MONITORING FRAMEWORK FOR SGÁAN KÍNGHLAS-BOWIE SEAMOUNT MARINE PROTECTED AREA, BRITISH COLUMBIA, CANADA

The SGáan Kínghlas-Bowie Seamount Marine Protected Area (SK-B MPA) logo depicts the seamounts as a Waaxaas, a giant sea monster that is half wolf and half Killer Whale (Wayne Edenshaw).

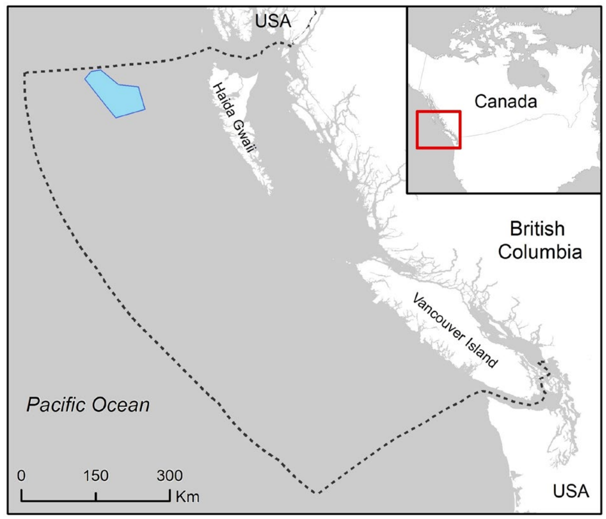

Figure 1. The SGáan Kínghlas-Bowie Seamount Marine Protected Area (SK-B MPA) is located 180 km from the coast of Haida Gwaii.

Context:

In 1997, the Haida Nation designated the area as a ***Xaads siigee tl'a damaan tl'a king giigangs*** *Haida Marine Protected Area (direct translation: “the ocean they will always take care of”) and, in 2008, the area was designated as a Marine Protected Area (MPA) under Canada’s* Oceans Act. *The SGáan Kínghlas-Bowie Seamount Marine Protected Area (SK-B MPA) is co-managed by the Haida Nation (as represented by the Council of the Haida Nation (CHN)) and the Government of Canada (as represented by the Minister of Fisheries and Oceans Canada (DFO)) to conserve and protect its unique biodiversity and biological productivity (e.g., seamount populations of cold-water corals, sponges, other invertebrates, fishes, and algae). In 2019, the management board published the SK-B* ***Gin siigee tl'a damaan kinggangs gin k'aalaagangs*** *MPA management plan (CHN and DFO 2019).*

On behalf of the SK-B MPA management board, DFO Oceans Management branch requested that Science branch develop a monitoring framework with science advice related to indicators, protocols, and strategies. The framework objectives are to (i) provide an ecosystem review, (ii) identify the ecological conservation objectives, (iii) propose monitoring indicators, protocols, and strategies, (iv) incorporate anticipated changes (e.g., climate change and post-fishing recovery), existing data sources, and feasibility, (v) evaluate the framework against the ecological conservation objectives, and (vi) examine uncertainties and limitations. This science advice will guide the future development of a monitoring plan and management for the area in support of the SK-B MPA conservation objectives.

This monitoring framework was co-created and co-authored by scientists from CHN and DFO. The co-authors acknowledge the power and history of these intrinsically valuable seamounts and respectfully *recognize the cultural and spiritual significance of SK-B and neighbouring seamounts to the Haida Nation, past, present, and future.*

This Science Advisory Report is from the May 3–5, 2022 regional peer review on the Proposed Monitoring Framework for SGáan Kínghlas-Bowie Seamount Marine Protected Area, British Columbia, Canada. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The SGáan Kínghlas-Bowie (SK-B) Seamount Marine Protected Area (MPA) (Figure 1) is co-managed by the Haida Nation and the Government of Canada to conserve and protect the unique biodiversity and biological productivity of the area. In 2019, the SK-B MPA management board published the management plan detailing the ecological conservation goals and objectives of the MPA.
- In the associated research document (Du Preez et al. in prep[1]), a monitoring framework is proposed summarizing the ecological monitoring options. It provides an ecosystem review and lists indicators (ecosystem components and metrics), protocols (tools), and strategies related to the SK-B MPA conservation objectives. Indicator groupings were generated for biological, environmental, and stressor ecosystem components, incorporating anticipated changes and specific indicator species where appropriate. Metrics for monitoring indicator groupings were described, then linked to standard protocols and strategies (i.e., tools and programs) used in the respective scientific fields (e.g., ecology, geology, oceanography). Information and best practices for designing a monitoring program, such as existing baseline data, statistics, sampling design, feasibility, and data management were also discussed. Trophic structure and ecosystem function were examined through a conceptual food web model. The proposed monitoring framework was then evaluated against the ecological conservation objectives to support adaptive and iterative re-evaluation of plans as an essential part of the MPA management process.
- The key result of the monitoring framework was connecting the four major components (i.e., the ecological objectives and the monitoring indicators, protocols, and strategies; Figure 5 and Table 1). Priorities and combinations were recommended to address the six ecological operational objectives, with the caveat that some information is unknowable at this time and that new or improved information (e.g., resolved through monitoring) should feed back into the frameworks and plans.
- While the SK-B MPA seamounts are some of the best-studied seamounts in the Northeast Pacific, monitoring of the area is still in its infancy, and there are many uncertainties and knowledge gaps.
- Limitations of the monitoring framework include the remoteness and size of SK-B MPA and the lack of comparable reference sites.
- Some uncertainties were handled in the associated research document (Du Preez et al. in prep[1]) by grouping potential ecosystem component indicators. Other uncertainties can be addressed through revisiting the management plan at a future date as part of an adaptive (iterative and responsive) management process. However, a lot of information is unknowable at this point but will potentially be resolved through continued and future

[1] Du Preez, C., Skil Jáada (Zahner, V.), Gartner, H., Chaves, L., Hannah, C., Swan, K., and Norgard, T. In prep. A Monitoring Framework for SGáan Kínghlas-Bowie Seamount Marine Protected Area, British Columbia, Canada. DFO Can. Sci. Advis. Sec. Res. Doc.

baseline monitoring and research (e.g., past, current, and anticipated states, including natural variability, especially as they relate to existing and future climate change impacts).

- Other uncertainties related to the monitoring framework include changes in the taxonomy of deep-sea species, future changes in sampling technologies, and biological responses to stressors (e.g., the nature of the disturbance, cascading effects, lag time, duration).
- Recommendations from the meeting include using the SK-B MPA monitoring framework to inform the development of a detailed monitoring plan (with stages of baseline and long-term monitoring), including a data management plan.
- It was highlighted that the future SK-B MPA ecological monitoring plan incorporates data and information collected by the other monitoring programs (e.g., on human activities, transient species, and climate change) to effectively interpret the cumulative effects of the conservation management measures, stressors, and unmanageable changes (i.e., beyond the scope of MPA spatial management).
- It was highlighted that extractive sampling, while contrary to the conservation goals, is likely essential for monitoring changes in trophic structure and ecosystem function. Metrics of gut content analysis and trophic biomarkers were proposed as additional methods for monitoring changes in trophic structure.
- It was noted that the SK-B MPA monitoring framework may support the development of monitoring frameworks and plans for other protected areas (especially in the case of the proposed large Pacific Offshore seamount and hydrothermal vent MPA to the south).

BACKGROUND

Natural History

The SGáan Kínghlas-Bowie (SK-B) Seamount Marine Protected Area (MPA) is located ~180 km west of Haida Gwaii, British Columbia (BC), in the Offshore Pacific Bioregion (OPB) (Figure 1). The 6,131 km^2 MPA encircles SK-B, Hodgkin, and Davidson/Pierce seamounts and their surrounding waters, seabed, and subsoil (CHN and DFO 2019).

Seamounts are ancient underwater volcanoes that rise over 1,000 m. Their complex geology and oceanographic conditions support a fantastic array of biological diversity. In Canada, seamounts are identified as ecologically and biologically significant areas (EBSAs) (Ban et al. 2016) and vulnerable marine ecosystems (VMEs) (reviewed in Du Preez and Norgard 2022 [Science Advisory Report available: DFO 2021a]).

The cold, nutrient-rich waters, rugged and complex substrates, and strong currents at shallower depths support rich assemblages of marine invertebrates (McDaniel et al. 2003; Gale et al. 2017). These diverse communities on the seamounts' summit and flanks also include resident and transient vertebrate species of cultural, conservation, commercial, and recreational interest. SK-B is the shallowest seamount (summits at 24 m depth) in the Northeast Pacific and is home to a uniquely diverse offshore community of shallow-water, transient, and deep-sea animals. Notable seamount populations include the cold-water corals, sponges, other invertebrates, rockfishes (*Sebastes* spp.) and other fishes (e.g., Sablefish, *Anoplopoma fimbria*), and coralline and macro-algae, as well as transient populations of birds, marine mammals, and pelagic fishes (CHN and DFO 2019) (Figure 2).

*Figure 2. Some of the biological diversity found within the SGáan Kínghlas-Bowie Seamount Marine Protected Area (SK-B MPA). The three seamounts rise steeply from the bathyal plains, transecting various zones of the ocean, until the shallowest, SK-B, reaches the sunlit waters just below the waves. This unique ecosystem is home to well-known shallow subtidal species, deep-sea animals new to science, and everything in between. From top-left to bottom-right: Black-footed Albatross (*Phoebastria nigripes*), Pom-pom Anemones (*Liponema brevicorne*), close-up of Brittle Star (*Ophiuroidea*), massive Red Tree Coral (*Primnoa pacifica*) with many associated animals, pelagic school of Widow Rockfish (*Sebastes entomelas*) over SK-B pinnacle, Sunflower Sea Star (*Pycnopodia helianthoides*) surrounded by Crimson Anemones (*Cribrinopsis fernaldi*), Fin Whale (*Balaenoptera physalus*), SK-B pinnacle carpeted Zoanthids, Blue Sharks (*Prionace glauca*), benthic and pelagic rockfishes (*Sebastes *spp.), Squat Lobsters (*Munida quadrispina*), Blob Sculpin (*Psychrolutes phrictus*), Deep-sea Octopus (*Graneledone boreopacifica*), Glass sponges (*Hexactinella*) surrounded by brittle stars, Dinner Plate Jellyfish (*Solmissus*), life on an around Parastenella cf ramosa coral, jellyfish, and a pair of crabs under large Chonelasma oreia glass sponge. Images from Fisheries and Oceans Canada, Shelton Dupreez, Pacific Wild, Ocean Exploration Trust, and the Northeast Pacific Seamount Expedition partners.*

Human Activities and Disturbances

The ancient underwater volcanic mountains within the SK-B MPA have been relatively stable for tens of thousands of years (Figure 3). However, human disturbances to its natural state began over a hundred years ago with commercial whaling, followed by the cumulative effects of climate change, vessel traffic, and commercial fishing.

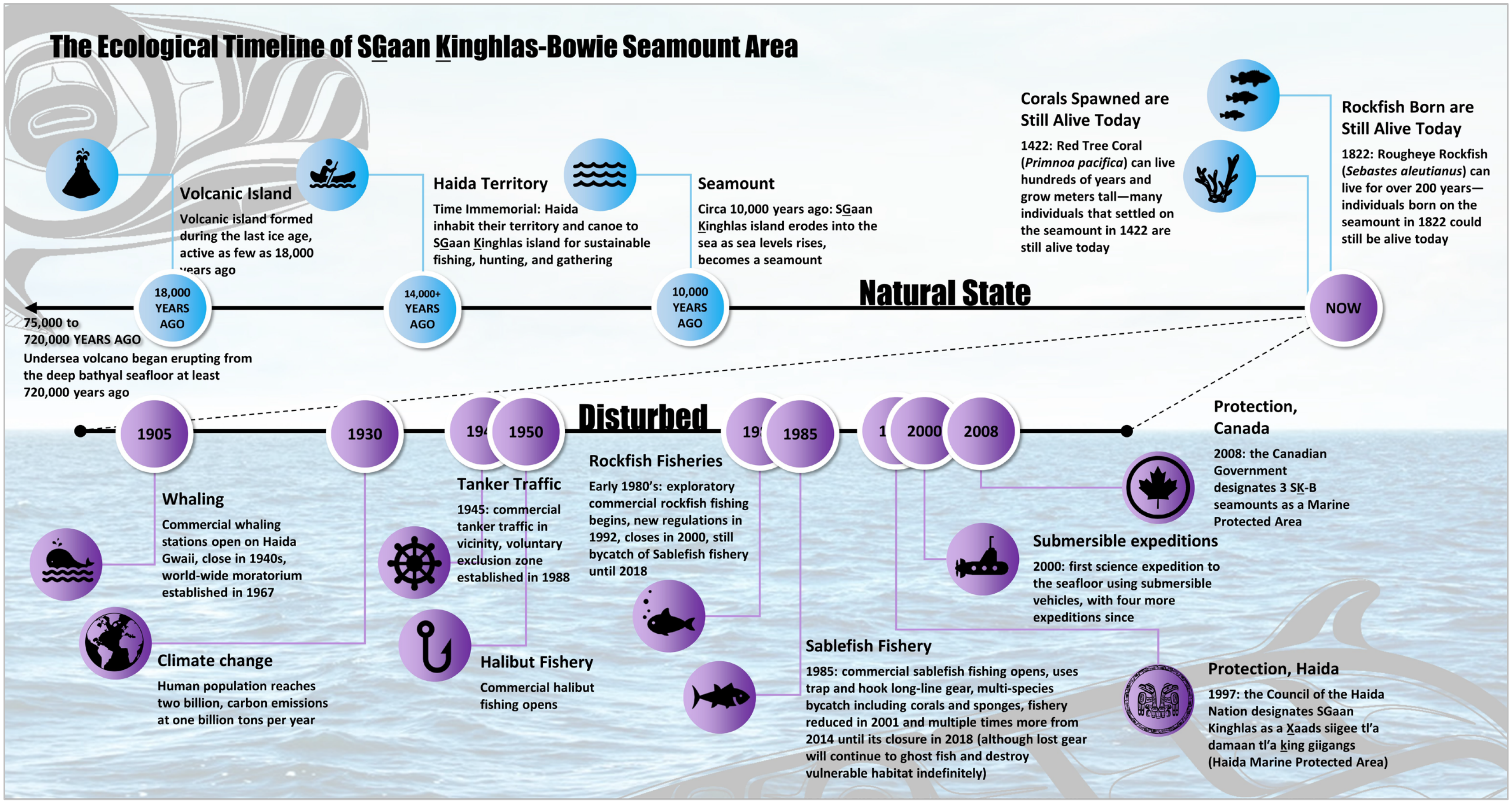

Figure 3. The ecological timeline of SG̲áan K̲ínghlas-Bowie (SK̲-B) Seamount area illustrates its long natural history and the comparatively short recent history of extraction, followed by scientific activities and protection. Haida art was shared by Iljuuwaas Tyson Brown (CHN and DFO 2019).

Haidas have historically fished SK-B Seamount for traditional (cultural, subsistence, and economic) purposes since time immemorial (CHN and DFO 2019). The seamounts were commercially fished for Pacific Halibut (*Hippoglossus stenolepis*) as early as the 1950s, but the majority of documented commercial activity started in 1985 as part of the directed rockfish and Sablefish fisheries (fisheries reviewed in Canessa et al. 2003). Commercial fishing primarily included mid-water trawls and bottom longlines with hooks or traps, now known to negatively impact habitat-forming species such as cold-water corals and sponges (Doherty et al. 2018; Buchanan et al. 2018), and the last bottom-contact fishery was closed in 2018 (CHN and DFO 2019).

All lost and discarded fishing gear from the past fisheries will remain entangled on the seamounts indefinitely, with no way to remove it and little to no degradation (Du Preez and Norgard 2022). This represents a significant ongoing impact on the ecosystem (average Sablefish trap longline gear length and footprint: 2,915 ±25 m and 3,994 ±24 m^2 with additional buoyant lines and floats at both ends extending to the surface; Du Preez et al. 2020). Cobb Seamount, a similar shallow-water seamount in the Northeast Pacific, is estimated to be entangled in hundreds of thousands of pieces of lost fishing gear - the perpetual impacts of which include ghost fishing and habitat alteration (e.g., damaging, crushing, removing cold-water corals and sponges) (Du Preez et al. 2020).

In addition to fishing, other human activities with management and monitoring measures within the SK-B MPA include vessel traffic (including ballast water), science activities, marine tourism, non-renewable resource extraction activities (e.g., seamount seabed mining outside the MPA) (CHN and DFO 2019), oil spills, marine debris and litter, other discharge, equipment abandonment, equipment installation (DFO 2015), and changes in transient and/or migratory species (e.g., catch changes in Albacore Tuna, *Thunnus alalunga*; Canessa et al. 2003).

Climate change is a relevant issue but was not included in detail in the SK-B MPA management plan (CHN and DFO 2019) or the Ecological Risk Assessment Framework (ERAF) (DFO 2015), likely in part because it is an unmanageable change with regards to the MPA spatial management scope. Given the unprecedented climate-related changes across all regions, monitoring indicators, protocols, and strategies that consider climate change should be a priority (Intergovernmental Panel on Climate Change [IPCC] 2021). In general, climate change is causing the ocean to become warmer, more acidic, and lose oxygen (Gruber 2011). It has and will continue to impact the environmental conditions and life of all OPB seamounts, including those within the SK-B MPA (Ross et al. 2020). Ocean basin-scale surface heat waves have started to appear and reappear for years at a time in the Pacific Northeast (e.g., 'the blob'; Freeland and Whitney 2014). Ocean acidification within the region is another significant concern with the shoaling of the aragonite and calcite horizons (Ross et al. 2020). Deoxygenation may warrant special consideration, given that the Northeast Pacific contains some of the lowest oxygen levels in the global ocean (Paulmier and Ruiz-Pino 2009; Ross et al. 2020). Other key ocean climate variables within the region include salinity, currents, and multi-decadal variability, such as the Pacific Decadal Oscillations (e.g., Garcia-Soto et al. 2021). It is highly likely that changing climate variables have, are, and will continue to affect all SK-B MPA ecosystem components, either directly or indirectly.

With regards to monitoring SK-B MPA, the impacts and potential recovery following the disturbances listed above may take hundreds to thousands of years given the lag time of impacts, the generation timeline of species of interest (some species live to hundreds of years old), and current and future compounding impacts - all complicated by rapid and anomalous climate change events and long-term climate change environmental trends.

ASSESSMENT

Data and Methods

Developing a Monitoring Framework

A monitoring framework is like a roadmap, providing a broad and high-level summary of selected suitable options for monitoring the ecological conservation objectives. These options are prioritized where appropriate (e.g., most suitable, practical, or effective). The framework supports the future development of a monitoring plan, which will provide prescriptive details for the selected monitoring pathways. In addition, the framework will also support adaptive management and future re-examination of the management and monitoring plans.

The associated research document (Du Preez et al. in prep[1]) is the first monitoring framework developed for the SK-B MPA, a **Xaads siigee tl'a damaan tl'a king giigangs** *Haida Marine Protected Area*, and an *Oceans Act* MPA in the Pacific Region. It builds on the development of monitoring frameworks in other Canadian jurisdictions (e.g. Cooper et al. 2011; Lewis et al. 2016) and most closely aligns with the format and contents recently developed for the national monitoring framework for coral and sponge areas identified as other effective area-based conservation measures (Neves et al.[2]).

The research document reviews, summarizes, and prioritizes monitoring options by dividing the monitoring framework into four major components: the objectives, indicators, protocols, and strategies. These can be simplified into “why”, “what”, “how”, and “ways” questions (Figure 4).

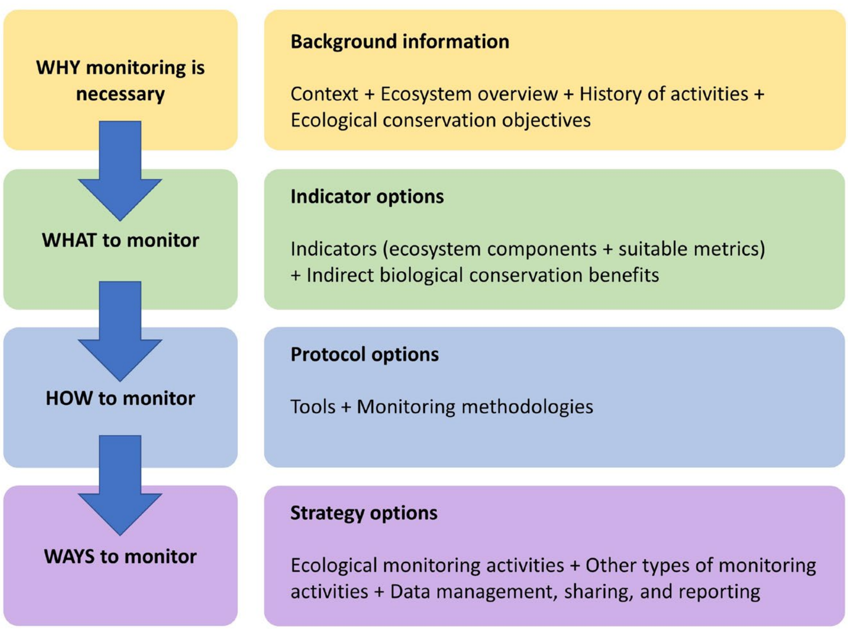

Figure 4. Flowchart illustrating the main components of this monitoring framework. A monitoring framework provides a high-level summary of prioritized options for monitoring the success of the conservation objectives; therefore, what to monitor (indicators), how to monitor (protocols), and ways to monitor (strategies). The framework supports the development of a monitoring plan and adaptive management.

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

Why Monitor?

Fortunately, the SK-B MPA conservation goals, strategic objectives, and operational objectives are clearly stated in the management plan (CHN and DFO 2019); this is not always the case for MPA or other effective conservation measures (OECMs). The ecological conservation objectives are reviewed and interpreted in the associated research document (Du Preez et al. in prep[1]).

What to Monitor?

The associated research document (Du Preez et al. in prep[1]) uses national guidance for the selection of monitoring indicator ecosystem components and metrics (DFO 2013). Similar to Neves et al.[2], they follow the first four of the eight steps of the analysis (steps 5–8 should be incorporated during the development of a monitoring plan).

Step 1. Identify conservation objectives

See section above (i.e., Why monitor)

Step 2. Identify suitable indicator ecosystem component groupings and metrics

Similar to Neves et al.[2], the co-authors developed indicator groupings of ecosystem components (biological, environmental, and stressors). Biological groups were defined based on phylogeny, morphology (e.g., body size, shape), life history traits, and habitat preferences. Specific indicator species were identified when appropriate, with priority given to species indicators proposed in the ERAF.

Step 3. Selection criteria for metrics

The associated research document (Du Preez et al. in prep[1]) uses the national guidance for selection criteria for indicators, inclusive of metrics (DFO 2012).

Step 4. Evaluate metrics for indicators

The associated research document (Du Preez et al. in prep[1]) builds on the efforts of DFO (2015) and Neves et al.[2] by utilizing their evaluated metrics for cold-water corals and sponge groupings, made reasonable deletions for other biological indicators groupings (e.g. removed reef context for fish) and resourced subject matter experts for final lists of environmental and stressor metrics (e.g., physical oceanography).

How to Monitor?

The protocol sections on tools and methods, found in the associated research document (Du Preez et al. in prep[1]), are reviews and suitability assessments based on Neves et al. (in prep), published literature, and/or consultation with subject matter experts. Reviewed tools and sensors are those that could be used for monitoring the SK-B MPA with relevance to the ecological conservation objectives and within the context of existing equipment and expertise within the Pacific Region. Reviewed methodology focused on best practices when designing monitoring programs related to baseline data, frequency, volume (amount), and location.

Ways to Monitor?

The protocol sections on strategies and data management, found in the associated research document (Du Preez et al. in prep[1]), are reviews and suitability assessments based on Neves et al. (in prep), published literature, and/or consultation with subject matter experts. Reviewed strategies are those that include one or more potential monitoring protocols identified for the SK-B MPA. Strategies are differentiated between spatial coverage within the SK-B MPA or just informative for the MPA and include feasibility (particularly if it would be beneficial to expand current programs to include the SK-B MPA). Considerations for data management are summarized in six steps.

While it is outside the practical limitations of any program to monitor all direct and indirect biodiversity conservation benefits (BCBs) (i.e., all ecological components and environmental conditions), understanding interrelationships of prioritized indicators can help monitor ecosystem function and trophic structure and identify knowledge gaps and stressors for adaptive management interventions (e.g., identification of new monitoring indicators and potential pathways to detect change). To this end, the interrelationships between biological groupings - inclusive of indirect BCBs - are examined through the seamount trophic structure.

Results

Why Monitor?

There are six ecological conservation operational objectives within the SK-B MPA management plan related to the seamount populations of cold-water corals and sponges, other invertebrates, and fishes, sensitive benthic habitats, pelagic and sea surface conditions, ecosystem function, and trophic structure (CHN and DFO 2019: Goal 1) (Figure 5 and Table 1). These objectives restrict what ecosystem components are relevant for monitoring the effectiveness of the management measures (Step 1 of 4 for indicator ecosystem components and metric selection). There are also at least another ten strategic and/or operational objectives (Goals 2-5) indirectly related to the ecological conservation objectives.

What to Monitor?

The associated research document (Du Preez et al. in prep[1]) proposes 19 biological indicator groupings (Figure 5) and provides the identification of significant ecosystem components (SECs) as potential priority indicator species where appropriate. The indicator groupings include seven cold-water corals, two sponges, three other invertebrates, three fishes, and four sensitive benthic habitats (SBHs) (macroalgae, coralline algae, cold-water corals and sponges), as well as environmental (geological, biological, physical, and chemical oceanography) and stressor indicator groupings.

The associated research document (Du Preez et al. in prep[1]) identifies, describes, and examines the suitability of 15 biological, 16 environmental, and 5 stressor indicator metrics. For biological metrics this included two priority metrics explicitly mentioned in the management plan: condition and abundance (CHN and DFO 2019: operational objectives 1.1.a-c) (Steps 3 and 4).

How to Monitor?

The associated research document (Du Preez et al. in prep[1]) identifies, describes, and examines the suitability of over 30 tools with relevance to the ecological conservation objectives and within the context of existing equipment and expertise within the Pacific region (Figure 5). It also identifies the preferred tools for proposed indicator ecosystem components grouping and metric combination (e.g., cores are the preferred tool to measure the abundance and condition of infauna). The tools and sensors fall within five high-level groups: imagery and biological sampling, seafloor gear, acoustic, oceanographic, and online data.

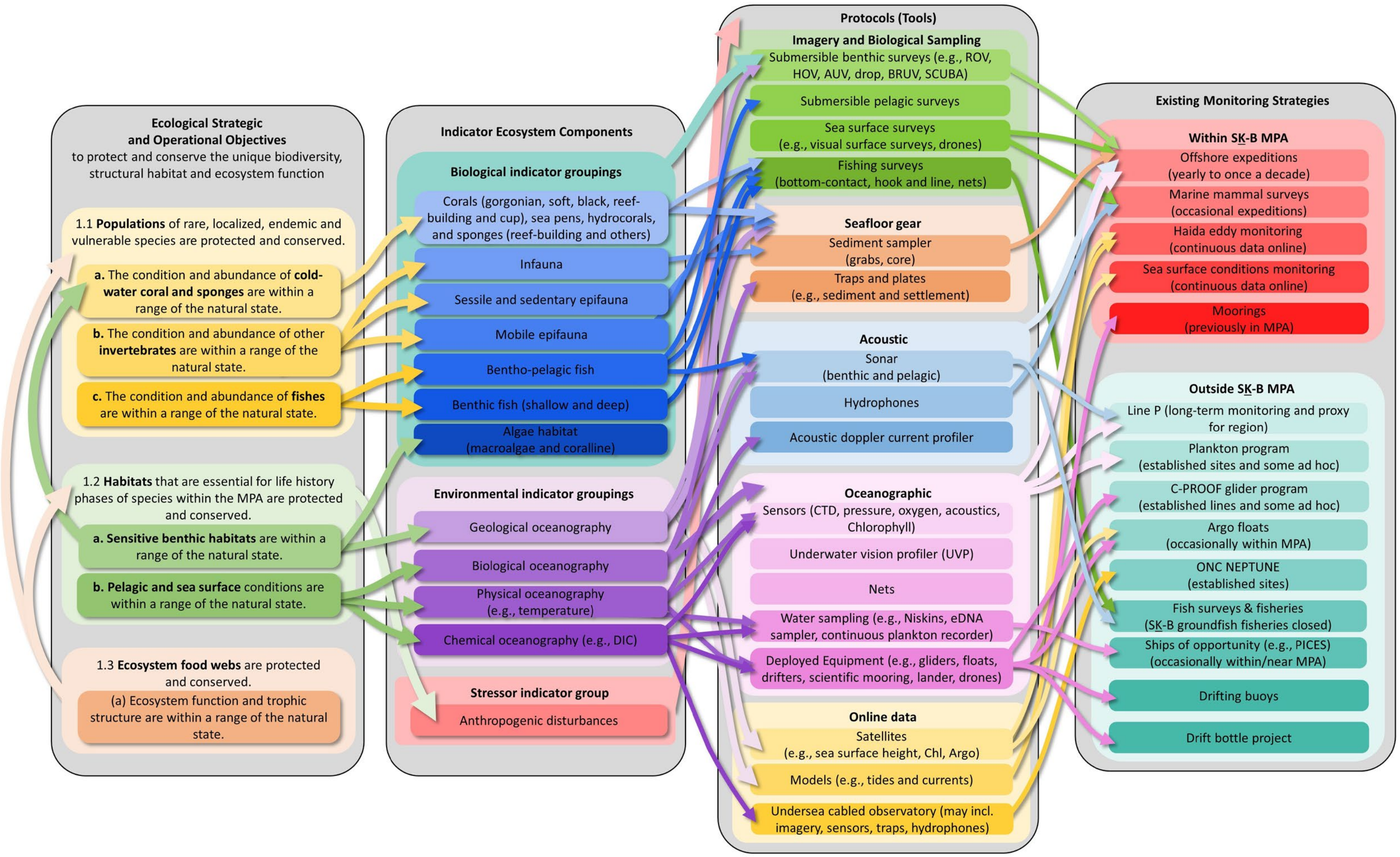

Figure 5. Connections between the four major components of the monitoring framework: the ecological strategic and operational objectives, the monitoring indicator groupings, protocols (tools), and strategies (programs). Details provided in the associated research document (Du Preez et al. in prep[1]) Table 11 to 13 and summarized here in Table 1.

Table 1. Summary of proposed monitoring indicators (ecosystem components and metrics), protocols, and strategies to directly monitor populations of rare, localized, endemic and vulnerable species, habitats that are essential for life history phase of species with the MPA, and ecosystem food webs (CHN and DFO 2019: Strategic Objective 1.1 to 1.3). The information is listed in order of priority (1° to 3°) or not if prioritization is still to be determined (TBD). Other monitoring efforts indirectly related and relevant to the ecological conservation objectives are included.

Operational Objectives	Monitoring Indicators: Ecosystem Components	Monitoring Indicators: Metrics	Monitoring Protocol[1]	Monitoring Strategy[1,2]	Other Monitoring Efforts
1.1.a. The condition and abundance of cold-water coral and sponges are within a range of the natural state	1° corals: *Primnoa pacifica* and *Isidella tentaculum* 2° corals: other Gorgonian corals[3] 3° corals: other known species of Soft, Black, Reef-building, and Cup Corals, Sea Pens, and Hydrocorals[3]	1°: abundance 1°: condition (i.e., health) 2°: other biological metrics (Table 3 to 6) 2°: other environmental and stressor metrics (indirect monitoring)	1°: submersible benthic imagery surveys (with associated sampling where appropriate) 2°: settlement plates Future possibility: eDNA water samples and hydrophones	1° Offshore expeditions	1° monitoring: climate change (same as Operational Objective 1.2.b) (relates to protection, maintenance, rehabilitation) 1° monitoring: fishing (e.g., non-compliance relates to protection) 2° monitoring: other human activities (e.g., vessel traffic, marine noise, and marine debris) 3° monitoring: transient species
	Known species of reef-building glass sponges and other sponges[3]				
1.1.b. The condition and abundance of other invertebrates are within a range of the natural state	1° invertebrates: *Munida quadrispina* (mobile epifauna) 2° invertebrates: brittle star mat complex (mobile epifauna) 3° invertebrates: other known species of infauna, sessile and sedentary epifauna, and mobile epifauna[3]				
1.1.c. The condition and abundance of fishes are within a range of the natural state	1° fishes: Widow Rockfish (*Sebastes entomelas*), Bocaccio (*Sebastes paucispinis*), Prowfish (*Zaprora silenus*), Yelloweye Rockfish (*Sebastes ruberrimus*), Backspotted/Rougheye Rockfish (*Sebastes melanostictus*/ *S. aleutianus*), Pacific Halibut (*Hippoglossus stenolepis*), Sablefish (*Anoplopoma fimbria*) 2° fishes: other Rockfish (*Sebastes* spp. and *Sebastolobus* spp.) 3° fishes: other known species of benthopelagic, shallow benthic, and deep benthic fishes[3]		1° shallow and deep benthic fishes: submersible benthic imagery surveys 2° shallow and deep benthic fishes: fishing surveys (may provide valuable biological samples but violate existing regulations)		
			1° benthopelagic fishes: submersible pelagic imagery surveys 2° benthopelagic fishes: sonar		

Operational Objectives	Monitoring Indicators:		Monitoring Protocol[1]	Monitoring Strategy[1,2]	Other Monitoring Efforts
	Ecosystem Components	Metrics			
			2° benthopelagic fishes: fishing surveys (may provide valuable biological samples but violate existing regulations)		
1.2.a. Sensitive benthic habitats (SBH) are within a range of the natural state	Habitat-forming coralline algae and macroalgae: known species[3]		1°: submersible benthic imagery surveys (with associated sampling where appropriate) Future possibility: eDNA water samples and hydrophones		
	Habitat-forming corals and sponges: same as Operational Objecitve 1.1.a				
	Geological, physical, chemical, and biological environmental and stressor ecosystem components	1° primary and secondary productivity, temperature, current, pH, oxygen (list primarily driven by climate change impacts) 2° other metrics[4]	1° remote sensing (relatively inexpensive and total coverage): satellite and model data 2° in situ: oceanographic sonar, sensors, nets, and water sampling (ship-based, deployed, or mounted on other tools)	1° remote sensing: eddy, sea surface, and mooring monitoring 2° remote sensing: other existing remote monitoring strategies[5]	
1.2.b. Pelagic and sea surface conditions are within a range of the natural state				1° in situ: Offshore expeditions 2° in situ: Line P, Plankton, Glider, Argo float programs 3° in situ: other existing strategies[5]	
1.3.a. Ecosystem function and trophic structure are within a range of the natural state	1° those ecosystem components already monitored/sampled (see above) 2° additional significant ecosystem components as they are identified	Stomach content and trophic biomaker metrics[6]	Guidance provided in text and Table 10 but specifics TBD through baseline monitoring (limited by the ability to collect biological samples)		

[1] The suitability of protocols (tools) and strategies (programs) will change in time (e.g., with changing techniques, technologies, and monitoring efforts). The lists provided are based on the best available current knowledge. Additional options and considerations are provided in the text.

[2] Guidance on methodologies provided in the text but specifics TBD through baseline monitoring and research and identification of specific indicators (ecosystem components and metrics), protocols, and strategies (e.g., sampling frequency may be influenced by cost and also needs to consider generation times and anticipated changes).

[3, 4, 5, 6] Listed in the associated research document (Du Preez et al. in prep[1]): Table 1 and Table A2; Table 6 and 7; Section 5.2 and Table 11; and Table 10, respectively.

Ways to Monitor?

The associated research document (Du Preez et al. in prep[1]) strategizes how to implement monitoring by identifying and describing 14 previous or ongoing monitoring strategies within or outside the MPA with relevance to the ecological conservation objectives (Figure 5). Tools, principal investigators, existing data sources, and feasibility (cost) information are among the details provided for each strategy.

As previously mentioned, there are four other goals for the MPA in addition to the ecological conservation Goal 1. The associated research document (Du Preez et al. in prep[1]) identifies and discusses the ecological importance of data and/or information sharing between other future or existing monitoring programs for other conservation objectives, such as human activity monitoring (i.e., fishing, vessel traffic, science activities, marine tourism, and non-renewable resource extraction), transient species monitoring, and climate change monitoring.

The topic of designing monitoring programs was recently and comprehensively reviewed by Neves et al.[2]. The information they provided is broadly applicable and, as such, is summarized in the associated research document (Du Preez et al. in prep[1]) with additional local considerations (e.g., the visual survey pilot study with 17 established monitoring sites within the MPA, several revisited in 2022).

The associated research document (Du Preez et al. in prep[1]) details the importance and potential challenges of developing a data management plan (i.e., to manage data streams that support timely and repeatable data assessment, as well as interpretation, reporting, and responses).

A conceptual food web model was developed to show how indicator groupings are connected, from primary producers to top predators, inclusive of local and transient species. Recommendations for future work to better resolve the trophic structure are provided (e.g., metrics of gut content analysis and trophic biomarkers but may violate existing regulations).

Sources Of Uncertainty

The following are uncertainties and knowledge gaps pertaining to the current understanding of monitoring options for the SK-B MPA.

- The extent of current and future climate change impacts on the SK-B MPA ecosystem is uncertain. Baseline and future monitoring will help detect some of these impacts and resolve linkages between direct and indirect effects. As such, climate change considerations are incorporated into most aspects of the monitoring framework.
- The framework was developed based on the anticipated changes - unanticipated stresses may require monitoring beyond the scope covered in the associated research document (Du Preez et al. in prep[1]).
- The species inventory for the MPA is incomplete and represents a knowledge gap. In deep-sea ecosystems, the knowledge base for species identity, distribution, and behaviours are always growing and changing. By grouping biological ecosystem component indicators, the associated research document (Du Preez et al. in prep[1]) facilitated moving forward with monitoring and adaptive management. The groupings are based on the ecological conservation objectives and the known current inventory of species. Groupings should be re-examined as further information becomes available and/or conservation goals are re-examined. Initial species indicators proposed in the ERAF were prioritized within groupings, but this list will also continue to be resolved during the baseline monitoring phase, based on

regional assessments and needs and consideration of broader initiatives (e.g., network monitoring, national indicators, species of conservation concern).

- Indicator-associated reference points (e.g., the definition and quantitative measure of “the natural state”), thresholds, response lag time post-disturbance, recovery potential, etc., are all unknowable at this time and should be determined through future assessments as baseline measurements are collected and/or become available and are assessed.
- This framework reflects the best available current knowledge of the authors. However, the fields involved in studying deep-sea environments - such as seamounts - are cutting-edge sciences known for their innovations. There may be more options available currently in development that should be considered in the monitoring plan (i.e., new protocols and strategies).
- Innovations will undoubtedly help overcome the inherent challenges of monitoring a deep-sea MPA (e.g., SK-B MPA is ~180 km offshore, encircles over 6,000 km^2 of seafloor and over 3,000 m of water depths, and essentially lacks comparable reference sites.
- Quantifying trophic structure and ecosystem functioning requires sophisticated modeling and long-term time series data on a multitude of species and oceanographic conditions. While trophic modeling and determining whether its “within a range of the natural state” is outside of the current scope of the monitoring framework, monitoring major indicator functional groups of the ecosystem is the first step to understanding a dynamic system. Once the future monitoring plan is established and more data becomes available, it is recommended to revisit and re-examine quantifying these trophic relationships, if possible.
- There is uncertainty regarding the achievability of the SK-B MPA ecological conservation objectives as written. The associated research document (Du Preez et al. in prep[1]) evaluated the operational objectives against the monitoring framework focusing on whether the objectives met the criteria to be considered Specific, Measurable, Achievable, Realistic, and Time-sensitive. The evaluation is intended to guide monitoring and can support future iterations of the management plan. The protection and conservation of ecosystem components that extend beyond the spatial limits of the MPA are particularly problematic (e.g., the pelagic and sea surface conditions, and ecosystem function and trophic structure, operational objectives 1.2.b and 1.3.a).

CONCLUSIONS AND ADVICE

- This science advice, and the accompanying research document[1], provide the basis for developing an ecological monitoring plan for the SK-B MPA. The advice that was developed on monitoring indicators (ecosystem components and metrics), protocols (tools, methods, etc.), and strategies (programs) will guide the management and monitoring of the SK-B MPA (Figure 5 and Table 1). The framework provides a summary of options for monitoring the ecological conservation objectives outlined in the management plan, and includes specific recommendations when appropriate.
- Existing and anticipated changes within the SK-B MPA related to the protection and conservation of its biodiversity, structural habitat, and ecosystem function include the recent prohibition of bottom-contact fishing and ongoing impacts of lost fishing gear, climate change, vessel traffic, and other human activities (e.g., non-renewable resource extraction outside the MPA, such as seabed mining). Anticipated ecological responses to changing conditions may occur immediately (e.g., the protection and maintenance afforded by prohibiting or managing an activity) or may take centuries or longer (e.g., the recovery of long-lived, slow-growing species such as cold-water corals and sponges). Monitoring plans

should consider the indicator-specific timelines (e.g., generation time) when designing and implementing monitoring schedules.

- It is recommended that future decisions on the SK-B MPA monitoring indicators use the proposed ecosystem component groupings (inclusive of cold-water corals, sponges, other invertebrates, fishes, sensitive benthic habitats, environmental conditions, and stressors groupings), metrics, and priorities (e.g., indicator species and condition and abundance measurements listed in Table 1) provided in the research document. However, baseline monitoring and research to fill knowledge gaps should be prioritized.
- Many components (e.g., thresholds and reference points) required to implement an effective long-term monitoring plan are unknowable at this time. Baseline monitoring and research to fill these knowledge gaps should be prioritized.
- It is recommended that future decisions on the SK-B MPA monitoring consider the use of the proposed protocols (tools) provided in the research document. The options provided adequately cover the indicator ecosystem components and metrics proposed and are used in the region within existing strategies (programs). It is recommended that future research examines the suitability of emerging technologies (e.g., hydrophones and eDNA).
- It is recommended that future decisions on the SK-B MPA monitoring strategies consider the use of 14 previous and ongoing programs (including potential spatial expansion to encompass the SK-B MPA). The importance of a program's data and its availability on a shared platform is key. At present, the ongoing offshore expeditions and the long-term time-series from the Line P and Plankton programs collect data relevant to almost all of the ecological conservation objectives.
- It is recommended that SK-B MPA monitoring practitioners consider the limitations of existing data to inform survey design, as well as the resources required to execute certain survey designs. For example, there is no ideal reference site for the SK-B MPA ecosystem.
- The unique ecosystem of the MPA makes for a challenging sample design but can also be an opportunity by (i) elevating the value of other existing knowledge (e.g., baseline data from previous SK-B MPA science surveys (Gale et al. 2017) and Haida Marine Traditional Knowledge (Haida Marine Traditional Knowledge Study Participants et al. 2011a-c)), (ii) prompting exploration of new designs, and (iii) potentially pulling from other data sources/surveys for comparisons with caution.
- It was noted that the SK-B MPA ecosystem is unique, and caution should be taken when inferences are made based on other ecosystems (e.g., other shallow seamounts and nearby coastal environments).
- It is recommended that the future SK-B MPA ecological monitoring plan incorporate data and information collected by all other SK-B MPA monitoring programs (e.g., on climate change, human activities, and transient species). Data sharing between all SK-B MPA monitoring practitioners will be essential for interpreting detected changes, or a lack thereof, in the context of cumulative effects and the effectiveness of management measures. A detected trend will be the result of various stressor effects, both positive and negative. For example, while an overall ecological trend maybe "negative", the individual management measures may be effective at removing or reducing stressors and creating positive pressures. An anticipated scenario is that climate change impacts (unmanageable at the scale of the MPA) will drive overall negative trends while the mitigation of manageable stressors (e.g., fishing) will be essential positive pressures.

- Trophic structure and ecosystem function were examined through a conceptual food web model, although direct data on trophic relationships within the SḴ-B MPA is limited. Metrics of gut content analysis and trophic biomarkers were proposed as additional methods for monitoring changes in trophic structure. Future research expanding on the previous ecosystem modeling of the SḴ-B MPA trophic structure and comparison with coastal environments is recommended to strengthen monitoring efforts.
- The use of non-destructive tools aligns with the management plan but has limitations, especially pertaining to research to resolve trophic interactions and ecosystem functioning. With regards to extractive sampling, there are advantages and disadvantages to consider when using targeted fisheries surveys to study these trophic relationships versus other sampling surveys (e.g., using remotely operated vehicles).
- Recommendations for the MPA practitioner community include the development of a common lexicon of what constitutes baseline information and working definitions for terms such as “natural state”.
- A comprehensive data management plan was highlighted as an essential element of any future monitoring plan. The complexity of multi-disciplinary monitoring programs will necessitate substantial budget and human resources allocation to support the assembly, management and evaluation of collected data. Information and data streams should be well documented and openly available to support repeatability and reproducibility. The data management plan should adopt standards such as the FAIR (Findable, Accessible, Interoperable, and Reusable; Wilkinson et al. 2016) and CARE principles (Collective benefit, Authority to control, Responsibility, and Ethics; Carroll et al. 2020).
- Easy to read and comprehensible reporting on MPA management measure effectiveness was highlighted to communicate research findings of monitoring plans to management staff and the general public. The concept of a ‘report’ card was highlighted as an effective tool for consideration that should be theoretically standardized across Canadian jurisdictions.
- The SḴ-B MPA management plan, which champions cooperative management of the MPA, should be adaptive and responsive, and that new information available through monitoring should feed back into an iterative process of re-examining the management and monitoring plans.
- It is recommended that future decisions on the SḴ-B MPA management consider the evaluation of ecological conservation objectives provided in the research document, where components of four of the six operational objectives may be unachievable (i.e., as written, owing to climate change, or owing to time-sensitivity).
- It was noted that the SḴ-B MPA monitoring framework may support the development of monitoring frameworks and plans for other protected areas, especially in the case of the proposed large Pacific Offshore seamount and hydrothermal vent MPA to the south.

OTHER CONSIDERATIONS

This framework was co-authored by the Council of the Haida Nation and Fisheries and Oceans Canada as part of the co-management of SḴ-B MPA. Knowledge sharing and co-creation should be an integral component of all conservation work.

The need for monitoring plans and supporting documents will only grow following the unprecedented establishment of protected areas currently underway. As mentioned above, the SḴ-B MPA monitoring framework will likely support the development of monitoring frameworks and plans for other protected areas. It was also noted that there are differences in the processes used by different regions and practitioners within Canada and that the processes (and use of terms) are changing over time. An effort to standardize practices where appropriate - while still promoting development and innovations - was viewed as a positive way forward.

LIST OF MEETING PARTICIPANTS

Last Name	First Name	Affiliation
Anderson	Erika	DFO Centre for Science Advice Pacific
Bates	Amanda	University of Victoria
Boyko	Rayne	Council of the Haida Nation
Campbell	Jill	DFO Centre for Science Advice Pacific
Chaves	Lais	Council of the Haida Nation
Clark	Lindsay	DFO Science
Cooper	Andrew	DFO Science
Davies	Megan	University of Victoria
Davies	Sarah	DFO Science
Dower	John	University of Victoria
Du Preez	Cherisse	DFO Science
Dudas	Sarah	DFO Science
Eisner	Noah	Council of the Haida Nation
Gartner	Heidi	DFO Science
Gauthier	Stephane	DFO Science
Guujaaw	Niisii	Council of the Haida Nation
Haggarty	Dana	DFO Science
Hannah	Charles	DFO Science
Harris	Laura	DFO Oceans (National Headquarters)
Jeffery	Sharon	DFO Science
Labbe	Daniel	University of Victoria
Lee	Lynn	Gwaii Haanas Parks Canada
Leus	Dan	DFO Fisheries Management (Marine Conservation Targets)
Lipski	Danielle	Greater Farallones and Cordell Bank National Marine Sanctuaries
Macnab	Paul	DFO Oceans (Maritimes)
Manning	Clayton	DFO Oceans
Murdock	Sheryl	University of Victoria
Nephin	Jessica	DFO Science
Neves	Bárbara	DFO Science (Newfoundland and Labrador)
Norgard	Tammy	DFO Science
O	Miriam	DFO Science
Robb	Carrie	DFO Science
Roizman	Raquel	DFO Fisheries Management (Marine Conservation Targets)
Rooper	Chris	DFO Science
Ross	Tetjana	DFO Science

Last Name	First Name	Affiliation
Rubidge	Emily	DFO Science
Samuels	Tasha	Council of the Haida Nation
Skil Jáada		Council of the Haida Nation
Stanley	Ryan	DFO Science

SOURCES OF INFORMATION

This Science Advisory Report is from the May 3–5, 2022 regional peer review on the Proposed Monitoring Framework for SG̲áan K̲ínghlas-Bowie Seamount Marine Protected Area, British Columbia, Canada. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Ban, S., Curtis, J.M.R., St. Germain, C., Perry, R.I., and Therriault, T.W. 2016. Identification of Ecologically and Biologically Significant Areas (EBSAs) in Canada's Offshore Pacific Bioregion. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/034. x + 152 p.

Buchanan, S., Gartner, H., and Keizer, A. 2018. SG̲aan K̲inghlas-Bowie Seamount At-sea Observer Coral and Sponge Sample Collection, May and June 2016. Can. Data Rep. Fish. Aquat. Sci. 1282: v + 14 p.

Canessa, R.R., Conley, K.W., and Smiley, B.D. 2003. Bowie Seamount pilot Marine Protected Area: an ecosystem overview report. Can. Tech. Rep. Fish. Aquat. Sci. 2461: xi + 85 p.

Carroll, S.R., Garba, I., Figueroa-Rodríguez, O.L., Holbrook, J., Lovett, R., Materechera, S., Parsons, M., Raseroka, K., Rodriguez-Lonebear, D., Rowe, R., Sara, R., Walker, J.D., Anderson, J., and Hudson, M. 2020. The CARE Principles for Indigenous Data Governance. Data Science Journal, 19(1), p.43.

Council of the Haida Nation (CHN) and Fisheries and Oceans Canada (DFO). 2019. SGaan Kinghlas-Bowie Seamount : 2019 marine protected area management plan = Gin siigee tl'a damaan Kinggaangs gin K'aalaagangs.

Cooper, J.A., Curran, K., Singh, R., Chang, B. and Page, F.H. 2011. Musquash Estuary: A Proposed Monitoring Framework for the Marine Protected Area (MPA) and Intertidal Area Administered (AIA) by Fisheries and Oceans Canada. DFO. Can. Sci. Advis. Sec. Res. Doc. 2011/055: vi + 38pp.

DFO. 2012. Development of a St. Lawrence Estuary Marine Protected Area Ecological Monitoring Plan. DFO Can. Sci. Advis. Sec. Sci. Adv. Rep. 2012/039.

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. 2015. Development of risk-based indicators for SGaan Kinghlas-Bowie Seamount Marine Protected Area using the ecological risk assessment framework. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/054.

DFO. 2021a. Identification of Representative Seamount Areas in the Offshore Pacific Bioregion, Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/041.

DFO. 2021b. A National Monitoring Framework for Coral and Sponge Areas Identified as Other Effective Area-Based Conservation Measures. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/048.

Doherty, B., Johnson, S.D.N., and Cox, S.P. 2018. Using autonomous video to estimate the bottom-contact area of longline trap gear and presence–absence of sensitive benthic habitat. Can. J. Fish. Aquat. Sci. 75(5): 797–812.

Du Preez, C., Swan, K.D., and Curtis, J.M. 2020. Cold-Water Corals and Other Vulnerable Biological Structures on a North Pacific Seamount After Half a Century of Fishing. Frontiers in Marine Science7: 17.

Du Preez, C. and Norgard, T. 2022. Identification of Representative Seamount Areas in the Offshore Pacific Bioregion, Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/042. viii + 136 p.

Freeland, H. and Whitney, F. 2014. Unusual warming in the Gulf of Alaska. PICES Press 22 (2): 51-52.

Gale, K.S.P., Curtis, J.M.R., Morgan, K.H., Stanley, C., Szaniszlo, W., Burke, L.A., Davidson, L.N.K., Doherty, B., Gatien, G., Gauthier, M., Gauthier, S., Haggarty, D.R., Ianson, D., Neill, A., Pegg, J., Wallace, K., and Zand, J.D.M. 2017. Survey Methods, Data Collections, and Species Observations from the 2015 Survey to SGaan Kinghlas-Bowie Marine Protected Area. Can. Tech. Rep. Fish. Aquat. Sci. 3206: vii + 94 p.

Garcia-Soto, C., Cheng, L., Caesar, L., Schmidtko, S., Jewett, E.B., Cheripka, A., Rigor, I., Caballero, A., Chiba, S., Báez, J.C., Zielinski, T., and Abraham, J.P. 2021. An Overview of Ocean Climate Change Indicators: Sea Surface Temperature, Ocean Heat Content, Ocean pH, Dissolved Oxygen Concentration, Arctic Sea Ice Extent, Thickness and Volume, Sea Level and Strength of the AMOC (Atlantic Meridional Overturning Circulation). Frontiers in Marine Science 8: 642372.

Gruber, N. 2011. Warming up, turning sour, losing breath: ocean biogeochemistry under global change. Phil. Trans. R. Soc. A 368: 1980-1996.

Haida Marine Traditional Knowledge Study Participants, Janet Winbourne, and Haida Oceans Technical Team, Haida Fisheries Program. 2011a. Haida Marine Traditional Knowledge Study. Volume 1: Methods and Results Summary.

Haida Marine Traditional Knowledge Study Participants, Janet Winbourne, and Haida Oceans Technical Team, Haida Fisheries Program. 2011b. Haida Marine Traditional Knowledge Study Volume 2: Seascape Unit Summary.

Haida Marine Traditional Knowledge Study Participants, Janet Winbourne, and Haida Oceans Technical Team, Haida Fisheries Program. 2011c. Haida Marine Traditional Knowledge Study Volume 3: Focal Species Summary.

Intergovernmental Panel on Climate Change (IPCC). 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press.

Lewis, S., Ramirez-Luna, V., Templeman, N., Simpson, M.R., Gilkinson, K., Lawson, J.W., Miri, C., and Collins, R. 2016. A Framework for the Identification of Monitoring Indicators Protocols and Strategies for the Proposed Laurentian Channel Marine Protected Area (MPA). DFO Can. Sci. Advis. Sec. Res. Doc. 2014/093. v + 55 p

McDaniel, N., Swanston, D., Haight, R., Reid, D., and Grant, G. 2003. Biological Observations at Bowie Seamount August 3-5, 2003. Preliminary Report Prepared for Fisheries and Oceans Canada.

Paulmier, A. and Ruiz-Pino, D. 2009. Oxygen minimum zones (OMZs) in the modern ocean. Progress in Oceanography 80(3-4): 113–128.

Ross, T., Du Preez, C., and Ianson, D. 2020. Rapid deep ocean deoxygenation and acidification threaten life on Northeast Pacific seamounts. Glob. Change Biol. 26(11): 6424-6444.

Wilkinson, M.D., Dumontier, M., Aalbersberg, I.J.J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J-W., da Silva Santos, L.B.,Bourne, P.E., Bouwman, J., Brookes, A.J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C.T., Finkers, R., Gonzalez-Beltran, A., Gray, A., Groth, P., Goble, C., Grethe, J.S., Heringa, J., ’t Hoen, P., Hooft, R., Kuhn, T., Kok, R., Kok, J., Lusher, S.J., Martone, M.E., Mons, A., Packer, A.L., Persson, B., Rocca-Serra, P., Roos, M., van Schaik, R., Sansone, S-A., Schultes, E., Sengstag, T., Slater, T., Strawn, G., Swertz, M.A., Thompson, M., van der Lei, J., van Mulligen, E., Velterop, J., Waagmeester, A., Wittenburg, P., Wolstencroft, K., Zhao, J., and Mons, B. 2016. The FAIR guiding principles for scientific data management and stewardship. Sci Data 3:160018.

THIS REPORT IS AVAILABLE FROM THE:

Centre for Science Advice (CSA)
Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

E-Mail: DFO.PacificCSA-CASPacifique.MPO@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-47864-7 Cat. No. Fs70-6/2023-011E-PDF

Correct Citation for this Publication:

DFO. 2023. Monitoring Framework for SG̲áan K̲ínghlas-Bowie Seamount Marine Protected Area, British Columbia, Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2023/011.

Aussi disponible en français :

MPO. 2023. Cadre de surveillance de la zone de protection marine du mont sous-marin SG̲áan K̲ínghlas-Bowie, en Colombie-Britannique (Canada). Secr. can. des avis. sci. du MPO. Avis sci. 2023/011.