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SCIENCE GUIDANCE ON HOW TO ACHIEVE REPRESENTATIVITY IN THE DESIGN OF MARINE PROTECTED AREA NETWORKS

Figure 1: Fisheries and Oceans Canada's (DFO) six administrative regions.

Context

Canada has made various domestic and international commitments to establish a network of marine protected areas (MPAs) (e.g., World Summit on Sustainable Development, the Convention on Biological Diversity, Canadian Biodiversity Strategy). As the lead department on national MPA network planning, Fisheries and Oceans Canada (DFO) is working with federal, provincial and territorial partners to design and establish the Canadian network of MPAs in accordance to Decision IX/20 of the Convention on Biological Diversity (UNEP 2008). The required network properties and components identified in Annex II of the CBD Decision, amongst others, include Ecologically and Biologically Significant Areas (EBSAs) and representativity.

In 2004, Science provided advice on the identification of EBSAs (DFO 2004). This advice was reviewed and updated in 2011 (DFO 2011). Further to this advice, Science hosted two advisory processes in 2009 that laid much of the foundation for how Canada can proceed to establish its representative networks of MPAs. The first advisory process addressed the identification of Canada's marine biogeographic units (i.e., marine bioregions) and guidance on factors to consider in the next level(s) of subdivision (DFO 2009). The second advisory process provided general guidance on the necessary properties of networks of MPAs, including representativity (DFO 2010).

However, the science advice from the 2009 (DFO 2009 and DFO 2010) did not provide guidance that could be followed to ensure consistency in the selection of the scale (level of subdivisions) at which representativity can be achieved adequately within a network, nor guidance on when a network would be considered representative of the range of species, habitats, and ecological functions of a given biogeographic unit (e.g., bioregional subdivision).

This Science Advisory Report (SAR), from the National Peer Review Process held on October 2, 2012 in Montreal, is in response to a request from DFO Program Policy Sector which sought scientific guidance for a nationally consistent interpretation of representativity and to provide guidance for MPA network practitioners on incorporating representativity within a bioregional MPA network.

SUMMARY

- This national science peer review process, based on international and domestic experience, focused on how to ensure consistency in the selection of the scale (level of subdivisions of a bioregion) at which representativity must be considered, and how a protected area or areas within an MPA network would be considered representative of a biogeographic unit within the bioregion.
- To conclude a network is representative, three requirements must be met:
    (i) an accepted biogeographic classification system to guide what biogeographic units of the bioregion are to be represented in the network to ensure the full range of ecosystems in the bioregion are captured;
    (ii) an accurate and informative map of the bioregion relative to that classification system to guide where to select areas so that they represent the intended biogeographic units; and
    (iii) a decision that the areas selected adequately represent the biogeographic units to guide how much of each biogeographic unit to include in the network.
- The classification of bioregions into ecological units should strive to incorporate detailed knowledge of species distribution and abundance patterns as well as their interactions with their habitat and other species. In cases where these data are not available, geophysical and oceanographic factors may be used where there is reason to believe these factors can discriminate among habitat and community types. When biological data become available, they should be used to validate or adjust boundaries of the biogeographic unit(s).
- Inshore areas are often significantly different than offshore areas due to differences in anthropogenic and naturally-induced pressures as well as differences in community structure. Due to such differences, it is recommended these environments be considered separately when selecting the appropriate scale for incorporating representativity in the MPA network.
- Similarly, because the scale of ecological patterns and processes that should be represented in the network may be more finely resolved in benthic environments than in pelagic environments, ecological classifications for benthic and pelagic systems should include some analyses conducted separately for the two environments because important ecological aspects of the systems can be resolved at different scales.
- Classification below a scale for which not enough data are available to create an accurate classification should be avoided. As long as sufficient data are available, the stopping rule for selecting the scale of subdivision at which to incorporate representativity within the network should be at the scale that most appropriately shows the patterns of community structure thought to be produced by the ecological functions characteristic of the bioregion.
- Functions served by representative areas in a network include ecological functions (e.g., primary productivity, benthic community processes, piscivorous predation) and management and policy functions (insurance policy, benchmark, and seed stock functions).
- For each of the ecological processes, there are often stable patterns that emerge at the scale of 10s to 1000s of square km, with piscivorous predation frequently showing stable

patterns at the larger scales. Thus, if the spatial scale of the representative areas is adequate to address the spatial scales of feeding, spawning, and juvenile development of the key top predators and forage fish, then it can be assumed that the spatial scales are large enough to give protection to the other ecological processes, as well.

- Requirements to ensure functions of representative areas are sustained include:
  - (i) stringent management inside the representative MPA network with activities vulnerable to management failure excluded;
  - (ii) representative areas need to be large enough to ensure the essential ecosystem structures and functional processes are sufficiently included within the MPA network so that pressures outside the MPA network do not impact these structures and functions inside the MPA network; and
  - (iii) integrated management approaches are in place between protected areas of the network to protect ecological functions that occur at scales larger than can be adequately protected by individual MPAs.

BACKGROUND

DFO Science has provided guidance on the design of networks of MPAs at both the national level (DFO 2010) and regional level (DFO 2012), which supports meeting Canada's domestic and international commitments to establish a national network of MPAs. These documents have provided some general guidance on achieving representativity in the design of MPA networks which is summarized below.

The bullets that follow were not created or peer reviewed at the October 2, 2012 meeting from which this Science Advisory Report resulted. Rather they provided the background context upon which discussions at the meeting were based.

National Guidance (see DFO 2010):

- A representative network of MPAs is one that captures examples of different biogeographic subdivisions that reasonably reflect the full range of ecosystems which are present at the scale of network development, including the biotic and habitat diversity of those ecosystems.
- Past guidance has focused on possible approaches of achieving the outcome described in the first bullet.
- Once an initial set of existing and potential MPAs that effectively achieves coarse representativity is identified, a review at a finer scale of habitat patchiness should take place. This review should seek individually significant areas, distinctive habitats, or communities not otherwise represented within the initial set of existing and potential MPAs, and ensure that they are captured appropriately in the network being developed.

Regional Guidance (see DFO 2012):

- During the regional Science advisory process, discussions on the representative network design property focused mostly on habitat classification systems that could be used for the Scotian Shelf bioregion to identify the diversity of ecosystems that should be represented in coastal and offshore areas. It was suggested that different classification systems should be used for the coastline (0 -10m depth), the coastal sub-tidal (10 -100m depth) areas, and offshore areas.
- For the Scotian Shelf bioregion, it was proposed that two separate but linked physiographic classification systems (i.e., coastline classification and coastal subtidal classification) be used for the coastal zone, and two distinct classification systems be used for the offshore

(i.e., a classification of seabed features, such as banks, basins, and channels, and a classification based on a benthic habitat characterization template). These classification systems are briefly reviewed in DFO 2012.

- It is important to validate the classification systems that are based on physical attributes with biological data, where available.

The National guidance (DFO 2010) described above recognized that "as the policy discussion and implementation of MPA networks evolve, further requests for Science advice are expected to address other implementation questions". Guidance is now requested to provide a nationally consistent interpretation of representativity and to provide guidance for MPA network practitioners on how best to adequately represent a bioregion within an MPA network. This science advisory process has focused on how to ensure consistency in the selection of the scale (level of subdivisions) at which representativity must be considered to achieve that design property of an MPA network, and how an area or areas within that network would be considered representative of a biogeographic unit within the bioregion. The advice that follows is based on international and domestic experience and complements existing previous advice.

ANALYSIS

Overview

To conclude a network is representative, three requirements must be met:

(i) an accepted biogeographic classification system to guide what biogeographic units of the bioregion are to be represented in the network;

(ii) an accurate and informative map of the bioregion relative to that classification system to guide where to select areas so that they represent the intended biogeographic units; and

(iii) a decision that the areas selected adequately represents the biogeographic units to guide how much of each biogeographic unit to include in the network.

A common set of principles (though not necessarily a common set of factors or variables) for a classification system should be used for each bioregion to ensure some measure of consistency across bioregions in how representativity is being assessed. It is recognised that some bioregions, which are more data rich in terms of biological and physical data, can be more refined in how they include representativity compared to data poor bioregions. However, following common principles, as outlined below, should lead to consistency in selecting the appropriate scale for incorporating representativity in a bioregional network.

A protected area or areas within a network is considered representative of a biogeographic unit if, when appropriately managed, the area(s) allows the natural ecological functions that occur within the biogeographic unit to proceed without significant perturbation from human activities. The process of incorporating representativity into an MPA network should be an iterative one that optimizes the other network design features of EBSAs, connectivity, replication, and adequacy and viability.

Considerations for the Selection of Scale

Appropriate factors to consider to ensure national consistency in the selection of scale (level of subdivision) of the areas that need to be represented in the network are as follows:

- The classification of bioregions into ecological units should strive to incorporate detailed knowledge of species distribution and abundance patterns as well as their interactions with their habitat and other species. However, there often are gaps in such knowledge, especially

in the marine environment. In such cases, geophysical and oceanographic factors, which have patterns in space and time and to which there is reason to expect the biological communities have responded, may act as indicators for the types of marine communities likely to be found in such habitats. The importance that these factors have in defining subdivisions should depend upon which factors have the greatest ability to discriminate among habitat and community types (Roff and Zacharias 2011).

- The scale of observation is an important factor to consider in order to resolve biogeographic subdivisions on various scales (e.g.,, grab or trawl data versus ecosystem surveys).
- Methods for classifying habitats that use both biological and physical factors to produce predicted species assemblage maps, such as Gradient Forest (DFO 2012), provide advantages over methods that use purely physical factors alone, as species do not respond to physical factors equally and do not respond evenly over the gradient of a physical factor. Although such methods are quantifiably predictive of species distribution and abundance patterns, they can be time/labour intensive, require extensive GIS and statistical expertise, and require biological data that are well distributed across the bioregion.
- The use of a marine landscape/seascape approach has been increasing over recent years for characterising biogeograhic patterns internationally because geophysical and oceanographic data, which are the basis for this approach, are more readily available. It is recommended that, when possible, maps of enduring and recurrent geophysical and oceanographic factors for depicting biogeographic subdivisions of bioregions should be calibrated by biological sampling at the appropriate scale and locations to validate or adjust boundaries.
- Much of the biological data that will be available initially for biogeographic classification could be biased towards commercially important species due to the purpose for which the data were originally collected and archived (i.e., fish population surveys for stock assessments). Thus, when calibrating the biogeographic subdivisions, it is suggested to start with the available biological data and, where necessary, continue working towards incorporating additional biological data that more accurately represents the complete species diversity and abundance of the bioregion.
- The environmental factors that are used to characterise biogeograhic patterns should be chosen based on those that are the most important drivers of species distribution and abundance patterns in the bioregion or subset of the bioregion. If these are not known, international examples and examples from the literature may be used. The more common types of environmental factors that have been shown to be important drivers in meta-analyses and multiregional studies include: depth / photic zone, nutrients, substrate, current / circulation patterns, seabed features / bathymetry, temperature, and salinity (Roff and Zacharias 2011).
- Inshore areas (defined for the purposes of this SAR to be the area from low water mark to a depth (approximately 100 m) where ecological discontinuity results from termination of the photic zone contact with the seabed) are often significantly different than offshore areas due to differences in anthropogenic and naturally-induced pressures as well as differences in community structure. Due to structural and functional differences, it is recommended that these environments be considered separately when selecting the appropriate scale for incorporating representativity in the MPA network. It is further recommended that decision makers should strive for coherence in the planning and management of these distinct environments.
- Similarly, because of differences in spatial scales at which ecological patterns and processes occur for benthic environments compared to pelagic environments, the scale of

representation may be more finely resolved in benthic environments than in pelagic environments. Ecological classifications for benthic and pelagic systems should include some analyses conducted separately for the two systems because important ecological aspects of the systems can be resolved at different scales (Roff and Zacharias 2011). Even if defined separately, there can be benefits of improved conservation outcomes when there is coherence in planning and management between these different environments.

- As the level of subdivision in the classification hierarchy gets finer (approximately three or four levels in the hierarchy), the available supporting data become limiting. Classification below a scale for which not enough data are available to create an accurate classification should be avoided. However, it is suggested that as finer level data becomes available, classifications at finer scales should be attempted. To the extent that data allow, the stopping rule for selecting the scale of subdivision at which to incorporate representativity within the network should be at the scale that most appropriately shows the patterns of community structure thought to be produced by the ecological functions characteristic of the bioregion.
- There is no specific scale of subdivision that will be appropriate for all policy and management uses, or even for all aspects of planning MPA networks, regionally or nationally. Science should undertake at least two or three additional subdivisions of each previously identified bioregion, following the current and past scientific guidance on practices for identifying biogeographic units. At each scale of subdivision Science should provide narrative (and if available quantitative) information about the ecosystem functions operating in, and structural properties characteristic of, the biogeographic units identified. Management can then use that information to choose levels of subdivision appropriate for their needs, and provide rationales for their choices.

Functions served by representative areas in MPA networks

Ecological Functions / Processes

- A central purpose of incorporating representativity in a bioregional MPA network is to protect the natural ecological functioning of the full range of ecosystems within the bioregion. A means of achieving this purpose is to protect and maintain to the extent possible ‘natural’ examples of the ecological functions / processes within the MPA network, such as those identified in Table 1 below. For each of the ecological functions listed, examples of indicators are provided that can be used to assess the spatial scale at which the function is operating, and therefore the minimum spatial scale necessary for representative areas constituting a network.

Table 1: Examples of ecological functions / processes that should be captured within a representative MPA network as well as potential indicators to asses the scale at which the function is operating.

Ecological Functions / Processes	**Examples of indicators**
Primary productivity	Chlorophyll a level; nutrient regeneration
Grazing of phytoplankton	Patchiness of plankton community structure
Benthic community processes	Patterns of community composition; spatial complexity of benthic habitats
Benthic-pelagic coupling	Nutrient loading; chlorophyll level
Piscivorous predation	Diet composition; spatial scale of aggregation of prey populatons; foraging range of predators within a season

- For these processes to be captured in a network, it is important for the network to include a diversity of the habitat types present in the bioregion at appropriate scales. The scale at which ecological functions play out will be reflected in the patterns of the fish community and benthic community structure. Pattern analysis of community structure could be a useful approach to establish the level of subdivision required to identify, locate and configure representative areas to achieve the representativity property of the network.
- If the ecological processes within the network are performing within normal bounds of variability, then it is reasonable to infer that communities are healthy and habitats are intact.
- For each of the ecological processes, there are often stable patterns that emerge at the scale of 10s to 1000s of square km, with piscivorous predation frequently showing stable patterns at the larger scales. Thus, if the spatial scale of the representative areas is adequate to address the spatial scales of feeding, spawning, and juvenile development of the key top predators and forage fish, then it can be assumed that the spatial scales are large enough to give protection to the other ecological processes as well. For example, to maintain the cod-capelin predator-prey ecological process, it is necessary to have representative areas on the scale of at least several thousand square kilometers. At this scale, it is assumed that the ecological processes of primary productivity, grazing, etc., also will be captured in the network.
- Likewise, if representative areas within a network are large enough to protect the key top down ecological processes, it can be assumed that the key bottom up processes also will be protected. However, the reverse does not hold true.
- If any of the ecological processes is demonstrably not being served, then one can conclude that the full biodiversity of the biogeographic unit from which the representative area(s) is drawn is not adequately represented in the MPA network.

Management and Policy Functions / Outcomes

A representative MPA network could serve three management and policy outcomes for the biogeographic region which it represents: (i) insurance policy, (ii) benchmark, and (iii) seed stock (Rice and Houston 2011).

- A representative MPA network is said to offer the insurance policy outcome if management failures outside the MPA network (whether due to incomplete knowledge of the ecosystem when developing management plans, poor implementation of a plan, poor compliance with a plan, and/or unexpected changes in conditions that make plans ineffective) do not seriously alter the ecological processes and relationships inside the MPA network, such that these can continue to function ‘normally’ even if the ecosystems outside the MPA network have been severely altered by unsustainable use. The insurance policy outcome can be important for most extractive uses (e.g., fishing, mining, etc.), but may not be effective for regional or basin scale perturbations such as climate change. However, the insurance policy outcome enables the protection of ecological structures and processes which improves resilience to larger scale perturbations.
- A representative MPA network is said to offer the benchmark outcome if the area inside the network is unperturbed by activities outside the network so that it provides a reference where natural variation in monitoring data can be quantified, allowing other patterns of variation in areas outside the network to be attributed to impacts of human use. If the areas within an MPA network had a history of human use, there will be a period of recovery of the system inside the network during which its suitability to serve this benchmark outcome increases.

- A representative MPA network is said to offer the seed-stock outcome if the network can help support the recovery of species in neighbouring impacted areas. Since a representative network should have species diversity and abundance as well as size and genetic composition of organisms much closer to a recovered or less modified state, the spillover, due to natural movement or other means, may greatly speed up the recovery of ecosystems outside the MPA network providing management regimes are in place for the impacted area(s).

Required properties to ensure functions are sustained

- To protect ecosystem structures and functional processes as well as the management and policy outcomes, management inside the representative MPA network must be quite stringent, with uses vulnerable to management failure excluded. The benchmark outcome is particularly vulnerable to being compromised if human activities within an MPA network cause changes to populations, communities, and habitats that are not readily and quickly reversible by natural ecological processes. Management should align with the objectives outlined in the IUCN Protected Areas Management Categories I – III (Dudley 2008). In cases where exploitation is considered within an MPA network, such exploitation rates should be far below exploitation rates considered sustainable and appropriate as targets for management in other areas.
- Representative areas also need to be large enough to ensure that: (i) essential ecosystem structures and functional processes are sufficiently included within the MPA network because if not, activities harmful to the ecosystem outside the network may harm their equivalent structures and functional processes within the network; and (ii) human drivers outside the MPA network do not dominate population and inter-species dynamics within the network.
- Some ecological functions and patterns occur at scales so large that they cannot be protected by individual MPAs (e.g., salmon and whale migrations) and require integrated management approaches that may include several members of a network of representative MPAs. Hence, to protect and maintain these ecological functions, it is critical to have effective integrated management between MPAs which is cognizant of and willing to contribute to meeting the objectives of the MPA network.
- There is no universal ‘right’ size for representative areas within an MPA network. Case-specific decisions on ecologically appropriate size should follow from considering the spatial scales of the key ecological processes in the biogeographic unit that have to be encompassed within the spatial scales of the representative areas of the network if they are to be capable of serving the ecological as well as the management and policy functions detailed above.

CONCLUSIONS AND ADVICE

- A common set of principles for a classification system should be used for each bioregion to ensure some measure of consistency across bioregions in how representative areas are identified. However, it is recognised that there is no specific scale of subdivision that will be appropriate for all policy and management uses, or even for all aspects of planning MPA networks, regionally or nationally.
- The classification of bioregions into ecological units should strive to incorporate detailed knowledge of species distribution and abundance patterns as well as their interactions with their habitat and other species. In cases where these data are not available, geophysical and oceanographic factors may be used where there is reason to believe these factors can discriminate among habitat and community types. The environmental factors that are used

to characterise biogeograhic patterns should be chosen based on those that are the most important drivers of species distribution and abundance patterns in the bioregion or subset of the bioregion. When biological data become available, they should be used to validate or adjust boundaries of the biogeographic unit(s).

- Classification below a scale for which not enough data are available to create an accurate classification should be avoided. The stopping rule for selecting the scale of subdivision at which to incorporate representativity within the network should be at the scale that most appropriately shows the patterns of community structure thought to be produced by the ecological functions characteristic of the bioregion.
- Due to differences in anthropogenic and naturally-induced pressures as well as differences in community structure, inshore and offshore areas should be considered separately when selecting the appropriate scale for incorporating representativity in the MPA network. Similarly, ecological classifications for benthic and pelagic environments should include some analyses conducted separately for the two environments because important ecological aspects of the environments can be resolved at different scales. It is further recommended that decision makers should strive for coherence in the planning and management of these distinct but connected environments.
- There is no universal 'right' size for representative areas within an MPA network. Case-specific decisions on ecologically appropriate size should follow from considering the spatial scales of the key ecological processes in the biogeographic unit that have to be encompassed within the spatial scales of the representative areas of the network if they are to be capable of serving the ecological as well as the management and policy functions.
- For each of the ecological processes, there are often stable patterns that emerge at the scale of 10s to 1000s of square km, with piscivorous predation frequently showing stable patterns at the larger scales. Thus, if the spatial scale of the representative areas is adequate to address the spatial scales of feeding, spawning, and juvenile development of the key top predators and forage fish, then it can be assumed that the spatial scales are large enough to give protection to the other ecological processes as well.
- Requirements to ensure functions of representative areas are sustained include:
    (i) stringent management inside the representative MPA network with activities vulnerable to management failure excluded;
    (ii) representative areas need to be large enough to ensure the essential ecosystem structures and functional processes are sufficiently included within the MPA network so that pressures outside the MPA network do not impact these structures and functions inside the MPA network; and
    (iii) integrated management approaches are in place between protected areas of the network to protect ecological functions that occur at scales larger than can be adequately protected by individual MPAs.

SOURCES OF INFORMATION

This Science Advisory Report is from the national advisory meeting of October 2, 2012 on Guidance on "Representative" Marine Protected Areas for Network Planning. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule.

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FOR MORE INFORMATION

Contact: Eddy Kennedy
Coastal Ecosystem Science Division
Fisheries and Oceans Canada
Bedford Institute of Oceanography
P.O. Box 1006, Dartmouth
Nova Scotia B2Y 4A2

Tel: 902-426-9917

E-Mail: Eddy.Kennedy@dfo-mpo.gc.ca

This report is available from the:

Canadian Science Advisory Secretariat
National Capital Region
Fisheries and Oceans Canada
200 Kent Street
Ottawa, Ontario K1A 0E6

Telephone: 613-990-0293
E-Mail: csas-sccs@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs

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