical hotspots and support diverse biological communities. Over the past 15 years, nine glass sponge reef complexes have been mapped by the Canadian Hydrographic Service in the Strait of Georgia and Howe Sound using remote sensing techniques. In 2015 DFO protected these complexes via formal bottom-contact fishery closures extending 150 m beyond the reef footprints. In order to monitor the established fishery closures, a baseline of the reef status and a monitoring plan must be developed. Glass sponge reefs largely occur beyond diving limits, restricting survey methods to remote visual survey platforms which can be resource-intensive and logistically challenging. The reefs require a monitoring program that uses relevant quantitative metrics at appropriate spatial and temporal scales and provides well-resolved time series data.

This paper is based on the results of two remotely operated vehicle surveys of nine sponge reefs and their associated communities in the Strait of Georgia and Howe Sound completed in 2012 and 2013 prior to bottom-contact fishery closure implementation. First, we applied a suite of both novel and previously published quantitative indices for assessing biogenic habitats to a subset of imagery data. Indices were evaluated based on consistency, ability to distinguish between reefs of qualitatively different status, and data processing effort involved. Indices that demonstrated the most potential – characterizing sponge cover, condition, and distribution, as well as associated community structure and indicator taxa abundance – were subsequently applied to the full imagery dataset. We then developed a composite quantitative index of reef status based on these indices and current understanding of sponge reef ecology. Reef complex status summaries were developed to serve as monitoring baselines.

To support the development of a reef monitoring program, considerations for survey design, sampling methods, and data analyses are provided. A range of monitoring indices and associated sampling methods are collated to provide options for comparing reef status over time and space. We recommend that management decisions are based on trend analysis and consider proposed indices in combination, rather than in isolation. A diagnostic decision tree is presented to guide reef monitoring and inform adaptive management.

The methods developed in this paper can be applied to other reefs in the Strait of Georgia and Howe Sound and adapted for assessment of glass sponge reefs in other areas such as Hecate Strait and Chatham Sound.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat

Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Review of Strait of Georgia Sponge Reef Status Assessment and Monitoring Protocols

March 1-2, 2017
Nanaimo, BC

Chair: Mary Thiess

DAY 1 – Wednesday, March 1

Time	Subject	Presenter
1000	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
1015	Review Terms of Reference	Chair
1030	Presentation of Working Paper	Authors
1200	***Lunch Break***	
1300	Presentation of Written Reviews Internal: Ellen Kenchington, DFO Maritimes External: Sally Leys, University of Alberta	Chair, Reviewers, & Authors
1430	Identification of Key Issues for Group Discussion	RPR Participants
1445	***Break***	
1500	Discussion & Resolution of Technical Issues • Technical Aspects & Methods of Working Paper	RPR Participants
1600	Discussion & Resolution of Technical Issues • Monitoring Advice	RPR Participants
1645	Plan for Day 2 • Review draft Science Advisory Report	RPR Participants
1700	***Adjourn for the Day***	

DAY 2 – Thursday, March 2

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Progress from Day 1	Chair
0915	Discussion & Resolution of Technical Issues • Uncertainties, Gaps and Future Directions	RPR Participants
1000	Wrap-Up Discussion: Outstanding Items	RPR Participants
1030	***Break***	
1045	Assess Consensus on Acceptability of Working Paper & Agreed Revisions	RPR Participants
1100	*Science Advisory Report (SAR)* Develop consensus on the following SAR sections: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1200	***Lunch Break***	
1300	*SAR (Continued)* Develop consensus on the following SAR sections: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1430	***Break***	
1445	*Science Advisory Report (SAR) (*Continued)	RPR Participants
1530	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair
1545	Other business arising from the review	Chair & Participants
1600	***Adjourn meeting***	

APPENDIX D: MEETING PARTICIPANTS

Last Name	First Name	Affiliation
Amyot	Jacinthe (Jazz)	Oceans
Archer	Erik	Contractor
Archer	Stephanie	Science
Ashcroft	Chuck	Sports Fish Advisory Board
Boutillier	Jim	Science
Byers	Sheila	Marine Life Sanctuaries Society
Caron	Chantelle	Aquaculture
Christensen	Lisa	CSAP
Chu	Jackson	Science
Conway	Kim	Natural Resources Canada (NRCan)
Davies	Sarah	Science
Dunham	Anya	Science
Eros	Carole	Oceans
Gale	Katie	Science
Govender	Rhona	CPAWS
Hannah	Lucie	Science
Harlow	Cindy	Sunshine Coast Conservation Society
Iacarella	Josie	Science
Kenchington	Ellen	Science
Ladwig	Aleria	Fisheries Management
Lessard	Joanne	Science
Leys	Sally	University of Alberta
MacDougall	Lesley	CSAP
Mossman	Janet	Science
Norgard	Tammy	Science
O	Miriam	Science
Pegg	James	Science
Richards	Steven	Pacific Prawn Fishermen's Association
Schultz	Jessica	Vancouver Aquarium
Scriven	Danielle	Oceans
Setterington	Lisa	Science
Thiess	Mary	Science
Wallace	Scott	David Suzuki Foundation

APPENDIX E: WORKING PAPER REVIEWS

DR. ELLEN KENCHINGTON, FISHERIES AND OCEANS CANADA

The objectives of the WP were to:

1. Describe and map the presence of live reef-building glass sponges in nine sponge reefs complexes in the Strait of Georgia and Howe Sound protected by DFO's bottom-contact fishery closure initiative.
2. Characterize the range of environmental conditions encountered by glass sponge reefs in the Strait of Georgia and Howe Sound.
3. Characterize megafaunal communities associated with glass sponge reefs.
4. Develop glass sponge reef condition and/or recovery potential metric(s) to enable objective quantitative comparisons over time and space.
5. Characterize condition of each of the nine reef complexes prior to commencement of bottom-contact fishery closures for use as the monitoring baseline.
6. Explore correlation between reef condition and associated megafaunal community structure.
7. Provide recommendations for monitoring strategy, methods, and protocol development.
8. Examine and identify uncertainties in the data and methods.
9. Provide recommendations on future research needs.

All of these objectives were addressed to varying degrees in the working paper and therefore it can be seen as a valuable discussion document for the meeting. The authors have done a commendable job of compiling a great deal of information into a single document. I also appreciate the rigor that went into reviewing the quality of the data. My comments are largely directed towards additional analyses. Additional editorial comments are provided on the PDF.

Objective 1: This has been done within the limits of the method (no extrapolation). The significant finding is of live reef building sponges present outside the area depicted by multibeam. In two cases the density was higher outside. These sponges should be considered in the conservation strategy.

Objective 2: The data collected at the time of sampling are well documented. Are there additional data that would put those in situ collections into a broader oceanographic setting? T-S plots might help to distinguish water masses.

Objective 3: The megafaunal communities associated with the glass sponge reefs were characterized, although there seems to be considerable variability in the data and differences among methods used. I think that as long as standard methods are applied the present study can be used for monitoring purposes however it is absolutely essential that a report showing images of all the taxa recorded is published as a companion document to the Res Doc. Without that this study cannot be repeated in future. Note that the comparison was made among reefs. This is of scientific interest but is probably not relevant for monitoring. The key comparison should be with reefs. For this reason I wonder why comparisons were not made between 2012 and 2103? This would be an interesting test of the use of this metric in monitoring, assuming that no changes occurred between the two time periods. Further, it would be interesting to know if there are differences among the various reef categories in species composition. The patch size within any one category, on any one transect, may be too small to detect differences if associations are weak but I am surprised that you did not look at that. The differences among reefs may be due to differences in the proportions of these categories.

Objective 4: The authors were very thorough in their evaluation of the various measures they used for determining live and dead sponge abundance. Without taking anything away from that work, I feel that more effort should have gone into evaluating these indicators as indicators. Two sampling years were available and they could have been used to determine how much difference would be needed to detect a change. For monitoring screening criteria for candidate indicators are usually applied (Rochet and Rice, 2005) and these include amongst others having a theoretical basis, sensitivity, responsiveness, and specificity. The error associated with the abundance estimates suggests that they would not pass this test, but this requires further investigation.

Other comments: -The grid cell method is not elaborated on in the working paper. As it is a key method it would be good to either provide references to what is meant or to create a figure showing what was done with each image. -Table 9 summarizes results within the reef complexes (and other tables are similarly constructed). I would also be interested in comparing like with like: so abundances of live reef only, assuming that the numbers are for the whole of the reef area, including dead reef. To me, the densities in a healthy reef are what matters. They will relate to population dynamics and food availability, while what you show is confounded by the proportion of dead and mixed reef. It tells you something different and both would be good to see.-The average size is one metric but it would be interesting to see the size frequency distributions. They could also be analyzed and might tell you more about recruitment than average size.-The clumpiness index has no variance in Table 11. What do those two years tell you? If you had done two transects per year you could at least see what the variance was.-Did you not consider other geo-spatial indices? What about nearest-neighbour to segment length of habitat type? There are quite a few out there.

Objective 5: The health index is an interesting means of assessing condition. I prefer the %damaged sponge metric and the % live and % dead reef metrics as they are more direct. I have no idea what the theoretical basis for the health index is and the text on page 24 sounds like the authors are not very sure either. Are there other health indicators? What about erosion of the reef. Does that occur? Are there colour changes? Predators? I do like the summary cards for management and communication purposes but have issues with some of the content due to the above.

Objective 6: Section 3.2.4.1 compares community structure inside and outside of reefs when data are pooled across reefs. Given that the previous section demonstrated significant differences among reefs, I don’t see the value in this test. I would like to see the MDS figure colour coded to show inside and outside reefs within each reef area (Fig 15). Then it would allow a better understanding of the variability. The Shannon and other community metrics have little meaning in this context. I don’t feel that this objective has been fully explored. As indicated above, the analyses could also be conducted on live and dead reef separately.

Objective 7: I feel that this section is well developed. I agree with the data indicating that fixed transects are likely the best way to monitor in the future. I am not very concerned about small deviations from the line, although if there are prominent features it might be useful to use those as guides (e.g., Bennecke et al., 2016). I still don’t feel confident that the metrics have been tested for their responsiveness and specificity in particular, or that the final set of metrics has been determined.

I have no further comments on Objectives 8 and 9, and would like to express my congratulations once again to the authors for preparing such a thorough and well written document.

Bennecke, S., Kwasnitschka, T., Metaxas, A. et al. Coral Reefs (2016) 35: 1227. doi:10.1007/s00338-016-1471-7

Rochet M-J., Rice J.C. Do explicit criteria help in selecting indicators for ecosystem-based fisheries management?, ICES Journal of Marine Science , 2005, vol. 62 (pg. 528-539).

DR. SALLY LEYS, UNIVERSITY OF ALBERTA

Overall assessment of the working paper:

Dunham and colleagues have produced an extremely useful document on a complex and challenging topic. This working paper represents a remarkable number of hours of work not only in diligently carrying out a thorough set of transects across all the known mapped reefs in the Strait of Georgia, but also in assessing methodologies of quantification of reef structure and character, and wrestling very difficult data into quantified endpoints that can be used by managers. This is the first attempt, in the world, to develop methods for assessing the status of a sponge reef. Necessarily it raises discussion points, but this working paper provides an excellent framework for building a solid mechanism for assessment and a future monitoring program for the sponge reefs in the Strait of Georgia and elsewhere.

Is the purpose of the working paper clearly stated?

The aim of the working paper as stated in section 1.5 is to provide an assessment of the current status of the reefs and to provide recommendations for future monitoring of the Strait of Georgia and Howe Sound sponge reefs. Perhaps ‘Status’ could be defined here because this has never been done before with a glass sponge reef. Status as described in the abstract refers to the use of indices to describe spatial and biological characteristics of the reef including habitat type, cover or area covered, density (clumpiness), damage, and abundance of associated fauna. In the discussion section of the working paper it becomes evident that although a numerical measure of these indices is referred to as ‘reef health’, what is implied by the range of values is a measure of reef ‘function’. This wording may not perfectly represent the authors’ intent, but some definition along these lines would make the purpose of the paper completely clear for future readers.

Are the data and methods adequate to support the conclusions?

There should be two levels of conclusions: conclusions regarding the status assessments, and conclusions regarding recommendations; the latter is addressed under point D below. The status summaries present the baseline condition of each reef based on the indices described above. There are no discrete conclusions made regarding use of different indices. There is a comprehensive discussion about the value of different indices used, but it would be useful to provide distinct conclusions regarding the value of the indices. Here, I review the methods that were used to obtain the data that support the summary status assessments: This is an extremely rigorous study that has carried out a very comprehensive set of ROV transects over 9 sponge reefs in the Strait of Georgia. The transects are well-spaced, well-documented (also as raw data in the appendices), and the image analysis has been carried out rigorously. The rigor of image analysis is paramount: they used two observers, incorporated methods to check consistency and resolve perceived inconsistencies using expert opinions and re-evaluation of methodology. The overall numerical indicator of reef ‘health’ on each summary ‘card’ is provided but no attempt is made to compare one reef complex with another or to evaluate the effectiveness of different indices across all reef complexes or within a set of reefs of a complex. I think as a baseline, two things need to be done in addition to providing the status cards. First, it would be useful for decision-makers to provide conclusions regarding the use of different index criteria for different reefs (see my comment in C below). Second, it would be useful for future monitoring efforts and for decision-makers if the authors could summarize or evaluate the differences between the various methods used for single indices.

I suggest the conclusions regarding the choice of indices in the summary assessment as follows:

1. Which criterion provides the most comprehensive index of reef cover?
2. What is the relative value or relative importance of the indices ‘live cover’, ‘number of oscula’, and ‘extent of broken sponges’?

I recommend distinct conclusions regarding that the analysis of methods including:

1. What is the minimum number of transects per reef area required to estimate status?
2. What is the relative value of using one, two or more observers of image and video data?
3. What is the most accurate method for determining reef cover (live/dead/none)?
4. What is the minimum number of images that should be analysed to achieve accurate estimates of the indices of sponge cover and habitat type?
5. What is the minimum transect time (video length and image number) required to assess the diversity of associated fauna.

Note that the status cards use the term ‘healthy reef’ for faunal diversity – but healthy reef is not described as an index, rather dense live reef, mixed reef and dead reef are used. In the Results/Discussion section, Table 22 shows species associations with the habitat criteria, but not with ‘healthy reef’. If the summary assessments mean ‘healthy reef’, then it should say on page 42 how that is calculated. On page 42 it says abundance of taxa but the cards show density of taxa (number per m^2).

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

Considering this report largely concerns the development of methodology to assess and review/monitor the status of sponge reefs, it is excellent that a lot of attention has been given to evaluating different methods. However, I found that it was difficult to determine which measure was used (percent live cover, density or abundance, oscula counts transferred to percent cover, and sponge size) for each index, how they were converted into common measures for the aster plots, and what the overall relative merits of each method were. For example, video bin counts were used in several analyses but did not appear to be a very good measure, and were not used in the final aster plots.

Terminology of the reefs was confusing. An explanation for where the names used in this working paper come from would be useful. In particular, Foreslope Hills refers to a reef previously called Fraser Ridge in publications. K Conway may offer thoughts here on the location of the reef and ridge and the Foreslope Hill region, but it seems confusing to refer to that reef or any other, which has been previously studied and referred to differently. If a new name is needed for fisheries purposes, then both names should be used. It would also be useful to have a summary table with all reefs for data presented graphically in the aster plot. In a number of instances, graphs would merit from greater explanation in the figure caption and or text to explain precisely how the numbers were obtained. Specifics have been annotated on the document for the authors.

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?

The recommendations outlined in Section 5, pg 68 could be more clearly stated for decision-makers (see my comments also in E below).

The first recommendation should be reworded to indicate that the authors recommend the status assessments be accepted as the baseline condition of the 9 reefs for future monitoring.

The second should be reworded to state that in future assessments composite indices of reef 'health' should be used to compare to the baselines provided here.

The third should recommend monitoring of the reefs by identical surveys every 3-10 years (numbers given in the discussion).

Fourth, the authors recommend future surveys cross reef closure boundaries.

Fifth, the authors recommend the Outer Gulf Island reef complex be divided into two complexes and treated separately.

Sixth, a recommendation that identical image platforms and software be used in subsequent surveys is unrealistic. I suggest instead a recommendation to carry out an analysis of methodology alone using repeat transects and different image and software platforms. This would be most useful for decision-makers.

Seventh, the most important recommendation is that trend analysis should be used in evaluating changes in reef status. However, probably better guidance as to how to evaluate the trends would be needed for decision makers to use of this approach. A recommendation could be made to study how best to apply trend analysis by using a mock set of data.

Uncertainty in the data and analysis is reflected in the summary statements (as recommendations) but without reading the discussion, which is very detailed, it would be difficult for a decision-maker to have a good grasp of the uncertainty involved in each recommendation. If space allows, it would be beneficial at this time of establishing the first protocols for future monitoring, to elaborate the recommendations more. I would reiterate the key points of uncertainty under each recommendation – one sentence or one line, no more. For example, the complexity of two different image annotators with different background knowledge, the complexity of carrying out the transects at different times of the year, and the complexity of determining what the relative value of the different indices is.

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

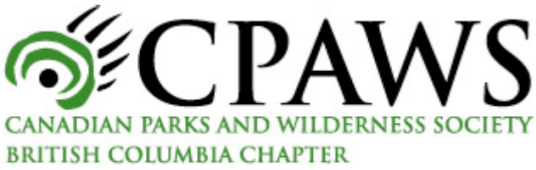
This is an excellent piece of work; it is focused, thorough, and rigorous. It represents a lot of time in analysis and interpretation. However, some additional analysis could be done to expand its usefulness for future monitoring efforts and to increase its use for decision-makers. These are methodological. To determine where these reefs fit on a scale relative to themselves in future assessments, and relative to each other in each assessment period, and relative to other reefs on the coast as additional assessments are made, I recommend several gauges to check the indices.

1. What is a 'healthy' reef? Would PCA analysis show which indices better align together? For example, would high oscula count group with dense reef and with high reef cover? A 'mock set of data' could be constructed to illustrate the range of values expected for each index. Live abundance as percent cover and number of oscula (100%, 75%, 50%, 25% and 0%), reef structure as dead % cover and visible reef structure (100-0), and so on. A matrix could be constructed with all the possible combinations of each, and used to make a principal component analysis. The combinations with high live abundance and low dead reef should group together. The assessed data from each reef could then be plotted on the same analysis and this could well indicate the range of values that the authors imply should be used as a composite indicator of reef health.
2. Reef health vs Reef function. The gauge of reef 'health' is complicated. Would it be possible to estimate reef function by rugosity using the measure from DuPreez and Tunnicliffe. This

might incorporate several of the indices used in this working paper, and also include use of the reef by other species.

3. An estimate of error at all stages should be carried out. Repeat transects (minimum 3) should be run to determine the difference in image analysis over the same set of transects by the same observers. The same transect set should be analysed by a minimum of three observers to determine annotator error/bias.
4. Patchiness: A grid rather than transect might be run to estimate reef patchiness. Estimates from Chu and Leys 2010 show patchiness at the scale of 25m. Patchiness is a value in reef structure – sponge mounds grow in response to ambient flow and local terrain – spaces between mounds may result from differences in ambient flow and terrain. Spaces between mounds also allow different species to live between reefs. It would be valuable to include patchiness into the composite index.

APPENDIX F: CPAWS FOLLOW-UP LETTER



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10 April 2017

Re: CSAS Participant Review: Strait of Georgia and Howe Sound Glass Sponge Reefs (March 1-2, 2017)

Dear Mary Thiess,

We appreciate the invitation and opportunity to review the draft CSAS report “Glass sponge reefs in the Strait of Georgia and Howe Sound: Status assessment and ecological monitoring advice”. We recognize the significant work that went into this research and we thank the authors for their efforts. This is important research that will guide efforts to assess whether the fisheries closures in the Strait of Georgia are effectively protecting the reefs.

We also recognize that the objectives for this work need to be clarified in order to properly design a monitoring program. Understanding that, we were encouraged by the recommendations that were agreed upon at 1-2 March 2017 CSAS review meeting. Consistent with the discussions that took place during that meeting, we would like to re-iterate the points outlined below.

Defining and measuring reef health and status

The authors stated that the initial request for science advice was to create a method to assess and monitor glass sponge reef *health*. Dr. Sally Leys’ raised questions in her written review and at the meeting regarding the terminology used regarding health and status. The draft paper refers to health, health status, function, and status almost synonymously. Leys suggested that the proposed methods actually examined reef function or characterization as opposed to health. Dr. Ellen Kenchington and others also questioned what the “composite index of reef health” was actually measuring, and the difficulties in interpreting the index.

Understanding the link between structure and function, and creating an index with that knowledge may assist with creating an metrics that are easier to understand and apply.

Recommendation: We support the need for a separate request for science advice to better define reef health and indicators of reef health, and look forward to engaging in this process. A comprehensive panel of indicators, in conjunction with this survey methodology, could create a robust monitoring plan to assess reef health. It is integral, as Kenchington noted that these indicators be based on a theoretical basis, sensitivity, responsiveness, and specificity.

Indicators of Reef Health

What constitutes a “healthy” glass sponge reef and the conditions they require to remain in good health are unknown. The presence of living, dead and broken sponge are good basic indicators for damage and recovery potential, however we question whether the number of oscula is a

good measure of sponge health for the two species present in the Strait of Georgia. For example, a very large, healthy *Heterchone calyx* may have one large oscula.

Size or age distribution of both individual sponges and the larger reef complex is a factor that is likely important in assessing the reefs, and was not captured in this assessment. We understand the authors' comments that it is difficult to differentiate individual sponges in areas of high sponge density.

Recommendation: We therefore recommend that a scale is created in which general size categories are identified so that new recruits are distinguished from mid size and very large sponges.

Recommendation: We also recommend glass sponge species composition as a potential indicator of reef health, assuming that greater diversity (even if between just two species) suggests greater resilience. Diversity of sponges would also be a potential indicator for the Hecate Strait and Queen Charlotte Sound glass sponge reef MPA.

Currently, we are unsure what the indicator species, as identified by the authors, are able to tell us about the reefs. While there might be strong associations with habitat categories within reefs, what does it mean for health, function, or status of the reefs? Additionally, certain smaller animals, or microorganisms such as foraminifera that are strongly associated with the reefs, are not included here as indicators, nor were they measured. These microrganisms could be necessary for or indicative of health, but since only megafauna, temperature, depth, and salinity are being measured, key factors like measuring microfauna or silica content is missing in the proposed survey methodology.

Glass sponge reefs contribute not just to the benthos, but also the entire water column through nutrient cycling. Therefore nutrient and oxygen levels would also be potentially valuable indicators of both reef health and potentially background stressors. Bacteria assays from the water column would also be beneficial in evaluating other environmental changes that may affect reef health.

Considering other threats and stressors

Kenchington suggested that oceanographic conditions such as temperature be looked at in a broader context in the Strait of Georgia. Comparing oceanographic data from the reefs to conditions at nearby stations will allow localized stressors to be differentiated from those that are occurring more broadly. If the reefs do not appear to be recovering, other causes need to be ruled out before we can conclude whether the fisheries closures have been effective or not. For example, there is also significant uncertainty about the effects of fishing gear on the re-suspension of sediment, and ultimately the health of the glass sponge reefs. Understanding these effects will help us to address Leys' question regarding how the 150m boundary was determined, and whether it is sufficient to protect the reefs.

Recommendation: We are supportive of the suggestions by Kenchington that comparisons between years be conducted in order to assess trends over time, in order that monitoring plans can be used to assess status. This will also help to identify changes within the local ecosystems and provide more insight into the range of environmental conditions.

Baselines for comparison and identification scales

There was variation between reviewers when assessing video and still footage of the reefs. Creating a scale and baseline against which to assess current reefs was suggested as an integral component for the final monitoring plan, in order to minimize these variations. Leys suggested that a scale be created using an image of a 100% non-degraded reef and a fully

degraded reef, against which reviewers can compare images. Most of the Strait of Georgia reefs have already been significantly degraded so they would provide a poor baseline for a 100% non-degraded reef.

Recommendation: We strongly reiterate the recommendation from the meeting that a reference point of a 100% non-degraded reef is based on more pristine areas of Hecate Strait and Queen Charlotte Sound or Malcolm Island glass sponge reefs.

Recommendation: It is also important that the seafloor adjacent to the reefs, and included within the fisheries closures, is surveyed and monitored. Not only is the type of surrounding substrate important in the understanding of potential reef growth, surveying non-reef (0% sponge cover) and fully intact reef (100% cover) is integral to setting upper and lower limits that could assess function, character, or status.

Adequacy of transects and analyses

Another key point raised at the meeting was the need to assess whether the number of transects is adequate to assess the reef complexes.

Recommendation: We strongly support the recommendation that a power analysis should be conducted to determine whether the current survey methodology and interpretation of results has enough resolution to define certain thresholds, and to determine if more data is needed.

Boutillier highlighted the need to ensure that each reef is sampled enough so that we have a baseline against which we can monitor; if each reef is not sampled enough, how much is adequate? We support Kenchington's inquiry into whether random stratified design is optimal, or if repeat transects will be better able to assess status. Leys suggested that the monitoring plan needs to be used in the context of a long-term framework, within which we are able to identify changes to the reefs.

Uncertainties with reef boundaries

The transects show areas of living glass sponge reefs, in some areas at high density, outside of the reef polygons and the boundaries of the fishing closures. The most notable case is that of Gabriola reef which appears to extend beyond the fishing closures. There was debate at the meeting as to whether this is due to inaccuracies in mapping, reef expansion, or whether these areas are just aggregations of glass sponges rather than reefs/bioherms. The last multi-beam mapping was completed in 2004, and we know that in some instances the thickness of the edge of the reef, the frequency of the multi-beam and surrounding slopes may produce inaccuracies in the mapping data.

Recommendation: It is critically important that the edges of reefs are accurately mapped. We know from the literature that the edges of the reefs are the most productive and that the edges of the reefs will be important for the expansion and recovery of the reefs. We also know that as fishers largely avoid the reefs themselves to avoid entanglement or damaging of gear, they fish around the edge of the reefs so the most likely area of impact of damage from fishing gear is the edge. Furthermore, the fishing closures will not be effective if the current polygons are not capturing the full extent of the reefs, and accounting for the effects of sedimentation and highly mobile gear.

Recommendation: We recommend a more comprehensive and accurate assessment of the reef boundaries as well as the effects of fishing gear on the reefs, before the final monitoring plan is developed, so that edge effects are fully understood. We also recommend that the transects are designed in a way that has good spatial coverage of the reef boundaries. We note that adaptive management to determine the effectiveness of a fishing closure works in two ways - if the

closures are not effective and damage continues to be observed, or if the boundaries of the fishing closure do not effectively encompass the reef, they will need to be expanded and/or strengthened accordingly.

Terminology

Aside from issues regarding the definition of reef health and status, there is also a need for a clear definition of a glass sponge reef (or bioherm) to distinguish it from sponge aggregations.

Recommendation: We recommend that the definition of a glass sponge reef be consistent with that of the literature. Creating a definition specifically for the context of this paper in the Strait of Georgia and Howe sound could be confusing in the future and problematic if this methodology is applied more broadly to other glass sponge reef areas such as Hecate Strait and Queen Charlotte Sound.

We also note confusion around the changing names of individual reefs throughout this process. It is not clear why the original names identified by Conway *et al* were not retained. The changing of the name of the reefs makes it difficult to trace historical work done on the reefs in the future.

Recommendation: We recommend that the original names given by Conway and colleagues in the first paper(s) on the Strait of Georgia reefs be used now and in the future for these glass sponge reefs.

We also note that the acknowledgements section overlooks key groups and individuals who were involved to a large degree in the early work to study the reefs and to secure their protection through fishing closures. In addition to the omission of CPAWS, which was the first organization to bring the need for protection for these reefs to DFO's attention, the acknowledgements also omitted the Canadian Hydrographic Service and NRCan who conducted much of the early survey work.

Recommendation: Ensure that the acknowledgements section is revised to include mention of the role of these organizations.

In conclusion, we would like to take the opportunity to recognize the excellent work done by the authors and the importance of this paper. The research paper presents a lot of data that was analysed to produce a useful document.

Monitoring of the reefs is vital and we understand the need for it to begin as soon as possible. However it is very important that the indicators and approach used are robust and comprehensive, and take into account the current degraded state of the reefs and other stressors. As this work may in future be applied to the monitoring of other glass sponge reefs, such as those in Hecate Strait, the methods selected for monitoring and assessment must to be based on the best available scientific advice. The lack of clarity around the definitions of reef health and status, and questions around the location of the edge of the reefs and transects need to be addressed before monitoring can begin. A key point made at the CSAS meeting, was that this data cannot serve as a baseline for the Strait of Georgia and Howe Sound glass sponge reef. We strongly caution against using this data as a baseline for the current status of these reefs in order to prevent a 'shifting baseline' in which the current degraded state becomes that to which we strive for in ongoing management.

As Leys stated at the meeting, Dr. Henry Reiswig believes that long-term studies are required to understand what is occurring with the glass sponge reefs. Glass sponge reefs are slow growing and we do not yet understand all the stressors that impact the reefs. Therefore it may be many years before significant changes in the reefs are observed. Kenchington noted that this was an iterative process, an important point to keep in mind. If it is demonstrated that the current

methodology is not optimal, we must not be afraid to start again. We look forward to reviewing the SAR document and any future iterations or drafts of this work, and to our continued engagement on any work that stems from this.

Sincerely,

Sabine Jessen
National Director, Oceans Program
Canadian Parks and Wilderness Society

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Canadian Parks and Wilderness Society of BC

APPENDIX G: REQUIRED WORKING PAPER REVISIONS

The following list of revisions will be made to the working paper by the authors prior to submission to the CSAP office for publication:

- A “Conclusions” section will be added to the working paper (WP), and include concluding statements that were originally in the “Recommendations” section.
- Replace “health” with “reef Character”/”verb: “characterize the reef” throughout the working paper (WP).
- Add more to section 2.2 terminology and/or state that given terminology is in the context of this project only (not general literature) e.g. “on polygon”/”off polygon” vs. “on reef” /”off reef”.
- “Uncertainties, Gaps and Future Directions” section will be reorganized and wording strengthened. Listed in same order as in Recommendations section.
- Remove the composite index from the aster plots (hub number and black arrows) in section 3.4; add discussion about need to develop a composite index and possible formulations to the future directions section;
- Change “%broken” metric to “% not broken” so that aster plots are internally consistent (improved interpretation: more colour is better for all petals).
- Expand figure/table captions to improve readability and provide more information on where numbers came from.
- Conduct power analysis to indicate minimum sampling effort required to obtain differences observed.
- Correct O et al. 2015 reference (WP page 4).
- Include “the Geological Survey of Canada” when referring to the discovery of the reefs.
- Four suggestions for future work provided in Ellen Kenchington’s review will be added to the future directions section.
- Add 2 columns to Table 1 (summarize Sarah Cooke work, Jackson high res mapping).
- Include a recommendation for image catalogue /species inventory tech report (not to form part of WP).
- Will add some text to provide broader temp-salinity context for the Strait of Georgia/Howe Sound (e.g., a couple of sentences to outline range of temperatures and salinities observed at Nanoose Station).
- Add figures to illustrate the methods (bin, grid, outline, oscula count, etc.); input table from Anya’s presentation to be added to WP (add column and assign “function” to each suite).
- Incorporate other editorial revisions as provided by formal reviewers, where feasible.