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International Approaches to Characterizing Marine Seascapes to Achieve Representativity in MPA Network Design

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Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

To design Marine Protected Area (MPA) networks in 12 bioregions across the country, Canada will apply the Convention on Biological Diversity's scientific guidance regarding required network properties and components; this list includes representativity. Currently, there is little guidance available regarding how to apply this network property in practice, particularly with respect to defining the appropriate scale of biogeographic subdivision to reflect the full range of marine ecosystems, including biotic and habitat diversity. Therefore, to inform the development of national scientific guidance to support bioregional MPA network planning in Canada, this paper investigates various approaches other jurisdictions have taken internationally to address this question. No jurisdiction took the approach of specifying outright the scale at which they will apply the representativity property. Most jurisdictions took a systematic approach to characterizing marine landscapes/seascapes, subdivided primarily using geophysical, plus some biological, factors. Such an approach is an option for the Canadian context considering benthic and pelagic ecosystems separately, and proceeding at different scales for coastal versus offshore areas. In order to achieve national consistency, scientific guidance on the types of factors to consider in bioregional landscape/seascape characterization is needed.

Approches internationales en matière de caractérisation des paysages marins afin d'assurer la représentativité dans le conception des réseaux d'AMP

RÉSUMÉ

Pour concevoir les réseaux d'aires marines protégées (AMP) dans les 12 biorégions du pays, le Canada va appliquer les directives scientifiques relatives aux propriétés et composantes obligatoires des réseaux qui figurent dans la Convention sur la diversité biologique; la représentativité est l'un des éléments de cette liste. Peu de directives existent à l'heure actuelle pour indiquer la manière de mettre cette propriété des réseaux en pratique, notamment pour définir l'échelle appropriée des subdivisions biogéographiques permettant de refléter toute la gamme des écosystèmes marins, y compris la diversité biotique et des habitats. Pour éclairer l'élaboration de directives scientifiques nationales relatives à la planification des réseaux biorégionaux d'AMP au Canada, on examine donc dans ce document diverses approches adoptées à l'échelle internationale par d'autres instances pour résoudre ce problème. Aucune administration n'a décidé de spécifier directement l'échelle à laquelle elle appliquera la représentativité. La plupart ont adopté une approche systématique pour caractériser les paysages/fonds marins, en les subdivisant essentiellement à l'aide de facteurs géophysiques complétés par quelques facteurs biologiques. Cette méthode est possible dans le contexte canadien en séparant les écosystèmes benthiques et pélagiques et en utilisant différentes échelles pour les zones côtières et extracôtières. Dans un souci de cohérence nationale, il est nécessaire de préparer des directives scientifiques sur les types de facteurs à prendre en compte dans la caractérisation des paysages et fonds marins à l'échelle biorégionale.

INTRODUCTION

The Convention on Biological Diversity's (CBD) scientific guidance for selecting areas to establish a representative network of marine protected areas identifies the following required network properties and components:

- Ecologically and biologically significant areas;
- Representativity;
- Connectivity;
- Replicated ecological features; and
- Adequate and viable sites.

The CBD defines representativity in the following way:

> *"Representativity is captured in a network when it consists of areas representing the different biogeographical subdivisions of the global oceans and regional seas that reasonably reflect the full range of ecosystems, including the biotic and habitat diversity of those marine ecosystems"* (Secretariat of the Convention on Biological Diversity, 2009).

Interpreted in the Canadian context, "representative MPAs should capture 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" (DFO, 2010).

In 2009, DFO developed a framework and principles for the biogeographic classification of Canadian marine areas (DFO, 2009) based on the six principles that guided the Global Open Oceans and Deep Seabed Biogeographic Classification (GOODS) system. GOODS is hypothesis-driven and based on a physiognomic approach, which uses geographic and physical characteristics of the benthic and pelagic environments to select homogeneous regions of similar habitat and associated biological community characteristics (DFO, 2009).

DFO (2009) identified 12 high-level spatial units for Canada's three oceans (three in the Atlantic, five in the Arctic, and four in the Pacific), primarily based on oceanographic and bathymetric similarities. Each of these coarse-scale biogeographic units can be disaggregated into smaller units that are also ecologically meaningful; however, the successive levels of subdivision are increasingly data intensive. Subdivisions can be attempted at various scales, from global to microcommunities; the appropriate level of resolution is case specific and depends on the management or policy purpose of the classification system.

In 2010, DFO also published *Science Guidance on the Development of Network of Marine Protected Areas (MPAs)* for Canadian waters (DFO, 2010), which states that the scale of the major biogeographic units or their first-order subdivisions "may be appropriate for the selection of representative MPAs, and appears to be a reasonable default for starting the process of selection of representative areas" (DFO, 2010). DFO (2009) recommended that at the first level of subdivision of Canada's major biogeographic units "coherence of bathymetry and/or water masses will be important considerations, along with food web functionality and, when available, coherence in variation in recruitment across groups of similar taxa" (DFO, 2009).

However, in DFO (2010) it was noted that at these broad scales, a single MPA cannot normally be expected to be representative of the entire biogeographic region within which it is found.

Therefore, to achieve representativity by capturing examples of the full range of ecosystems within each biogeographic unit, including the biotic and habitat diversity of those ecosystems, further guidance is required regarding the appropriate scale for regional representative network development. Representation at the habitat scale assumes that by representing all habitats, most elements of biodiversity (species, communities, etc.) will also be represented in the network. Given that the majority of species are limited in their distributions by combinations of environmental parameters and variables, such as depth, salinity, temperature, benthic substrate type, and dominant flora and fauna, assessing habitats in this manner can provide a proxy for species diversity and distribution. This enables management decisions to be made regarding the value of sites as reservoirs of biodiversity in the absence of detailed species-level data – the basis of the marine landscape/seascape theory (Roff and Zacharias, 2011; IUCN World Commission on Protected Areas, 2008).

This paper examines the application of the marine landscape/seascape theory internationally, specifically looking at what environmental parameters, variables and marine features have been used to define appropriate ecosystem/habitat classification scales (subdivision of biogeographic units) for the purpose of designing representative networks of MPAs. The primary purpose of this paper is to inform the development of national guidance on this subject, applicable to the Canadian context – what parameters, variables and marine features should be used in the subdivision of Canada’s biogeographic units for representative MPA network planning?

MARINE LANDSCAPE/SEASCAPE THEORY

Marine landscapes/seascapes are small-scale ecosystems or medium-scale marine habitats (synonymous for the purposes of this paper). Central to the marine landscapes/seascapes concept is the assumption that geophysical and oceanographic information at the ecosystem/habitat scale (for which there is generally better broadscale coverage than biological information) can be used in lieu of biological information to classify medium scale marine habitats and to set marine conservation priorities. The justification for this assumption is the strong ecological relationship that exists between geophysical and hydrographic factors and the characteristics of biological communities (Vincent et al., 2004); faunal boundaries, for example, are related to factors that vary with depth (e.g., temperature, nutrients, oxygen) (Howell, 2010).

There is an extensive scientific literature describing these ecological relationships. In 2000, Roff and Taylor developed one of the first examples of representative habitat mapping – they classified the Scotian Shelf using, in relation to the seabed, factors such as water temperature, depth/light, substratum type, exposure and slope, and, in relation to the water column, factors such as water temperature, depth/light and the stratification/mixing regime. The intention was that this classification would then be used to inform management action, including conservation and protection. Although physical variables can account for anywhere from 25-75% of community variability depending on the system (Greenlaw et al., 2013), these ecological relationships have formed the basis for the European Nature Information System (EUNIS) marine habitat classification, among others (Vincent et al., 2004).

Particularly in regions where complete knowledge of all biological features, abundance and distribution of species at their different life stages is not available, the protection of representative examples of all occurring landscape/seascape types is essential and is considered to be the only means to ensure that the ecological functioning of the ecosystem is maintained (Roff and Zacharias, 2011). Adequate protection of a full range of representative habitats, defined by oceanographic, physiographic and biotic characteristics, requires analysis of how these characteristics are distributed (IUCN World Commission on Protected Areas, 2008).

“If a system of classification is based on enduring and recurrent geophysical features that predict the biological communities, and if these factors can be mapped, then a complete system of classification can be undertaken for all regions” (Roff and Zacharias, 2011). Mapping the marine environment based largely on enduring and recurrent geophysical and oceanographic factors to depict representative areas has been undertaken or is in progress in many countries globally, including UK and other EU countries, Australia and elsewhere, as this paper explores below. Such mapping, with international collaboration, can form the foundation for a truly comprehensive approach to global representative network of MPAs (Roff and Zacharias, 2011).

INTERNATIONAL APPROACHES

The following is a review of international examples of the marine landscape/seascape theory in practice for the purposes of representatively MPA network planning (in no particular order). A summary of the findings can be found in Table 2.

THE EUROPEAN NATURE INFORMATION SYSTEM (EUNIS)

EU member states pledged as early as 1992 to create a coherent network of protected areas with the adoption of the Habitats Directive (Directive 92/43/EEC, 1992). The Natura 2000 network is comprised of Sites of Community Importance (SCIs) or Special Areas of Conservation (SACs) under the Habitats Directive and Special Protection Areas under the Birds Directive (Directive 79/409/EEC, 1979). The aim of the network is to maintain and restore biodiversity on land and at sea.

Natura 2000 sites will form a coherent European ecological network of special areas of conservation. This network, composed of sites protecting the natural habitat types listed in Habitats Directive Annex I and habitats of the species listed in Annex II, shall enable the natural habitat types and the species' habitats to be maintained or, where appropriate, restored to a favourable conservation status in their natural range.

Annex I lists 231 European natural habitat types (terrestrial and marine), including 71 priority habitats (i.e., habitat types in danger of disappearance and whose natural range falls mainly within the territory of the EU). Annex I is based on the hierarchical classification of European habitats developed by the CORINE Biotopes project, as that was the only existing classification at the European level at the time (in 1992).

Annex I marine habitat types generally correspond to the European Nature Information System (EUNIS) Level 3 classification, or sometimes 4. The EUNIS Habitat types classification scheme (Davies et al., 2004) is a comprehensive pan-European system to facilitate the harmonised description and collection of data across Europe through the use of criteria for habitat identification. It covers all types of habitats from natural to artificial, from terrestrial to freshwater and marine.

The first level of the hierarchy splits off marine habitats from coastal and terrestrial habitats. In general, marine Level 2 uses the biological zone and the presence/absence of rock as classification criteria. Marine Level 3 introduces energy into the classification for hard substrata (e.g., EUNIS habitat code A1.1 = High-energy littoral rock), and splits the softer substrata by different sediment types (e.g., EUNIS habitat code A5.4 = Sublittoral mixed sediments). In total there are 56 marine EUNIS Level 3 habitat types.

CONVENTION FOR THE PROTECTION OF THE MARINE ENVIRONMENT OF THE NORTH-EAST ATLANTIC (OSPAR)

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) Commission, in 2003, adopted recommendation 2003/3, of which one purpose is the establishment of the OSPAR Network of MPAs and to ensure that by 2010 it is an ecologically coherent network of well-managed sites. As the target had not been achieved by 2010, the OSPAR Ministerial Meeting in Bergen, Norway (20-24 September 2010), adopted a consolidated version of Recommendation 2003/3 (amended by OSPAR Recommendation 2010/2) including renewed targets (i.e., to continue the establishment of the OSPAR Network of Marine Protected Areas in the North-East Atlantic) and to ensure that:

- by 2012 it is ecologically coherent, includes sites representative of all biogeographic regions in the OSPAR maritime area, and is consistent with the CBD target for effectively conserved marine and coastal ecological regions;

- by 2016 it is well managed (i.e. coherent management measures have been set up and are being implemented for such MPAs that have been designated up to 2010).

The OSPAR (2007) *Guidelines for the Identification and Selection of MPAs in the OSPAR Maritime Area* set out components of the network, individually and collectively, will aim to:

- protect, conserve and restore species, habitats and ecological processes which are adversely affected as a result of human activities;

- prevent degradation of and damage to species, habitats and ecological processes, following the precautionary principle;

- protect and conserve areas that best represent the range of species, habitats and ecological processes in the OSPAR area.

Representation of the range of marine habitats (and ecological processes), as required by aim (c), requires consideration of the characterisation or classification of these features either at the OSPAR-area scale or at the scale being considered by each Contracting Party (e.g., their EEZ). The approaches by which the fifteen Contracting Parties (Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom), together with the European Community, identify areas which best represent the range of features in the OSPAR area may vary, but could include considerations of geographic variation and variation in habitat types. The use of a standard classification system is preferable to ensure consistency of approach between Parties.

> In 2004, OSPAR's Biodiversity Committee agreed (BDC 04/14/1-E) that the EUNIS habitat classification scheme would be a working habitat classification system for characterising the OSPAR maritime area (OSPAR, 2006). It is therefore appropriate that it forms the main system for characterising the marine environment for the purposes of establishing the OSPAR MPA network. The level of classification possible will vary widely across the OSPAR maritime area due to the level of data held by Contracting

> Parties. Where possible, classification of the marine environment to EUNIS Level 3 would be preferable (to reasonably reflect the variation in biological character of the habitats in the OSPAR area), but it is acknowledged that classification only to EUNIS Level 2 is inevitable in some sea areas. Where only Level 2 can be applied, classification of the environment to a higher level of the EUNIS classification could happen progressively over time as Contracting Parties' knowledge of the marine environment increases.

The Guidelines recommend that where biological data are available, these data be used to their fullest extent to select sites that best represent habitats, species and ecological processes. When detailed biological survey data are not available, existing biological data should be used in conjunction with the other approaches, to ensure that biological representativity is likely to be achieved.

UK MARINE CONSERVATION ZONE PROJECT (MCZP)

Based on shared physical and biological characteristics, 12 biogeographic regions in UK waters, referred to as UK Regional Seas, have been identified. The MCZP *Ecological Network Guidance* states: "To be representative an MPA network needs to protect the range of marine biodiversity found in our seas. This can be achieved by grouping species and habitats into broad-scale habitat types and protecting examples of these across the MPA network." The UK considers broad-scale habitats (based on a shared set of ecological requirements) as acting as surrogates for biodiversity at finer scales and capturing the coarse biological and physical diversity of their seabed. "Broad-scale habitats must be biologically meaningful (i.e., represent true differences in marine communities) and use a 'common language' (i.e., a recognized classification scheme)" (Natural England and the Joint Nature Conservation Committee, 2010).

Ecological network guideline #1 states: "Examples of each of 23 broad-scale habitats should be protected within MPAs in each regional MCZP area, where they occur. These 23 broad-scale habitats were taken from Level 3 of the EUNIS habitat types classification scheme and were considered to reasonably reflect the variation in biological character of the marine environment" (Natural England and the Joint Nature Conservation Committee, 2010). For the purposes of network planning, the nine EUNIS Level 3 deep-sea bed habitat types were combined into a single habitat termed 'deep-sea bed', as this habitat is only found in the south-west tip of one regional MCZP area. A further 25 EUNIS Level 3 habitat types were excluded, because some do not occur in UK waters, some are based on water column features that are extremely mobile and are therefore unlikely to directly benefit from spatial protection, and some are not considered broad-scale habitat types.

Experts interviewed in Jones and Carpenter (2009), looking at ecological coherence, agreed that representativity must be the primary consideration, but that it is important to include the larval dispersal potential of rare/scarce invertebrates in MPA network design and the presence of rare/scarce species should be a secondary criterion for selecting amongst replicates of representative habitats.

IRISH SEA PILOT

The purpose of the Irish Sea Pilot (2004) was to help develop a strategy for marine nature conservation that could be applied to all UK waters and, with international collaboration, the adjacent waters of the north-east Atlantic. The Pilot tested the concept of 'Marine Landscapes', based on using geophysical and hydrographical data to identify habitat types in the absence of biological data. Practical criteria were developed to enable the separation of marine landscapes into distinct types. Key among these criteria were: depth, substratum type, bed-stress/current strength, topography/slope and related factors. The Pilot successfully applied this approach to the Irish Sea, identifying and mapping 18 coastal and seabed marine landscape types along with a summary of the distinguishing geophysical and hydrographical characteristics of each. The pilot also identified four water column marine landscape types based on stratification (more or less than 40 days) and salinity (more or less than 34%) (Vincent et al., 2004).

The Irish Sea Pilot concluded that the marine landscape approach should be adopted as a key element for marine nature conservation, and utilised in spatial planning of the marine environment. Further investigation is needed to determine whether, in water areas significantly deeper than 300m, the water column types should be further defined in terms of depth. The Pilot confirms both the practicality and value of identifying coastal and seabed marine landscapes, and considers that this approach will have a major future role in relation to the sustainable development of the marine environment, contributing to the environmental assessment of development proposals, the regulation of marine activity, and the implementation of spatial planning. The value of marine landscapes in the identification of an ecologically-coherent network of important marine areas was also confirmed. The Pilot agreed that the identification of water column marine landscapes is a practical proposition but, in relation to the Irish Sea, was not able to determine how the classification could be translated readily into management action, and noted that this aspect needs further work (Vincent et al., 2004).

HELSINKI COMMISSION (HELCOM)

The Helsinki Commission (HELCOM) is the governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea Area (under the Helsinki Convention). HELCOM member states are: Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. Under the HELCOM Baltic Sea Action Plan (HELCOM, 2007), ecological objectives for nature conservation and biodiversity will be measured by indicators and targets, including: “By 2010 to have an ecologically coherent and well-managed network of Baltic Sea Protected Areas (BSPAs), Natura 2000 areas and Emerald sites in the Baltic Sea”.

In the Baltic Sea, a broad-scale classification system based on the marine landscape concept has been used to evaluate the existing MPA network for representativity and cohesiveness, and to select an efficient and representative network of BSPAs using MARXAN. A suitable network should represent adequate quantities of the entire range of species, habitats and ecological processes in the Baltic marine area and should also ensure sufficient representation in each of the sub-basins where they occur.

In the Baltic continental shelf waters (300m or less) there are three basic types of benthic marine landscapes (Al-Hamdani and Reker, 2007):

- the physiographic marine features of the coast;
- the topographic features of the seabed; and
- the benthic marine landscapes based on physio-chemical characteristics of the seabed.

Pelagic landscapes are not identified.

Mapping topographic and bed-form features of the seabed and coastal physiographic features are only the first steps towards a broad-scale characterisation of the marine environment of the Baltic Sea. A variety of physical and hydrographic parameters were also considered based on their influence on shaping the broad-scale distribution of major species assemblages, enabling an ecologically meaningful characterisation of the marine ecosystem.

The BALANCE project (or Baltic Sea Management – Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning) mapped benthic marine landscapes of the Baltic Sea, based on physio-chemical characteristics of the seabed rather than topographical features, and used this dataset as the main conservation feature for the BALANCE Marxan analyses (Al-Hamdani and Reker, 2007). The benthic marine landscape map for the Baltic Sea was constructed by combining three physical data sets using a GIS platform; the modeled data are based on bottom substrate, photic depth and salinity. These layers were characterised into different classes based on ecological criteria justified by expert judgement. Altogether, 60 benthic marine landscapes were identified in the Baltic Sea, which could be seen as a surrogate for broad-scale variation in the biodiversity of the Baltic Sea region. Some of these benthic habitats are widespread in the region while others cover only very limited areas. In summary, eight of the 60 benthic marine landscapes identified cover the majority of the seabed while 40 benthic habitats cover less than 1% each. The most abundant benthic marine landscapes include non-photic mud, non-photic hard clay, non-photic sand and non-photic hard bottom complexes.

To ensure that the Baltic Sea biodiversity is well represented in the selected protected areas network, as much relevant data as possible were compiled to support the coarse filter features. Data layers used as fine filter features were: charophyte richness; grey seal haul-outs; Important Bird Areas; *Mytilus* densities; and *Zostera* distribution (Leth, 2008).

Each of the 60 marine landscapes is assumed to reflect the broad-scale ecological requirements of the benthic species assemblages that may exist in the specific physical and geological environment defined by the individual landscape. Following a survey aimed at testing whether it is possible to distinguish between the species present within closely related benthic marine landscapes, of this first attempt to map the benthic marine landscapes of the Baltic Sea it appears that even closely related marine landscapes do represent significantly different species assemblages.

GERMANY

In Germany, Marine Natura 2000 sites are mainly selected according to the presence and distribution of specific species of sea birds, marine mammals and fish, and of sandbank and reef habitats of high conservation value and international importance. The species and habitats concerned are listed in the annexes to the EU Birds Directive and Habitats Directive. The aim of designating the sites is to protect these special, threatened habitats and species (DFO and WWF-Canada, 2009).

Annex I to the EU Habitats Directive lists the natural habitat types of “community interest” whose conservation requires the designation of SACs across Europe at a national level. In the German marine regions of the EEZ, two of these habitat types occur and have been protected: reefs and sandbanks (meaning permanently submerged sandbanks that are not exposed at the low water level). According to Article 1(e) of the Habitats Directive, the natural habitats must be maintained at or restored to a favourable conservation status. Simply stated, this means the following:

- The habitat areas and their natural extent have lasted over many years and should remain unaffected by negative human influences, or even be allowed to expand.

- The typical elements (e.g., sediment, salinity, current) of these habitats and specific functions can continue in the long term according to their natural dynamics.

- The typical animal and plant populations of these habitats can survive in the long term or even increase.

Habitats Directive sites are assessed by the European Commission to ensure coherence in the Natura 2000 network. The eight marine protected areas under the Habitats Directive in the German EEZ were adopted by the EU in November 2007. They consequently became SCIs in January 2008. Germany must now place these sites under the protection of national law and complete management plans for them. Germany is the first EU member state to have identified a full network of offshore marine nature protected areas, with ten sites nominated and recognised covering about 31 percent of the German EEZ.

AUSTRALIA'S NATIONAL REPRESENTATIVE SYSTEM OF MARINE PROTECTED AREAS (NRSMPA)

Australia's NRSMPA aims to establish and manage a comprehensive, adequate, and representative system of marine protected areas to contribute to the long-term ecological viability of marine and estuarine systems, to maintain ecological processes and systems, and to protect Australia's biological diversity at all levels. The guidelines for developing the NRSMPA establish Integrated Marine and Coastal Regionalisation of Australia (IMCRA) as the national and regional framework for the NRSMPA.

IMCRA v4.0 is a spatial framework for classifying Australia's marine environment into bioregions that make sense ecologically and are at a scale useful for regional planning. The national network of Commonwealth marine reserves will represent the 41 provincial-scale bioregions recognised in Commonwealth waters (comprising 24 provinces and 17 transitions), as identified by IMCRA v.4.0 (Commonwealth of Australia, 2006).

IMCRA v4.0 has a structure that incorporates information about patterns and processes which occur at different spatial scales. IMCRA v4.0 consists of two separate regionalisations: a benthic bioregionalisation based on biogeography of fish supplemented with a geophysical classification; and a pelagic regionalisation based on oceanographic characteristics of water bodies.

The benthic bioregionalisation incorporates three separate layers of information:

- Provincial bioregions that reflect biogeographic patterns in distributions of bottom-dwelling fish (each province can be characterised by a suite of endemic fish species).

- 60 Meso-scale regions on the continental shelf. The meso-scale regions were defined (IMCRA v3.3) using biological and physical information, including the distribution of demersal fishes, marine plants and invertebrates, sea floor geomorphology and sediments, and oceanographic data (IMCRA Technical Group, 1998).

- Geomorphic units for the whole of the EEZ. These units have been defined by clustering 1,334 separate geomorphic units into 14 categories and mapping areas of similar geomorphology.

The pelagic regionalisation is divided into continental shelf and offshore components:

The continental shelf regionalisation divides the continental shelf into four provincial bioregions based on classification of pelagic fish species diversity and richness (descriptions can be found in the IMCRA v3.3 report). The offshore pelagic regionalisation divides Australia's offshore waters into 25 water masses, defined largely by latitudinal oceanographic processes and three-dimensional in nature (occurring across different latitudes and depths), and adds detail about sea surface circulation patterns and energetics at a regional scale for the 10 water masses that were present on the ocean surface.

To maximise conservation outcomes, four national goals are guiding the identification of areas suitable for inclusion in the NRMSPA and the identification of representative marine reserves in all the marine regions. Additionally, a number of supporting principles are assisting in determining the location, selection (when more than one option to meet the goals is available), design and zoning of suitable areas.

Goal 1 - Each provincial bioregion occurring in the marine region should be represented at least once in the marine reserve network. Priority will be given to provincial bioregions not already represented in the National Representative System.

Goal 2 - The marine reserve network should cover all depth ranges occurring in the region or other gradients in light penetration in waters over the continental shelf.

Goal 3 - The marine reserve network should seek to include examples of benthic/demersal biological features (for example, habitats, communities, sub-regional ecosystems, particularly those with high biodiversity value, species richness and endemism) known to occur in the marine region at a broad sub provincial (greater than hundreds of kilometres) scale.

Goal 4 - The marine reserve network should include all types of seafloor features. There are 21 seafloor types across the entire Exclusive Economic Zone. Some provincial bioregions will be characterised by the presence of a certain subset of features, such as continental slope or seamounts.

The Peer Review Panel supported the use of geomorphic datasets as province-wide surrogates for broad-scale ecosystems and habitats. However, geomorphic datasets should be refined or interpreted at finer scales with ecological datasets that may be available, including ecological and oceanographic data that may apply to only parts of the Province, or to broader-scale processes that may affect the Province. Where such data on the actual biodiversity (as opposed to the high level geomorphic surrogates) is limited, modelled biological attributes may be required (such as the modeled distribution of fish populations) to provide province-wide data useful for MPA selection (Scientific Peer Review Panel for the National Representative System of Marine Protected Areas, 2006).

NEW ZEALAND

To address the objectives and actions of the New Zealand Biodiversity Strategy (NZBS), the objective of the MPA Policy is to:

> Protect marine biodiversity by establishing a network of MPAs that is comprehensive and representative of New Zealand's marine habitats and ecosystems (Government of New Zealand, 2005).

The MPA Policy covers New Zealand's entire marine environment including internal waters, the territorial sea (coastline to 12 nautical miles) and the exclusive economic zone (12 to 200 nautical miles). One of the key components of the MPA Policy is a consistent approach to classification of the marine habitats and ecosystems, which will help to ensure the MPA network is representative. This consistent approach to classification will be applied to the marine environment as part of the MPA planning process.

The MPA Policy states that the process to establish New Zealand's protected area network will differ in coastal and deepwater environments. This decision was made for three main reasons: (i) the different composition of stakeholders for coastal and deepwater areas; (ii) the nature of the information available to guide the implementation process; and (iii) the regulatory tools available for establishing protected areas. For the purpose of implementing the network of protected areas, the coastal/deepwater boundary will be the limit of the Territorial Sea (12 nautical miles). It was decided to develop a separate coastal and deepwater approach to marine classification for marine protected area planning. See Appendix A for a description of New Zealand's "coastal" classification system.

In deepwater marine environments, the scale and nature of the information available necessitates a different approach to classification compared to the coastal environment. Implementation of the classification in deep water will be guided by the following spatial scales:

- Broad scale variation at the meso-scale (100s to 1000s of kilometres); and
- Habitats and ecosystems at the local-scale (10s to 100s of kilometres).

The Marine Environment Classification (MEC) uses predominantly physical variables (depth, Sea Surface Temperature (SST) winter, solar radiation mean, SST amplitude, SST gradient, mean orbital velocity, tidal current, slope) to create proxies for marine environments and groups them into broadly similar areas, called "environment classes" (Snelder et al., 2005). The marine environments can be mapped to different levels of detail, ranging from two to more than 70 groups. While the MEC currently does not predict the biota that is present in a specific area, the pattern of physical variables provides an indication of possible broad-scale environment types that are likely to influence the biota associated with a particular environmental class. Areas within the same environmental class are assumed to have more in common with each other than with areas falling into other classes.

It is generally accepted that the MEC is a primary tool for classification in the deepwater marine environment, although it is not ideal for defining protected areas; rather, it identifies general areas that may warrant further investigation. The "20 class" level of the MEC is considered to provide a useful surrogate for ecological (biological and environmental) variation. However, given that MEC represents environmental variation only at a broad scale, it is proposed that additional information be represented within each MEC class to capture further variation at the habitat and ecosystem level. Within each MEC class, it is desirable that protected areas represent the variation in substrate that is known to have a significant influence on the associated biota at a variety of different depths. A hierarchical classification scheme, which aims to identify habitat and ecosystem variability in the pelagic and benthic environments within the MEC at the 20 class level, can be found in New Zealand Ministry of Fisheries and Department of Conservation (2008).

Recent government decisions to close large areas of New Zealand's EEZ to bottom trawling and dredging have shifted the emphasis on protected area implementation to focus on the New Zealand Territorial Sea (12 nautical miles) until 2013. Implementing the MPA Policy in the EEZ will not commence until 2013, but in the interim, further preparatory work on marine classification in the deep water will continue. This work will further refine the current MEC and lead to a more comprehensive classification of deepwater marine habitats and ecosystems.

CONVENTION ON THE CONSERVATION OF ANTARCTIC MARINE LIVING RESOURCES (CCAMLR)

Article II establishes the basic objective of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) as the conservation of Antarctic marine living resources (where conservation includes rational use) and sets out the principles by which harvesting and associated activities shall be carried out. CCAMLR is establishing a scientific basis for the future development of a representative network of MPAs in the Southern Ocean.

The 2005 CCAMLR workshop on MPAs considered the scientific work needed for considering a system of protected areas to assist CCAMLR in achieving its broader conservation objectives (SC-CAMLR-XXIV/Annex 7. 2005). The key tasks in this process (not necessarily undertaken sequentially) include:

- a broad-scale bioregionalisation of the Southern Ocean;
- a fine-scale subdivision of biogeographic provinces, which may include hierarchies of spatial characteristics and features within regions, giving particular attention to areas identified in the bioregionalisation;
- identification of areas that might be used to achieve the conservation objectives identified in paragraph;
- determination of areas requiring interim protection.

A 2007 CCAMLR Scientific Committee workshop was held to advise on a bioregionalisation of the Southern Ocean, including, where possible, advice on fine-scale subdivision of biogeographic provinces (SC-CAMLR-XXVI/11, 2007). It was agreed that the benthic and pelagic systems should be considered separately, since current knowledge of benthic-pelagic coupling is not sufficient to produce a combined benthic-pelagic bioregionalisation at this stage. The workshop considered available bathymetric, physical oceanographic and biological data for the pelagic bioregionalisation. The workshop also considered which datasets would be most useful for a benthic bioregionalisation, the robustness and quality of these datasets, and use of other datasets that could potentially be useful. It was agreed that bathymetric data, sea-floor temperature and current data, geomorphology data, sediment data and sea-ice concentration data are all important.

The workshop recommended a hierarchical, two-level approach to bioregionalisation of the pelagic domain:

1. broad-scale circumpolar bioregionalisation, which provides delineation of approximately 20 regions;
2. fine-scale bioregionalisation of each broad-scale region.

The three-step approach to benthic bioregionalisation began with the identification of physical regions, then biological data were overlaid, and finally the classification evaluated. A benthic bioregional classification was undertaken with physical data that were considered robust and to have a strong relationship with the distribution of species. All datasets used for the broad-scale classification covered the entire Southern Ocean. The datasets used for the initial broad classification were: bathymetry; slope; sea-floor temperature; sea-floor sediment types.

Biological datasets used for validation of the benthic bioregional classification included eight taxonomic groups, 33000 records, 7600 stations and 3000 taxa (species). The data were selected for their robustness, for their quantitative nature and for their good spatial coverage. Combined, these data provided circumpolar coverage, although this was not the case for every individual dataset. The datasets included in the analysis were: Antarctic Echinoids; SOMBASE; Southern Ocean Sea Stars Biogeography; Ant'phipoda (a database of amphipods); FishBase (benthic fish); Hexacorallia; ZIN Brittlestars; CCAMLR scientific survey and commercial finfish database.

The workshop endorsed the broad-scale 'primary' [pelagic] regionalisation produced by an Experts Workshop on Bioregionalisation of the Southern Ocean held in Hobart, Australia, in September 2006. This bioregionalisation used clustering based on four environmental variables (log10 depth, SST, silicate concentration, nitrate concentration). The workshop re-displayed the 'secondary' classification, including chl-*a* and ice, with 20 groups.

The workshop was also satisfied that the benthic methods were consistent with the 2006 Hobart Workshop, and that they could be used as a basis for an initial benthic physical classification. In particular, inclusion of the sediment data will likely improve the bioregionalisation due to the relationship between sediment type and biota. The workshop noted that the degree of heterogeneity that would arise when the sediment data are included would likely be greatest in the continental slope and nearshore zones. It also noted that increasing the number of classes above 20 would result in greater diversity of physical habitats, particularly in the coastal region.

Whilst ecological process information should be used at the circumpolar scale considered at this workshop, it was noted that these data will become more important at a finer-scale regional level. This is because many process datasets are regional in scale (e.g., tracking data for top predators) and expert knowledge of spatially defined ecosystem processes can be more easily incorporated at a regional scale. It therefore follows that the best areas to further develop fine-scale bioregionalisation are most likely those geographical areas where most information and expert knowledge exists. Future work could include efforts to delineate fine-scale provinces, where possible. Inclusion of process and species information could be considered further, particularly in the context of systematic conservation planning, and in developing a spatial decision-making framework; this may be particularly applicable at finer scales.

SOUTH AFRICA'S NATIONAL SPATIAL BIODIVERSITY ASSESSMENT

The identification and implementation of an offshore MPA network was identified as a priority action by South Africa's National Spatial Biodiversity Assessment (Lombard et al., 2004) and is reiterated in South Africa's National Protected Area Expansion Strategy. Guidelines for the development of an ecologically representative network of effectively managed MPAs that include all marine habitat types in all bioregions of South Africa offshore were published by Sink and Attwood (2008). The planning area for the Offshore MPA project extends from the 30 m depth contour out to the 200 nautical mile boundary of the South African EEZ, using the same boundaries as the National Spatial Biodiversity Assessment.

A 2011 national marine and coastal habitat classification incorporates several key drivers of marine biodiversity patterns: terrestrial and benthic-pelagic connectivity, substrate, depth and slope, geology, grain size, wave exposure and biogeography. The national classification revises the bioregions and biozones used in the 2004 National Spatial Biodiversity Assessment to include six ecoregions and 22 finer scale ecozones that nest within these ecoregions. Each ecozone is considered to have distinct species assemblages that need to be considered in biodiversity assessments and in planning for a representative MPA network. The 2011 classification presents and maps a total of 136 habitat types, including: 37 coast types, 17 inshore (5-30 m) habitat types, 3 island-associated types, 1 lagoon, and 52 offshore (deeper than 30 m) benthic habitat types, plus 16 offshore pelagic habitat types. Offshore, benthic and pelagic habitat types were considered and assessed separately as these types of habitats show different responses to different types of pressures, and separate management of benthic and pelagic habitats is feasible in water deeper than 30m (Sink and Holness, 2011).

A separate classification undertaken to define the 16 offshore pelagic habitat types was based on differences in sea surface temperature, productivity, chlorophyll, depth and the frequency of eddies, temperature fronts and chlorophyll fronts. The aim of the South African pelagic bioregionalisation project was to map and describe the pelagic habitats of South Africa's EEZ. The intended outcome was a set of pelagic bioregions, biozones and habitats for the EEZ that will underpin a spatial framework to support conservation planning and management. The framework presented by Lagabrielle (2009) is a synthesis of the approaches developed by Grant et al. (2006), Lyne and Hayes (2005) and Post (2008).

The pelagic bioregionalisation of the South African EEZ involved the following steps (adapted from Grant et al., 2006):

1. Identification of the key ecological patterns and processes, and the major environmental drivers or properties that produce these patterns and processes;
2. Identification of the relevant parameters describing these drivers and properties;
3. Collection of relevant data sets and pre-processing of the data (e.g. normalise, transform, smooth, resample, clip, etc.);
4. Application of clustering procedures to group sites with similar properties; and
5. Validation with regional experts (still to be undertaken).

Key ecosystem properties and relevant parameters and variables that best reflect these properties were identified – steps #1 & 2 above (see Table 1).

Table 1. Ecosystems properties, variables and parameters identified for the classification of pelagic bioregions, biozones and "habitats". The following acronyms are used to name the parameters: sea surface temperature (SST), chlorophyll-a (CHLO), net primary productivity (NPP), and turbidity (K490). CV represents the coefficient of variation (from Lagabrielle, 2009).

Ecosystem properties, variables and parameters	**Parameter**
Level 1 – Broad scale oceanic patterns and circulation regimes	
The distribution of pelagic communities is globally driven by the physical structure of the ocean i.e., broad scale bathymetry reflecting continental shelves and ocean basins. Then, latitude and global circulation patterns are key drivers of pelagic biodiversity pattern. The key variables at this scale are therefore depth and mean sea surface temperature and chlorophyll. The net primary productivity, partially linked to the previous two variables, also affects the distribution of biota at this scale.	SST Mean SST Max CHLO Mean NPP Mean Depth
Level 2 – Mesoscale: variability of broader oceanic patterns and circulation regimes	
The distribution of marine biota is driven by permanent or semi-permanent mesoscale variations. The variables driving this variability include changes in the distribution of broad scale structure and circulation patterns, caused by mesoscale features such as upwelling and eddies. This variability can be detected by deriving a coefficient of variation for SST, CHLO and NPP time series. Eddies are detected using sea surface height anomalies.	SST CV CHLO CV NPP CV Eddy distribution
Level 3 – Fine scale oceanic processes	
This level describes the fine-scale variability that may determine the distribution of biota. These variations are associated with the occurrence of SST and chlorophyll fronts (often induced by currents, plumes or eddies).	SST fronts CHLO fronts

The final pelagic bioregions map contained 29 clusters that can be nested into four pelagic bioregions, nine pelagic biozones and 24 pelagic "habitats". Only 20 clusters occur in the South African EEZ, with three pelagic bioregions, seven biozones and 16 pelagic "habitats" recognised within the EEZ.

CALIFORNIA MARINE LIFE PROTECTION ACT AND MPA NETWORKS

One of the goals of California's *Marine Life Protection Act* is to protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value (section 2853). According to the *Act* (section 2857), the preferred siting alternative shall include MPA networks with an improved marine life reserve component, and shall be designed according to the following guideline: Marine life reserves in each bioregion shall encompass a representative variety of marine habitat types and communities, across a range of depths and environmental conditions (California Department of Fish and Game, 2008).

The MLPA requires that representative habitats be included, to the extent possible, in more than one state marine reserve in each biogeographical region. California's coastline spans two of these large-scale biogeographic provinces – the Oregonian and the Californian Provinces – with a boundary in the vicinity of Point Conception. This prominent biogeographical boundary has been recognized for more than half a century; however, on the basis of the distribution of species' borders for key coastal species groups, there are three biogeographical regional boundaries and four regions along the California coast. Summaries of species abundance and diversity data, especially for shallow water species (<30 m depth), suggest that there are four points of transition along the California coastline that demarcate distinct marine assemblages: Point Conception, Monterey Bay, San Francisco Bay, and Cape Mendocino. Three of these locations are identical to those defined above solely on the basis of species' borders for prominent groups. The new boundary that emerges from abundance and biodiversity data is San Francisco Bay. A task force recommended that the Commission adopt the two biogeographic provinces as the biogeographical regions for purposes of implementing the MLPA, but that the more refined information on other breaks be used in designating study regions and in designing networks of MPAs. The five study regions are: the north coast region, the north central coast region, the San Francisco Bay region, the central coast region, and the south coast region. Task force recommendations are described below (California Department of Fish and Game, 2008).

The strong association of most demersal marine species with particular habitat types (e.g., sea grass beds, submarine canyons, shallow and deep rock reefs), and variation in species composition across latitudinal, depth clines, and biogeographical regions, implies that habitat types must be represented across each of these larger environmental gradients to capture the breadth of biodiversity in California's waters. The science team identifies five depth zones which reflect changes in species composition: intertidal, intertidal to 30 meters, 30 meters to 100 meters, 100 meters to 200 meters, and deeper than 200 meters(California Department of Fish and Game, 2008) .

The habitats defined in the MLPA implicitly focus on open coast ecosystems and ignore the critical influence of estuaries. Given their critical ecological roles and ecosystem functions, estuaries warrant special delineation as a critical California coastal habitat. Three of the habitats defined in the MLPA – rocky reefs, intertidal zones, and kelp forests – are generic habitat descriptions (broad categories) that include several distinct habitats that warrant specific consideration and protection. In the case of rocky reefs and intertidal zones, the type of rock that forms the reef greatly influences the species using the habitat. For example, granitic versus sedimentary rock reefs harbour substantially different ecological assemblages and should not be treated as a single habitat. Similarly, the term kelp forest is a generic term that subsumes two distinct ecological assemblages dominated by different species of kelp. These two types of kelp forests harbour distinct assemblages and should be treated as separate habitats (California Department of Fish and Game, 2008).

Finally, the science team recommends expanding the habitat definitions to include ocean circulation features, principally upwelling centers, freshwater plumes from rivers, and larval retention areas – "defining habitats for the MLPA and MPA networks must include habitats defined by coastal oceanography as well as the composition of the seafloor" (California Department of Fish and Game, 2008). Although a wide range of oceanographic habitats could be defined for the California coastline, the science team suggests that three prominent habitats stand out because of their demonstrated importance to different suites of coastal species: upwelling centers; freshwater plumes; retention areas. It is not recommended that such features (some of which are of very large scale) be isolated as habitats to be designated as MPAs or specifically encompassed within MPAs. However, MPAs could be designated that included or benefited from the presence or proximity of such features and processes.

There are often multiple habitat types within a relatively small area, and these are often incorporated into proposed MPAs. The science team distinguished these habitat types using the highest resolution bathymetry data available, when calculating percent of each habitat within proposed MPAs. For the purposes of linking habitats within a network or network component, each MPA was characterized by the habitats that it includes in an ecologically meaningful amount. For the purpose of evaluating whether habitats are adequately represented within individual MPAs, the following factors must be considered: the relative amount of that habitat in the entire region, the overall size of the MPA, and the home range of species that rely upon that habitat that are likely to benefit from protection in an MPA.

SUMMARY AND FINAL CONSIDERATIONS

In addition to the accompanying detailed summary spreadsheet, Table 2 provides a quick snap-shot summary of the most common environmental parameters, variables and marine features used by the various international examples examined in this paper.

Table 2. Most common environmental parameters, variables and marine features used by jurisdictions in their characterisation of marine seascapes.

	Depth/ Photic Zone	**Sediment/ Substratum**	**Energy/ Current/ Circulation**	**Topography/ Slope**	**Seabed features/ geomorphology/ Bathymetry**	**Sea Surface Temperature**	**Chlorophyll**
EUNIS (Level 3)	X	X	X				
Irish Sea	X	X	X	X			
HELCOM (benthic only)	X	X					
Australia	X	X	X		X		
New Zealand	X			X		X	
CCAMLR	X	X		X	X	X	X
South Africa (pelagic)	X		X			X	X
South Africa (benthic)	X	X	X	X	X		

Other parameters, variables and features used by jurisdictions included:

- Salinity (Irish Sea; HELCOM)
- Stratification (Irish Sea);
- Distribution of bottom dwelling fish (Australia – benthic);
- Distribution of demersal fish, marine plants and invertebrates (Australia – benthic);
- Pelagic fish species diversity and richness (Australia – pelagic);
- Oceanographic processes/water masses (Australia – pelagic);
- Benthic/demersal biological features (Australia);
- Mean annual solar radiation (New Zealand);
- Amplitude of sea surface temperature (New Zealand);
- Spatial gradient of annual mean sea surface temperature (New Zealand);
- Orbital velocity at the bed for the mean significant wave height (New Zealand);
- Sea floor temperature (CCAMLR);
- Silicate concentration (CCAMLR);
- Nitrate concentration (CCAMLR);
- Ice (CCAMLR);
- Terrestrial and benthic-pelagic connectivity (South Africa); and
- Biogeography (South Africa).

Roff and Zacharias (2011) propose a set of guiding principles for the classification of marine habitats or “marine representative units” and the following five important considerations for the development of a generalized habitat classifications scheme:

1) The potential set of factors that can be used to discriminate among habitat types must be determined by what can be mapped from available data and what can be readily obtained by remote or in situ sensing;

2) There may be some redundancy between factors or they may need to be computed in different ways; thus, some combinations of factors may be used as surrogates for others;

3) The actual set of factors chosen for a classification hierarchy within any region will depend upon the natural range of variation in each one; some factors may not be applicable within a particular region because they show little variation;

4) The sequence in which factors enter a hierarchy should depend upon which has the greatest ability to discriminate among habitat types; and

5) The number of levels in a hierarchical classification depends on data availability, its spatial resolution and spatial coverage and statistical considerations.

There is broad consensus that where possible, maps of enduring and recurrent geophysical factors for depicting representative areas should be calibrated by biological sampling at the appropriate scale and locations, in order to validate or adjust ecological boundaries. The number of representations considered to be adequate depends on the entire target area and the aim of protection. Finally, as noted in DFO (2010), once representative MPAs are located; a review at a finer scale of habitat patchiness should be applied. This review should seek individually significant areas, distinctive habitats, or communities not yet represented within the “representative” MPAs, and ensure that they are captured appropriately in the network being developed.

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APPENDIX A: NEW ZEALAND'S COASTAL CLASSIFICATION

Implementation of the classification in the coastal area will be guided by the following spatial scales:

- Biogeographic regions defined at the meso-scale (100s to 1000s of kilometres); and
- Habitats and ecosystems defined at the micro-scale (100s to 1000s of metres).

The coastal classification system consists of a hierarchy of five layers which categorise the physical environment.

- The first layer of the classification is the biogeographic region. 14 biogeographic regions have been identified in the classification. This approach assumes that physical habitats and ecosystems, if separated by enough space (100s to 1000s of kms), will contain different biological communities due to a combination of broad-scale factors. Such factors may include water temperature, oceanography, current dynamics, large-scale latitudinal gradients, climate or barriers to dispersal.
- The second layer of the classification is the environment: estuarine and marine. This recognises that there are fundamental differences in biology associated with estuarine and marine environments. Nested within the 14 biogeographic regions, the hierarchical classification scheme is divided into two major environment types:
    - **Estuarine environments** are large coastal water regions that have geographic continuity, are bounded landward by a stretch of coastline with fresh-water input, and are bounded seaward by a salinity front
    - **Marine environments** include the saline waters of the open sea, the seabed and water column of open sea coasts
- The third, fourth and fifth layers of the classification are depth, exposure and substrate type. These three factors are thought to most strongly influence a site's biology. Within each biogeographic region and environment type, combinations of depth, exposure and substrate type will represent habitats to be protected. These three key physical variables that influence coastal biodiversity will be used to identify habitat and ecosystems within each coastal biogeographic region.
    - **Depth:** There are three depth categories (intertidal, shallow subtidal to 30 metres, and deeper subtidal – between the 30 and 200 metre depth contours). This broadly reflects the role of light and physical disturbance in the coastal marine environment.
    - **Substrate:** There are eight substrate categories (mud, sand, gravel, cobble, boulders, bedrock, biogenic structures and artificial). These have been defined based on their role in structuring ecological communities. The 'artificial' category has been included to aid mapping for the purpose of protected area planning. Substrates are more fully explained in the Glossary.
    - **Exposure:** There are three exposure categories (low, medium and high). These have been defined based on their role in structuring intertidal and shallow subtidal communities.
- This means that <u>within each of 14 coastal biogeographic regions, there are 44 potential habitats that should be protected</u>; however, not all of these will be present in every biogeographic region.