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SCIENCE GUIDANCE ON APPROACHES FOR MARINE BIOREGIONAL NETWORK MONITORING AND EVALUATION

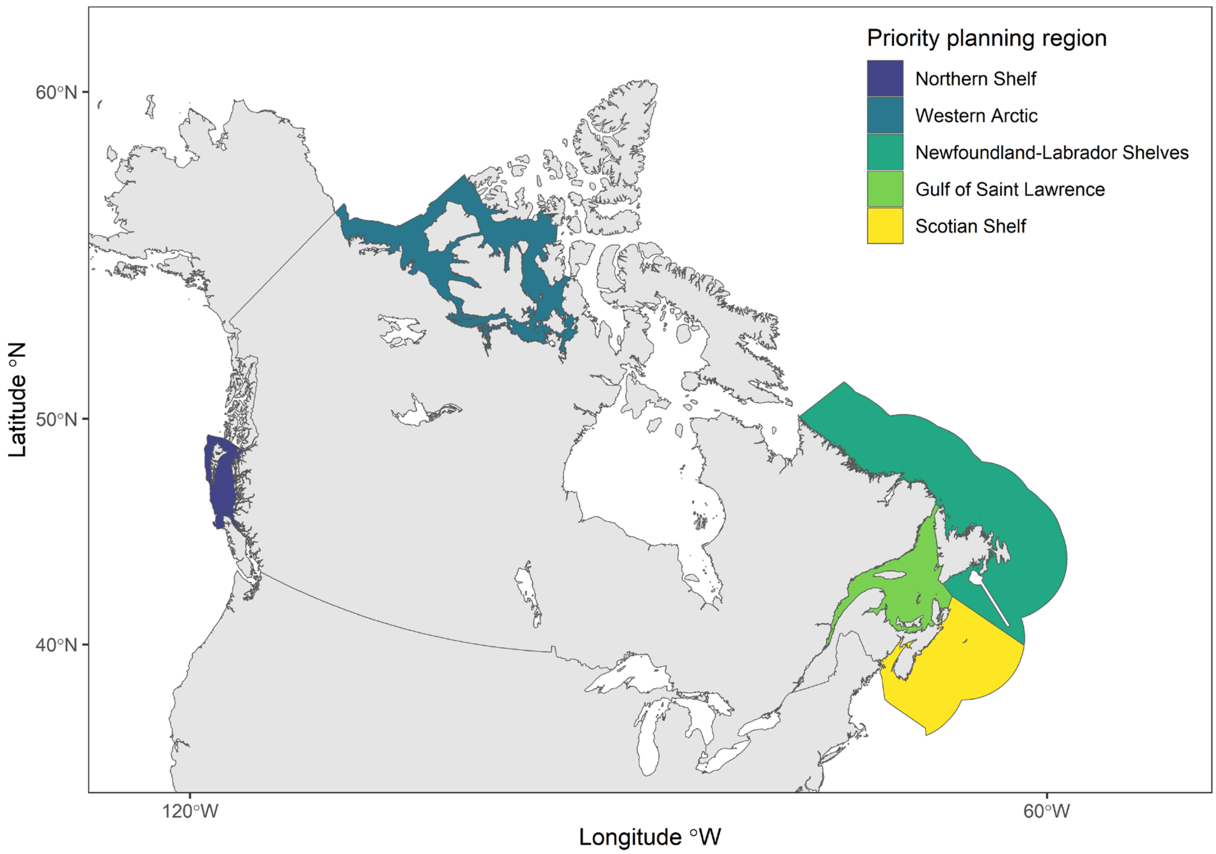

Figure 1. Map of Fisheries and Oceans Canada's (DFO) 5 priority bioregions. Estuary and Gulf of St. Lawrence, Scotian Shelf, Newfoundland-Labrador Shelves, Western Arctic, and Northern Shelf.

Context:

Canada has both national and international commitments, e.g., World Summit on Sustainable Development, the Convention on Biological Diversity, Canadian Biodiversity Strategy, to establishing a national network of marine protected areas (MPAs) and other effective area-based conservation measures. As the lead department on network planning, Fisheries and Oceans Canada (DFO) is responsible for coordinating the development of a network of marine protected areas for each of Canada's 13 bioregions, and is currently working with federal, provincial and territorial partners on networks in 5 priority bioregions (Figure 1).

Development of Canada's marine bioregional networks is being guided by the 2011 National Framework for Canada's Network of Marine Protected Areas (Government of Canada 2011). In 2009, general guidance regarding the design of MPA networks was provided through a DFO Science Advisory Process (DFO 2010). In 2012, guidance was provided on the development of measurable

Conservation Objectives, and identification of indicators, monitoring protocols and strategies to evaluate the effectiveness of bioregional MPA networks in achieving their objectives (DFO 2013a).

This Science Advisory Report is in response to a request from the DFO Oceans Program for additional guidance on the development of a science framework and common indicators to enable the monitoring of the effectiveness of bioregional marine networks in achieving their stated conservation objectives and the evaluation of network design.

This Science Advisory Report is from the September 10-12, 2019, Review of Approaches for Marine Conservation Network Monitoring. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Guidance is provided to support development of a nationally consistent framework for evaluation of marine bioregional network design and monitoring of the effectiveness of marine bioregional networks in achieving their stated objectives. This framework allows for flexibility to reflect regional and local conditions, differences in conservation objectives among networks, and circumstances that might change over time.
- The recommended framework includes:
  - Stream 1: Evaluation of whether design features (e.g., representation, replication, connectivity) have been effectively included in network design and implementation.
  - Stream 2: Monitoring to inform our understanding of whether marine bioregional networks, as they are implemented, are achieving their conservation objectives.
- Bioregional network monitoring and evaluation will be an incremental and an iterative process. This information could be useful to make course corrections on the management and monitoring of existing or new protected areas.
- Different types of ecological monitoring, such as ecological performance, human pressure, ambient condition, and reference site monitoring, can be used to track changes in ecological components of interest.
- While a single approach to network monitoring is unlikely to be applied in all Canadian bioregions, development of standard practices and approaches for evaluation of common elements of network design and intended outcomes could support synthesis and reporting at the national level.
- Existing monitoring programs can be leveraged to inform network design evaluations and monitor for effectiveness, thus drawing benefits from existing time series. However, the tools and techniques used to monitor networks are also expected to change with evolving technologies and legislative requirements.
- Networks are not yet fully implemented; Canada currently has a collection of protected areas and other effective area-based conservation measures (OECMs). However, monitoring of progress towards the ultimate achievement of bioregional network conservation goals and objectives should and can start now to establish baselines and prioritize next steps.

Stream 1: Evaluation of Network Design Features

- Evaluation of bioregional networks includes evaluation of how well design features (e.g., representation, replication, connectivity, adequacy, and viability) have been included in the

network design and implementation; for example, how well the spatial conservation targets are captured by the proposed and implemented network.

- Evaluation of bioregional networks is feasible with existing tools and available data. In most cases, the same tools that were used to design the networks may be used to complete initial evaluations, along with the most recent data.
- At a minimum, it is recommended that bioregional network evaluation be conducted as new areas are added to the network, with the addition of substantial new data, or at periodic intervals (e.g., at least every 5 years).

Representation

- For the purpose of bioregional network evaluation, representation can be considered to be achieved if the agreed to network design strategies (with associated conservation targets) are met and maintained within the implemented network.
- The ability to evaluate representation may be limited by the spatial data sets used in design (e.g., the original classification systems or modelled species distributions used). New data on species distributions, habitat extent, and habitat quality should be integrated into updated classifications, and the evaluation of conservation targets should be updated accordingly.

Replication

- Evaluation of replication should explicitly define what constitutes a “replicate” in terms of patch size and quality, and it should incorporate iterative feedback of newly collected data on habitat use, patch size, and quality into the description and accounting of replicates.

Connectivity

- Connectivity, i.e., the linkages between habitats, has, for the most part, only been considered partially or *post-hoc* in the design of the five priority marine bioregional networks in Canada, corresponding to a general limitation in baseline connectivity information.
- Evaluation of connectivity should focus on those conservation priorities for which conservation objectives depend on spatial linkages within the network.
- Various tools are available for evaluating and monitoring connectivity at different spatial and temporal scales, each with different information requirements and costs.
- Consensus was not reached on a nationally consistent approach to the evaluation of connectivity in bioregional network design. However, it was agreed that determination of the appropriate approach to connectivity within each bioregion (including research, monitoring, evaluation, and implementation within the network design) should carefully consider cost and benefits, and reflect available tools, data, capacity, and resources.

Stream 2: Monitoring of Network Effectiveness

- A rigorous monitoring plan to assess effectiveness of the network at the bioregional scale for all conservation objectives, and with the ability to attribute cause, would require significant investment.
- Identification and prioritization of subsets of network sites, conservation objectives, and associated indicators are recommended to demonstrate the effectiveness of the networks, and for reporting purposes. It is recommended that a small suite of well-understood indicators be used in the short-term while continuing to develop and adjust a broader suite of indicators for long-term monitoring.

- Indicators should address clear questions related to conservation objectives.
- Indicator selection should be an iterative, adaptive, hierarchical process. The suite of indicators should be evidence-based, harmonized, and validated at the bioregional and national levels.
- Monitoring indicators, protocols and strategies may differ for the coastal, shelf and deep-water/remote areas. These distinctions should be included in bioregional planning.
- Indirect indicators (proxies) of conservation priorities, e.g., the use of vulnerability assessments or indicator species, are recommended in data-poor situations or where they are more efficient than direct ones.

Overall Considerations

- Planning and capacity for data management, processing, and availability should be prioritized nationally to optimize the efficiency of assessments and adaptive monitoring (within and outside of government).
- Utilization of available expertise and resources within and external to government is essential to undertaking network monitoring. Determining potential opportunities for collaboration with Indigenous communities, as well as universities, environmental organizations, and other ocean stakeholders in Canada and abroad, to increase scientific research and monitoring capacity for networks monitoring, is recommended as a distinct step in monitoring program planning.

BACKGROUND

Canada's *Oceans Act* assigns responsibility to the Minister of Fisheries and Oceans Canada (DFO) to lead and coordinate development and implementation of a national network of marine protected areas (MPAs) on behalf of the Government of Canada (GOC), which includes requirements to clearly identify objectives of each MPA and ensure the network of MPAs covers diverse habitat types, biogeographic regions and environment conditions. There is no specific directive in the *Oceans Act* on monitoring of the network of MPAs; however, the National Framework for Canada's Network of MPAs (GOC 2011) explicitly mentions monitoring as the final step in the MPA network planning process (see Analysis section of this report). *Oceans Act* MPAs established to date have included commitments to develop monitoring plans and actions as part of their individual management plans. Other federal agencies responsible for MPAs are required (e.g., *Parks Canada Agency Act*, 1998) to report at least every 5 years on the state of national parks, national marine conservation areas, and national historic sites, and both the *Canada National Parks Act* (2000) and *Canada National Marine Conservation Areas Act* (2002) have management plan requirements that include regular performance evaluations.

In 2011, members of the Canadian Council of Fisheries and Aquaculture Ministers reviewed and approved in principle a National Framework for Canada's Network of MPAs (GOC 2011). The National Framework provides overarching direction for the development of nationally consistent bioregional networks of MPAs. It includes definitions, geographic scope and eligibility criteria of Canada's Network of MPAs; describes the 13 bioregions in which these will be implemented; and provides guiding principles for the establishment of MPA networks in Canada, steps to planning each bioregional network, and the expected elements of network design, including:

- Ecologically and Biologically Significant Areas (EBSA),
- Ecological Representation (or Representativity),

- Additional Design Properties of Connectivity, Replication, and Adequacy/Viability, and
- Culturally Important Areas.

Guidance has been provided through the DFO Science advisory process to ensure national consistency in the implementation of these principles, while allowing flexibility for adaptation to regional and local conditions. In 2009, advice was provided on MPA networks, including the incorporation of Convention on Biological Diversity (CBD) design features, particularly at regional scales (DFO 2010). In 2012, guidance was provided on the development of measureable Conservation Objectives and the identification of indicators, monitoring protocols and strategies to help evaluate the effectiveness of bioregional MPA networks in achieving their stated objectives and to help ensure greater national consistency in their planning and implementation (DFO 2013a). Guidance has also been provided on the identification of Ecologically and Biologically Significant Areas (DFO 2004; 2011) and on how to achieve representation in the design of MPA networks (DFO 2013b).

Design of bioregional MPA networks has been active in 5 priority bioregions: the Pacific Northern Shelf, Western Arctic, Scotian Shelf, Newfoundland and Labrador shelves, and Gulf of St. Lawrence. Conservation objectives have been developed, or are in development, for each of these networks, which reflect the unique physical, ecological, and biological attributes of these bioregions. Various approaches to implement bioregional network design are being considered and applied (DFO 2015, 2017a, 2018). Discussion of bioregional network monitoring (as something beyond what is currently underway within existing protected areas) is happening in anticipation of potential future network monitoring expectations and requirements.

In June 2016, Canada announced a 5-point plan to reach its national and international conservation targets (e.g., 10% of marine and coastal waters to be protected by 2020), which included advancing other effective area-based conservation measures (OECMs) as contributors to these targets. Areas that meet the OECM criteria are now included as part of the bioregional “marine conservation networks”, a naming convention that has been adopted by DFO Oceans to reflect the inclusion of these measures in the marine bioregional networks.

This Science Advisory Report is the next step in providing guidance for the evaluation and monitoring of marine bioregional networks, based on the experience gained over the past 7 years through MPA network planning and individual MPA monitoring in Canada, as well as international experience and best practices. Specifically, guidance is provided to support development of a nationally consistent framework for evaluation of bioregional network design and monitoring of the effectiveness of marine bioregional networks in achieving their stated objectives. This framework allows for flexibility to reflect regional and local conditions, differences in conservation objectives among networks, and circumstances that might change over time.

ANALYSIS

What Constitutes Ecological Monitoring and Evaluation at the Network Scale?

According to the National Framework for Canada’s Network of MPAs (GOC 2011), the final step in the network planning process (after compilation of baseline information, setting of measureable objectives and conservation targets, application of design features, consideration of economic and social impacts, development of an action plan, site-specific planning and implementation) (see definition in Annex 1) is to manage and monitor the MPA network. It states:

> *Once the network starts to take shape, ongoing research, monitoring and adaptive management will be needed to ensure management practices are achieving network goals and objectives. This monitoring should be above and beyond monitoring that takes places at the site level. Reporting to Canadians on the effectiveness of bioregional networks in achieving their stated goals and objectives will occur routinely* (GOC 2011).

While guidance has been provided previously on the development of monitoring protocols and strategies that would be applicable for MPA networks, including general guidance on scale and frequency, data management, and methodologies, this advice was not provided in the form of an agreed to approach to network monitoring that would be applied in a nationally consistent manner (i.e., a national "framework" for monitoring). The current DFO Science advisory process reported here was considered a first step towards the development of such a framework. The recommended framework includes:

Stream 1: Evaluation of whether design features (e.g., representation, replication, connectivity) have been effectively included in marine bioregional network design and implementation.

Stream 2: Monitoring to inform our understanding of whether marine bioregional networks, as they are implemented, are achieving their conservation objectives.

The desired outcome stemming from the implementation of monitoring and evaluation programs, in general, is to enable analysis, conclusions, and reporting on the success or failure of management measures (i.e., the implementation of bioregional networks) to meet stated objectives. Bioregional network monitoring and evaluation will be key processes to ensure managers have the requisite information to validate and, where necessary, adapt bioregional network designs, with a goal of improving network performance and achieving stated bioregional conservation objectives. Bioregional network monitoring and evaluation will be an incremental and an iterative process. This information could be useful to make course corrections on the management and monitoring of existing or new protected areas, and network monitoring will need to be harmonized with individual protected area monitoring and evaluation.

Evaluation

Evaluation is the systematic and objective examination of the relevance, effectiveness, efficiency, and impact of activities in light of specified objectives. The intent of evaluation is to identify shortcomings (hopefully to avoid repeating them) and highlight successes to inform and support future planning. An important goal of evaluation is to provide recommendations to managers for the performance and, in some cases, efficacy of the management measures, providing a basis for accountability, including the provision of information to the public.

In Stream 1, evaluation is expected to make use of existing information to assess and report on progress towards the incorporation of design strategies (including conservation targets) and design features (e.g., connectivity, replication, representation) into the network design and implementation. As new sites are added to the network, or ecological conditions change with time, evaluation can provide information to managers and the public on the evolving state of network design and implementation.

Ecological Monitoring

Monitoring is the systematic and ongoing process of collecting, analyzing, and using information to track progress on a specific question or objective (e.g., an indicator) over time. Ecological monitoring will improve our understanding of how species, habitats, and ecosystems change over time and the degree to which these changes are in response to management actions. Underlying this approach is the assumption that drivers of change can be effectively partitioned between natural processes and management interventions. The complexity of performance evaluations increases with the number and diversity of ecological components being assessed (as with multiple conservation priorities within bioregional networks) and the number of and interactions among human pressures. Ultimately, the degree of shared features in network-specific objectives will determine commonality in monitoring approaches across bioregions.

In Stream 2, monitoring may provide information on the current state of conservation priorities, as reflected by individual protected area or network monitoring indicators, as well as on the effectiveness of the management measures that have been applied to protect those features. In the Canadian context, the diverse types of management tools (e.g., *Ocean's Act* MPAs, national marine conservation areas, national wildlife areas, marine national wildlife areas, migratory bird sanctuaries, and OECMs), and varying levels of protection, will need to be taken into account.

Different types of ecological monitoring, such as ecological performance, human pressure, ambient condition, and reference site monitoring, can be used to track changes in ecological components of interest to Canadian MPA networks. Development of standard practices and approaches for evaluation of common elements of network design and intended outcomes could support synthesis and reporting at the national level.

Ecological performance monitoring is carried out to track the outcomes of protection and whether conservation objectives are being achieved. This type of monitoring focuses on trends in ecosystem status, function, and services using specific “health” indicators (e.g., biodiversity metrics, indicator species abundance) that are linked explicitly to network conservation objectives. Notably, achieving conservation objectives does not always require improvement in performance indicators. Maintaining baseline or even declining at slower rates compared to unprotected areas may be considered a success in some instances. Ecological performance monitoring is a key component in determining whether conservation objectives are being met and enables evaluation and reporting on protected area performance, increasing transparency and stakeholder acceptance.

Human pressure monitoring involves the monitoring of human activities (e.g., fishing, aquaculture, energy development) and their associated pressures (e.g., removals, organic deposition, noise) within and adjacent to protected areas. This activity is essential at the network level to identify, assess, and take action to address pressures that will impact the conservation objectives. The monitoring of human pressures makes it possible to understand better the response of ecosystem components to these pressures. This monitoring is particularly relevant for multiple overlapping pressures, where different kinds of pressures will need to be addressed in different ways. For example, ocean acidification may be addressed differently from fisheries. The ability to assess and rank threats resulting from human pressures according to scope, severity and irreversibility (e.g., in a risk-based approach) will allow prioritization of mitigation strategies at key intervention points.

Ambient condition monitoring observes the state of environmental conditions over time within (and outside) the boundaries of the marine bioregional network, but independently of its protection status. This type of monitoring is not intended to measure the attributes or consequences of protection, but, rather, to characterize the broader ecological system. An example of ambient condition monitoring is a time series of oceanographic data historically collected at stations within (and outside) the network to support reporting on the state of the ocean. Ambient monitoring can help highlight relationships between performance monitoring metrics and external factors. This is necessary when assessing the effectiveness of networks in a marine environment going through sustained and directional (climate) change.

Reference site monitoring uses reference areas, organisms, populations, or processes within protected areas to help explain the effects of climate change and other global-scale processes in marine ecosystems. This monitoring type can also be used to evaluate human-impacted ecosystems. Reference sites within protected area networks can serve as natural baselines or as controls for tracking recovery. In addition, for fished species, reference site monitoring can help evaluate fisheries management measures and minimize the shifting baseline phenomenon in defining healthy stocks.

Existing monitoring programs (such as the Atlantic Zonal Monitoring Program in the Atlantic Region, or the Multispecies Synoptic Surveys in the Pacific Region) can be leveraged to inform network design evaluations and monitor for effectiveness, thus drawing benefits from existing time series. However, the tools or protocols that are currently being used to monitor the ecosystem (e.g., Research Vessel biological surveys) may not be fit for purpose or may need to be modified to acquire the type of information required for network monitoring. The tools and techniques used to monitor networks are also expected to change with evolving technologies and legislative requirements.

Networks are not yet fully implemented; Canada currently has a collection of protected areas and other effective area-based conservation measures (OECMs). However, monitoring of progress towards ultimate achievement of bioregional network conservation goals and objectives should and can start now to establish baselines and prioritize next steps. Where bioregional network monitoring is likely to be insufficient or leave substantial uncertainty (e.g., in remote locations), “overdesign” of network or network sites (e.g., inclusion of more than the minimum number of replicates, greater representation, or increased size of inaccessible sites) may enhance the likelihood of network effectiveness, which would be consistent with the application of the precautionary approach.

Development, monitoring, and evaluation of MPAs and MPA networks are inherently multidisciplinary processes that include consideration of social, cultural, economic, and ecological components. While the current DFO Science advisory process, and resulting Science Advisory Report, focusses on the ecological aspects of bioregional network monitoring and evaluation, network monitoring in general would benefit from similar discussion and advice on the non-ecological aspects of network performance. Feedback from these types of discussions could help inform the planning process for ecological network monitoring, for example by providing information on human well-being and ecological constraints and opportunities.

Stream 1: Evaluation of Network Design Features

Network design features highlighted in the National Framework for Canada’s Network of MPAs (GOC 2011) include EBSAs, ecological representation (or representativity), connectivity, replication, adequacy, and viability. The DFO Oceans Program has requested advice on approaches for evaluating the incorporation of design features, specifically replication, representation and connectivity, in marine network designs. Adequacy and viability, while identified as important elements of network design, were not specifically addressed in this report. Evaluation of bioregional networks includes evaluation of how well design features (e.g., representation, replication, connectivity, adequacy, and viability) have been included in the network design and implementation; for example, how well the spatial conservation targets are captured by the proposed and implemented network.

Although theoretical insight into the design of MPA networks is well established in the literature and in practice, there remains little empirical evidence for their predicted outcomes, and current perspectives on how to monitor the performance of these networks remain largely conceptual. However, it is proposed that evaluation of bioregional network designs is feasible with existing tools and available data. In most cases, the same tools that were used to design the networks may be used to complete initial evaluations, along with the most recent data.

A review of the network planning processes indicates that incorporation of design features has varied among the five Canadian priority bioregions. Some design features have not been incorporated explicitly, *a priori*, into the network configuration due to lack of data availability. Alternatively, they have been incorporated “post hoc”. Regardless, it should be possible to develop standardized approaches to evaluate how well each of the features are incorporated into the network design. Then, as networks continue to be implemented, these approaches could also be used to monitor how well design features are captured by the evolving networks over time, as well as to improve network design. Recognizing that changes may occur due to climate change and other human pressures, some design features may only be incorporated at a later date.

Guidance is provided below on both new insights into the incorporation of representation, replication, and connectivity into network design, to inform bioregional networks still under development, as well as approaches to evaluating network design over time. At a minimum, it is recommended that bioregional network evaluation be conducted as new areas are added to the network, with the addition of substantial new data, or at periodic intervals (e.g., at least every 5 years, as is required for National Marine Conservation Areas).

Representation

An ecologically representative network will ideally include the full range of diversity within the bioregion. Protected areas within the network should capture examples of different biogeographic subdivisions that reflect the full range of ecosystems present within the bioregion (i.e., the species and habitat diversity of those ecosystems). Striving for ecological representation in a systematic fashion helps ensure that networks meet domestic and international conservation targets (e.g., Aichi targets) in an ecologically meaningful way, rather than focusing on protection of areas with low opportunity costs (i.e., low hanging fruit).

Approaches to Incorporating Representation in Canadian Networks to Date

Regional Science Advice on representation to date has been similar among the five priority bioregions. In all bioregions, spatial datasets that represent the conservation priorities for the planning areas were identified using broad-scale habitat classifications (coarse-filter spatial features) and priority species or habitats (fine-filter spatial features). These spatial features, representing the conservation priorities, were assigned a range of conservation targets (i.e., proportion of the spatial feature to be included in the network) that vary based on ecological characteristics, including size, uniqueness/rarity, vulnerability, and status (DFO 2015, 2017b, a, 2018, 2019). In four of the five bioregions, Marxan spatial optimization analyses were used to provide options for meeting conservation targets, whereas the Western Arctic bioregion used ‘moving-window’ and overlay analyses (DFO 2015). All approaches were based on available spatial data to characterize the planning landscape.

Approaches to Evaluating Representation in Network Design

A common approach to evaluating representation is to compare the proportion of each representative spatial feature within the network footprint with the representation design strategies (and associated conservation targets). The degree of conservation target achievement (e.g., Mean Target Achievement) for all spatial features captured in the network is a transparent, repeatable and easily understood metric for reporting the evaluation of networks at both the bioregional and national scale that has been previously used with ecological classification systems (e.g., marine bioregions).

The evaluation of conservation target achievement could be independent of the classification systems used to define the representative areas, and be presented simply as a percentage of the biogeographic subdivisions, however determined, contained within the network (e.g., 90% of the biogeographic subdivisions identified within a planning region may be captured by the network). This evaluation would be revised as protected areas are added to or modified in the network design or if new information can be used to update spatial feature layers. This approach could also be adapted to assess the incorporation of other spatial priority areas, including EBSAs, Important Bird Areas (IBAs), and Key Biodiversity Areas (KBAs).

Ongoing ecological monitoring can be used to update habitat maps that are the basis of classification systems and determine whether representation is maintained in lieu of new information.

Approaches to Evaluating Changes in Network Representation Over Time

Analyses focused on representation, when repeated over time, can be valuable for long-term efforts to determine how well representation-based conservation targets are being captured by the network (i.e., are they increasing, being maintained, or decreasing). When conducted in tandem with monitoring efforts that facilitate improved spatial information through the collection of new data, repeated evaluations of representation can detect changes in species diversity and habitat quality, which can be integrated into an adaptive management framework. Monitoring approaches will be specific to the particular conservation priority being monitored. For example, a representation conservation target for deep-water sponge reef with very slow recovery times will need to be monitored on a different time frame than canopy-forming kelp forests that have rapid growth rates, respond to disturbance on much shorter time scales, and die off annually.

Meeting Conclusions

For the purpose of bioregional network evaluation, representation can be considered to be achieved if the agreed to network design strategies (with associated conservation targets, see definition in Annex 1), which may be periodically re-assessed, are met and maintained within the implemented network.

The ability to evaluate representation may be limited by the spatial data sets used in design (e.g., the original classification systems or modelled species distributions used). New data on species distributions, habitat extent, and habitat quality should be integrated into updated classifications, and the evaluation of conservation targets should be updated accordingly.

Development of a unified Canadian marine classification scheme could be a long-term goal that would facilitate national and international evaluation and reporting.

Replication

According to the National Framework for Canada's Network of MPAs (GOC 2011), replication is intended to ensure that more than one example of each ecological feature is protected to safeguard against unexpected loss from natural events or human disturbance. Various approaches have been used to determine how well seabed features, habitat classes, and areas of importance for priority species are replicated throughout a proposed or final network design. In the case of very rare features, the opportunity for replication may be limited.

Approaches to Incorporation of Replication in Canadian Networks to Date

Regional Science Advice on replication to date varies among the five priority Canadian bioregions. For example, for the Pacific Northern Shelf Bioregion, the number of replicates was recommended to be based on patch size and rarity, in addition to being stratified by a broad-scale physical habitat classification system or by planning areas with similar ecological characteristics (DFO 2019). For the Scotian Shelf, science advice recommended at least two spatial replicates for coarse-filter features (DFO 2018). Specific advice was not requested on the number of replicates to include for the Newfoundland & Labrador and the Western Arctic MPA network processes (DFO 2015, 2017a). The Gulf regional process[1] recommended at least three replicates, based on recommendations from the literature, though also included two replicates for some specific features, stratified by broad-scale physical habitat classification.

Assessing Minimum Size of Replicate Areas

Assessments of the MPA network in California have used species-area curves developed locally to determine the minimum area required to capture 90% of the species known to use a habitat, using that information to define which habitat patches within the network qualify as a replicate (Saarman et al. 2013; Young and Carr 2015). Ideally, habitat-specific species-area curves would be available in the Canadian context and a similar threshold could be applied. However, these data are often unavailable and, therefore, the "replicate" definition must be derived from other information such as patch size. Monitoring efforts can help identify the biodiversity and ecological processes associated with habitat patches at varying scales, informing the patch sizes appropriate for replication and the efficacy of MPA networks in protecting those habitats.

Assessing Habitat Quality of Replicate Areas

Another key component of a "replicate" definition is habitat quality. Most MPA network assessments rely on spatial (e.g., Geographic Information Systems - GIS) layers of habitat types, some of which are outdated and contain known data gaps. An MPA network monitoring program can provide information, as appropriate, to update spatial datasets and integrate new habitat quality indices (e.g., eelgrass blade density) into habitat type maps. Alternatively, habitat quality can be measured using an index derived from human impact scores and proximity to human-derived stressors, identifying those areas that are pristine.

Information on habitat quality can then be incorporated into the "replicate" definition, further improving the ability to assess whether the network is meeting its replication objectives. The resulting definition of what constitutes a "replicate" in an MPA network would have a minimum area (defined by species-area curves) and associated habitat quality index (e.g., eelgrass blade density).

Assigning Number of Replicates Needed

Once a definition of what constitutes a replicate of the various habitat types is determined, the next step is to assign the number of replicates needed. Less information is available to guide the appropriate number of replicates for a given habitat type, though many studies have recommended at least three spatial replicates be included in MPA networks (e.g., IUCN-WCPA 2008; Fernandes et al. 2012). However, it is unlikely that there is a uniformly appropriate number of replicates needed for each habitat type; rather, the suitable number of replicates should be informed by risk, sensitivity, and considerations of habitat quality and should be assessed at a bioregional (or finer) scale. Another consideration for determining replicate number is the relationship (spacing) of the replicates to each other. From the perspective of protection against loss, it may make sense to select replicates that are far from each other, so that a single disturbance event is less likely to impact all replicates, while from a recovery perspective, it may make sense to ensure that replicates are reasonably well-connected so that one replicate may contribute to the recovery of others.

[1] Faille, G., Dorion, D., and Pereira, S. unpublished. Methodology for the Development of the Marine Protected Area Network. Draft Document November 2014 for the Technical Committee on the Marine Protected Area Network.

Evaluating Changes in Replication over Time

Monitoring over time will permit the ongoing evaluation of whether replication targets are maintained as replicate patches could become degraded or disappear and new patches may arise that provide a more suitable or additional replicate.

Meeting Conclusions

Evaluation of replication should include explicit definition of what constitutes a “replicate” in terms of patch size and quality, and it should incorporate iterative feedback of newly collected data on habitat use, patch size, and quality into the description and accounting of replicates.

Connectivity

Ecological spatial connectivity refers to the movement of organisms, genes, energy, chemicals, or materials among habitats, populations, communities, or ecosystems (Table 1). If integrated into the design of a network, connectivity is assumed to promote the resilience of protected habitats and ecosystems. Connectivity should guide the placement, size, and spacing of MPAs at the onset of establishment and in a growing network.

Types of Connectivity

There are multiple types of connectivity that could be considered in network design. Table 1 provides a definition of each, along with considerations for monitoring of these within or across a network.

Table 1. Definition of the types of ecological spatial connectivity and considerations for MPA network monitoring. The movement of organisms refers to spores, eggs/larvae, juveniles or adults. Each metric is explained in more detail in the following sections.

Type of connectivity	Definition	Considerations for MPA network monitoring
Landscape connectivity	The degree to which the landscape facilitates or impedes movement among habitats, populations, communities or ecosystems.	• Lowest data requirements • Can address multispecies questions • Gives information about network-scale connectivity patterns • Species-specific models require field validated resistance values
Population – genetic connectivity	Movement of genes among distinct populations through the movement of organisms of a single species among distinct populations.	• Detects changes over multiple generations • Detects realized connectivity patterns • Spatial resolution is an issue and limited/defined by sampling
Population – demographic connectivity	Movement of organisms of a single species among patchy or discontinuous subpopulations or habitats.	• In-situ measurement tools can provide real-time dispersal information (e.g. satellite tags) • Models provide network scale connectivity patterns • Models can predict changes to connectivity patterns under future climate conditions • Validating models can be challenging

Type of connectivity	Definition	Considerations for MPA network monitoring
Ecosystem connectivity	Movement of energy and nutrients through the movement of organisms, as well as chemicals and materials among ecosystems.	• Logistically challenging • May be suitable in specific cases (e.g., movement of detritus)

A variety of approaches can be used to incorporate or evaluate connectivity within the design of MPA networks (reviewed in Balbar et al. unpublished report[2]). The approach by which ecological connections are incorporated into network design will depend on the available information and resources, ranging from generally relatively low cost rules of thumb (limited information) to direct observations of connectivity (e.g., population genetics, tags) that require considerably more resources and effort to collect. Evaluation of connectivity in network design (i.e., through post-hoc analysis) can be used to compare different configurations (iterative design comparisons) and to identify gaps in connectivity. As new information becomes available (e.g., new landscape features or information on spatial connectivity) connectivity evaluations can be revised (Figure 2). The decision about whether the appropriate level of connectivity is achieved within a bioregional network will ultimately depend on the conservation priorities and whether their persistence depends on spatial linkages within the planning region. Until additional information is gained about the feasibility and benefits of different types of connectivity information and associated methods of collection, the application within each bioregion should be commensurate on the tools, data, capacity, and resources available.

[2] Balbar, A.C, Daigle, R.M., Heaslip, S.G., Jeffery, N.W., Proudfoot, B., Robb, C.K., Rubidge, E., and Stanley, R. unpublished. Approaches for Assessing and Monitoring Representation, Replication, and Connectivity in Marine Conservation Networks.

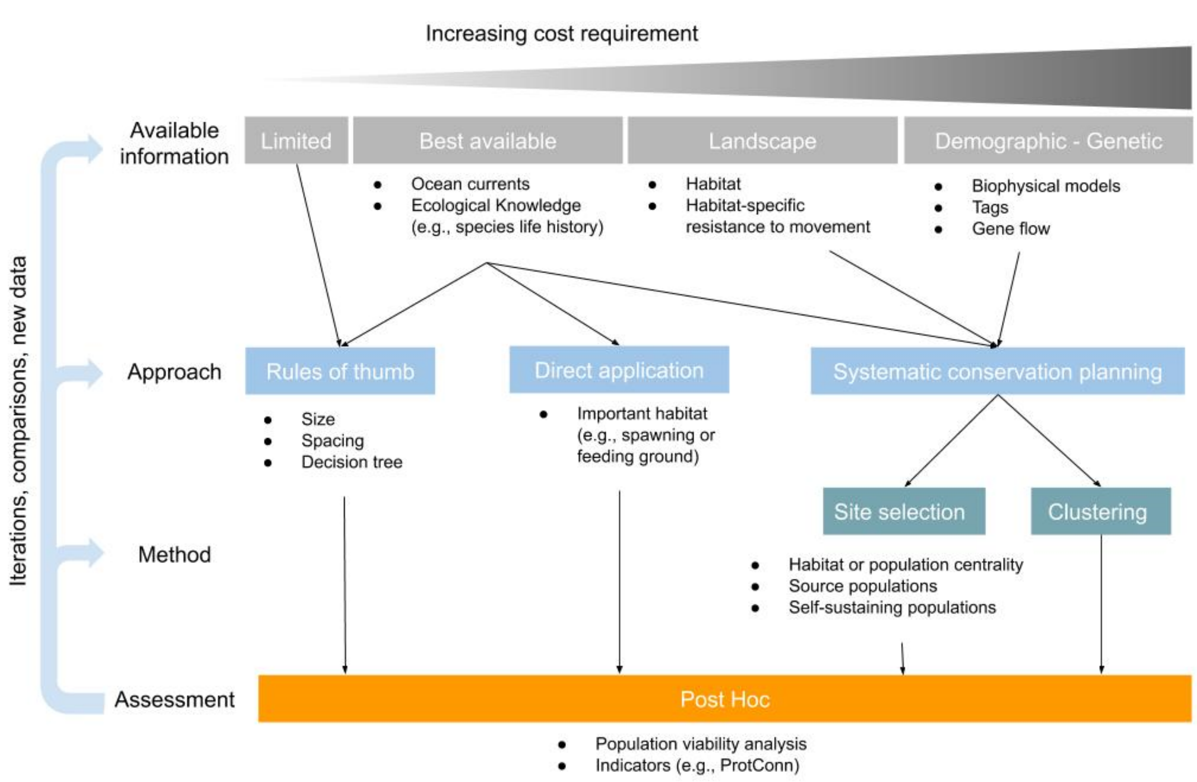

Figure 2. Potential workflows to incorporate connectivity-based knowledge into Marine Conservation Network planning and monitoring with varying cost requirements (Balbar et al. unpublished report).

Approaches to Incorporation of Connectivity in Canadian Networks to Date

Even though connectivity is an important design feature, for the most part, it has only been considered partially or post-hoc in the design of the five priority marine bioregional networks in Canada, corresponding to a general limitation in baseline connectivity information. This may be related to technological and analytical challenges and costs associated with collecting and interpreting this type of information.

There are, however, good examples of how connectivity has been incorporated into the design and placement of migratory bird sanctuaries and other conservation areas of importance to migratory birds, including consideration of connectivity of important locations (e.g., feeding and nesting areas) and life-histories stages into MPA network design.

For planning regions that employed spatial optimization using Marxan, the Boundary Length Modifier (BLM), in conjunction with spatial dependencies (i.e., boundary definitions) that represent the shared boundary length among neighbouring planning units, was used as a proxy of connectivity. By modifying the clustering of adjacent planning units during optimization, the BLM directly influences the edge to area ratio and thus the size of selected areas. This size, in general, correlates with the potential spillover, and conversely self-recruitment, expected of the area (e.g., larger reserves are expected to have more self-recruitment and less spillover). The BLM, however, does not directly control the spatial arrangement of individual reserves and, thus, only incidentally influences between reserve connectivity via the change in clustering of planning units, which affects the size and shape of reserves.

Approaches to Evaluating Connectivity in Network Design

Not all conservation priorities and objectives require explicit consideration of connectivity (e.g., unique bathymetric features). A useful first step evaluating the incorporation of connectivity into network design will be to determine those conservation priorities to be assessed, which may include prioritization of focal species or communities (e.g., Smith and Metaxas 2018). A nationally consistent approach to identification of conservation priorities for which connectivity is considered to be important, and where monitoring of connectivity is considered feasible, could facilitate standardized national evaluation and reporting. In addition, identification of locations where known barriers to connectivity could be most consequential (e.g., straits, channels, estuaries) could provide a risk-based approach to addressing connectivity values, using best available information.

Once agreement is reached on those aspects of connectivity that will be assessed, there are a number of different approaches available for evaluating how well connectivity has been incorporated into network design. These approaches can range from “rules of thumb”, such as comparing the distance between protected areas in relation to assumed or relative scales of dispersal distance (e.g., larval pelagic dispersal or adult movement), to the application of spatial analytical tools (e.g., Marxan Connect; Daigle et al. 2018) that integrate existing connectivity information (e.g., empirical connectivity data, biophysical models or habitat-based landscape metrics) into spatial prioritizations.

This diversity of potential approaches to measure connectivity, and associated spatial variability, highlights the necessity of conducting post-hoc evaluations of effectiveness for all relevant methods. There is also need to conduct ground truthing, wherever possible and applicable. Finally, it is important that evaluation methods are chosen to reflect the objectives of the network.

There are multiple spatial tools (e.g., Marxan Connect) that could be used to re-evaluate network performance over time by incorporating new or revised connectivity information, in addition to other baseline data (e.g., information on species distribution), to evaluate network configuration(s) against an (revised) optimized baseline. Such evaluations should be conducted iteratively to assure that the network remains adequately connected.

Tools for Measuring Network Connectivity

Various tools are available for evaluating and monitoring connectivity, directly (e.g., tagging, genetics) and indirectly (e.g., rules of thumb, biophysical models), at different spatial and temporal scales, each with different information requirements and costs (Figure 3). Many tools overlap at spatial resolutions of 1–10,000 km and day–annual ranges. Tools with a finer-scale resolution, such as biophysical modelling, parentage analysis, otolith chemistry, and stable isotopes, can help explain connectivity patterns over a single generation. Conversely, tools with a coarse-scale resolution, such as phylogenetics and population genetics, can help explain connectivity patterns over multiple generations. The approach to be implemented in monitoring plans should consider spatial and temporal scales, in addition to certainty (i.e., direct vs indirect methods), required to inform the assessment. Continued collection of connectivity and ecological baselines (e.g., habitat quality, status, and distribution) will be required to support ongoing evaluation of network design and monitoring of performance, particularly as new sites are added and marine ecosystems are altered by climate change.

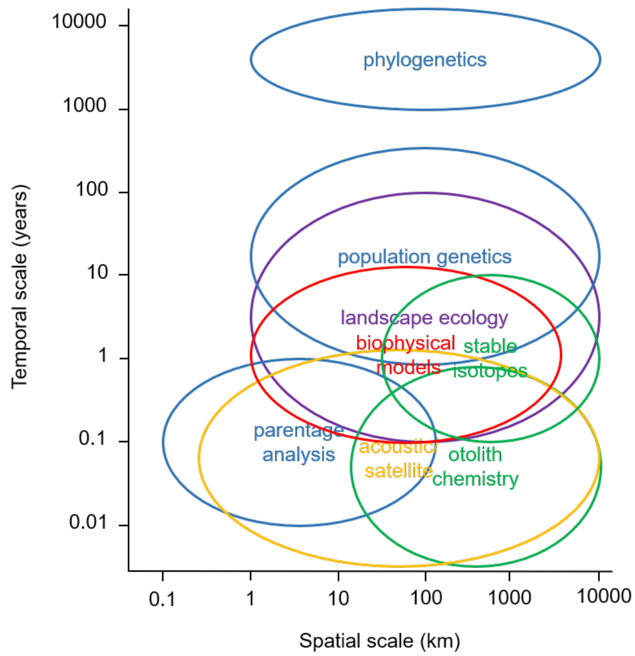

Figure 3. Spatial and temporal scales for different tools used to measure connectivity in MPA network monitoring. Blue circles indicate genetic approaches, green circles indicate chemistry tools. Note that parentage analysis can refer to mark-recapture studies, genetic or natural tagging approaches. Adapted from Jones et al. (2009).

Meeting Conclusions

Evaluation of connectivity should focus on those conservation priorities for which conservation objectives depend on spatial linkages within the network.

Consensus was not reached on a nationally consistent approach to the evaluation of connectivity in bioregional network design. However, it was agreed that determination of the appropriate approach to connectivity within each bioregion (including research, monitoring, evaluation, and implementation within the network design) should carefully consider cost and benefits, and reflect available tools, data, capacity, and resources.

Connectivity can be iteratively assessed each time the network is modified, when new data become available, or when properties of the network have been modified (e.g., climate change). A wide variety of knowledge, approaches, and methods can be used in isolation or in combination, but ultimately all should inform network performance (e.g., population viability, resilience) and be periodically evaluated for their effectiveness.

Stream 2: Monitoring of Network Effectiveness

What to Monitor?

Canada's *Ocean Act* states that, in leading and coordinating the development and implementation of a national network of MPAs on behalf of the Government of Canada, the Minister of Fisheries and Oceans Canada shall ensure that clearly identified objectives are set for each *Oceans Act* MPA. The regulatory authorities for other types of protected areas (e.g., National Marine Conservation Areas, National Wildlife Areas, etc.) hold their own accountabilities to their guiding legislation. The National Framework for Canada's Network on MPAs goes on to suggest that clear, measurable network objectives and conservation targets be set for each bioregion, and that objectives for the bioregional network are identified, consistent with national MPA network goals. It also states that, as networks are implemented, monitoring and adaptive management will be necessary to ensure that management practices are achieving network goals and objectives, and that reporting to Canadians on the network effectiveness will occur routinely.

The primary goal of the national network of MPAs is to provide long-term protection of marine biodiversity, ecosystem function and special natural features. This goal is reflected in bioregional strategic objectives (conservation objectives), which are relatively high-level statements that outline what a bioregional network aims to achieve. While expressed differently across the five priority bioregions, these objectives can be considered fairly consistent in their intent. More detailed network operational objectives have been or are in the process of being developed in each priority bioregion; previous advice (DFO 2007, DFO 2008, DFO 2013a) recommended that operational objectives should be sufficiently specific to guide the selection of suitable indicators and appropriate reference points. However, some bioregions may have tens to several hundred conservation targets (each with one or more corresponding operational objectives) related to the conservation priorities within each bioregion.

A rigorous monitoring plan to assess effectiveness of the network at the bioregional scale for all conservation objectives, and with the ability to attribute cause, would require significant investment. Identification and prioritization of subsets of network sites, conservation objectives, and associated indicators is recommended to demonstrate the effectiveness of the networks. Several approaches have been proposed to identify the subset of sites or objectives that could be the focus of initial network effectiveness monitoring, versions of which have been applied in other jurisdictions.

Approaches for prioritization of monitoring include:

- Use of human pressure monitoring to identify conservation objectives at greatest risk, which could then become the focus of effectiveness monitoring.
- Focus on conservation priorities (or their proxies) that are already adequately monitored by existing monitoring programs (e.g., biomass of key species and functional groups, environmental variables). However, there is a risk that monitoring programs designed for other purposes may not be adequate to address questions of network effectiveness and may require adjustments (e.g., to monitoring protocols) if they are to be used for network monitoring in addition to their initial purpose.
- Focus on conservation priorities for which there is a high likelihood of seeing a positive response to management intervention through the creation of the bioregional network, recognizing this response may take decades to detect (e.g., corals and sponges; Bennecke and Metaxas 2017).
- Use of thematic groupings (e.g., corals and sponges, groundfish, large pelagics, small pelagics, marine mammals, birds, benthic habitat) to identify key priorities and opportunities, and well as indicators, strategies and protocols, for effectiveness monitoring.
- Focus on the national conservation goal of protecting marine biodiversity, ecosystem function, and special natural features, which applies across all bioregions, and select high-level, synoptic indicators (e.g., diversity metrics) that reflect this goal.

While it may not be feasible to monitor all network conservation objectives, it also may not be feasible to monitor all protected areas within a bioregional network. Some jurisdictions (e.g., the California MPA Network) have developed a tiered approach to MPA monitoring, using a set of standard criteria to select MPAs and reference sites for monitoring, based on importance, risk, and feasibility. This approach may also be useful in a Canadian context, particularly as the network expands.

A nationally consistent approach to the selection of an initial subset of sites or conservation objectives upon which to focus effectiveness monitoring would facilitate national evaluation and reporting. Once the subset has been selected, previous guidance on the selection of appropriate indicators for monitoring and evaluation would be applicable (e.g., DFO 2013a). A range of monitoring options could be prepared, including costs and benefits.

How to Monitor Networks?

One of the key challenges for monitoring network effectiveness will be establishing relationships between management actions (for example, the selection of management tools such as *Oceans Act* MPAs versus *Fisheries Act* closures, with their corresponding restrictions and levels of compliance) and ecological responses. Given the complexity of these relationships, this linkage may not be possible without significant investment. In some cases, it may be feasible to design a research and monitoring program that provides information on the effectiveness of a management action for a particular conservation objective. These examples can be used to “tell the story” of the success or failure of the network and inform plans for future effectiveness monitoring efforts. In the interim, while effectiveness monitoring information is being collected, some jurisdictions have made use of proxies (e.g., vulnerability or risk assessments) to report on the “state” of their networks.

The selection (design, form and function) of monitoring approaches will be specific to the particular indicator being monitored, the expected spatial-temporal scales of response, and the stressors and natural disturbances at the individual sites. This will, in turn, dictate the frequency and spatial extent of surveys to ensure resources are used efficiently.

Interpretation of trends in indicators (e.g., cause and effect) can be challenging. While there may be a desire to attribute improvements in indicators to a successful network, the challenge will lie in disentangling those changes from changes arising from other anthropogenic and environmental factors.

Indicator Selection

Indicators serve many functions in the context of MPAs and protected area networks, including evaluating the effectiveness of the network design, measuring the performance of management decisions and objectives, determining the overall health of the ecosystem and its attributes over time and space, assessing impacts (e.g., anthropogenic, environmental) on the ecosystem, and acting as decision-support and/or communication tools (DFO 2013a).

Monitoring of many Canadian MPAs is already taking place, with indicators selected to address the specific conservation objectives and priorities for each area (e.g., monitoring of cetaceans in the Gully MPA). Notably, monitoring indicators, protocols, and strategies generally differ for the coastal, shelf, and deep-water or remote areas. These distinctions should be considered in planning for bioregional network monitoring.

Identifying, prioritizing, and selecting appropriate ecological indicators and their reference points is a complex scientific process. Not surprisingly, the selection of indicators and the development of monitoring programs can require significant investments of time and effort. It is recommended that a small suite of well-understood indicators be used in the short-term while continuing to develop and adjust a broader suite of indicators for long-term monitoring.

It can be difficult to determine reference points at the network level. Instead of working towards reference points for each indicator, it may be useful to consider reference directions, stability, or reduced rates of decline as appropriate targets. Caution should also be used when characterizing the state of the ecosystem based on ecological indicators from only one data type (e.g., only fisheries-independent survey data). Using a variety of data sources can lead to more robust and compelling analysis, and increase confidence in the interpretation.

Baseline Data Collection; Reference and Ambient Condition Monitoring

International experience has demonstrated the importance of baseline data collection to inform future monitoring and evaluation. This may also include the monitoring of reference sites.

Consideration of spatial-temporal scales of the ecological baselines and the expected responses is integral for designing monitoring programs and interpreting their findings. Reports such as DFO's State of Canada's Oceans, produced for each of the Atlantic, Pacific, and Arctic oceans, are mainly based on established and peer-reviewed time series and offer a wealth of information on contextual ecosystem indicators, such as sea surface temperature, dissolved oxygen, phytoplankton, fish and invertebrate communities, seafloor habitat, and seabirds. If any of these features are chosen to be indicators for Canada's marine networks, the State of Canada's Oceans reports may provide useful baseline information.

As with evaluations of network design, data from existing monitoring programs (and time series) and partnerships can be leveraged in inform effectiveness monitoring.

Sampling Design for Effectiveness Monitoring

When designing a monitoring program, it is important to determine how much sampling effort is required, and what resources are available, prior to data collection. The ability to draw reliable statistical inference (power to detect change or trends) from monitoring will depend on the magnitude of change observed (e.g., 50% increase in abundance) and the underlying background variability associated with the sampled system (e.g., spatial-temporal variation) and the sampling itself (i.e., precision). Estimating the statistical power of a given sampling design and effort can provide information for setting priorities and understanding how effort and investment relate to certainty. Ultimately, the efficacy of monitoring will depend on matching objectives (e.g., indicators) with a sampling design that has sufficient statistical power to answer the key monitoring questions.

Thorough evaluation of statistical design and statistical efficiency should preface any monitoring program development. Conducting monitoring without some knowledge of the underlying variability in the ecosystem could lead to inefficient or insufficient sampling and ultimately risk undermining the efficacy of networks and their associated monitoring investments. Continued monitoring of natural variability through collection of baseline data is critical for a monitoring program to draw conclusive statistical inference.

Spatial-Temporal Considerations

Guiding network monitoring program development requires a standard framework for effective decision-making regarding spatial-temporal considerations. This development should commence with a mobilization phase, including determination of the minimum standard of sampling as well as consideration of the trade-offs between temporal and spatial sampling investments. When determining the appropriate spatial and temporal scales for network monitoring, questions include:

- What are the relevant spatial-temporal ecological baselines of conservation priorities associated with each MPA (within and outside)?
- What are the spatial-temporal scales associated with the expected response?

- Can the spatial scale of the monitoring design measure site-specific objectives as well as network objectives?
- How do we prioritize monitoring resources and effort? i.e., space – spacing; time – frequency; species – community.

Data Management Requirements for Network Monitoring

The Government of Canada is committed to making government information more accessible and open to the public as described in the Directive on Open Government . Monitoring data should be integrated and consolidated into comprehensive data repositories that are publicly accessible. This integrated approach will enable network-level summaries to be derived efficiently from site-level monitoring programs and on a timeframe that meets the management planning cycle, to facilitate iterative assessments.

Planning and capacity for data management, processing, and availability should be prioritized nationally to optimize the efficiency of assessments and adaptive monitoring (within and outside of government). Given the long-term nature of the investments that are required for conservation network monitoring, it is very important to establish comprehensive data management plans upfront.

Data management and processing currently constrain the proper assessment and eventual monitoring of networks in Canada, but this should not be a limitation given available technology. General literacy on data management is limited, and even though significant progress is being made towards better practices, the focus is still primarily on sharing and archiving of data. A key concept that will need to be addressed in Canada to allow for efficient adaptive monitoring is interoperability of data (Wilkinson et al. 2016), which will allow management of data in a way that is comparable and allows for efficient generation of integrated datasets (e.g., Dutil et al. 2012).

For example, efforts towards a Canadian Integrated Ocean Observing System (CIOOS), or similar approaches, could enable building of integrated datasets and data processing workflows that allow for more rapid evaluation of measures of network and individual MPA effectiveness. It will also allow us to build interactive tools that can help visualize and analyze data in meaningful ways for managers.

Partnerships and Collaboration

Partnerships between government scientists and academic researchers and/or institutions can increase the capacity to undertake research and monitoring by combining resources and sharing ideas, data, and information.

Indigenous knowledge may be used for the design and evaluation of spatial conservation measures, including protected area networks. For example, Indigenous knowledge was instrumental in the design and designation of Anguniaqvia niqiqyuam MPA in the Beaufort Sea. In the Pacific Northern Shelf Bioregion, network design has been a process co-led by agencies representing federal, provincial, and Indigenous organizations. Indigenous and local knowledge (including, for example, Indigenous Guardian programs) can provide current and historical information on local distribution and species' movements. The incorporation of knowledge and traditional use information in conservation planning can also promote stronger collaboration with Indigenous groups and local communities, enabling collaborative governance structures, such as co-management.

Community and citizen science engage members of the public to collaborate with professional scientists to conduct research-based investigations, engage in monitoring activities, collect data and interpret results, and produce new knowledge used for natural resource management or basic research. Citizen science is a growing strategy for monitoring natural systems. By coordinating observations by members of the general public, citizen science has and will continue to provide an avenue to collect data at a greater spatial-temporal extent than dedicated monitoring programs alone. This increased coverage is required as monitoring programs expand beyond the individual site level. Public focused monitoring initiatives also provide opportunities for education and outreach, promoting greater ocean literacy and awareness, which ultimately can lead to improved management and conservation outcomes.

Industry-based observations can also increase our knowledge of the marine environment. Sentinel fisheries and at-sea fisheries observers can provide information on total catch, commercial discards, and bycatch mortality. Increasing at-sea observer coverage in fisheries that catch significant numbers of species of interest can add to our understanding of ecosystem status and function. Logbook programs can also provide a valuable platform for data collection when partnered with MPA monitoring programs (e.g., Janes 2009).

Utilization of available expertise and resources within and external to government organizations is essential to undertaking network monitoring. Determining potential opportunities for collaboration with Indigenous communities, as well as universities, environmental organizations, and other ocean stakeholders in Canada and abroad, to increase the scientific research and monitoring capacity for network monitoring, is recommended as a distinct step in monitoring program planning.

Adaptive Management Approach to Monitoring and Evaluation of Networks

An adaptive management approach is advised to enable adaptation to a variety of factors relevant to network monitoring, including new technologies, policies, governance structures, datasets and methods, as well as the climate change considerations described in the next section. Approaches to network evaluation and monitoring need to be flexible enough to respond to these changing conditions. The robust and well-documented adaptive management literature can inform network monitoring design and implementation.

Decision support frameworks are designed to increase planning rigor, project accountability, stakeholder participation, transparency in decisions, and learning (Schwartz et al. 2017). This goal is achieved through collective adoption of a framework and approach that is standardized, open, transparent, and well-supported. For conservation planning, such frameworks should explicitly consider ecological, and human well-being values, and use associated performance metrics as a basis for adaptive management. Using a decision-support framework, performance measures derived from indicators associated with individual objectives can be used to evaluate effectiveness of management actions expected to ultimately lead to network level outcomes.

Climate Change Considerations

The distribution of many marine species is regulated by physiological tolerances and temperature. With a general warming of marine waters associated with climate change, the distribution of many species have shifted northward or into deeper waters. These changes in distribution influence marine ecosystems in myriad ways.

At least some of the indicators selected for network monitoring need to be able to capture impacts of climate change on network conservation priorities; however, other effects of climate change may require their own specific indicators. Given the wide-reaching current and future effects of climate change on marine ecosystems, MPA network managers and science advisory processes should take into account a broad suite of physical and biological indicators, many of which may be generated by other ocean research and management-oriented monitoring programs. These should include indicators of ocean forcing (e.g., North Atlantic Oscillation, air temperature), sea ice (e.g., total coverage, thickness), coastal habitat (e.g., sea level rise, storm event frequency and severity, wetland flooding and loss), oceanographic properties (e.g., temperature, salinity, stratification), and a range of indicators related to individual organisms, populations, and community structure (e.g., prey selection, size, reproduction, mortality, geographical range, species composition).

The resiliency of a network (e.g., to climate change) will depend on whether design features including representation, replication, and connectivity are adequately achieved in the final configuration. Well-designed and connected networks could increase the resilience of biological systems under the influence of climate change by minimizing further human disturbance and maintaining ecosystem function.

CONCLUSIONS AND ADVICE

Effective marine bioregional networks must be representative (e.g., of their conservation objectives and the planning region as a whole), have sufficient replication (where appropriate) to ensure resilience to disturbance, and be well-connected so that individual network components interact with each other to maintain ecological function and provide conservation outcomes that exceed the summed results of network components. Maintenance of these core design features is a prerequisite to achieve the overarching objectives of the network. Network monitoring programs can provide the requisite information to determine the efficacy of the implementation of the network design through time, as the network develops and as the environment changes. As marine ecosystems respond to climate change, monitoring programs will be essential for adaptive management and insurance that bioregional networks continue to produce the conservation outcomes they were designed to produce in the most (spatially) efficient way possible.

Many tools exist for measuring representation, replication, and connectivity design features. No one tool or approach should be used to evaluate these design features. Network monitoring in some ways is challenged by the very diversity that networks are developed to protect. Monitoring efficiency is more than a cost-limited decision, and the selection of the most *appropriate* tools should explicitly consider the spatial-temporal scales of the ecological features of interest in addition to cost of deployment. Research that improves the efficiency of these tools, for both cost and (spatial, temporal, and taxonomic) comprehensiveness, should be prioritized for regional and national MPA programs. Given that design features and, generally, strategic objectives, are shared within the Canadian bioregional networks, bioregional monitoring programs should implement, wherever possible, standardized approaches for monitoring and evaluation. These standardized approaches would provide for more efficient and targeted investments (i.e., shared technical equipment or expertise) and reporting for the bioregional networks. Additionally, investment and integration with existing broad-scale monitoring programs within DFO (e.g., multi-species RV surveys, the Atlantic Zone Monitoring Program) and other scientific regional monitoring programs (e.g., Parks Canada National Marine Conservation Area monitoring and Marine Plan Partnership Protected Management Zone monitoring in the Pacific Region) should be prioritized to ensure comprehensive long-term data baselines are available to contribute to evaluation of network performance.

Network scenarios have been developed in each of the five priority bioregions; however, at the time of writing, no network design has been fully implemented, and no timeframe for implementation has been set. Advice on monitoring program development and strategies for assessing the network design principles should be specific to the design of each bioregion and linked to their respective objectives. Though specific advice for monitoring program development cannot be fully developed until final network configurations have been agreed upon, guidance from this report could provide a useful framework outlining the approaches, requirements, and rationale for design-based monitoring moving forward.

SOURCES OF UNCERTAINTY

As mentioned previously, although theoretical insight into the design of networks is well established in the literature and in practice, there remains little empirical evidence for their predicted outcomes, and current perspectives on how to monitor the performance of these networks remain largely conceptual.

Monitoring and evaluation of connectivity, including its role in enhancing the effectiveness of marine networks is an evolving field, with questions remaining about the relative value in using rule of thumb proxies (e.g., standard minimum distance between sites) as compared to more complex, and potentially costly, approaches for measuring connectivity and incorporating it into network design, evaluation, and eventually monitoring.

Effective representation and replication of habitats, species, communities and processes within the network are limited by the quality of the available spatial datasets available for each conservation priority, and the ecological classifications used. These gaps can be closed with data collection, including information on habitat quality, in addition to an improved understanding of the relationships between species and their habitats.

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This Science Advisory Report is from the September 10-12, 2019, Review of Approaches for Marine Conservation Network Monitoring. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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ANNEX 1: DEFINITIONS

Conservation Objectives (CO): Conservation objectives are those objectives that deal specifically with ecological outcomes, as distinct from economic or human use objectives. This term may be used to refer to higher-level, strategic goals and objectives, as well as operational objectives.

Conservation Priorities (CP): Specific species, habitats or other ecological features a regional MPA network aims to protect.

Design Features: MPA network design features outlined in CBD COP 9 Decision IX/20 (UNEP 2008) are characteristics of the MPA network that are necessary in order for the network to have a high likelihood of delivering the objectives set for it; however, these design features are not conservation objectives in their own right. They include EBSA, representativity, connectivity, replicated ecological features, as well as adequate and viable sites.

Design Strategies: Detailed statements that, for each Operational Objective, specify: (1) the types of areas or features to be conserved (e.g., significant concentrations, feeding aggregations, nursery areas, spawning areas), and (2) the relative targets for those area types (e.g., high, medium, or low).

Marine Conservation Network: Operationally, Fisheries and Oceans Canada has recently adopted the term “marine conservation network” to refer to the collection of marine protected areas (e.g., *Oceans Act* MPAs, National Marine Conservation Areas, National Marine Wildlife Areas) and OECMs (e.g., marine refuges) that operate cooperatively to safeguard function and biodiversity in marine ecosystems. This term has the same policy usage as “MPA network”.

Marine Protected Area (MPA): A clearly defined geographical space recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. In the Canadian context, MPAs must have as their main objective the conservation of nature, and fall within IUCN categories I-VI. Examples include Oceans Act MPAs, National Marine Conservation Areas, and National Marine Wildlife Areas.

Monitoring Protocols: Describe the specific methodologies required for monitoring (DFO 2013a).

Other Effective Area-Based Conservation Measures (OECMs): Defined by the CBD as 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, social, economic, and other locally relevant ecosystem values.

Operational Objectives (OO): Specific and measurable statements that indicate the desired state for each conservation priority for a regional MPA network.

Strategic Objectives: Relatively high-level statements that outline what a marine bioregional network aims to achieve.

Conservation Targets: There are international biodiversity targets, such as Aichi target 11, e.g., “By 2020, at least 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes”, and there are specific targets (related to operational objectives – see definition above) set for conservation priorities as part of a Design Strategy, e.g., “protect 80-100% of known large gorgonian coral concentrations.”

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