Fisheries and Oceans Canada | Pêches et Océans Canada

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Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2017/026

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

An example of dense live glass sponge reef observed at the Howe Sound – Queen Charlotte Channel site. Photo credit: DFO ROV Team.

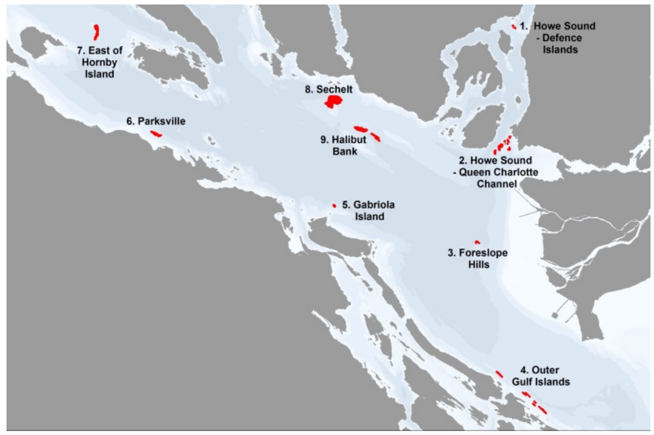

Figure 1. General overview of the nine Strait of Georgia and Howe Sound glass sponge reef complexes currently protected by fishing closures.

Context

Glass sponge reefs are structured habitats unique to the North East Pacific, which result from the life processes of 3 main sponge species. Glass sponge reefs play an important role in bentho-pelagic coupling and support diverse biological communities. The protection of sponge reefs is the focus of several regional and national policies and a key component of 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.

Over the past 15 years, nine glass sponge reef complexes have been mapped by the Canadian Hydrographic Service and the Geological Survey of Canada in the Strait of Georgia and Howe Sound using remote sensing techniques. In 2015, DFO protected these complexes via formal bottom-contact fishing closures extending 150 m beyond the reef footprints. In order to monitor the established fishing closures, a baseline of reef status and a monitoring plan must be developed.

DFO Fisheries Management requested Science Branch provide an assessment of the current health status of the nine reef complexes prior to protection by fishing closures in the Strait of Georgia and Howe Sound, along with science advice on how reefs could be monitored on an ongoing basis.

This Science Advisory Report is from the March 1-2, 2017 review of Glass Sponge Reefs in the Strait of Georgia and Howe Sound: Status assessment and monitoring advice. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Over the past 15 years, nine glass sponge reef complexes have been mapped by the Canadian Hydrographic Service and the Geological Survey of Canada in the Strait of Georgia and Howe Sound using remote sensing multibeam swath bathymetry imagery.
- In 2015, DFO protected the nine sponge reef complexes via formal bottom-contact fishing closures. In order to monitor these closures, a baseline of reef status is required and a monitoring plan must be developed.
- This work presents the first attempt at comprehensively and quantitatively characterizing the nine sponge reef complexes currently protected by bottom-contact fishing closures in the Strait of Georgia and Howe Sound. The work is based on the results of two Remotely Operated Vehicle (ROV) surveys completed in 2012 and 2013, prior to the implementation of the closures. Although there is insufficient data to form a comprehensive "baseline", the information presented in this review is considered to be the best available reference for reef status prior to implementation of the closures.
- There is insufficient understanding of glass reef ecology and ecosystem function to define and assess reef "health" at this time. Instead, suites of potential quantitative indices characterizing reef-building glass sponges and associated megafaunal communities were developed and evaluated based on consistency, ability to distinguish between reefs of qualitatively different status, and data processing effort involved. Standardized summaries characterizing reef complex status were derived from a compilation of the most informative indices.
- To support the development of a reef monitoring program, considerations for survey design, sampling methods, and data analyses are provided. In particular, a range of monitoring indices and associated sampling methods are collated to provide options for comparing reef status over time and space. Evaluation of the relative utility of potential indices can only be completed once explicit conservation objectives for the reefs have been established.
- It is recommended that management decisions be based on trend analysis and consider multiple indices in combination, rather than a singular increase or decrease in any one index. A few exceptions exist that could trigger management action. For example, a dramatic, statistically significant decrease in live sponge cover could be viewed as evidence of (an) acute stressor(s) affecting sponge reef health. A diagnostic decision tree to guide monitoring of the sponge reefs is provided as an example.
- The methods developed in this paper can be applied to other reefs in the Strait of Georgia and Howe Sound and could be adapted for assessment of glass sponge reefs in other areas such as Hecate Strait and Chatham Sound.
- Key sources of uncertainty include the natural variability of glass sponge reef communities in comparison with human-caused changes; limited information on functional relationships within a reef ecosystem and on the factors affecting recruitment and growth of glass sponge reefs; and uncertainty as a result of visual survey method limitations (e.g., consistent visual species identification, cryptic species, highly mobile species).
- Ongoing and future research efforts, including field surveys, are needed to address current gaps in understanding of sponge reef biology and ecology and to better understand reef ecosystem function and the key indicators of overall reef "health". The outcomes of these ongoing efforts will be needed to help develop and refine glass sponge reef monitoring programs.

BACKGROUND

Over the past 15 years, nine glass sponge reef complexes have been mapped by the Canadian Hydrographic Service and the Geological Survey of Canada in the Strait of Georgia and Howe Sound using remote sensing multibeam swath bathymetry imagery. This remote sensing technique readily identifies glass sponge reefs as they are much less acoustically reflective than the surrounding and underlying substrates (Conway et al. 2005). However, this and other acoustical techniques available to date 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 current live reef extent or status. A subset of the nine Strait of Georgia and Howe Sound reefs have previously been surveyed for presence and abundance of live glass sponges and associated community structure using Remotely Operated Vehicles (ROVs), while others remained unexplored. Further, no commonly accepted practice for quantitatively assessing glass sponge condition or monitoring sponge reef status has yet been established.

In 2014, DFO requested that fisheries using bottom-contact gear (prawn trap, crab trap, shrimp trawl, groundfish trawl and hook-and-line) voluntarily avoid the nine glass sponge reef areas while DFO consulted on formal protection measures. In 2015, after consultations with First Nations, commercial and recreational fisheries representatives, and conservation organizations, DFO proceeded with formal bottom-contact fishing closures under the DFO Policy for Managing Impacts of Fishing on Sensitive Benthic Areas (also referred to as the Sensitive Benthic Area Policy). Beginning April 1, 2016, the closures also applied to First Nations Food, Social, and Ceremonial fisheries that use bottom-contact fishing activities for prawn, shrimp, crab, and groundfish. The protection of sponge reefs is the focus of several regional and national policies and a key component to a number of international commitments made by Canada such as those made through the United Nations Convention on Biological Diversity and the United Nations Food and Agriculture Organization Code of Conduct for Responsible Fisheries.

In order to obtain the necessary baseline information and develop approaches to manage these fishing closures, DFO Fisheries Management requested that DFO Science Branch provide an evaluation of the health status of the nine reefs prior to implementation of the closures, along with science advice for how these reefs could be monitored on an ongoing basis.

ASSESSMENT

Reef Characterization

Video and still imagery data to assess glass sponge reefs and associated communities were collected via predetermined line transect surveys of the nine reef complexes in September 2012 and December 2013 using a Phantom ROV HD2+2 (Deep Ocean Engineering). The resulting data set consisted of 79 transects crossing 31 of 33 reefs within the nine closure areas (Appendix A). Extensive and rigorous quality control protocols were implemented to ensure the resulting data for use in the status assessments was validated and representative of the reef area being evaluated (e.g., calculated estimates of inter-annotator variability, comparison of three methods for estimating sponge abundance from still images, use of expert review to resolve low confidence annotations).

To provide a comprehensive characterization of the reef complexes, four suites of quantitative reef-building sponge-based status indices were evaluated for potential effectiveness based on consistency, ability to distinguish between reefs of qualitatively different status, and data processing effort involved (Table 1). Additional information was derived from habitat category analyses. A power analysis was conducted to determine minimum sampling effort required to be able to detect significant differences among reef complexes (i.e. minimum number of transects completed, minimum number of still images processed, minimum number of video minutes annotated).

Diverse megafaunal communities, including 9 phyla and 101 unique taxonomic groups, were observed in association with the glass sponge reefs. A series of univariate and multivariate statistical methods were used to compare community structure within and between reef complexes. Univariate indices included megafaunal density, species richness, diversity, and evenness. Species-habitat associations within reef complexes were explored via indicator species analysis (Dufrêne and Legendre 1997) by linking megafaunal records from video and still imagery with habitat categories within which they occurred. Community-based indicator suites were derived from identifying and associating indicator species with dense live and live reef, reef structure, and no visible reef habitat categories (Table 1). Finally, standardized summaries characterizing each of the reef complexes were derived from a compilation of the most informative indices (an example summary is shown in Appendix B).

Monitoring Considerations

Monitoring is required to inform effective adaptive management (i.e. management that is responsive to the state of the protected ecosystem). Although monitoring strategies and protocols have already been developed for a number of biogenic habitats (e.g. coral reefs, Flower et al. 2017), they cannot be directly translated and applied to monitoring glass sponge reef ecosystems. Glass sponge reefs largely occur at depths beyond safe SCUBA diving limits, which restrict visual survey methods to ROVs, autonomous underwater vehicles (AUVs), and drop cameras. These survey platforms are expensive, time consuming, and logistically challenging, which imposes additional constraints on developing a cost-effective monitoring program. Further, unlike for corals, exposed dead glass sponge skeletons are a necessary component of a well-functioning sponge reef ecosystem rather than an indicator of poor "health". A comprehensive assessment of sponge reef "health" must therefore incorporate a number of relevant metrics to accurately capture the complex nature of sponge reef ecosystem dynamics. This underscores the importance of a carefully developed monitoring strategy that uses relevant metrics at appropriate spatial and temporal scales and provides well-resolved time series. The recommendations provided here are strictly to guide the development of an effective monitoring program and are not intended to be prescriptive or exhaustive (nor a proxy for reef "health"); knowledge gaps and uncertainties identified through this review are addressed in a later section of this document.

Overall, an effective monitoring program will result in:

- The collection of data that allows the evaluation of current reef status and that can be used to track trends indicative of recovery or decline;
- The collection of information that can assist in identifying chronic and acute stressors of human or environmental origin that may be affecting the reefs; and
- The ability to support adaptive management decisions that will guide management actions.

Table 1. Suggested suites of indices for characterizing nine glass sponge reef complexes in the Strait of Georgia and Howe Sound currently protected by bottom-contact fishing closures.

Suites of indices		Index	Glass sponge reef complex								
			Howe Sound - Defence Islands (1)	**Howe Sound - QCC (2)**	**Foreslope Hills (3)**	**Outer Gulf Islands (4)**	**Gabriola Island (5)**	**Parksville (6)**	**East of Hornby Island (7)**	**Sechelt (8)**	**Halibut Bank (9)**
Reef-building sponge-based	Live sponge abundance	Live abundance, oscula method (count/m^2)	2.22	7.43	3.84	0.39	0.69	2.52	3.42	2.14	0
		Live % cover, grid method	0.65	9.84	6.93	0.22	0.30	0.09	3.76	2.03	0.01
		Live sponge habitat categories combined (%)	54.3	65.3	42.5	26.8	71.8	8.4	81.9	27.6	24.4
	Live sponge distribution	Clumpiness index[1]	0.34	0.66	0.71	0.50	0.49	0.15	0.55	0.56	n/a[2]
	Live sponge condition	% images with intact sponges	81.2	51.2	76.2	25.0	86.2	50.0	75.3	83.8	n/a[2]
	Recovery potential	Dead % cover, grid method	1.53	7.65	4.68	1.21	0.36	0.05	9.05	3.94	0.05
		Visible reef structure habitat categories combined (%)	89.2	81.9	68.9	65.4	94.8	38.2	96.9	72.5	75.4
Community-based	Community structure	Shannon-Wiener diversity index	2.28	2.31	2.9	3.04	1.97	0.69	1.78	1.47	2.39
	Indicator taxa of dense live and live reef (ind/m^2)	*Chorilia longipes*	0.003	0.022	0.013	0.002	0	0	0.007	0.003	0.001
		Sebastes maliger	0	0.004	0.002	0.005	0	0.004	0.004	0.001	0
		Family Sebastidae	0.001	0.033	0.027	0.019	0.026	0.014	0.029	0.010	0.004
	Indicator taxa of visible reef structure (ind/m^2)	*Rhabdocalyptus dawsoni*	0.012	0.048	0	0.001	0.057	6.252	0.5	0.393	0.035
		Pandalus platyceros	0.038	0.075	0.005	0.008	0.025	0.040	0.018	0.006	0
		Munida quadrispina	0.100	0.275	0.653	0.725	0.959	0.914	1.369	1.230	0.261
	Indicator taxa of no visible reef (ind/m^2)	Order Pennatulacea	0.005	0.002	0	0.140	0	0.001	0	0	0
		Class Ophiuroidea	0.206	0.245	0.061	0	0.01	0.117	0	0.009	0.072

[1] Prior research on the reefs used different naming conventions for the various reef complexes. The reef complex names used here match those found in the DFO Fishery Notice (FN0415).

[2]The “clumpiness index” assesses the level of sponge aggregation, and is unique from other measures of “patchiness” or “density”. See the help files at McGarigal et al. (2002) for additional information. Maximum value recorded per transect is presented.

[3] Value not available due to insufficient number of live sponges in the image dataset used for index calculation.

Key considerations to guide the development of a monitoring program include:

- Regular monitoring that uses a combination of broad-scale and intensive surveys of all reef complexes is recommended. Each reef complex exhibits a unique set of characteristics that cannot be adequately assessed or represented by monitoring a subset of reef complexes.
- Given the dynamic nature of sponge reef ecosystems, incorporating transects that cross both reef footprint and fishing closure boundaries into the survey design will assist in the assessment of the necessity for adjustments to the adaptive management zones around the reef complexes.
- It is crucial for any future monitoring program to use standardized, compatible sampling platforms and data processing hardware and protocols to allow for valid comparisons across space and time. If a change to the sampling platform is necessary, surveys should be conducted using both the old and new platforms to allow for statistical comparison of indices calculated from imagery collected in the same location at the same time. This will allow data collected using the new platform to be compared to previously collected datasets in a meaningful way.
- It is recommended that management decisions be largely based on trend analysis and consider multiple indices in combination, rather than a singular increase or decrease in any one index. A few exceptions exist that could trigger management action. For example, a dramatic, statistically significant decrease in live sponge cover could be viewed as evidence of (an) acute stressor(s) affecting sponge reef health. As an example, Figure 2 illustrates a diagnostic decision tree that could be used to incorporate information from a number of indices to guide adaptive management decisions.

Sources of Uncertainty

As the first project of its kind, this work to develop and implement a comprehensive assessment of glass sponge reefs in the Strait of Georgia and Howe Sound highlights a number of sources of uncertainty. Future research is expected to improve the ability to better estimate uncertainty in some cases, and provide improved mechanistic understanding to help minimize it, where possible.

Key sources of uncertainty:

- Evaluation of potential indices as indicators to support ecosystem-based management of human activities affecting glass sponge reefs (e.g., theoretical basis, sensitivity, specificity, cost-effectiveness) cannot be accomplished without explicit conservation objectives for the sponge reef complexes and further knowledge of glass sponge reef ecology and their response to stressors.
- Considerable variability currently limits the ability to detect real change in reef character over time. Despite incorporating over 39 hours of high-quality video and accompanying still imagery, the visual survey datasets underlying these analyses covered only a small percentage of each reef complex (0.24-0.78%). Currently, we cannot determine whether the variability observed in this study is a result of biology or methodology. As such, we are limited in our ability to attribute any differences observed during the next visual survey time period to measurement error, seasonal variability, and/or inherent ecosystem variability, rather than change in reef character due to ecosystem recovery/decline. Incorporating repeat transects into future survey designs will allow for estimation of measurement error associated with the visual survey method. Gathering long-term datasets from fixed transects or index sites will shed light on the natural variability of sponge reef ecosystems.

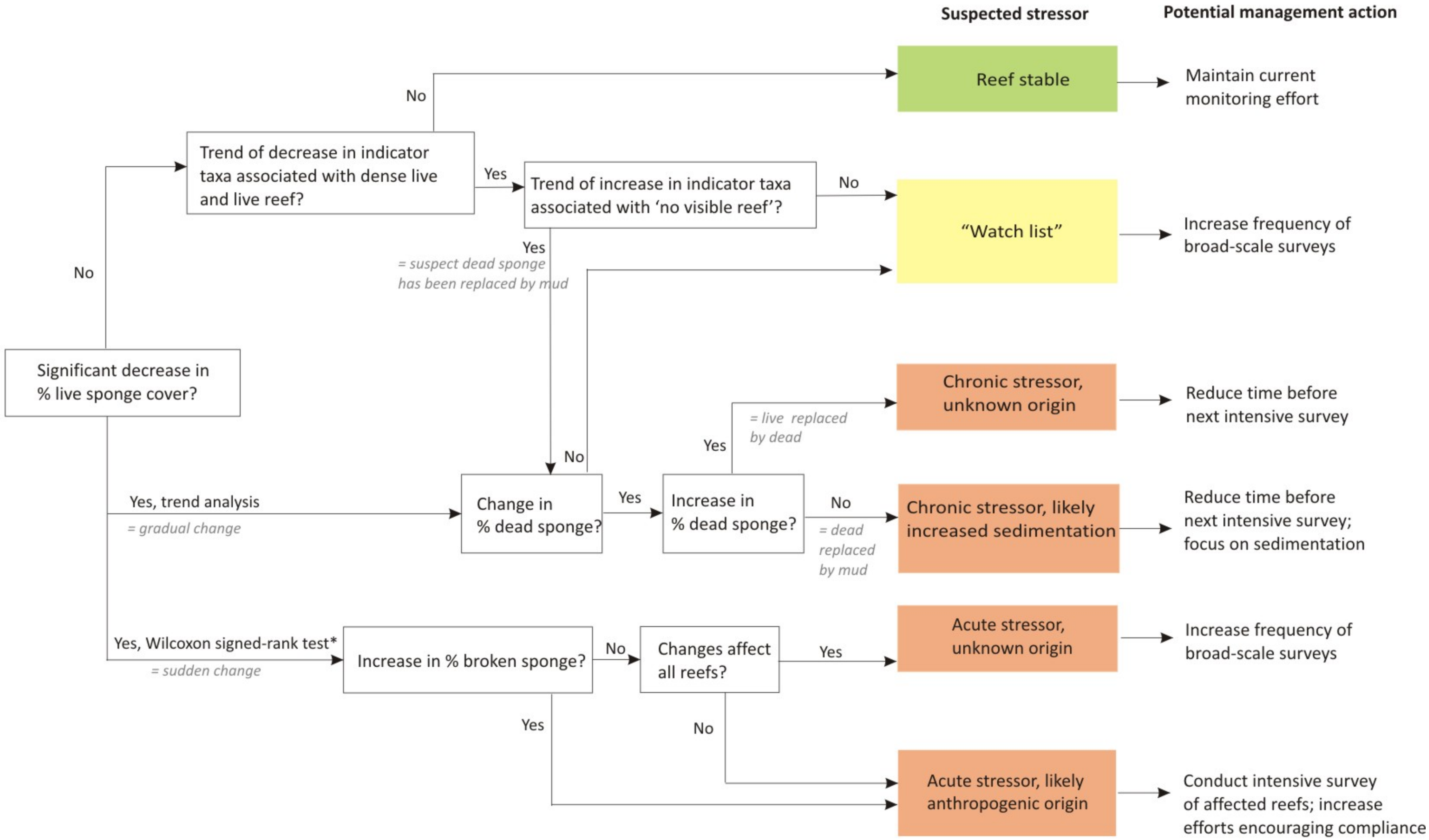

*Figure 2. Diagnostic decision tree for monitoring glass sponge reefs in the Strait of Georgia and Howe Sound. Note that the "Yes, trend analysis" and "Yes, Wilcoxon signed-rank test" pathways are not mutually exclusive. *Difference is statistically significant when compared against immediately preceding sampling period.*

- Given the lack of understanding of factors affecting recruitment and growth, there may be a need to update or review the multibeam bathymetry data in the future to assess the ongoing accuracy of the reef boundary definitions. There have also been observed discrepancies between the biological reef boundaries and the geological reef boundary definitions used to define the fishing closures. The degree to which the geological features will continue to overlap the biological features intended to be protected is presently uncertain.
- The use of multiple video and image annotators introduces challenges for data analyses. The uncertainty introduced by the moderate level of annotation success was partially offset by the fact that each annotator reviewed transects from all reef complexes, thus balancing the data processing design. As new annotators are likely to be employed for future analyses, considering the long-term nature of monitoring programs, it will be necessary to develop and maintain a “training set” to assess inter- and intra-annotator variability over time.
- Consistent and reliable visual species identification is a key source of uncertainty that will be important for monitoring changes in reef community structure over time. The current lack of physical samples to confirm species identification from these surveys is another source of uncertainty. Although much has been learned about the basic biology and ecology of glass sponge reefs since their discovery in the 1980s, some aspects remain poorly understood (e.g. factors affecting recruitment, species-specific biology, reef-specific community structure). Primary research in these areas is ongoing and will be available to inform monitoring plans in the future.
- Better understanding of the functional relationships that exist within the glass sponge reef ecosystem will improve our ability to characterize the natural dynamic state of the ecosystem. For example, how does “patchiness” of the sponge reefs affect its function? Is there an optimum degree of “patchiness” that supports maximum growth or the most diverse community?
- In general, visual survey methods are likely to underestimate the abundance and richness of megafaunal organisms in dense sponge areas, as they are harder to see in complex habitats. In addition, some mobile taxa are quick to move out of the field of view and may thus be underestimated and/or underrepresented in species counts. This caveat, however, does not diminish the significance of any of the findings incorporated into monitoring advice: they are based on datasets collected solely through visual survey, and thus this caveat would apply to them in a consistent manner, enabling quantitative comparisons over time.

CONCLUSIONS AND ADVICE

Although there is insufficient data to form a comprehensive “baseline”, 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 of reef status prior to implementation of the bottom-contact fishing closures. 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 only a subset of the 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/responsiveness, specificity, and cost-effectiveness. These elements cannot be assessed until there are explicit conservation objectives in place for the reef complexes.

This paper 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, Royal BC Museum) to produce a common online repository for this information.

As the first 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*., ecologically and biologically significant areas (EBSAs) and implementation of the Sensitive Benthic Area 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.

ECOSYSTEM CONSIDERATIONS

The advice for development of an ongoing monitoring program provided here addresses only the biological components of interest (i.e., indices and metrics related to the significant ecosystem components (SECs) of the ecological risk assessment framework (ERAF; O et al. 2015)). Specifically, the work reviewed here does not comprehensively address other aspects of the ERAF, such as stressor-specific interactions with the biological components. The work reviewed here can be used to inform a more comprehensive ecological risk assessment(s) 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). Further, it is recommended that sponge-specific oceanographic measures (nutrients, bacteria, silicate) be included in the suite of properties measured at this station.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 1-2, 2017 regional peer review on Glass sponge reefs in the Strait of Georgia and Howe Sound: status assessment and monitoring advice. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available

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APPENDIX A. MAP OF STRAIT OF GEORGIA AND HOWE SOUND GLASS SPONGE REEFS

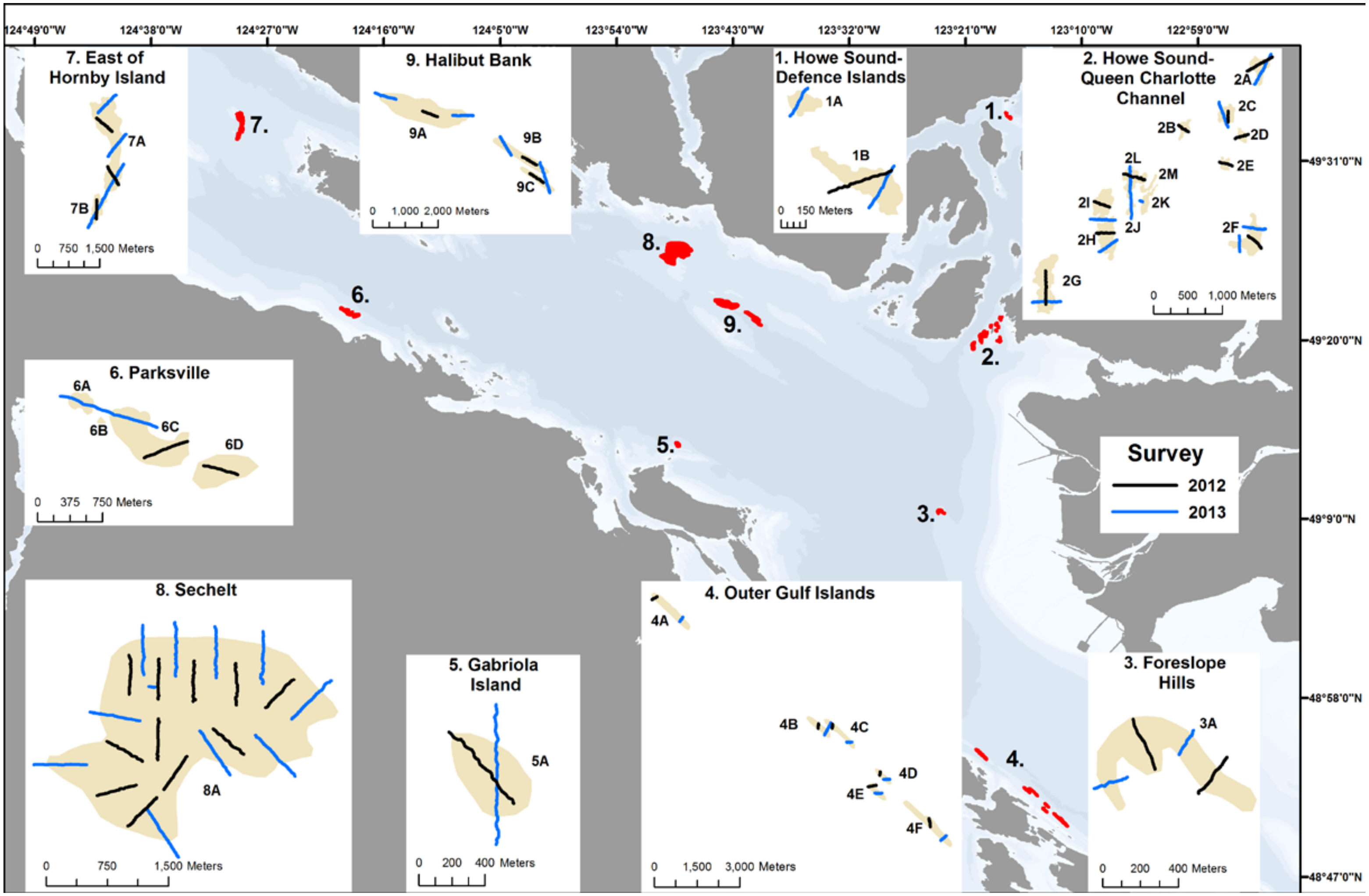

Figure 3. Maps of the nine Strait of Georgia and Howe Sound reef complexes showing individual reefs (identified by letters) and transects completed during the 2012 and 2013 ROV surveys.

APPENDIX B. SAMPLE OF REEF CHARACTERIZATION SUMMARY REPORT

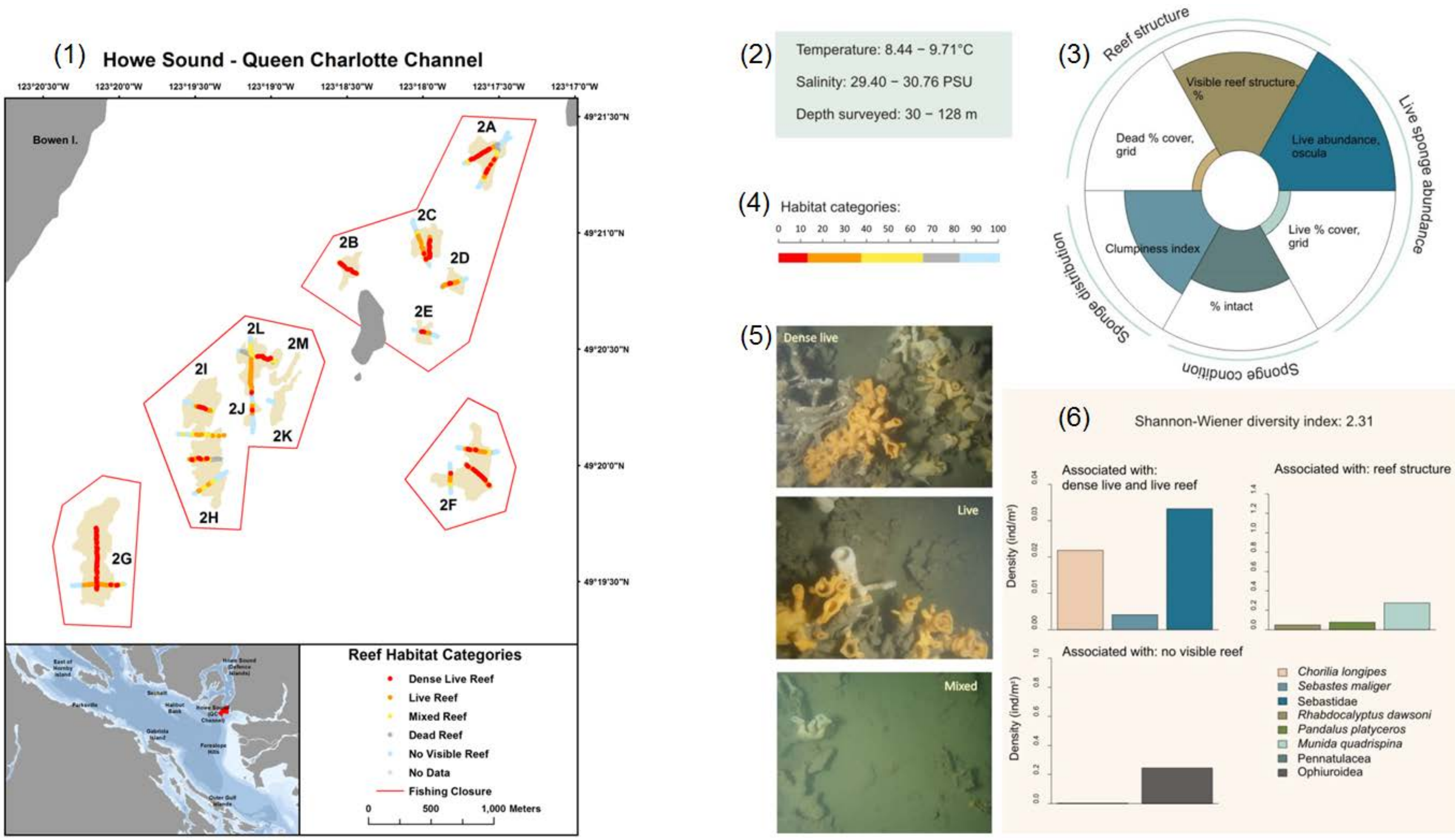

Figure 4. Example of a summary card: Howe Sound – Queen Charlotte Sound reef complex. Each summary card contains the following elements: (1) Map of reef complex showing location, fishing closure boundaries, individual reef(s), transects, and point-based heat maps of habitat categories; (2) Temperature, salinity, and depth ranges recorded, (3) Aster plots showing the values of six sponge-based indices found most relevant for characterizing reef complexes (the scale for live % cover, dead % cover, % intact, and visible reef structure indices is 0 to 100%, for Clumpiness index from 0 to 1, for oscula index from 0 to 7.4, the maximum mean number of oscula per m^2 observed in this study); (4) Summary of the frequency of occurrence of five habitat categories; (5) Representative image examples; and (6) Densities of indicator taxa.

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