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A review of the use of biogeography and different biogeographic scales in MPA network assessment

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Summary

Biogeography is the study of patterns of distribution of biological diversity. These patterns are a key consideration in the various principles and criteria which have been drawn up at global and regional levels to guide the design and assessment of an ecologically coherent network of Marine Protected Areas (MPAs). This is recognised in the joint statement by UK Administrations which considers that "there is a strong scientific case for an assessment of a marine protected area network to be based on biogeographic regions, rather than administrative regions, in line with OSPAR guidance."

The report reviews the use of biogeography and biogeographic scales in MPA network design and assessment globally and makes recommendations for JNCC and the country conservation bodies based on the findings. The recommendations are framed in the context of current data availability and scientific understanding, and include consideration of whether there is a scientific case to use different biogeographic scales to assess the UK's contribution to an MPA network in the north-east Atlantic against each of the OSPAR MPA network design principles.

The literature review reveals that it is most often a factor when reporting on 'representativity' and 'features' (particular species, habitats and ecosystem processes) in MPA networks. These are two of the five main principles for an ecologically coherent MPA network agreed by OSPAR and being used by the UK Administrations to guide the identification and selection of national MPAs. The three other principles (connectivity, resilience and management) may be influenced by biogeography but the literature review indicates that this is generally not the main concern when trying to apply them to MPA networks.

Biogeography is typically noted as being relevant to both the design and assessment of MPA networks, but it is most often applied at the assessment stage. This is probably because apart from regions of the world where there are few MPAs, such as the deep sea and Antarctica, most networks are being built up by identifying gaps in an existing suite of sites. The data presented on MPA networks in biogeographic regions are typically the number, size and percentage cover of MPAs. Whilst such analysis may be rudimentary, statistics of this type are essential to appreciating how well the principles of 'representativity' and 'features' are being addressed.

The main recommendations of this review are that biogeography should be used for the assessment of the UK MPA network against the OSPAR network design principles of 'representativity' and 'features', and that this should be done at the scale of UK Regional Seas.

- A wider scale e.g. OSPAR/Dinter (2001) is considered to be too broad and fail to capture geographic variation between habitats in UK waters;
- a finer scale is considered to be less useful, because it starts to reflect patterns of individual species distribution rather than regional characteristics;
- careful consideration should be given to assessing the contribution of habitats and species in transition zones between biogeographic regions as these can be unique environments.

Finally it should be noted the recommendations have been drawn from a review of the science of biogeography and its relevance to MPAs. Other scientific questions will need to be considered when applying the OSPAR principles. There are also policy considerations such as other UK obligations and reporting frameworks which might influence the design and assessment of the UK MPA network but these have not been considered in this report.

Contents

1 Introduction

1.1 Background

> Networks of Marine Protected Areas
> *"a collection of individual Marine Protected Areas or reserves operating cooperatively and synergistically, at various spatial scales, and with a range of protection levels that are designed to meet objectives that a single reserve cannot achieve."*
> (International Union for the Conservation of Nature 2008)

The need to establish networks of Marine Protected Areas (MPAs) is enshrined in a number of international and regional conventions and European Directives:

- under the Convention of Biological Diversity (CBD) - to establish comprehensive, effectively managed and ecologically representative national and regional systems of marine protected areas;
- under the United Nations (UN) World Summit on Sustainable Development (WSSD) - to establish representative networks of MPAs (UN para 32(c));
- under the OSPAR Convention (Annex V) - to establish an ecologically coherent network of well-managed MPAs in the north-east Atlantic; and
- under OSPAR & HELCOM (the Baltic Marine Environment Protection Commission or Helsinki Commission) - to identify and establish a joint network of well-managed MPAs that, together with the Natura 2000 network, is ecologically coherent.

At a European level the European Union (EU) Habitats Directive (1992) requires a "coherent European ecological network of Special Areas of Conservation" (Article 3) which, together with Special Protection Areas, classified under the EU Birds Directive, will make up the Natura 2000 network.

The EU Marine Strategy Framework Directive (MSFD) (2008) includes a requirement to establish coherent and representative networks of MPAs (Art.13(4)) contributing to Good Environmental Status of Europe's seas.

Taken together these agreements commit the UK to contributing to a *'comprehensive', 'ecologically coherent', 'representative',* and *'well-managed'* network of MPAs at global, north-east Atlantic and European level, as well as contributing to the conservation or improvement of the marine environment in the UK marine area.

A joint statement by the UK Administrations (Defra *et al* 2012) describes the UK commitment to substantially completing an ecologically coherent, well-managed network of MPAs by 2016. The conditions of this network are set out in the Marine and Coastal Access Act 2009, the Marine (Scotland) Act 2010 and the Marine Act (Northern Ireland) 2013.

Oslo/Paris (OSPAR) Commission guidance (OSPAR 2006) outlines five main principles for an ecologically coherent MPA network (features - species, habitats and ecological processes, representativity, connectivity, resilience, and management). These principles are guiding the UK Administrations in their identification of national MPAs. The importance of taking biogeography into account and working at an appropriate spatial scale is also mentioned in the OSPAR guidance (OSPAR 2008).

Biogeography is the study of patterns of distribution of biological diversity and these patterns, as they exist today, are a key consideration in the various principles and criteria which have been drawn up at global and regional levels to guide the design and assessment of an ecologically coherent network of MPAs. This is recognised in the joint statement by UK Administrations which considers that “there is a strong scientific case for an assessment of a marine protected area network to be based on biogeographic regions, rather than administrative regions, in line with OSPAR guidance.” The concept can be applied at a variety of scales, with reference to different species, habitats or ecological processes and be more relevant to some criteria than others. Taking biogeography into account also has implications for network design as well as determining the ability to meet network objectives. At the same time it is important to recognise that biogeography is only one of many elements that will need to be considered in designing and assessing an ecologically coherent network of MPAs.

1.2 Aims and objectives

The aim of this report is to provide JNCC and the country conservation bodies with a review of the use of biogeography and biogeographic scales in MPA network design and assessment globally, and based on the findings to explore and develop recommendations on the consequences of using different biogeographic scales to assess the UK’s contribution to an MPA network in the north-east Atlantic against each of the OSPAR MPA network design principles.

The OSPAR Commission guidance proposes that an MPA network should reflect biogeographic variation within the network. The UK Administrations have stated that they consider there to be a strong scientific case for an assessment of an MPA network to be based on biogeographic regions, rather than administrative regions.

OSPAR Contracting Parties are currently considering approaches to assess the ecological coherence of networks of MPAs and work is underway in the UK to develop an approach across all Administrations. JNCC wish to consider how different biogeographic scales may influence the assessment of each of the network design principles and then formulate advice on which biogeographic scale(s) is most appropriate. It could be that the use of different biogeographic scales, or the use of a finer scale than those currently identified in the biogeographic regions most relevant to current UK MPA policy, will allow for the network to maximise the biodiversity benefits of the network.

The specific objectives of this report are:

1. A literature review on how biogeography and different biogeographic scales have been considered when developing and assessing MPA networks globally.

2. Based on findings from the literature review, to make recommendations as to whether there is a scientific case to use different biogeographic scales to assess the UK’s contribution to a wider MPA network in the north-east Atlantic against each of the OSPAR MPA network design principles in UK waters.

The recommendations are framed in the context of current data availability and scientific understanding, and include consideration of whether there is a scientific case to use different biogeographic scales to assess the UK’s contribution to a wider MPA network in the north-east Atlantic against each of the different OSPAR MPA network design principles in UK waters.

1.3 Methods

The literature review was undertaken as a desk study, using internet-based keyword searches and British Library facilities to source relevant information. Whilst peer reviewed literature provided much of the theoretical information on the subject, the practical application of methods is reported in both scientific journals and grey literature. The latter, which included project reports and management plans, are often the most up-to-date as this is an evolving field with ongoing interpretation and analysis. Both types of information sources were considered appropriate for this review.

The following key words were used in various combinations for the literature searches:

- biogeography;
- protected area;
- marine protected area;
- network;
- ecological coherence;
- assessment;
- design;
- representativity;
- connectivity;
- resilience; and
- management.

Four of OSPAR network design principles are included in this list. A fifth OSPAR principle ‘features’ was also used at the outset, however as the term has many meanings the search results were not particularly focused or informative to the research review, so it was not pursued as a main search term. Websites and databases of the European Commission (in relation to Natura 2000) and the three Regional Sea conventions covering European seas were also searched as all of these bodies are involved in the design and assessment of MPA networks:

- OSPAR - in relation to the North East Atlantic;
- HELCOM - in relation to the Baltic; and
- BARCELONA (Convention for the Protection Of The Mediterranean Sea Against Pollution) - in relation to the Mediterranean

The findings of the literature review are summarised for each of the five OSPAR network design principles being used to guide the UK programme (Section 3). Key issues are reviewed in Section 4 and recommendations presented in Section 6.

Case studies have been included to illustrate how biogeography is being taken into account in the design and assessment of other MPA networks globally.

References are listed at the end of the report. There is also an expanded bibliography of key references in Appendix 1. This has been provided to JNCC in an electronic format (Excel) to facilitate updating.

2 The Role of Biogeography in Conservation

> *"It will be evident in the first place that nothing like a perfect zoological division of the earth is possible. The causes that have led to the present distribution of animal life are so varied, their action and reaction have been so complex, that anomalies and irregularities are sure to exist which will mar the symmetry of any rigid system."*
> Alfred Russel Wallace (1876) discussing the principles on which zoological regions should be formed. The Geographic Distribution of Animals (1876) pg 53.

Biogeography is the study of patterns of distribution of biological diversity. These patterns can be observed at many scales so they may relate to genes, species, communities and ecosystems; they are driven by both geographic parameters and ecological processes; have occurred in the past; or are apparent today (Lomolino *et al* 2005). Although the term was not in common use until the latter part of the 20th century there is a longer history of interest in the subject as demonstrated by the work of scientists such as Alexander von Humboldt, Alfred Russel Wallace, Charles Darwin and Joseph Hooker in the late 18th and early 19th centuries.

The questions to be addressed by this review are essentially questions of conservation biogeography. This is defined by Whittaker *et al* (2005) as "*the application of biogeographical principles, theories, and analyses, being concerned with the distributional dynamics of taxa individually and collectively, to problems concerning the conservation of biodiversity*". Some of the earliest studies in this field were also concerned with the subject of this review – the use of biogeography to design and assess the sufficiency of networks of protected areas (e.g. Dasmann 1974; Udvardy 1975).

Ladle & Whittaker (2011) identify lack of knowledge about the geographical distribution of species ('the Wallacean shortfall') and the gap between known and yet to be described species ('the Linnean shortfall') as problematic in conservation biogeography. There are similar uncertainties in relation to habitats as illustrated by the ongoing development and refinement of habitat maps and classifications such as European Union Nature Information System (EUNIS) and, particularly for the marine environment, discoveries of previously unknown habitats types in more remote locations such as deeper offshore waters. The recommendations made in Section 6 have been framed in the context of current data availability and scientific understanding.

2.1 Conservation biogeography and protected areas

At the Second World Parks Congress in 1975, Dasmann, who was Senior Ecologist for IUCN at that time, expressed the view that for most species, conservation requires the protection and management of the ecosystems to which they belong as well as rational use of land and resources outside protected areas. The protection he envisaged was *"a network of reserves…. to include representative areas of all natural communities on earth, along with manmade communities of interest"* (Dasmann 1975). Given that the identification of representative areas requires an understanding of the biogeographical distribution of species and habitats, this statement shows that thinking about biogeographic distribution and protected area programmes has been interlinked for more than 40 years.

The work of Alfred Russel Wallace laid the foundations of many aspects of biogeography. In correspondence with Samuel Stevens during his expedition to the Malay Archipelago (1854-1862) Wallace commented on differences in bird species which *"throw great light on the laws of geographical distribution of animals in the East"* (Wallace 1856). His records of the occurrence of species made during his travels in the Far East led him to identify boundaries in the ranges of species, including a clear boundary between Asian and Australian faunas which has since become known as ‘the Wallace Line’ (Figure 1). Wallace referred to his investigations as zoological geography and he proposed zoogeographical divisions of land as regions and sub regions, each with an associated list of families and genera (Wallace 1876). Although not the first to do so (Sclater 1858), his regional classification underpinned by his field data and including several taxa is widely credited as providing the scientific basis for the discipline of biogeography.

Figure 1. Illustration of the Oriental Region and its four sub-regions (Indian, Celonese, Indo-Chinese, Indo-Malayan) as proposed by Wallace (1876). Map 10. Vol.1. Chapter XII, pg.315. Arrow indicates boundary referred to as ‘the Wallace line’.

Moving forward to the 20th century but still building on the work of Wallace, Dasmann (1973, 1974) suggested a hierarchical system of geographic areas, as a way of classifying the world’s biotic areas for the purposes of conservation. The largest were referred to as biogeographical regions. Biotic provinces were identified in each of these, characterised by the major biome or biome-complex which dominated the geographic area.

As knowledge of patterns of distribution increased, biogeographic classifications evolved and so did the terminology. In 1975 the unified system for biogeographical and conservation purposes proposed by Udvardy (1975) used the terms biogeographic realm and biogeographic province and Hayden *et al* (1984) did a parallel exercise for coastal-marine areas. Whist this terminology is still in use today, a plethora of other terms are also used, often to describe different levels of biogeographic classifications or different elements within such classifications (Box 1).

Box 1: Common Terms used in Biogeography as defined by Spalding *et al* (2007)

Biogeographical realm: Very large regions of coastal, benthic or pelagic ocean across which biotas are internally coherent at higher taxonomic levels, as a result of a shared and unique evolutionary history. Realms have high levels of endemism, including unique taxa at generic and family levels in some groups. Driving factors behind the development of such unique biotas include water temperature, historical and broadscale isolation, and the proximity of the benthos.

Biogeographical province: Large areas defined by the presence of distinct biotas that have at least some cohesion over evolutionary time frames. Provinces will hold some level of endemism, principally at the level of species. Although historical isolation will play a role, many of these distinct biotas have arisen as a result of distinctive abiotic features that circumscribe their boundaries. These may include geomorphological features (isolated island and shelf systems, semi enclosed seas); hydrographic features (currents, upwellings, ice dynamics); or geochemical influences (broadest-scale elements of nutrient supply and salinity.)

Ecoregion: Areas of relatively homogeneous species composition, clearly distinct from adjacent systems. The species composition is likely to be determined by the predominance of a small number of ecosystems and/or a distinct suite of oceanographic or topographic features. The dominant biogeographic forcing agents defining the ecoregions vary from location to location but may include isolation, upwelling, nutrient inputs, freshwater influx, temperature regimes, ice regimes, exposure, sediments, currents, and bathymetric or coastal complexity.

The role of biogeography in protected areas programmes has long been recognised through the often stated goal of 'representativeness' - identifying areas which represent or sample the full variety of biodiversity, ideally at all levels of organisation (e.g. Olsen & Dinerstein 2002; Dudley and Parish 2006; IUCN-WCPA 2008). This was described by Margules & Pressey (2000) as one of the two basic principles of conservation planning (the other being persistence of reserves).

The case for proactive and systematic consideration of biogeography is apparent from its inclusion in many site selection criteria (Eken *et al* 2004) although, in practice, protected area networks have generally become established in an opportunistic way (e.g. Fraschetti *et al* 2005; Ray 1996). As a result, biogeography has frequently been considered retrospectively, through an assessment of the sufficiency of existing protected areas. For example, Hoekstra *et al* (2005) developed a Conservation Risk Index by comparing habitat loss and protection in terrestrial biomes and ecoregions and, on this basis, recommended improving the degree and distribution of habitat protection both within and among these regions. A national example is the assessment of the extent to which vegetation communities in the USA were adequately covered in protected areas (Scott *et al* 1993). Today this type of work is part of a national Gap Analysis Program, analysing the representation of terrestrial biotic elements in the US conservation network (e.g. Aycrigg *et al* 2013).

Consideration of biogeography in MPA programmes has also been both proactive and reactive. There have been combined studies of terrestrial and marine protected areas such as analysis of the 2003 UN list of protected areas in south-east Asia (ASEAN 2010) but also a growing body of work specifically concerned with biogeography and MPAs. The approaches, issues, and lessons learnt from this marine work are described below and used to draw up the recommendations in Section 6.

2.2 Marine Biogeography

One of the earliest descriptions in the scientific literature of biogeography and biogeographic patterns in the marine environment can be found in the work of Edward Forbes. Forbes proposed the idea of zoogeographic provinces, which he described as ‘the core area of distribution of particular species’ (animals), in his 1859 publication *The Natural History of European Seas*. A century later, this idea was taken further by Ekman based on a systematic examination of the patterns of animal distribution in the marine environment. His work, published in English as ‘Zoogeography of the Sea’ in 1953, and that of Briggs (1944) who proposed regions and provinces, laid the foundations of marine biogeography.

Much of this early work was based on the distribution of fishes, but other taxa (e.g. molluscs, algae, crustaceans, ophiuroids) have since been studied to identify marine areas where there are high levels of endemism and hence define biogeographical boundaries. Briggs (1944) identified provinces on the basis of having at least 10% endemism and Earll & Farnham (1983) refer to endemism rates of over 25% as beginning to suggest where there is sufficient difference in speciation to be designated a biogeographic province. Whilst boundaries were initially proposed largely on the basis of very limited information more recent studies have analysed distribution data in a variety of ways to provide a more extensive assessment of endemism (e.g. van den Hoek, 1975).

Another development has been the move from coastal to offshore areas. Much early work was concerned with shelf areas starting with Hayden *et al* (1984) but this was extended by Longhurst (1998) who proposed a biogeographic classification based on oceanographic data, aimed mainly at pelagic systems. Biogeographic classifications have also been proposed for the deep sea most recently by UNESCO (2009) and by Watling *et al* (2013).

For the purposes of conservation biogeography Spalding *et al* (2007) refined existing classification systems to distinguish Marine Ecoregions of the World (MEOW). This global biogeographical system for coastal and shelf areas is based on biodiversity and is a mosaic of existing recognised spatial units. The authors describe it as a hierarchical system based on taxonomic configurations, influenced by evolutionary history, patterns of dispersal and isolation. There are 12 realms, 62 provinces and 232 ecoregions (Figure 2). In this system, the waters around the British Isles are part of the Temperate Northern Atlantic realm, Northern European Seas province, and are classified into 3 ecoregions; the Faroe Plateau, the North Sea, and the Celtic Sea. More recently Briggs & Bowen (2012) have proposed bringing together the warm temperate and tropical regions in each ocean basin into a single warm region, to better reflect close phylogenetic relationships.

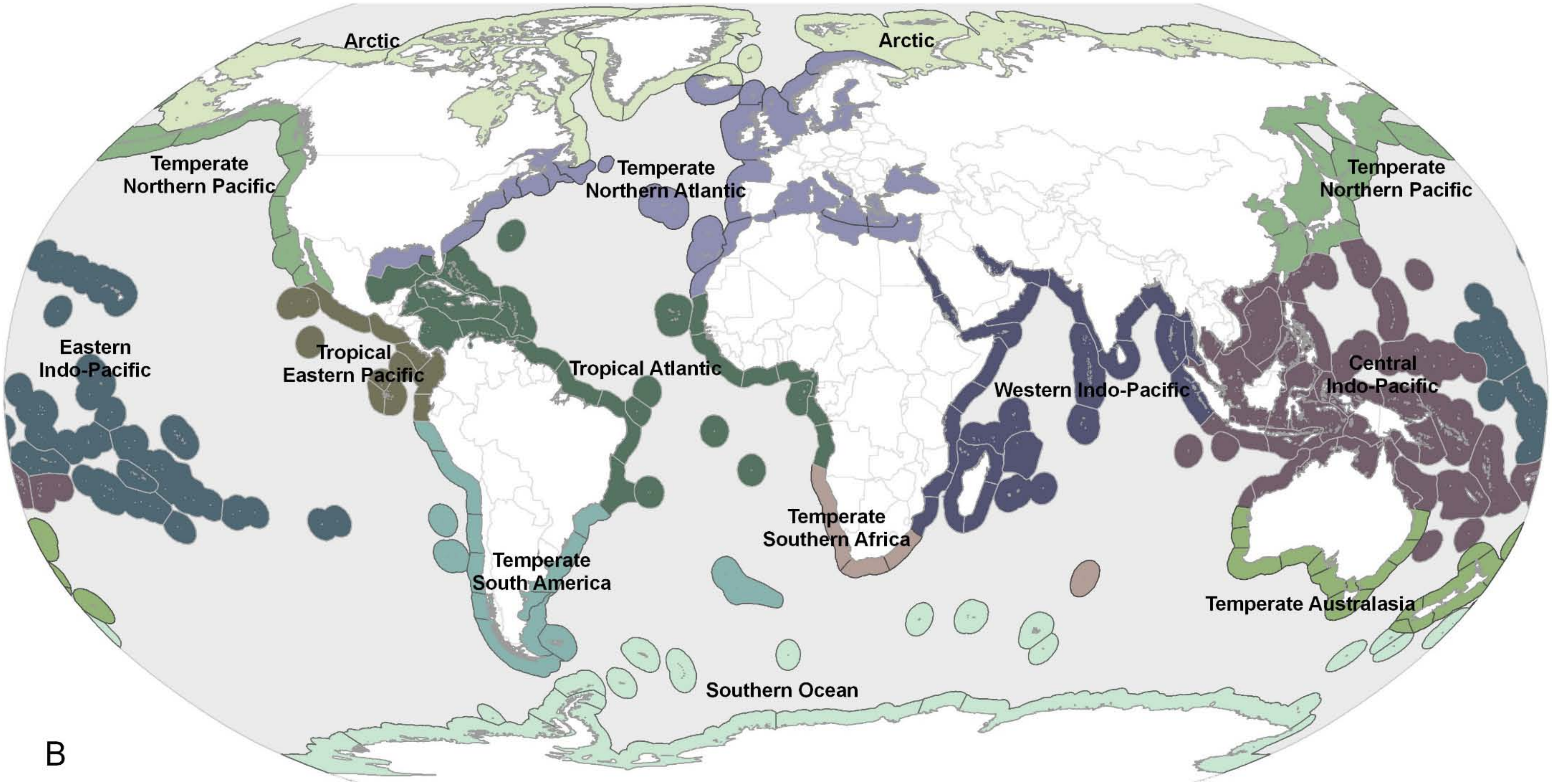


Figure 2. Marine Ecoregions of the World (from Spalding *et al* 2007)

At a regional level a review of biogeographical distribution patterns for the North East Atlantic (Dinter 2001; Figure 3) has provided context for the work of the Oslo/Paris Commission (OSPAR), including its assessment of the sufficiency of the MPA network in the OSPAR Maritime Area). This classification has informed UK considerations of how biogeography can help assess MPA networks. There are also UK specific classifications such as those used for report on the state of UK seas (e.g. Defra 2005). These are described in more detail in Section 5.1.

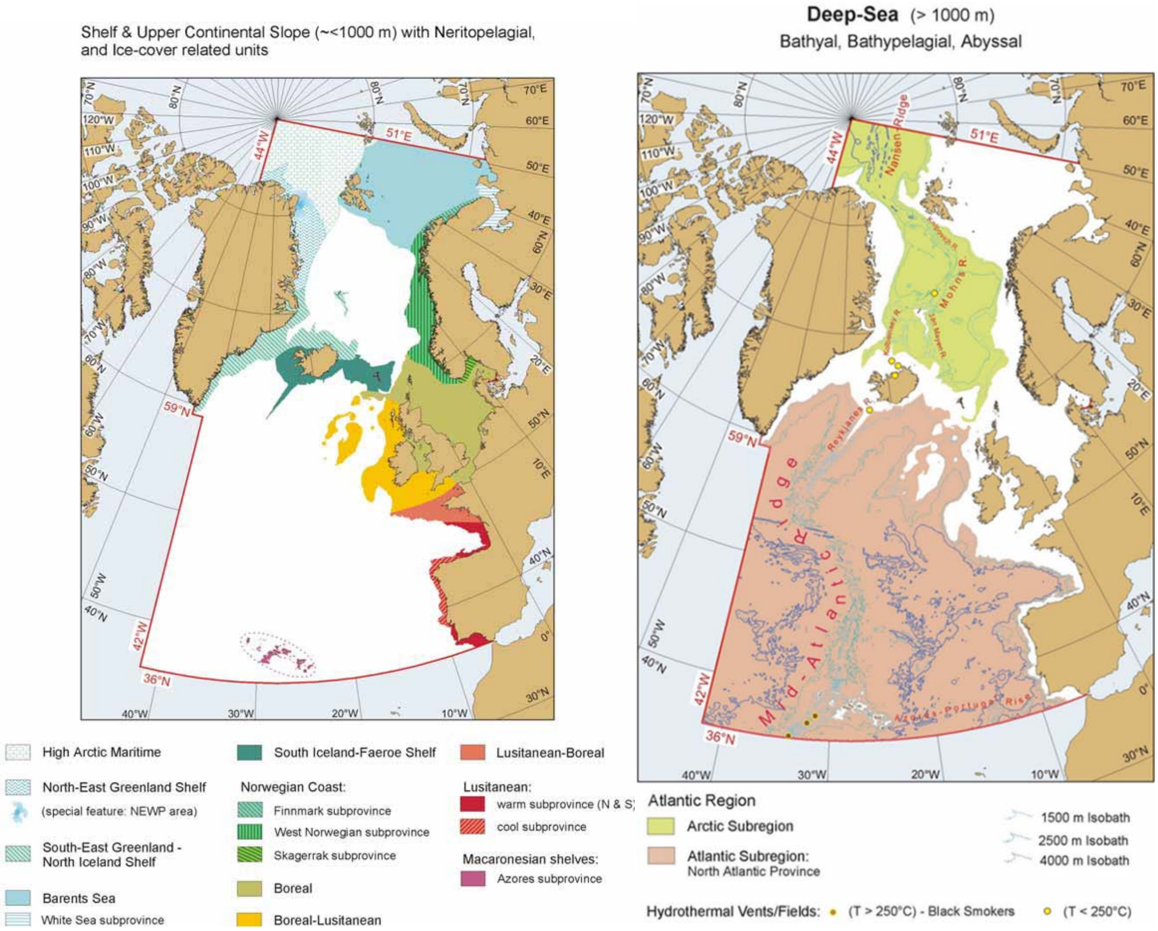


Figure 3. Biogeographic classifications proposed by Dinter (2001) for the shelf, upper continental slope, and deep sea of the OSPAR Maritime Area (Figures 105 & 107 from Dinter 2001)

2.3 Marine biogeography and MPA networks

An understanding of biogeography is being used to inform the design and assessment of MPA systems around the world; from polar oceans to tropical seas and from the continental shelf to the deep ocean floor. One of the earliest at a global scale was the work co-ordinated by IUCN in the 1990's leading to the publication of four volumes *"to provide a basis for development and implementation of a global system of MPAs to protect and manage representative examples of the world's rich marine biodiversity".* This brought together information on the location of existing and proposed MPAs in 18 biogeographic regions, supporting information for each of the regions including an overview of the regional marine biodiversity and biogeography particularly as they relate to MPAs, and identification of further information required for a network of MPAs to cover each region's marine biological and geographic diversity (Kelleher *et al* 1995).

At a national level there are well known examples of biogeography being a consideration in MPA programmes (e.g. Dudley & Parish 2006; Kendall & Poti, 201; Turpie *et al* 2000). They include programmes in Australia, Canada, New Zealand, USA, as well as less frequently cited examples from the Caribbean, South Africa, American Samoa, and the Southern Ocean. As well as using biogeography as a framework for site selection and assessment, these and other MPA programmes have also highlighted issues that arise. They include the effects of scale, climate-forced shifts in biogeography, the challenges of assessing MPA networks that span biogeographical gradients, the scope for using physical environmental data where taxonomic data are unavailable to define biogeographic boundaries, and how to take account of both benthic and pelagic environments (e.g. Allen 2008; Mueter F.J. & Litzow, M.A. 2008; Hamilton *et al* 2010; Rice *et al* 2011). Approaches to tackling these and other relevant issues are often interconnected. The role of biogeography in network design and assessment including ways of addressing issues such as these are reviewed in Section 3.

3 Biogeography and network design/assessment principles

The ecological criteria used to select individual MPAs are typically focused on critical and typical habitats as well as threatened habitats and species (e.g. Salm & Price 1995). For offshore and deep sea areas the CBD refers to these as ecologically and biologically significant areas (CBD Decision IX/20, Annex 1). In recent years there has also been a recognition of the role MPA networks as a 'scaling up' of conservation as well as introducing the concept of resilience (UNEP-WCMC 2008).

The five principles being used to underpin an ecologically coherent network of MPAs in the UK are based on OSPAR (2006) (Box 2). They are very different constructs describing ecological concepts such as 'connectivity', decision processes such as 'representativity' and 'management' which is a human activity. Our underpinning knowledge and understanding of these principles and how best to apply them also differs. Less is known about how to apply the principle of connectivity for example than how to identify features which could be the focus of conservation action. The role of biogeography in relation to each of these network design principles is reviewed below.

Box 2. Summary of network design principles agreed by OSPAR and being used by the UK to assess the ecological coherence of its network of MPAs

Features: Sites should represent the range of species, habitats and ecological processes in the area. The proportion of features included in the MPA network should be determined on a feature-by-feature basis, considering whether features that are in decline, at risk or particularly sensitive are of a higher priority and would benefit from a higher proportion being protected by MPAs.

Representativity: To support the sustainable use, protection and conservation of marine biological diversity and ecosystems, areas which best represent the range of species, habitats and ecological processes.

Connectivity: This may be approximated by ensuring the MPA network is well distributed in space and takes into account the linkages between marine ecosystems.

Resilience: Adequate replication of habitats, species and ecological processes in separate MPAs in each biogeographic area is desirable where possible. The size of the site should be sufficient to maintain the integrity of the feature for which it is being selected.

Management: MPAs should be managed to ensure the protection of the features for which they were selected and to support the functioning of an ecologically coherent network.

Defra *et al* 2012

These types of principles can be applied to assess MPA networks at a variety of scales depending on issues such as data availability and the scale of the features being assessed. Further discussion of the question of scale is presented in Section 4.1.

3.1 Features

Selection of sites for the OSPAR network may include some areas that are selected to best represent the range of species, habitats and ecological processes in the OSPAR Maritime Area. (OSPAR, 2006)

Species, habitats and in some cases ecological processes have been identified as 'features' around which MPA networks are designed and assessed. In the UK these are subject to consultation in Northern Ireland and have been identified for England (JNCC/NE 2010), Wales (WAG 2010) and Scotland (SNH/JNCC 2012) as follows:

- **England:** broad scale habitats, habitat features of conservation importance, low mobility species features of conservation importance, highly mobile species of conservation importance;
- **Scotland:** broad scale habitats, OSPAR threatened and/or declining species (with limited home ranges) and habitats; and
- **Wales:** broad scale habitats, other important habitats, species of conservation concern (NB. the MCZ selection process in Wales is currently under review).
- **Northern Ireland:** Priority marine features for habitats, limited/low mobility species, highly marine features and types of geological and geomorphological features. (NB. currently subject to consultation).

Features may have a very specific role in the site selection process, such as being represented in the MPA network, or have a wider function such as acting as an indicator of ecosystem health. Biogeography is relevant in both cases as it not only influences the distribution of the feature but also the scope for any changes that could come about as a result of introducing particular management measures. Case study 1 (Channel Islands) demonstrates the relevance of taking biogeography into account when trying to determine the effects of protected areas.

Case Study 1: Channel Islands National Marine Sanctuary, USA

The Channel Islands reserve network spans a major environmental and biogeographical gradient over a relatively short distance (100km). Three main biogeographical regions were identified when designing the network of MPAs around the islands and several reserves were placed in each of these. Biogeographic information, using fish community structure data from kelp forests, was used to identify the scale at which sites should be grouped for analysis. This was to ensure that biogeographic differences could be distinguished from potential reserve effects when evaluating the performance of the MPA network. The analysis suggested that for this particular sanctuary the different levels of protection between sites should be compared on an island-scale rather than the three bioregions identified during the design phase of the reserve network which was based on available literature at that time.

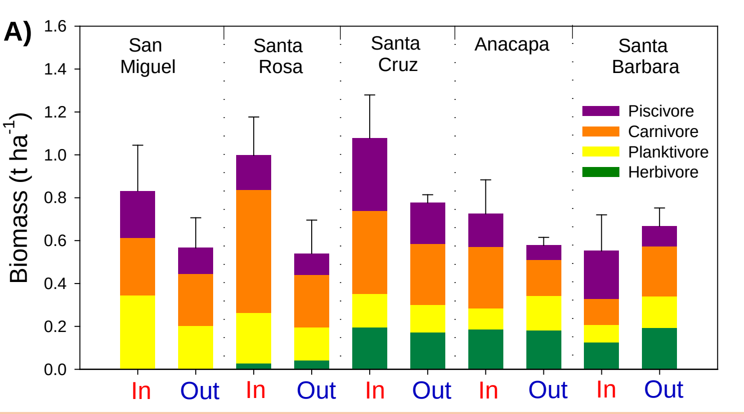


Figure 5: (A) Biomass of different trophic groups of fishes at sites inside and outside reserves on each island in the Channel Islands reserve network. (Fig 5(A) from Hamilton *et al* 2010). Taking biogeography into account it was considered more relevant to compare within island areas as these better reflected biogeographic influences.

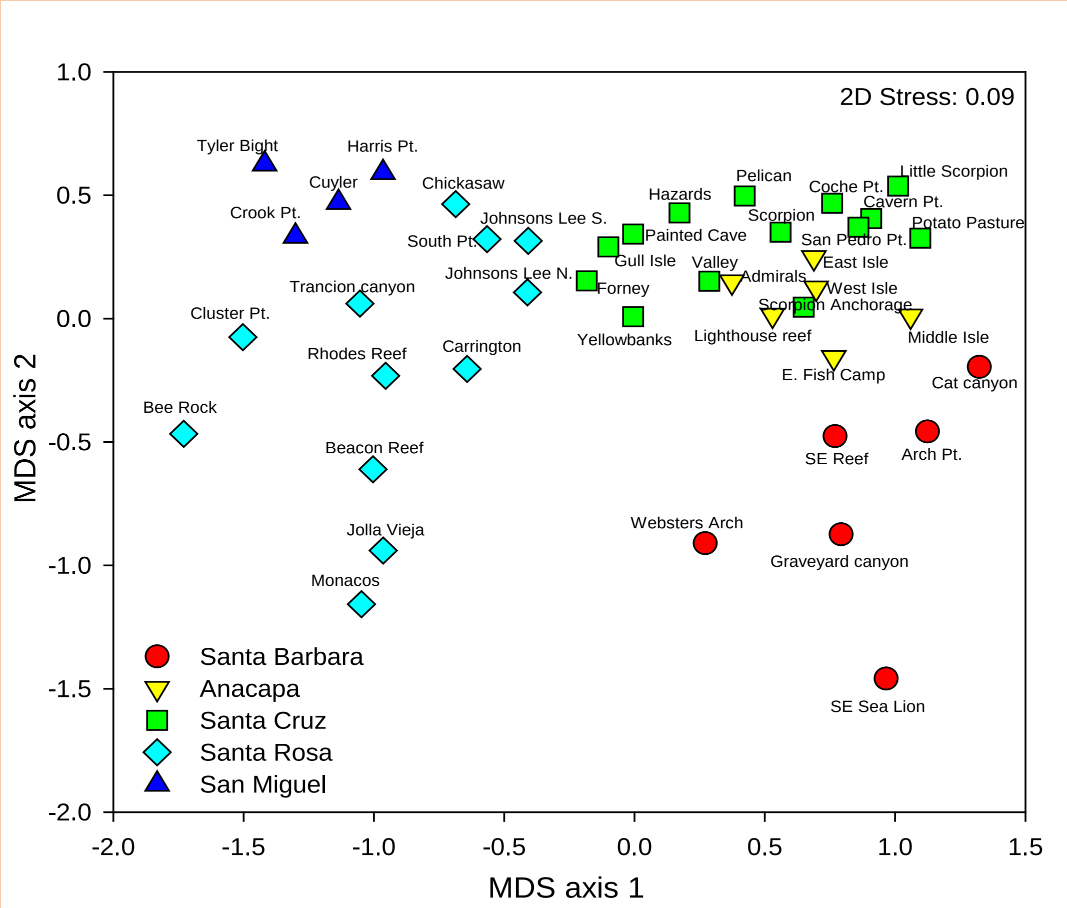


Figure 5: (B) Similarities in fish community structure among survey sites indicated by nonmetric multidimensional scaling analysis of the 30 most common fish species. Most sites group at the island-scale (Fig 2(B) from Hamilton *et al* 2010).

As biogeography is the study of the geographic distribution of species, it is the species and biogenic habitats which are most relevant here. Some will be unique to a particular biogeographic province. Broadly ranging species would occur in more than one province but in general the expectation is to find the same set of species occurring in a given habitat in a given life zone (Allen 1982a&b). Biogeography will therefore influence where MPAs might be established to best represent the range of species, habitats and ecologically process, and demersal fish assemblages as well as grouping of different taxa (birds, cetaceans, fish) have variously been used to define biogeographic regions for such purposes. Another consideration will be the scale which is most relevant for analysis of a particular feature. The importance of this aspect is apparent from the analysis of reef habitats and hotspots for three coral/fish variables within MPAs in America Samoa (Poti *et al* 2011). Reporting at the level of bioregions suggested that these features were adequately represented but, more detailed examination of the two MPAs in Bioregion 1, revealed that they included less than 0.4km^2 of potential reef ecosystem. The vast majority of the area covered by this feature within Bioregion 1 was therefore outside MPAs (Figure 6).

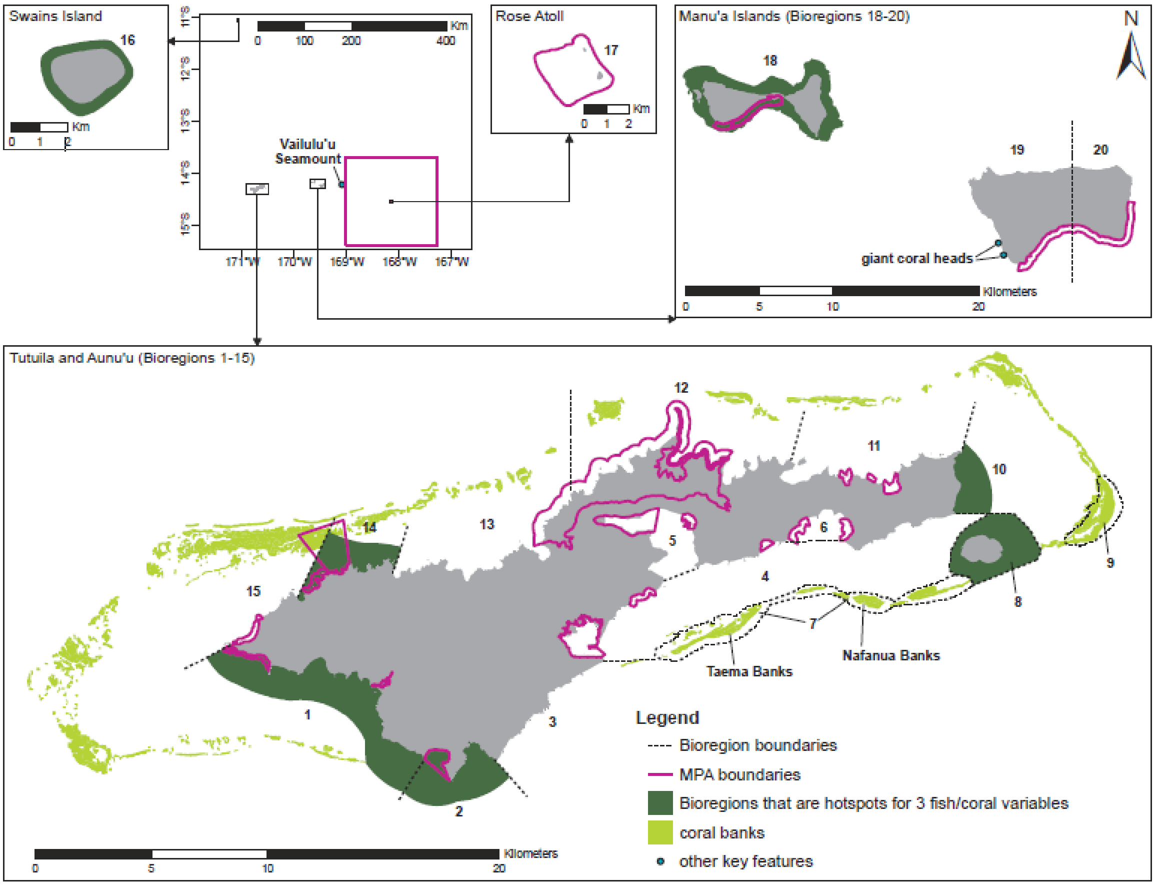


Figure 6. Distribution of existing MPAs relative to the locations of significant ecological features, including Bioregions that are hotspots for three fish/coral variables and the mesophotic coral banks surrounding Tutila, American Samoa (Fig 5.66, Poti *et al* 2011).

More than one level of biogeographical classification (provinces, biomes and large scale geomorphological units) has also been used when determining how to adequately represent features in Australian MPAs (Case Study 6). The issue of scale is discussed further in Section 4.1.

Summary:
Biogeography has been used to provide a reporting framework for features. This is typically done at a larger scale that for the other principles and at more than one level of biogeographical classification.

3.2 Representativity

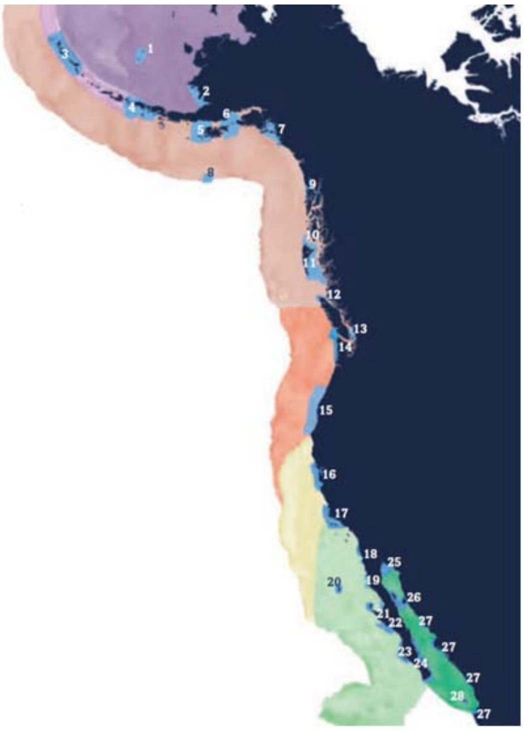
A well accepted approach for planning a representative marine protected areas suite or network is to subdivide the area of marine environment under consideration into relatively homogeneous geographic units displaying similarity among a number of oceanographic and biological elements (biogeographic areas) and, to represent each unit by at least one marine protected area. (OSPAR 2006)

Representativity has been described as including 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, in a network of protected areas (Heap *et al* 2007, Stevens 2002). At a global level, Olson & Dinerstein (2002) identified the need to target representative examples of all the world's biomes within each biogeographical realm where they occur. This is enshrined in the CBD (2008) which advocates the identification and protection of representative examples of all the world's ecosystems. An understanding of biogeography is clearly key to designing a 'representative' network of MPAs and this can be seen in guidance provided by international organisations, Regional Sea Conventions and many national programmes (e.g. UNEP-WCMC 2008; Gabrié *et al* 2012; OSPAR 2006; DoC/Min Fish 2005).

Analysis of 2003 UN List of Protected Areas showed big discrepancies in protection of the world's biomes and minimal coverage of the oceans (Dudley & Parish 2006). For the marine environment both early and more recent analyses reveal uneven coverage by protected areas and lack of representation as measured at a variety of biogeographic scales (Kelleher *et al* 1995; Wood *et al* 2008). The target set by the CBD is for 10% of coastal and marine areas to be conserved by 2020, including through ecologically representative and well-connected systems of protected areas (Aichi target 11).

An example of how representativity has been linked to biogeography in planning MPA networks can be seen in the identification of priority conservation areas along the western seaboard of North America (Figure 7). Although less advanced a similar approach is being taken for MPAs in the Southern Ocean (Case Study 2).

PCA
1 Pribilof Islands
2 Bristol Bay
3 Western Aleutian Islands/Bowers Bank
4 Unimak Pass/Aleutian Islands
5 Western Kodiak Island/Shelikof Strait
6 Lower Cook Inlet/Eastern Kodiak Island
7 Prince William Sound/Copper River Delta
8 Patton Seamounts
9 Glacier Bay/Sitka Sound/Frederick Sound
10 Dixon Entrance/Langara Island/Forrester Island
11 Northern Queen Charlotte Sound/Hecate Strait/Gwaii Haanas
12 Scott Islands/Queen Charlotte Strait
13 Southern Strait of Georgia/San Juan Islands
14 Barkley Sound/Pacific Coastal Washington
15 Central Oregon/Cape Mendocino
16 Central California
17 Upper Bight of the Californias/Channel Islands/San Nicolas Island
18 Lower Bight of the Californias/Islas Coronados
19 Bahia San Quintin/Bahia El Rosario
20 Isla Guadalupe
21 Vizcaino/Isla Cedros
22 Laguna San Ignacio
23 Bahia Magdalena
24 Corredor Los Cabos/Loreto
25 Alto Golfo de California
26 Grandes Islas del Golfo de California/Bahia de Los Angeles
27 Hurnedales de Sonora, Sinaloa y Nayarit/Bahia de Banderas
28 Islas Marias



ECOREGIONS (from north to south, Bering Sea, Aleutian Archipelago, Alaskan/fjordland Pacific, Columbian Pacific, Montereyan Pacific Transition, Southern California Pacific, Gulf of California

Figure 7. Results of workshop which identified ecologically significant regions and Priority Conservation Areas (PCAs) from the Baja California to the Bering Sea (Morgan *et al* 2005).

Case study 2: Biogeography and MPA planning in the Southern Ocean

The designation of MPAs in the Southern Ocean is being taken forward principally through the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) and the Antarctic Treaty through Antarctic Treaty Consultative Meetings (ATCM). In 2005 a CCAMLR workshop agreed on the types and objectives of MPAs, including the need for representative areas (CCAMLR 2005). This was followed by a CCAMLR workshops in 2006 and 2007 with the main aim of advising on a bioregionalisation of the Southern Ocean, including, where possible advice on fine-scale subdivision of biogeographic provinces (Grant *et al* 2006; CCAMLR 2007). Benthic and pelagic systems were considered separately and it was agreed that the definition of appropriate scales would be data-driven but that this would often need to be supplemented with expert advice. The pelagic bioregionalisation considered bathymetric, physical oceanographic and biological data. For the benthic bioregionalisation, bathymetric data, sea floor temperature and currents, geomorphology, sediments and sea ice concentrations were considered important. Biological data were generally restricted to the shelf area and were patchy but it was possible to include some data sets on invertebrate abundance and composition and the presence/absence of finfish. Physical regions were defined first and these were overlaid by the biological data and the classification evaluated.

Using this work eleven priority areas likely to be of particular importance were identified at a circumpolar scale and CCAMLR recommended that Member Countries initiate a process to develop representative systems of MPAs across these areas. Finer scale bioregionalisation has since been developed for the Ross Sea and areas containing functionally important ecosystem processes or habitats identified (Sharp 2011). Three proposals for MPAs (Ross Sea, East Antarctica and Antarctic Peninsula Ice Shelves) have been considered by CCAMLR in 2012 and 2013 but have not been agreed due to objections from two Member Countries.

The analysis carried out by OSPAR (2013) illustrates how biogeography has provided a framework for reporting on representativity in the North East Atlantic (Table 1) and the work by MedPan takes the same approach for the Mediterranean (Case Study 3). National and Regional Sea programmes are therefore typically proposing and reporting on representativity in terms of the geographic area or percentage cover of MPAs in defined biogeographical regions.

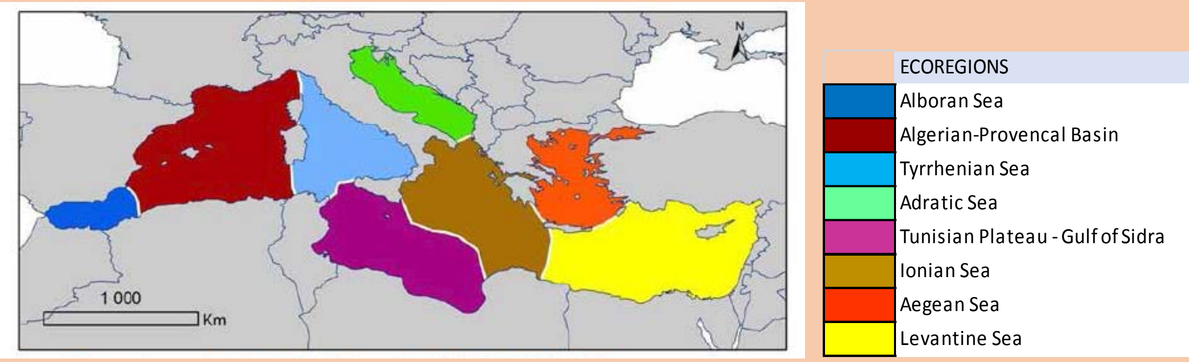
A further consideration in selecting locations which are representative of particular biogeographic regions is the need to recognise that biogeographical boundaries are rarely sharp. Whilst this might suggest the best approach is to select locations well within biogeographic zones, this is not necessarily sufficient. A study on the selection of representative MPAs for the conservation of coastal fish diversity in South Africa suggests that it may be necessary to include locations at zonal boundaries as well as clearly within different biogeographic zones to maximise species representation (Turpie *et al* 2000).

Table 1. Analysis of the representation of the MPA network in the OSPAR Maritime Area based on biogeographic provinces defined by Dinter (2010). The table excludes the Wider Atlantic which was not characterised in the study. Green indicates provinces where the test criteria of at least 3% coverage and 2 or more replicates were met (OSPAR 2013).

Region	Sub-region	Province	Total Area (km^2)	Area protected (km^2)	MPA Coverage (%)	Replicates
(Holo)Pelagic						
Arctic			3 334 941	76002	2.28	7
Atlantic	East Atlantic Temperate	Cool-temperate waters	6 690 666	462 869	6.92	305
Atlantic	East Atlantic Temperate	Cool-temperate waters	3 522504	146 940	4.17	45
Shelf and Continental Slope						
Arctic		North-East Greenland Shelf	277 879	0	0	0
Arctic		Northeast Water Polynya	71 845	0	0	0
Arctic		High Arctic Maritime	809 874	11 036	1.36	4
Arctic		Barents Sea	1 258 371	67 285	5.81	6
Arctic		South East Greenland - North Iceland Shelf	425 600	0	0	2
Atlantic	East Atlantic Temperate	Norwegian oast (Finnmark and Skagerrak and West Norwegian)	413 698	4 688	1.13	13
Atlantic	East Atlantic Temperate	South Iceland-Faeroe Shelf	306 382	156	0.05	9
Atlantic	East Atlantic Temperate	Boreal	710 185	55 823	7.86	210
Atlantic	East Atlantic Temperate	Boreal-Lusitanean	455 947	39 882	8.75	73
Atlantic	East Atlantic Temperate	Lusitanean-Boreal	151 202	16 844	11.14	24
Atlantic	East Atlantic Temperate	Lusitanean (Cool and Warm)	118 277	3 972	3.36	14
Atlantic	East Atlantic Temperate	Macronesian Azores	22 545	812	3.6	4
Deep Sea						
Arctic			2 235011	0	0	0
Atlantic			6 995 818	483 218	6.91	23

Case study 3: Reporting on the Status of the MPA network in the Mediterranean

Progress towards establishing an ecological network of MPAs in the Mediterranean was assessed by MedPAN[1] in collaboration with the Regional Activity Centre for Specially Protected Areas (RAC/SPA) in 2012. Some of the data were presented at an ecoregional level revealing differences in progress towards achieving representativity across these biogeographical regions. Outputs include, number of MPAs, surface area coverage and management type in each of the 8 ecoregions of the Mediterranean. In the case of the former, figures are provided both with and without taking into account the Pelagos marine reserve, a large MPA that has been established for the conservation of marine mammals (see figures below). The analysis reveals disproportionate geographical distribution of MPAs across the Mediterranean, very variable representativity of ecological sub-regions, habitats and species, and that the Aichi target of protecting at least 10% of marine and coastal waters is far from being achieved. The data collected for this analysis have been incorporated into the MAPAMED database to facilitate future analysis.



	Number of MPAs	By % of total number	% ecoregion surface (without Pelagos)	% ecoregion surface (with Pelagos)	% Surface/MPA per ecoregion (without Pelagos	% Surface/MPA per ecoregion (with Pelagos)	Number of MPAs being planned
Alboran Sea	10	6.49	1.05	1.05	4.89	0.86	
Algerian-Provencal Basin	59	38.31	1.42	12.55	39.32	60.94	4
Tyrrhenian Sea	18	11.69	0.91	12.51	12.75	30.66	1
Adratic Sea	17	11.04	0.42	0.42	3.05	0.54	
Tunisian Plateau - Gulf of Sidra	9	5.84	0.13	0.13	2.95	0.52	2
Ionian Sea	11	7.14	0.28	0.28	6.22	1.09	
Aegean Sea	10	6.49	2.35	2.35	24.57	4.31	
Levantine Sea	20	12.99	0.21	0.21	6.25	1.1	7

Figure 8: Ecoregions according to UNEP-MAP-RAC/SPA, 2010 and Table showing distribution of MPAs per ecoregion **(**Figure 19 and table 11 From Gabrié et al 2012).

Summary:
Biogeography has been considered both proactively for site selection and as a reporting framework for MPA network analysis. Most examples fall into the latter category with figures provided on number, area and percentage cover for different biogeographic regions. In some cases the assessment is cross-referenced to Aichi target 11 (10% protected area coverage).

[1] http://www.medpan.org/en;jsessionid=CA3F23E9EC2C133552D4071111188E8C

As biogeographical boundaries are rarely sharp it may be necessary to include locations at zonal boundaries as well as clearly within different biogeographic zones to maximise species representation.

3.3 Connectivity

Connectivity between different MPAs enables the mutual support of MPAs within the network and will contribute to providing ecological coherence in a network through the consideration of ecological connections between marine areas. (OSPAR 2006)

The design and assessment of the connectivity of MPA networks is complex given that it can operate on many scales, differ according to the species being considered, and be influenced by numerous variables such as currents, larval characteristic and suitability of downstream habitat (Treml *et al* 2007). The patterns of distribution observed through the study of biogeography are influenced by connectivity hence its relevance to MPA networks and the question of how the principle of connectivity might be incorporated into MPA design and assessment is the subject of research and discussion (e.g. Palumbi 2003; Gaines *et al* 2010). Guidance has typically been based on modelling, incorporating what is known about the dispersal characteristics of particular species and hydrographic conditions (e.g. Roberts 2011; Berglund *et al* 2012; Andrello *et al* 2013; Gallego *et al* 2013).

Rice *et al* (2011) highlight the importance of considering biogeography when designing connectivity into MPA networks as most species should be responding to the same dominant environmental drivers within such ecologically meaningful units. They also consider that the predator/prey and competitive links are likely to be stronger within such units than between them.

The connectivity of MPA networks has been considered in a variety of ways at both design and assessment stages but is most often expressed as distances between MPAs in the network (e.g. Palumbi 2003). Biogeography may be mentioned when discussing connectivity within an ecoregion or, at a finer scale within particular habitat types. MPA design for the Lesser Sundra Ecoregion of Indonesia is an example of the former (Wilson *et al* 2011) and analysis of Baltic MPAs illustrate both approaches. HELCOM (2006) provide data on the connectivity of MPAs within the different Baltic Sea basins, as well as reporting on the connectivity between five benthic marine landscape types with reference to the dispersal patterns of five species (Baltic tellin (*Macoma baltica),* Turbot *(Psetta maxima),* Black carrageen *(Furcellaria lumbricalis),* Baltic isopod *(Idotea baltica),* and Bladderwrack *(Fucus vesiculosus)*) (HELCOM 2010).

As there is limited understanding of connectivity within or between biogeographical regions for many species, this type of analysis is usually very limited. A further layer of complexity is that the biogeographical patterns seen today may still be some reflection of past conditions. For example there is research which suggests that in some cases the distribution of adults may reflect biogeographic patterns in historical ocean basins rather than be a strict association between the current dispersal potential and movement of planktonic larvae (Case Study 4).

Case study 4: Connectivity and historical biogeography

The genetics of populations of mantis shrimp from 11 reef systems in Indonesia, in which 36 MPAs are presumed to be connected by strong ocean currents were studied by Barber *et al* (2000). Results reveal strong regional genetic differentiation that mirrors separation of ocean basins during the Pleistocene. Ecological connections are rare across distances as short as 300-400km, even though the species of mantis studied has a 4-6 week planktonic larval period, with a dispersal potential around 600km.

The sharp genetic break that was observed, a potential marine equivalent of Wallace's line suggests that biogeographic history also influences contemporary connectivity between reef ecosystems in this area. This is despite 6-10,000 years of modern oceanographic conditions. The researchers conclude that reef populations throughout Indonesia cannot simply be assumed to be interconnected units and that MPAs need to be designed that also take biogeographic and historical oceanography into account.

Summary:
Biogeographical patterns have been referred to when considering the design and assessment of the connectivity of MPA networks but usually only to provide a framework for reporting. Biogeography is a reflection of connectivity rather than *vice versa*.

3.4 Resilience

Resilience is the ability of an ecosystem to recover from disturbances within a reasonable timeframe. Components of resilient MPA networks include effective management, risk spreading through the inclusion of replicates of representative habitats, full protection of refugia that can serve as reliable sources of seed for replenishment, and connectivity to link these refugia with vulnerable areas within the network (IUCN 2003)(OSPAR 2006).

The need to build resilience into protected areas has received greater attention in recent decades because of the scale of human pressure on terrestrial and marine systems and the predicted effects of climate change (Glicksman & Cumming 2012). The benefits in relation to climate change, for example, include reducing risk, providing corridors for shifting species and habitats, and serving as sentinel sites to monitor changes (NOAA 2013). Resilience is influenced by institutional, economic social and ecological factors. In the latter case, there is a link with other MPA network design criteria because replication, as well as biological and ecological connectivity between protected areas, are often cited as important elements of a resilient MPA network (IUCN-WCPA 2008).

There appears to be little direct consideration of biogeography in designing resilient MPA networks at the present time with the exception of the scope for resilience to be enhanced through replication of MPAs. This is possibly because resilience is influenced by the health of the wider environment as well as the health of the environment within a particular MPA and therefore where much effort is being focused (e.g. the EC Marine Strategy Framework Directive). It is however being addressed to some extent through the number of examples of a feature within MPA networks and the connectivity of MPAs within biogeographic regions (see Section 3.3).

Summary:
Biogeography is recognised as being relevant to building resilient MPA networks but, to date, it is a concept which is mostly being taken into account through representativity and connectivity.

3.5 Management

OSPAR MPAs should be managed to ensure the protection of the features for which they were selected and to support the functioning of an ecologically coherent network (OSPAR 2006).

Rice *et al* (2011) promote the need to consider biogeography in implementing an ecosystem-based approach to management. They set out three major areas where this is likely to be particularly useful; using biogeographic regions as a framework for assessing status, trends and threats; for ecosystem-based management of human activities; and as a basis for research, forecasting and proactive management. The following are examples of how each of these applications have been used in relation to MPAs:

- providing a reporting structure for MPA management measures in countries which span more than one biogeographic area or across a regional sea. E.g. New Zealand (Case Study 5) and the Mediterranean;
- providing the framework for MPA governance structure e.g. using bioregional MPA network planning teams of federal and provincial/territorial government representatives in Canada who will also engage with other interested parties; and
- informing site specific changes to MPA management such as the review of boundaries of the Channel Islands Marine Sanctuary.

Case Study 5: Biogeography as a reporting framework for management measures

New Zealand policy aims to protect representative examples of the full range of marine habitats and ecosystems, as well as outstanding, rare, distinctive, internationally or nationally important marine habitats and ecosystems. A hierarchal classification nests broad combinations of depth, substrata and exposure within the estuarine and marine environments in 14 marine biogeographic regions (bioregion).

Protection Standard was developed to assess which management tools offered sufficient protection and the findings collated and presented for each bioregion. Table 2 shows the area and percentage of individual habitat types protected within Type 1 & Type 2 MPAs for the Southern South Island bioregion (New Zealand Government 2011).

Table 2. Area of Habitats in MPAs in each Coastal/marine bioregion (from Appendix 4. NZG 2011)

Southern South Island km^2	Type 1 Marine Reserve	Notake Marine Park	Cable or Pipeline Zone	No Trawl, danish seine, dredge or setnet	No trawl, danish seine, dredge	Total Type II MPA	Total no take	Total MPA	Total habitat in bioregion
Deep Sand									7899.5
High Current Deep Sand	0.07			0.23		0.23	0.07	0.31	2593.2
Upper Slope									2194.9
Deep Gravel									1259.8
Exposed Shallow Sand									1221.3
High Current Deep Gravel	0.002			0.18		0.18	0.002	0.18	1161.8
Moderate Shallow Gravel									1031.4
Moderate Shallow Sand									700.6
Deep Mud									528.0
High Current Shallow Sand	1.00			5.22		5.22	1.00	6.22	459.2
High Current Shallow Gravel	0.16			0.74		0.74	0.16	0.91	454.0
Exposed Shallow Reef									214.9
Shallow Mud									172.9
Biogenic				4.08		4.08		4.08	157.0
High Current Shallow Reef	0.94			1.02		1.02	0.94	1.96	144.3
Exposed Shallow Gravel									141.7
Moderate Shallow Reef									123.1
Mudflat				6.85		6.85		6.85	99.2
Estuarine Sand	3.04			12.11		12.11	3.84	15.95	75.7
Deep Reef									69.2
Estuarine Sand									44.5
Estuarine Reef	1.56			15.00		15.00	1.56	16.57	44.3
Estuarine Gravel	0.69			19.51		19.51	0.69	20.20	38.7
High Current Deep Reef									31.3
Estuarine Mud	2.45			23.17		23.17	2.45	25.63	26.3
Sheltered Shallow Sand									24.8
High Current Beach									24.3
Exposed Beach									12.0
Moderate Beach									11.4
Exposed Rocky Shore									9.4
Sheltered Shallow Reef									5.8
Estuarine Beach	0.02			0.53		0.53	0.02	0.55	3.4
Moderate Rocky Shore									3.3
High Current Rocky Shore									1.7
Sheltered Shallow Gravel									1.0
Sheltered Beach									0.5
Estuarine Rocky Shore	0.01			0.06		0.06	0.01	0.07	0.4
Sheltered Rocky Shore									0.1

Apart from providing a framework for reporting, an assessment carried out for the Channel Islands National Marine Sanctuary, USA (CINMS), illustrates how biogeography can be used to inform management decisions at a site level. The CINMS was established in 1980. In 2003, as part of the routine review and revision of the management plan, consideration was given to the need for any changes to the sanctuary boundary in light of improved information. Six options were put forward and these were subsequently evaluated from a biogeographic perspective covering invertebrates, fishes, birds, mammals and the physical setting (Clark *et al* 2005). The conclusions will be used to inform any decision-making on sanctuary boundary changes by the National Marine Sanctuary Program.

Summary:
Biogeography has been used to provide a structure for reporting on the management of MPAs but this is mostly at a very general level e.g. no-take or multiple use areas. It has been used to inform the development of coherent management measures for both individual MPAs and MPA networks.

4 Significant issues

4.1 Scale

Biogeography is typically described using a hierarchical system of classification. At the top of the hierarchy are biogeographical realms which may extend over thousands of square kilometres of the global oceans. At the other end of the spectrum are ecosystems and communities. These are also manifestations of biogeography, but they may be limited to very small areas, perhaps less than 1km^2 in extent. In New Zealand, for example, coastal biogeographic regions are defined at the meso-scale (100s to 1000s of km). Habitats and ecosystems are defined at the micro-scale (100s to 1000s of metres). For deep waters the scales are meso (100s to 1000s km) and habitats and ecosystems at the local scale (10s to 100s km) (New Zealand Government 2011).

Conservation planners need to determine the most appropriate level and scale at which to consider biogeography when assessing MPA networks. Many factors will influence this decision and, in practice, different levels have been used to address different questions (Hoekstra *et al* 2005; Jepson *et al* 2005).

Ladle & Whittaker (2011) give some examples of the scales and levels of biogeographical classification that have been used for particular purposes such as the identification of priority areas and site-specific monitoring e.g. mapping scales of >1:10,000,000 for Ecoregions and >1:10,000 for marine habitat classes. Case study 6 illustrates how this has been applied in practice in Australia.

Case study 6: Bioregionalisation in Australia; the use of biogeographical classifications at different scales for MPA network design

Australia has been developing a biogeographic classification as the basis for planning a system of MPAs since the 1980s. In 2006, the schemes developed up to that time for inshore waters (the Interim Marine & Coastal Regionalisation of Australia- IMCRA v3.3) and for offshore areas (the National Marine Bioregionalisation- NMB) were combined to produce the Integrated Marine and Coastal Regionalisation of Australia (IMCRA v4.0) (DEH 2006). The combined scheme, which has both a benthic and pelagic component is intended to capture spatial patterns in the distribution of species and habitats at different scales (Table 3), as well as incorporating information about patterns and process which occur at different spatial scales (Figure 10).

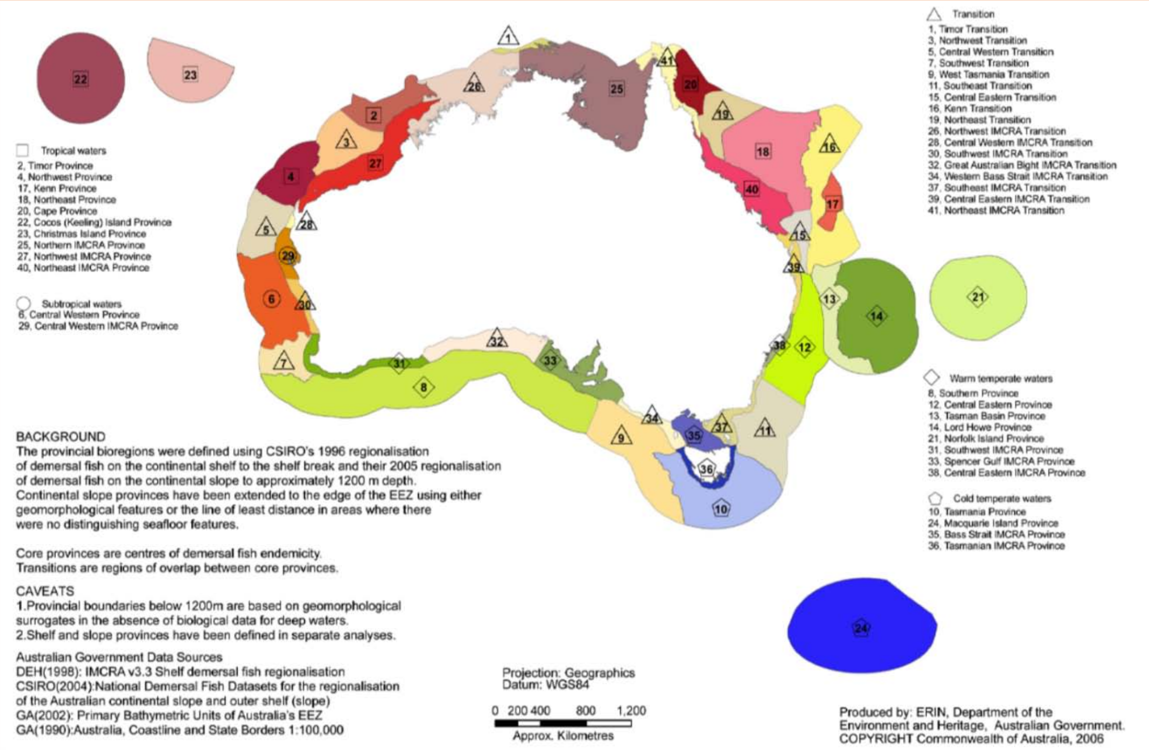


Figure 10. Map of the 24 Provincial bioregions defined around Australia based on provincial structure in the demersal fish data, where available and then by geomorphology (from Department of the Environment and Heritage 2006 © Copyright Commonwealth of Australia 2006).

Table 3. Hierarchical framework for the draft Benthic Marine Bioregionalisation in Australia (Table 1.1 from Heap *et al* (2005).

Name	Description	Indicative Area
Ocean Basins	Provide biogeographic and evolutionary context with origins dating back to the separation of Gondwana	> 100,000 km^2
Ocean Climate Zones	Contemporary modifiers of biogeographic distributions and evolutionary traits of benthic marine faunal assemblages	> 100,000 km^2
Primary Bathymetric Units	Regional scale bathymetric features and benthic marine faunal distributions of slope, rise and abyssal plain	> 100,000 km^2
Provincial Bioregions	Large biogeographic regions principally based on the broad-scale distribution of benthic marine fauna	10,000 - 100,000 km^2
Biomes (slope only)	Biogeographic regions based on benthic marine faunal communities, some with narrow spatial distributions and depth ranges. These units have only been defined on the slope due to available data	<1,000- 10,000 km^2

Representativity across the MPA network is being built in at the mesoscale and at the level of geomorphic features. To assist stakeholders ‘broad areas of interest’ have also been identified as places to focus as they include examples of the full suite of geomorphic features for the region. The guidance for stakeholders recommends the selection of 2-3 MPAs within each province that target the full range of biogeomorphological features in that region by focusing on these broad areas of interest.

For the benthic bioregionalisation there are three key layers of information in IMCRA v4; provinces that reflect biogeographic patterns in distributions of bottom-dwelling fish; meso-scale regions on the continental shelf using regional biological and physical information; and geomorphic units defined by clustering geomorphic features. There is also a hierarchical framework for regionalising the pelagic marine system which defines 25 offshore water masses and, for ten of these, the inherent circulation regimes.

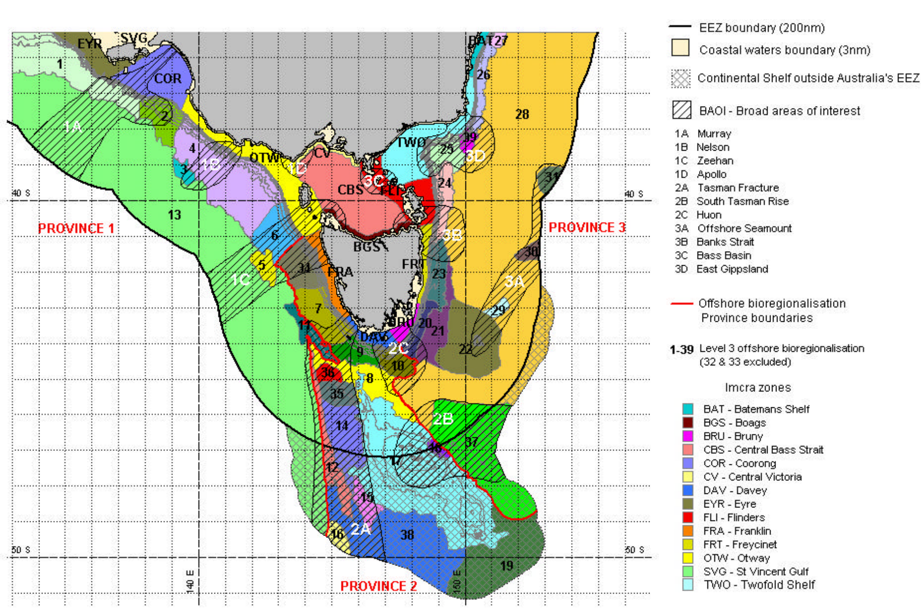


Figure 11. S.E. Marine Region of Australia showing the provincial bioregions, and Broad Areas of interest. The guidance for stakeholders recommends the selection of 2-3 MPAs within each province that target the full range of biogeomorphological features in that region, by focusing on the Broad Areas of Interest (from Department of the Environment and Heritage 2003 © Copyright Commonwealth of Australia 2003).

The literature reviewed for this report show that when considering biogeography, representativity has been assessed over levels from the macro to micro scale, and features from the meso- to micro scale. Resilience has rarely been examined directly in terms of biogeography but rather through representativity and therefore at a macro to micro scale.

Connectivity is mostly an issue within biogeographic regions as connectivity helps determine biogeographic patterns rather than *vice versa*. Biogeography is therefore generally not a major part of assessments of connectivity. Management measures to protect links are likely to be most effective when applied at the scales of the links, with the finer scale perhaps being most appropriate to accommodate interactions among species (Waltner-Toews *et al* 2008). However, where MPAs are being promoted for a variety of species and habitats it seems unlikely that all the relevant scales of connectivity can be taken into account in addressing siting and replication (Gallego *et al* 2013). Furthermore, whilst there is a growing understanding of the elements of connectivity and how they might contribute to the design of MPA networks (Palumbi 2003), few species have been studied in detail.

Biogeographical patterns at many scales from macro to micro are relevant to management and indeed Rice *et al* (2011) consider that flexibility of using biogeography at different scales is essential to enable management measures to be developed at scales that are both ecologically meaningful and appropriate to the management needs. The Channel Islands National Marine Sanctuary (Case Study 1) shows how this has worked in practice by analysing reserve effects at an island scale rather than the larger bioregions used to design the representative network (Hamilton *et al* 2010).

The literature review confirms that there is no single ‘correct’ biogeographic scale on which to base MPA design and assessment with different scales or combinations of scales being used.

4.2 Data limitations

The limitations of data underpinning biogeographical classifications has always been an issue. This was recognised by Wallace in the 19th century when he started to define biogeographic zones and it is still pertinent today. Murray *et al* (1980) note that “biogeographical studies have always been plagued by the necessity of interpreting distributional data which may be incomplete or affected by different levels of taxonomic study”. There is also a complexity of data to analyse (e.g. across many taxa). Whilst GIS based assessment tools such as Spatial Analysis and Resource Characterization (SPARC) and Marxan (NOAA 2012; Ball *et al* 2009) can handle large amounts of data they also drive the demand for data to improve models. Against this background national, regional and international assessments are working with available data, recognising its limitations, and refining them over time.

Dealing with data gaps is routine when working in the marine environment and there are a variety of ways in which this can be tackled. In the case of biotope distributions for example, the use of proxies such as physiographical and physically distinct habitats has been suggested by Abdulla *et al* (2009) for the deeper parts of the Mediterranean where patterns of community wide endemism may not be known for some time. Predictive habitat models are also increasingly being used to give an overview of potential distribution. EUSeaMap[2] which covers over 2 million sq km of the European seabed is an example of this (Figure 12). The map was developed by bringing together habitat models for a number of sea areas in the EU, including waters around the UK which were covered by the UKSeaMap project and using the European Union Nature Information System (EUNIS) habitat classification, both of which are discussed further in Section 5.1. Data layers used for the model include seabed substrate, energy at the seabed, biological zone and salinity at the seabed. Confidence layers are also produced to demonstrate the level of certainty across the study area (Cameron & Askew 2011).

[2] http://jncc.defra.gov.uk/page-5534

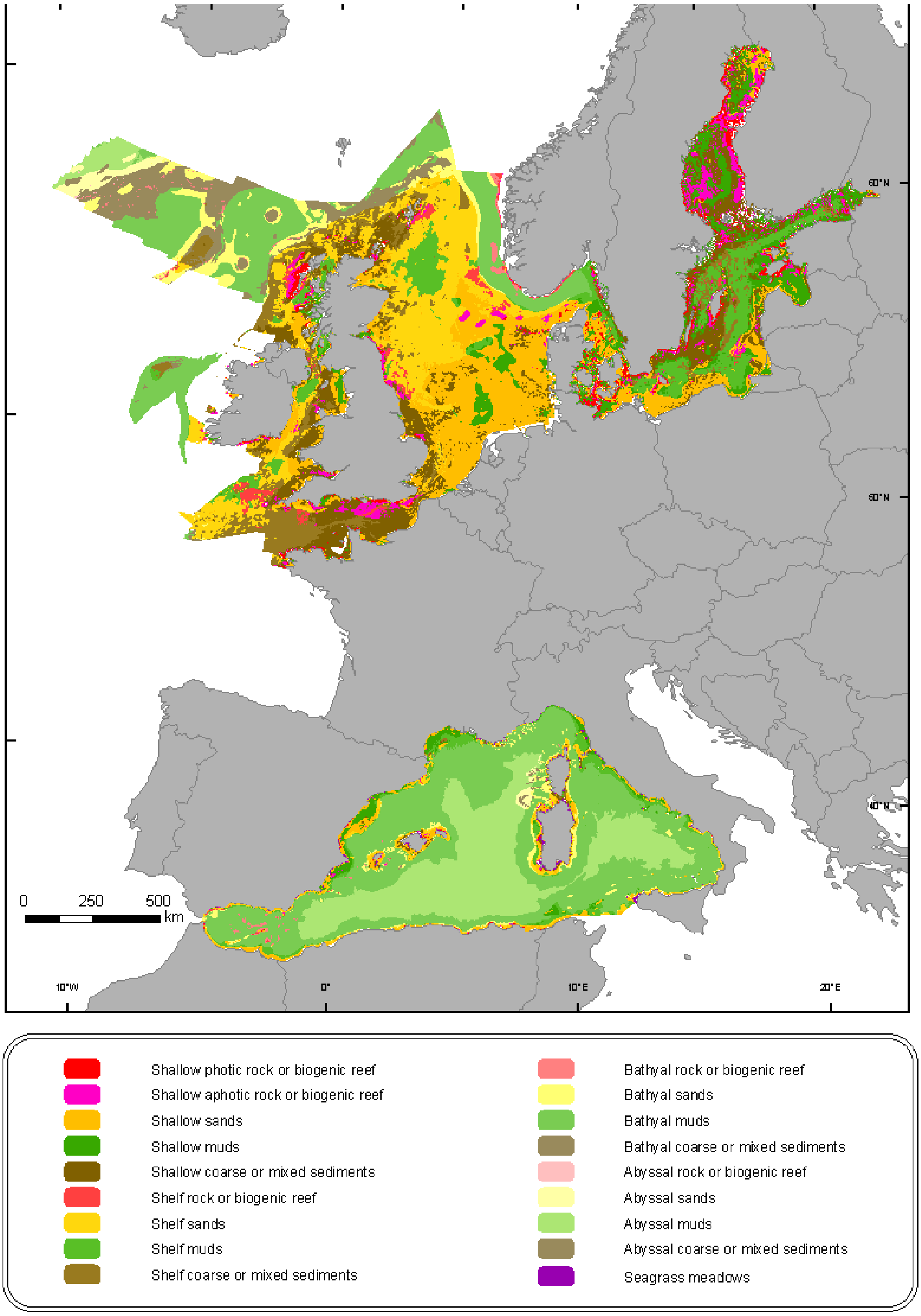


Figure 12. EUSeaMap Aggregated version of the modelled maps from different sea basins. This presentation of the maps, based on substrata and biological zone information, shows how consistent maps might be achieved for very high level visualisation of habitats across Europe. Areas without substrata data have been omitted from this representation (Cameron & Askew 2011).

For deep sea and offshore areas where there is usually greater uncertainty, a recent development is the generation of 'Habitat Suitability Models' (HSM) which aim to predict the likely distribution of the deep water species (in this case cold water corals) by linking known distribution data with a set of environmental variables (Davies & Guinotte 2011). More recently Rengstoft *et al* (2013) refined this for the Irish continental shelf margin, Rockall Bank and Porcupine Bank, using the high resolution multi-beam data collected for the Irish National Seabed Survey. Their study used twenty nine environmental predictor variables to predict the distribution of cold water corals *Lophelia pertusa* reef at a spatial resolution of 0.002°. The authors note that the higher resolution and quality controlled data set has reduced overestimates of the extent of the habitat, which can happen at the global scale analysis, and have illustrated how the outputs can support MPA network design (Figure 13). For example on the basis of their HSM they predicted that only 2% of the study area was likely to be suitable habitat for *L.pertusa* reef, and that existing Special Areas of Conservation only account for 10% of this predicted distribution.

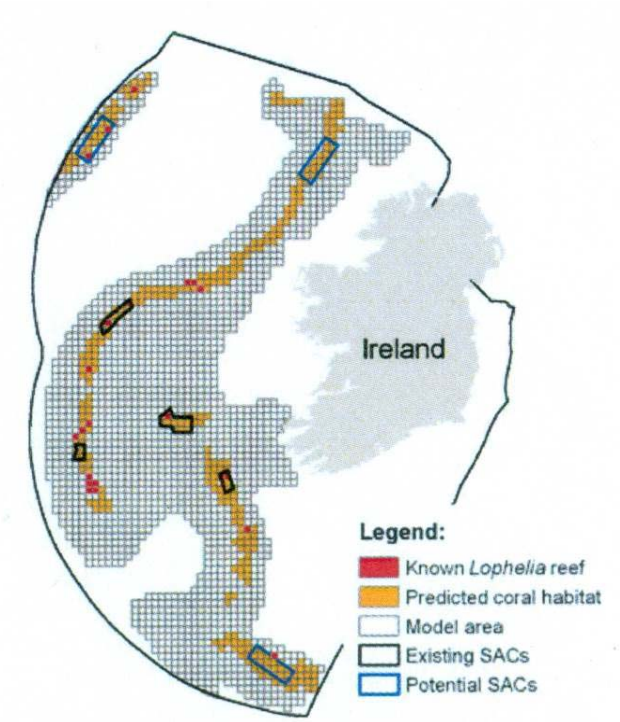


Figure 13. Map showing the distribution of known and predicted *L.pertusa* reef habitat for the Irish continental margin, as well as existing and potential coral Special Areas of Conservation within the Irish Exclusive Fisheries Zone (solid black line). Figure 5 from Rengstorf *et al* (2013).

The marine bioregionalisation work in Australia illustrates how programmes can work but also evolve as more data become available (Heap *et al* 2005). When the classification was first developed in 1985 it was generalised, broad scale and considered to lack sufficient details to assist detailed bioregional conservation planning. By 1998 this had been improved to produce the Interim Marine and Coastal Regionalisation of Australia (IMCRA v3.3) for both demersal and pelagic environments. The former was based on a classification of demersal fish species diversity and richness, and the latter on pelagic fish species diversity and richness as well as water mass types. IMCRA v4.0 (DEH 2006) defines twenty-four provincial bioregions and 300 biomes but limitations in the data meant that biomes could only be defined for the 15 Provincial Bioregions adjacent to the mainland. The authors also make it clear that the bioregionalisation has been developed on the premise that there are valid relationships between geomorphology, oceanography, sediment type and benthic marine biota, yet these relationships are not well-understood.

5 The UK Context

5.1 Biogeographical and marine biotope classifications

In the UK an understanding of marine biogeography is being used in a variety of ways to help deliver the Government's vision of 'clean, healthy, safe, productive and biologically diverse oceans and sea'. The Review of Marine Nature Conservation (Defra 2004) which examined the effectiveness of the system for protecting nature conservation in the marine environment considered what needed to be done at five spatial scales:

- The wider sea
- Regional seas
- Marine landscapes
- Important marine areas
- Priority marine features

The 'Regional Seas' represented biogeographic subdivisions and were considered to provide a useful scale at which to implement the ecosystem approach in UK waters. Eleven such areas were proposed, dividing UK waters on roughly the same scale using similar criteria, based on biogeographic considerations. These proposed areas were not restricted by administrative boundaries and took full account of all information available at that time (Turnbull 2004). This division has provided the basis for further consideration of biogeographical boundaries in UK marine work but with various modifications. For example the definition of eight UK Regional Seas to provide the reporting framework for the first integrated assessment of the state of UK seas (Defra 2005) and the subsequent assessment 'Charting Progress 2'. Further subdivision into 12 draft Regional Seas was suggested and used for UK SeaMap 2010 (McBreen *et al* 2011) and the Marine Conservation Zone (MCZ) Ecological Network Guidance (JNCC/NE 2010) (Figure 14). They also provide the most detailed biogeographical boundaries currently available for UK waters.

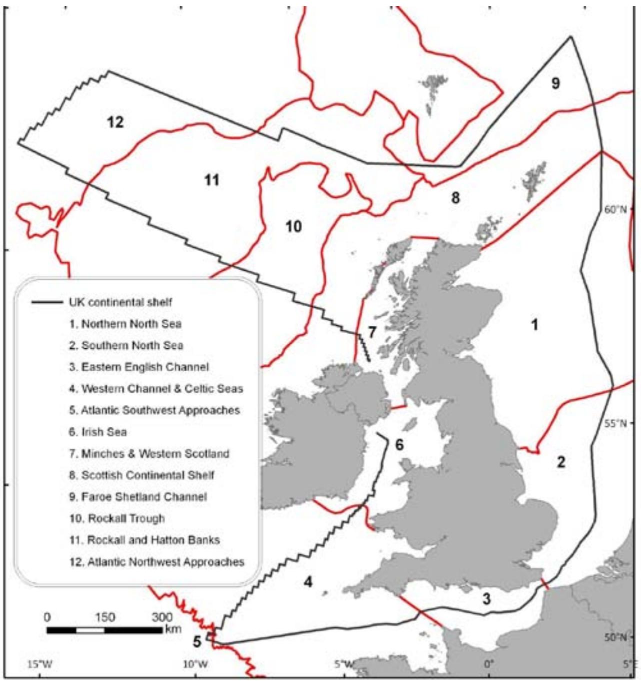


Figure 14. Draft Regional Sea Boundaries based on biogeography (Figure 24 from McBreen *et al* 2011)

Habitat classification systems provide the basis for seabed habitat mapping and are important in the context of this review as various levels of such classifications are used to describe the features which are assessed in MPA networks. Case Study 4 (New Zealand) and Case Study 6 (Australia) illustrate how habitat classification is used as part of the MPA assessment process.

The Marine Habitat Classification for Britain and Ireland was developed as part of the EC BioMar project. The first edition was published in 1997 and it was updated and revised in 2004 (Connor *et al* 1997; Connor *et al* 2004). Work in the UK has made an important contribution to the development of the European Habitat Classification system (EUNIS) although biogeography is not currently used to structure the upper levels of either the Marine Habitat Classification for Britain and Ireland or EUNIS. Some of the EUNIS level 3 habitats are features for which MPAs have been identified within the UK MPA network to provide protection.

UKSeaMap 2010 (McBreen *et al* 2011) and the more recent EUSeaMap (Cameron & Askew 2011) are relevant to the UK MPA network assessment as they predict the distribution of sublittoral marine habitats mostly at levels 3 and 4 of the EUNIS habitat classification system with additional categories for deep sea areas (Figure 15). Input data layers are seabed substrates, depth, proportion of surface light reaching the seabed, energy (disturbance) at the seabed caused by tidal currents and waves. The result is a map of 15 EUNIS level 3 habitat types in UK waters with supporting information on the confidence of the predictions. The outputs and data layers are also available on an interactive mapping portal[3].

UKSeaMap 2010 reported on the occurrence of 44 EUNIS level 3 and 4 habitats including additional categories for the deep sea and Arctic in the 12 Regional Sea areas (McBreen *et al* 2011). An extract of this is shown in Table 4. Although the EUNIS level 3 habitat types are not necessarily directly equivalent to MPA features, this type of analysis provides essential information for reporting on attributes such as the proportion of a particular habitat type within the MPA network in a defined biogeographic area such as the UK Regional Seas. More recently advice to the Scottish Government on the MPA network from SNH and JNCC has reported on the representation and replication of EUNIS level 3 habitats in OSPAR regions (SNH/JNCC 2012) but not on the biogeographical provinces as defined by Dinter (2010) (Figure 3, Section 2.2). Natural England and JNCC have also examined how broad habitats and habitats of particular interest in proposed Marine Conservation Zones in England and adjacent offshore waters contribute to MPA network design principles (JNCC/NE 2012). Figure 16, which illustrates the relationship between the 12 UK Regional Seas, OSPAR biogeographic provinces, and UKSeaMap 2010 habitats shows that data collected in this format can be collated to report at higher levels such as the Regional Seas or OSPAR provinces if needed.

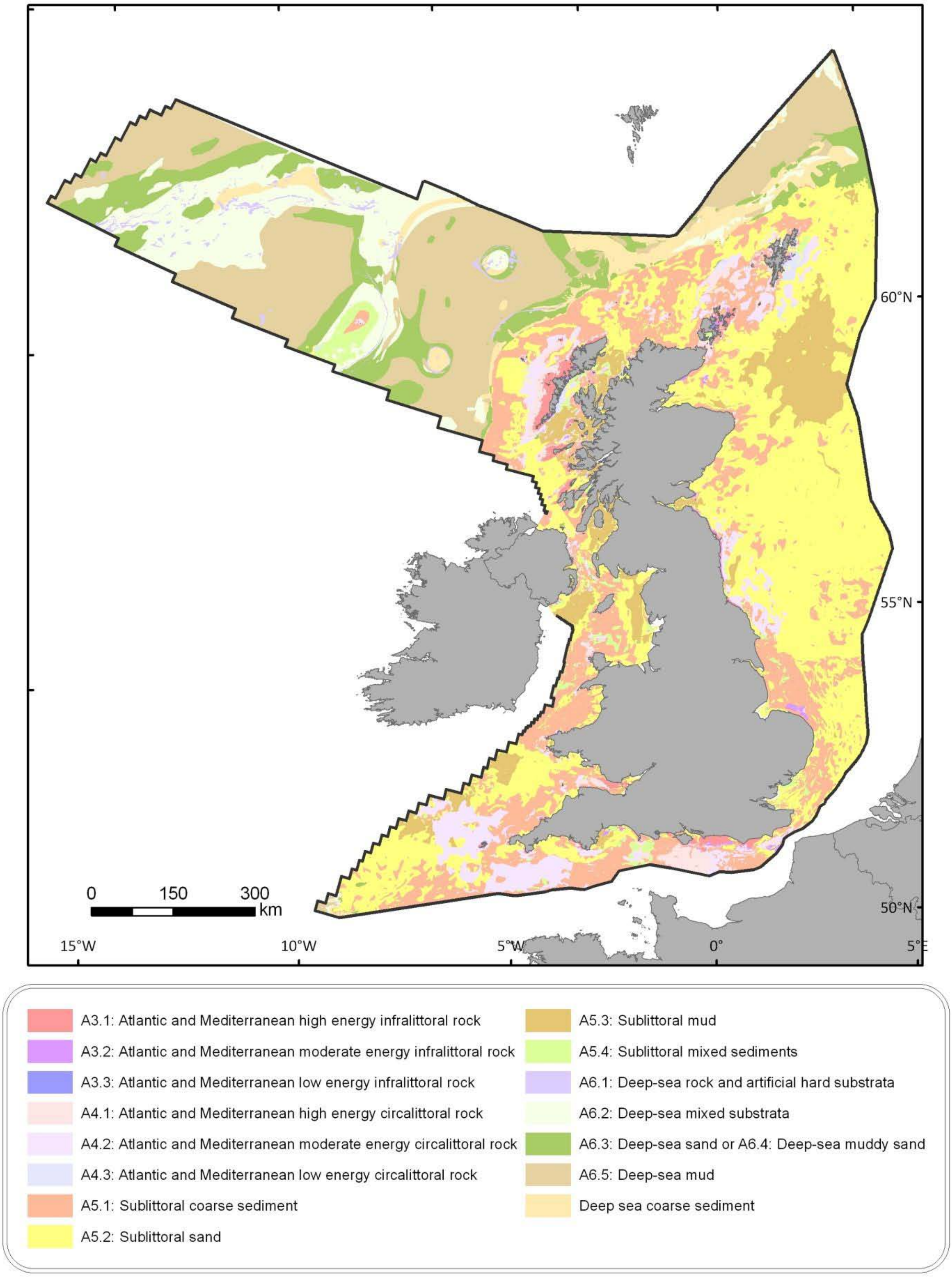


Figure 15. UKSeaMap 2010 predictive seabed habitat map of EUNIS Level 3 habitats and additional deep sea categories (Figure 23 from McBreen *et al* 2010).

Table 4. Total area and proportion of the UK marine area covered by some EUNIS level 3, Deep Sea and Arctic habitats for regional sea areas in UK waters. Extract from Table 14, McBreen *et al* 2011.

Habitat	Area km^2	Total area %	Percentage of each habitat with each of 12 UK regional seas											
			1	2	3	4	5	6	7	8	9	10	11	12
A5.44	3,509	0.41	0.19	0.87	4.83	0.12	0	2.22	2.24	0.08	0	0	0.02	0
AtSI s&ms	15,211	1.77	0.01	0	0	0.28	0	0.02	0.29	7.56	0	0	3.41	0
AtLB m&sm	31,944	3.72	0	0	0	0.02	75.47	0	0	0.01	0	45.53	0	3.20
ArMB m&sm	21,298	2.48	0	0	0	0	0	0	0	0	50.35	0	0	0

5.44 - Circalittoral mixed sediments

AtSI s & ms - Atlantic slope sand and muddy sand

ATLB m sm - Atlantic lower bathyal sand and muddy sand

ArMB m 7 sm - Artic mid bathyal mud and sandy mudy

UK Biogeographic regions	OSPAR Biogeographic provinces
1	B
2	B
3	B, B-L
4	B-L, L-B
5	L-B
6	B
7	B, B-L
8	B-L, B,
9	B
10	L-B
11	B, SI-SF
12	SI-SF

EUNIS level 3, +Arctic, +Deep Sea
A5.43, A5.44, A5.45, AtSI rock, ATSI s&ms, AtSI m&sm

OSPAR provinces: B (Boreal), B-L(Boreal-Lusitanean), L-B (Lusitanean-Boreal), SI-SF (South Iceland-Faeroe Shelf)

Habitat types: A5.43 (infralittoral mixed sediments) A 5.44 (Circalittoral mixed sediments) A5.45 (Deep circalittoral mixed sediments), AtSI rock (Atlantic slope rock or reef), AtSI s&ms (Atlantic slope sand & muddy sand), AtSI m&sm (Atlantic slope mud & sandy mud).

Figure 16. Illustration of relationship between UK biogeographic regions, OSPAR Biogeographic provinces and the UK SeaMap 2010 habitat types (for UK region 1 only), at EUNIS level 3 with Arctic and Deep Sea added. NB. The small scale of available OSPAR maps means the overlap with OSPAR provinces is only indicative.

5.2 Uncertainties

The nature of biogeography means that it is the subject of continual discussion and refinement as we learn more about the distribution of species and endemism across the globe. Whilst there is general acceptance of the broad patterns of marine biogeography even this will continue to be debated. A recent example is the suggestion for new divisions and redefinition of some existing ones in light of more extensive data on endemism (Briggs & Bowen 2012). Discussion and refinement is part of the scientific process, as is being clear about any assumptions and uncertainties. All of this should be recognised when considering biogeography in assessing the sufficiency of MPA networks, by working with a system that can evolve rather than one that needs to start again as our knowledge and understanding of marine biogeography improves.

Biogeographic patterns and associated communities are not static. Some may change over a short time scale e.g. decades, whilst other changes operate over longer time scales. The shift toward a warm dynamic regime in the North Sea in 1989 as indicated by changes in the abundance and seasonal patterns of various planktonic species is an example (Alvarez-Fernandez *et al* 2012). A confounding variable is that historic patterns of distribution may still be apparent despite very significant changes, such as sea level rise. A related issue is that all biogeographic classifications, particularly at the macro scale, contain generalised boundaries and therefore should not be interpreted as 'hard' management lines. It is also the case that marine biogeographical boundaries are more often transition zones rather than sharp delineations. Because of their 'permeability' Vermeij (1978) considers they should be viewed as 'biogeographical filters' rather than strict barriers. These points must be acknowledged because using the framework of biogeography as part of MPA network assessment will, for practical purposes, require 'lines on charts'.

The underpinning data on which to base biogeographical classifications has been discussed above. Biogeographers work with limitations such as inconsistent biological data across a particular region or between regions. The significance of such data limitations depend on how the classifications are being used and the scale at which they are being used. For example if detailed mapping of the extent of biotopes is not comprehensive, there is more meaning in reporting on the geographic extent of a particular biotope in a biogeographical region than its percentage cover. On the other hand when working at the macro scale, for example the very large areas of sea within biogeographical provinces, the boundary effect would be less significant and therefore reporting on the geographical extent of MPAs as area as well as percentage cover will provide a useful overview of the status. The resolution of the model should guide the level of detail to which interpretation is provided.

Finally it is relevant to note that much remains to be done in describing the links between pelagic and benthic classifications.

6 Conclusions

> *"Each province is not so entirely distinct from its neighbours as to be exclusively inhabited by creatures peculiar to itself but shares more or less in the population of those regions which impinge upon its boundaries; so that the line between these zoological and botanical kingdoms, or rather republics, is not sharp and defined, like that which marks the limits of political states, but is softened off and melted, as it were, into the margins of the neighbouring territories; nor, in most cases, is it easy or possible to say where the one terminates and the next begins.*
> FORBES & GOODWIN-AUSTIN (1859) The Natural History of European Seas. Pgs. 1-2

Describing and trying to understand the patterns of distribution of flora and fauna around the world was a rich field of study for eminent 19th century scientists such as Edward Forbes, Charles Darwin, and Joseph Hooker. In the marine environment the presence and extent of marine biogeographic zones are still being debated, but some aspects, such as the observations made by Forbes, are as true today as they were in the 19th century. Rigid systems and sharp boundaries can only provide a guide to patterns of biogeography, especially in the marine environment, and interpretation will be influenced by what is being studied and the scale at which it is studied. The regime shift in plankton communities in the North Sea in the 1980s, and in the demersal fish communities in the Bering Sea in the latter part of the 20th century, where changes have taken place over relatively short periods of time (decades), illustrate another key element of biogeography. Assemblages of species and biotopes are dynamic relative to their geographical distribution as well as over time. Furthermore, as with all areas of science, there are differences in the quantity and quality of our knowledge base.

The science of biogeography, as well as information on the current distribution of marine species and biotopes, is part of the design and assessment process of many MPA programmes (globally as well as nationally). The literature review reveals that it is most often a factor when reporting on 'representativity' and 'features' (particular species, habitats and ecosystem processes) in MPA networks. These are two of the five main principles for an ecologically coherent MPA network agreed by OSPAR and being used by the UK Administrations to guide the identification of national MPAs. The three other principles (connectivity, resilience and management) may be influenced by biogeography but the literature review indicates that this is generally not the main concern when trying to apply them to MPA networks. In the case of connectivity, for example, dispersal potential of particular species is often the focus; in the case of resilience the quality of the wider environment is likely to be more significant than biogeographical considerations although the number of examples of a feature in MPAs in a biogeographical area can contribute to the resilience of networks and in the case of management, actions need to be initiated on the scale at which particular activities are managed rather than any particular biogeographical scale.

Biogeography is typically noted as being relevant to both the design and assessment of MPA networks, but it is most often applied at the assessment stage. This is probably because apart from regions of the world where there are few MPAs, such as the deep sea and Antarctica, most networks are being built up by identifying gaps in an existing suite of sites. The data presented on MPA networks in biogeographic regions are typically the number, size and percentage cover of MPAs. Whilst such analysis may be rudimentary, statistics of this type are essential to appreciating how well the principles of 'representativity' and 'features' are being addressed.

6.1 Features

The OSPAR network principles state that sites should represent the range of species, habitats, and ecological processes in the area and that the proportion of each should be determined on a feature by feature basis.

Biogeography is very relevant to the principle of ‘features’ as it describes the species and biotopes that are likely to be present in particular geographic areas as well as their distribution and extent.

6.2 Representativity

The OSPAR network principles state that areas should be selected which best represent the range of species, habitats and ecological processes. This principle is essentially a decision tool to select the number of sites which should be included in the MPA network.

Biogeography is very relevant to the principle of representativity as it not only describes species and biotopes that might occur in a particular geographic area but also the extent and possible boundaries of their distribution. An understanding of these patterns is needed in order to locate ‘representative’ areas for MPA networks.

Representativity has been reported at a many scales depending on whether it is being assessed in relation to national, regional or global targets. There are, for example reports on the number of MPAs across the entire Mediterranean region (which is a biogeographic province) as well as in each of the eight Mediterranean ecoregions. The hierarchical framework of biogeographical classifications accommodates such an approach.

As biogeographical boundaries are rarely sharp it may be necessary to include locations at zonal boundaries as well as clearly within different biogeographic zones to maximise species representation.

6.3 Connectivity

The OSPAR network principles state that for connectivity to be achieved, the MPA network should be well distributed in space and take account of the linkages between marine ecosystems. Connectivity is an ecological concept relating to the biology, ecology and the distribution of species and habitats.

Connectivity results in the patterns of distribution of marine life described by the science of biogeography rather than *vice versa*. Biogeography is therefore less relevant to this OSPAR principle than the others examined in this review. Other factors such as identifying locations important for key species life stages (e.g. ‘sources’ and ‘sinks’ of larvae), dispersal distances and migration corridors, rather than biogeography are typically discussed when applying the connectivity principle.

6.4 Resilience

The OSPAR network principles state that adequate replication and sufficient size of MPAs are needed to build resilient MPA networks. Biogeography does not appear to be a major consideration in relation to this principle to date. It can however be used to make decisions about the number of examples of a feature that are needed in a biogeographic area within MPA networks.

6.5 Management

The OSPAR network principles state that MPAs should be managed to ensure the protection of the features and support the function of an ecological coherent network. Management is a societal rather than an ecological concept. It is focused on human activities, whilst recognising the biology and ecology of the protected species and habitats.

Biogeography has limited relevance to the principle of ‘management’ as the activities which need to be managed are likely to have few if any biogeographical characteristics. Certain activities may coincide with patterns of distribution of species, but the management regime used to regulate them is unlikely to be based on biogeographical patterns. An understanding of biogeographical patterns may however be a relevant consideration when setting management objectives such as the recovery of a specific biotope or species in a particular area.

6.6 Scientific knowledge

Scientific knowledge underpinning our understanding of the five MPA network principles is at different stages. Representativity and features are generally well understood through the description of particular habitat types and recognising the need to map their distribution and extent. The science of connectivity in relation to MPAs, on the other hand, is still its infancy. Computer modelling and review of relevant biological data such as residence times of larvae, are being used to inform the design of MPA networks which support connectivity. However, as relatively few species are well studied in this regard, current guidance is very generic. The design and assessment of the ‘resilience’ of MPA networks is another principle whose requirements in terms of biogeography are not well understood. Finally, whilst there has been some research on biogeography and the management of MPAs, this is mostly concerned with the setting of appropriate objectives rather than how biogeography should be taken into account when ensuring appropriate management of MPAs.

6.7 Survey and monitoring

Survey and monitoring data as well as modelling has been used to map the distribution of the major benthic habitats in European shallow seas. This includes the broad habitat types and some of the other important habitats and species which have been identified as features of the UK MPA network. In UK waters the distribution patterns of the major biotope forming species such as maerl and *L. hyperborea* are reasonably well known, but ground-truthing and new surveys, often unrelated to MPA work, can add detail and help refine distribution maps. Comprehensive mapping to the detail of EUNIS level 4 classification is still a long way off, but this is being built up as work is undertaken within existing MPAs. In time, accurate mapping at this level of detail would provide a more complete picture of the distribution of marine biotopes for analysis of the UK MPA network. As MPAs are monitored, data which improve our understanding of temporal changes in the distribution and extent of marine biotopes in UK waters, and hence potential changes in biogeographic patterns over time, will also become available for analysis.

6.8 Scale

MPA network principles have been examined at various biogeographic scales influenced by factors such as the scale at which particular features can be observed and mapped, and the scale at which a particular network objective is set (e.g. global, regional or national). Political and administrative boundaries have also been used for reporting on MPA networks although these do not necessarily coincide with biogeographical boundaries. Such an approach could however be accommodated, if required, by merging or separating data that is based on biogeographical boundaries. The strengths and weaknesses of four possibilities relevant to UK waters are summarised in Table 5.

Table 5: The potential strengths and weakness of assessing 'representativity' and 'features' under four classification schemes.

Scheme*	Strengths	Weakness
Marine Realms (Spalding *et al* 2007)	• Globally defined • Macro scale which means that data from reporting schemes using regional or national biogeographic classifications can be accommodated as they are sub-sets of Marine Realms • MPA features present in each region can be listed	• MPA features not mapped at this scale • Known biogeographic patterns around UK waters not distinguished at this level
OSPAR regions[4]	• Macro scale which means that data from reporting schemes using regional or national biogeographic classifications can be accommodated as they are sub-sets of OSPAR regions • MPA features present in each region can be listed	• Not a biogeographic classification • MPA features not mapped at this scale
OSPAR provinces (Dinter 2010)	• Macro and meso scale based on review of biogeographical classifications • Considers both benthic and pelagic biogeography • MPA features present in each region can be listed	• Limited data underpinning recommendations for offshore and deeper areas • MPA features not mapped at this scale
UK Regional Seas (McBreen *et al* 2011)	• Meso and micro scale based on review of biogeographic classifications • Some MPA features (broad scale habitats) have been mapped at this scale using survey data and modelling Finer scale than OSPAR provinces	• Presence of MPA features identified by predictive mapping with a range of confidence limits

* see figures 2, 3 & 11 for associated maps.

7 Recommendations

The main recommendations of this review are that biogeography should be used for the assessment of the UK contribution to a wider MPA network in the north-east Atlantic a wider MPA network in the north-east Atlantic against the OSPAR network design principles of 'representativity' and 'features', and that this should be done at the scale of UK Regional Seas.

Biogeography has a clear and direct relevance to applying the principles of 'representativity' and 'features' as both these principles are concerned with the patterns of distribution of

[4] http://www.ospar.org/content/regions.asp?menu=00020200000000_000000_000000

habitats and species. As such it is appropriate for any assessment of these principles to take biogeographic patterns into account and be reported for different biogeographic regions. The role of biogeography in relation to the principles of ’connectivity’ and ‘resilience’ is less well understood therefore it is unclear what attributes might most usefully be reported within such a framework and their meaning in terms of the sufficiency of MPA networks. Biogeography is not considered to be particularly relevant to the principle of ‘management’ therefore reporting from a biogeographical perspective is not deemed to be particularly meaningful in terms of MPA network design and assessment.

The UK Regional Seas have been defined on the basis of biogeographic patterns in UK waters. Eight regions were formally agreed and used for the Charting Progress 2 reports, and twelve regions were used for UK SeaMap 2010 although these remain draft proposals. The UK Regional Seas fits into global (Spalding *et al* 2007) and regional (North East Atlantic –OSPAR) biogeographic classifications and has been developed with reference to the scientific literature. It provides the most detailed, ecologically meaningful, biogeographical boundary definitions for UK waters currently available and is therefore recommended as the most an appropriate framework for assessment. Another option could be to use the three provinces defined by OSPAR for the shelf and Continental Slope around UK waters (Boreal/Boreal-Lusitanean/Lusitanean). This scheme is not considered to be fine enough to reflect well defined patterns in the distribution of marine biotopes and species in UK waters nor, more specifically, to reflect differences in the patterns of distribution of ‘features’ of the MPA network. For example the different combinations of maerl species which form maerl beds in northern Britain compared with those characteristic of maerl beds in the south west would fall into the same OSPAR province and therefore considered to be identical in terms of representing this habitat type. At the other end of the spectrum, as biogeographic divisions become finer, there is a danger of moving into the sphere where they start to reflect patterns of distribution of individual species rather than regions with a characteristic flora and fauna. For this reason, further sub-divisions into smaller biogeographical regions for the assessment of features and representativity is not recommended. In summary:

- Regional Seas/Charting Progress 2 regions are considered to be the most appropriate scale to assess MPAs in UK waters;
- a wider scale e.g. OSPAR/Dinter is considered to be too broad and fail to capture geographic variation between habitats in UK waters;
- a finer scale is considered to be less useful, because it starts to reflect patterns of individual species distribution rather than regional characteristics;
- careful consideration should be given to assessing the contribution of habitats and species in transition zones between biogeographic regions as these can be unique environments.

The attributes reported in MPA network assessments of ‘representativity’ and ‘features’ with reference to biogeography are typically the number of MPAs the area and proportion of habitat features in MPAs and the presence of species features in MPAs (Table 6). Reporting using more complex attributes for more complex assessment of MPA networks, may be possible in future but there will always be a need for the simpler attributes which provide an overview of the current status of the MPA network.

Table 6: Examples of attributes that could be used for reporting and assessing 'representativity' and 'features' of the UK MPA network in UK Regional Seas

OSPAR Principle	**Attributes**
Representativity	Number of MPAs Area/proportion covered by MPAs
Features - Broad scale habitats	Presence in the MPA network Number of MPAs with this feature in the network Proportion of the feature in the MPA network
Features - Listed Habitats	Presence in the MPA network Number of MPAs with this feature in the network Proportion of the feature in the MPA network Extent the habitat within the MPA network
Features - Listed Species	Presence in the MPA network Number of MPAs with this feature in the network

Following this approach, for 'representativity' relevant attributes for UK reporting would be the number of MPAs in each Regional Sea and the proportion of the Regional Sea area. For habitat features, presence in the MPA network and how much of the habitat features lies within the MPA network as a percentage of the extent of that habitat within each Regional Sea. Percentage cover figures of this sort will need to be set into context by describing the confidence limits of the underpinning habitat mapping.

In the case of species 'features', their presence in MPAs in each biogeographic region could be reported but this will not be sufficient to assess the network for such features. Other factors that are not relevant to biogeographic scales, such as species population size and trends will also be needed for a robust assessment of the sufficiency of the MPA network for species features. A complementary approach, could be to select a number of taxa which are found around the British Isles but which are represented by different species depending on biogeographical zones. The presence of these within the MPA network would act as a further check on whether biogeographical considerations are adequately covered. Three possibilities might be to carry out such an assessment for kelp species, demersal fish assemblages, and plankton communities. Furthermore, as biogeographical boundaries are rarely sharp it may be necessary to include locations at zonal boundaries as well as clearly within different biogeographic zones to maximise species representation.

These recommendations have been framed in the context of current data availability and scientific understanding. They can also accommodate improved knowledge and understanding of biogeographical patterns in UK waters such as further clarification of the boundaries of the UK Regional Seas.

Finally it should be noted the recommendations have been drawn from a review of the science of biogeography and its relevance to MPAs. Other scientific questions will need to be considered when applying the OSPAR principles. There are also policy considerations such as other UK obligations and reporting frameworks which might influence the design and assessment of the UK MPA network but these have not been considered in this report.

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Appendix 1 Expanded Bibliography of selected references

See separate Excel file

An expanded bibliography of selected references relevant to application of some or all of the OSPAR principles for the design and assessment of MPAs.

KEY

D	Design of MPAs
A	Assessment of MPAs
F	Features
Rep	Representativity
C	Connectivity
Res	Resilience
Mn	Management

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Abdulla, A. *et al* (2009) Challenges facing a network of representative marine protected areas in the Mediterranean: prioritizing the protection of under represented habitats. ICES J.Mar Sci. 66:22-28.	✓	✓	✓	✓			✓	Assessment of sufficiency of the network of MPAs using the 7 ecoregions in the Med as defined by Spalding et.al (2007). Analysis considers representativity and habitats of special ecological importance by taking into account existing protection and management regimes and presence of threatened habitats and species in each of the ecoregions. Results are presented in terms of number of MPAs, %, surface area and area of no-take zones. Regional gaps and discrepancies have been identified using this approach with reference to the CBD target of protecting at least 10% of each of the world's ecoregions. In the deeper parts of the Med regional patterns of community wide endemism may not be known for some time. Under these circumstances the distribution of physiographically and physically distinct habitats may provide a starting point for identifying potential MPA sites e.g. bathymetric features. Recommended next steps include systematic surveys of marine biodiversity at key sites to identify understudied regions and biomes and designing an integrated network of MPAs within each sub region.
Aycrigg, J.L. *et al* (2013) Representation of Ecological Systems with the Protected Areas Network of the Continental United States. PLoS ONE 8(1):		✓	✓	✓				Terrestrial study evaluating representation of ecological systems in existing protected area networks based on national level data. The PA network has evolved over time typically through a mix of opportunity, available resources and agency specific conservation priorities. Assessment has also been carried out on many occasions, using the best data available at the time but recognising its limitations. National Gap Analysis Programme was used examining percentage available versus percentage protected for different land cover groups. Sufficiency was viewed with reference to geographic area protected (the CBD/Aichi target of 17% for terrestrial areas). Analysis undertaken for multiple use areas and those where biodiversity protection the main objective.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Barber, P.H., Palumbi, S.R., Erdmann, M.V. & Moosa, M.K. (2000) Biogeography. A marine Wallace's line? Brief communications Nature 406:692-693	✓				✓			Populations of mantis shrimp from 11 reef systems in Indonesia in which 36 MPAs are presumed to be connected by strong ocean currents were studied. Results reveal strong regional genetic differentiation that mirrors separation of ocean basins during the Pleistocene indicating ecological connections are rare across distances as short as 300-400km, and that biogeographic history also influences contemporary connectivity between reef ecosystems. The species of mantis studied has a 4-6 week planktonic larval period, dispersal potential around 600km show a sharp genetic break among oceanographic regions - potential marine equivalent of Wallace's line. This is despite 6-10,000 years of modern oceanographic conditions. Reef populations throughout Indonesia cannot simply be assumed to be interconnected units. MPAs need to be designed that also take biogeographic and historical oceanography into account.
Commonwealth of Australia (2003) Australia's South-east Marine Region: A user's guide to identifying candidate areas for a regional representative system of Marine Protected Areas.	✓	✓	✓	✓				Specifications for site selection in the SE Marine Region. Eleven Broad Areas of Interest have been identified. These are based on bioregionalisation studies for the continental shelf and deep-water areas beyond. There is a hierarchical structure defined at three scales; large scale provinces, biomes and at the finest scale geomorphological units. As fine scale information often lacking representativeness is the primary driver for ensuring the diversity within each bioregion is sampled with a system of candidate MPAs. Eleven Broad Areas of Interest have been identified to ensure full range of level 3 bioregions could be sampled within candidate MPAs. This should also help address the comprehensiveness principle.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Department of Conservation and Ministry of Fisheries (2011) Coastal marine habitats and marine protected areas in the New Zealand Territorial Sea: a broad scale gap analysis. DoC/Min Fish. Wellington, New Zealand.	✓	✓	✓	✓			✓	New Zealand policy aims to protect representative examples of the full range of marine habitats and ecosystems, as well as outstanding, rare, distinctive or internationally or nationally important marine habitats and ecosystems. Hierarchal classification within 14 marine biogeographic regions. A Protection Standard was developed to assess which management tools offered sufficient protection. Analysis in this report shows % of the total area of all coastal marine bioregions protected within Type 1 & Type 2 MPAs. Also the area and percentage of individual habitat types for each bioregion.
Dudley, N. & Parish, J (2006) Closing the gap. Creating ecologically representative protected area systems. CBD Technical Series 24.	✓	✓	✓	✓				Recommended approach for carrying out a gap analysis for protected areas including MPAs. This is based on setting conservation targets, evaluating biodiversity distribution and status, as well as analysing protected area distribution and status. The first guiding principle is to ensure full representation across biological scales (species and ecosystems) and biological realms. At the scale of the realm, it is possible to at least get a picture of where the largest gaps are likely to be found. The crudest form of gap analysis and not suitable to be used alone. Other levels are environmental domains and enduring features; ecosystems or habitats; and species. The strengths and weaknesses in terms of collecting information for gap analyses at the different levels are described

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Gabrié C. *et al* (2012) The Status of Marine Protected Areas in the Mediterranean Sea. MedPAN & RAC/SPA. Ed:MedPAN Collection, 256pp.		✓	✓	✓	✓	✓	✓	Evaluation of progress with Mediterranean MPAs in 2012 including whether the network covers 10% of the Mediterranean, whether it is representative of the Mediterranean's diversity and whether the MPAs are well-connected and well managed. Analysis includes representativity at three scales, the entire Mediterranean, eight ecoregions and on a country scale. Summaries provided on % cover and extent and considers benthic and pelagic environments. Representativity of benthic habitats is reported on the Mediterranean scale using 19 categories of benthic sedimentary habitat. Coralligenous and seagrass habitats are assessed in the western basin due to data gaps. Total number of MPAs with a management body are identified including those in different epipelagic bioregions. Reporting for species groups (cetaceans, turtles) is for the whole Mediterranean.
Government of Canada (2011) National Framework for Canada's Network of Marine Protected Areas. Fisheries and Oceans Canada, Ottawa 31pp.	✓	✓						Strategic direction for the design of a national network of MPAs that will be composed of a number of bioregional networks. Twelve ecologically defined bioregions identified covering Canada's oceans (and a thirteenth for the Great Lakes). These were identified through a national science advisory process that considered oceanographic and bathymetric similarities, important factors in defining habitats and their species. The ecological representation criterion at its most basic, broad scale, means protecting relatively intact, naturally functioning examples of the full range of ecosystems and habitat diversity found within a given planning area such as a bioregion or Parks Canada marine region. The different habitats in a bioregion can be identified and delineated using habitat classification schemes based on best available physical and biological information.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Grant, S. *et al* (2006) Bioregionalisation of the Southern Ocean: Report of Experts Workshop, Hobart, September 2006. WWF-Australia and ACE CRC.	✓							Workshop report on bioregionalisaton for the Southern Ocean. Environmental data used as the primary input for analysis, based on their spatial coverage across the Southern Ocean e.g.bathymetry, sea ice concentration and extent, and nutrient data (silicate, nitrate and phosphate). Clustering procedure used to classify individual sites into groups. Workshop established proof of concept for bioregionalisaton of the Southern Ocean. A statistical hierarchical approach was the most useful. Output an important contribution to the achievement of a range of scientific management and conservation objectives, including the development of an ecologically representative system of MPAs
Hamilton, S.L., Caselle, J.E., Malone, D.P. & Carr, M.H. (2010) Incorporating biogeography into evaluations of the Channel Islands marine reserve network. PNAS vol 107 (43)18272-18277	✓	✓						Evaluation of the Channel Islands reserve network which spans a major environmental and biogeographical gradient over a relatively short geographic scale (100km). Three main biogeographical regions emerged when designing the network and multiple reserves were placed in each of these. Fish community structure was used to identify persistent geographic patterns of community structure and the scale at which sites should be grouped for analysis. The framework presented was to guide evaluating MPA network performance in light of biogeographic effects. Biogeographic information was used to identify the scale at which sites should be compared (island scale). This was slightly different from the 3 bioregions identified during the design phase. Authors conclude that biogeographical differences e.g. in species abundance should be taken into account when assessing overall network responses.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
HELCOM (2010) Towards an ecologically coherent network of well-managed Marine Protected Areas. Implementation report on the status and ecological coherence of the HELCOM BSPA network. Baltic Sea Environment Proceedings No.124B.	✓	✓	✓	✓				Ecological coherence assessed for 3 MPA networks in the Baltic with reference to four assessment criteria; adequacy, Representativity, replication and connectivity. Under Representativity the representation of all biogeographic regions or ecological landscapes was considered a prerequisite for the protection of biodiversity since species assemblages will be distinct in each region (1.4.2). Baltic sea basins are used as a proxy for biogeographical regions. Three analysis undertaken as part of the assessment of ecological coherence; representation of indicator species and biotopes, of benthic marine landscapes and of geographical representation (TW, EEZ) each of which had a biogeographical/sub-basin analysis. Connectivity was examined in relation to benthic marine landscape types but not analysed for each sub-basin. Assessment methodology is evolving.
Kendall M. & Poti, M. (Eds) (2011). A Biogeographic Assessment of the Samoan Archipelago.NOAA Technical Memorandum NOS NCCOS 132. Silver Spring MD. 229pp.	✓	✓	✓		✓			Part of larger study. Includes evaluation of the distribution of MPAs in Samoa and American Samoa in the context of biogeographic regions and ecological hotspots. In Chapter 4, 30 biogeographically distinct regions identified and 51 hotspots based on coral and fish variables. In Chapter 5 information for the 23 MPAs summarised focusing on reef ecosystem habitats, reef fish and coral communities and the bioregions in which they sit (20 in American Samoa and 36 hotspots). Overlays reveal that 14 of the 20 bioregions include at least one MPA. Hotspots overlay suggest that some bioregions may have greater ecological and conservation importance. Recognition that other factors e.g.size and type of protection not taken into account in this simple analysis but it has revealed poor coverage in some bioregions. As the MPA programme evolves the components of the biogeographical assessment can be used to evaluate the ecological contributions of additions to the network on the basis of protected habitats reef fish and coral communities and larval connectivity.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Margules, C.R. & Pressey, R.L. (2000) Systematic Conservation Planning. Insight review article. Nature 405:243-253	✓	✓						Reserves established principally for the protection of biodiversity, including ecosystems, biological assemblages, species and populations fit with IUCN definition as protected areas. The extent to which they separate elements of biodiversity from processes that threaten their existence in the wild depends on how well they meet two objectives. Representativeness - a long-established goal referring to the need for reserves to represent or sample the full variety of biodiversity, ideally at all levels of organisation. Persistence - reserves, once established should promote the long-term survival of the species and other elements of biodiversity they contain by maintaining natural processes and viable populations and by excluding threats. To meet these objectives conservation planning must deal with the location of reserves in relation to natural physical and biological patterns as well as other elements such as size, connectivity and replication. Conservation planning has generally not been systematic and new reserves have often been located in places that do not contribute to the representation of biodiversity for a variety of reasons. Authors set out a framework for systematic conservation planning as a process in six stages. The first of these is to measure and map biodiversity. Higher levels in the biological hierarchy, such as species assemblages, habitat types and ecosystems have less biological precision than taxa but have other advantages. They can integrate more of the ecological processes that contribute to the maintenance of ecosystem function and the relevant data are more widely and consistently available.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Monaco, M.E. *et al* (2003) Quantifying habitat utilization patterns of U.S. Caribbean and Hawaii reef fish to define Marine Protected Area Boundaries: The Coupling of GIS & Ecology. Proceedings of the 13th Biennial Coastal Zone Conference, Baltimore, MD July 13-17, 2003. 6pp.		✓						Biogeographical approach enables coupling of digital benthic habitat maps and species habitat utilisation patterns to define biologically relevant Protected Area boundaries, define the strength of species habitat affinities, and evaluate MPA effectiveness. This has been used by the US Caribbean Fisheries management Council to define essential fish habitats, to characterize US Virgin Island marine parks and monuments and by the University of Puerto Rico to define biologically relevant MPA boundaries.
Morgan, L. *et al* (2005) Marine Priority Conservation Areas. Baja California to the Bering Sea. Commission for Environmental Cooperation of North America/ Marine Conservation Biology Institute	✓			✓				Report describes the process for identifying priority conservation areas (PCAs) along the west coast of North America. The North American MPA network (NAMPAN) was set up to enhance and strengthen the conservation of biodiversity in critical marine habitats through North America by creating a functional system of ecologically based MPA networks that cross political boarders and depend on broad cooperation. They are a portfolio of continentally significant sites which can serve as nodes around which a network of reserves can be built. The process involved workshops using experts. The first element was the identification of ecologically significant regions (ESRs). This was to be based on available data, personal knowledge of species habitat and the physical and oceanographic features in the B2B region. A mapping programme was used to bring together proposals and consensus was reached. In a subsequent exercise experts were asked to review and refine the specific criteria for each ESR. Priority Conservation Areas were proposed within these regions.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Mueter, F.J. & Litzow, M.A. (2008) Sea ice retreat alters the biogeography of the Bering Sea continental Shelf. Ecological Applications 18:309-320	✓	✓						Trawl surveys in the SE Bering Sea from 1982-2006 investigating the distribution of demersal fishes and crustaceans revealed a shift in the ecotone between arctic and subarctic communities, approx 230km northwards, since the early 1980s. Several measures suggest warming climate as the primary cause of changing biogeography however internal community dynamics also appear to have contributed to changing biogeography. An important feature of distribution changes in response to warming is variability in the species responses, such that new community combinations may be caused by warming, instead of existing communities simply shifting poleward
New Zealand Ministry of Fisheries (2010) Bioregionalisation and spatial ecosystem processes in the Ross Sea region. IP 107. XXXIII Antarctic Treaty Consultative Meeting 3-14th May, 2010.Information paper submitted by New Zealand.	✓			✓				In 2008 CCAMLR used a circumpolar-scale bioregionalisation to identify priority areas for potential MPA designation in the CCAMLR area and encouraged Member States to progress spatial management planning in particular regions of interest, using bioregionalisation at a smaller regional scale and also systematic conservation planning to identify particular areas of high value for conservation. One result is the South Orkney islands MPA. This paper reports on an expert workshop for the Ross Sea. Outputs included fine scale pelagic and benthic/demersal bioregionalisation to guide design and implent a representative and effective marine spatial protection and management network for the Ross Sea Region.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
OSPAR (2013) An assessment of the ecological coherence of the OSPAR Network of Marine Protected Areas in 2013. Biodiversity Series. 619/2013.	✓	✓		✓				Includes three spatial test on the OSPAR network of MPAs. These were undertaken across the whole OSPAR Maritime Area, by OSPAR region, by Dinter (2001) biogeographic regions, and by ecosystem feature. The test of representation at biogeographic level used a suggested threshold of at least 3% of most (7 out of 10) relevant biogeographic provinces. Thresholds set at 1/10th the value commonly found in the literature. Table 1 summarises the findings in terms of % and number of replicates in 10 of the biogeographical provinces. The sufficiency of replicates needs to be set in the context of the significant difference in area of the different biogeographic provinces.
Poti, M. *et al* (2011) The Existing Network of Marine Protected Areas in American Samoa. Chapter 5. Pg123-128 In KENDALL, M.S. & POTI, M. (Eds). A Biogeographical Assessment of the Samoan Archipelago. NOAA Technical Memorandum NOS NCCOS 132. Silver Spring, MD. 229pp.	✓	✓	✓	✓				Part of larger study. Includes evaluation of the distribution of MPAs in Samoa and American Samoa (AS) in the context of biogeographic regions and ecological hotspots. In Chapter 4, 20 biogeographically distinct regions identified in AS based on the distribution of reef fish and corals and 36 hotspots based on coral cover, coral richness, fish biomass and fish richness. Boundaries of existing MPAs were overlaid to determine which were already represented and to identify any gaps in coverage. There was also a determination of 15 benthic structure types around AS and in each of the MPAs (patch reefs, spur and grove, algal plain, mud etc.). Analysis identified which bioregions had MPAs and whether these included the ecological hotspots. Some bioregions were considered relatively 'high-value' as they had hotspots for 3 out of the 4 variables. The summaries do not take into account size of MPA and type of protection. More detailed examination is required, to see if the habitat within the Bioregion is adequately covered by the MPA. For example Bioregion 1 had replicates of MPAs but only a very small amount of reef ecosystem was covered by these MPAs.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Rengstorf, A.M *et al* (2013) High-resolution suitability modelling can improve conservation of vulnerable marine ecosystems in the deep sea. J.Biogeogr 40:1702-1714	✓	✓	✓	✓				Modelling was used to predict *L.pertusa* reef distribution at a spatial resolution of 200m. Coral occurrences were assembled from public databases, publications and video footage and filtered for quality. Environmental predictor variables were produced by re-sampling global oceanographic data sets and a regional ocean circulation model. Multi-scale terrain parameters were computed from multibeam bathymetry. Suitable habitat was predicted on mound features and in canyon areas along a narrow bank following the slopes of the Irish continental margin, Rockall Bank and the Porcupine Bank. The first regional coral habitat suitability modelling study to incorporate full coverage multibeam bathymetry in the deep sea. The use of high resolution environmental data and quality controlled distribution data significantly reduces habitat overestimation demonstrated by global-scale analyses and produces detailed maps to support MPA network design. The comprehensive environmental data set compiled for this analysis could be used for habitat suitability mapping for other benthic and demersal species in the region.
Rice, J. *et al* (2011) Policy relevance of biogeographic classification for conservation and management of marine biodiversity beyond national jurisdiction, and the GOODS biogeographic classification. Ocean & Coastal Management 54:110-122	✓	✓		✓			✓	Describes development of the GOODS biogeographic classification which has both benthic and pelagic zones each of which divided into biogeographic provinces. Some simplifications but considered a reasonable basis for advancing management based on the best available science. Building and assessing networks of MPAs recognised as one of the potential uses of biogeographical classification. Policy roles include applying the ecosystem approach and implementation of representative networks of MPAs. Biogeographical classifications identify the units which should be represented in the network. Case studies of experience in the Southern Ocean, NE Atlantic, Australia, Mexico and Canada on application of classifications. All have data issues but even for the GOODs classification with currently limited knowledge they broadly differentiate major ecosystem types and can serve as a basis for management and further subdivision.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Rodriguez-Rodriguez, D. *et al* (2013) Criteria for assessing ecological coherence of MPA networks. A review. PANACHE Project Work Package 1.	✓	✓	✓	✓				Discussion of criteria to assess ecological coherence of MPA networks. Biogeographical aspects identified in relation to viability/adequacy (between 10-20% of each EUNIS level 3 habitat present within each OSPAR biogeographic region), Representativity (at least one spatial unit of each defined habitat type in the MPA system - which is influenced by the limits of the search area (i.e. biogeographical context), replication (to increase likelihood of the range of marine biological variation present in each biogeographic area being incorporated in the network) and the level of habitat classification used. Several classifications available depending on the underlying consideration e.g. temperature, depth etc. Case studies provide more detail on the criteria used in various MPA programmes
Spalding, M.D. *et al* (2007) Marine ecoregions of the World. A bioregionalisation of coastal and shelf areas. BioScience 57(7) 573-583	✓	✓		✓				Proposed global system of biogeographic classification for coastal and shelf areas - Marine Ecoregions of the World (MEOW). A nested system of 12 realms, 62 provinces and 232 ecoregions which can be cross-referenced to many regional biogeographic classifications. The system is based on taxonomic configurations, influenced by evolutionary history, patterns of dispersal and isolation. Definitions are given for Realms, Provinces, and Ecoregions. UK is in Temperate Northern Atlantic Realm, the Northern European Seas province and three ecoregions, the Faroe Plateau, North Sea and Celtic Seas Authors note that biogeographical classifications are essential for developing ecologically representative systems of protected areas. One identified role is to use this to strategically plan and prioritise new marine conservation measures.

Reference	D	A	F	Rep	C	Res	Mn	Relevant details
Turpie, J.K. *et al* (2000) Biogeography and the selection of priority areas for conservation of South African coastal fishes. Biol.Cons 92:59-72	✓		✓	✓				Study on selection of MPAs for the conservation of coastal fish diversity in South Africa comparing 'hotspot', biogeographical and, iterative and 'complementarity' (seeking the minimum number of sites to cover the target group of species) approaches. Species richness of coastal fish analysed using cluster analysis and multi-dimensional scaling. This reveals that they conform to the same 3 biogeographical provinces as other marine taxa although boundaries vary between groups and difficult to determine. Authors conclude that selection of potential MPAs at the centre and boundaries is therefore not only relatively difficult but would miss out several localised endemics. The proposed areas may cover 97% of the species but of the 31 not included, 17 are endemic to southern Africa so additional protection measures/selection may be needed. No evidence that most representative areas are in the centre of a biogeographic zone or that there is greater advantage in siting additional MPAs at zonal boundaries than elsewhere to maximise species representation. Pragmatic approach would be to use species core distributions only.
UNEP (2013) Guidance for Building Marine Protected Areas Networks. Mediterranean Action Plan. Eleventh Meeting of Focal Points for SPAs. Rabat (Morocco) 2-5 July, 2013. UNEP(DEPI)/MED WG. 382/Inf.10. 21 June 2013	✓	✓		✓		✓		Guidance for SPAMIS but apply equally to other types and systems of MPAs in the Mediterranean. Network design principles set out consistent with elsewhere in Europe. Biogeography mentioned in relation to Representativity and resilience (which is related to degree of replication of representative habitats). Guidelines advocate the defining of ecoregions in the Med and that these are used as the basic planning regions through which to analyse current sites and assess the need and location of further sites to progress work on SPAs and build the MPA network. There is the practical benefit that they are convenient units within which to set targets e.g. for replication and representativity and a framework against which to track percentage targets under the CBD. Also recommends having an agreed list of features of conservation importance.