Criteria for assessing ecological coherence of MPA networks: A review

Marija Sciberras, David Rodríguez-Rodríguez, Benjamin Ponge, Emma Jackson

Coherence

PANACHE
Protected Area Network Across the Channel Ecosystem

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A review

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Prepared on behalf of

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by

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Criteria for assessing ecological coherence of MPA networks: A review

Critères d'évaluation de la cohérence écologique des réseaux d'AMP : une synthèse

ABSTRACT

Identifying and protecting marine features through the establishment of marine protected areas (MPAs) is an important step towards conserving biodiversity, yet it is insufficient from an ecological perspective. An ecologically coherent network of well-managed MPAs is now a requirement of a number of international, regional and national directives to effectively protect biodiversity. This means having a network of well-conserved MPAs representing the full variety of a region's ecosystems, with sites close enough together to allow movement of individuals among them.
Historically, MPAs have been established on an ad-hoc basis over varying timescales and with different conservation objectives. Thus, a range of MPA characteristics and a number of ecological processes need to be evaluated to determine if a collection of MPAs within a given region forms an ecologically coherent network.
Several criteria have been proposed to further improve the assessment and design of ecologically coherent MPA networks and ensure consistency across regions. Six of these criteria are reviewed here: representativity, replication, adequacy, connectivity, level of protection and resilience.
Four case studies are then discussed, providing examples of how these criteria have been used in the establishment of ecologically coherent MPA networks.

KEYWORDS: protection, network, coherence, connectivity, representativity, replication, adequacy

RÉSUMÉ

Identifier et protéger les caractéristiques marines d'intérêt à travers la création d'aires marines protégées (AMPs) est une étape importante dans la conservation de la biodiversité, mais pourtant insuffisant du point de vue écologique. Un réseau écologiquement cohérent d'AMPs bien gérées est désormais une nécessité de plusieurs directives internationales, régionales ou nationales, afin de gérer effectivement la biodiversité. Cela signifie avoir un réseau d'AMPs bien conservées représentant tout l'éventail des écosystèmes d'une région, avec des sites suffisamment proches les uns des autres afin de permettre le mouvement des individus entre eux.
Historiquement, les AMPs ont été établies de façon ad-hoc à différents intervalles et pour des objectifs différents. Un ensemble de caractéristiques d'intérêt et de processus écologiques ont donc besoin d'être évalués afin de déterminer si un groupe d'AMPs dans une région donnée forme un réseau écologiquement cohérent.
Plusieurs critères ont été proposés afin d'améliorer l'évaluation et le design d'un réseau écologiquement cohérent d'AMPs, et ce dans les différents régions. Six critères ont été étudiés dans ce rapport : représentativité, réplication, adéquation, connectivité et niveaux de protection et de résilience. Quatre études de cas ont été ensuite discutées, permettant de montrer comment ces critères ont été utilisés dans la création d'un réseau écologiquement cohérent d'AMPs.

MOTS-CLÉS : protection, réseau, cohérence, connectivité, représentativité, réplication, adéquation

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Contents

I. Introduction

Whilst identifying and protecting marine features by establishing marine protected areas (MPAs) is an important step towards safeguarding biodiversity, this is insufficient from an ecological viewpoint (Jones et al., 2007). Throughout their life cycle marine species are likely to disperse in different parts of the oceans through their larvae, juvenile and/or adult stages (Shanks et al., 2003). Therefore, what is needed to protect biodiversity more effectively is an ecologically coherent network of well-managed MPAs (OSPAR, 2006) coupled with the long term sustainable anthropogenic use of the ocean (Halpern et al. 2010).This means having a network of well-conserved sites representing the full variety of a region’s ecosystems, large enough to protect rare, threatened and valued species, habitats and ecological processes throughout our seas, with sites close enough for species to move between them and enough sites to conserve a range of features that are vital for the health of marine ecosystems.

1.1 Defining Ecological Coherence (EC)

There is no universally accepted definition of “ecological coherence” (EC) within the scientific community. The term is not often used in the scientific literature (mainly owing to the legal origin of the concept), and when it is, it may be used in a different context to MPA networks, for example it may imply genetic relatedness (Ardron, 2008). Nevertheless, the term appears more often in the grey literature, usually in the context of Natura 2000 network, where it generally implies some sort of connectivity among structures or ecological processes (Ardron, 2008). Most scientific and technical documents on the topic refer to “ecological representativeness” of MPA networks instead (Wells et al., 2007; UNEP-WCMC, 2008; Australian Government, 2013). For example, the global target of the Convention on Biological Diversity is to explicitly establish a global network of representative MPAs. Thus, although having different implications, the terms “representativeness” and “coherence” are often used synonymously when referring to protected area networks or systems (CBD, 2010).

According to OSPAR, an “ecologically coherent network” of MPAs is defined as follows (OSPAR, 2007):

> “An ecologically coherent network of MPAs:
> (i) interacts and supports the wider environment;
> (ii) maintains the processes, functions, and structures of the intended protected features across their natural range;
> (iii) functions synergistically as a whole, such that the individual protected sites benefit from each other to achieve the two objectives above; and
> (iv) (additionally) may be designed to be resilient to changing conditions”.

The World Commission on Protected Areas defines a MPA network as “a collection of individual MPAs or reserves operating co-operatively 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” (IUCN-WCPA, 2008).

Other definitions exist in the literature. According to Bennet and Wit (2001), an ecological network is regarded as "a coherent system of natural and/or semi-natural landscape elements that is configured and managed with the objective of maintaining or restoring ecological functions as a means of conserving biodiversity while also providing appropriate opportunities for the sustainable use of natural resources". In the context of Natura 2000 network (EU, 1992), Catchpole (2012) states that “…at the scale of the whole network, coherence is achieved when: the full range of variation in valued features is represented; replication of specific features occurs at different sites over a wide geographic area; dispersal, migration and genetic exchange of individuals is possible between relevant sites; all critical areas for rare, highly threatened and endemic species are included; and the network is resilient to disturbance or damage caused by natural and anthropogenic factors”.

Some countries have their own definitions. For example, Canada defines a network, in its Federal MPA strategy (Government of Canada, 2005), as: “A set of complementary and ecologically linked MPAs, consisting of a broad spectrum of MPAs, established and managed within a sustainable ocean management planning framework and linked to trans boundary, global and terrestrial protected area networks”.

1.2. Policy background

1.2.1. International and regional requirements for Ecologically Coherent Network (ECN) of MPAs

The Birds Directive (Council Directive 79/409/EEC; EU, 1979) was perhaps the first environmental policy document to refer to “coherence”. Article 4.3 of this Directive states: “Member States shall send the Commission all relevant information so that it may take appropriate initiatives with a view to the coordination necessary to ensure that the areas provided for in paragraphs 1 and 2 above form a coherent whole which meets the protection requirements of these species in the geographical sea and land area where this Directive applies”.

One of the first mentions of the term “ecological coherence” was made in the preamble to the Habitats Directive (Council Directive 92/43/EEC; EU, 1992). Article 3.1 of this Directive states: “A coherent European ecological network of special areas of conservation shall be set up under the title Natura 2000. This network, composed of sites hosting the natural habitat types listed in Annex I and habitats of the species listed in Annex II, shall enable the natural habitat types and the species' habitats concerned to be maintained or, where appropriate, restored at a favourable conservation status in their natural range”. In addition, Article 10 of the same Directive states that “Where they consider it necessary, Member States shall endeavour to improve the ecological coherence of Natura 2000 by maintaining, and where appropriate developing, features of the landscape which are of major importance for wild fauna and flora".

In 2003, the Helsinki and OSPAR Commissions committed to establish an ecologically coherent network of well-managed MPAs by 2010 (HELCOM, 2003a). This network consists of Baltic Sea Protected Areas (BSPAs) in the Baltic Sea, OSPAR Marine Protected Areas in the North East Atlantic and the Natura 2000 network (coastal and marine Special Areas of Conservation and Special Protection Areas). According to the Ministerial Declaration, the assessment of the ecological coherence of the network should be done in 2010 and periodically thereafter (HELCOM, 2003a). As a result of this meeting, a joint HELCOM/OSPAR Working Programme on MPAs was adopted in 2003 (HELCOM, 2003b) to develop both theoretical and more practical criteria to evaluate the networks. In 2006, OSPAR disclosed a guidance document on "developing an ecologically coherent network of marine protected areas" aimed at setting up principles to help interpreting the concept of an "ecologically coherent network" in the context of a network of OSPAR MPAs (OSPAR, 2006). This guidance was further complemented with the disclosure of a "Background Document to Support the Assessment of Whether the OSPAR Network of Marine Protected Areas is Ecologically Coherent (OSPAR, 2007). Despite the collective efforts by OSPAR Contracting Parties in selecting and establishing MPAs in the North-East Atlantic in the period 2005-2010, the network of MPAs in 2010 was not considered to be ecologically coherent throughout the entire OSPAR maritime area. Therefore, a revised target to establish an ecologically coherent network of MPAs in the north-east Atlantic by 2012 and to ensure it is well-managed by 2016 was recommended (OSPAR, 2010).

The target of establishing an ecologically coherent network of protected areas was also incorporated into the Programme of Work on Protected Areas (PoWPA; CBD, 2004). The overall objective of the PoWPA was the establishment and maintenance of a global network of comprehensive, effectively managed and ecologically representative national and regional systems of protected areas by 2010 for terrestrial and by 2012 for marine areas (CBD, 2004). This target was later on reaffirmed in the 2010 Xth CBD COP, where "the need to enhance efforts towards achieving the 2012 target of establishment of a representative network of marine protected areas" was stated (CBD, 2010).

Article 13.4 of the Marine Strategy Framework Directive (MSFD; EU, 2008) also refers to ecological coherence of MPAs: "…measures established pursuant to this Article shall include spatial protection measures, contributing to coherent and representative networks of MPAs, adequately covering the diversity of the constituent ecosystems, such as special areas of conservation pursuant to the Habitats Directive, special protection areas pursuant to the Birds Directive, and marine protected areas as agreed by the Community or Member States concerned in the framework of international or regional agreements to which they are parties".

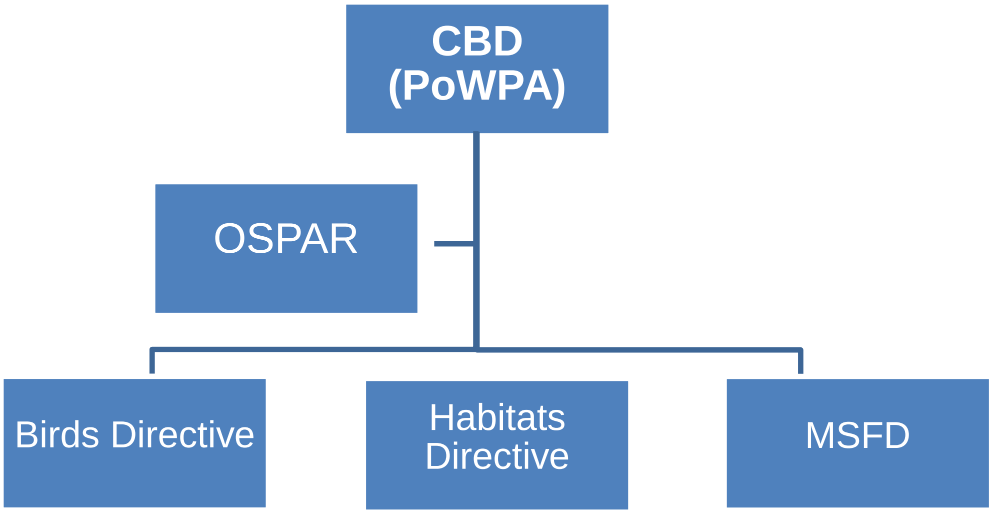

Figure 1. Summary of the policy drivers for ecological coherence of marine protected area networks in Europe

1.2.2. National requirements for ECN of MPAs: The UK

MPAs describe a wide range of marine areas which have some level of restriction of activity to protect living, non-living, cultural and/or historic resources. In the UK, MPAs have primarily been set up to help conserve or recover nationally significant or representative examples of marine biodiversity, including threatened or declining species and habitats of European and national importance (DEFRA, 2012). As defined in the joint administration policy document on ecological coherence published in December 2012 the UK MPA network will include European marine sites (Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), the marine components of Ramsar sites and Sites of Special Scientific Importance (SSSIs), Marine Conservation Zones (MCZs in English and Welsh waters), Nature Conservation MPAs (Scottish Inshore waters and the Scottish offshore region), and future MCZs in Northern Ireland territorial waters (DEFRA, 2012).

The UK has committed to a number of international agreements on MPAs including an ecologically coherent network of MPAs in the North East Atlantic. Together with neighbouring countries, the UK network will act as a contribution to the network based on OSPAR Convention, World Summit on Sustainable Development and Convention on Biological Diversity (DEFRA, 2012). There are also links to European Directives such as the Marine Strategy Framework Directive and EC Birds and Habitats Directives which make reference to establishing coherent networks. National requirements under Clause 123 of the Marine and Coastal Access Act ("Creation of network of conservation sites") requires that MCZs and European marine sites established in the UK marine area form a network that satisfies the following conditions:

(a) that the network contributes to the conservation or improvement of the marine environment in the UK marine area;
(b) that the features[1] which are protected by the sites comprised in the network represent the range of features present in the UK marine area;
(c) that the designation of sites comprised in the network reflects the fact that the conservation of a feature may require the designation of more than one site."

[1] Features are described under Clause 117 of the Marine and Coastal Access Act as referring to marine flora and fauna; marine habitats or type of marine habitat; features of geological or geomorphological interest

1.2.3. National requirements for ECN of MPAs: France

a) Environmental code Article L334-1 / *Code de l'environnement Article L334-1*

I. Is created a national public establishment of an administrative nature named: "Marine Protected Areas Agency" (Agence des aires marines protégées).

II. The Agency coordinates the network of French marine protected areas and contributes to the French participation for the creation and management of marines protected areas decided at the international level.

To this end, the Agency can be appointed for the direct management of marines protected areas.

The Agency provides a technical, administrative and scientific assistance to other managers of marine protected areas and initiates projects of marine protected areas in order to form a coherent network. The Agency thus contributes to the implementation of international commitments of France in the interest of marine and coastal biological diversity.

I.-Il est créé un établissement public national à caractère administratif dénommé " Agence des aires marines protégées ".

II.-L'agence anime le réseau des aires marines protégées françaises et contribue à la participation de la France à la constitution et à la gestion des aires marines protégées décidées au niveau international.

A cette fin, elle peut se voir confier la gestion directe d'aires marines protégées. Elle apporte son appui technique, administratif et scientifique aux autres gestionnaires d'aires marines protégées et suscite des projets d'aires marines protégées afin de constituer un réseau cohérent. Elle contribue ainsi à la mise en œuvre des engagements internationaux de la France en faveur de la diversité biologique marine et côtière.

b) French National Strategy on Biodiversity 2010-2020 (SNB 2010-2020) / Stratégie française pour la biodiversité 2010-2020 (SNB 2010-2020)

The French National Strategy on Biodiversity for 2010-2020 entails 20 objectives turned on 6 strategic orientations, among which some directly involve the network of marine protected areas:

5 – build up an ecological infrastructure including a coherent network of protected areas;

La SNB 2011-2020 comprend 20 objectifs articulés en 6 orientations stratégiques, parmi lesquels certains concernent directement le réseau des aires marines protégées :

5 – construire une infrastructure écologique incluant un réseau cohérent d'espaces protégés ;

c) French National Strategy on Marine Protected Areas 2012 / Stratégie nationale française pour les aires marines protégées 2012

1.5 Principles for a complete and coherent network	1.5 Principes pour un réseau complet et cohérent
1.5.2 A network contributing to the good status of marine ecosystems: representativeness, connectivity, replication	1.5.2 Un réseau contribuant au bon état des écosystèmes marins : représentativité, connectivité, réplication

1.3. MPA categories within the framework of the PANACHE project

MPAs may be designated under international conventions, european or national legislation (see below). Additionally, MPAs may also be established under voluntary codes of conduct and through fisheries bye-laws targeting the management of particular stocks. For example, in the Western Channel, Wembury and the surrounding coastline on the UK coast is a Voluntary Marine Conservation Area (VMCA) and the area in Start Bay is a trawling exclusion area established under the Devon and Severn Inshore Fisheries Conservation fisheries bye-laws.

For the purpose of this review, we will focus on statutory MPA categories occurring within the Channel area that are included towards achieving an ecologically coherent network of MPAs within each respective country (i.e. France and UK).

1.3.1. UK

1. Special Areas of Conservation (SACs). This category of protected areas falls within the broader category "European Marine Sites", and was originally set up in the article 3 of the Habitats Directive. According to the directive, SACs "hosting the natural habitat types listed in Annex I and habitats of the species listed in Annex II, shall enable the natural habitat types and the species' habitats concerned to be maintained or, where appropriate, restored at a favourable conservation status in their natural range" (EU, 1992).

2. Special Protection Areas (SPAs). This category is also included within the broader category "European Marine Sites", and was originally established in the Birds Directive (EU, 1979). SPAs should be made up of the most suitable territories in number and size for the conservation of the bird species mentioned in the Annex I in the geographical sea and land area covered by the Directive in order to ensure their survival and reproduction in their area of distribution.

3. Sites of Special Scientific Interest (SSSIs). SSSIs are designated for the protection of the most significant sites for the conservation of wildlife (species & habitats) and/or geology (NE, 2013).

4. Ramsar sites with marine components. These sites are designated under the Ramsar Convention (Ramsar Convention, 1971) to protect wetlands of international importance in terms of ecology, botany, zoology, limnology or hydrology. In the first instance wetlands of international importance to waterfowl at any season should be included. "Wetlands" are defined as: "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres".

To date, all OSPAR MPAs in the UK are also "European Marine Sites" (i.e. N2000 sites). Marine Conservation zones (MCZs) may form an additional MPA category within the Channel area. Under the Marine and Coastal Access Act (2009), MCZs can be established for conserving marine fauna, flora, habitats, geological or geomorphological features. Although 13 potential MCZ areas have been proposed for the Channel area, the consultation process is still on-going and to date, no MCZs have been designated in the UK.

1.3.2. France

In France, there were originally 6 categories of MPAs in use, but these have been currently extended to 15 categories in 2011, 8 of which are in use in the Channel:

1. *Natura 2000 sites*
   - Site d'importance communautaire (SAC)
   - Zone de protection spéciale (SPA)

2. *Reserve naturelle nationale ou régionale* (National or Regional Nature Reserves). These sites are mainly terrestrial and are created to protect fauna, flora, soil, waters, mineral deposit and fossils or whichever environment of particular significance or that needs to be prevented from artificial activity susceptible to degrade them. They are created by the state (national) or on local impulse (regional), and are considered to be MPAs if they have a maritime part.

3. *Parcs naturels marins* (Marine natural parks). Recent creation (2006) the marine natural parks are MPAs designed for an integrated management of a large scale area. They contribute to knowledge, as to protection and sustainable development of the marine environment. They are created following a public inquiry and always managed directly by a team attached to the Agence des aires marines protégées.

4. *Arrêtés de protection de biotope* (Prefectoral Orders for the Protection of Biotopes). These protected areas are established by the prefect to protect the biotopes necessary for feeding,

breeding, resting and surviving for protected vegetal or animal species to prevent their extinction. They are considered as MPAs if they have a maritime part.

5. *Parties maritimes du domaine relevant du Conservatoire de l'espace littoral et des rivages lacustres* (Public Coastal Domain Sites entrusted to Coastline Conservation). Public land policy, carried out in partnership with local authorities to conserve the coastal area and the maintenance of natural sites and the ecological balance by acquiring land in order to ensure long term protection of fragile and threatened sites.

6. *Ramsar Sites with marine components*. These sites are designed under the Ramsar Convention (Ramsar Convention, 1971) as in UK, to protect the same wetlands of international importance in terms of ecology, botany, zoology, limnology or hydrology.

7. *OSPAR Sites*. To date, some of the Natura 2000 sites, Marine Natural Parks or Nature Reserves are registered as OSPAR sites, meeting the requirements asked by the commission.

8. Biosphere Reserves

II. Criteria for assessing ecological coherence of MPA networks

Several criteria have been proposed to help build and assess an ecologically coherent network of MPAs. In 2006, OSPAR Contracting Parties developed five key criteria of Ecological Coherence: Features, Representativity, Connectivity, Resilience and Management that sat under 13 agreed MPA network design principles (OSPAR, 2006). Replication was also considered within OSPAR (2006), expressed as a contributory factor towards network Resilience. However, in subsequent OSPAR papers, Replication is noted as an element of ecological coherence in its own right (OSPAR, 2008a). Adequacy/Viability is widely accepted as an additional element of ecological coherence, as identified by HELCOM in collaboration with BALANCE (Piekäinen and Korpinen, 2008). The seven network design principles used to guide the development of an ecologically coherent network of MPAs in the UK (refer to DEFRA, 2010; NE and JNCC, 2010) include Representativity, Connectivity, Replication, Viability, Adequacy, Protection and Best available evidence. Under these principles, Viability necessitates that MPAs within the network are large enough to enable most ecological processes to operate within it and is sufficient to encompass the home ranges of species which are target for protection (NE and JNCC, 2010). Adequacy, on the other hand, necessitates that areas should be large enough to ensure the ecological viability and integrity of populations, species and communities, by retaining that the proportion of each feature included within the MPA network is sufficient to enable its long term protection and/or recovery (NE and JNCC, 2010). Protection addresses the range of protection levels that may occur within the MPA network. Together, these principles are expected to deliver an MPA network that contributes to the resilience of the marine ecosystem (DEFRA, 2010).

Table 1 identifies the criteria that different authors or organizations proposed as a basis for assessing the ecological coherence of a MPA network.

Reference	Criteria
OSPAR, 2008a	Representativity, replication, connectivity, resilience, adequacy/viability
OSPAR, 2008b	Connectivity, representativity, replication
Day and Laffoley, 2006 (In OSPAR, 2007)	(1)[2]Adequacy/viability, representativity, replication, connectivity; (2) resilience, precautionary design, external spatial & temporal considerations; (3) Clear objectives, scientific information, socioeconomic info, monitoring & assessment; (4) management, socioeconomic issues, governance, financing
UNEP-MED, 2009	Status, representativity, effectiveness
Sundblad et al., 2011	Adequacy, representativity, replication, connectivity
Piekainen and Korpinen, 2008	Adequacy/viability, representativity, replication, connectivity
HELCOM, 2010	Adequacy, representativity, replication, connectivity
Catchpole, 2012	Representativity, replication, connectivity, viability, resilience
Bennet and Wit, 2001	Connectivity
Lawton et al., 2010	Representativity, size, protection, management, connectivity, human accessibility
Day and Roff, 2000	Size, shape, connectivity, management, replication, redundancy
University of Queensland, 2013	Representativity, replication, costs
NE and JNCC, 2010	Representativity, replication, adequacy, viability, connectivity, protection, best available evidence

Table 1. Criteria used as a basis for assessing the ecological coherence of a MPA network

The next sections describe some of the ecological criteria mentioned above and the indicators and thresholds that have been described in the literature to assess these criteria.

[2] Numbers between parentheses refer to the applicability of the criteria or to their relatedness to EC.

2.1. Representativity

In general, species diversity increases with habitat diversity, therefore the greater the variety of habitats protected, the richer the biodiversity being protected. MPAs that represent and replicate all habitat and community types within well-connected networks are more likely to lead to the persistence and resilience of ecosystems and ecological processes in a changing world (Roberts et al., 2003). Therefore, in its simplest form Representativity is achieved when the full range of ecosystems, habitats and the biotic diversity, ecological processes and environmental gradients (e.g. depth, wave exposure) are included in the network (Chiappone et al., 2000, Day and Roff, 2000, Airamé et al., 2003, Roberts et al., 2003, IUCN-WCPA, 2008).

Stevens (2002) referred to representativity of MPA networks: “MPAs within a network (should) contain core areas that meet at least one (preferably more) of the following criteria: high biodiversity, uniqueness, critical habitat for ecosystem function or for a species of particular interest, high productivity”. In the review for the criteria to identify nationally important marine features in the UK (Connor et al., 2002), representativity is called ‘typicalness’ and is defined as: “the area contains examples of marine landscapes, habitats and ecological processes or other natural characteristics that are typical of their type in their natural state.” Similarly, ‘representativeness’ is equated with ‘typicalness’ within the guidelines for the identification of biological SSSI (Joint Nature Conservation Committee, 1998). Sometimes, representativity is also referred to as ‘comprehensiveness’ (Australian Government, 2013).

2.1.1. Scale of representativity

a) Biogeographic regional scale

Representation of all biogeographic regions is a prerequisite for protection of biodiversity (Airamé et al., 2003, Roberts et al., 2003). Day and Roff (2000) have argued that representation of different biogeographic regions in a network of MPAs should be a core conservation objective, because the species assemblages will be distinct in each.

There is no unanimity with regard to the biogeographic consideration of the English Channel. Beaugrand et al. (2000) split the English Channel into three zones, characterized after their similar biological composition and their seasonal and inter-annual evolution (1979–1995) in plankton communities: the first zone corresponds to the Eastern Basin of the English Channel (EBEC), the next to the Western Basin of the English Channel (WBEC) and the third is the Ushant front. Arvanitidis et al. (2009) examined whether biogeographical/managerial division across the European seas – i.e. OSPAR, IHO, Longhurst (2007), ICES, LME – could be validated using soft-bottom macrobenthic data. They found that the only marine biogeographic system supported by the analysis was the one proposed by Longhurst (2007), even if this partition was developed to interpret plankton multi-species distribution patterns as a function of regional oceanographic characteristics. These results suggested a strong bentho-pelagic coupling. Following Longhurst (2007), the English Channel is the area from the Strait of Dover west to Ushant and belongs to the Atlantic coastal biome and the Northeast Atlantic shelves province (NECS). Spalding et al. (2007) proposed a global nested system for coastal and shelf areas: the Marine Ecoregions of the World (MEOW). In this classification, EBEC belongs to the North Sea ecoregion, WBEC to the Celtic seas ecoregion, with a boundary between EBEC and WBEC.

For the assessment of the OSPAR MPA network, the OSPAR guidance promotes the use of Dinter (2001) biogeographic regions, which were primarily identified using temperature, depth and current data validated with biological data. However, at a national level finer-scale subdivisions of biogeographic regions, incorporating geomorphology, provide a more ecologically meaningful scale for biodiversity conservation planning and practical application of representation (Jackson et al., 2008).

b) Marine landscape scale

This level represents an intermediate scale between regional seas and habitats, which have consistent physical and ecological character and provide a sensible scale to relate to the management of certain human activities such as fishing (Golding et al., 2004).

In general, the classification of marine landscapes has been based on readily available broad-scale geophysical and hydrographical data to define and map a series of marine landscape types for the seabed and water column (e.g. see Roff and Taylor, 2000 for Canadian waters; Golding et al. 2004 for UK waters). The classification is based on the assumption that geophysical and hydrographical information (e.g. bathymetry, seabed sediments, bedforms, maximum near-bed stress) can be used in lieu of biological information to classify medium scale marine habitats and to set marine nature conservation priorities (Vincent et al. 2004). The justification for this assumption is the very strong ecological relationship which exists between geophysical and hydrographic factors and the character of biological communities. There is an extensive scientific literature describing this ecological relationship, (e.g. Hiscock 1998 for the UK), and the relationship is used as the basis of both the UK (Connor et al., 2003) and the European EUNIS marine habitat classifications.

c) Habitat/species scale

Representation of individual habitat types and species ensures that areas of high biodiversity value and species of high conservation importance are maintained within protected areas where damaging anthropogenic activity is regulated. Invertebrates and, particularly, fish species use different habitats at different life stages (Ruzycki and Wurtsbaugh, 1999; Beck et al., 2001; Hiddink, 2003; Mumby et al., 2004). Therefore, special care should also be taken to guarantee inclusion of rare habitats (Roberts et al., 2003) and areas of ecological importance such as spawning areas, nursery areas, feeding areas, breeding areas and wintering areas (Roberts and Sargants, 2002).

The difficulty with assessing representativity at this scale is that more often than not knowledge of the distributions of all known habitats and species is generally lacking (due to issues related to time and money) and tends to be available for a handful of species and habitats, particularly for those of high conservation concern.

2.1.2. Targets for representativity

OSPAR guidelines recommend that within each OSPAR biogeographic region the OSPAR MPA network should contain one example of each EUNIS level 3 habitat present within that region (OSPAR, 2008a). The 5th IUCN World Parks Congress recommends that in order to establish representative networks of marine and coastal protected areas, at least 20-30% of each habitat should be included within the network (IUCN, 2003). Jackson et al. (2008) suggested that applicable baseline targets for representativity within English territorial waters are; 20% of area or known occurrences of priority species and habitats (BAP, OSPAR threatened or declining and cNIMF), a minimum of 10% representation of all other habitats (EUNIS level 4) and a minimum of 10% of the known area for landscape representation (for EUNIS level 3 habitats). For the assessment on representativity of the network of MPAs in the Baltic Sea, a three-level classification scheme for the proportionate representation of benthic marine landscapes was applied: < 20% protection was considered inadequate representation; 20 – 60% protection as questionable (depending on feature), and > 60% as adequate representation (HELCOM, 2010).

Conclusions/Recommendations

- Given the hierarchy of scales identified above, it would be valuable to assess the coherence of the MPA network at different scales
- Where biological data are inadequate, geomorphological data, or even more simple surrogates could be used to help define habitats. Surrogates may include depth, distance from the shore, hard seabed substrates versus soft seabeds, primary productivity and thermal fronts
- Areas of ecological importance that are critical for different life stages of species should be represented within the network.

2.2. Replication

Replication refers to protecting a sufficient number of individuals of species, habitats and ecological processes in sufficiently distant MPAs it order to prevent their loss from risks affecting individual MPAs (Roberts et al., 2003). A similar definition of replication is given by the Secretariat of the Convention on Biological Diversity (2004): "All habitats within each region should be replicated and these should be spatially separate to safeguard against unexpected failures and collapse of populations". The replication of a feature within a single MPA should be taken into account when planning MPA boundaries, whereas the replication of a feature within the network of MPAs ensures a higher level coherence.

There are several reasons to replicate representation of species, habitats and ecological processes within a MPA network:

- to increase the likelihood of the range of marine biological variation present in each biogeographic areas being incorporated in the network. Habitat diversity and complexity is often poorly understood, and replication of protected areas increases the likelihood that all aspects of habitats and communities are represented within the network (Roberts et al., 2003; IUCN-WCPA, 2008);
- to provide stepping stones for dispersal of marine species, thereby enhancing connectivity in the network (Cowen and Sponaugle, 2009);
- to provide a safeguard against local environmental disaster should one example be degraded (either by damaging events or via long-term change affecting individual MPAs). This also enhances network resilience by reducing feature susceptibility to catastrophic events (IUCN-WCPA 2008);
- to provide locations that could act as a source for re-colonization if a similar area is damaged (Crowder et al. 2000).

2.2.1. Targets for replication: How many replicates?

Feature (i.e. species, habitats or ecological processes) vulnerability is an important consideration for determining the number of replicates of a particular feature within the MPA network. MPA networks are most effective when each biotope type is represented in more than one MPA. Several recommendations have been put forth:

- at least three replicates per habitat type are included in the network (IUCN-WCPA, 2008; McLeod et al., 2009; HELCOM, 2010);
- within each OSPAR biogeographic region, at least two MPAs for each EUNIS level 3 habitat and at least three MPAs for threatened and declining habitats are recommended (OSPAR 2008b);
- the Representative Areas Program guidelines used for the development of a network of no-take areas in the Great Barrier Reef Marine Park recommended three to four replicates of no-take zones for each bioregion (Fernandes et al. 2005);

- within the Irish Sea Pilot (Roberts et al., 2003) it was agreed that habitats should be replicated in at least three, and preferably five or more, protected areas spread throughout the Irish Sea region, wherever the extent and distribution of a habitat allowed
- for the English territorial waters, Jackson et al. (2008) based their targets on OSPAR guidelines and experiences of the Irish Sea Pilot Priority and recommended a target of 5 replicates for priority species and habitats (BAP, OSPAR threatened or declining and cNIMF), 3 replicates for habitat based on EUNIS level 4 classification and 6 replicates for marine landscapes, given that broader/coarser scale classifications require greater replication to include gross variation in habitat types.

Figure 2. Zostera field (Zostera marina) in Chausey (France), protected feature in the English Channel (Thomas Abiven)

Conclusions/Recommendations

- Replication is important at the marine landscape scale as well as at the specific habitat and species scale
- At the marine landscape and habitat/species scale the existing uses and threats to that feature should inform the adequate number of replicates within the MPA network. The more vulnerable the feature is to existing threats, the higher the number of replicates should be to reduce risk of disappearance.

2.3. Adequacy

For an MPA to be considered adequate, several factors have to be satisfied. The area should have an appropriate size and shape, as well as a satisfactory location and characteristics that minimise the impact of natural or anthropogenic threats (HELCOM, 2010). Overall, it has to safeguard the ecological viability and integrity of the populations, species, and communities; and therefore an adequate MPA network must also protect large enough proportion of features, so as to secure their long-term persistence and recovery where necessary (OSPAR 2008b; Rondinini, 2010).

2.3.1. Size and Viability

A long scientific debate has been centred on the question, should a network of MPAs consist of "several small sites or a single large" (SLOSS) or, alternatively, "few large or many small" (FLOMS). Large MPAs support many habitats and landscapes, have large populations of organisms, and reduce edge effects (Airamé et al., 2003; Fernandes et al., 2005). On the other hand, from the perspective of meta-population theory, many interconnected MPAs support more persistent populations than a single or few large (e.g. Zhou and Wang, 2006), given that these are well-connected. Connectivity among MPAs in the network is addressed in section 2.4.

The size of an MPA necessary to afford adequate protection over the long term is influenced by a variety of factors, both ecological and human:

(i) The purpose of the site - For an individual site, where the aim of protection is purely to protect biodiversity it is probably better the larger the site is. The size is not a target itself but the biodiversity it can support;

(ii) Adult dispersal ability - To gain protection from an MPA, organisms must spend at least part of their time within its boundaries. Species whose ranges of movement can be entirely enclosed by an MPA will gain more protection from effectively managed sites, compared to those that move beyond MPA boundaries (Roberts et al. 2010). Larger MPAs will afford protection to a wider range of organisms because they will accommodate the range of movements of more species;

(iii) Larval dispersal ability - To provide any significant protection for a species, the size of an individual MPA must be large enough to allow for self-seeding by short-distance dispersers (Palumbi, 2004; IUCN-WCPA, 2008);

(iv) Minimum viable population - ensuring that a population has a reasonable chance of survival is a critical element for viability, as a reduction of genetic fitness can reduce the ability of a species or group of species to survive environmental change (Hill et al., 2010). Small MPAs may not support populations that are large enough to persist, and very small reserves will function only to the degree that essential linkages to other habitats are maintained (Roberts et al., 2003);

(v) Habitat continuity - small MPAs will only function if there are essential linkages (connectivity) between sites and features. Therefore, where a habitat is abundant in a region, small fragments are more likely to be viable than if the habitat is rare, since linkage to other sources of recruits will be greater for abundant habitats (Roberts et al., 2003). In contrast, if a habitat or a landscape is rare in the area or fragmented, then larger areas will probably be needed. Hence, viability and size of a MPA must be viewed in the context of habitat extent and distribution;

(vi) Anthropogenic threats - The size of the MPA should be set according to the degree of anthropogenic pressure (such as eutrophication, shipping traffic intensity or fishing intensity) experienced by a species or habitat (HELCOM, 2010). Large MPAs are able to offset impacts on features better than small MPAs (Roberts et al., 2010).

How big should individual MPAs be within a network?

Most recommendations in the literature regarding the size of individual MPAs come from information on species' dispersal distance. To date, known larval dispersal distances for species with a planktonic stage, vary from a few meters to ten of meters (e.g. some corals, ascidians, bryozoans, algae) to hundreds of kilometres or even greater (e.g. some fish) (Shanks et al., 2003; Shank, 2009). To ensure persistence, Shanks et al. (2003) recommended that individual no-take areas should be 4 to 6 km in diameter for short distance dispersers and close enough to each other to receive long-distance propagules (20 km is close enough for the long-distance propagules). Lockwood et al. (2002) suggest that MPA size should be about twice the mean dispersal distance of species to ensure sustainable self-recruitment and thus long-term persistence of a given population in an isolated reserve. Based on the result that 81% of 72 species reviewed in the English waters, typically move less than 10 km as adults, Roberts et al. (2010) recommended that for English territorial seas, the median size of MPAs in the network should be no less than 5 km in their minimum dimension, and that the average size of MPAs in the network should lie between 10 and 20 km in their minimum dimension. For most species of commercial importance that inhabit offshore areas and move longer distances than nearshore species, Roberts et al. (2010) recommended that MPAs in the region of 12 to 200 nautical miles offshore should be at least 30 to 60 km in their minimum dimension. For the assessment on adequacy of the networks of MPAs in Baltic Sea, HELCOM (2010) recommended a minimum MPA size of 30 km2. The Representative Areas Program guidelines used for the development of a network of no-take areas in the Great Barrier Reef Marine Park proposed a minimum 20 km radius for no-take zones (Fernandes et al. 2005).

For reasons highlighted above, MPA size recommendations should not only take into account species' dispersal distance but also the number of individuals required for a high probability of survival of the population over a given time (i.e. minimum viable population; Traill et al. 2007). There is no simple cut-off point in size where a habitat patch goes from being viable to non-viable (Roberts et al., 2003). The critical area will be different for each species the habitat supports. Using species densities from literature and surveys and a cut-off point of 5000[3] individuals as a proxy for the minimum viable population (MVP) size, Hill et al. (2010) calculated the area required for a MVP for a number of

[3] cut-off point in good agreement with the median MVP identified by Traill et al. (2007) in their review of 212 species as well as the recommendations of Frankham (1995) based on genetic information

species and habitats of conservation importance in the UK. Hill et al. (2010) recommended that a combination of the MVP area and the dispersal distance would be the most appropriate data upon which to base the design of a viable network of MPAs.

Conclusions/Recommendations

- Where the objective of the MPA is to conserve biodiversity, MPA size should be the largest possible, taking into account the political and socio-economic constraints
- Where the objective of the MPA is to protect particular species, then
  - local information on target species dispersal distances and adult home ranges can be used to describe ideal MPA sizes for those species, where information is available
  - information from other closely-related species or species groups can be used to set MPA size thresholds, where information on specific species is not available
- Where habitat is discontinuous, the optimal MPA size may be constrained by the size of habitat patches
- The size of the MPA should be greater than the area required for a minimum viable population.

2.3.2. Shape

Not only size but also shape affects an MPA. The shape of an MPA determines which landscapes or habitats are included in the MPA. IUCN-WCPA (2008) recommends that the shape of the MPA should capture the gradient from onshore-offshore or habitat-habitat shifts of species of interest. Furthermore, the shape of an MPA may influence its conservation effectiveness by reducing edge effects from threats coming from outside the MPA (e.g. fishing effort concentrating along a MPA border, Stobart et al., 2009). A circular shape is thought to minimize the perimeter-area ratio and thus edge effects affecting the MPA (Pullin, 2002). This may be especially relevant for the viability of small MPAs.

Compactness, as suggested in OSPAR (2007), numerates MPA shape by the equation C = (4πA/p2)0.5. In this equation, C is the compactness, A is an area of the site, and p is its perimeter. This is based on Selkirk's (1982) circularity ratio, 1 where a circle receives a score of 1; i.e. it is the most compact shape, and all others will be less than that.

Conclusions/Recommendations

- In a small site where edge-effects can be considerable, compactness of the site is most likely advantageous. However, in larger sites, compactness might be less important and less compactness might even be preferred to allow spill-over to adjacent areas.

2.3.3. Proportion of a feature in the network

Determining how much should be contained within a MPA network is complex, and requires good information regarding the known distribution of habitats and species within the study area. Ultimately, the amount of area protected will depend: (i) on the dispersal ability of the species, (ii) on the distribution range of the species and habitat of interest, (iii) on the degree of threat experienced by the species and habitat of interest, and (iv) on the conservation status of the respective habitats and species. Furthermore, the total area set aside for the protection of each habitat should be approximately related to its relative prevalence in the region. Therefore, for example, short-distance, threatened and rare or endemic species could need 100% of their habitat being protected for long-term persistence (Jones et al., 2007).

Percentage targets for no-take areas, or marine protected areas, have been implemented in a few cases. In the Channel Islands, off California, USA, 30 to 50% of each habitat in each biogeographic region was recommended to be included in no-take MPAs (Airamé et al., 2003). The Scientific Advisory Panel for the Channel Islands process estimated that this would conserve 80% of the species of concern (Airamé et al., 2003). On the Great Barrier Reef, in 2004, at least 20% of every bioregion (33% overall) was included in a network of no-take areas where the remaining area of marine park (encompassing most of the Great Barrier Reef ecosystem) is included in other categories of marine protected area (Fernandes et al., 2005). Rondinini (2010) provided habitat-specific thresholds for EUNIS level 3 habitat types and habitats of conservation importance in the UK. Thresholds were developed using species-area curves that relate the number of species found in a habitat type with the area of the habitat type (Rondinini, 2010). Other suggestions for the total MPA area that should be protected within a network have been provided: >35% (Bostford et al., 2001); 40% (Sala et al., 2002); 30 - 50% (Airamé et al., 2003); 20 - 50% (Roberts et al., 2003); <50% (Halpern et al., 2004); 20 - 30% (McLeod et al., 2009). It is important to note that in the majority of cases, recommendations assumed that the MPA is a no-take area.

2.4. Connectivity

Connectivity describes the extent to which populations in different parts of a species' range are linked by the exchange of eggs, larvae recruits or other propagules, juveniles or adults (Palumbi, 2003). The connectivity between two populations is dependent on (i) the larval characteristics of the species (e.g. duration of the planktonic stage and swimming behaviour of propagules), (ii) the abundance of the source population, (iii) the availability and suitability of surrounding habitat and (iv) the characteristics of the physical environment (e.g. speed and direction of ocean currents, temperature, salinity) (Shanks et al., 2003; Treml et al., 2007).

2.4.1. MPA spacing: How far is enough?

MPAs of the sizes recommended in section 2.3 should be able to support self-sustaining populations of species that disperse only short distances, but may be unable to sustain populations of long-distance dispersers. For the latter species, it is necessary that MPAs are established in networks of sites that are sufficiently close to exchange enough offspring of these organisms.

Optimal spacing of MPAs in a network is strongly influenced by the spatial scale of movement of the target species (Palumbi, 2004; Gaines et al., 2010). Using data on the larval dispersal of 67 tropical and temperate marine species (including algae, invertebrates and fishes), Shanks (2009) found that larval dispersal varies from less than 1 m to 500 km. After examining a wide range of evidence that included oceanography, modelling, micro-chemistry, population genetics, the rate of spread of invasive species, and the separation of known spawning and nursery grounds, Roberts et al. (2010) found that typical dispersal distances range from a few tens to more than 100 km per year. In general, scientists suggest locating MPAs 10 to 30 km apart. Gaines et al. (2010) recommend 10 to 100 km distance between protected areas. Shanks et al. (2003) recommend a spacing of 10 to 20 km for species with typical pelagic larval durations to promote connectivity among adjacent no-take reserves. McLeod et al. (2009) proposed a general 15 to 20 km distance threshold between MPAs to allow population exchange via larval dispersal. HELCOM (2010) recommended using a theoretical 25 km and 50 km distance thresholds between seascape patches when a network is not targeted to a certain species, or if spatial information on habitat or species distribution is unavailable (Piekäinen and Korpinen, 2008). IUCN-WCPA (2008) suggests a spacing of 10 to 20 km, up to 50 to 100 km between individual MPAs and recommends variable spacing, as opposed to even spacing. It is important to note that research into the question about spacing of MPAs focuses strongly on no-take areas.

There is another dimension to population connectivity that needs to be taken into account; the distribution of suitable habitat. Larvae/propagules will only be able to survive when they reach sites that have appropriate habitats. Therefore, potential distances travelled by propagules only provide a part of the connectivity picture, realized connectivity distances will be a product of distances dispersed by planktonic propagules and the distribution of their habitats (Roberts et al., 2003). Roberts et al.

(2010) recommend that sites in the network supporting similar habitats should be no more than 40 to 80 km apart in order to assure sufficient ecological connectivity.

Ultimately, adequate MPA site size and spacing will depend on detailed meteorological, oceanographic and biological research (Roberts et al., 2010).

Conclusions/Recommendations

- A regional list of species needs to be agreed for which dispersal patterns will be investigated and considered for MPA spacing. This can be supplemented over time to assess or improve effectiveness of the sites
- When data is not available on larval dispersal distances for all the species, grouping of taxa with similar life histories and habitat requirements should be considered
- Information on the distribution of different habitats is important to assess how well connected networks of MPAs are for each habitat type
- For a meaningful assessment of connectivity the biological as well as the physical characteristics of the environment should be taken into account

2.5. Level of protection

Many types MPAs that afford different levels of protection exist. Fully protected areas, such as marine reserves and no-take MPAs, where all extractive activities are prohibited, offer greater benefit for biodiversity and whole-ecosystem conservation. Marine reserves are often advocated when environmental or management uncertainty exists (Grafton and Kompas, 2005). Partially protected areas such as multiple-use marine areas and gear restrictions that allow some types and levels of fishing offer less protection to the entire community because impacts on non-target species and the surrounding environment (e.g. through cascading effects and habitat degradation) may still occur. European Marine Sites (i.e. SACs, SPAs) are one example of MPAs that selectively provides a basis for the well-being of only some species. This has great implications for the assessment of the coherence of the MPA sites within the network.

High levels of protection from exploitation and harm will foster greater build-up of abundance, biomass and egg producing capacity in protected populations (e.g. Mosquera et al., 2000; Pipitone et al., 2000; Garcia-Charton et al., 2004; Beukers-Stewart et al., 2005; Sciberras, 2012). Highly protected sites will therefore support more viable populations and export more offspring than less protected places (Roberts et al., 2010). They will therefore foster greater ecological resilience and have lower extinction risks than more lightly protected sites (Roberts et al., 2010). The required spacing of MPAs also depends on the level of protection afforded to them. The trade-off between level of protection, connectivity and adequacy of MPAs is clear. Roberts et al. (2010) recommended that a lightly protected network will need to have more closely spaced and larger MPAs than a highly protected network to deliver the same benefits. Furthermore, networks that contain a greater coverage of highly protected sites can be expected to perform better under changing environmental conditions (i.e. climate change) than networks that have few such sites (Roberts et al., 2010).

Several sub-criteria should be taken into consideration to determine how much protection is afforded by MPAs within the network:

2.5.1. Conservation objectives of the various MPAs

Only MPAs which are managed towards comparable conservation objectives can be linked. Given that MPAs within a network may have different conservation objectives (e.g. the Channel MPA network), it is important to assess the contribution of individual MPAs to the overall network aims. In the case of partially protected areas, it is important to determine whether the activities that are permitted to take place within the MPA are compatible with the conservation objectives of the MPA sites and also with the overall MPA network.

2.5.2. Management effectiveness

While establishing MPAs is a first step for marine conservation, adequate management and effective enforcement are important if MPAs are to be successful (Cinner et al., 2005). Ineffective or poor management is likely to limit MPA performance (Hockings et al., 2006) and thus their use towards achieving an 'ecologically coherent' network of MPAs. A network of paper parks might meet every one of the spatial design criteria and look excellent on paper, but it would achieve nothing in the way of effective protection and the long-term survival of habitats and species within. Three fundamental questions that need to be taken into consideration when assessing management effectiveness of a MPA include:

- Enforcement: Is there an effective enforcement and policing system in place against illegal infringements?
- Monitoring & assessment: Is there a good monitoring and evaluation system in place that regularly assesses the progress against the objectives of the MPAs within the network?
- Adaptive management: Is the network able to incorporate changes when new information (biological and socio-economical) becomes available?

We strongly recommend the integration and/or addition of these sub-criteria in this section to the OSPAR guidelines as protection level and management effectiveness is essential components for an 'ecologically coherent' MPA network.

2.6. Resilience

Global change is posing new pressures and threats to protected areas and protected area systems (Barber, 2004). The combined impacts of increased human disturbance, climate change, atmospheric and water pollution, and biotic invasions exert pervasive impacts on species and communities, modifying their behaviour, reproduction and mortality rates, and distribution ranges (Gaines et al., 2010). In the marine environment, the combined effects of climate change and alien invasive species are known to have caused the decline and collapse of numerous ecosystems as well as important economic losses (Occhipinti-Ambrogi, 2007).

Resilience is usually defined as the capacity of an ecosystem to maintain key functions and processes in the face of stresses or pressures, either by resisting or adapting to change or by recovering from change (Holling, 1973; Nyström and Folke, 2001).

Figure 3. Oiled razorbill (Alca torda) on the coast of the Irosie Marine Nature Park (Benoît Dumeau)

A number of characteristics of the MPA network will increase resilience:

- Species diversity – Species diversity generally increases with habitat diversity and complexity, therefore protecting large areas with a broad range of habitats and high diversity of species increases ecosystem resilience by ensuring that enough redundancy exists to maintain ecological processes and to protect against environmental disturbance (McClanahan et al., 2002; but see also Bellwood et al., 2003; Hughes et al., 2005)
- Functional group diversity – Communities with high functional redundancy (i.e. more species that can assume the role of the others, so the loss of one species is potentially compensated for by the actions of another) may have a better chance of recovery if a species is lost from a functional group (McLeod et al. 2009)
- Critical areas - critical areas that include nursery grounds, fish spawning aggregation sites, regions that feature high species diversity or high rates of endemism, and areas that contain a variety of habitat types in close proximity to one another (Sadovy, 2006) should be included in the network. It may be important to include areas that exhibit high productivity, predictable upwelling, and efficient larval retention as well
- Replication and Representation – protecting a representative range of habitat types and communities and multiple replicates of each increase the potential of the network to protect a region’s biodiversity, biological connections between habitats and ecological function from anthropogenic pressures (IUCN-WCPA, 2008; McLeod et al., 2009). Although MPAs are expected to provide higher ecological insurance against a number of anthropogenic pressures such as fishing compared to unprotected areas, MPAs do not reduce the effects of environmental stressors such as pollution and climate change (Cote and Darling, 2010). In the light of climate change, McLeod et al. (2009) recommended selecting MPAs in a variety of temperature regimes to spread the risk of habitats in certain areas deteriorating due to thermal stress.

III. Essential sub-criteria

A number of ecological considerations listed in the OSPAR and DEFRA guidance for the identification and selection of MPAs within the MPA network (OSPAR 2003-7; DEFRA, 2010b) are worth including among the sub-criteria that may be used for assessing whether or not MPA networks are ecologically coherent. These sub-criteria are highlighted below.

3.1. Areas of ecological importance

NE and JNCC (2010) described areas of ecological importance as areas which “make a disproportionately greater contribution than other areas to ecosystem function, biodiversity or resilience in the marine environment. These include areas that support particular ecological processes, are important for particular life stages and behaviours of species, are highly productive or support high biodiversity.” Areas of ecological importance identified by NE and JNCC (2010) include the following:

- Areas for ley life cycle stages and behaviours (e.g. breeding, spawning, foraging, moulting, resting and wintering sites)
- Areas of high biodiversity, as these capture a greater number of features within individual MPA sites and hence may improve the efficiency of achieving an ecologically coherent MPA network
- Areas of high productivity, as these may lead to high local densities of herbivorous species feeding on this food source

Whenever possible and data is available inclusion of and connectivity among areas such as nursery, feeding, moulting, wintering, resting sites should be considered in the design of MPA networks (OSPAR, 2008a; McLeod et al., 2009; NE and JNCC, 2010). It is difficult to provide meaningful thresholds for these areas as they are very much species-specific (OSPAR, 2008a).

3.2. Vulnerability, rarity & degree of threat of protected features

Human activities exert pressures on the marine environment which may adversely impact features. Vulnerable, rare and threatened species and habitats should receive higher conservation efforts as their chances of extinction or degradation beyond the point of sustainability is the highest (Pullin, 2002). High levels of protection are likely to be needed in areas which contain extremely vulnerable habitats or species (NE and JNCC, 2010).

3.3. Risks - Past, present and foreseeable future threats

Man-made disasters such as pollutant spills or shipwrecks and natural catastrophes (e.g. tsunamis, red tides) are common in certain parts of the world (Gaines et al., 2010). Some of them can be mitigated, whereas others cannot (Roberts et al., 2003). Depending on their scale, intensity and frequency they can seriously compromise biological conservation and thus the efficacy of MPA networks (Jameson et al., 2002; Jones et al., 2007). As a result, past, present and foreseeable future threats to protected features should be taken into account in order to properly assess the likelihood of a set of MPAs achieving an ecologically coherent MPA network.

IV. Factors influencing Ecological Coherence

Apart from all the above-mentioned criteria and sub-criteria, there are a number of non-ecological factors influencing ecological coherence to different degrees:

4.1. Governance

Governance can be defined as “the interactions among structures, processes and traditions that determine how power is exercised, how decisions are taken, and how citizens or other stakeholders have their say” (Graham et al., 2003). Participative, coordinated and agreed governance is likely to facilitate the meeting of objectives of a network of MPAs (Cicin-Sain and Belfiore, 2005).

4.2. Legislation

Similarly as with governance, a coordinated and coherent legal framework eases the effective management of a network of MPAs.

4.3. Planning

Simplicity of the legal framework regulating the functioning of an MPA network should also be sought in order for managers to have clear, unified aims and objectives to be translated into effective planning and, at a later stage, into precise and measurable management objectives (Chape et al., 2008). Effective MPA network planning needs to be addressed through integrated approaches, considering not only MPAs, but the wider environment and human uses in and around those MPAs. Integrated coastal and ocean zone management provides a large scale, adequate planning framework for linking feature protection with other uses of the coast and sea (Cicin-Sain and Belfiore, 2005).

4.4. Society

The degree of knowledge, use and valuation of protected areas by local populations is key for the success of conservation policies (Rodriguez-Rodriguez, 2012). Too often, protected areas have been considered as limitations to human development, thus facing little support or even active opposition by affected individuals. Proper social communication, awareness and outreach strategies have proved useful to reconcile local populations with nature conservation policies thus facilitating management and effective conservation (Blyth et al. 2002; Borrini-Feyerabend et al., 2004).

4.5. Economy

Economic activities performed inside or in the vicinity of MPAs may influence their conservation effectiveness through associated impacts. They may condition social support for the MPA as well as. Ecosystem service provision and sustainable economic activities should be promoted within a network of MPAs when and where adequate to ensure not only a long-term profitable future for individuals and businesses in the area, but also to gain social support for conservation (Abesamis et al., 2006).

4.6. Culture

Cultural practices can determine the structure and composition of biological communities and thus the characteristics of landscapes and seascapes, especially in intensely and/or historically-transformed regions such as Europe (Jongman, 2002). In the marine environment, some traditional fishing techniques may influence MPA conservation differently for the good or for the bad. Similarly, shipwrecks are also marine cultural features that may have positive conservation value (acting as artificial reefs), and/or negative impact on conservation (e.g. due to fuel leakage). The IUCN widely accepted definition of “protected area” includes the consideration (and subsequent protection) of nature “and associated ecosystem services and cultural values” that do not interfere with nature conservation aims of protected areas (Dudley, 2008). Whereas “nature” and “ecosystem services” are considered to some extent within the OSPAR definitions of “feature” and “MPA” that include species, habitats, ecosystems and ecological processes (OSPAR, 2007), cultural features are not considered at all. This omission should be addressed if a comprehensive and truly coherent network of MPAs is to be achieved.

V. Case studies of ecologically coherent MPA networks

5.1. Case-study 1: Kimbe Bay MPA network, West New Britain, Papua New Guinea

Objectives of Kimbe Bay MPA network:

- To establish a resilient network of MPAs to conserve marine diversity, coral reef ecosystems, and critically important habitats for rare and threatened whales and sea turtles;
- To address local marine resource management needs (e.g. a productive tuna fishery exists in the bay).

The design of the Kimbe Bay MPA network was based on the identification of 15 Areas of interest (AOIs or individual MPAs) (Figure 2). The process for designating these AOIs involved expert scientific advice, targeted research and monitoring and an analytical design process using the marine reserve design software MARXAN. The specific design principles adopted to select AOIs are defined in Table 3.

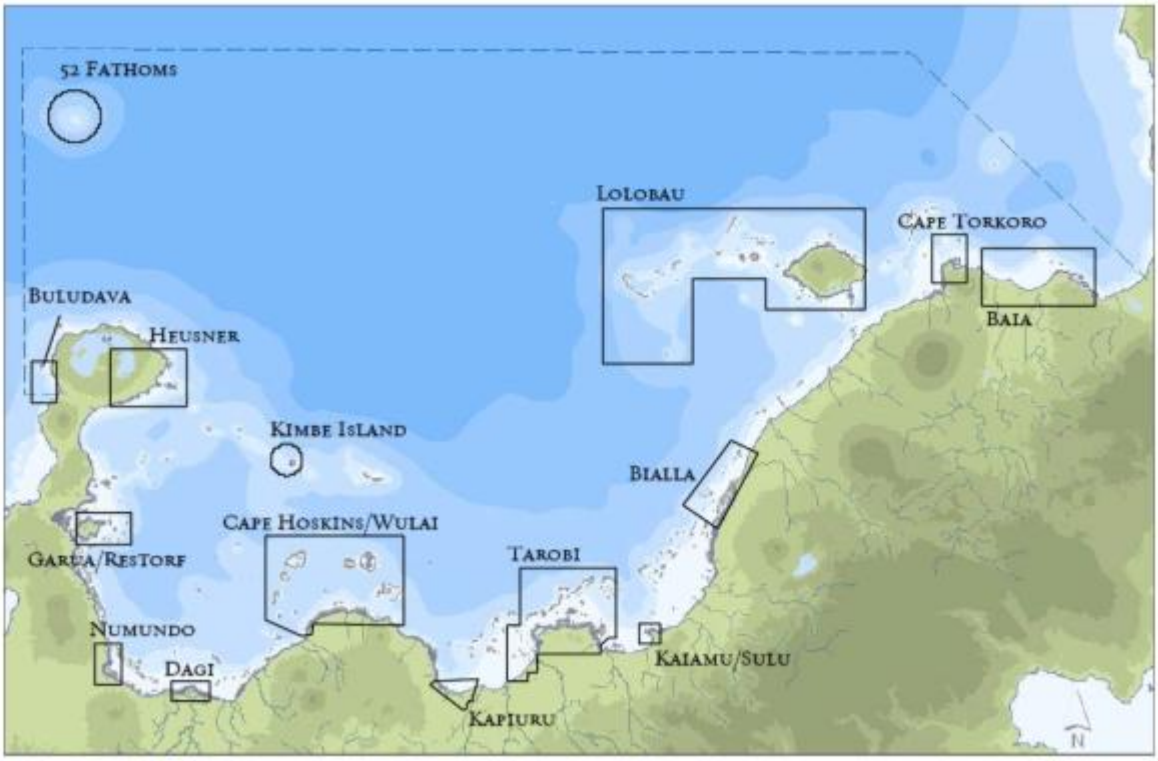

Figure 4. Design of the MPA network for Kimbe Bay, Papua New Guinea, showing Areas of Interest (bozed areas) for biodiversity conservation (taken from Green et al. 2007)

Representation and replication criteria were accounted for by:

- Conserving representative examples of each shallow-water habitat type and key oceanic habitats (seamounts)
- Including a “sufficient” number and area of each habitat type
- Protecting 20% of each habitat type
- Aiming to protect at least 3 replicate areas of each habitat type, and spreading them out geographically to reduce the possibility that all areas will be affected by the same disturbance
- Choosing representative areas based on knowledge to maximize number of species protected
- Choosing sites that are more likely to be resistant or resilient to global change

Critical area criteria were accounted for by:

Including key habitats, namely:

- Areas that may be naturally more resistant or resilient to coral bleaching
- Permanent or transient aggregations of large groupers, humphead wrasses and other key species
- Turtle nesting areas
- Cetacean preferred habitats (breeding, resting, feeding areas and migration corridors)
- Breeding areas for crocodiles
- Areas supporting high diversity
- Areas supporting species with limited abundance/distribution
- Areas that are preferred habitats for vulnerable species
- Areas that contain a variety of habitat types in close proximity to one another

Connectivity criteria were accounted for by:

- Taking a system-wide approach that recognizes patterns of connectivity within and among systems (particularly coral reefs, mangrove forests and seagrass beds)
- Where possible, including entire ecological units (e.g. whole offshore reefs, seamounts) and a buffer around the core area of interest. Where this wasn’t possible, larger areas of continuous ecological units were included (e.g. coastal fringing reefs)
- Using rules of thumb for MPA network design, i.e. where possible AOIs or MPAs were a minimum size of 10 km^2 (10 to 20 km in diameter) with a maximum spacing distance of 15 km between them.

Table 2. Criteria used to establish Kimbe Bay MPA network (taken from IUCN-WCPA, 2008)

5.2. Case-study 2: Channel Islands, California MPA network

The MPA network in the Channel Islands National Marine Sanctuary (CINMS) was primarily established to restore the integrity of the ecosystem and to rebuild collapsed fish populations (Davis, 2005).

The Marine Life Protection Act (MLPA) that came into force in 1999. It required the preparation and implementation of the Marine Life Protection Program throughout the state of California. One of the goals of this plan was to improve and manage the state's MPAs as a network. Following discussions between representatives from the local community, federal, state and local government agencies, the final recommendation was to create a network of 10 MPAs that constituted approximately 20% of the state and federal waters within the National Marine Sanctuary (Figure 3). The establishment of MOAs within state waters became effective in April 2003, whereas the establishment of MPAs in the federal water was put in place in July 2007. The criteria used to design the network are described in Table 4.

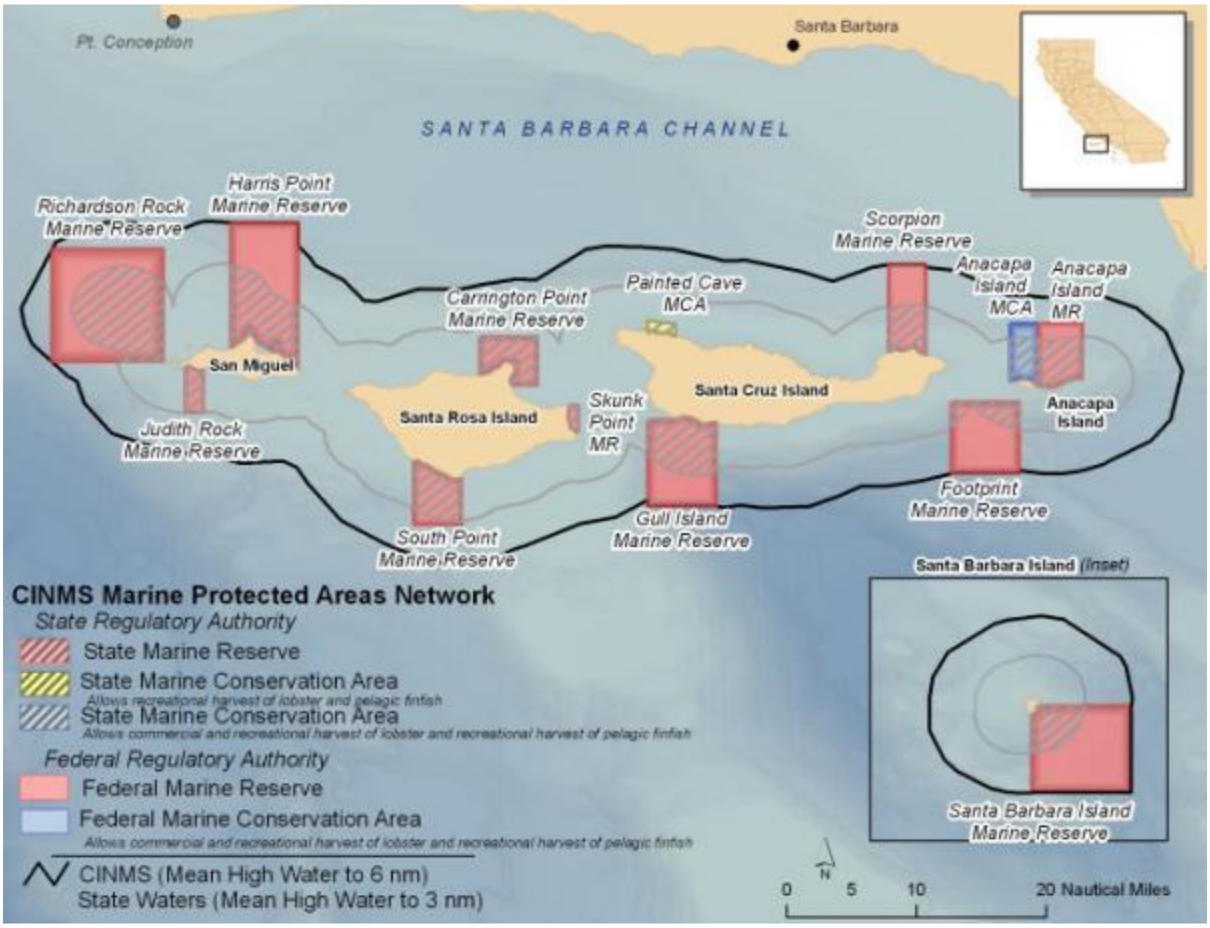

Figure 5. Marine reserve network map for the Channel Islands National Marine Sanctuary, California (taken from: http://channelislands.noaa.gov/marineres/main.html)

MARXAN was used to identify areas of high habitat diversity and areas most likely to represent all habitats within the smallest area possible. Data on representative and unique habitats, and distributions of vulnerable species was used to identify reserve network scenarios with the potential to achieve both fisheries and conservation goals (Airamé et al. 2003). In the absence of data on many of the ecological criteria, reserve networks were identified on the basis of a precautionary approach for the reserve placement. The location of potential reserve sites required evaluation of potential reserve networks using the ecological criteria, but also an evaluation of the best set of sites that provided the greatest degree of flexibility to accommodate various interests of stakeholders (Airamé et al. 2003).

Active public involvement and interest throughout the whole process had been a driving force in the establishment of the reserve network. Strong collaborations between the Channel Islands National Marine Sanctuary, California Department of Fish and Game, the U.S. Coast Guard, the Channel Island National Park and research institutions facilitate a lasting commitment to monitoring and enforcement of the network.

Representation and replication criteria were accounted for by:

- 3 major biogeographical regions identified using data on biota and sea surface temperature (SST)
- Representative and unique marine habitats in each biogeographical region classified using depth, exposure, substrate type and dominant plant assemblage
- 1 to 4 reserves designated within each of the 3 biogeographic regions, comprising an area of 30 to 50% of all representative habitats in the Channel Islands National Marine Sanctuary
- Habitats likely to support exploitable species, especially rockfish, included for specific representation

Critical area criteria were accounted for by:

- Vulnerable habitats (such as coral reefs, mudflats, rocky intertidal areas and seagrasses) considered unique habitat types
- Island coastlines and emergent rocks weighted according to the distributions of pinniped haul-outs and seabird colonies

Connectivity criteria were accounted for by:

- Zones spaced no more than 50 to 100 km apart to facilitate larval and adult exchange between zones

Size was accounted for by:

- Individual zones designed to accommodate species' home ranges

Table 3. Criteria used to establish the Channel Island MPA network (taken from IUCN-WCPA, 2008)

5.3. Case study 3: Commonwealth marine reserves network, Australia

In 1998, the Commonwealth and state and territory governments committed to the creation of a National Representative System of Marine Protected Areas (NRSMPA) by 2012. This commitment was reaffirmed at the World Summit on Sustainable Development in 2002. The Australian Government has established additional Commonwealth marine reserves around Australia, taking the number of marine reserves from 27 to 60. The NRSMPA covers some 3.1 million square kilometres of ocean and is the largest system of marine reserves in the world (Figure 4).

The overall goal of the NRSMPA is to establish and effectively manage a comprehensive, adequate and representative system of marine reserves to contribute to the long-term conservation of marine ecosystems and to protect marine biodiversity. This system aims to be:

- comprehensive by including the full range of ecosystems recognised at an appropriate scale within and across each bioregion;
- adequate by having the required level of reservation to ensure the ecological viability and integrity of populations, species and communities;
- representative by reasonably reflecting the biotic diversity of marine ecosystems.

The Australian Government developed a set of goals and principles to provide a consistent framework for identifying new marine reserves in Commonwealth waters (Table 5). Scientific data and information provided the foundation for identifying and designing new Commonwealth marine reserves. The types of information were varied and covered biophysical data, information about the location and distribution of human activities in each marine region and information provided by industry, managers and regulators, ocean users and stakeholders in each marine region.

The Commonwealth Marine Reserves networks have been designed to minimise both social and economic impacts while creating a system of marine protected areas that represents Australia's diversity of marine ecosystems and habitats. The work of the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), together with the assistance of the commercial fishing industry assessed at both the direct and indirect impacts of the proposed networks on the fishing industry (including commercial and charter fishing) and the potential impacts on related communities. Hence, the social and economic implications of each of the regional marine reserves network proposals played an important role in the design of the networks.

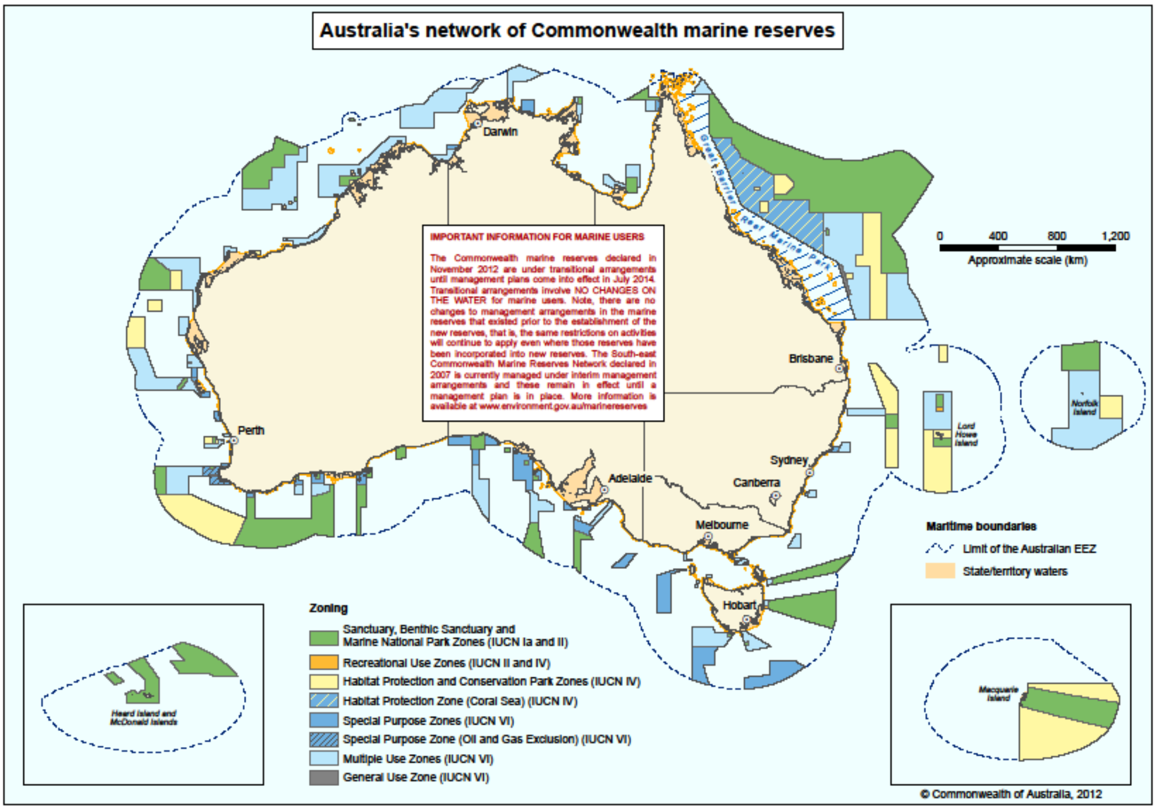

Figure 6. Australia's network of Commonwealth marine reserves (taken from: http://www.environment.gov.au/marinereserves/pubs/map-national.pdf)

Representativity in the network was accounted for by:

- including each **provincial bioregion** at least once in the marine reserve network Priority is given to provincial bioregions not already represented in the National Representative System
- covering all **depth ranges** occurring in the region or other gradients in light penetration in waters over the continental shelf
- including examples of **benthic/demersal biological** features (for example, habitats, communities, sub-regional ecosystems, particularly those with high biodiversity value, species richness and endemism) known to occur in the marine region at a broad sub provincial (greater than hundreds of kilometres) scale
- including all **types of seafloor** features (e.g. seamounts)

Critical area criteria were accounted for by selecting areas with:

- the capacity of a marine reserve to mitigate identified threats to conservation values
- habitats for and/or aggregations of threatened and/or migratory species

• the occurrence of known small-scale (tens of kilometres) ecosystems associated with the benthic/demersal environment • the occurrence of listed heritage sites (where inclusion in the marine reserve network would improve administration of protection regimes)
Replication criteria were accounted for by:
• replicating features wherever possible within the system of marine reserves (that is, included more than once)
Size and shape considerations included:
• selecting the least number of separate marine reserves (that is, a smaller number of larger marine reserves rather than many small marine reserves) to maximize conservation outcomes • accounting for the inclusion of connectivity corridors and biological dispersal patterns within and across marine reserves • boundary lines should be simple, as much as possible following straight latitudinal/longitudinal lines • boundary lines should be easily identifiable, where possible coinciding with existing regulatory boundaries • the size and shape of each area should be set to minimize socio-economic costs (see also Zoning)
Zoning considerations in developing the regional systems of marine reserves included:
• selecting some highly protected areas (IUCN Categories I and II) in each provincial bioregion • considering the threat that specific activities pose to the conservation objectives of each marine reserve. Hence, zoning ensures that the conservation objectives of the area are protected, taking into account a precautionary approach to threats as well as the relative costs and benefits (economic, social and environmental) of different zoning arrangements

Table 4. Criteria used to establish the Channel Island MPA network (adapted from http://www.environment.gov.au/coasts/mbp/publications/general/goals-nrsmpa.html)

5.4. Case study 4: Towards establishing an ecologically coherent network in the UK: Marine Conservation Zones

Under international (OSPAR Convention, The World Summit on Sustainable Development, The Convention on Biological Diversity), regional (EU Marine Strategy Framework Directive) and national (Marine and Coastal Access Act 2009) commitments, the UK Government and Devolved Administrations are committed to creating an ecologically coherent network of MPAs. The MPA network will comprise of existing and new MPAs including Special Areas of Conservation (SACs), Special Protection Areas (SPAs), the marine components of Sites of Special Scientific Interest (SSSIs), Ramsar sites and Marine Conservation Zones (MCZs) that will be designated under the Marine and Coastal Access Act 2009.

In 2009, the Joint Nature Conservation Committee (JNCC) and Natural England set up a project to give sea-users and interest groups (stakeholders), from local fishermen to international corporations, the opportunity to recommend possible MCZs to UK Government. The project is known as the Marine Conservation Zone Project and consisted of four regional MCZ projects covering the south-west (Finding Sanctuary), Irish Sea (Irish Sea Conservation Zones), North Sea (Net Gain) and south-east (Balanced Seas). The criteria and principles set by government policy and used by regional stakeholder groups to identify sites that will protect the range of marine biodiversity within the regional MCZ project areas and contribute to an ecologically coherent MPA network are given in Table 6.

In September 2011, these regional MCZ projects recommended 127 MCZs including 65 reference areas to JNCC and Natural England (Figure 5). The recommended MCZs cover approximately 15% of English territorial waters and UK offshore waters adjacent to England, Wales and Northern Ireland).

Representativity in the network was accounted for by including:
• examples of each of the 23 broad-scale habitats • examples of each of the 22 habitats of conservation importance • examples of each of the 29 low or limited mobility species of conservation importance • the three highly mobile species for which MCZs are an appropriate tool within MPAs in each regional MCZ project area
Replication within the network was achieved by including:
• at least two separate examples of each broad-scale habitat, and at least three to five separate examples of each feature of conservation importance in MPAs within each regional MCZ project area
Adequacy within the network was accounted for by protecting:

• between 11 – 42% of each broad-scale habitat (EUNIS Level 3 habitats) within MPAs for each of the regional MCZ project areas
Size considerations of MPAs in the network:
• MCZs for broad-scale habitats should have a minimum diameter of 5 km with the average size being between 10 and 20 km in diameter • For features of conservation importance (FOCI), habitat- and species-specific recommendations for the minimum diameter of the MCZ was provided **Connectivity criteria were accounted for by:**
• Using species-specific dispersal distances or critical areas for life-cycles of FOCI to determine the spacing between MPAs • In the absence of specific information, MPAs of similar habitat should be separated by no more than 40 – 80km • Ensuring that MPAs are well distributed across the regional MCZ project areas **Protection level of each MPA, which determines the range of activities prohibited and allowed within the MPA were set by:**
• Considering the current condition of the features • Considering the pressures to which the features are sensitive • Including at least one viable reference area within each of the four regional MCZ project areas where all extraction, deposition or human-derived disturbance is prevented

Table 5. Criteria used to identify Marine Conservation Zones in England and Wales which will contribute towards creating an ecologically coherent network of MPAs in the UK. (adapted from NE and JNCC, 2010)

Figure 7. Recommended Marine Conservation Zones by each of the four regional MCZ projects
Source: http://www.pbo.co.uk/news/529658/marine-protection-reports-go-to-government

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PANACHE

Protected Area Network Across the Channel Ecosystem

PANACHE is a project in collaboration between France and Britain. It aims at a **better protection** of the Channel marine environment through the **networking** of existing marine protected areas.

The project's five objectives:

- **Assess** the existing marine protected areas network for its ecological coherence.
- **Mutualise** knowledge on monitoring techniques, share positive experiences.
- **Build** greater coherence and foster dialogue for a better management of marine protected areas.
- **Increase** general awareness of marine protected areas: build common ownership and stewardship, through engagement in joint citizen science programmes.
- **Develop** a public GIS database.

France and Great Britain are facing similar challenges to protect the marine biodiversity in their shared marine territory: PANACHE aims at providing **a common, coherent and efficient reaction**.

PANACHE est un projet franco-britannique, visant à une **meilleure protection** de l'environnement marin de la Manche par la **mise en réseau** des aires marines protégées existantes.

Les cinq objectifs du projet :

- **Étudier** la cohérence écologique du réseau des aires marines protégées.
- **Mutualiser** les acquis en matière de suivi de ces espaces, partager les expériences positives.
- **Consolider** la cohérence et encourager la concertation pour une meilleure gestion des aires marines protégées.
- **Accroître** la sensibilisation générale aux aires marines protégées : instaurer un sentiment d'appartenance et des attentes communes en développant des programmes de sciences participatives.
- **Instaurer** une base de données SIG publique.

France et Royaume-Uni sont confrontés à des défis analogues pour protéger la biodiversité marine de l'espace marin qu'ils partagent : PANACHE vise à apporter **une réponse commune, cohérente et efficace**.

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