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National Capital Region

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Science Advisory Report 2021/048

A NATIONAL MONITORING FRAMEWORK FOR CORAL AND SPONGE AREAS IDENTIFIED AS OTHER EFFECTIVE AREA-BASED CONSERVATION MEASURES

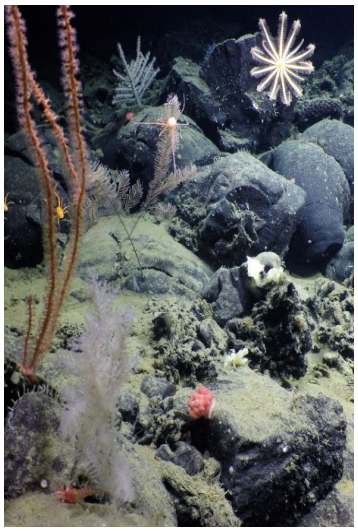
A) B)  C)

Figure 1. A) Coral garden (includes gorgonian and scleractinian corals) (Photo credit: DFO 2007), B) Canadian Pacific seamount (Photo credit: Ocean ExplorationTrust/Northeast Pacific Seamount Expedition Partners, 2018) C) Carnivorous sponge (Chondrocladia spp.) from Baffin Bay (Photo credit: ArcticNet 2015).

Context:

As of 2020 Canada, through its commitments to national and international marine conservation targets, has protected 13.81% of its marine and coastal areas through the establishment of marine protected areas and other effective area-based conservation measures (OECMs). Fisheries and Oceans Canada (DFO) has also taken steps to conserve benthic ecosystems through its "Policy to manage the impacts of fishing on sensitive benthic areas" (DFO 2009). Canada currently has 59 OECMs, 38 of which are established to protect cold-water corals and/or sponge benthic ecosystems.

Marine OECMs can include fisheries area closures established for the long-term to contribute towards the conservation of biodiversity. Marine OECMs provide biodiversity conservation benefits (BCBs), which are benefits for a habitat, species or other component of the ecosystem resulting from the implementation of an OECM. They result in a net positive change in, or prevent the loss of, biodiversity in the OECM. BCBs include the focus of the conservation area, a direct BCB, and indirect BCBs or "co-benefits" which can occur incidentally as a result of conservation measures implemented in the area.

Those OECMs that conserve coral and/or sponge aggregations, prohibit bottom-contact fishing activities in order to protect these fragile, often slow-growing species. For coral and sponge OECMs, the direct BCBs are for the coral and sponge species and their habitats. Indirect BCBs for corals and sponges vary by region and type of coral and/or sponge. Regional variations of coral and/or sponge species assemblages and their associated habitat influence the types of BCBs and the monitoring techniques that can be used.

November 2021

Canada

A Science advisory meeting was held to provide national guidance on how to monitor coral and/or sponge OECMs to demonstrate that they achieve BCBs. The objectives for the meeting included advice on the categorization of corals and/or sponges found within Canadian OECMs the indirect BCBs that might be inferred from the ecological components being monitored, and indicators, and techniques for monitoring that can be used in these systems.

This Science Advisory Report is from the December 1–3, 2020, National Peer Review on A National Monitoring Framework for Coral and Sponge Areas Identified as Other Effective Area-Based Conservation Measures. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- This advice provides national guidance on the selection of monitoring indicators along with the tools, techniques, methodologies, and ecological monitoring design of coral and sponge other effective area-based conservation measures (OECMs). Fisheries and Oceans Canada (DFO) regions can utilize this advice while adapting it as appropriate for their individual OECMs.
- For efficient monitoring, corals and sponges have been grouped based on their characteristics, habitat type, or ecological function. These groupings will facilitate the discussion and development of monitoring plans and aid in understanding coral and sponge biodiversity conservation benefits (BCBs).
- Baseline data are required to develop ecological monitoring plans. The level of baseline knowledge for existing coral and sponge OECMs was summarized to determine where gaps exist and where efforts should be focused to collect additional data.
- Indirect biodiversity conservation benefits were reviewed, and multiple indirect BCBs are likely to exist within each OECM. However, to ensure efficient design of monitoring, priority should be placed on monitoring direct BCBs.
- Several criteria were used to select suitable ecological indicators for coral and sponge OECMs. Ecological indicators should include both state and stressor types. The conservation objective(s) as well as the availability of data need to be considered when choosing indicators for monitoring specific OECMs.
- Monitoring plans should include short- and long-term indicators which are able to inform management actions and detect ecological trends. It was recognized that time scales for short-term and long-term indicators will vary depending on the OECM, the conservation objectives, and the corals and sponges that are being assessed. The monitoring timeframes should be revisited as knowledge of the coral and sponge communities improves.
- Best practices were reviewed for monitoring the direct and indirect BCBs of coral and sponge OECMs with a comprehensive overview of potential tools, techniques, and methodologies as well as their strengths and limitations. These should be shared across regions to encourage consistency where practical, recognizing that regional differences will need to be taken into consideration.
- Indicator selection, coral and sponge groupings, monitoring tools, techniques, methodologies, and sampling design should be reviewed as knowledge increases and technological advances occur.

INTRODUCTION

In 2010, Canada committed to conserve ten per cent of coastal and marine areas through effectively managed networks of protected areas and other effective area-based conservation measures (OECMs) by 2020. Canada has now protected 13.81% of its marine and coastal areas and is working toward a new target of conserving 25% of these areas by 2025.

DFO has created 59 OECMs under the *Fisheries Act.* Thirty-eight of these 59 OECMs have been established to protect cold-water coral and/or sponges. In Canada, cold-water corals and sponges are found in the Atlantic, Pacific and Arctic. In these coral and/or sponge OECMs, bottom-contact fishing activities have been prohibited.

Preceding the 2018 international definition of an OECM agreed to parties to the Convention on Biological Diversity (CBD), previous science advice described an OECM as an area-based management measure that provides biodiversity conservation benefits (BCBs) with a goal to create a net positive change in, or to prevent the loss of, biodiversity within the area (DFO, 2016). Canada has since adopted the CBD definition of an OECM which is a geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in-situ conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio–economic, and other locally relevant values.

A direct BCB is a benefit resulting from a conservation action that provides benefits for a habitat, species, or other components of the ecosystem. OECMs also provide indirect BCBs, or “co-benefits” which occur indirectly as the result of the OECM that has been designed to achieve other objectives (DFO, 2016).

Canadian OECMs will be evaluated on a regular basis to ensure ecological components of interest continue to be conserved. To do this, monitoring programs for OECMs focus on the conservation objectives to determine that these objectives are being met. Corals and sponges should be monitored directly, and monitoring should also be adaptable, as appropriate, for individual OECMs and regions.

Given that monitoring is essential to determine if OECMs are effective, the Marine Planning and Conservation and Fisheries Resource Management programs requested national guidance on how to monitor coral and/or sponge OECMs to demonstrate that they achieve direct and indirect BCBs. The advice aims to provide a categorization of corals and/or sponges found within Canadian OECMs, the indirect BCBs that might be inferred from the ecological components being monitored, indicators, and techniques for monitoring that can be used in these systems. The details of this review are presented in Neves et al. (In prep.)[1].

[1] Neves, B.M., G. Faille, F.J. Murillo, C. Dinn, M. Pućko, S. Dudas, A. Devanney, P. Allen. A national monitoring framework for coral and sponge areas identified as Other Effective Area-Based Conservation Measures. DFO Can. Sci. Advis. Sec. Res. Doc. In preparation.

ASSESSMENT

Canadian Coral and Sponge OECMs

To help facilitate the development of monitoring plans, including the selection of monitoring indicators, and aid in understanding their BCBs, species of corals and sponges were grouped. This can also help alleviate the need for species-level information where it can often be hard to obtain or validate. For the purpose of this advice, grouping has been done based on phylogeny, morphology (e.g. body size, shape), life history traits, and/or habitat preferences (Neves et al. In prep.[1]).

Corals were divided into seven groups: Gorgonian corals; soft corals; sea pens; black corals; reef-building corals; cup corals; and hydrocorals. Sponges were divided into four groups: glass sponge reef species; *Vazella* sponge grounds; Astrophorid sponge grounds; and mixed sponge habitats.

Neves et al. (In prep.)[1] includes a detailed overview of Canadian coral and sponge OECMs including their conservation objectives, the represented coral and sponge groups, discussion of the available baseline information, and knowledge gaps.

Indirect Biodiversity Conservation Benefits (BCBs)

Coral and sponge communities provide many ecosystem functions in marine environments. They provide biodiversity conservation benefits (BCBs), which are benefits for a habitat, species or other component of the ecosystem resulting from the implementation of an OECM. It results in a net positive change in, or prevents the loss of, biodiversity in the OECM. BCBs include the focus of the conservation area, a direct BCB, and indirect BCBs or “co-benefits” which can occur incidentally as a result of conservation measures implemented in the area. Ecosystem functions of coral and sponge assemblages include roles in biogeochemical cycling, predator/prey interactions, habitat provision, and increased biodiversity.

Biogeochemical cycling by corals and sponges, through processes such as removing nutrients or particulates from the water, plays a key role in aquatic ecosystems. This is essential for many processes including nutrient cycling and energy transfer in aquatic food webs. Certain corals and sponges can also provide food for species such as crabs, sea stars, and nudibranchs, which can have implications for the communities found in these ecosystems. Corals and sponges also provide habitat for many species, often in areas where there is little geographic relief that could otherwise provide structure for fish and invertebrates. This can lead to an increase in local biodiversity. Benefits of the structure provided by corals and sponges include increased feeding opportunities, protection from predators, shelter from high current flows, spawning and nursery areas, spawning aggregation sites, and attachment sites for fish eggs and certain invertebrates.

Research on indirect BCBs of coral and sponge OECMs across Canada is still limited and as research in Canada and elsewhere advances, further linkages and their importance will be identified. However, it is likely that all the indirect BCBs mentioned in this section exist in some fashion in each of Canada’s OECMs. The development of monitoring plans should consider this to be true even in the absence of data confirming localized indirect BCBs for each OECM.

Ecological Monitoring Indicators

Identifying ecological indicators is an important step in the development of monitoring plans. Ecological indicators provide information on the effectiveness of conserved areas. In the Northeast Atlantic, the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Commission) provides advice on the selection of such indicators, and defines marine biodiversity indicators as 'any measurable feature or condition of the marine environment that is relevant to the stability and integrity of habitats and communities, the sustainability of ecosystem goods and services (e.g. primary productivity, maintenance of food chains, nutrient cycling, biodiversity), the quality and safety of seafood, and the status of amenities of socio-economic importance' (Neves et al. In prep.[1]).

Several steps and criteria (listed below) were used to select suitable ecological indicators for monitoring Canadian coral and sponge OECMs. Ecological indicators should include both state and stressor types, and the conservation objective(s) as well as the availability of data need to be considered when choosing indicators for monitoring specific OECMs.

State indicators are those related to ecological components, including species, assemblage characteristics, biotic functional groups, habitat characteristics, and physico-chemical properties (i.e., nutrient levels) (Neves et al. In prep.[1]). A number of state indicators were reviewed during this process, including: abundance; biomass; distribution; diversity indices; size structure; proportion of live and dead corals and condition; percent coral colonies colonized by zoanthids; patch area and density; patch isolation / proximity of sponge grounds; patch connectivity; patch contagion index; *Lophelia* reef extent; sponge-reef indicators; indirect BCB indicators; and environmental indicators.

Stressor indicators are those that are related to human activities in the area. The following stressor indicators were reviewed during this process: distribution and aggregation of fishing; areas not impacted by bottom-contacting gear; distribution of oil and gas activities; anthropogenic sediment deposition; chemical impacts related to oil and gas activities; timing and duration of anomalous events; timing, duration, and magnitude of phytoplankton blooms; timing and duration of sea ice cover; seabed litter presence; and activities related to submarine cables.

Steps and Criteria to Select Ecological Indicators

Previously, DFO (2013) has suggested seven steps to identify ecological indicators, including: 1) identify conservation objectives; 2) identify suitable indicators; 3) identify selection criteria; 4) evaluate indicators; 5) assess whether there is redundancy; 6) agree on the final suite of indicators; and 7) establish reference levels. The previous advice also suggested the following eight criteria for reviewing the appropriateness of ecological indicators:

1. **Theoretical basis**: The indicator is based on concepts that are consistent with established theory;
2. **Measurement**: Data used to estimate indicators should be easily and accurately measured;
3. **Historical data**: Data from earlier time periods should be available, ideally with a time series of at least 10 to 20 years;
4. **Sensitivity**: The amount of change in indicator value corresponds to a change in the pressure (e.g., fishing, pollution);

5. **Responsiveness**: The type of response (linear, non-linear, random) of the indicator to the pressure, the timelines of the response, and the signal-to-noise ratio (i.e., the data used to estimate the indicators should be measurable accurately enough that any change or trend in the indicator is greater than the variance in its measurement) can be reasonably measured;
6. **Specificity**: Indicators may be influenced by more than one pressure (e.g., fishing and temperature). How specific is the indicator to the pressure of concern? Can it be disentangled from other pressures (i.e., it is critical to know why an indicator is changing)?
7. **Public awareness**: The indicator should be easily understandable by non-scientists, and can be clearly communicated; and,
8. **Cost-Effectiveness**: Sampling, measuring, processing, analyzing indicator data, and reporting assessment outcomes should be feasible and within existing financial resources.

For this advice, potential indicators were identified based on the scientific literature. Appropriateness of the selected indicators was then assessed based on criteria 1 to 4 above. It was agreed that criteria 5 to 8 should be reviewed by individual regions when determining ecological monitoring indicators for specific OECMs. Most of the coral and sponge OECMs share potential indicators, with some additional specific indicators suggested for the monitoring of glass sponge and coral reefs (e.g., *Lophelia*).

Indicators that were considered most suitable for monitoring each group of corals and sponges and their indirect BCBs are presented in Table 1 along with their strengths and limitations and potential tools for ecological monitoring. Among the pre-selected *state indicators*, it was found that most had a good theoretical basis and public awareness qualities for the monitoring of corals and sponges. The availability of historical data was difficult to generalize, as it is variable across regions. Cost-effectiveness was evaluated in terms of whether data could be used for more than one indicator. While most indicators described here focus on direct BCBs, in several cases the same indicator can also be used in the context of indirect BCBs.

The conservation objectives of each area and the availability and appropriateness of data will need to be considered when choosing indicators to include in a monitoring plan. For the purposes of this advice, we identified indicators based on monitoring metrics that could aid our understanding of whether corals and sponges are benefiting from the protective measures, and therefore benefiting the broader ecosystem. In addition, as our knowledge of cold-water corals and sponges increases through research, and with technological advances as well as increased monitoring, indicator selection will need to be reviewed. This is especially true in frontier and other areas where little research has occurred previously. Indicators are not static; their selection and analysis will need to be iterative and responsive to advancements in knowledge.

Tools, Techniques and Methodologies

The selection of appropriate tools, techniques, and methodologies for ecological monitoring is essential for a successful monitoring program, and the program needs to be directly linked to OECM conservation objectives. Different tools might collect data at different scales and resolution. Therefore, careful consideration and, when possible, trials should be undertaken to

make sure that the selected tools and the data they provide are at the appropriate scale and well-aligned with conservation objectives.

Most of the Canadian coral and sponge OECMs are in deep, offshore waters (i.e., > 200 m and up to 4700 m), which imposes logistical constraints and requires the use of specific tools and platforms (e.g., vessels). Some OECMs are large (e.g., half of them are > 800 km^2, and one is 55,350 km^2), which will be challenging for data collection (including baseline data) and monitoring. These challenges and limitations will need to be considered during the development of monitoring designs. Best practices will need to be followed to ensure that the collected data will allow for meaningful statistical analyses. Robust monitoring programs are essential for optimizing available resources and allowing for the detection of change in the benthic environment, as well as to inform which management measures have been successful.

Neves et al. (In prep.)[1] contains a review of potential tools for surveys of benthic organisms, including limitations and benefits, as well as suggested best practices. The potential tools examined included imagery techniques and bottom contacting gear. A few other types of tools were also discussed including acoustic techniques, eDNA, oceanographic moorings, and benthic landers (Table 2). While not exhaustive, this review includes current tools which have been used in Canadian waters.

Table 1. Summary of suitable state indicators that could potentially be used in the monitoring of Canadian corals and/or sponge OECMs (Neves et al. In prep.[1]). Corals and sponges are listed by groups. Criteria based on DFO (2013). The indicators in this table identify those that are best suited for each coral and sponge group. The column "Preferred tools" does not include all other potential methods, which are discussed in Neves et al. (In prep.)[1].

Indicator	Gorgonians	Sea pens	Soft corals	Cup corals	Black corals	Reef–forming corals	Glass sponges (reef)	Glass sponges (non-reef)	Astrophorid sponges (e.g., *Geodia*)	Mixed sponges	Purpose / Strengths	Limitations	Preferred tools
Numerical abundance	X	X	X	X	X	X[1]	X[2]	X	X	X	• Biodiversity • Population structure • Function • Reproductive success • Easy to measure	• Small specimens and rare species might be overlooked	• Imagery surveys

Indicator	Gorgonians	Sea pens	Soft corals	Cup corals	Black corals	Reef–forming corals	Glass sponges (reef)	Glass sponges (non-reef)	Astrophorid sponges (e.g., *Geodia*)	Mixed sponges	Purpose / Strengths	Limitations	Preferred tools
Biomass	X	X	X	X	X	X[3]	X[3]	X[4]	X	X	• Population structure (proxy for numerical abundance and size/age) • Predictor of metabolism and related traits, and secondary productivity • Ecological function • Reproductive success • Identification of hotspots of diversity • Can use scientific trawl data • Direct weight is easy to measure	• Data on biomass for glass sponges should be interpreted with caution, as they are very light[4] • Would need calibration of size-weight relationships if using imagery	• Scientific trawls (if surveys continue inside of OECMs) • Imagery surveys (potential use if numerical abundance data can be converted to biomass)

Indicator	Gorgonians	Sea pens	Soft corals	Cup corals	Black corals	Reef–forming corals	Glass sponges (reef)	Glass sponges (non-reef)	Astrophorid sponges (e.g., *Geodia*)	Mixed sponges	Purpose / Strengths	Limitations	Preferred tools
Distribution	X	X	X	X	X	X	X[5]	X	X	X	• Informs on biodiversity status (e.g., shifts) • Ecosystem resilience • Ecosystem function • Genetic diversity • Can use scientific trawl data	• Depends on good taxonomic resolution • Limited by sampling effort (i.e., less data available for coastal, deep-water, and Arctic environments)	• Imagery surveys associated with sampling
Diversity indices	X	X	X	X	X	X	X	X	X	X	• Biodiversity • Community structure • Ecosystem resilience • Ecosystem function • Genetic diversity	• Depend on quality of abundance / biomass and richness data • Small-size species and rare species might be overlooked	• Imagery surveys associated with sampling

Indicator	Gorgonians	Sea pens	Soft corals	Cup corals	Black corals	Reef–forming corals	Glass sponges (reef)	Glass sponges (non-reef)	Astrophorid sponges (e.g., *Geodia*)	Mixed sponges	Purpose / Strengths	Limitations	Preferred tools
Size structure	X	X	X	X	X	-	-	X	X	X	• Ecological function • Reproductive success • Population structure	• Difficult to measure from imagery • Trawl samples might be size-biased (e.g., fragmented specimens, cod-end mesh size) • Small specimens might be missed in imagery data.	• Imagery surveys associated with samples

Live:dead ratio and condition	X	X[6]	X[6]	X[6]	X	X	X	X	X[6]	X[6]	• Mortality rate • Physiological stress	• Live:dead ratio challenging to quantify for gorgonians due to difficulty to accurately determine the number of dead colonies (2 fragments equal one or more colonies) • Clear visual contrast between living and dead portions of *Lophelia* colonies and sponge reefs • Potential markers to assess health condition in Canadian coral and sponge species have not yet been defined.	• Imagery surveys • Physical samples (condition assessments)
% corals with zoanthids	X	-	-	-	X	-	-	-	-	-	• Physiological stress • Mortality metric	• Might be difficult to measure • Need target-imagery	• Imagery surveys (ROV preferred)
Patch area and density	X	X	X	X	X	X	X	X	X	X	• Biodiversity • Ecological function • Reproductive success	• Need clear definitions of patches formed by each coral	• Imagery surveys

Indicator	Gorgonians	Sea pens	Soft corals	Cup corals	Black corals	Reef–forming corals	Glass sponges (reef)	Glass sponges (non-reef)	Astrophorid sponges (e.g., *Geodia*)	Mixed sponges	Purpose / Strengths	Limitations	Preferred tools
												and sponge group • Extensive sampling may be needed for some coral and sponge groups that form large patches	
Patch isolation / proximity	X	X	X	X	X	X	X	X	X	X	• Reproductive success • Genetic diversity	• Need clear definitions of patches formed by each coral and sponge group • Extensive sampling may be needed for some coral and sponge groups that form large patches	• Imagery surveys

Indicator	Gorgonians	Sea pens	Soft corals	Cup corals	Black corals	Reef–forming corals	Glass sponges (reef)	Glass sponges (non-reef)	Astrophorid sponges (e.g., *Geodia*)	Mixed sponges	Purpose / Strengths	Limitations	Preferred tools
Patch connectivity	X	X	X	X	X	X	X	X	X	X	• Reproductive success • Genetic diversity	• Need clear definitions of patches formed by each coral and sponge group • Extensive sampling may be needed for some coral and sponge groups that form large patches • Sampling required for genetics	• Imagery surveys associated with sampling (genetic studies)

Indicator	Gorgonians	Sea pens	Soft corals	Cup corals	Black corals	Reef–forming corals	Glass sponges (reef)	Glass sponges (non-reef)	Astrophorid sponges (e.g., *Geodia*)	Mixed sponges	Purpose / Strengths	Limitations	Preferred tools
Patch contagion index	X	X	X	X	X	X	X	X	X	X	• Reproductive success	• Need clear definitions of patches formed by each coral and sponge group • Extensive sampling may be needed for some coral and sponge groups that form large patches	• Imagery surveys associated with sampling (genetic studies)
Lophelia reef extent	-	-	-	-	-	X	-	-	-	-	• Provides information on reef extent • Can be used to assess reef physical damage (e.g., broken reef)	• Lack of data on actual reef extent in Canada	• Imagery surveys • Acoustic surveys

Indicator	Gorgonians	Sea pens	Soft corals	Cup corals	Black corals	Reef–forming corals	Glass sponges (reef)	Glass sponges (non-reef)	Astrophorid sponges (e.g., *Geodia*)	Mixed sponges	Purpose / Strengths	Limitations	Preferred tools
Reef indicators: Indicator taxa of live reef	-	-	-	-	-	X	X	-	-	-	• Certain taxa have significant associations with specific habitat types and their presence can indicate reef status	• More information on potential indicator taxa in a Canadian context is needed.	• Imagery surveys (ROV preferred)
Reef indicators: Reef structure habitat categories (no visible reef, dead reef, mixed reef, live reef)	-	-	-	-	-	X	X	-	-	-	• Relative proportions of these four habitat categories	• Requires very specific surveys	• Imagery surveys
Reef indicators: Recovery potential	-	-	-	-	-	X	X	-	-	-	• Recolonization and regrowth • Dead % cover • % visible habitat categories combined	• Recruits can be difficult to visualize • Requires very specific surveys	• Imagery surveys associated with sampling

Indicator	Gorgonians	Sea pens	Soft corals	Cup corals	Black corals	Reef–forming corals	Glass sponges (reef)	Glass sponges (non-reef)	Astrophorid sponges (e.g., *Geodia*)	Mixed sponges	Purpose / Strengths	Limitations	Preferred tools
Indirect BCBs	X	X	X	X	X	X	X	X	X	X	• Species associations • Infauna diversity • Sponge filtration rate • Contribution to biogeochemical cycles	• More information on indirect BCBs associated with coral and sponge taxa is needed	• Imagery data (sponge oscula metrics), species associations • Sediment sampling (ROV push-core preferred)
Environmental indicators	-	-	-	-	-	-	-	-	-	-	• Collection of environmental data to assist with interpretation of changes	• No significant limitations	• Oceanographic sampling (e.g. CTD casts, plankton tows) • Satellite data

[1] When colonies can be distinguished from one another. [2]Measured as percent cover. [3]Biomass of *Lophelia* colonies has been measured through a combination of imagery (surface area) and specimen dry weight, but the technique is currently being developed and may be applicable to other species (e.g. sponges). [4]Data on biomass for glass sponges should be interpreted with caution, as they are very light. [5]Live sponges. [6]Condition only.

Table 2. Characteristics of current technologies suitable for benthic surveys. The occurrence of a certain characteristic is represented by an "X" Neves et al. (In prep.)[1].

Characteristic	Imagery Surveys							Bottom-contacting Gear Surveys			Other tools				
	Remotely Operated Vehicle (ROV)	Mini ROV	Human-operated sub	Automated Underwater Vehicle (AUV)	Drop camera	Towed Underwater Video (TUV)	Baited Remoted Underwater Video System (BRUV)	Sled, Trawl	Dredges	Grabs, corers	Multi-Beam Echosounder (MBES)	eDNA	Moorings	Benthic lander	Hydrophones
Continuous broad-scale spatial coverage	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-
Continuous fine-scale spatial coverage	X	X	X	X	-	-	-	-	-	-	-	-	X	-	X
Non-extractive	X	X	X	X	X[1]	X[1]	X	-	-	-	X	X	X	X	X
Repeatability	X	-	X	X	-	-	-	-	-	-	X	X	X		X
Able to sample over a variety of environments	X	X	X	X	X[2]	X[2]	X	-	X	-	X	X	-	X	X
Direct Species-level identifications (i.e. sampling possible)	X	-	X	-	-	-	-	X	X	X	-	X	-	-	-
Genetics, morphological analyses possible	X	-	X	-	-	-	-	X	X	X	-	X	-	-	-
Behaviour observed	X	X	X	-	X	X	X	-	-	-	-	-	-	X	X
Cryptofauna observed	X	X	X	-	-	-	-	X	X	X	-	-	-	-	X
Quantitative data	X	X	X	X	X	X	X	X[3]	-	X	X	X	X	X	X
Concurrent physical and biological data	X	-	X	X	-	-	-	X[4]	-	X	-	X	X	X	X
Minimal technical expertise	-	X	-	-	X	X	X	X	X	X	-	-	-	-	-
Vessel flexibility	-	X	-	-	X	X	X	-	-	X	X	X	-	X	X
Access to equipment (easiness)	-	X	-	-	X	X	X	X	X	X	X	X	-	-	X

[1]Drop cameras and TUV can be invasive when deployed blindly; [2]Limited in areas of high vertical relief; [3]Quantitative data are limited for corals and sponges; [4]Can be associated with CTD (but not common).

Imagery Technologies

The types of imagery tools considered included: remotely operated vehicles (ROVs); human-operated submersibles; underwater cabled observatories; autonomous underwater vehicles (AUVs); drop camera systems; towed underwater video systems (TUVs); and baited remote underwater video systems (BRUVs).

The choice of imagery tools is dependent on the conservation objectives of the OECM, the ecological monitoring indicators chosen, the objectives of the survey, the habitat being monitored, and environmental conditions. It is important that imagery data collection is planned with specific and predetermined survey objectives. It is also critical to consider how the data will be analyzed and managed, for example the imagery tools generate a considerable amount of data, and requires specific skills and expertise, from gear deployment to data analysis.

Bottom-Contacting Gear

Bottom trawls, sleds and dredges, and sediment samplers (i.e., grabs and corers) were considered during the review of bottom-contacting gear. While bottom trawls are an efficient method to sample fish, they are considered a less efficient method for the study of corals and sponges. Trawl gear have low catchability for corals and sponges, but they can collect physical samples and might be used to complement imagery surveys. The use of bottom trawls is also limited to “trawlable” bottom (i.e., relatively soft bottom areas), which can limit their applicability. Despite the advantages of these tools to collect benthic samples, they are an invasive method and alternatives should be used whenever possible. Furthermore, these types of gear are not recommended for surveys in coral or sponge reef areas.

Table 2 outlines the characteristics of the tools reviewed (Neves et al. In prep.)[1].

Monitoring Design

A monitoring design is developed after the monitoring objectives have been identified, indicators selected, and monitoring tools chosen. Any monitoring design needs to be statistically robust in order to detect change and draw appropriate conclusions (cause and direction).

There are a number of considerations that go into monitoring design. These include the availability of baseline data and how they can be used, frequency of sampling, how much sampling should be done, and where. Neves et al. (In prep.)[1] reviewed recommended best practices and general information that should be considered, but specific regional processes would need to be conducted for specific OECMs.

Baseline Data

Some baseline data are available which can provide information to guide the development of a monitoring program sampling design, but for many OECMs, baseline data gaps exist, which will need to be addressed. Baseline data needs can be assessed regionally. However, before using any existing data in a monitoring program, the data should be carefully evaluated to ensure that they are suitable for the purpose. The availability of bathymetric data and bottom type, which can be used to describe habitats, are key factors for the development and implementation of a good sampling design.

How Much to Sample and Statistical Considerations

It is important that the monitoring design be statistically robust. This includes considerations of sampling size and replication, statistical power, and data independence. The sampling unit needs to be related to the size and expected distribution of the indicator to allow the detection of

spatial patterns. Replication and the careful placement of reference sites should be considered. Power analysis is useful here for determining the optimal number of samples. This should be done both *a priori* and *post hoc* when possible.

Temporal Consideration and Frequency

Coral and sponge ecology and life history will be important considerations when determining the timing and frequency of sampling. Seasonality may be important for some indicators and optimal frequency will vary for different taxa/indicators and between OECMs. Species with different lifespans will differ in the time it takes for trends in indicators such as numerical abundance to develop. Biological responses can take from a few years to decades to be detectable. Stressors should also be considered when determining sample frequency, so areas under greater stress should be monitored more often. Frequency should be revisited as the monitoring progresses and data on various trends are collected and analyzed.

Sampling Design

Neves et al. (In prep.)[1] contains a discussion of the factors involved in monitoring program sampling design including types of sample designs, Before-After-Control-Impact (BACI) design, and reference sites.

Sampling design can be divided into probabilistic and non-probabilistic methods. Probabilistic methods are those where sampling units have the same theoretical probability of being selected, and therefore this type of design is generally considered more statistically robust. Non-probabilistic methods involve the researcher subjectively selecting the sampling units (judgement sampling). Each type of design has their strengths and limitations, and a brief overview is given in Neves et al. (In prep.)[1].

Before-After-Control-Impact (BACI) design is one of the more appropriate methods to look at effectiveness of management measures. This type of design is particularly powerful because it controls for both temporal and spatial variation, improving the robustness of conclusions on management effects. For a BACI design, sampling periods before and after the measure are implemented are compared along with impacted and control sites. A suitable reference site (control site) must be available, and sites should remain fixed, whilst within-site sampling units may be re-randomized or fixed. The use of external reference sites is highly recommended to optimize the scope of conclusions and is required for BACI or similar sampling designs. These sites should not be placed too close to the protected area to avoid problems with edge effects, they should also have comparable environmental conditions and substrates, and the level of historical pressure should be similar.

CONCLUSIONS AND ADVICE

This science advice, and the accompanying Research Document (Neves et al. In prep.[1]), provide the basis for development of effective monitoring programs for Canadian coral and sponge OECMs. The advice that was developed on selecting monitoring indicators, along with tools, techniques, methodologies, and ecological monitoring design of coral and sponge OECMs will provide guidance that can be adapted by regions for their individual OECMs.

Groupings were recommended for corals and sponges which should facilitate efficient monitoring as well as the discussion and development of monitoring plans and aid in understanding of coral and sponge BCBs. Indirect BCBs were reviewed, and although specific research on these benefits in Canada is limited, they are broadly applicable and should be considered in the development of monitoring plans. The need for further research on indirect

BCBs associated with corals and sponges was noted. To ensure efficient monitoring design, it is recommended that priority should be placed on monitoring direct BCBs and focus on the conservation objectives of an area to make sure these objectives are being met.

Generally, suitable ecological indicators for corals and sponges were identified, but selecting indicators for specific OECMs will need to take into consideration their individual conservation objective(s) and the availability of data regionally. Monitoring tools should be selected based on their usefulness and efficiency to measure the indicator that was selected. It is also important to apply proper sampling design and statistical techniques for effective data collection and facilitate data analysis.

When developing a monitoring plan, it is recommended that short- and long-term indicators are included to better inform management actions and detect ecological trends. There are still gaps in the available baseline data required for developing ecological monitoring plans and efforts should be focused on collecting additional data to fill these gaps.

As knowledge increases and technological advances occur, it will be important to revisit indicator selection, coral and sponge groupings, monitoring tools, techniques, methodologies, and sampling design.

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SOURCES OF INFORMATION

This Science Advisory Report is from the December 1 to 3, 2020 National Peer Review on A National Monitoring Framework for Coral and Sponge Areas Identified as Other Effective

Area-Based Conservation Measures. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2009. Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas.

DFO. 2013. Guidance on the Formulation of Conservation Objectives and Identification of Indicators, Monitoring Protocols and Strategies for Bioregional Marine Protected Area Networks. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/081.

DFO. 2016. Guidance on Identifying "Other Effective Area-Based Conservation Measures" in Canadian Coastal and Marine Waters. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/002.

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