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Policy relevance of biogeographic classification for conservation and management of marine biodiversity beyond national jurisdiction, and the GOODS biogeographic classification

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ABSTRACT

This article 1) examines the policy context that created a demand for biogeographic information, 2) describes early national and regional experiences in applying biogeographic classifications, 3) extracts lessons about their usefulness, 4) introduces a broad-scale biogeographic classification for the open ocean and deep seabed called the Global Open Ocean and Deep Seabed (GOODS) biogeographic classification and explains its relevance in this policy context. In so doing it highlights potential uses of biogeographic classifications for the open ocean and deep seabed: these include ecosystem-based management approaches, marine spatial planning and identification of representative networks of MPAs. It also discusses approaches for dealing with problems of uncertainty and connectivity. The article concludes with recommendations for the further development of the GOODS and finer-scale biogeographic classifications.

1. Introduction

1.1. Background

Recent discussions amongst international policy and management bodies have underscored the need to improve the scientific and technical basis for managing human activities in marine areas beyond the limits of national jurisdiction. Though remote and poorly understood, these areas are under mounting pressure from overfishing, habitat degradation, pollution, climate change, ocean acidification, and other pressures (Halpern et al., 2008). This has resulted in calls for integrated, proactive and ecosystem-based approaches to their management(MA, 2005; Nellemann et al., 2008). One of the fundamental requirements for such management is the delineation of ecologically meaningful regions and units(Vierros et al., 2006; Roff and Evans, 2002; Gilliland and Laffoley, 2008). Since the beginnings of biogeography as a discipline, scientists have used a process known as biogeographic classification to support analyses of patterns in biodiversity and the understanding of evolutionary and ecosystem processes, even for areas where knowledge is incomplete. Now this process is also being applied in conservation of marine biodiversity and is emerging as useful for a variety of related management purposes.

1.2. What is a biogeographic classification?

Biogeographic classification is a method that uses biological and physical data to partition ecological units at a chosen scale (UNEP-WCMC, 2006). It identifies broad patterns of co-occurrence of species, habitats and ecosystem processes (Spalding et al., 2007).

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Marine biogeographic classifications have been based on either biological information (e.g., known distribution of certain species) or edaphic environmental variables (such as bathymetry, water masses and currents, substrate, nutrients, and oxygen levels), or a combination of both indicating groups of plants and animals, and physical features and processes that are relatively distinct or different from adjacent areas.

Biogeographic classifications have been developed and used at a range of scales from broad-scale ecological provinces, such as the GOODS classification (see 1.3), to finer-scale classifications, often based predominantly on geomorphic units, such as the “seascapes” approach (Heap et al., 2009; Harris and Whiteway, 2009). Having classifications at different scales represents an essential element for allowing the development of management-related uses to be developed at scales that are both ecologically meaningful and appropriate to the management needs. This is particularly important in setting priorities for coordinated sectoral or cross-sectoral planning and integrated management activities. Classification units may be hierarchical (i.e. smaller units are ‘nested’ within larger ones). This feature can complement many policy and management initiatives which also have hierarchical aspects; as often strategic goals are set at national or regional scales but implementation takes place at more local scales.

1.3. What is the GOODS biogeographic classification?

The recently published Global Open Ocean and Deep Seabed (GOODS) biogeographic classification (UNESCO, 2009) divides the ocean beyond the continental shelf into biogeographic provinces based on both environmental variables and biological information. The ocean is first stratified into benthic and pelagic zones. The pelagic zone is divided into 30 biogeographic provinces, largely on the basis of properties of water masses and currents. The benthic zone is divided into 37 biogeographic provinces distributed in three large depth zones: 14 bathyal (between 300 and 3500 m in depth), 13 abyssal (3500–6500 m) and 10 hadal (>6500 m). In addition, 10 hydrothermal vent provinces have been delineated, for a total of 77 large-scale biogeographic provinces. The classification includes simplifications, particularly in presenting a static “snapshot” that does not address inter-annual or intra-annual variation, and in not resolving the biologically important coupling of benthic and pelagic systems. Nonetheless, it provides a reasonable basis for advancing management based on best available science.

The GOODS biogeographic classification was initiated at an expert workshop held in Mexico City, Mexico, in January 2007. That workshop reviewed the biogeographic classifications proposed previously for the high seas, such as Large Marine Ecosystems (Sherman and Alexander, 1989), and Longhurst’s productivity regimes (Longhurst, 2001), as well as recent developments in biogeographic classifications for coastal waters(Gilliland and Laffoley, 2008) and new information sources on marine biodiversity (Snelgrove, 2010; O’Dor et al., 2009). That workshop commenced a synthesis of these foundations that has subsequently evolved with input from many experts in science, policy, and management, including meetings of the Convention on Biological Diversity (CBD) and the UN *Ad Hoc* Open-ended Informal Working Group to study issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction (referred to subsequently as “the UN Working Group”). Primary papers summarizing the structure and scientific bases of the pelagic and benthic classifications have been prepared and will appear with or soon after this paper (Spalding et al., submitted for publication; Watling et al, submitted for publication).

1.4. Aims of this article

This article has two aims: 1) to highlight the policy relevance of biogeographic classifications for the conservation and sustainable management of marine biodiversity beyond national jurisdiction; and 2) to explore avenues for their future use and development. It reviews the role of biogeographic classifications in major marine policy initiatives currently under development, summarizes the international policy context that created a demand for biogeographic knowledge for the open ocean and deep seabed, and describes five case studies on the expanding use of marine biogeographic classifications on regional and national scales. It then outlines some possible future developments and applications of the GOODS classification, focusing on how the classification could inform upcoming discussions at the CBD and the UN.

2. Results: policy and management uses of biogeographic classification

2.1. Potential uses of biogeographic classifications

By defining units where conditions and species are more alike than others, a biogeographic classification can be useful to identify management units for a variety of purposes and at a range of scales (Thackway and Cresswell, 1995). Different uses include:

1. Units that provide a framework for assessing status, trends and threats at the scales of specific regions or sub-regions. Examples of specific uses include:
   a) **Monitoring and state of the environment reporting**, based on biogeographic units with similar characteristics.
   b) **Assessing the risk of species extirpations, non-native species introductions**, etc, in areas with similar habitats or species.
2. Units for ecosystem-based **management of human activities** where the units can be expected to respond in more coherent and consistent ways to management actions than if the actions were applied across boundaries of the units. Examples of specific uses include:
   a. **Planning for management** – either for sector specific activities, such as fisheries and biodiversity conservation, or cross-sectoral management. In either case, biogeographic units can be used as a basis for integrating scientific and socio-economic information on human uses, potential threats, policies and legislation.
   b. **Fisheries conservation and management measures**, including stock assessments, catch monitoring and biodiversity conservation, as the biogeographic units are likely to contain relatively discrete populations of exploited or bycatch species.
   c. **Impact and threat assessments** for assessing risks and predicting potential impacts of specific activities and uses of the marine environment at meaningful spatial scales.
   d. **Identifying potentially vulnerable marine ecosystems (VMEs)** through organizing biogeographic information into units that allow evaluation of rarity, functional significance, and other indicators of a VME.
   e. **Building and assessing representative marine protected area networks** through identification of priority components (in combination with other criteria) for a given representative unit, and assessment of gaps.
3. Units that can be used as a basis for research, forecasting and proactive management, including possible ecosystem responses to climate change. Examples include:

a. **Prediction of areas** where habitats or species, including ones indicative of VMEs, are likely to occur or to shift, to direct further research, management planning, and identification of VMEs in information-poor areas.
b. **Broad-scale ecological modeling** to enhance understanding of ecosystem structure, functions and processes and predict responses to cumulative stresses as well as chronic impacts such as climate change and ocean acidification.
c. **Planning and directing future research** in poorly-understood areas.

2.2. Policy roles for biogeographic classifications

Over the past two decades a number of international, regional and national policy developments have given increasing prominence to spatial aspects of management, including the ecosystem approach, integrated management, marine spatial planning and the establishment of representative networks of marine protected areas. Correspondingly, biogeographic information has contributed to this policy-making in multiple ways, including underpinning policy goals related to greater protection of biodiversity and more sustainable uses of marine resources beyond national jurisdiction (CBD Cop Decision Vii/5, para 54). Future challenges, such as climate change, will necessarily give even more prominence to biogeographic information in planning and management.

These initiatives in policy and management require not just biogeographic information, but also robust biogeographic classifications based on that information.

2.2.1. The ecosystem approach

The ecosystem approach applies established ecosystem concepts (Odum, 1953; Golley, 1993) in policy and management. It highlights the connectivity among species, their habitats and physical environment, as well as the connection between humans and their environment. It has been adopted within a wide range of policy instruments internationally, regionally and nationally, including by the WSSD (UNEP, 2002), the CBD (Convention on Biological Diversity) and FAO (FAO, 2002; FAO, 2003). Although many countries have taken action to implement the ecosystem approach within their national waters, its implementation is in early stages, particularly in marine areas beyond the limits of national jurisdiction, and is a priority for the near future.

In the implementation of the ecosystem approach, biogeographic classifications are necessary to delineate appropriate management boundaries, units and scales through identifying areas with similar biological and physical characteristics. Broad-scale classifications, such as that provided by GOODS, can assist in determining management units that would respond to management actions in more coherent and consistent ways than would units that cross biogeographic boundaries. This expectation is reasonable both because within an ecologically meaningful biogeographic unit most species should be responding to the same dominant environmental drivers(Hollowed et al., 2001; PICES, 2004; Stenseth et al., 2005; Visbeck et al., 2001) and because predator-prey and competitive linkages should be stronger within such units(Link, 2002; Cury et al., 2005). Consequently management measures intended to protect linkages among species and/or accommodate the effects of environmental drivers should be most effective when applied at the scales of the linkages and/or drivers (Waltner-Toews et al., 2008).

Additionally, biogeographic classifications can provide information about the relationship between human uses and ecosystem characteristics that may influence the success of management measures. For example, fisheries management measures can more readily incorporate the effects of major environmental drivers affecting the dynamics of exploited fish stocks, if management is applied within broad-scale biogeographic units reflecting those drivers. Finer biogeographic units, (for example, at the scale of dominant fish stocks) may be appropriate for management measures intended to accommodate interactions among species, such as the requirements of seabirds that feed on a harvested species.

2.2.2. Integrated management

Integrated marine management is a process in which interested parties, stakeholders and regulators reach general agreement on a desirable mix of conservation, sustainable resource use and economic development objectives for coastal and marine areas. (http://www.dfo-mpo.gc.ca/oceans-habitat/infocentre/archives/iczm-gizc/index_e.asp) Measures that are expected to achieve the agreed objectives are then identified and applied. Integrated ocean management requires the participation of many parties: usually multiple levels of government and both commercial and non-commercial interests (UNU-AIS, 2005). Some countries began undertaking integrated coastal area management over 35 years ago (Sorensen, 2002), but integrated management has not yet been widely applied in deep and open ocean areas beyond national jurisdiction.

The spatial scale(s) for integration of sectoral management is an important consideration. Scale is affected by the number and level of political jurisdictions involved. However, for integrated management measures to achieve their common goals, their design and application should also take account of ecological units which respond in coherent ways to management actions. Integrated management often applies adaptive management methods, particularly when management faces complex trade-offs or high uncertainty about potential outcomes. Adaptive management requires feedback on progress towards agreed objectives and application of structured decision-rules to adapt management interventions when assessments indicate that progress is not satisfactory.

Sound biogeographic classifications are useful because they provide guidance on ecologically appropriate units for integrated management. Agreed objectives may not be achieved if the management measures are being applied to spatial units that reflect dominant ecological processes poorly. Likewise adaptive management strategies might fail if the feedback monitoring and assessment, or decision rules are poorly matched to coherent responses of the ecosystems to the management action (McDonald et al., 2008).

2.2.3. Marine spatial planning

Marine spatial planning is an explicit planning approach within ‘an integrated, policy-based approach to the regulation, management and protection of the ecosystem, including the allocation of space, that addresses the multiple, cumulative and potentially conflicting uses of the sea and land and thereby facilitates sustainable development’ (MSSP, 2006). The overall aim of spatial planning is to ‘…create and establish a more rational organization of the use of space and the interactions between its uses, to balance demands for development with the need to protect the environment, and to achieve social and economic objectives in an open and planned way (DEFRA, 2006)’. This approach has been successfully used in the marine coastal areas of many countries around the world and by regional organizations, such as HELCOM in the Baltic Sea (Pickaver, 2003; http://www.helcom.fi/environment2/biodiv/en_GB/MSP/) and could provide a practical way forward in deep and open ocean areas.

Implementation of marine spatial planning augments the spatial biogeographic information used in establishing a biogeographic classification with mapping of the spatial and temporal extent of human uses to identify conflicts and synergies. These maps form the basis for spatial planning and decision-making on proposals for marine development, resource exploitation, and investment projects. They also can inform management about appropriate scales of interventions and protection of valued environments on multiple time scales. These uses require not simply that human activities and distributions of species are mapped together, but also that units are identified which reflect both patterns of human activity and coherent ecosystem responses. Hence biogeographic classifications are an important component of marine spatial planning.

2.2.4. Implementation of representative networks of MPAs in the world's oceans

MPAs are widely considered to be one of the essential tools and approaches for conservation and sustainable use of biodiversity, and an important component of an ecosystem approach to marine management (Ehler and Douvere, 2003). Approximately 0.79% of the oceans and 6% of territorial seas are protected in some form of marine protected area, reflecting very slow progress towards the 2012 target agreed at the WSSD, UNGA and CBD. These protected areas cover only a small proportion of the ranges of all marine habitats and are heavily biased towards the continental shelf and associated coastal ecosystems.

The CBD has adopted guidance for designing a network of MPAs for the open ocean and deep sea(CBD Decision IX/20, 2008); paragraph 14 and Annexes 1,2 & 3). In addition to criteria for identifying ecologically and biologically significant areas which require enhanced protection, "representativity" is listed as a criterion at the network scale. A network of protected areas is understood to be *representative* when it incorporates the range of known habitats, associated biodiversity, and ecological processes, both at the scale of coarser biogeographic units, and at the finer scale within those units [(Heap et al., 2007); see also (Stevens, 2002)].

Biogeographic classifications are necessary to identify the units which should be "represented" in the network. To date it has been difficult to undertake strategic action towards the development of representative networks in deep and open ocean areas due to our incomplete knowledge about how and where species and their habitats are distributed geographically. A biogeographic classification, such as GOODS, is the first step in providing some differentiation of the spatial distribution of habitats and the species within them.

As guidance on the implementation of the CBD criteria and guidance, the CBD COP IX took note of four initial steps to be considered in the development of representative networks of marine protected areas. The development of a biogeographic classification is essential for the second step of this process ("develop/choose a biogeographic habitat and/or community classification") and facilitates the third step ("drawing upon steps 1 and 2 above, iteratively use qualitative and/or quantitative techniques to identify sites to include in a network, considering representativity, connectivity, and replication"). Ensuring that biogeographic units are well represented within a system of protected areas globally helps ensure that the full range of marine biodiversity and ecosystem processes will also be protected, and is often the best that can be achieved with the current state of knowledge(UNEP-WCMC, 2007).

3. Policy context for the development of a biogeographic classification for open ocean and deep seabed areas globally

Recent international policy developments have not only increased the need for biogeographic classifications, they provide a policy-enabling framework in which such classifications can be developed and utilized.

3.1. International legal framework

The 1982 United Nations Convention on the Law of the Sea (UNCLOS) provides the overarching international legal framework for human activities in marine areas beyond national jurisdiction. UNCLOS is complemented by other sector-based and environmental agreements; several are briefly described below. While the preamble to UNCLOS includes the principle that "the problems of ocean space are closely related and need to be considered as a whole" its division of ocean space based on man-made rather than ecological boundaries has created some obstacles to coherent management of human activities both within and beyond national jurisdiction. A solid biogeographic classification that would allow to map human uses against identified representative regions and provinces would greatly enhance implementation of UNCLOS.

The 1992 Convention on Biological Diversity (CBD) provides an integrated basis for the conservation and sustainable use of biological diversity and the equitable sharing of benefits derived from the utilization of genetic resources. The Conferences of the Parties to the CBD are now recognised as having a key role in supporting the work of the UN General Assembly with regard to marine protected areas beyond national jurisdiction, by focusing on provision of scientific and, as appropriate, technical information and advice relating to marine biological diversity, the application of the ecosystem approach and the precautionary approach, and in delivering the 2010 target (CBD Cop Decision VIII/24, para 42). To provide a scientific basis for discussion on areas for protection beyond national jurisdiction, the CBD initiated work on what was to become the GOODS biogeographic classification, but as described herein, it has many other policy applications as well.

The foundations for sustainable management of fishery resources are set forth in the 1995 FAO Code of Conduct for Sustainable Fisheries and the 1995 UN Fish Stocks Agreement addressing highly migratory and straddling fish stocks. This is further elaborated in the concept of an Ecosystem Approach to Fisheries Management (EAFM) for implementation by regional fisheries management organizations (RFMOs) (FAO, 2002; FAO, 2003) EAFM depends on ecologically defined boundaries for taking into account the impacts of fisheries on the marine ecosystem and the impacts of the marine ecosystem on fisheries.

3.2. WSSD targets for action

To accelerate marine conservation efforts to stem the loss of biodiversity, world leaders at the 2002 World Summit on Sustainable Development (WSSD) committed to a series of time-limited concrete actions. These include, *inter alia*, implementing the ecosystem approach by 2010, restoring fish stocks by 2015 (where possible), and establishing representative networks of marine protected areas by 2012 (UNEP, 2002). The UN General Assembly Resolution 57/141 endorsed these commitments and targets in the same year, and has repeated this endorsement annually.

Since 2002, several UN bodies have devoted significant attention to the need to enhance international cooperation and action in areas beyond national jurisdiction. These include, *inter alia*, the CBD, United Nations Informal Consultative Process on Oceans and the Law of the Sea (UNICPOLOS), the UN Food and Agricultural Organization (FAO), the International Maritime Organization (IMO) and the UN Working Group. As described in Annex 1, each of these bodies has or is considered/considering rules and/or mechanisms that could benefit from the enhanced understanding of biogeographic patterns and distribution of marine life provided by biogeographic classifications.

As much as biogeographic classification can act as an important tool to enhance the effectiveness of relevant environmental treaties, these international legal instruments and policy-making fora also provide an appropriate enabling environment for pursuing research underpinning biogeographic classification such as the GOODS classification and for applying the findings of such research to address relevant policy needs, as illustrated in the section below.

3.3. Relevance to biogeographic classifications

Aside from Annex 2 to CBD COP Resolution IX/20, none of these international instruments explicitly references biogeographic classifications. Nonetheless, each of them requires spatial considerations in implementation. This is prominent in the commitments to MPAs and the spatial delineation of the jurisdictions of RFMOs and implicit in many provisions of these and other instruments. Much of the progress on the policy and management initiatives summarized in 2 reflects efforts to implement these agreements. Hence, although it is not intended (or necessary) for biogeographic classifications to have formal status under these international agreements, the agreements have a central role in providing both the motivation for their further development and a framework for their use.

4. From theory to practice: case studies on the application of biogeographic classifications – accrued benefits and lessons learned

Biogeographic classifications have been developed and applied in many different countries and regions for many different purposes. A review of experiences in the Southern Ocean, the Northeast Atlantic, Australia, Mexico and Canada highlights some of these uses as well as some of their benefits. From these can be derived lessons for further development and application of the GOODS classification.

4.1. CCAMLR (Antarctic and Southern Ocean)

4.1.1. Background

The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) was adopted in 1980, and forms an integral part of the Antarctic Treaty System. The CCAMLR Commission has a wider conservation mandate than any other Regional Fisheries Management Organization (RFMO), and has pioneered a precautionary, ecosystem approach to fisheries management.

The boundary of the CCAMLR Area is itself derived from a broad biogeographic classification. Unlike the Antarctic Treaty, which applies to the area south of 60°S, the CCAMLR Convention covers a larger area that is bounded in the north by a line approximating to the mean position of the Antarctic Polar Front. This oceanographic boundary separates cold Antarctic waters from warmer waters to the north, and forms a major biological barrier to the distribution and migration of many marine species, including the Antarctic krill. This recognition of the importance of a biogeographic boundary for conservation and fisheries management highlights CCAMLR's commitment to an ecosystem approach for the Southern Ocean.

The CCAMLR Area is further divided into statistical areas and subareas, which are defined on oceanographic and biological grounds, and incorporate areas which are thought to contain relatively discrete populations of certain species (Kock, 2000). These subareas are used as the spatial basis for catch reporting and implementation of conservation and management measures on a stock-by-stock basis. The use of such areas by CCAMLR demonstrates the importance of delineating appropriately scaled and biologically relevant management units for implementing an ecosystem approach.

During the past five years, CCAMLR has started to address the topic of marine protected areas as a matter of priority (CCAMLR, 2004), recognising that such areas can form an important component of its ecosystem-based approach to the conservation of marine living resources. In 2005, it identified a series of key tasks to be undertaken in establishing a scientific basis for establishing MPAs, including the development of a broad-scale biogeographic classification of the Southern Ocean, and the fine-scale subdivision of biogeographic provinces (CCAMLR, 2005).

An experts' workshop was held in 2006 with the aim of developing a 'proof of concept' for a broad-scale biogeographic classification of the Southern Ocean (Grant et al., 2006), This workshop recognised that an understanding of spatial ecosystem characteristics is necessary to achieve a range of objectives including broad-scale ecological modeling, ecosystem-based management of living resources, effective and systematic planning of other human activities, establishment of a representative system of MPAs, and direction of further research.

Although some regions and taxonomic groups are relatively well known, much of the Southern Ocean is poorly studied, and there is a lack of comprehensive data on species distributions and abundances. Remotely-sensed physical environmental data were therefore used to classify units on the basis of environmental properties, physical processes, primary production and habitat type. A key aspect of the biogeographic analysis was the consideration of how important ecological processes correspond to physical parameters, and whether these parameters are appropriate for use as proxies or surrogates for delineating distributional boundaries for species' ranges.

4.1.2. Identification of priority areas for a system of protected areas

CCAMLR has now adopted broad-scale classifications for both the pelagic and benthic environments of the Southern Ocean. The pelagic biogeographic classification maps have been used to define priority areas in which further work to identify systems of marine protected areas should now be focused(Sc-CAMLR, 2008). This further work is likely to concentrate on the inclusion of additional biological information to determine important conservation features at finer-scales. Information on the spatial extent of different biogeographic units (termed 'bioregions' by CCAMLR) may also be used as part of a process to identify representative areas for protection.

4.1.3. Identification of vulnerable marine ecosystems

CCAMLR has also initiated a process to identify and protect vulnerable marine ecosystems (VMEs) in the benthic environment that are at risk from the effects of bottom fishing activities, in accordance with UNGA Resolution 61/105. In the absence of detailed information on the locations of vulnerable species, communities, and habitats, biogeographic maps may be useful in predicting where similar types of habitats are likely to occur. This could help with directing further research to establish the spatial extent and characteristics of areas that may be assessed as VMEs, and implementing measures to ensure their protection. In particular, habitat models can be used to develop risk-assessment maps for predicting impacts on VMEs in different fishing locations (CCAMLR, 2008).

4.1.4. Scale matching

The experience of CCAMLR in developing biogeographic classification products for a range of applications demonstrates the importance of considering appropriate scales for analysis and management uses. This experience has also shown that a hierarchical approach may be useful, where classifications at different scales can be applicable in different contexts.

4.1.5. Next steps and lessons learned

The choice of data and extraction of relevant parameters to capture ecological properties is a key to generating products that are appropriate for use in a range of conservation and management applications. Although the use of physical environmental data can provide a useful proxy where taxonomic data are unavailable, it may also be necessary to incorporate additional biological data at finer-scales. The contribution of scientific experts has also been shown to be critical in determining appropriate data inputs, as well as in assessing the validity of spatial classification products. Although CCAMLR has some way to go on enhancing its biogeographic classification products, and developing further methods for how they can be used, it provides a useful illustration for how classifications can contribute to effective policies and management practices.

4.2. OSPAR (Northeast Atlantic)

4.2.1. Background

OSPAR is the regional seas organization by which governments of fifteen European countries together with the European Community have cooperated since 1992 to protect the marine environment of the Northeast Atlantic. The OSPAR Maritime Area comprises the territorial waters, exclusive economic zones (EEZs) and areas beyond national jurisdiction. The annex on biodiversity and ecosystems adopted in 1998 has allowed for the development of MPAs (OSPAR, 2003a).

In 2003, the OSPAR Parties committed themselves to establish an "ecologically coherent network of well-managed MPAs in the northeast Atlantic by 2010" (OSPAR, 2003b). The concepts of representativity and connectivity underlie the notion of "ecologically coherent networks." The use of biogeographic classifications allows for a first look at the question of representativity, and is embedded within the OSPAR definition of representativity itself, as an area that "contains a number of habitat/biotope types, habitat complexes, species, ecological processes or other natural characteristics that are typical and representative for the OSPAR-Area as a whole or for its different biogeographic units" (OSPAR, 2003b).

Within the OSPAR Maritime Area, the Dinter (2001) biogeographic classification is recognised as the most thorough classification to date (OSPAR, 2006a). It has been used by Contracting Parties when submitting MPA nominations to OSPAR, as well as in the status reports reporting on the progress of the MPA network (OSPAR, 2006b).

Looking at representativity using the Dinter biogeographic classification has enabled the parties to assess progress with respect to the degrees to which the various biogeographic units are represented within the emerging OSPAR network of MPAs and the extent to which it is "ecologically coherent". Such ecologically-based analyses can avoid the political awkwardness of comparing individual progress of Contracting Parties (based on political boundaries), and instead focus on shared ecological goals in ecological regions shared by several Contracting Parties.

In developing the Dinter classification, existing classifications within the Northeast Atlantic were collated and scientists were consulted regarding their latest research. This information was merged into a unified regional classification resulting in a delineation of three large *biomes*: 1) a benthic biome considers the seafloor (benthos) less than 1000 m depth, of which there are 17 zones; 2) a deep sea biome treats the seafloor and waters deeper than 1000 m, into two broad zones; and 3) a pelagic biome considers the water column less than 1000 m in depth, of which there were three zones. Thus altogether, there are 22 biogeographic zones. The second biome is innovative in its grouping together of deep pelagic waters (>1000 m) and the seafloor, assuming that the deep pelagic and benthic habitats share more in common than what commonly separates them in waters less than 1000 m.

In practice the two "benthic" layers (biomes 1 & 2, described above) have dominated MPA network assessments looking at the question of ecological coherence (OSPAR, 2008). While scientifically relevant, the broader pelagic layer (<1000 m) has not yet found its niche within OSPAR to inform decision-making.

4.2.2. Next steps and lessons learned

4.2.2.1. Boundary selection. The difficulties inherent in boundary selection offer a useful lesson learned from the OSPAR experience. Developers of current biogeographic classifications have inevitably found themselves making difficult decisions on boundary placement. In the benthic environment, where features are often more fixed, this may be easier to do than in the more fluid pelagic; but in both instances, some features can exhibit high spatial variabilities and/or gradients, that make such boundary selection somewhat arbitrary. As was done in the OSPAR context, this "fuzziness" should be clearly communicated to users of the classification systems, and be reflected in the interpretation of biogeographical units based on variable features.

4.2.2.2. Scale matching. The scale of the biogeographic classification should approximately match the scale of the planning exercise in which it is employed. OSPAR, for example, recognises that while the Dinter classification is recommended at the scale of OSPAR-wide assessments, other finer-scale classifications, such as EUNIS (http://eunis.eea.europa.eu/) should be considered when smaller subareas are being examined (OSPAR, 2006a).

4.2.2.3. Pelagic application. To date the implementation of the Dinter classification as an aid to the establishment of an ecologically coherent network of marine protected areas in the OSPAR area has focused on benthic features, even though it has separate pelagic and benthic layers. However, the pelagic biogeographic classification could also be used in the context of the identification and protection of areas focused on consistent pelagic features. Such areas could address two general classes of features: biogeographically distinct areas above fixed benthic formations such as seamounts, reefs, and hydrothermal vents; and variable pelagic formations such as convergences, upwellings and gyres (Norse et al., 2005; Hyrenbach et al., 2000). Such pelagic areas are also often associated with increased productivity, and the need for especially risk averse management (CBD Resolution IX/20). Researchers are beginning to address the spatial protection of both types of pelagic features and have demonstrated feasibility of at least some mobile features (Alpine and Hobday, 2007).

4.2.2.4. Other uses. In the recently adopted EU Marine Strategy Framework Directive, *Marine Regions* and *Sub-Regions* are "…designated for the purpose of facilitating implementation of this Directive and are determined taking into account hydrological, oceanographic and biogeographic features." (EC, 2007, article 3, section). Although the sub-regions are laid out under article 4 of the Directive, existing administrative sub-divisions of regional seas bodies (e.g., OSPAR Regions) and data collection (e.g., ICES statistical rectangles) imply that biogeographic classification will be important to identify ecologically meaningful sub-divisions within each of these designated Sub-Regions. For such a sub-regional analysis, finer-scale data remain relevant and approaches like the Dinter classification offer a solid basis by which to proceed.

4.3. Australia

4.3.1. Background

In Australia the development of a federal Oceans Policy (released in 1998) established the overarching framework for ecologically sustainable development (ESD) for the vast majority of Australia's marine jurisdictions through integrated and ecosystem-based planning and management (Riecheldt and Wescott, 2005). Australia's Oceans Policy recognised that an agreed spatial framework that provided ecosystem boundaries for planning and management in the natural environment was needed. Indeed in Australia biogeographic classifications of both the terrestrial and marine environments had been under development for much of the decade preceding the adoption of Oceans Policy for use as tools for conservation planning, but at that time no single marine biogeographic classification existed for the entire EEZ.

Several government processes led to the development and adoption of agreed biogeographic classifications for use in conservation planning and management. These sought to classify Australia's coastal and marine ecosystems into units that made sense ecologically, were at a scale useful for planning and management (Cresswell and Thackway, 1998).

In 1998 an Interim Marine and Coastal Regionalisation of Australia (IMCRA v3.3 (Interim Marine and Coastal Regionalisation for Australia Technical Group, 1998)) was agreed as the ecosystem-based, spatial planning framework for the development of a national representative system of marine protected areas, and to support planning resource development and biodiversity conservation. The development of IMCRA was a cooperative effort between Australian Government, State and Territory marine management and research agencies, and at that time concentrated on waters of the continental shelf (Interim Marine and Coastal Regionalisation for Australia Technical Group, 1998). This was enhanced by additional work in deeper offshore waters leading to the adoption in 2006 of a new version, the Integrated Marine and Coastal Regionalisation of Australia (IMCRA v.4.0). In combining the two national scale marine biogeographic classifications, IMCRA v4.0 covered Australia's waters from the coast to the edge of the Exclusive Economic Zone excluding Antarctica and Heard and Macdonald Islands.

Like the GOODS, CCAMLR and OSPAR biogeographic classifications, IMCRA v4.0 is made up of two separate biogeographic classifications: a benthic classification (mostly based on biogeography of fish supplemented with a geophysical classification); and a pelagic classification (based on oceanographic characteristics of water bodies). The benthic classification contains three separate layers of information: a set of larger scale provinces for the entire EEZ (also called provincial bioregions) that reflect biogeographic patterns in distributions of bottom-dwelling fish; a set of meso-scale regions for the continental shelf only where more information has allowed finer-scale differentiation of regions; and a set of geomorphic units for the whole of the EEZ, which have been defined by clustering of geomorphic features into 14 categories and mapping areas of similar geomorphology.

Australia has committed to the development of a national system of marine protected areas using IMCRA as the basis for a comprehensive, adequate and representative system (http://www.environment.gov.au/coasts/mpa/nrsmpa). A set of guidelines has been agreed on how to use the biogeographic classification in order to achieve a representative set of MPAs (http://www.environment.gov.au/coasts/mpa/publications/nrsmpa-guidelines.html). Further to these the Australian government issued guidance on the goals and principles it will use in the identification and selection of MPAs, that are representative of the 41 provincial bioregions that occur in federal waters (http://www.environment.gov.au/coasts/mbp/publications/general/pubs/goals-nrsmpa.pdf). Each of the goals relates to some aspect of the information contained in IMCRA 4.0.

The use of biogeographic classification in the marine realm is not limited to the development of Australia's national representative system of Marine Protected Areas. The biogeographic classification is a key layer in the Australian Government's program to roll out marine bioregional plans for all federal waters (generally from 3 to 200 nautical miles from shore). These plans are prepared under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*), the key piece of federal environmental legislation, and will identify conservation and heritage values and include a range of measures to ensure the long term maintenance of those values (http://www.environment.gov.au/coasts/mbp/index.html).

The marine regional plans will collate existing marine science and socio-economic information for each marine region. Using the units from the biogeographic classification as the framework, the plans will describe each region's key habitats, plants and animals; natural processes; human uses and benefits; as well as known and potential threats to the long term ecological sustainability of the region. The plans will give details about the various statutory obligations under the EPBC Act that apply, as well as the range of conservation measures that will be put in place.

Other applications in Australia that have used biogeographic classifications include decision-making in the assessment of applications for regulated use of the marine environment; identifying areas that have particular values for conservation or use (e.g., zoning in the Great Barrier Reef Marine Park); finer-scale habitat mapping(North West Shelf Joint Environmental Management Study, 2002) and fine-scale biogeographic assessments as part of marine protected area planning (Edyvane, 1999).

For the Great Barrier Reef Marine Park the Australian Government has prepared a biogeographic classification at a finer level below the IMCRA meso-scale level detailing 70 spatially finer biogeographic units, called bioregions in this jurisdiction, for the entire Park. This classification was then used to derive new boundaries for highly protected zones within the Park. The proportion of the Marine Park protected by 'no-take' zones (known locally as 'green' zones) was increased from less than 5% to more than 33%, and now protects representative examples of each of the Bioregions. Existing data sets used as the basis for the GBR sub-IMCRA biogeographic classifications were: reef fish, soft corals, hard coral, reef biota, macroalgae, seagrass, reef geomorphology, bathymetry, mean tidal range, and broad-scale currents.

4.3.2. Next steps and lessons learned

Three areas have been identified that if addressed would improve the utility of the current classification: 1) clarifying the conceptual classification models underlying the biogeographic classification; 2) improving the data coverage of input data to the classification; and 3) improving the understanding of ecosystems, the links between ecosystems and use of surrogates (both biological and physical) for ecosystems. More specifically, it is hoped that a refined biogeographic classification would incorporate more biological data, particularly in the pelagic environment, with more detailed descriptions of the ecological components and processes of deep water systems, and links between the benthic and pelagic environments. Better understanding of marine processes and attributes in both space and time and at multiple scales, as well as links between these scales and their application to management, is an ongoing need. The Australian Government through the Commonwealth Environmental Research Facility (CERF) is funding a marine biodiversity research hub that has brought together all of Australia's major marine science research in 2010; http://www.marinehub.org/index.php/site/home/.

The Australian Government Environment Department is the custodian of the national marine biogeographic classification IMCRA. As such, it maintains oversight of the conceptual framework for the classification, coordinating consultation amongst jurisdictions and agencies affected by proposed changes to boundaries and other matters pertaining to the classification through inter-governmental committees.

4.4. Mexico

4.4.1. Background

Mexico's marine environment encompasses a wide variety of ecosystems and habitat types including regionally significant areas of high endemism and biological diversity (Salazar Vallejo and González, 1993). Deep sea ecosystems and habitats represent 37% of the total 3 149 920 km^2 Exclusive Economic Zone (EEZ) in the marine environment.

In response to international commitments accepted by Mexico with respect to the ecosystem approach and the development of ecologically representative marine protected area networks, Mexico undertook a major initiative to explore options for marine biodiversity management and conservation. This initiative built on Mexico's main marine conservation strategy which until then focused primarily on the establishment of protected areas covering 1.38% of the EEZ (CONABIO, 2006). This expanded initiative proceeded through four steps.

1. Gap and omission analysis workshop: (CONABIO, 2007). A group of experts from the major environmental (CONABIO-CONANP-TNC-PRONATURA, 2007) and research institutions in Mexico (UNAM, CICESE; CIBNOR; UABC; UABCS; UV; UAM) then identified major priority areas, identified based on the eight ecological criteria identified in Salm et al. (Salm et al., 2000).

   Products of the workshop included a digital and printed environmental cartography at scales 1: 250 000 and 1: 10 000 000; databases of biodiversity geo-referenced records of marine and island ecosystems; and a review of the regional conservation activities and technical cards on each location identified.
2. Transboundary Diagnostic Analysis (TDA) to evaluate the environmental problems of the Gulf of Mexico within a Large Marine Ecosystem framework. This project informed the Strategic Program of Marine Protected Areas with important information about priority areas and threats in the Gulf of Mexico.
3. Classification of the marine environment: these classification programs worked on a four-stage strategy based on technical studies in which the natural environment and socio-economic and sectoral components of the units were described. It was at this step that the biogeographic classification was pursued most diligently, in combination with a threat analysis. Then, at the scale of the regions and below marine areas with strategic properties requiring conservation were identified including offshore and deep sea habitats.
4. Other ongoing efforts: Marxan analysis and modeling are being used as tools to strengthen the coverage, extent and definition of polygons to help define networks of marine protected areas including deep sea ecosystems in the Mexican EEZ.

4.4.2. Next steps and lessons learned

The need to evaluate and improve the protected areas system is of interest at the global scale. To Mexico it is of great importance that these efforts be carried out on a technical basis and not as an *ad hoc* process. Hence information on the biogeographic distribution of species and habitats is a fundamental cornerstone for conservation.

The gap analysis was an important first step that has served as a baseline for monitoring expansion of marine protected areas coverage and as an indicator of progress towards the goal of reducing the loss of biodiversity through improved conservation strategies by 2010. The use of Marxan analysis and modeling tools provided a further complement as they were used to help improve coverage of deeper ecosystems within a protected area system.

More needs to be done just to reach the goal of 10% habitat coverage for representative protected areas systems(Langhammer et al., 2007). Some experts have even suggested a more ambitious goal for the world ocean with figures ranging from 12 to 25% (Hoekstra et al., 2005). Moreover, developing comprehensive and effective networks of marine protected areas must go beyond identifying individual areas as ecologically significant or vulnerable. Planning that takes account of hydrographic and biological connectivity, stratified by depth zone, would be particularly important in the deep sea because different water masses in the water column act deter larval dispersal, isolating populations that occasionally evolve as different species within a similar depth zone.

Mexico's marine environment is still under-protected, as is the global ocean where many species and ecosystems are critically threatened. There is a need to continually update and adapt what are considered to be "best practices" in order to reach an effective level of conservation coverage, considering different geographical (local, regional, global) and conservation (one MPA – a network of MPAs) scales. Thus biogeographic classification at a variety of scales is a necessary component of achieving the global goals of ecologically coherent and representative networks of MPAs.

4.5. Canada

4.5.1. Background

The Preamble to Canada's Oceans Act (1998; http://laws.justice.gc.ca/en/O-2.4/) calls for adoption of both an ecosystem approach to management and integrated management. The Ocean Action Plan – Part 1 (http://www.dfo-mpo.gc.ca/oceans-habitat/oceans/oap-pao/index_e.asp) was a major initiative to implement this mandate. The framework for OAP I began with a comprehensive Ecosystem Overview and Assessment Report (EOAR), used as a basis for establishing Conservation Objectives for the area used as the management unit. The Conservation Objectives would constrain the aggregate industry impacts to ensure the key structural and functional components of the ecosystems would not suffer serious harm. While the EOAR was being conducted, the Oceans managers were establishing Integrated Management Tables, with participation by all relevant industry sectors, levels and departments of government, and stakeholders. At these IM tables, marine spatial planning tools would be used to identify combinations of industry opportunities and management constraints that would be the basis for Social and Economic Objectives whose achievement would provide social and economic benefits without violating the Conservation Objectives.

The Oceans Action Plan also included provision for networks of Marine Protected Areas (http://www.dfo-mpo.gc.ca/oceans/marineareas-zonesmarines/mpa-zpm/index-eng.htm). Depending on their objectives, MPAs could be established by three different government departments at the federal level, and by provincial and territorial governments. An overarching

Federal–Provincial–Territorial Working Group would coordinate efforts at building these networks and ensuring management was coherent within and among network members.

4.5.2. Role of biogeographic classifications

Five pilot Large Ocean Management Areas were to be used as trials for the overall framework. Each needed to be an ecologically coherent unit. Initially a variety of spatial units were under consideration, with substantial debate among various departments, levels of government, and industry and stakeholder groups about which units were most convenient for their operations. A working group of experts reviewed available information on species' distributions in all three oceans bordering Canada, using analytical clustering methods as the primary guide to identifying biogeographic units. The report of that working group (Powles et al., 2004) identified over 20 biogeographic units at a relatively coarse scale. This information was a major factor in leading to rapid agreement of all parties on the five pilot areas; Pacific North Coast, Eastern Beaufort Sea, Gulf of St. Lawrence, Placentia Bay – Grand Bank, and Eastern Scotian Shelf. These became the basis for OAP I activities.

At the end of OAP I it was clear that the full implementation of IM was going to be a lengthy process of dialogue and compromise. Lessons learned from OAP I also identified shortcomings some of the biogeographic units identified in Powles et al. (Powles et al., 2004). Data on occurrence of larger marine fish dominated the databases available; their analyses, leading to some biogeographic units that might reflect fish distributions well, but did not capture ecological processes particularly well. Others, such as units along the continental shelf breaks a few tens of km wide but over a thousand km long, had some ecological reality but would not be amenable to spatial management planning.

All agencies and interest groups participating in the establishment of MPA networks acknowledged the importance of biogeographic classifications to their efforts. However, the three federal agencies involved (Fisheries and Oceans, Environment Canada, and Parks Canada), some of the major coastal provinces, and some ENGOs each used their own classification as a basis for their efforts. Each classification was developed using data sources and methods that differed to varying degrees, depending largely on the relative role of marine and terrestrial ecosystems in their mandates or interests.

To address both issues, a second expert meeting reviewed the biogeographic information again, and all the classifications being used in Canadian waters. The second review gave greater weight to oceanography and bathymetric information and knowledge of functional food webs. This meeting (DFO, 2009) identified 11 major biogeographic units (3 Atlantic, 4 Pacific, and 4 Arctic), and for several units a second level of subdivision of between 2 and 5 subunits. These units and subunits were not identical to the units used by other agencies at the federal level. However boundaries of almost all biogeographic units coincided well, and only levels of nesting differed among agencies. There was consensus among all agencies that the differences reflected jurisdictional requirements and would be trivial when practitioners worked to develop the MPA networks.

4.5.3. Next steps and lessons learned

A key lesson learned was that the classifications were robust to different groups of experts working with somewhat different information and for somewhat different goals. Major biogeographic units appeared consistently, although levels of nesting varied. It was also apparent that rigid adherence to results of formal algorithms applied to incomplete and uncertain data produce some insightful results and some results that are unhelpful to policy, management, and even science. Some flexibility to apply knowledge is necessary.

These major and minor biogeographic units will form the spatial basis for developing networks of MPAs, including representative MPAs, and several additional marine spatial planning initiatives. Fisheries Management is also using these units as major features for bringing spatial tools into their efforts to adopt an ecosystem approach to fisheries management under their fisheries renewal initiative (website). All these initiatives required the biogeographic classification as an objective basis for framing the multi-stakeholder dialogue and planning, and found progress accelerated when the results of the two classifications became available.

4.6. Discussion

Each of the case studies has made use of biogeographic classification for planning ecologically coherent, representative and comprehensive networks of marine protected areas. Each of them has also recognised the utility of biogeographic classification for broader ecosystem-based management of the marine environment, including predicting the distribution of habitats, directing further research, spatial approaches to fisheries management, and for identifying areas that are priorities for conservation and management – areas that might be particularly vulnerable, or areas that have enhanced value for certain uses. These examples highlight the ways in which biogeographic classification can support decision-making in a policy context, particularly where such classifications become a part of broader management frameworks collating scientific and socio-economic information.

The case studies also demonstrate some of the challenges of developing and applying biogeographic classification, including the importance of considering appropriate scales for analysis and management, the difficulties of selecting boundaries in a fluid marine environment, and the importance of improving the underlying data as well as the scientific understanding of ecosystems and their relationships.

5. Future use and development of biogeographic classifications

5.1. Overview

The issues and challenges encountered in developing the GOODS classification were generally similar to the regional and national examples, as were the outcomes reached, for example the development of separate benthic and pelagic classifications. While the regional and national classifications are already being used in various degrees to underpin management, the GOODS classification has not yet been similarly applied. There is an opportunity to learn from these early examples. For instance, all marine biogeographic classifications contain boundaries that are generalized and not precise, and should not be interpreted as 'hard' management lines, particularly in the context of inter- and intra-annual variability. All of them also suffer from a lack of consistent biological data covering the entire study area.

This problem is even more acute for the global GOODS classification. The large provinces delineated differentiate "individual" ecosystems weakly and provide limited information about their structure and function. However, even with the currently limited knowledge of high seas biodiversity these provinces broadly differentiate major ecosystem types, and can serve as a basis for management and further subdivision. As was found with several of the case histories, such as in Australia and Canada, classifications do not have to be perfect to be useful. Even with incomplete data and a diversity of approaches, important biogeographic units do emerge from soundly conducted expert processes. Done well, the classification can serve needs of multiple agencies with diverse missions.

One lesson that the GOODS classification can already draw from the national and regional examples is the need for further refinement in the future as improved data become available. This was demonstrated by all the case histories but especially with the several iterations of the original biogeographic classification of the Australian EEZ. The Australian example also demonstrated that while the first iterations of the classification were not perfect, each held increasing value for management. As biogeographic information is increasingly used nationally, regionally, and globally to underpin planning and ocean management, a transfer of lessons learned from these early examples provide for "learning by doing" in the context of adaptive management.

All the national and regional case histories reported limitations in understanding of ecological processes and relationships as well as shortcomings in data sets used in the classifications. Such limitations and shortcomings will, in general, only be greater in the open ocean and deep sea areas. These sources of uncertainty, and the concomitant need for precaution, will characterize management in the open oceans for some time to come. Hence, future research underpinning biogeographic classification will need to be complemented with proactive measures to ensure precaution, such as limiting human uses known for being associated with adverse impacts on marine biodiversity i.e. bottom trawling and its related impacts on seamount ecosystems. Ultimately, precautionary management measures will be more likely to succeed if they are applied at scales where the ecosystem(s) can be expected to respond in coherent and predictable ways, based on sound biogeographic theory, data and classifications. Biogeographic classification will be a valuable aspect of policy development and management on the open ocean and deep seas, as States strive to meet the commitments summarized in Section 3.

5.2. *Recommendations for further use and development*

5.2.1. *Uses of biogeographic classification in the open ocean and deep seas*

There is scope to improve the GOODS biogeographic classification as new information comes available, and as further analyses are completed with existing data. Nonetheless, a major lesson from the national and regional case histories is that policy and management benefit from use of classification systems in many tasks, even if those systems are based on incomplete information and may be refined in future. Therefore we can revisit a number of the conservation and management initiatives reviewed in Sections 2 and 3, relative to the contribution that the GOODS classification or its successors can make.

Several international initiatives are converging as their various deadlines of 2010, 2012, and 2015 approach. These initiatives include guidelines for management of deep sea fisheries on the high seas (FAO, 2008), establishment of a network of MPAs on the high seas(CBD Decision VII/28, 2004), focused work on the selection of MPAs within defined priority areas (UNU-AIS, 2005), guidelines for identifying ecologically and biologically significant areas and steps for selecting sites for networks of MPAs (report of upcoming CBD workshop 30 Sept–2 Oct, 2009) and a regular process for assessments of the marine environment, including socio-economic considerations (GRAME:) http://www.unga-regular-process.org/index.php%3Foption%3Dcom_content%26task%3Dview%26id%3D18%26Itemid%3D20 (http://www.unep.org/dewa/assessments/Ecosystems/water/marineassessment/meetings.asp).

The FAO guidelines for high seas fisheries are intended to guide actions to prevent serious adverse impacts to vulnerable marine ecosystems (VMEs). The guidelines include criteria for identifying VMEs (FAO, 2008, Para 42). These criteria are very similar to the CBD criteria for Ecologically and Biologically Significant Areas. The Guidelines further specify that the management measures to be applied are to be designed to ensure that the natural structure and functioning of the high seas ecosystems is not impaired. It is also stressed that management should be planned and delivered by fisheries management agencies with regional structure, including establishment of RFMOs where they do not exist. Application of several VME criteria, including rarity and functional significance has an inherently spatial aspect. Likewise measures to protect the structure and function of ecosystems require that the ecosystems to be protected are delineated spatially. For all these measures, biogeographic classification units will be an essential component of planning and implementation.

The dependence of MPA networks on biogeographic classifications was discussed fully in Section 2.2.4. The urgency of progress on the global commitments merely underscores the importance of proceeding with use of the GOODS systems, improving it where feasible. The comparable urgency of progress on regional networks of high seas MPAs makes it imperative to commence or expand efforts to develop the next (regional) level of nesting of finer-scale units, such that regional network initiatives can progress as well.

Finally the UN Regular Process for global integrated assessments of the marine environment, including socio-economic considerations is designed around integrating assessments done at regional scales. The Assessment of Assessments review cited above found existing assessment of the world's oceans to be scattered and lacking an overall spatial organization. Application of the GOODS biogeographic classification of the open ocean, combined with the MEOW classification of the continental shelf seas (Spalding et al., 2007), will be a necessary cornerstone of the detailed planning for implementation of the Regular Process.

All of these initiatives can only be implemented through spatially-based approaches. Those approaches have to be ecologically coherent to achieve their individual objectives, and consistent across initiatives if they are to work synergistically rather than impede each other. For that reason alone, a sound and widely accepted biogeographic classification, such as GOODS, is necessary for future progress on conservation and sustainable use of the high seas. The benefits of a sound and common biogeographic classification extend more widely than these three initiatives, however. There is an increasingly clear recognition of the importance of the contribution of biogeographic classification to priority-setting in the policy context, and also an increasing policy demand for biogeographic information on open ocean and deep sea areas beyond national jurisdiction.

5.2.2. *Research and data collation to improve biogeographic classifications in the open ocean and deep sea*

Three aspects could improve the utility of the current GOODS biogeographic classification: 1) clarifying and expanding the classification models underlying the biogeographic classification; 2) improving the variety and coverage of input data to the classification; and 3) improving our understanding of ecosystems, the links between ecosystems, and use of surrogates (both biological and physical) for ecosystems. Specifically, a refined biogeographic classification would incorporate more detailed understanding of the distribution of the major determining physical features that at a given location drive biological responses, benefit from more biological data, and include more detailed descriptions of the ecological components and processes of deep water systems, accounting for links between the benthic and pelagic environments.

Improved mapping of biogeographic units, and associated ecosystems and habitats can also improve our understanding of connectivity. This understanding is critical for application of ecosystem approaches, marine spatial planning as well as the design of representative networks of open ocean and deep sea marine protected areas. It may also be useful for the development of proactive conservation strategies to protect species associated with degraded and fragmented seascapes or shifting habitats due to climate change. While the complexities of connectivity are outside of the scope of this paper, the use and refinement of biogeographic classifications can help inform management measures on likely patterns of greater or lesser connectivity, and hence on scales where management actions are most likely to have robust outcomes.

5.2.3. Closing observations

There remains a need to bridge the gap between policy demand and scientific research aimed at generating biogeographic knowledge. One factor impeding the filling of this gap is lack of adequate funding for a project that would be a global project in dimension, beyond the remit of any one organization or nation. Biogeographic investigations, especially in the open and deep ocean realms, are expensive and time-consuming, and the analysis of the data collected presents complex challenges. Such programmes would benefit from the political support needed to build international scientific cooperation at a global scale, as well as adequate funding. An example is provided by the Census of Marine Life (CoML) and its Ocean Biogeographic Information System (OBIS). During the decade in which these initiatives have been supported by a major private foundation and a number of governments, CoML and OBIS have developed a body of scientific knowledge that is unique and the most comprehensive ever collected, with important implications for policy and applications for both conservation and development. Yet, the funding future of these and of similar programmes is unclear.

Similarly, the GOODS biogeographic classification will require further funding in the future. The classification is primarily a science product that has a number of uses in the policy arena, in management, and in ongoing scientific endeavour. It is only the first edition, and experience globally has shown that its continuing relevance will lie in continuing to improve it and to build on new information as it becomes available. In Australia, the Government has formally supported the development of the first version of its biogeographic classification in 1998, and then an update in 2006, and importantly has requested further development and update ten years later. This reflects a reasonable balance between the need for stability for use of the product in implementation of policy such as MPAs, and the need to reflect new scientific knowledge to help improve our understanding and hence management.

In the ten years following the Rio Conference the policy initiatives requiring underpinning scientific information grew rapidly, and in the further seven years since WSSD the complexity of the policy environment, and the urgency of the need for action, has grown exponentially. This is not only in the biodiversity and sustainable use domain, but also particularly in the climate change domain. Increased understanding of the role of the oceans in maintaining the life systems upon which we depend has been possible through far greater knowledge of physical processes through programs such as the Global Oceans Observing System (GOOS). This work is far from complete, and is increasing at a rapid pace as the expected threats from climate change drive science to meet policy demands. Continuing to also improve our biogeographic understanding of the distribution of life in deep and open oceans will be a valuable addition to our knowledge base, as the 21st century will surely be the time of integrated management across the globe, as we deal with the myriad of problems and opportunities facing humanity.

Annex 1. Annotated synopsis of meetings showing the evolution of recent policy discussions

The synopsis of meetings below highlights international policy mandates and discussions regarding conservation and sustainable use of the open ocean and deep sea that the GOODS biogeographic classification can now contribute to. Although initially these meetings did not include specific reference to biogeographic classifications in their recommendations or products, in every case such systems are necessary in order to take action on them.

- February of 2004: the 7th Conference of the Parties to the CBD called for effectively managed and ecologically representative marine protected areas (MPAs). *Such a representative network requires a biogeographic classification system to guide choices of what must be "represented".*
- March 2005: the FAO Committee on Fisheries recommended FAO develop technical guidelines on the design, implementation and testing of MPAs and assist members to achieve the goal of representative MPA networks by 2012. *This assistance requires working on ecologically meaningful geographic scales*.
- February 2006: the first meeting of the UN *ad hoc* informal Working Group to study issues related to conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction explicitly called for further work to develop criteria for the identification of ecologically and biologically significant areas, the development of systems of marine protected areas and biogeographic classification systems (Paragraph 60 of the report of the meeting).
- March 2006: the 8th Conference of the Parties of CBD requested the CBD Executive Secretary to work with others to "refine, consolidate and, where necessary, develop further scientific and ecological criteria for the identification of marine areas in need of protection, and biogeographical and other ecological classification systems, drawing on expertise and experience at the national and regional scale" (COP Decision VIII/24, para. 44(b)).
- June 2006: The seventh meeting of UNICPOLOS noted that the implementation of integrated ecosystem approaches calls for geographically specific management approaches to be "**applied within geographically specific areas based on ecological criteria"** (Report of UNICPOLOS 7, paragraphs 5& 6).
- December 2006: the United Nations General Assembly adopted a resolution calling 'upon States to identify areas where vulnerable marine ecosystems … are known to occur or are likely to occur' (UNGA Resolution 61/105, para.83 (c)). Because it is not feasible to inventory and map all the species and habitat features that may delineate *VMEs for the world's oceans, biogeographic studies on the distribution of deep sea species and habitats are essential for systematizing existing knowledge*.
- March 2007: The FAO Committee on Fishery Investigations (COFI) Resolutions call for strengthening RFMOs in their efforts to implement an ecosystem approach. *To realize the expanded mandate of RFMOs*, for them to function effectively, and for implementation of an Ecosystem Approach to Fisheries, management has to be applied in biogeographically coherent units.
- April/May 2008: The second meeting of the UN *ad hoc* Working Group (28 April to 2 May 2008) considered, among other items, the role of area-based management tools. Support was expressed for the work on biogeographic classification, following a scientific presentation of the GOODS report in the opening session. *The Co-Chairperson's report noted that biogeographic biogeographic information* could support

decision-making with regard to spatial planning and other conservation and management measures.

- May 2008: the 9th CBD COP noted the report on Global Open Oceans and Deep Seabed (GOODS) Biogeographic Classification and requested the Secretariat to make the report available for information at the next meeting of the CBD Subsidiary Body on Scientific, Technical and Technological Advice (CBD COP IX, para 6). To provide scientific and technical guidance on the use and further development of biogeographic classifications and guidance on the identification of ecologically and biologically significant areas beyond national jurisdiction, the COP decided to convene an expert workshop to review and synthesize progress and experience with their use (CBD COP IX, para 6).
- April 2009: The Group of Experts conducting the "Assessment of Assessments" to "establish by 2004 a Regular Process under the United Nations for global reporting and assessment of the state of the marine environment, including socio-economic aspects, both current and foreseeable, building on existing regional assessments United Nations General Assembly (UNGA resolution 57/141) has included the GOODS report in its annex of underlying documents for the Regular Process, and acknowledged that the regional assessments must be for biogeographically meaningful units.
- December 2008: in its annual Resolution on Oceans and the Law of the Sea (UNGA resolution A/63(L.42)), the United Nations General Assembly reasserted many of the previous commitments including the development of representative networks of marine protected areas by 2012 (paragraph 134).
- Also in December, 2008: in paragraph 102 of the Sustainable Fisheries Resolution, the General Assembly urges the implementation of the International Guidelines for the Management of Deep Sea Fisheries in the High Seas of the Food and Agriculture Organization of the United Nations. The Guidelines include the provision according to which States and Regional Fisheries Management Organizations should collate *biogeographic information and oceanographic parameters used for predictive mapping of vulnerable marine ecosystems.*

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