Assessment of the ecological coherence of the UK's marine protected area network

A report prepared for the Joint Links

Louise Lieberknecht, Tom Mullier, Jeff Ardron

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About this report

This report was prepared for the Joint Links by Louise Lieberknecht (GoBe Consultants Ltd.), Tom Mullier (Marine Mapping Ltd.), and Jeff Ardron (PacMARA) in fulfilment of a contract to assess the ecological coherence of the UK's MPA network, identify gaps in the network, and provide pragmatic recommendations for moving towards a more ecologically coherent MPA network in the UK. The report presents the key results of a series of spatial ecological coherence tests, and is presented alongside an accompanying Excel document containing detailed outputs and a series of PowerPoint slides summarising key findings.

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1. Executive Summary

This report presents the results of a series of spatial tests of the ecological coherence of the UK's Marine Protected Area (MPA) network. The tests conducted in this analysis indicate that while MPA network properties vary across UK regions, with good percentage coverage in some places, overall the network is some distance away from being ecologically coherent. The inclusion of sites currently proposed for future MPA designation would significantly improve the status of the network, particularly in Scottish waters. However, even with these additional sites, notable gaps remain. Waters of the deeper continental shelf and continental slope require further attention, for example, as well as several benthic habitat types in different sub-regions. The adequate protection of mobile species remains an open question, requiring further consideration. We stress the importance of management measures that holistically protect sites, without which many species and habitats within MPAs remain exposed to threats, undermining the core assumptions of ecological coherence.

The concept of *ecological coherence* arose out of the recognition that a network of protected areas should ideally be regarded as a whole, greater than the sum of its individual protected areas. Accordingly, achieving ecological coherence has become part of UK marine policy, particularly with regard to Marine Conservation Zones (MCZs). However, the exact origin of the term is unclear, and definitions vary. Based on the guidance in OSPAR (2007, 2008) and building on its recently commissioned analysis (OSPAR 2013, Johnson *et al.* in review), this assessment of ecological coherence is divided into coarse filter and fine filter tests. The coarse filter tests are designed to provide a rapid, simple and very broad assessment of whether or not there are big gaps in the spatial network configuration. They are 'generous', overestimating the ecological coherence of the network, only identifying the largest and most significant gaps. These tests are relatively simple to complete, and do not require species or habitat distribution data – as such, they are a suitable first step, especially in data-limited situations. The fine filter tests take into consideration the distribution of biota, as far as is possible. The fine filter tests are designed to be more stringent, and to identify gaps that the coarse filter may fail to identify. By their nature, fine-filter tests are more time-consuming, and require more data to yield meaningful results. Because ecological coherence is a multifaceted concept, each test can only consider one aspect at a time; hence, the results presented in this report should be considered as a whole.

The coarse filter tests showed that the current network, at the whole UK level, is close to meeting the Convention on Biological Diversity's Aichi target of 10%. However, the biogeographic coverage of the current network is very uneven, with a more than tenfold difference between the region with the lowest coverage (Scottish Continental Shelf at 3.3%), and the region with the highest coverage (The Southern North Sea at 38.8%). Several regions fail to meet the Aichi target of 10% by a significant margin. These are mainly located in Scottish waters, although the coverage in the south-west is also relatively low (at 8.4%). The coarse filter tests further revealed significant gaps in spacing and depth strata, again most notably in Scottish offshore waters, and to a lesser degree in offshore areas of the south-west of England. When the potential future Scottish sites are included in the coarse filter tests, some, but not all, of these gaps are filled.

Extensive fine filter tests were conducted that considered replication and benthic habitat coverage, as well as proximity of sites containing similar habitat types. These tests revealed a variety of gaps of different kinds in different regions. Using thresholds from the Ecological Network Guidance (ENG) developed for England's MCZ process (Natural England and JNCC 2010) as benchmarks, the tests showed a relatively good level of broad-scale habitat replication within the network at the UK scale, though there were regional shortfalls in the far north-west. The tests showed variation in the percentage representation of benthic habitats, with some habitats under-represented both at the UK level, as well as at a regional level. This included widespread sublittoral sediment habitat types. The habitat-based proximity test revealed gaps in coverage for most habitats, from the intertidal to the deep sea.

The above tests of ecological coherence did not have the data required to assess highly mobile species. However, a visual inspection of combined data layers for some mobile species suggests that there are potential gaps in the network which will require further investigation.

In addition to testing the ecological coherence of the existing MPA network, this analysis also assessed the contribution that potential future MPAs would make towards improving the ecological coherence of the network. The potential future sites that were analysed were those which, at the time of writing, had been proposed for possible future designation within the MPA process in Scotland, and the MCZ process in England. For each test, those potential future sites that would make the largest overall contribution towards filling gaps were identified. The table on the next page (a copy of Table 5.1) presents an overview of these sites (please see the main text and supplementary spreadsheet for details of the tests, as well as the scoring systems applied).

The report concludes with a series of recommendations, which can be summarised as follows:

i. Addressing the larger spatial and depth gaps should be seen as a matter of first priority;
ii. The fine filter tests can be used to "fine tune" at a regional and sub-regional scale;
iii. An agreed-upon UK-wide list of sites which are seen to constitute the UK MPA network, and the features that are protected within them, would facilitate future analyses;
iv. Given the progress in designating sites in the UK, attention should now be focused on their effective management;
v. An assessment of the efficacy of current management measures in protecting ecosystems as a whole, and their gaps, would aid the transition towards taking an ecosystem-based approach in the UK;
vi. To properly address ecological coherence, governance across agencies and jurisdictions will need to be better coordinated.

This analysis has achieved a comprehensive assessment of ecological coherence at the scale of the UK continental shelf. As reflected in OSPAR and other guidance, an iterative approach, starting with simpler tests first, is a defensible and efficient use of resources. This analysis focused primarily on broad-scale network principles and on benthic habitats, as it was considered that these would yield the most meaningful results within the time and data limitations of the project. In any future analyses, data limitations would continue to constrain what could be achieved. However, a more in-depth EBSA-like mapping exercise, using expert judgement combined with available data to identify ecologically important areas across the UK, would provide a valuable layer of additional information to inform future planning. Given the difficulty of combining multiple ecological coherence criteria into efficient network-level recommendations, one additional approach to consider would be to feed the results of this analysis into optimisation tool like Marxan, to highlight efficient options for filling the various gaps.

Potential future MPA	CF area	CF prox	CF b dsh	CF b us	CF b ds	FF rep	FF %	FF prox
NE Faroe-Shetland Channel	26,968	40,233		1,288	13,447	6	3	A6
Rosemary Bank Seamount	7,413	25,067			4,266		2	A6
Faroe-Shetland Sponge Belt	6,379	25,749		2,371	4,008	6	2	A6
Skye to Mull	6,224		4,819					
South-West Deeps East	5,801	9,771	5,623				2	
Barra Fan & Heb. Terr. Seamount	4,701	12,050			2,182	7	2	
North-west Orkney	4,389		4,372				2	A4, A5
West Shetland Shelf	4,047		4,047				2	
East of Gannet & Montrose Fields		14,266	1,838				2	
SW Sula Sgeir & Hebridean Slope		14,049				4	2	
Western Fladen		10,781						
Geikie Slide and Hebridean Slope		10,767		864		5	2	
Central Fladen		10,536						
Fulmar		10,283	2,437				2	A5
Hatton-Rockall Basin		9,936					2	
Greater Haig Fras (rMCZ)			2,032					A4
Southern Trench			1,845					
Firth of Forth Banks Complex			1,609				2	A5
Western Channel (rMCZ)			1,596				2	
North St George's Channel Ext.			1,289					
North St George's Channel			1,231					
Fetlar to Haroldswick						6		A3
Bembridge						4		
Dover to Deal						3		A1
Dover to Folkestone						3		A1
East Caithness Cliffs						3		A3
Bideford to Foreland Point								A2
Compass Rose								A4
Coquet to St Mary's								A2, A3
East of Jones Bank								A4
Farnes East								A4
Hartland Point to Tintagel								A1, A2
Holderness Inshore								A2
NW sea lochs and Summer Isles								A1, A3

Copy of table 5.1 (section 5, page 59). Green = rMCZ, dark blue = Scottish pNCMPA, light blue = Scottish MPA search area; some site names are abbreviated. Columns marked CF area, CF prox and CF b show areas (in km^2) contributed to filling gaps identified in the coarse filter area coverage, proximity, and bathymetric representation tests, respectively, with the latter divided into figures for deep shelf (dsh), upper slope (us), and deep slope (ds). FF rep and FF % show fine filter replication and habitat percentage cover scores. The final column displays EUNIS A2 habitats for which a site was highlighted as filling a gap identified in the habitat-based proximity test. Blank column cells indicate that a site was not identified as making a particularly significant contribution towards filling gaps for a given test, though this does not signify its contribution would be zero (please refer to the information in the Excel document supplied with this report for details).

2. Introduction

2.1 The concept of ecological coherence

2.1.1 Origins and emergence of systematic protected area network principles

Spatial design principles for protected area networks started being articulated in the 'SLOSS[1] debate' of the 1970s and 1980s, when emerging knowledge in fields such as biogeography, population ecology and ecosystem dynamics fuelled discussions over whether a single large reserve would deliver more or less benefit than several small reserves of the same total area (see Kingsland 2002 or Neigel 2003 for a summary). The debate gave rise to ideas on how to optimise the shape, size and spacing of protected areas, so as to maximise the conservation benefits from any given amount of area protected and make efficient use of available conservation resources. One view was that large reserves are better than small reserves, as they are more likely to protect minimum viable populations (Shaffer 1981), as well protecting a larger number of species, based on island biogeography theory (e.g. Diamond 1975). Another emerging view was that isolated reserves are less effective than sets of reserves designed with ecological linkages (such as habitat corridors), allowing movement of species and individuals between reserves (Diamond 1975).

From the 1990s onwards, the SLOSS debate receded with the recognition that the problem was more complicated than just choosing the optimal size of any one given site, but rather that it was a question of how the individual sites contributed to wider networks. The concept of 'systematic conservation planning' emerged, advocating the integrated planning of conservation measures to optimise conservation effort at the network scale (Margules and Pressey 2000), where individual sites connect and complement each other, maximising their collective conservation benefits. Building on elements of the SLOSS debate, a series of systematic reserve network design principles were developed (e.g. see Allison *et al.* 2003, Ballantine and Langlois 2008, Pressey *et al.* 1993, 1994, Shafer 2001, Stewart *et al.* 2003, 2006, Olsen *et al.* 2013, Vane-Wright *et al.* 1991). These systematic principles include representativity / representativeness (reserve networks should protect the full range of biodiversity), adequacy / viability (individual sites and overall areas covered by the network should be large enough), replication (any given feature should be represented in more than one location), and connectivity (pathways for ecological linkages should be designed into a reserve network).

These principles are not static criteria to be applied to individual sites one by one, picking out a single set of the most suitable areas for protection. Rather, the principles allow flexible solutions: within any given planning region, there will be many configurations of sites that would meet all of them. Whether or not any given individual site forms a valuable contribution will depend on what other sites form part of the configuration. This is captured by the concept of 'irreplaceability', which essentially describes the proportion of all the possible efficient alternative network configurations that a given site forms part of (e.g. Leslie *et al.* 2003, Pressey *et al.* 1993 and 1994, Roberts *et al.* 2003, Stewart *et al.* 2003, 2006, Vane-Wright *et al.* 1991). A site which, in itself, may not be 'special' might still be located within a planning region in such a way that it forms a crucial component of multiple alternative network configurations, and thus have high 'irreplaceability' value. However, exclusively selecting sites with high irreplaceability scores would not automatically result in an efficient systematic network, as such a site configuration would be unlikely to represent the full range of biodiversity.

The systematic planning principles emerged in the context of a need for efficiency, i.e. to 'maximise (conservation) bang for buck'. Recognising multiple pressures on land and sea use, opportunity costs of protecting areas (in terms of economic development), as well as costs associated with policing and enforcement, the idea is to design networks that make efficient use of limited conservation resources,

[1] 'Single large or several small'

e.g. by selecting sites with different features / habitat types that complement each other rather than picking a series of 'hotspots' containing similar features.

2.1.2 Ecologically and Biologically Significant Areas

A number of criteria and methods have been put forward for identifying high-value marine areas, e.g. based on high biodiversity ('hotspots' - e.g. Hiscock and Breckels 2007), or based on a combination of criteria, including biodiversity, vulnerability and others (e.g. Derous *et al.* 2007). The term 'Ecologically and Biologically Significant Area' (EBSA) was coined in Canada (DFO 2004, Clarke and Jamieson 2007), and subsequently adopted and expanded on by the Convention on Biological Diversity (CBD). Dunn *et al.* (2014) describe the evolution and application of the EBSA concept under the CBD, culminating in the definition of the following set of seven EBSA criteria for the global oceans: Uniqueness or rarity; Special importance for life history stages of species; Importance for threatened, endangered or declining species and / or habitats; Vulnerability, fragility, sensitivity or slow recovery; Biological productivity; Biological diversity; and Naturalness (CBD 2008).

A full review of criteria, methods and challenges of defining and mapping EBSAs is beyond the scope of this report. However, it is clear from the above that it is a multifaceted concept with no single objectively correct way of identifying 'high value' areas. Within the context of any given analysis, there will have to be discussion and decisions over what criteria are important to consider and, if multiple criteria are used, over how these are combined and evaluated in combination. The CBD guidance (CBD 2010) and supporting documentation (Ardron *et al*. 2009) are clear that criteria should not be pitted against one another. It is nonsensical to ask, for example, if biodiversity is more 'valuable' or 'significant' than productivity. Different criteria focus on different aspects of ecological significance, all of which are important.

Unlike the systematic network principles outlined above (which allow for a flexible set of alternative efficient network configurations), EBSA criteria are static criteria against which any given locality is evaluated in its own right. A site will either meet the criteria, or it won't, irrespective of which or how many other sites also qualify. Therefore, it is helpful to differentiate very clearly between analyses aimed at identifying and mapping areas that are considered particularly important or valuable, and the task of prioritising and selecting groups of sites to protect. Qualifying as an EBSA does not automatically make a site a good candidate for inclusion in a systematic, efficient protected area network.

Clearly, good arguments can be made for prioritising the protection of EBSAs. However, 'cherry picking' a set of high-value areas (EBSAs) identified on a site-by-site basis carries risks of significant opportunity costs and less efficient reserve networks. For example, if multiple 'hotspots' are identified based on a single set of criteria, these sites are likely to share similar characteristics, which will mean that in combination with each other, they are not efficient at representing the full range of species and habitats within a planning region (e.g. Fox and Beckley, 2005). Furthermore, not every EBSA will automatically benefit from being designated as an MPA. Notably the CBD, which has adopted an EBSA approach for the global oceans, has drawn a clear distinction between EBSA criteria and MPA network criteria (Dunn *et al.* 2014, CBD 2008).

2.1.3 What is an 'ecologically coherent' MPA network?

The term 'ecologically coherent MPA network' has emerged as a common phrase in the grey literature on MPAs in the OSPAR region, in Europe and within the UK. There is no single agreed definition of the term, and different sets of practical design principles / ecological coherence assessment benchmarks have been defined under different UK jurisdictions and within different processes (OSPAR, *Natura 2000*, and national MPA processes in England, Wales and Scotland – see the legal and policy context sections below).

The existing definitions of the term combine an element of prioritisation of EBSAs with the flexible systematic planning principles introduced above, giving rise to a multifaceted set of ecological coherence principles which can be grouped as follows:

1) **Representativity / representativeness**: This is a key principle of systematic planning, which can be translated as 'protect a bit of everything' – i.e. a network should represent the full range of biological features (species, biotopes, habitat types) present within the planning region, rather than limiting protection to a narrow range of priority features.
2) **Adequacy / viability:** To realise conservation benefits, networks have to be 'fit for purpose', therefore individual sites need to be large enough (e.g. to contain viable species populations, or other ecosystem components), and the overall network should cover a sufficient proportion of the planning region and the different features present within it.
3) **Replication**: Networks should contain an element of insurance to safeguard against uncertainty and natural variability. Resilience against catastrophic loss of any given site can be designed into a network by selecting ('replicating') sites with similar habitats in separate areas of the planning region.
4) **Connectivity**: Different areas are ecologically linked (species migrate and disperse), and these links are important to minimise risks of extinction in isolated sites, as well as maintaining genetic diversity within populations. Thus, it is desirable to design pathways for ecological linkages into the spatial configuration of a network, e.g. by linking sites with 'habitat corridors', protecting sites along migration or dispersal routes, and / or by ensuring sites are located close enough together to allow movement and dispersal of key species between them.
5) **EBSAs**: Priority should be given to sites that fulfil EBSA criteria (biodiversity, naturalness, importance for life history stages, etc.).

Note that these ecological coherence principles, which are the focus of the analysis presented in this report, purely cover site selection and spatial network design, and do not incorporate considerations about levels of protection and management measures. The success of MPAs depends on effective management (Halpern 2014), and failure to plan management actions at the same time as prioritising sites for protection has been highlighted as a common mistake in conservation priority setting (Game *et al.* 2013). It is important to bear this in mind when interpreting and building on the results of the analysis presented here, as discussed in more detail in section 5.

2.1.4 Applying the concept in practice

The establishment of an ecologically coherent MPA network is an inherently multifaceted goal. Whilst the above overarching principles are simple and intuitive to grasp at a broad level, each one brings its own set of challenges in its practical application. There is no universal, objectively 'correct' set of tests or benchmarks to define the concept in detail. Though significant gaps in a network are readily identified by basic tests, determining at what point ecological coherence has been achieved is more challenging; this will ultimately be a judgement call, probably made in the political arena. Applying the principles in practice requires them to be translated into a practical set of spatial design guidelines or targets (e.g. see Chapter 4 in Ardron *et al.* 2010). This has been done for several processes, including the California Marine Life Protection Act (California Department of Fish and Game 2008, Carr *et al.* 2010), England's MCZ process (JNCC and Natural England 2010), and under OSPAR (2006, 2007, 2008).

Whilst it is possible to develop sound rules of thumb based on scientific information (e.g. Carr *et al.* 2010, OSPAR 2008), doing so is fraught with challenges. Decisions on specific targets or thresholds will inevitably need to involve some value judgements and pragmatic considerations. The principle of connectivity is particularly challenging to apply in practice, as it requires an understanding of larval dispersal and adult movements, which depend on hydrographic conditions (e.g. currents), and on species considered: different species have very different rates and ranges of movement and dispersal (e.g. Gaines *et al.* 2003, Grantham *et al.* 2003, Jones and Carpenter 2009, Kinlan and Gaines 2003, Largier 2003, Palumbi 2003). Rules of thumb on the size and spacing of marine reserves have therefore been developed, aiming to make individual reserves large enough to contain ranges of species with low levels of movement and dispersal, and to locate reserves containing similar habitat types close enough to each other to allow for the exchange of species that move and disperse across greater distances (e.g. Appendix R of California Department of Fish and Game 2008, Carr *et al.* 2010, Shanks *et al.* 2003).

Recognising that applying systematic network principles is a spatial optimisation problem, software tools have been developed that use optimisation algorithms to support decision-making in conservation planning (e.g. Ball *et al.* 2009, Sarkar *et al.* 2006, Leslie *et al.* 2003). Perhaps the most widely known is Marxan / Marxan with Zones (Ball *et al.* 2009, Watts *et al.* 2009). Marxan can help optimise spatial reserve configurations, maximising the representation of conservation features (e.g. species, habitats, high ecological value areas) per unit of cost. Marxan has proved to be a popular tool, used by planners and researchers in many different parts of the world; however, in data-poor planning regions, or where data distribution is patchy, decision support software is of limited use, as selection of sites will inevitably be biased towards data-rich locations. Furthermore, Marxan only has limited capabilities for addressing the principle of connectivity (e.g. Ardron *et al.* 2010).

As with the systematic planning principles, significant practical challenges also arise at the point of applying EBSA-style criteria when mapping important / high value areas within a planning region - even against a just single criterion. For example, mapping biodiversity hotspots will entail decisions on which diversity indices to use and the appropriate spatial resolution for the analysis, as well as the addressing of data quality issues (e.g. correcting for the inevitable unevenness of sampling effort across large planning regions). These practical challenges are multiplied in any analysis which considers multiple criteria. Prior to the advent of software like Marxan, 'scoring' systems appeared to be an intuitive solution, but in practice have several serious shortcomings (e.g. Game *et al.* 2013, Klein *et al.* 2014, also see box 4.1).

As argued in OSPAR (2008) and Ardron (2009), tests (such as those used in the analysis presented in this report) cannot unequivocally determine if ecological coherence has been achieved; rather, they can only indicate where there are gaps. Once a simple test has been 'passed' then more complicated tests will be required to tease out the next level of detail. For example, in order to assess connectivity, a simple proximity test (as done here) can be constructed to measure the distance between sites. This test can highlight large spatial gaps in the network that signify a lack of ecological connectivity. However, meeting a simple proximity test, in itself, is not equivalent to meeting the principle of connectivity, as the proximity test does not take more detailed considerations into account, e.g. migration routes, larval dispersal pathways, etc. These would require more in-depth tests, based on much more detailed scientific information and data analysis.

In applying ecological coherence tests, pragmatic considerations around resource and data availability are key, because in reality, much of the interpretation and translation of ecological coherence principles will be driven by what data are available, their quality and regional coverage, as well as the time, expertise, and tools available. There is no practical value in developing detailed ecological coherence benchmarks that depend on high-resolution scientific data or analytical tools that are not going to be available within the timeframe of the analysis in question, however valid the underpinning rationale might be. As an example, there may be good information about minimum viable population sizes for a range of species, but without high resolution spatial data of their distribution covering the extent of the planning region, setting quantitative targets for representing minimum viable population sizes within protected areas serves no practical purpose. In order to address the adequacy and representativeness principles, UK conservation bodies have developed target ranges for percentage coverage of broad-scale habitats (Natural England and JNCC 2010), to act as surrogates to ensure the protection of a certain proportion of benthic species. This is an example of a pragmatic approach for implementing ecological coherence principles in relatively data-poor areas.

If an ecological coherence assessment is designed to provide input to or feedback on a real-world planning process, it may also be important to ensure that benchmarks and tests are designed to incorporate legal and / or policy benchmarks and priorities (irrespective of whether or not these are in line with current thinking in conservation science). For example, whilst the inclusion of socio-economic considerations within a conservation planning process might be seen as undesirable by conservationists, in real-world processes these will inevitably have a significant influence on decision-making. In view of this reality, the concept of 'ecosystem-based marine spatial planning' has emerged in conservation science, which aims to integrate marine spatial planning across multiple human use sectors whilst placing the sustainability of the ecosystem at the foundation of planning decisions (e.g. Halpern *et al.* 2010, Katsanevakis *et al.* 2011).

2.2 UK MPAs: Legal and policy context

2.2.1 Obligations under UK and international legislation

This section briefly summarises key MPA legislation and policy within the UK (see the introduction to Olsen *et al.,* 2013 for wider context). The key point to note is that there is no formal definition of 'ecologically coherent MPA network' in UK or international legislation. Nonetheless, policy has grown around the concept as part of meeting legal obligations (under EU and national legislation) relating to MPAs and MPA networks.

The most relevant piece of EU legislation is the **EU Marine Strategy Framework Directive (MSFD)[2]**, which requires EU Member States to achieve good environmental status (GES) in the marine environment of the EU by 2020, through strategies based on an ecosystem-based approach (Article 1). By 2016, Member States are required to implement a programme of measures to achieve GES. Article 13 stipulates that these 'shall include spatial protection measures, contributing to coherent and representative networks of marine protected areas', adequately covering the diversity of the constituent ecosystems. Thus, the MSFD builds a key principle of ecological coherence (representativeness) into EU law, and includes a wider requirement for 'coherent' networks (albeit without defining the term in detail).

The **EU Habitats & Birds Directives[3,4]** have driven the designation of the *Natura 2000* network of protected areas, consisting of Special Areas of Conservation (SACs) and Special Protection Areas for Birds (SPAs). The directives are transposed into UK law through different pieces of legislation[5]. Marine *Natura 2000* sites (also known as European Marine Sites or EMS) are extensive, and form a key component of the UK's existing MPA network.

Under *Natura 2000*, frequent reference is made to 'coherence' and 'network'. However, in practice the set of criteria for selecting *Natura 2000* sites is narrow. The annexes of the underpinning legislation list a relatively restricted set of marine habitats and species that qualify for protection (under the Habitats Directive), as well as specific criteria for what birds and bird assemblages qualify for protection (under the Birds Directive). Like EBSA criteria, these criteria are essentially fixed - if a given location meets any one of them (e.g. because of the presence of habitat listed on Annex I of the Habitats Directive), it qualifies for designation as a *Natura 2000* site, irrespective of what other sites are already contained within the network. Thus, the legal framework of the Habitats and Birds Directives leaves little scope for the consideration of systematic network design criteria.

[2] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF

[3] EU Habitats Directive: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1992:206:0007:0050:EN:PDF

[4] EU Birds Directive: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:020:0007:0025:EN:PDF

[5] For more information on the transposition of the Birds Directive, see here: http://jncc.defra.gov.uk/page-1373; and for the Habitats Directive, see here: http://jncc.defra.gov.uk/page-1374

The most relevant UK legislation for an ecologically coherent MPA network is the UK Marine and Coastal Access Act (2009), and the equivalent acts in Scotland and Northern Ireland. Whilst there is no formal legal obligation for a UK MPA network that meets all the principles of systematic conservation planning, there *is* a legal obligation (both under the MSFD and national marine acts) to put in place a network that meets the principle of representativeness in particular, and coherence more generally.

The relevant provisions of the **UK Marine and Coastal Access Act (2009) (MCAA)**[6] are as follows:

- Requires the designation of Marine Conservation Zones (MCZs) in the UK marine area, including territorial waters and offshore waters to the limits of the continental shelf (except territorial waters adjacent to Scotland and Northern Ireland).
- MCZs can be designated for the protection (conservation or recovery) of marine flora or fauna (in particular, rare or threatened), marine habitats, and features of geological or geomorphological interest.
- Designation orders must state the protected feature(s) in the MCZ, and the conservation objectives for the MCZ.
- Social and economic considerations may be taken into account when making decisions on designating MCZs.
- Section 123 stipulates that MCZs have to form part of a network representing the range of marine flora and fauna present in UK waters (together with marine *Natura 2000* sites, SSSIs and Ramsar sites).

The **Marine (Scotland) Act (2010)**[7] contains provisions for Nature Conservation MPAs (NCMPAs) that are equivalent to the MCZ provisions in the MCAA, but apply to inshore (territorial) waters adjacent to Scotland. Scottish Ministers have the duty to comply with these provisions. The Scottish legislation also provides for the designation of research MPAs and historic MPAs.

The **Marine Act Northern Ireland (2013)**[8] contains provisions for MCZs to be designated in territorial waters adjacent to Northern Ireland. The provisions are equivalent to the MCZ provisions in the MCAA and Scottish Act, with the exception that, in contrast to the MCAA and Scottish Act, social and economic considerations *must* be taken into account when making decisions on MCZ designation.

Additional pieces of relevant national legislation exist, such as the **UK Wildlife and Countryside Act (1981)**[9] that underpins the designation of Sites of Special Scientific Interest in England and Wales, its Scottish equivalent, the **Nature Conservation (Scotland) Act 2004**[10], and the **Environment (Northern Ireland) Order 2002**[11] underpinning the designation of Areas of Special Scientific Interest (ASSIs) in Northern Ireland. These sites are designated to protect specific, named species and / or habitats. A very small number of these sites extend below the low water mark (within enclosed water bodies such as estuaries), and a larger number include intertidal areas, some of which are designated to protect marine species and habitats. These 'marine SSSIs / ASSIs' are officially considered to form part of the UK's MPA network (HM Government, 2010), albeit a small part compared to MCZs and marine *Natura 2000* sites. It is in fact not straightforward to decide which SSSIs / ASSIs 'count' as MPAs. For example, there are sites that include intertidal areas, but that are designated to protect terrestrial (coastal) species and habitats, or mobile species (such as water birds) that only make occasional forays into the intertidal area. There is at present no officially agreed UK-wide list of marine SSSIs (Ridgeway *et al.*, 2014), though there is information delineating those SSSIs that contribute to the MPA network in

[6] http://www.legislation.gov.uk/ukpga/2009/23/contents
[7] http://www.scotland.gov.uk/Topics/marine/seamanagement/marineact
[8] http://www.legislation.gov.uk/nia/2013/10/contents
[9] http://www.legislation.gov.uk/ukpga/1981/69/pdfs/ukpga_19810069_en.pdf
[10] http://www.legislation.gov.uk/asp/2004/6/contents
[11] http://www.legislation.gov.uk/nisi/2002/3153/contents/made#28

Wales (Welsh Government 2014) and Scotland (Scottish Natural Heritage and the Joint Nature Conservation Committee 2012).

In addition to the above obligations under EU and UK legislation, the UK is a signatory to a number of international conventions relating to environmental protection. The most relevant to MPA networks are OSPAR[12] and the Convention on Biological Diversity (CBD)[13], as well as the Ramsar Convention[14].

2.2.2 International and EU MPA policy objectives and guidelines relevant to the UK

As stated above, there is no legal definition of 'ecological coherence'. Nevertheless, the term is often used in policy documents that have been developed by the different UK administrations under the different processes that are in place to implement the obligations under the various legal mechanisms summarised above. The exact definition, interpretation and application of the ecological coherence concept has varied, both between processes and over time. Generally, the definitions contain elements of flexible systematic reserve network design principles on the one hand and static EBSA-style criteria for selecting and protecting particularly important areas on the other. The following provides a brief summary of key policy commitments and guidelines, as well as a brief summary of progress made on applying these guidelines and implementing the stated policy objectives.

Under the **CBD**, the term 'ecological coherence' is not used in relation to MPA networks. Nevertheless, the guidance adopted by the CBD for MPA networks (Decision IX/20 Annex 2) is very similar to the OSPAR background guidance for ecological coherence (OSPAR 2007). In 2010, contracting parties of the CBD adopted the Aichi targets[15], including Aichi target 11: '*By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes*.' This 2020 target replaced the earlier CBD target of 2012, which was based on a commitment made at the 2002 Johannesburg Earth Summit.

Aichi target 11 mentions 'areas of particular importance for biodiversity and ecosystem services' (EBSAs) along with systematic network principles (representativeness, connectivity). However, unlike other processes, the CBD has drawn a clear distinction between the identification of site-level EBSAs and the design of MPA networks, highlighting that not all EBSAs will be suitable candidates for MPAs (Dunn *et al.* 2014).

Under **Ramsar**, the UK is committed to the protection of wetlands, including coastal wetlands, and sites designated as Ramsar sites officially contribute to the UK's MPA network. However, given that Ramsar sites overlap spatially with other designations (most notably, *Natura 2000* sites), for the purpose of the analysis presented here, this has no practical impact. For brevity, Ramsar sites are not discussed further in this report.

Ministerial Statements at Sintra, Portugal in 1998, Bremen, Germany in 2003 and Bergen, Norway in 2010 committed the contracting parties to **OSPAR** to establish an ecologically coherent MPA network (originally by 2010). Initially, the term was not explicitly defined, nor was there any specific guidance on how ecological coherence might be assessed (see Ardron 2008, 2009); thus in 2006, OSPAR published guidance on developing an ecologically coherent OSPAR MPA network (OSPAR 2006),

[12] http://www.ospar.org/
[13] http://www.cbd.int/
[14] http://www.ramsar.org/cda/en/ramsar-home/main/ramsar/1_4000_0__
[15] http://www.cbd.int/sp/targets/default.shtml

containing 13 guidance principles, and a year later further guidance (OSPAR 2007) covering the systematic network design principles of representativeness, replication, adequacy, and connectivity.

Subsequent work was carried out to develop a more applied series of benchmarks and tests for evaluating the ecological coherence of the OSPAR MPA network, starting with three simple tests (Ardron *et al.* 2008 and 2009, Johnson *et al.* in review, OSPAR 2007, 2008, 2013). These simple tests were recognised as a starting point, not the final word on ecological coherence, and have been used in OSPAR MPA network assessments for the past six years.

The OSPAR ecological coherence guidance was in addition to already developed site-level criteria, which include sensitivity, ecological significance, biodiversity, naturalness, as well as the presence of high priority habitats or species (defined under OSPAR's Texel-Faial criteria – see OSPAR 2003).

2.2.3 Developing UK MPA policy and processes

In the UK, the stated overarching vision guiding marine policy is that of having 'clean, healthy, safe, productive and biologically diverse oceans and seas' (Defra 2002, HM Government 2009, 2011). As a contribution to achieving this vision, the UK Government stated an aim to develop a 'well-managed ecologically coherent network of MPAs' in UK waters, 'well-understood and supported by sea-users and other stakeholders' (Defra, 2010, HM Government, 2010). 'Ecological coherence' was defined on the basis of systematic planning principles, which specifically arose out of OSPAR (2007), including representativeness or 'representativity', replication, viability and connectivity, as well as on the basis of existing legal and policy commitments to protect specific features (e.g. under the Habitats and Birds Directives), and whilst prioritising areas of special ecological importance (defined using EBSA-style criteria).

By the time the policy commitment to an ecologically coherent MPA network was made, the UK had already designated MPAs under existing legal mechanisms. It was recognised that the network would have to build on the existing sites, so it would ultimately be composed of *Natura 2000* sites, Ramsar sites, SSSIs / ASSIs, and MCZs (as well as their Scottish and Northern Irish equivalents) designated under the (then new) marine acts in the UK. Effectively, it was the passing of these marine acts (the MACAA and its Scottish and Northern Irish equivalents) which provided the opportunity to attempt to bring together the different MPA puzzle pieces, and plan a new set of MPAs explicitly within a whole-network context, using the newly defined ecological coherence principles to fill in 'gaps' in the existing assemblage of sites.

In 2012, the UK administrations published a joint statement on the UK's contribution to an ecologically coherent MPA network within the OSPAR area (Defra *et al.* 2012). This statement summarises the UK's interpretation of the OSPAR principles, placing significant emphasis on a 'feature-by-feature' approach that prioritises the protection of threatened and declining species and habitats, whilst the systematic planning principles of representativeness, connectivity and resilience are only very generally addressed.

Because there is no single marine act to cover all of the UK's waters, it was clear from the outset that there would not be a single MPA network planning process for the UK. The UK MACAA formally applies to most of UK waters, but it does not cover the inshore waters (within 12 nautical miles) of Scotland and Northern Ireland - separate marine acts apply under the Scottish and Northern Irish devolved administrations (see previous section). In practice, matters are further complicated by the fact that the planning processes established to meet the MPA requirements of these marine acts do not coincide with the spatial coverage of the three pieces of legislation. In this report, the different processes are referred to as follows:

- 'England's MCZ process', managed by Defra, was set up to cover English inshore and offshore waters, and waters beyond 12 nautical miles off Wales. This process is on-going at the time of writing, with a first tranche of MCZs designated and others awaiting consultation.

- The 'Welsh MCZ process', managed by the Welsh Assembly Government, covers Welsh territorial waters.
- The 'Scottish MPA' process, managed by the Scottish Government, covers Scottish territorial and offshore waters.
- The process under the Marine Act Northern Ireland covers Northern Irish inshore waters, managed by the Department of the Environment Northern Ireland.

Each one of these planning processes operates under its own guidelines that interpret and apply the ecological coherence principles in different ways. Furthermore, these guidelines have shifted and evolved over time, in particular within England's MCZ process. Under the circumstances, it is not surprising that the stated policy aim to develop a single ecologically coherent network at the UK level has faced some challenges.

England's MCZ process developed detailed Ecological Network Guidance or ENG (JNCC and Natural England 2010), which translated the ecological coherence principles into practical design guidelines that could be used by non-experts to guide the design of a suitable configuration of MCZs. Although these guidelines contained elements of EBSA criteria (e.g. favouring the selection of diverse and productive areas over other areas with equivalent habitats, where possible), the main emphasis of the ENG was on flexible systematic planning principles. Sites were initially proposed through a stakeholder-centred process, and the inherent flexibility in the ENG was vital to allow the stakeholders room for negotiating how to meet the ecological benchmarks whilst attempting to minimise negative socio-economic impacts. The stakeholder process ended in 2011, with recommendations for 127 MCZs (rMCZs). The relevant statutory nature conservation bodies as well as an independent Science Advisory Panel considered these recommendations to meet the principal ENG guidelines (MCZ Science Advisory Panel 2011, JNCC and Natural England 2012a).

However, following the end of the stakeholder process, the ENG were dropped from England's MCZ process as a benchmark for evaluating ecological coherence[16]. In order to prioritise sites for a first tranche of designations in 2013, sites from within the set of the stakeholder proposals were evaluated individually (no longer within a network context), on the basis of entirely different criteria, such as the quality of the underpinning ecological information for the site location, or the economic costs of designation, calculated through a separate Impact Assessment (Defra 2013, JNCC and Natural England 2012b). Five of the rMCZs were discarded permanently from the set of sites recommended through the stakeholder process. Following a public consultation[17] on a possible first tranche of 31 sites, 27 MCZs were designated in November 2013[18]. For an in-depth analysis of England's MCZ process between 2009 and 2013, see Lieberknecht *et al.* (2013), and Lieberknecht and Jones (*in prep.*).

At the time of writing, a new assessment at the network level is being carried out by the JNCC to identify remaining gaps in the overall network covered by England's MCZ process (i.e. excluding the areas off Scotland and Welsh inshore waters), and help prioritisation of sites from the remaining set of rMCZs for designation in a second tranche due in 2015 (Ridgeway *et al.* 2014). This new assessment is using a new set of ecological coherence tests that are based on OSPAR ecological coherence principles, which are less specific and open to wider interpretation than the ENG (Defra *et al.* 2013).

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[16] See Hansard HC, 14 March 2013, coll. 311W http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm130314/text/130314w0002.htm

[17] https://www.gov.uk/government/consultations/marine-conservation-zones-consultation-on-proposals-for-designation-in-2013, accessed May 2014

[18] https://www.gov.uk/government/collections/marine-conservation-zone-2013-designations, accessed May 2014

As 36% of Welsh territorial waters are already designated as MPAs (notably under the *Natura 2000* process), the Welsh process initially focused entirely on the selection of a small number of highly protected marine reserves, following 11 principles that included an element of systematic network design (e.g. connectivity, viability), but which largely consisted of static EBSA-style criteria (Welsh Government, 2010). The process took a fully top-down planning approach, which generated a lot of stakeholder opposition in subsequent consultation. As a result, the initial proposals for highly protected MCZs in Welsh territorial waters were withdrawn, and the Welsh Government have instead suggested a review and evaluation of the existing sites against ecological coherence principles such as those developed under OSPAR, following recommendations from an advisory group (Welsh Government 2013).

The Scottish MPA process has taken a largely top-down, expert-led approach, following another set of selection guidelines (Scottish Government 2011). In contrast to the ENG of England's MCZ process, the interpretation of 'ecological coherence' in the Scottish guidance is focused on EBSA-style criteria, prioritising sites considered special, and offering arguably less flexibility in terms of which sites could qualify as part of the network. The guidance contains a step-by-step process for criteria to be applied to given locations in sequence, with only the final step considering the location within the wider network context. The guidance has been applied to identify 33 potential Nature Conservation MPAs (pNCMPAs) proposed for designation in Scottish inshore and offshore waters, with further work proposed on an additional four 'areas of search' (Scottish Natural Heritage and the Joint Nature Conservation Committee 2012). A public consultation on the pNCMPAs was carried out from 2013 to early 2014[19], and decisions on site designation are pending at the time of writing.

The marine act in Northern Ireland was passed later than the MACA and its equivalent in Scotland, and the Northern Irish MCZ process is therefore in earlier stages than the processes in other parts of the UK. At the time of writing, public consultations have been carried out on a draft Strategy for Marine Protected Areas (DOENI 2013a), setting out the context and broad objectives of the wider MPA process, and on more specific draft guidance on MCZ selection (DOENI 2013b). The latter sets out a process that has broad similarities with the Scottish MPA process, with initial search areas set to be defined primarily through an expert-led approach, based on principles focussing primarily on priority species and habitats. A series of stakeholder workshops is set to be carried out, which will define proposed MCZs boundaries and management options in more detail. The draft guidance includes a proposed timeline, which indicates that site proposals will be developed over 2014, with options finalised and consulted upon in 2015, and MCZs designated in 2016.

2.2.4 A note on MPA management

Existing MPAs in the UK are not designated to protect areas, but to protect specific features (e.g. species & habitats) present in those areas. Designation orders for each site name the species and habitats which are formally protected and formulate conservation objectives targeted exclusively at these individual features.

Proposed new activities or developments within MPAs are assessed to determine whether or not they would impede the achievement of the stated conservation objectives for the 'designated' features. These assessments are carried out on a case-by-case basis as part of marine licensing and consenting processes, e.g. through environmental impact assessments / Appropriate Assessments[20]. It is often not clear upfront which activities will ultimately be permitted to go ahead in a given site, and which will not. Spatial protection measures (clearly stated limitations on or exclusions of specified activities

[19] http://www.scotland.gov.uk/Topics/marine/marine-environment/mpanetwork, accessed May 2014

[20] There are different processes and assessment requirements under different legal mechanisms and responsible authorities, depending on the location, type and scale of a given proposed new development, plan or activity (not all activities require licensing). These differences are not covered here, as they are of no direct relevance to the assessment presented in this report.

within specific areas) are put in place only where particularly sensitive ‘designated’ features are known to be located within given sites – this means that clearly defined upfront spatial protection measures are often only applied to a small proportion of any given MPA.

This feature-based approach to MPA management caused significant practical challenges for the ecological coherence analysis presented in this document, as described in the methods section of the report and discussed in more detail in the final section.

3. Methods

3.1 Analytical Approach

3.1.1 Background

The analysis presented in this report is based on an evaluation of the spatial network configuration at a national scale, identifying gaps in the network, and highlighting ways of filling them using potential future MPAs (based on existing proposals, i.e. recommended MCZs that are currently being assessed for designation in future tranches, and sites proposed during the on-going Scottish MPA process).

The introduction highlighted that 'ecological coherence' is a multifaceted concept, guided by a set of consistent but broad principles. In order to evaluate whether or not a given set of MPAs constitutes an ecologically coherent network, these principles need to be translated into practical spatial tests. There is no single agreed set of tests that are appropriate in all circumstances - tests need to be tailored to the given context of each specific piece of work. The analysis presented here builds on work that has been carried out under OSPAR (OSPAR 2007, 2008, 2013) as explained by Ardron (2008, 2009) and Johnson *et al.* (in review), as well as the on-going work within England's MCZ process (Ridgeway *et al.* 2014). This helps ensure that the analysis is embedded in relevant policy. Pragmatism in using what data were available was another key consideration in selecting the tests for this analysis.

3.1.2 Coarse filter and fine filter

Based on the guidance in OSPAR (2007, 2008) and building on their recently commissioned analysis (OSPAR 2013, Johnson *et al.* in review), this analysis carried out a series of ecological coherence tests, divided into coarse filter and fine filter tests. The coarse filter tests were designed to provide a rapid, simple and very broad assessment of whether or not there are big gaps in the spatial network configuration. They are 'generous', overestimating the ecological coherence of the network, only identifying the largest and most significant gaps. These tests are relatively simple to complete and do not require species or habitat distribution data – as such, they are a suitable first step, especially in data-limited situations.

The fine filter tests take into consideration the distribution of biota, as far as is possible within the constraints of this piece of work. The fine filter tests are designed to be more stringent and to identify gaps that the coarse filter may fail to identify. By their nature, fine-filter tests are more time-consuming and require more data to yield meaningful results. Furthermore, because each test only considers one aspect of ecological coherence, different tests identify different gaps, which can make the overall interpretation of the results a complex task.

The Joint Links steering group that guided this work stated an ambition to also assess the performance of the UK's MPA network in relation to the protection of mobile species (birds, cetaceans, etc.). An in-depth assessment for mobile species would, as a first step, require identification of the most important areas for these species at a UK scale, an exercise requiring data gathering and analysis well beyond the scope and timescale of this contract. The assessment for mobile species carried out was therefore kept at an exploratory level, mapping the information on mobile species distribution that was readily available, together with the existing network (and potential future MPAs). This provides a "first glance" assessment of the performance of the network in relation to these features.

3.1.3 Biogeographic regions

The project specification called for a comprehensive, UK-scale assessment. All tests were therefore applied at the scale of the UK Continental Shelf (UKCS) area, which includes territorial and offshore waters of England, Scotland, Wales, and Northern Ireland. Note that Isle of Man territorial waters were not included, as the Isle of Man is not part of the UK.

In addition to the analysis at the UK scale, several of the fine filter tests were also carried out at a regional scale, using the biogeographic regions defined in the Charting Progress 2 project (which recently completed a comprehensive assessment of the state of the UK seas, carried out by the UK Marine Monitoring and Assessment community – see UKMMAS, 2010). The Charting Progress 2 (CP2) regions are shown in figure 3.1. Breaking down the ecological coherence tests by CP2 region allows a comparison of the distribution of network gaps between different biogeographic regions within the UK's waters.

3.1.4 Current and potential future network configurations

The specification for this contract was to assess the ecological coherence of the current network, and to carry out a gap analysis to identify potential future sites that could fill gaps. This has been achieved by applying each coarse and fine filter test to two spatial scenarios: 1) the current network configuration (MPAs that are currently designated), and 2) a potential future network configuration which includes sites that have been proposed for possible designation in the future. The analytical results are presented side by side for each test in turn, allowing a direct comparison between how well the current and future network configurations perform (in their entirety) against each ecological coherence test.

In addition, the relative effectiveness of individual potential future MPAs at filling gaps in the current network was assessed for each test, using the various methods described below. Potential future sites that would contribute significantly towards filling gaps are listed along with the results of each test. Rather than listing the 'top five' or 'top ten' sites for each test, the number of 'top contributors' to list was decided upon based on natural breaks in the distribution of the relative effectiveness scores. If, for example, the there was a significant drop in gap-filling effectiveness after the top three sites, then only the top three were listed.

As highlighted above, UK MPAs are designated not to protect integral areas, but specific species and habitats within them, which are named in conservation objectives formulated in the designation orders for each site. This poses a significant complication for this analysis, which is based on a series of spatial tests. In the coarse filter tests, this complication was not taken into consideration – tests were carried out solely on the spatial configuration of site boundaries, without considering what specifically 'counts' as protected in each site. This was considered appropriate, given that the coarse filter tests were designed to overestimate the ecological coherence of the network, and to highlight only the biggest and most significant gaps.

For the fine filter tests, a comprehensive and detailed assessment of existing conservation objectives and related management measures in each MPA was not feasible within the scope of this project, because of the sheer number of sites and conservation objectives within the current network, and the fact that site designations do not always use standard EUNIS nomenclature. However, the JNCC were helpfully able to provide a list of protected features (translated into standardised EUNIS nomenclature) for SACs, based on detailed work carried out as part of their own on-going MPA network gap analysis (Ridgeway *et al.* 2014). Along with information taken directly from designation orders for the small number of existing MCZs (which do follow EUNIS nomenclature), this enabled the inclusion of an additional 'protected features only' current MPA network scenario within two of the fine filter tests, within CP2 regions 1-5 (i.e. those regions covered by the JNCC's gap analysis).

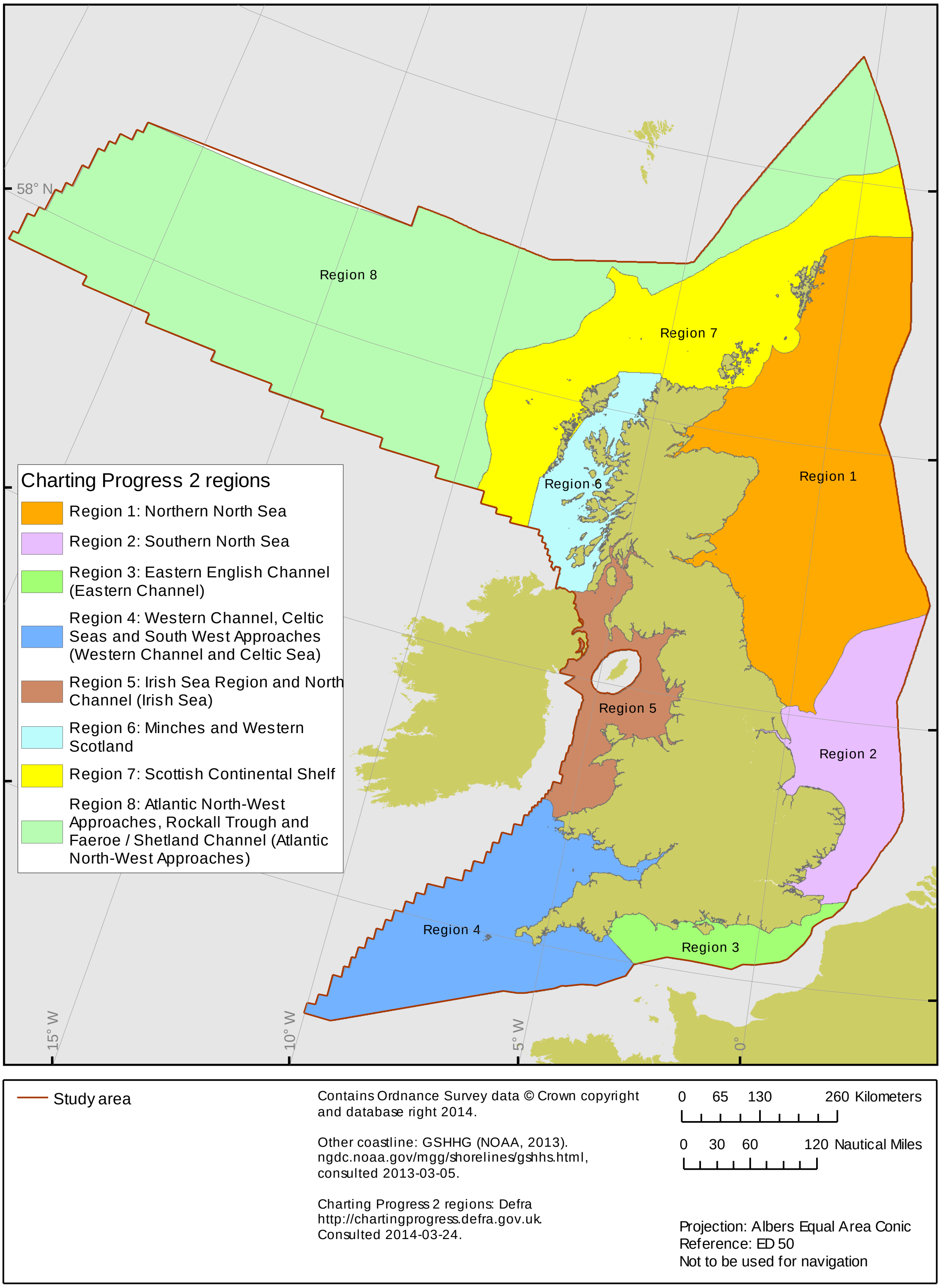

Figure 3.1. Map of the Charting Progress 2 (CP2) regions referred to throughout this analysis. The regions are defined based on biogeographic boundaries (for more information, see UKMMAs 2010)

3.2 Overview of data sources

3.2.1 Boundaries

- The UK Hydrographic Office (UKHO) Continental Shelf boundary was used to delineate the study area[21]. Note that changes to this boundary came into force on March 31st, 2014, following the Continental Shelf (Designation of Areas) Order 2013[22]. These changes are marginal at the UKCS scale, and would not have affected the substance of the findings of the analysis in this report. For pragmatic reasons, the 'old' UKCS boundary was used to delineate the study area for the analysis presented here.
- The Ordnance Survey (OS) Mean High Water mark was used as the landward boundary (OS Boundary-Line, licensed under OS OpenData[23]).
- The UKHO continental shelf boundary is an incomplete line. The median line available on the DECC website was used to fill these gaps, including the Northern Ireland land boundary as no better mean high water boundary was available [24].
- The NOAA GSHHC shoreline[25] (amalgamated from World Vector Shorelines and CIA World Data Bank II data on lakes) was used for mapping (though not for analysis) Northern Ireland, The Isle of Man and other European countries.
- Charting Progress 2 boundaries were downloaded from the Defra Charting Progress 2 Google earth service[26].

3.2.2 MPAs

- SAC and SPA boundaries were downloaded from the JNCC website[27]. SACs that include conservation objectives for mobile species were selected using the JNCC's summary spreadsheet of UK SAC information[28].
- MCZ boundaries (for both designated and recommended sites) were downloaded from the Natural England website[29].
- Scottish pNCMPA and areas of search were downloaded from the Scottish National Heritage website[31]
- English SSSI boundaries were downloaded from the Natural England website[29].
- Welsh SSSI boundaries were downloaded from the Countryside Council for Wales website[30].
- Scottish SSSI boundaries were downloaded from the Scottish National Heritage website[31].
- Northern Irish ASSI boundaries were downloaded from the Northern Ireland Environment Agency website[32].

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[21] www.data.gov.uk/dataset/uk-continental-shelf, accessed April 2014
[22] www.un.org/Depts//los/LEGISLATIONANDTREATIES/PDFFILES/DEPOSIT/gbr_mzn100_2014_continental_shelf_order_2013.pdf
[23] www.ordnancesurvey.co.uk/business-and-government/products/boundary-line.html, accessed April 2014
[24] www.gov.uk/oil-and-gas-offshore-maps-and-gis-shapefiles, accessed April 2014
[25] www.ngdc.noaa.gov/mgg/shorelines/gshhs.html, accessed April 2014
[26] chartingprogress.defra.gov.uk/google-earth-stories, accessed April 2014
[27] www.jncc.defra.gov.uk/protectedsites/SACselection/gis_data/terms_conditions.asp, accessed April 2014
[28] www.jncc.defra.gov.uk/page-1461, version 11 February 2014
[29] www.naturalengland.org.uk/publications/data/, accessed April 2014
[30] www.ccgc.gov.uk/landscape--wildlife/protecting-our-landscape/gis-download---welcome.aspx, accessed April 2014 – note that at this time this website, though created by CCW, was being managed and updated by Natural Resources Wales
[31] gateway.snh.gov.uk/natural-spaces/index.jsp, accessed April 2014
[32] www.doeni.gov.uk/niea/other-index/digital-intro.htm, accessed April 2014

3.2.3 Bathymetry

- High resolution bathymetry data were downloaded from the European Marine Observation and Data Network (EMODnet) hydrography portal[33]. This dataset consists of aggregated bathymetry data sets collated from public and private organisations. Specific information regarding the data aggregated can be found on the referenced link.
- The General Bathymetric Chart of the Oceans (GEBCO[34]) was used as supplementary bathymetry where the EMODnet data were lacking, specifically, in the north-west and north-east of the study area.

3.2.4 Environmental data

- Broad-scale habitats: A draft version (v0.2) of the "EUNIS level 3 seabed habitat map integrating data originating from maps from field surveys and the EUSeaMap model" referred to as the "UKSeaMap combined map" was used[35]. This contains greater detail than the EU SeaMap dataset[36] though is still a broad-scale map with a coarse spatial resolution. This polygon dataset provides comprehensive coverage of the UKCS area. There are known limitations with this dataset, including limited overlaps in some areas and probable under-representation of finer scale habitats.
- The OSPAR threatened and/or declining habitats dataset was downloaded from the OSPAR Commission's website[37]. This dataset includes point and polygon data.
- The Marine Recorder database was downloaded from the JNCC website[38]. This is a database of point survey records collated from offshore and shoreline surveys conducted over several decades within UK waters. Records of Features of Conservation Importance (FOCI), as defined in the ENG written for England's MCZ process (JNCC and Natural England 2010), were extracted from this database using SQL queries provided by Natural England.
- A GIS data layer on Areas of Additional Pelagic Ecological Importance (APEI) was provided by the Wildlife Trusts. This was developed as a contribution to England's MCZ process, and combines information on a number of pelagic interest features to form a single layer indicating areas of particular ecological importance for pelagic and mobile species.
- Data on the frequency of formation of sea surface temperature fronts across the UKCS was provided by Peter Miller of Plymouth Marine Laboratory (Miller and Christodoulou 2014, Miller *et al.* 2010). A 1km summer front raster was used for this analysis, which shows the relative frequency of occurrence of fronts within each grid cell, based on an analysis of satellite data collected over several years.
- A Basking shark sightings database was provided by the Marine Conservation Society, which includes collated sightings data from Manx Basking Shark Watch, The Wildlife Trusts, The Shark Trust, The Hebridean Whale and Dolphin Conservation Society, RSPB, Seawatch and Seawatch Southwest (Bloomfield and Solandt 2008).
- The European Seabirds at Sea database[39] was provided by Mark Lewis at JNCC in April 2014. This is an extremely large database containing around 1.5 million records collected on ship-based and aerial offshore seabird surveys between 1979 and 2002.

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33 www.emodnet-hydrography.eu, accessed April 2014
34 www.gebco.net, GEBCO 08 grid, September 2010 version
35 www.jncc.defra.gov.uk/page-6655#EUNIScombined
36 www.jncc.defra.gov.uk/pdf/20140311_combinedEUNISL3mapMethod__v1.0.pdf
37 www.ospar.org/content/content.asp?menu=01511400000000_000000_000000, accessed March 2014
38 http://jncc.defra.gov.uk/page-1599, accessed April 2014
39 http://jncc.defra.gov.uk/page-4469, accessed April 2014

3.3 Ecological coherence tests

3.3.1 Coarse filter tests

All protected areas that could potentially be considered part of a UK MPA network were included in the coarse filter tests, including SSSIs and their Northern Irish equivalents, ASSIs. Many coastal SSSIs / ASSIs encompass intertidal and supralittoral / terrestrial areas. Only those parts of the sites that intersect the study area, i.e. areas below the OS Boundary Line mean high water mark / the Northern Ireland shoreline, were included in the spatial tests in this analysis. For England and Northern Ireland, all site portions intersecting with the study area were included. For sites in Wales and Scotland, the analysis only included (the portion below MHW of) those SSSIs that are officially considered to contribute to the MPA network, as listed in the annex of Welsh Government (2014), and in Scottish Natural Heritage and the Joint Nature Conservation Committee (2012).

The two network configurations assessed in the coarse filter tests were as follows:

- Current network configuration: SACs, SPAs, SSSIs / ASSIs, designated MCZs
- Potential future network configuration: the above, plus the rMCZs that are still under review and consideration for designation in a future tranche of England's MCZ process (the 5 rMCZs that were permanently discarded prior to the first tranche designations in 2013 were not included), and all 33 Scottish pNCMPAs as well as the 4 additional 'areas of search' proposed for further work in Scotland's MPA process.

Note that many of the existing MPAs overlap with each other. In order to avoid double-counting the same area in any of the tests, the MPA polygons were simplified into a single layer (using the ArcGIS dissolve function) for each of the above configurations.

Coarse filter overall network coverage test

This simple test calculated the proportion of area within the network, to test whether the current and potential future networks meet the Aichi target of 10%. This test was performed at the whole UKCS level as well as for each CP2 region. The amount of area that each individual potential future site would add to the network was calculated, and the sites that would add the largest amount of area to the network at the UK scale are listed.

Coarse filter site proximity test

This test was designed to assess the distance between sites, in order to identify any particularly large spatial gaps in the current network, and assess how potential future MPAs may fill them. The sites in both the current and potential future networks had a 40km buffer applied to them (representing an 80km gap between neighbouring sites). The buffered future network then had the area of the buffered current network eliminated, showing how future MPAs individually contribute to filling gaps. The results from this test are presented as both a map and a list showing how each future MPA contributes to filling the gaps.

Coarse filter bathymetric representation test

This test assessed the representation of different depths within the current and potential future networks, compared to the distribution of depths across the UKCS as a whole. The aim was to investigate whether or not the depth distribution within the network configurations reflects the depth distribution of UK waters. The high resolution bathymetric raster data from EMODnet was used as a base, with GEBCO data filling gaps in the far north-west and north-east. Histograms showing the depth distribution within the whole UKCS, the current MPA network, and the potential future network were generated from the GIS rasters using the NumPy scientific computing package[40], then charted in Microsoft Excel.

The results are presented as two charts:

- The first chart contains shows the 3 histograms, for the UKCS and both networks, displayed as moving average trend lines that smooth out fluctuations in the data (the period, or number of points used for the moving average, was 2).
- The second chart bins the same data into 5 representative classes (shallow shelf, deeper shelf, upper slope, deep slope and abyssal plain), which were defined using natural breaks in the histogram data. These are presented as a bar chart with percentage figures indicating the percentage of area falling into each depth class (within the UKCS as a whole, within the current network, and within the potential future network).

To assess the relative contributions that individual potential future MPAs would make towards improving the bathymetric representation of the MPA network, under-represented depth classes were identified from the results of the above tests. The areas containing pixels falling into each of these depth classes were extracted from the bathymetry raster, and converted into polygon features. These polygons were intersected with the potential future MPAs, and the area of intersection calculated for each site. This gave a measure of how much area each individual potential future site would add for each of the under-represented depth classes. The top contributors amongst the potential future sites are listed along with the results of the coarse filter bathymetry test.

3.3.2 Fine filter tests

The fine filter tests were designed to represent a more stringent set of tests, therefore a more selective set of sites was included in the network configurations assessed. The fine filter tests did not include SSSI/ASSIs, as there is no comprehensive official UK list of marine SSSIs /ASSIs. The coarse filter test approach of selecting all site components below the high water mark in England and Northern Ireland represents a likely overestimation of the true SSSI / ASSI contribution to the network, as not all of these sites are necessarily designated to protect any marine features at all. The approach of excluding these sites from the assessment follows the approach taken by the JNCC in their current 'big gaps' analysis for England's MCZ process (Ridgeway *et al.* 2014).

Fine filter replication test

This test was designed to assess the number of separate sites within the network that protect a given feature. The test was carried out at the UKCS level, and for each CP2 region. Replicates were counted for a number of benthic species and habitats - EUNIS level 3 broad-scale habitats, OSPAR threatened and declining habitats and benthic ENG FOCI. It is important to bear in mind the highly uneven spatial data coverage for these features when interpreting the results of this test for the OSPAR threatened and declining habitats, and the FOCI point data extracted from Marine Recorder (see figure 3.2). Survey effort tends to be clustered along the coastline and within nearshore areas, while in offshore areas there are large gaps in data coverage. The data sources also include data that have been collated from multiple surveys over several years – note that no age filter was applied to data in this analysis.

To achieve a conservative estimate of replication, multi-part MPAs (i.e. sites with a single name, but consisting of several spatially separate areas) were treated as one entity. This means that if a feature occurs in both site components, the site was nevertheless only counted as a single replicate for that feature. Where several MPA designations overlap, the boundaries were merged together, to avoid double-counting areas. For broad-scale habitats, a minimum patch size threshold applied in order for a habitat patch to count as an occurrence of that habitat within a given site. Following the approach

[40] http://www.numpy.org/, version 1.7.1

of OSPAR (2013), broad-scale habitat patch sizes under 1 km^2 were not considered as an occurrence, which meant that in order for a site to count as a replicate for a broad-scale habitat, it had to contain at least one habitat patch above that size threshold.

As highlighted at the end of the introduction, not all species and habitats that occur within existing UK MPAs are protected by the existing site designations. As the replication test focused on benthic features, sites designated (or known to be proposed) exclusively for the protection of mobile species (such as SPAs) were excluded from this test. For a number of practical reasons, limiting the replication counts to protected benthic species and habitats was not feasible within the scope of this analysis at the whole UK scale. However, for MPAs in England and Welsh offshore waters, the JNCC were able to supply a comprehensive dataset specifying the protected features in each site. Thus, for those CP2 regions covered by the JNCC's on-going gap analysis (Ridgeway *et al.* 2014), we were able to include an assessment of replication which counted protected features only.

Three network scenarios were evaluated in this test:

- Current MPA network (counting all features in site boundaries): SACs and designated MCZs
- Current MPA network (protected features only): SACs and designated MCZs (for a subset of CP2 regions)
- Potential future MPA network (counting all features in site boundaries): SACs, designated MCZs, recommended MCZs, Scottish pNCMPAs, and one of the Scottish areas of search (Shiant East Bank, the only area of search for non-mobile features)

Further analysis was carried out to assess the relative contribution of individual potential future MPAs towards improving replication within the network. For some of the assessed features, the current network configuration was found to contain fewer than 3 replicates. Where the potential future configuration improved these low scores, the potential future sites that increased replication figures were listed for each feature. The number of times each individual site appeared on lists for different features was counted, and the potential future sites were ranked by this count. The top ranked sites are shown along with the results of the replication test.

Fine filter percentage representation test

This test was designed to assess whether the network captures a sufficient overall amount of different features. Because this test relies on area calculations, it did not include point data, and it focused on those features for which there is reasonable certainty that their distribution is comprehensively mapped in the available polygon data layers. Specifically, this test covered EUNIS level 3 habitats and the three OSPAR threatened and declining habitats for which there is reliable and comprehensive data coverage (intertidal mudflats, maërl beds, and seamounts). The ENG FOCI, for which the above replication tests used point data extracted from Marine Recorder, were not included in this test.

For the current and potential future network configurations, the MPA polygons were dissolved into a single feature. For each habitat, the total area present within the UKCS and within each CP2 region was summed and the percentage of the total falling within the network boundaries was calculated. Note that, unlike in the replication test, all areas of habitat were counted as contributing to the total and percentage figures, including small patches of habitat less that 1km^2 in size.

The current and future network scenarios included in this analysis were identical to those in the replication test above, with the same site combinations included, and a 'protected features only' figures calculated for some of the CP2 regions. The results of this test are presented in a series of tables immediately alongside the results of the replication test, allowing for direct comparisons between test results for any given feature. Since the tables contain a considerable amount of detail, the test results are also presented in an Excel document accompanying this report, allowing further exploration of the results.

Assessing the relative effectiveness of individual potential future sites at filling the gaps identified in this test is challenging, because any given site will contribute different amounts to filling gaps for different habitats. In this analysis, potential future MPAs were intersected with areas of habitat not covered by the current network, in order to determine how much of each habitat any given site would add. The outputs of this intersection were turned into a pivot table, which can be used to explore the results by site and by habitat (this pivot table is provided in the spreadsheet accompanying this report).

To arrive at an overall measure of how effective a given site is at generally adding missing habitat (and hence representativity), two measures were put together: i) the average size of the habitat patches in a given site, and ii) the overall amount of habitat area added to the network. The geometric mean of the two measures was calculated. Reflecting the non-normal distribution in the sizes of proposed MPAs, the geometric means are also far from normally distributed, hence the results were square-root transformed[41]. To avoid reading too much into the resulting measure, and reflecting the large grouping of 'minor players', the scores were linearly scaled from 1 to 3 (i.e. 0-2, plus 1). The potential MPAs with a score of 2 or 3 (i.e. of a moderate or high potential in filling habitat gaps) are listed following the results of the replication and habitat percentage representation tests.[42]

Fine filter broad habitat-specific proximity test

This test assessed site proximity broken down by EUNIS level habitat 2, in order to test whether there are any large areas of distribution of a given habitat within which no protected areas are present. For each EUNIS level 2 habitat in turn, a kernel density analysis was performed with a search radius of 40km around habitat patches within the boundaries of the network. A density analysis is more nuanced than hard buffers because it takes into consideration the amount of existing protected habitats (within the specified search radius); hence isolated small protected areas (low density) have less effect than clusters of protected habitat (higher density). In order to carry out the density analysis, the EUNIS L2 habitats falling within MPA boundaries were converted to raster layers with a 1km cell size. Each raster layer was then converted to a point layer (with the points at the centre of the raster cells) and used as the input for the kernel density. This analysis was carried out for all sites in the current network configuration, and for the potential future sites, using the same site combinations as the fine filter representation and replication tests.

The results were represented on a series of UK-scale maps showing the kernel density results for the current and future sites in different colour ramps. This provides a direct visual assessment of any spatial gaps for any given habitat, as well as a visual representation of how well potential future sites would perform in closing those gaps. An additional map was generated to demonstrate the difference between the visual assessment provided by the kernel density test and an assessment based on simple buffers around habitat patches within protected areas.

Potential future sites that significantly increase the coverage of the kernel density were selected based on a visual assessment of the kernel density maps and presented in a table, ordered by area of the EUNIS level 2 feature within their boundary.

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[41] $\sqrt{\frac{(\sum a)^2}{n}}$ where a is the area of each missing habitat that is filled, and n is the number of different habitats.

[42] The calculations described above can be found in the formula bar of rows 37-40 of the relevant spreadsheet in the Excel document supplied with this report. Note that this calculation looked at all habitat types across the UKCS. However, the same calculations could be used to consider which sites would fill specific habitat gaps within specific regions or sub-regions.

Fine filter mobile species test

This test was designed to provide a visual assessment of the performance of the network in protecting mobile species, and the sites included in the analysis were selected accordingly:

- Current network configuration: Only those sites which are designated to protect mobile species were included. These were SPAs and SACs with mobile features listed in the JNCC SAC summary data spreadsheet[43] (including D grade features).
- Potential future network configuration: the above SACs and SPAs, as well as Scottish pNCMPAs that reference mobile features (sandeels are mentioned as a feature in several MPAs, these have not been considered as a mobile feature), and three of the areas of search being proposed for further focus within Scotland's ongoing MPA process (those for mobile features).

Note that MCZs were not included in either configuration, as they are not being designated for the protection of mobile species.

The two network configurations were mapped over layers showing the following data:

- The Wildlife Trusts areas of Additional Pelagic Ecological Importance dataset. This data layer was created by the Wildlife Trusts during the UK MCZ process from summer thermal fronts (mapped separately here, see below), RSPB foraging radiuses, Whale and Dolphin Conservation Society important areas for marine mammals, Cefas and ICES nursery and spawning areas and Marine Conservation Society basking shark sightings data (also mapped separately here, see below).
- Seasonal frequent front data. This dataset was provided by Peter Miller at Plymouth Marine Laboratory (Miller and Christodoulou 2014, Miller *et al.* 2010). The map shows processed composite data generated from satellite (AVHRR) sea surface temperature observations over several years. The front metric shown on the map represents the frequency of seasonal frontal occurrence within the analysed data. Note that this dataset represents surface fronts, though strong and persistent surface fronts tend to indicate a profile through the whole surface layer. Marine Conservation Society basking shark sightings database, which contains data from Manx Basking Shark Watch, The Wildlife Trusts, The Shark Trust, The Hebridean Whale and Dolphin Conservation Society, RSPB, Seawatch and Seawatch Southwest (Bloomfield and Solandt 2008). The sightings data were spatially joined to a 0.1 decimal degree grid, symbolised and mapped.

The creation of maps showing spawning and nursery areas of commercial fish species (from Ellis *et al.* 2011) was also considered for this analysis, but given the coarse data resolution and the fact that most of these areas extend across very large swathes of the UKCS, this would have yielded limited additional information of value.

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[43] jncc.defra.gov.uk/page-1461, accessed April 2014

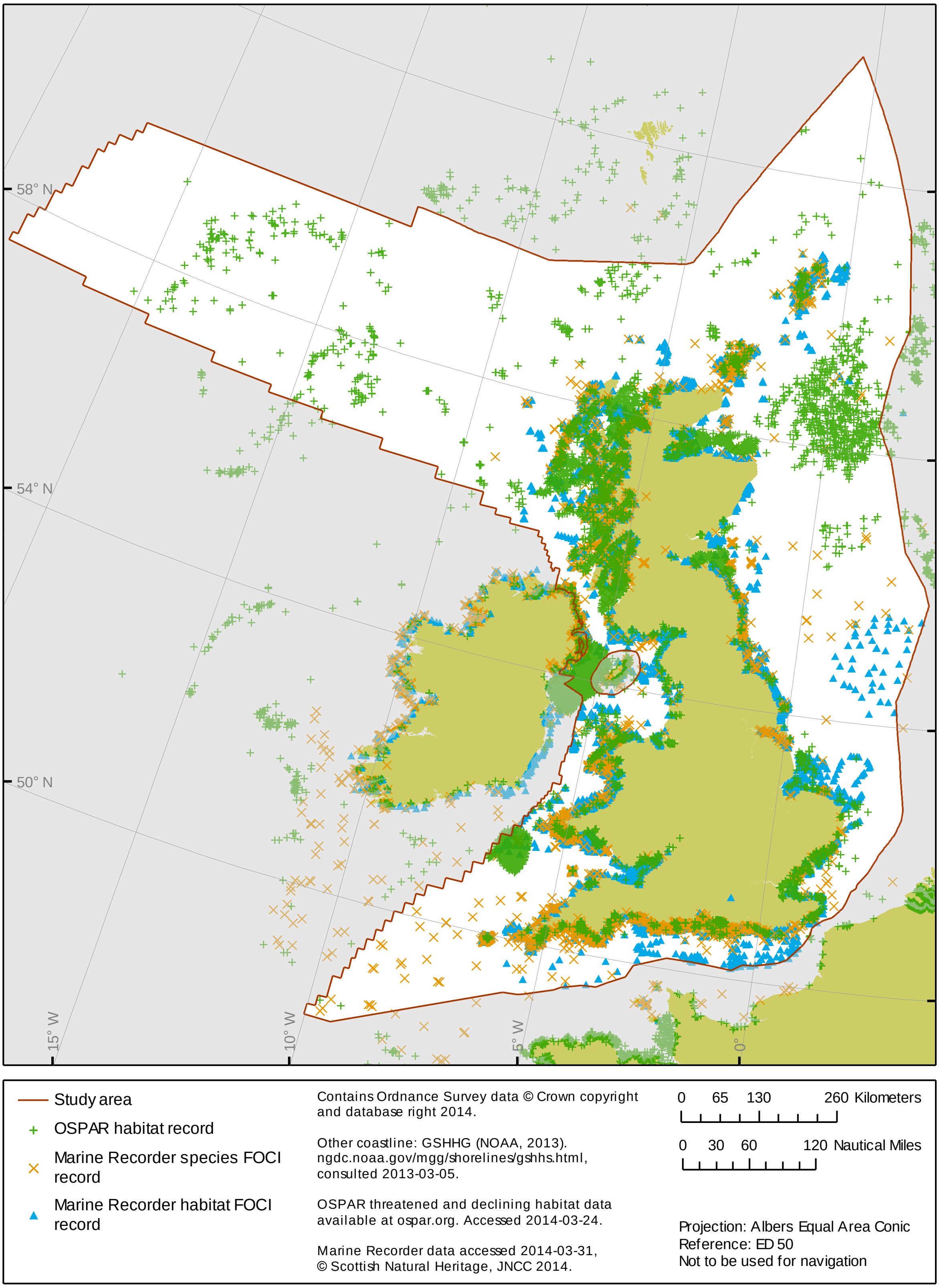

Figure 3.2. Map of available point data for OSPAR threatened and declining habitats and ENG FOCI. The large point symbols have been chosen highlight the broad-scale distribution of point records across the UKCS, which is highly uneven. This unevenness is, to a large extent, driven by uneven sampling effort.

4. Results

4.1 Coarse filter tests

4.1.1 Coarse filter overall network coverage test

Table 4.1 and figure 4.1 show the percentage of the UKCS area and CP regions falling within the current and future network configurations. The information suggests that the current network, at the whole UK level, is close to meeting the Aichi target of 10%. However, the biogeographic coverage of the current network is very uneven, with a more than tenfold difference between the region with the lowest coverage (CP2 region 7 – Scottish Continental Shelf at 3.3%), and the region with the highest coverage (CP2 region 2 - The Southern North Sea at 38.8%). Several CP2 regions fail to meet the Aichi target of 10% by a significant margin. These are mainly located in Scottish waters, although the coverage in the south-west is also relatively low (at 8.4%). The contrast between the 38.9% coverage of the Southern North Sea, and the 5.1% coverage for the adjoining Northern North Sea is particularly striking.

Adding all potential future MPAs would bring each region above the Aichi target. Specific potential future sites that would contribute the most additional area are listed in table 4.2 (and mapped in the figures in Appendix 1). The largest of the potential future MPAs are at the top of this list, which are primarily the pNCMPAs in the Scottish offshore, though other large potential future sites are located in the far southwest and in northeast England. These sites are located within the largest spatial gaps in the network, identified in the coarse filter proximity test (see below).

Note that table 4.2 only lists the top contributors amongst the potential future MPAs. A full list of potential future MPAs showing how much they would contribute to the area coverage of the network is provided in the Excel document accompanying this report.

	Area (km^2)	% MPA network coverage	
		Current	Potential future
Whole study area – UK Continental Shelf	874,310	9.7%	21.6%
CP2 regions			
1 - Northern North Sea	181,372	5.1%	12.3%
2 - Southern North Sea	61,745	38.9%	43.7%
3 - Eastern Channel	21,964	12.9%	24.9%
4 - Western Channel and Celtic Sea	93,670	8.2%	21.8%
5 - Irish Sea	38,391	17.0%	27.8%
6 - Minches and Western Scotland	29,912	5.0%	34.9%
7 - Scottish Continental Shelf	121,562	3.3%	18.0%
8 – Atlantic North-West Approaches	323,407	8.4%	21.3%

Table 4.1. Total area of CP2 regions and the UKCS as a whole, and percentage coverage of the current and potential future MPA network configurations. Percentage figures below the Aichi target of 10% are shown in red. Note the uneven biogeographic coverage of the current network.

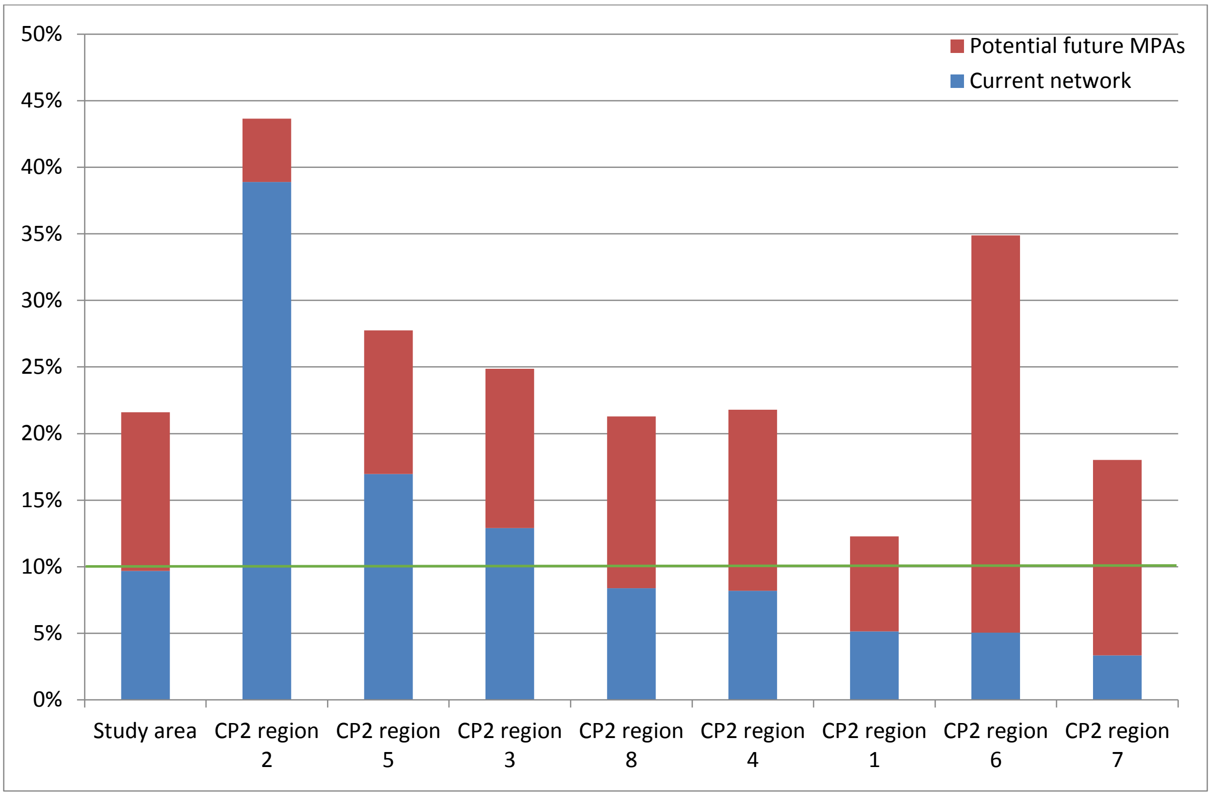

Figure 4.1. Percentage sea area covered by current and potential future MPAs, for the UKCS as a whole, and each CP2 region, shown as a bar chart. The green horizontal line highlights the benchmark of the Aichi target for 10% coverage.

Potential future MPA	**Area added (km^2)**
North-East Faroe-Shetland Channel (pNCMPA)	26,968
Rosemary Bank Seamount (pNCMPA)	7,413
Faroe-Shetland Sponge Belt (pNCMPA)	6,379
Skye to Mull (Scottish MPA area of search)	6,224
South-West Deeps East (rMCZ)	5,801
The Barra Fan and Hebrides Terrace Seamount (pNCMPA)	4,701
North-west Orkney (pNCMPA)	4,389
West Shetland Shelf (pNCMPA)	4,047

Table 4.2. Potential future MPAs that would add the most to the overall area coverage of the network. The area figures show the amount of area each site would add, not counting any spatial overlaps with the current network. The location of these potential future MPAs is mapped in the figures in Appendix 1. Information on the area added by potential future sites not shown in this table are included in the Excel document supplied along with this report.

4.1.2 Coarse filter site proximity test

Figure 4.2 shows the current and potential future networks with a 40km buffer applied to the boundary of each site, identifying gaps exceeding 80km between MPAs. Echoing the findings of the biogeographic differences in spatial coverage identified in the previous test, the main spatial gaps in the current network are located in the Scottish offshore areas, and in the far south-west. Table 4.3 provides area figures for the amount of gap each of the top twelve contributing sites would fill. Figures for the fill list of potential future sites are provided in the Excel document supplied along with this report.

Notably, figure 4.2 illustrates that the addition of all potential future MPAs would not fill all of the spatial gaps, the most significant remaining gaps in the potential future network configuration being in the very far north-west of the UKCS. Nevertheless, the addition of the potential future sites would greatly diminish the current large spatial gaps. Those new sites that would contribute the most to filling these gaps are identified in figure 4.2 and table 4.3. As with the overall network coverage test shown above, those MPAs that best contribute to filling gaps are pNCMPAs in the Scottish offshore areas. The South-West deeps (East) rMCZ also fills a significant gap.

Whilst the area figures in table 4.3 provide a measure of the relative contribution that each individual site would make towards filling existing large spatial gaps, the figures should not be interpreted as a rank order for prioritising the addition of new sites to fill gaps, because the relative location of the areas and spatial overlaps between them are not accounted for. For example, the top two sites, North-East Faroe-Shetland Channel pNCMPA and Faroe-Shetland Sponge Belt pNCMPA, are located adjacent to each other. If the aim is to fill the largest spatial gaps in the network, then after adding the first site on the list, arguably the most suitable next addition would be a site that begins filling a gap in a different region. The third site on the list (Rosemary Bank Seamount pNCMPA) or the eleventh (Hatton-Rockall Basin pNCMPA) might deliver more in terms of improving overall connectivity of the network than adding the second. This illustrates the fact that in applying systematic network planning principles, it is not possible to assess the value of any given site in absolute terms, in isolation from the network; the contribution of any given site will depend on what other sites are also selected.

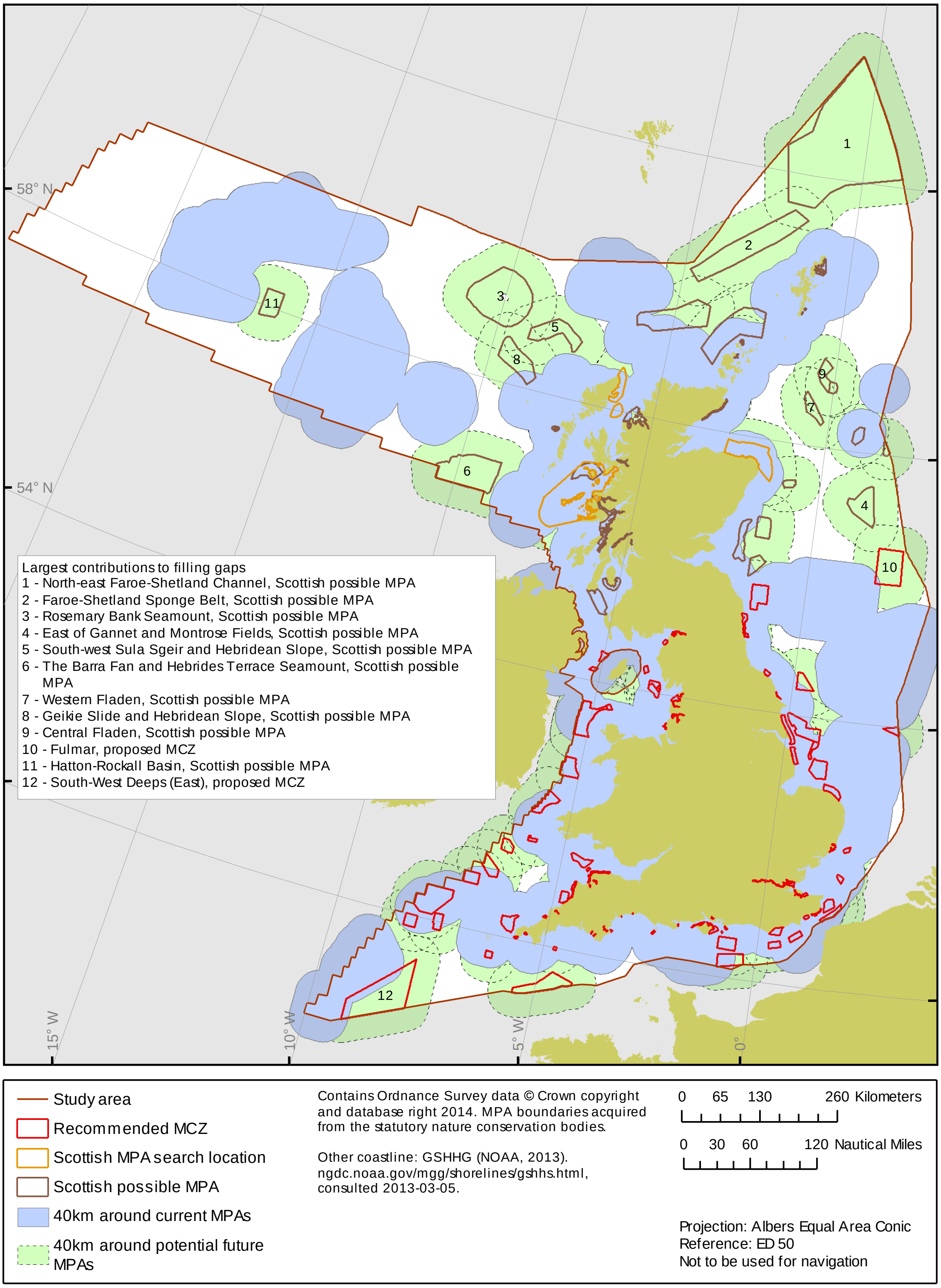

Figure 4.2. Results of the coarse filter proximity test. The map shows sites in the current and potential future network configurations with 40km buffers applied to their boundaries. Potential future sites that would fill particularly large areas of 'gap' are listed and labelled.

Potential future MPA	Area contributed to filling gaps (km^2)
North-east Faroe-Shetland Channel (Scottish pNCMPA)	40,233
Faroe-Shetland Sponge Belt (Scottish pNCMPA)	25,749
Rosemary Bank Seamount (Scottish pNCMPA)	25,067
East of Gannet and Montrose Fields (Scottish pNCMPA)	14,266
South-west Sula Sgeir and Hebridean Slope (Scottish pNCMPA)	14,049
The Barra Fan and Hebrides Terrace Seamount (Scottish pNCMPA)	12,050
Western Fladen (Scottish pNCMPA)	10,781
Geikie Slide and Hebridean Slope (Scottish pNCMPA)	10,767
Central Fladen (Scottish pNCMPA)	10,536
Fulmar (rMCZ)	10,283
Hatton-Rockall Basin (Scottish pNCMPA)	9,936
South-West Deeps East (rMCZ)	9,771

Table 4.3. List of the top twelve potential future MPAs that would add the largest amount of area to the filling of large spatial gaps in the current network (the location of these sites is mapped in Appendix 1). The area figures show the surface area of the sites, plus a 40km buffer area around their boundaries, minus any spatial overlap with existing MPAs or their equivalent buffer areas. Thus, the figures quantify the amount of gap filled by each site individually. Note that these figures aren't additive, as there are spatial overlaps between the buffer areas of the different sites in the table. Area contributions from potential future sites not shown in this table are included in the Excel document supplied with this report.

4.1.3 Coarse filter bathymetric representation test

The results of the coarse filter bathymetric representation test are shown in figures 4.3 and 4.4, with table 4.4 listing potential future sites that would contribute to filling gaps identified in the current network. Figure 4.3 shows three depth value histograms generated from the bathymetry raster GIS layer, for the whole UKCS, the current network configuration, and the potential future configuration. The x axis shows the range of depth values within the dataset, and the y axis the number of pixels with each value (note the log scales used for both axes). The data are plotted as a moving average trend line, which evens out minor fluctuations along short intervals on the y axis whilst displaying the overall shape of the histogram. The moving average trend line of an MPA network containing a depth distribution that matched that of the UKCS as a whole would be parallel to the UKCS trend line.

Figure 4.3 shows that, whilst the current MPA network well represents the shallow regions of the UKCS area (to 50m), the deeper shelf (50 -200m), which forms the largest portion of the UKCS, is less well represented. The deepest depths of the UKCS area (>1,500m) are not well covered in the current network configuration (note there is currently little or no fishing beyond 1,500m (Morato *et al.* 2006). The trend line for the potential future network configuration shows that the addition of all potential future MPAs to the current network would improve bathymetric representation, although the deeper shelf depths would still be relatively less well represented than shallower depths, and the very deepest depths of the UK's seas would still not be captured within the network at all. This is illustrated more simply in figure 4.4, which groups the depth data into five depth bands, and shows the surface area within each (for the UKCS as a whole and for the two network configurations). Although this figure contains less detail than the previous one, the simplified depth classes and lack of log transformation on the y axis provide a more visually intuitive representation of the UKCS's depth distribution, and its representation within the two network configurations.

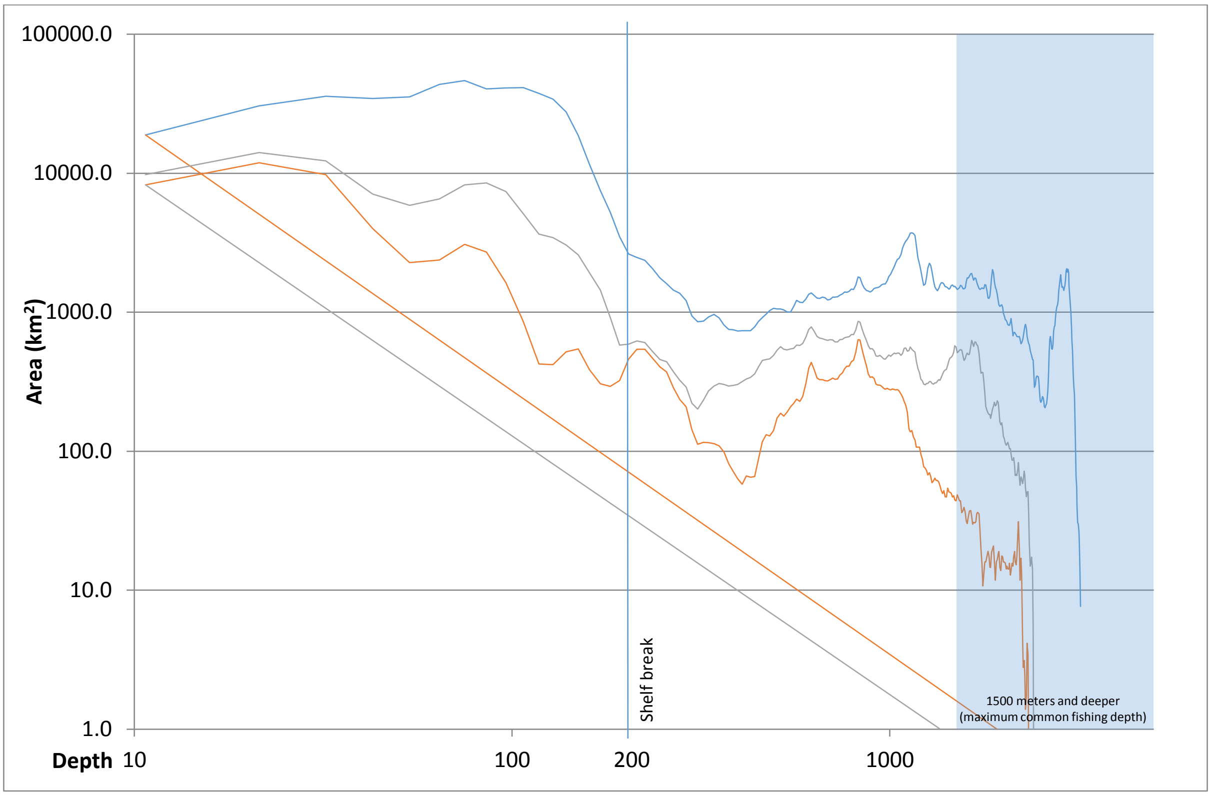

Figure 4.3. Histograms showing bathymetric distribution in the study area, current MPA network and potential future MPA network. The histograms are displayed as moving average trend lines, smoothing out fluctuations along short sections of the x-axis. Note the log scales on both axes.

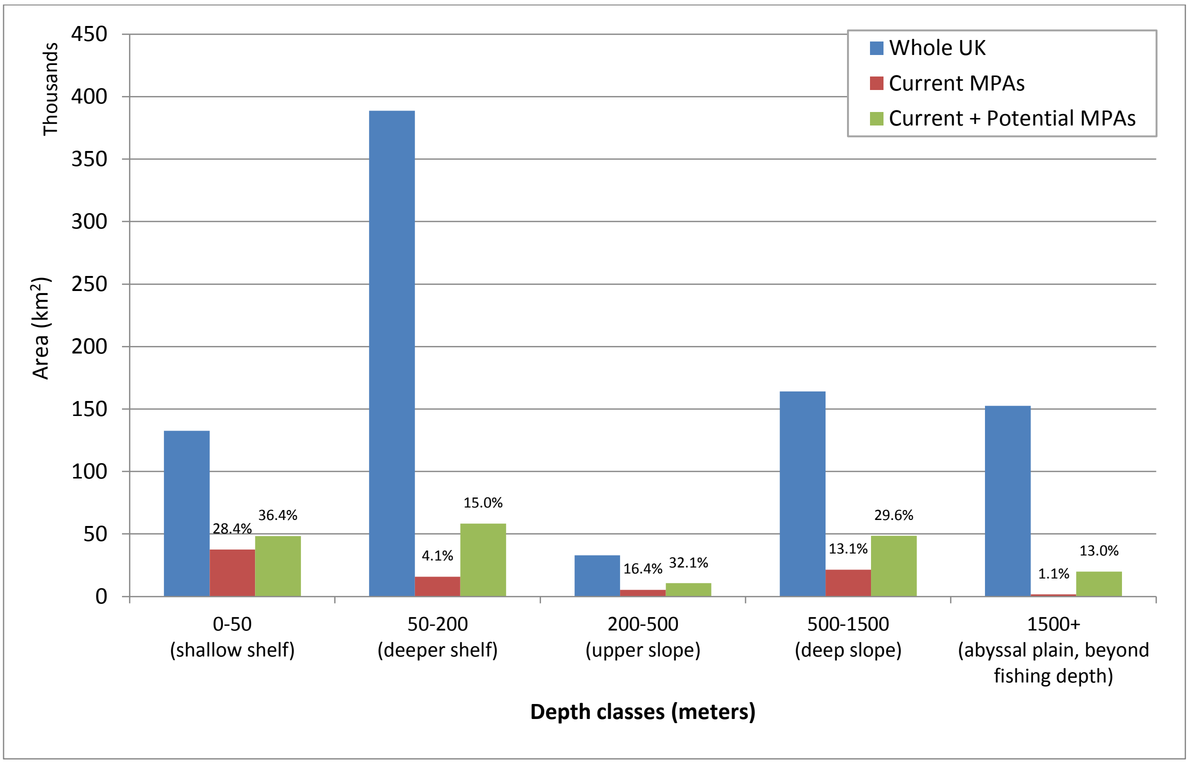

Figure 4.4. Representation of depth classes within the current and potential future network configurations. Blue bars show the amount of area of the UKCS falling into each depth class. Red and green bars show the area of each depth class within the current and potential future network configurations, respectively. The percentage figures show the percentage of the total area of each depth class captured in each network configuration.

Table 4.4 lists potential future MPAs that would contribute to an increase in the representation of the deeper shelf, upper slope, and deep slope depth classes, all of which are less well represented in the network than shallower areas. Note that there are no potential future MPAs within the abyssal plain depth class.

MPA	Area (km²)	depth class
South-West Deeps East (rMCZ)	5,623	deeper shelf (50-200m)
Skye to Mull (Scottish MPA search location)	4,819	
North-west Orkney (Scottish pNCMPA)	4,372	
West Shetland Shelf (Scottish pNCMPA)	4,047	
Fulmar (rMCZ)	2,437	
Greater Haig Fras (rMCZ)	2,032	
Southern Trench (Scottish MPA search location)	1,845	
East of Gannet and Montrose Fields (Scottish pNCMPA)	1,838	
Firth of Forth Banks Complex (Scottish pNCMPA)	1,609	
Western Channel (rMCZ)	1,596	
North St George's Channel Extension (rMCZ)	1,289	
North St George's Channel (rMCZ)	1,231	
Faroe-Shetland Sponge Belt (Scottish pNCMPA)	2,371	upper slope (200-500m)
North-east Faroe-Shetland Channel (Scottish pNCMPA)	1,288	
Geikie Slide and Hebridean Slope (Scottish pNCMPA)	864	
North-east Faroe-Shetland Channel (Scottish pNCMPA)	13,447	deep slope (500-1,500m)
Rosemary Bank Seamount (Scottish pNCMPA)	4,266	
Faroe-Shetland Sponge Belt (Scottish pNCMPA)	4,008	
The Barra Fan and Hebrides Terrace Seamount (Scottish pNCMPA)	2,182	

Table 4.4. Potential future MPAs that would contribute towards increasing the representation of deeper depth classes that are less well represented in the current MPA network configuration. Information on the contribution that other potential future sites would make is included in the Excel document supplied along with this report. The location of these sites is mapped in Appendix 1.

4.2 Fine filter replication and percentage representation tests

4.2.1 Presentation of results

The results for the fine filter replication and percentage representation test are complex, given the number of features and network scenarios covered for multiple biogeographic regions, and there is no single ideal way to present them in static tables. The key results are shown in tables 4.5 to 4.13, broken down by region. Additional results are included in the Excel document provided alongside this report. The Excel document contains an embedded pivot table layout to aid the interrogation and exploration of the test results in more detail and with more flexibility than is possible within the limited space of this report.

When interpreting the results of these tests, it is very important to bear in mind that some broad-scale habitats (e.g. sublittoral sand) cover much larger areas of the UKCS than others (e.g. deep sea habitats), and that habitats are not evenly distributed across biogeographic regions. Tables 4.5 to 4.13 include a column to show the total amount of each habitat present in each region.

Both tests covered EUNIS level 3 habitat features and OSPAR threatened and declining habitats (although the percentage representation test only included those for which there is reasonable certainty of comprehensive polygon data coverage). The replication test also covered ENG FOCI. The test results for EUNIS level 3 habitats listed in the MCZ ENG (JNCC and Natural England 2010) and the OSPAR habitats are shown in tables 4.5 to 4.13. Additional EUNIS level 3 habitats and ENG FOCI are not included in these tables, in order to reduce their length and complexity - however, the results for these additional features are fully included in the pivot table in the Excel document supplied with this report.

Tables 4.5 to 4.13 break down the test results by biogeographic region, with the first table displaying results for at the UKCS scale. The tests calculated replicates and percentage coverage for each feature for the current network configuration and the potential future network configuration, based on the features falling within the boundaries of the sites. Taking account of the fact that not all features that fall within site boundaries are automatically afforded protection, for the current network configuration an additional set of calculations was performed focusing only on the features that are formally protected. However, this additional set of calculations was only possible for a limited number of CP2 regions, for which the JNCC were able to supply relevant information.

The results are colour coded for each feature using a series of thresholds that were based largely on the MCZ ENG (JNCC and Natural England 2010), this guidance representing the most comprehensive set of quantitative MPA network guidelines based on ecological coherence principles researched and written for UK waters. The ENG target ranges for broad scale habitats are:

- 21% – 38% for High energy intertidal rock (A1.1), Moderate energy intertidal rock (A1.2)
- 22% – 39% for Low energy intertidal rock (A1.3)
- 25% – 42% for Intertidal coarse sediments (A2.1), Intertidal sand and muddy sand (A2.2), Intertidal mud (A2.3), Intertidal mixed sediments (A2.4)
- 15% – 31% for High energy infralittoral rock (A3.1)
- 17% – 32% for Moderate energy infralittoral rock (A3.2), Subtidal coarse sediment (A5.1)
- 16% – 32% for Low energy infralittoral rock (A3.3), Low energy circalittoral rock (A4.3), Subtidal mixed sediments (A5.4)
- 11% – 25% for High energy circalittoral rock (A4.1)
- 13% – 28% for Moderate energy circalittoral rock (A4.2)
- 15% - 30% for Subtidal sand (A5.2), Subtidal mud (A5.3)

Colour codes for replication figures are as follows:

(green)	3 or more replicates
(yellow)	1-2 replicates
(red)	Zero replicates

Colour codes for percentage representation figures are as follows:

(green)	Above upper ENG target
(yellow)	Within ENG target range
(orange)	Between 5% and lower ENG target
(red)	Below 5%
	No colour indicates that the habitat is above the 5% threshold, but a target was not set for the feature in the ENG

Whole UKCS	Replication			Percentage coverage			
EUNIS level 3 habitats	Current	PF	Future	Total area (km²)	% Current	% PF	% Future
A1.1 (high energy littoral rock)	29	Information not available	40	56	41.1	Information not available	52.1
A1.2 (moderate energy littoral rock)	32		45	79	43.9		51.0
A1.3 (low energy littoral rock)	44		56	89	40.2		42.8
A2.1 (Littoral coarse sediment)	36		51	77	43.2		50.0
A2.2 (Littoral sand & muddy sand)	41		56	1,678	72.5		75.0
A2.3 (Littoral mud)	36		52	1,120	70.9		78.4
A2.4 (Littoral mixed sediments)	33		43	85	36.6		47.5
A3.1 (high energy infralittoral rock)	22		32	6,284	11.2		14.5
A3.2 (moderate energy infralittoral rock)	29		45	4,017	16.0		24.9
A3.3 (low energy infralittoral rock)	5		11	648	6.9		17.2
A4.1 (high energy circalittoral rock)	20		26	5,955	41.0		45.5
A4.2 (moderate energy circalittoral rock)	37		69	30,257	6.2		19.5
A4.3 (low energy circalittoral rock)	12		28	18,068	2.0		10.6
A5.1 (sublittoral coarse sediment)	55		106	128,455	7.8		19.9
A5.2 (sublittoral sand)	52		101	252,655	9.9		16.0
A5.3 (sublittoral mud)	28		53	49,660	2.1		12.5
A5.4 (sublittoral mixed sediments)	35		54	20,023	13.7		21.5
A6 (deep-sea bed, EUNIS level 2)	5		12	27,849	12.9		42.0
A6.1 (deep-sea rock and artificial hard substrata)	7		13	6,054	32.2		50.0
A6.2 (deep-sea mixed substrata)	5		10	75,816	21.9		30.2
A6.3 (deep-sea sand)	8		16	67,672	7.3		17.9
A6.5 (deep-sea mud)	7		15	167,805	0.5		17.0
A6.6 (deep-sea bioherms)	1		1	20	100.0		100.0
OSPAR T&D habitats							
Carbonate mounds	1	Information not available	1			Information not available	
Coral gardens	3		4				
deep-sea sponge aggregations	5		9				
Intertidal mudflats	42		67	1,308	73.2		79.7
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	15		17				
Littoral chalk communities	12		17				
Lophelia pertusa reefs	11		12				
Maërl beds	17		27	82	28.5		43.0
Modiolus modiolus beds	12		20				
Ostrea edulis beds	1		1				
Sabellaria spinulosa reefs	17		24				
Seamounts	1		3	6,852	3.1		85.0
Sea-pen and burrowing megafauna communities	22		45				
Zostera beds	25		30				

Table 4.5. Results of the fine filter replication and representation tests for the whole UKCS. 'Current' refers to the current MPA network configuration, 'PF' to calculations carried out for protected features only, and 'Future' refers to the potential future network configuration. For more information, please refer to the text. Information on replication figures for additional ENG FOCI is included in the Excel document supplied along with this report.

CP2 region 1 - Northern North Sea	Replication			Percentage coverage			
EUNIS level 3 habitats	Current	PF	Future	Total area (km²)	% Current	% PF	% Future
A1.1 (high energy littoral rock)	5	Information not available	7	5	45.5	Information not available	47.3
A1.2 (moderate energy littoral rock)	4		7	11	30.6		41.4
A1.3 (low energy littoral rock)	6		9	7	38.0		43.0
A2.1 (Littoral coarse sediment)	6		8	8	65.7		68.8
A2.2 (Littoral sand & muddy sand)	5		7	127	65.6		68.6
A2.3 (Littoral mud)	5		6	31	81.6		81.7
A2.4 (Littoral mixed sediments)	2		4	3	45.4		59.6
A3.1 (high energy infralittoral rock)	1		4	282	7.4	0.2	39.1
A3.2 (moderate energy infralittoral rock)	2	1	7	672	18.0	13.2	29.1
A3.3 (low energy infralittoral rock)	1		1	63	14.6	0.1	14.6
A4.1 (high energy circalittoral rock)	2	2	5	804	86.8	86.6	89.0
A4.2 (moderate energy circalittoral rock)	4	4	10	4,241	6.3	6.1	25.0
A4.3 (low energy circalittoral rock)	1		4	3,670	0.1		1.3
A5.1 (sublittoral coarse sediment)	6	3	17	16,686	4.8	3.6	15.2
A5.2 (sublittoral sand)	4	3	15	123,449	4.4	4.3	9.1
A5.3 (sublittoral mud)	5	1	9	28,287	1.3	0.0	9.2
A5.4 (sublittoral mixed sediments)	4	1	7	2,155	30.9	7.6	32.9
A6 (deep-sea bed, EUNIS level 2)		Information not available		0	0.0	Information not available	0.0
A6.1 (deep-sea rock and artificial hard substrata)				2	0.0		0.0
A6.3 (deep-sea sand)				18	0.0		0.0
A6.5 (deep-sea mud)			1	12	0.0		77.1
OSPAR T&D habitats							
Intertidal mudflats	5	Information not available	6	44	86.0	Information not available	86.1
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	2		2				
Littoral chalk communities	2		4				
Lophelia pertusa reefs	1		1				
Maërl beds	1		2	7	0.3		99.3
Modiolus modiolus beds	1		1				
Sabellaria spinulosa reefs	1		1				
Sea-pen and burrowing megafauna communities	2		7				
Zostera beds	2		2				

Table 4.6. Results of the fine filter replication and representation tests for CP2 region 1 - Northern North Sea. 'Current' refers to the current MPA network configuration, 'PF' to calculations carried out for protected features only, and 'Future' refers to the potential future network configuration. For more information, please refer to the text. Information on replication figures for additional ENG FOCI is included in the Excel document supplied along with this report.

CP2 region 2 - Southern North Sea	Replication			Percentage coverage			
EUNIS level 3 habitats	Current	PF	Future	Total area (km²)	% Current	% PF	% Future
A1.1 (high energy littoral rock)	2	Information not available	3	1	92.5	Information not available	92.5
A1.2 (moderate energy littoral rock)	3		4	5	85.9		96.1
A1.3 (low energy littoral rock)	3		3	1	43.4		55.0
A2.1 (Littoral coarse sediment)	4		5	6	68.1		68.3
A2.2 (Littoral sand & muddy sand)	6		7	296	90.8		93.1
A2.3 (Littoral mud)	6		7	533	78.5		89.3
A2.4 (Littoral mixed sediments)	6		7	23	31.6		47.3
A3.1 (high energy infralittoral rock)	2	2	2	7	87.6	74.3	88.2
A3.2 (moderate energy infralittoral rock)	1	1	3	46	30.7	9.3	74.3
A3.3 (low energy infralittoral rock)				0	0.0		0
A4.1 (high energy circalittoral rock)	1	1	1	8	60.0	56.4	63.7
A4.2 (moderate energy circalittoral rock)	1	1	2	316	4.0	3.8	49.3
A5.1 (sublittoral coarse sediment)	8	6	12	17,608	25.5	25.4	36.7
A5.2 (sublittoral sand)	9	8	14	37,814	38.1	38.1	39.1
A5.3 (sublittoral mud)	4	3	7	303	40.7	21.3	43.8
A5.4 (sublittoral mixed sediments)	7	4	8	3,982	18.6	17.7	28.5
OSPAR T&D habitats							
Intertidal mudflats	6	Information not available	8	598	78.8	Information not available	88.5
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	4		5				
Littoral chalk communities	1		1				
Modiolus modiolus beds	2		3				
Ostrea edulis beds	1		1				
Sabellaria spinulosa reefs	6		8				
Zostera beds	1		2				

Table 4.7. Results of the fine filter replication and representation tests for CP2 region 2 - Southern North Sea. 'Current' refers to the current MPA network configuration, 'PF' to calculations carried out for protected features only, and 'Future' refers to the potential future network configuration. For more information, please refer to the text. Information on replication figures for additional ENG FOCI is included in the Excel document supplied along with this report.

CP2 region 3 - Eastern Channel	Replication			Percentage coverage			
EUNIS level 3 habitats	Current	PF	Future	Total area (km^2)	% Current	% PF	% Future
A1.1 (high energy littoral rock)	2	Information not available	4	2	46.9	Information not available	52.9
A1.2 (moderate energy littoral rock)	3		7	9	49.7		78.1
A1.3 (low energy littoral rock)	2		3	0	31.5		31.7
A2.1 (Littoral coarse sediment)	6		12	17	49.7		59.4
A2.2 (Littoral sand & muddy sand)	6		9	29	39.9		53.1
A2.3 (Littoral mud)	6		11	104	48.9		53.4
A2.4 (Littoral mixed sediments)	5		8	14	33.5		48.7
A3.1 (high energy infralittoral rock)	3	2	4	286	15.2	13.7	17.6
A3.2 (moderate energy infralittoral rock)	4	2	9	632	22.8	20.8	28.0
A3.3 (low energy infralittoral rock)		1	1	3	53.3	48.1	57.0
A4.1 (high energy circalittoral rock)	3	2	6	1,967	51.8	49.7	62.2
A4.2 (moderate energy circalittoral rock)	6	2	15	3,817	2.9	1.1	22.1
A4.3 (low energy circalittoral rock)			1	1	23.2		85.6
A5.1 (sublittoral coarse sediment)	7	4	16	9,476	7.4	5.4	21.9
A5.2 (sublittoral sand)	7	5	13	2,379	5.1	2.9	14.1
A5.3 (sublittoral mud)	1	1	3	457	2.3	1.5	5.2
A5.4 (sublittoral mixed sediments)	5	1	7	2,343	18.6	0.6	19.1
OSPAR T&D habitats							
Intertidal mudflats	6	Information not available	14	107	47.9	Information not available	52.6
Intertidal *Mytilus edulis* beds on mixed and sandy sediments							
Littoral chalk communities	3		5				
Maërl beds	1		2	28	0.0		0.0
Sabellaria spinulosa reefs	4		9				
Sea-pen and burrowing megafauna communities	1		3				
Zostera beds	3		4				

Table 4.8. Results of the fine filter replication and representation tests for CP2 region 3 – Eastern Channel. 'Current' refers to the current MPA network configuration, 'PF' to calculations carried out for protected features only, and 'Future' refers to the potential future network configuration. Note that the replication calculations for OSPAR habitats included point data, which was not included in the percentage representation test. This explains why for the maërl bed habitat, zero percentage coverage is shown despite there being a replicate count of 1. For more information, please refer to the text. Information on replication figures for additional ENG FOCI is included in the Excel document supplied along with this report.

CP2 region 4 – Western Channel and Celtic Sea	Replication			Percentage coverage			
EUNIS level 3 habitats	Current	PF	Future	Total area (km²)	% Current	% PF	% Future
A1.1 (high energy littoral rock)	10	Information not available	15	33	35.5	Information not available	53.8
A1.2 (moderate energy littoral rock)	10		14	16	30.1		37.5
A1.3 (low energy littoral rock)	11		16	27	66.2		69.8
A2.1 (Littoral coarse sediment)	9		13	15	15.2		34.8
A2.2 (Littoral sand & muddy sand)	12		18	221	78.4		80.7
A2.3 (Littoral mud)	11		18	202	77.0		80.3
A2.4 (Littoral mixed sediments)	7		10	13	44.7		60.5
A3.1 (high energy infralittoral rock)	7	7	8	428	81.2	80.9	81.9
A3.2 (moderate energy infralittoral rock)	9	8	11	288	65.9	64.4	67.1
A3.3 (low energy infralittoral rock)		1	1	4	83.6	82.7	83.6
A4.1 (high energy circalittoral rock)	6	7	8	954	33.4	33.3	33.6
A4.2 (moderate energy circalittoral rock)	11	8	19	9617	9.1	8.6	17.1
A4.3 (low energy circalittoral rock)	4	1	6	9,212	0.8	0.1	11.7
A5.1 (sublittoral coarse sediment)	12	7	30	27,866	5.5	3.3	20.0
A5.2 (sublittoral sand)	12	8	27	35,906	7.6	7.1	22.1
A5.3 (sublittoral mud)	3	3	11	5,743	2.2	2.2	22.7
A5.4 (sublittoral mixed sediments)	6	6	10	907	12.5	11.8	45.6
A6 (deep-sea bed, EUNIS level 2)	1	Information not available	2	362	12.8	Information not available	34.8
A6.1 (deep-sea rock and artificial hard substrata)	1		1	42	65.8		65.8
A6.2 (deep-sea mixed substrata)	1		1	405	66.3		66.3
A6.3 (deep-sea sand)	1		2	248	9.5		32.2
A6.5 (deep-sea mud)	1		1	568	48.5		48.5
A6.6 (deep-sea bioherms)			1	0	100.0		100.0
OSPAR T&D habitats							
Intertidal mudflats	11	Information not available	20	209	76.6	Information not available	79.8
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	1		1				
Littoral chalk communities	2		3				
Lophelia pertusa reefs	1		1				
Maërl beds	2		2	19	77.2		77.2
Modiolus modiolus beds			1				
Sabellaria spinulosa reefs	3		3				
Sea-pen and burrowing megafauna communities	3		6				
Zostera beds	4		4				

Table 4.9. Results of the fine filter replication and representation tests for CP2 region 4 – Western Channel and Celtic Sea. 'Current' refers to the current MPA network configuration, 'PF' to calculations carried out for protected features only, and 'Future' refers to the potential future network configuration. For more information, please refer to the text. Information on replication figures for additional ENG FOCI is included in the Excel document supplied along with this report.

CP2 region 5 - Irish Sea	Replication			Percentage coverage			
EUNIS level 3 habitats	**Current**	**PF**	**Future**	**Total area (km^2)**	**% Current**	**% PF**	**% Future**
A1.1 (high energy littoral rock)	8	Information not available	9	12	54.5	Information not available	54.5
A1.2 (moderate energy littoral rock)	9		9	35	45.2		45.2
A1.3 (low energy littoral rock)	9		10	30	29.7		30.5
A2.1 (Littoral coarse sediment)	9		10	17	71.4		72.8
A2.2 (Littoral sand & muddy sand)	10		12	983	68.5		70.7
A2.3 (Littoral mud)	6		8	239	60.3		64.6
A2.4 (Littoral mixed sediments)	6		6	17	66.9		69.0
A3.1 (high energy infralittoral rock)	4	5	8	345	51.0	50.4	54.3
A3.2 (moderate energy infralittoral rock)	5	5	9	128	32.2	25.9	41.3
A3.3 (low energy infralittoral rock)			1	40	0.7	0.1	16.2
A4.1 (high energy circalittoral rock)	6	4	8	649	28.0	50.4	28.1
A4.2 (moderate energy circalittoral rock)	6	3	11	1255	6.9	25.9	15.6
A4.3 (low energy circalittoral rock)	2	1	7	179	6.4	0.1	33.1
A5.1 (sublittoral coarse sediment)	10	9	17	14821	9.7	9.3	21.9
A5.2 (sublittoral sand)	11	8	18	8859	16.9	15.0	26.3
A5.3 (sublittoral mud)	6	1	13	6876	3.9	0.8	17.2
A5.4 (sublittoral mixed sediments)	6	5	12	2962	9.9	8.8	21.2
A6 (deep-sea bed, EUNIS level 2)*		Information not available		27*	0.0	Information not available	0.0
A6.1 (deep-sea rock and artificial hard substrata)*				22*	0.0		0.0
A6.2 (deep-sea mixed substrata)*				27*	0.0		0.0
A6.3 (deep-sea sand)*				23*	0.0		0.0
OSPAR T&D habitats							
Intertidal mudflats	8	Information not available	12	338.7	69.7	Information not available	72.7
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	6		7				
Littoral chalk communities	2		2				
Maërl beds	3		5	7.1	20.1		20.1
Modiolus modiolus beds	3		6				
Sabellaria spinulosa reefs	3		3				
Sea-pen and burrowing megafauna communities	4		9				
Zostera beds	4		5				

Table 4.10. Results of the fine filter replication and representation tests for CP2 region 5 – Irish Sea. ‘Current’ refers to the current MPA network configuration, ‘PF’ to calculations carried out for protected features only, and ‘Future’ refers to the potential future network configuration. For more information, please refer to the text. Information on replication figures for additional ENG FOCI is included in the Excel document supplied along with this report. *Note that this region does not extend to the continental shelf break. The UKSeaMap combined broad-scale habitat data layer used for this analysis includes some small patches of deep sea habitat in the northern Irish Sea, but this does not constitute deep sea habitat located beyond the shelf break.

CP2 region 6 - Minches and Western Scotland	Replication			Percentage coverage			
EUNIS level 3 habitats	**Current**	**PF**	**Future**	**Total area (km^2)**	**% Current**	**% PF**	**% Future**
A1.1 (high energy littoral rock)	2	Information not available	2	2	13.9	Information not available	13.9
A1.2 (moderate energy littoral rock)	2		3	2	17.5		22.4
A1.3 (low energy littoral rock)	6		8	13	10.1		14.7
A2.1 (Littoral coarse sediment)	2		3	11	0.1		0.3
A2.2 (Littoral sand & muddy sand)	3		4	14	18.4		21.4
A2.3 (Littoral mud)	1		1	1	8.2		8.2
A2.4 (Littoral mixed sediments)	4		5	14	3.3		8.7
A3.1 (high energy infralittoral rock)	1		6	1308	2.3		6.1
A3.2 (moderate energy infralittoral rock)	3		11	881	6.0		27.4
A3.3 (low energy infralittoral rock)	4		8	391	7.0		22.2
A4.1 (high energy circalittoral rock)	2		7	438	15.5		24.2
A4.2 (moderate energy circalittoral rock)	5		10	1418	2.3		14.1
A4.3 (low energy circalittoral rock)	3		9	1091	5.3		16.2
A5.1 (sublittoral coarse sediment)	7		11	3873	1.3		6.1
A5.2 (sublittoral sand)	6		11	9690	2.0		4.4
A5.3 (sublittoral mud)	7		13	7522	2.2		13.0
A5.4 (sublittoral mixed sediments)	7		13	1382	4.4		20.7
A6 (deep-sea bed, EUNIS level 2)				0	0.0		100.0
A6.1 (deep-sea rock and artificial hard substrata)	1		2	27	67.4		67.4
A6.2 (deep-sea mixed substrata)			1	5	61.4		61.4
A6.3 (deep-sea sand)	1		1	86	3.7		4.0
A6.5 (deep-sea mud)	1		2	108	22.5		24.8
OSPAR T&D habitats							
Intertidal mudflats	3	Information not available	4	1.1	8.2	Information not available	8.2
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	2		2				
Littoral chalk communities	2		2				
Lophelia pertusa reefs	1		1				
Maërl beds	8		13	16.8	39.8		48.8
Modiolus modiolus beds	4		7				
Sea-pen and burrowing megafauna communities	9		13				
Zostera beds	7		9				

Table 4.11. Results of the fine filter replication and representation tests for CP2 region 6 – Minches and Western Scotland. 'Current' refers to the current MPA network configuration, 'PF' to calculations carried out for protected features only, and 'Future' refers to the potential future network configuration. For more information, please refer to the text. Information on replication figures for additional ENG FOCI is included in the Excel document supplied along with this report.

CP2 region 7 - Scottish Continental Shelf	Replication			Percentage coverage			
EUNIS level 3 habitats	**Current**	**PF**	**Future**	**Total area (km²)**	**% Current**	**% PF**	**% Future**
A1.1 (high energy littoral rock)	2	Information not available	2	1	16.1	Information not available	16.1
A1.2 (moderate energy littoral rock)	3		3	2	86.0		86.0
A1.3 (low energy littoral rock)	9		9	10	44.4		44.4
A2.1 (Littoral coarse sediment)	1		1	1	25.2		25.2
A2.2 (Littoral sand & muddy sand)	1		1	6	58.6		58.6
A2.3 (Littoral mud)	1		1	2	0.5		0.5
A2.4 (Littoral mixed sediments)	4		4	1	17.7		17.7
A3.1 (high energy infralittoral rock)	6		11	3,643	2.1		3.5
A3.2 (moderate energy infralittoral rock)	4		10	1,366	5.3		7.5
A3.3 (low energy infralittoral rock)			2	149	2.0		3.0
A4.1 (high energy circalittoral rock)	2		4	1,139	13.5		13.6
A4.2 (moderate energy circalittoral rock)	5		8	9,501	5.0		19.1
A4.3 (low energy circalittoral rock)	2		5	3,763	3.2		12.3
A5.1 (sublittoral coarse sediment)	6		12	37,129	2.4		14.3
A5.2 (sublittoral sand)	5		10	34,426	1.6		9.8
A5.3 (sublittoral mud)	2		2	463	2.2		2.2
A5.4 (sublittoral mixed sediments)			4	726	0.4		35.1
A6 (deep-sea bed, EUNIS level 2)	2		7	10,822	6.1		39.1
A6.1 (deep-sea rock and artificial hard substrata)			6	466	0.4		25.2
A6.2 (deep-sea mixed substrata)			3	2,446	0.0		77.1
A6.3 (deep-sea sand)	1		7	11,896	0.9		19.5
A6.5 (deep-sea mud)	1		4	2,298	2.2		34.5
OSPAR T&D habitats							
deep-sea sponge aggregations	1	Information not available	3			Information not available	
Intertidal mudflats	3		3	2	0.5		0.5
Littoral chalk communities							
Lophelia pertusa reefs	2		4				
Maërl beds	2		4	7	9.0		97.8
Modiolus modiolus beds	2		3				
Sea-pen and burrowing megafauna communities	3		6				
Zostera beds	4		4				

Table 4.12. Results of the fine filter replication and representation tests for CP2 region 7 – Scottish Continental Shelf. 'Current' refers to the current MPA network configuration, 'PF' to calculations carried out for protected features only, and 'Future' refers to the potential future network configuration. The particularly low figures for intertidal habitats in this region suggest that the coverage of intertidal data is limited here. This renders the intertidal figures for this CP2 region less useful. For more information, please refer to the text. Information on replication figures for additional ENG FOCI is included in the Excel document supplied along with this report.

CP2 region 8 - Atlantic North-West Approaches	Replication			Percentage coverage			
EUNIS level 3 habitats	Current	PF	Future	Total area (km²)	% Current	% PF	% Future
A3.2 (moderate energy infralittoral rock)		Information not available		3	0.0	Information not available	0.0
A4.2 (moderate energy circalittoral rock)				94	0.0		0.0
A4.3 (low energy circalittoral rock)	1		1	152	59.2		59.2
A5.1 (sublittoral coarse sediment)	1		1	985	9.8		9.8
A5.2 (sublittoral sand)	1		1	112	19.4		19.4
A5.4 (sublittoral mixed sediments)	1		1	5,566	7.9		7.9
A6 (deep-sea bed, EUNIS level 2)	4		10	16,638	17.3		44.1
A6.1 (deep-sea rock and artificial hard substrata)	5		7	5,494	34.6		52.1
A6.2 (deep-sea mixed substrata)	4		8	72,930	22.4		28.4
A6.3 (deep-sea sand)	6		11	55,396	8.7		17.5
A6.5 (deep-sea mud)	5		12	164,811	0.3		16.7
A6.6 (deep-sea bioherms)	1		1	20	100.0		100.0
OSPAR T&D habitats							
Carbonate mounds	1	Information not available	1			Information not available	
Coral gardens	3		4				
deep-sea sponge aggregations	4		8				
Lophelia pertusa reefs	6		7				
Seamounts	1		3	6,847	3.1		85.0
Sea-pen and burrowing megafauna communities	1		2				

Table 4.13. Results of the fine filter replication and representation tests for CP2 region 8 – Atlantic North-West Approaches. 'Current' refers to the current MPA network configuration, 'PF' to calculations carried out for protected features only, and 'Future' refers to the potential future network configuration. For more information, please refer to the text. Information on replication figures for additional ENG FOCI is included in the Excel document supplied along with this report.

Tables 4.5 to 4.13 show that at the scale of the whole UKCS (table 4.5), the ENG replication threshold of three replicates per feature is comprehensively achieved for all EUNIS level 3 habitats, although there are relatively low replicate numbers for three OSPAR threatened and declining habitats: carbonate mounds, *Ostrea edulis* beds and seamounts. The ENG replication threshold is also generally well met at the scale of individual biogeographic regions. Low replication figures are generally only found for habitats that have low total area coverage figures in a given region, with the exception of CP2 region 8 (the far north-west, table 4.13), where there are shortfalls in replication figures for extensive habitats. For some of the CP2 regions, replication figures were also calculated for protected features only (as well as for all features falling within site boundaries), resulting in reduced replication figures. The potential future MPAs that would contribute particularly significantly to improving replication figures are listed in table 4.14.

Percentage coverage targets are not met for all habitats covered in this analysis at the UKCS scale. The addition of potential future sites significantly improves the figures, but notably, minimum ENG thresholds would still not be met for some habitats. The analysis revealed significant variation in percentage coverage figures between habitats as well as between CP2 regions:

- Subtidal sediments are poorly represented in the current network in CP2 region 1 (Northern North Sea, table 4.6). The addition of the potential future MPAs would resolve this to some degree, but for some of the sublittoral sediment habitats that cover extensive areas in this region, the minimum ENG thresholds would still not be met even with all the potential future sites added.
- Percentage habitat coverage figures for region 2 (Southern North Sea, table 4.7) are comparatively high for the current network. The addition of the potential future MPAs would bring virtually all figures above the ENG thresholds.
- Coverage of sublittoral sediment habitats and moderate energy circalittoral rock within region 3 (Eastern Channel, table 4.8) is particularly lacking in the current network. The addition of the potential future MPAs would significantly improve these percentage coverage figures, bringing most (but not all) above the minimum ENG threshold.
- Within region 4 (Western Channel and Celtic Sea, table 4.9) coverage of subtidal sediments and moderate energy circalittoral rock within the current network is relatively low, with the addition of the potential future MPAs leading to significant improvement.
- Subtidal sediment habitats within region 5 (Irish Sea, table 4.10) are not well covered, though there is improvement with the addition of potential future MPAs. Note that the UKSeaMap combined EUNIS habitat data layer used in this analysis contains small patches of deep-sea habitat (EUNIS A.6) in region 5. Whilst the St George's Channel running through the northern Irish Sea is comparatively deep (up to 250 m), this CP2 region does not extend to the continental shelf break and the deep sea beyond.
- Within region 6 (Minches and Western Scotland, table 4.11), the current network fails to achieve the minimum threshold for more than half of the habitats for which there are ENG targets, with the remainder between the upper and lower limits of the ENG target ranges. The addition of the potential future MPAs would significantly improve the figures, though it would fail to bring many of the habitat coverage figures above the minimum threshold.
- Region 7 (Scottish Continental Shelf, table 4.12) has poor habitat percentage coverage figures for the current network, compared to other regions. The addition of the potential future MPAs would significantly improve the figures, but would notably still fail to bring many of the figures above the minimum ENG threshold, especially for the wide-spread subtidal sediment habitats.
- The majority of region 8 (Atlantic North-West Approaches, table 4.13) is covered by deep-sea habitats (EUNIS A6). Most have at least one replicate and some coverage within the current network, though significant increases are seen with addition of the potential future MPAs. The OSPAR seamounts habitat is particularly poorly represented at the moment, though there is great potential to improve this in the future.

Table 4.15 lists individual sites that would contribute particularly significantly to the improvement of percentage habitat coverage figures. As highlighted in the methods section, because there are so many different features to consider, and each potential future site contributes different amounts of coverage for different habitats, it was challenging to come up with a single score to rank their relative contribution. The challenges and potential pitfalls of combined scoring approaches are described in more detail in box 4.1.

Box 4.1 Combined scoring can produce misleading results

Caution must be taken in interpreting or combining the results of the various analyses in this report. The approach that may come to mind; i.e. some sort of additive scoring system, brings with it several limitations and can produce misleading results (Klein *et al.* 2014, Ferrier and Wintle 2009). Therefore, in this report we have not attempted to develop a global ranking of the relative gap-filling effectiveness of the potential future MPAs by combining effectiveness scores or rank orders from all tests, but rather have presented the ‘top contributing’ sites separately for each test. The issues described below are not unique to this analysis, but rather are a reflection of the complexities of any multi-criteria analysis and the hazards in reducing these complexities to a single measure.

To illustrate some of the shortcomings of scoring, imagine a simple additive example whereby for each of the gap analyses, a relative value is assigned to each potential MPA site, on a range of 0-5, where 5 is a very high value site (for filling a gap for that particular species or habitat), and 0 means it doesn’t address it at all. It might be tempting to think that adding together the various scores would provide a clear ‘winner’. Unfortunately, it is not necessarily so. One site could get five scores of ‘1’ (low), whereas another site could receive one score of ‘5’ (excellent). Their total scores are therefore the same. However, it is broadly accepted that protecting many weak examples of features is not as valuable as protecting one excellent example. Furthermore, one has to question if it even makes sense to add together values for completely different features (‘apples and oranges’). Does a ‘2’ for a seabird and a ‘3’ for a rocky coast equal a ‘5’ for a deep mud habitat?

In the above examples, when the values are statistically independent (‘orthogonal’), addition is mathematically incorrect. With orthogonal values, using the square root of the sum of squares is the correct approach (such as with a right-angled triangle), and avoids the problem of five 1’s adding up to a high value score of 5. The total of five 1’s for the square-root of summed squares would instead be 2.2 (i.e., medium-low). However, this does not avoid the other issue regarding the meaningfulness of adding together such scores in the first instance. Additionally, adding scores together produces opaque results. A single score cannot tell you what is being protected. Indeed, it could be that the top three scores happen to all protect more or less the same subset of (more common) features, leaving many others unaccounted for.

Finally, different tests bring with them different kinds of error. Some tests may have errors of omission (i.e. some places are being missed) whereas others may have errors of commission (too many places are identified). Some analyses may also have higher inherent variability than others (seasonality, etc.). Difficult to deal with separately, these considerations become intractable when combined into a single score or map layer.

MPA	Contribution
The Barra Fan and Hebrides Terrace Seamount (pNCMPA)	7
Faroe-Shetland Sponge Belt (Scottish pNCMPA)	6
Fetlar to Haroldswick (Scottish pNCMPA)	6
North-east Faroe-Shetland Channel (Scottish pNCMPA)	6
Geikie Slide and Hebridean Slope (Scottish pNCMPA)	5
Bembridge (rMCZ)	4
South-west Sula Sgeir and Hebridean Slope (Scottish pNCMPA)	4
Coquet to St Mary's (rMCZ)	3
North-west Orkney (Scottish pNCMPA)	3
Small Isles (Scottish pNCMPA)	3

Table 4.14. Potential future MPAs contributing particularly well to improved replication figures. The contribution is the sum of different features for which the MPA would improve replication. Please refer to the Excel document supplied with this report for details on which features each site would add, and for information on the contribution made by potential future sites not listed here. The sites listed in this table are mapped in Appendix 1.

MPA	Score
North-east Faroe-Shetland Channel (Scottish pNCMPA)	3
East of Gannet and Montrose Fields (Scottish pNCMPA)	2
Faroe-Shetland Sponge Belt (Scottish pNCMPA)	2
Firth of Forth Banks Complex (Scottish pNCMPA)	2
Fulmar (rMCZ)	2
Geikie Slide and Hebridean Slope (Scottish pNCMPA)	2
Hatton-Rockall Basin (Scottish pNCMPA)	2
North-west Orkney (Scottish pNCMPA)	2
Rosemary Bank Seamount (Scottish pNCMPA)	2
South-West Deeps East (rMCZ)	2
South-west Sula Sgeir and Hebridean Slope (Scottish pNCMPA)	2
The Barra Fan and Hebrides Terrace Seamount (Scottish pNCMPA)	2
West Shetland Shelf (Scottish pNCMPA)	2
Western Channel (rMCZ)	2

Table 4.15. Potential future MPAs that would make a particularly significant contribution towards improving percentage habitat coverage of the network, based on scores (1-3; low, medium, high) derived from the formula described in section 3.1.1. This formula was used to avoid some of the potential pitfalls of combining multiple measures for coverage contributions for different habitats to develop a single score per site (see box 4.1). However, in this aggregated score all habitat types and regions were combined. The results will vary significantly by sub-region and habitat type. Please refer to the Excel document supplied with this report for details on which specific habitats each site would improve coverage figures for, and for the scores of the potential future sites not listed here. The sites listed in this table are mapped in Appendix 1.

4.3 Fine filter broad habitat-based proximity test

Compared to the coarse filter simple buffer analysis which was used to identify large spatial gaps in the current network configuration, this test provides a more nuanced proximity test. Firstly, the test is broken down into a series of analyses, one per EUNIS level 2 broad-scale habitat. This means that only sites containing the same habitat are 'counted' in each test, providing an assessment of whether there are any large spatial gaps in the protection of any given broad-scale habitat.

Rather than representing proximity with a series of fixed distance buffers around the EUNIS level 2 habitat areas within each site, a kernel density analysis was performed (figures 4.6 to 4.11). This emphasises larger areas over smaller ones and will group together sites that are close to one another (within a given search radius). The difference between the two approaches is illustrated in figure 4.5, where even though the buffer covers large areas of the coast, the density analysis tells a different story. Many of the MPAs in the buffer analysis were actually very small (and given broad-scale habitat areas within them potentially even smaller) which will reduce their potential capacity to act as ecological stepping stones. The density analysis can therefore be construed as a more nuanced rendering of the coarse level proximity test. Therefore, whilst this test does not fully address ecological connectivity *(*it does not assess specific ecological pathways for movement and dispersal between sites), it provides a more detailed, fine-filter assessment than the simple buffer analysis presented earlier.

Figures 4.6 to 4.11 reveal several gaps in habitat-based proximity in the current network, i.e. areas of distribution of a given broad-scale habitat within which no MPAs containing that habitat are located. Table 4.16 contains some examples of potential future MPAs that would contribute to filling the gaps revealed in this analysis.

The kernel density map in figure 4.6 shows gaps in the coverage for littoral rock habitat, particularly along north-east England's coast, along Scottish coastlines, and in the south-west. Potential future MPAs would contribute to filling gaps in several areas, most effectively around the south-west coast. Littoral sediment (figure 4.7) is relatively well covered by the current network, based on this proximity test, with the exception of a gap along the north-east coast of England and in the western isles of Scotland.

Infralittoral rock (figure 4.8) has good coverage around much of the coast, especially around south-west England. Significant gaps occur around eastern Scotland, eastern England and north-east Scotland. Circalittoral rock (figure 4.9) is less well represented, though the potential future network would comprehensively fill many of the gaps. Sublittoral sediments (figure 4.10) are the most common habitat in the study area. There are significant gaps when visualising the current network which can be filled to varying degrees with potential future MPAs. As many of the potential MPAs are large and this habitat so common, many potential sites contribute significantly to filling these gaps (table 4.16). Significant extents of deep-sea habitats (figure 4.11) are limited to north-west Scotland and south-west England. The south-west deep-sea bed is covered by the Canyons MCZ. In Scottish waters, there are large gaps, which would be significantly reduced but not filled comprehensively by potential future sites.

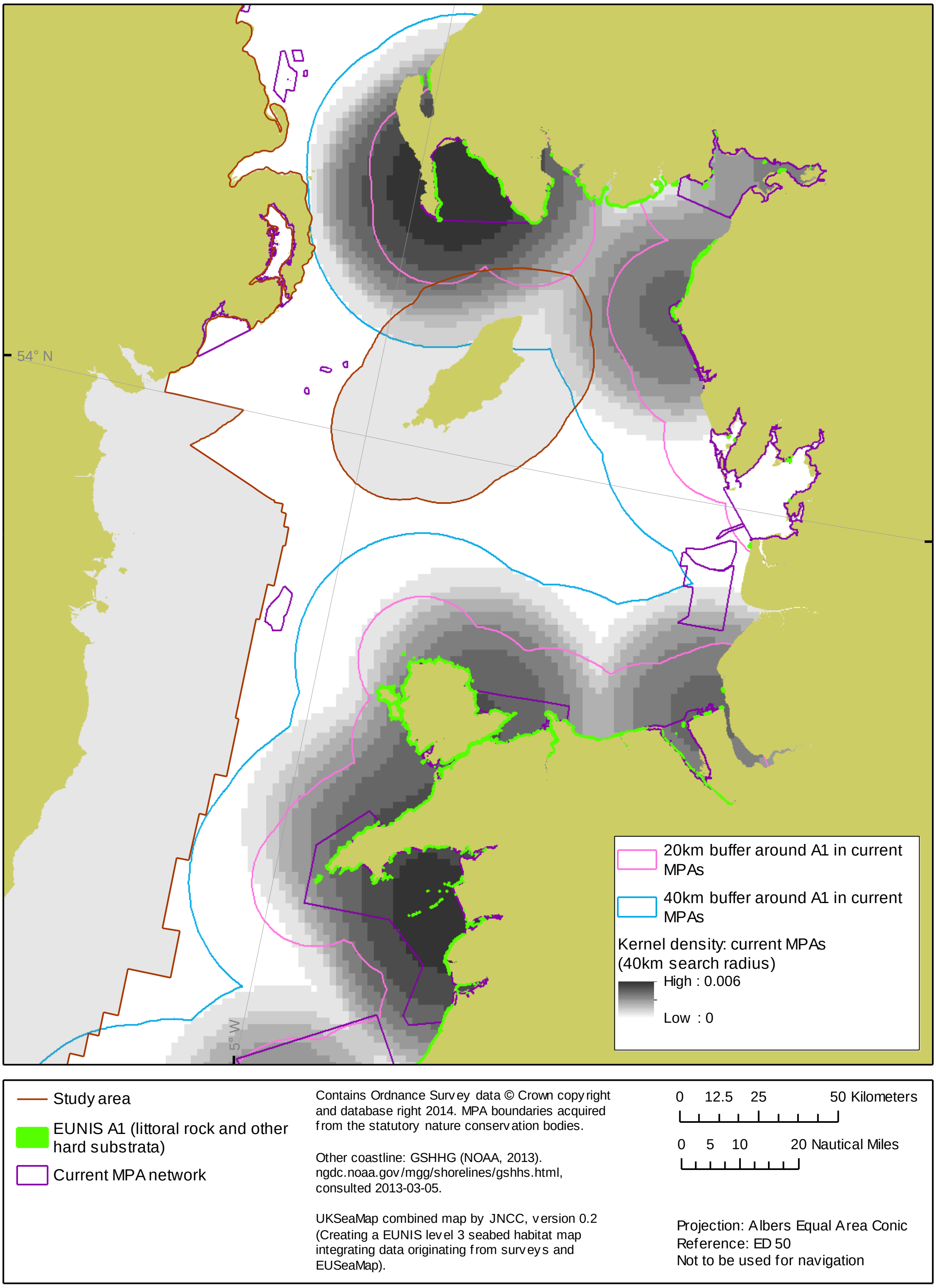

Figure 4.5. This map illustrates the difference between using a kernel density analysis to visualise habitat-based MPA proximity, compared with a simple buffer around habitat patches within the sites. The kernel density analysis provides a more nuanced representation highlighting both larger areas and where multiple habitat patches occur in close proximity.

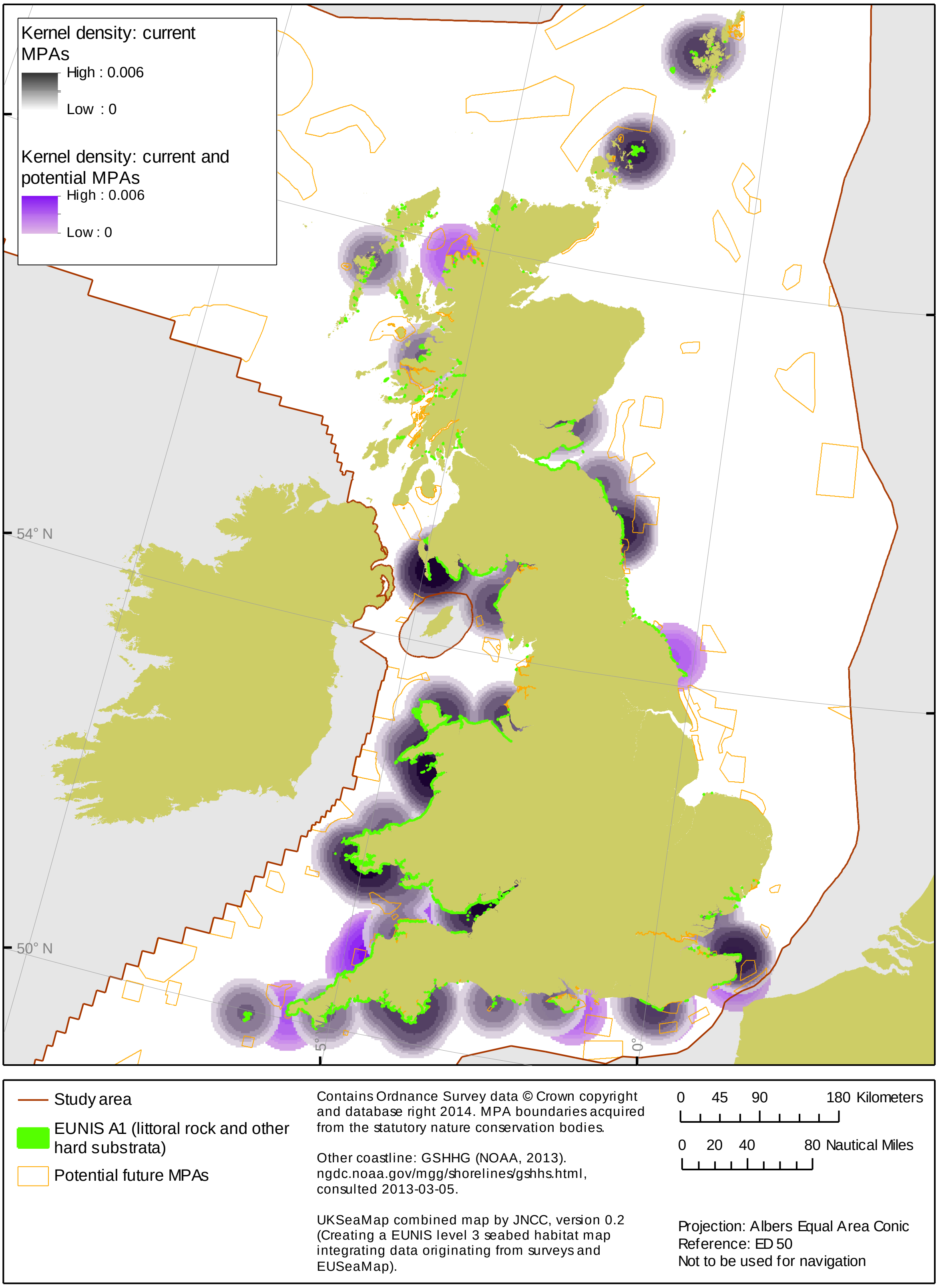

Figure 4.6. Kernel density proximity map for littoral rock habitat.

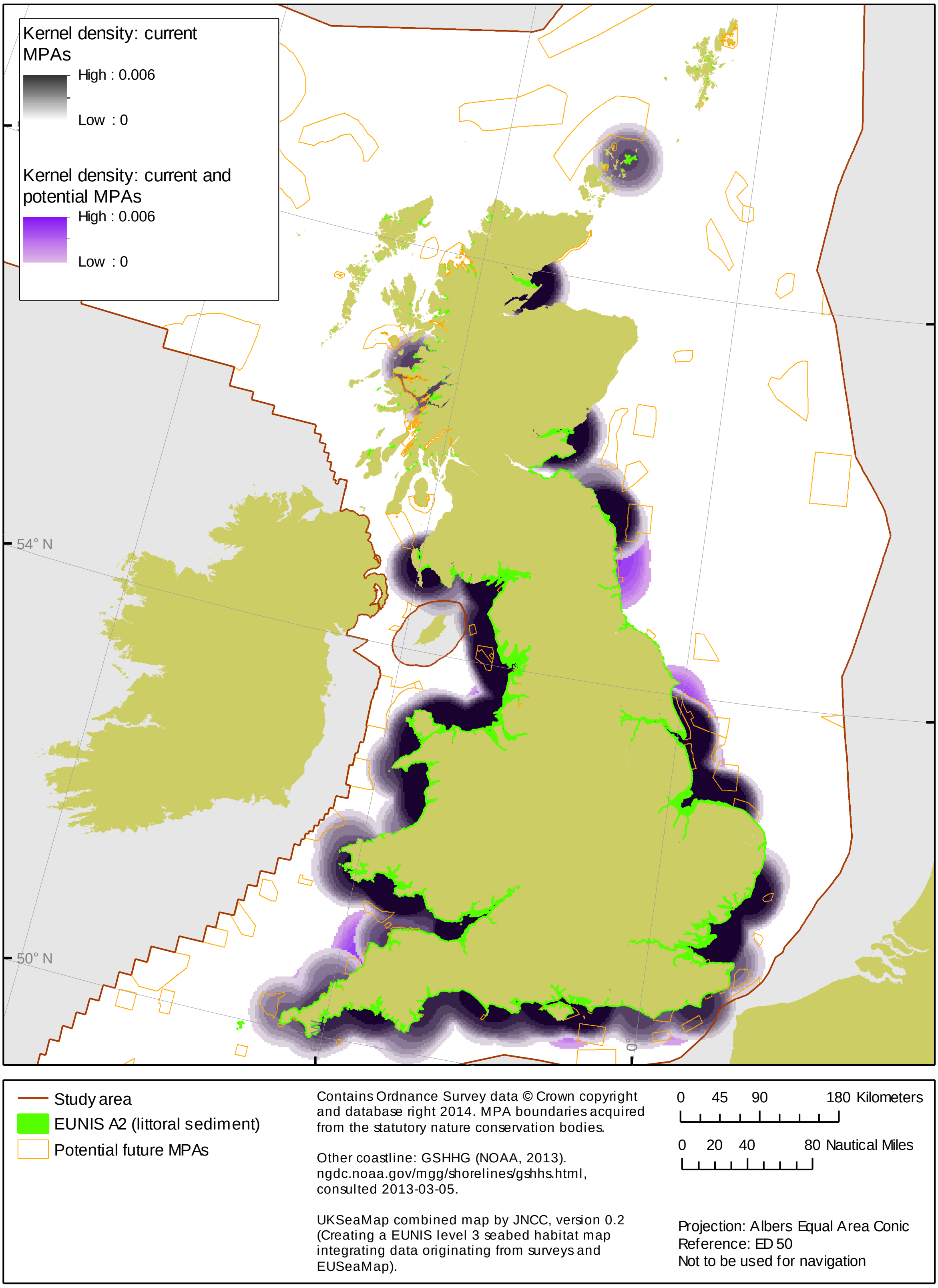

Figure 4.7. Kernel density proximity map for littoral sediment habitat.

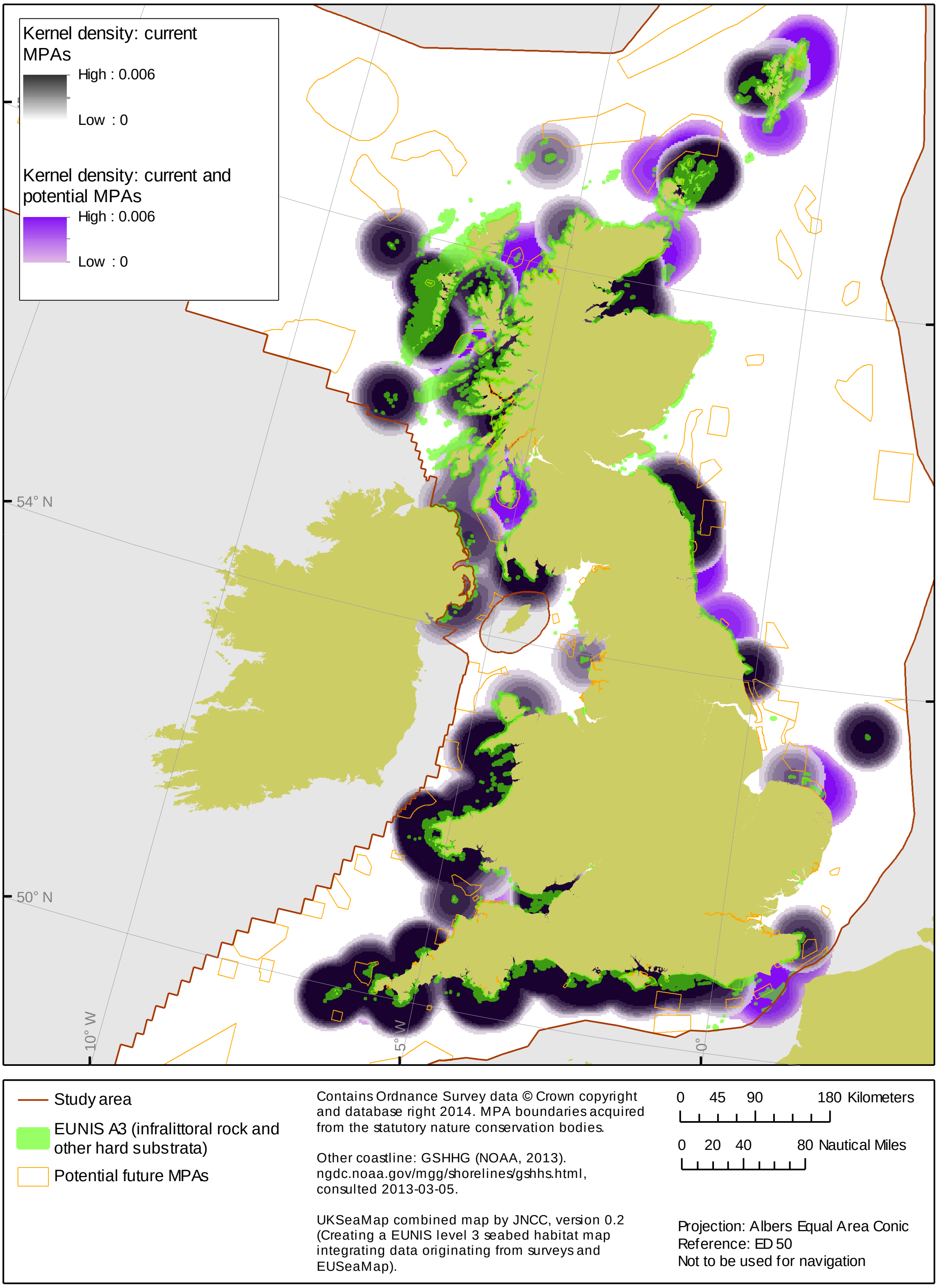

Figure 4.8. Kernel density proximity map for infralittoral rock habitat.

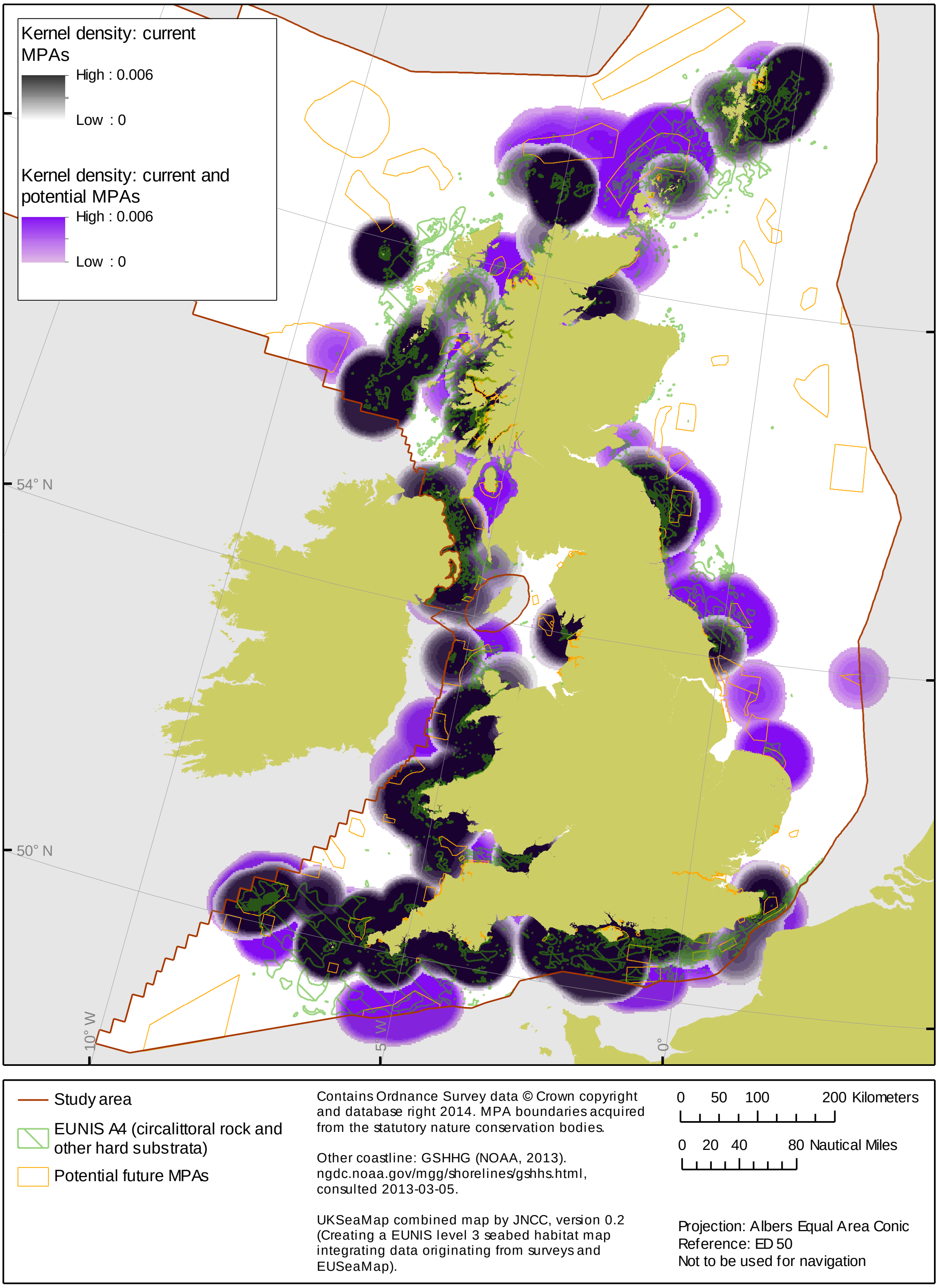

Figure 4.9. Kernel density proximity map for circalittoral rock habitat.

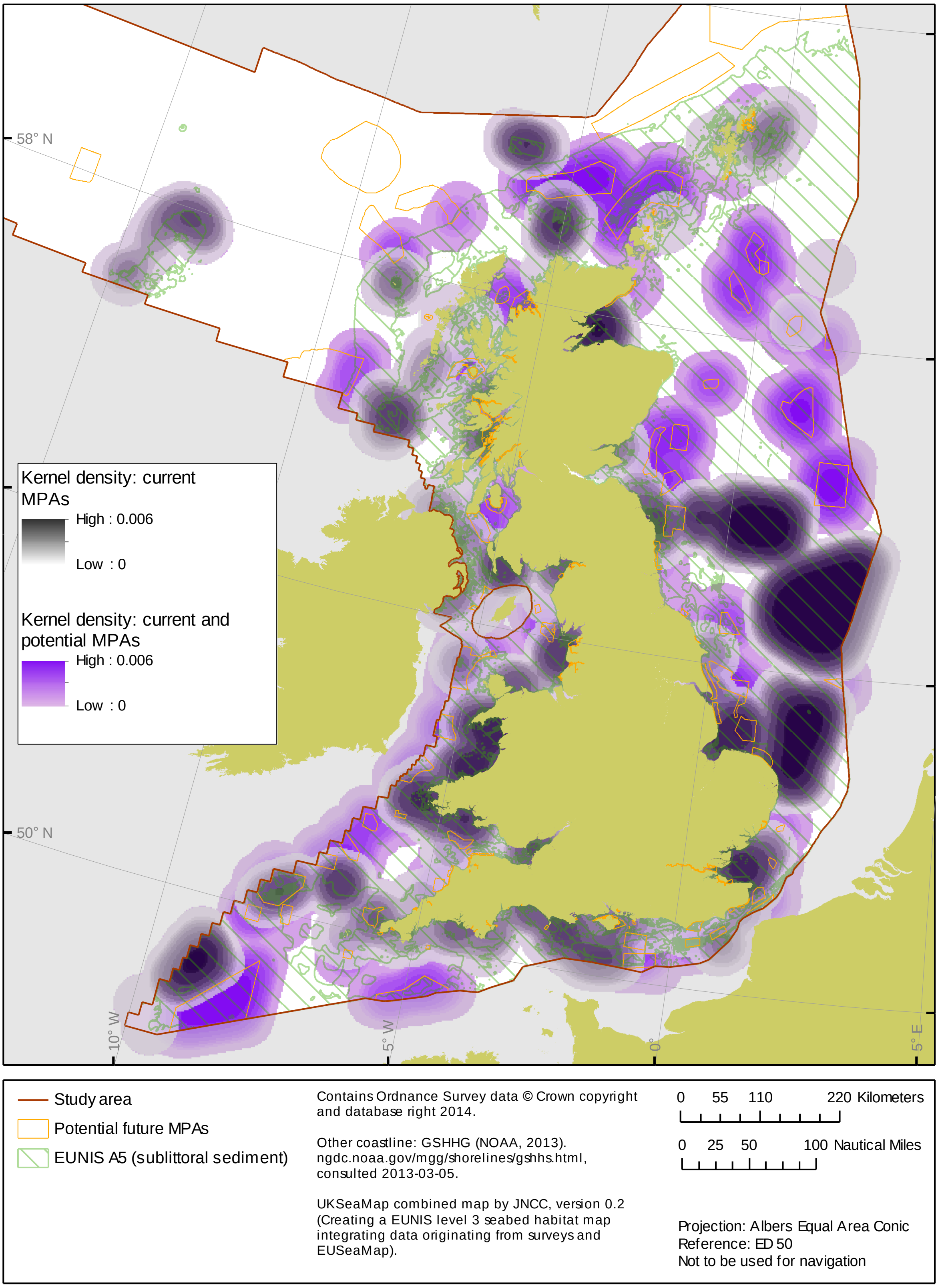

Figure 4.10. Kernel density proximity map for sublittoral sediment habitat.

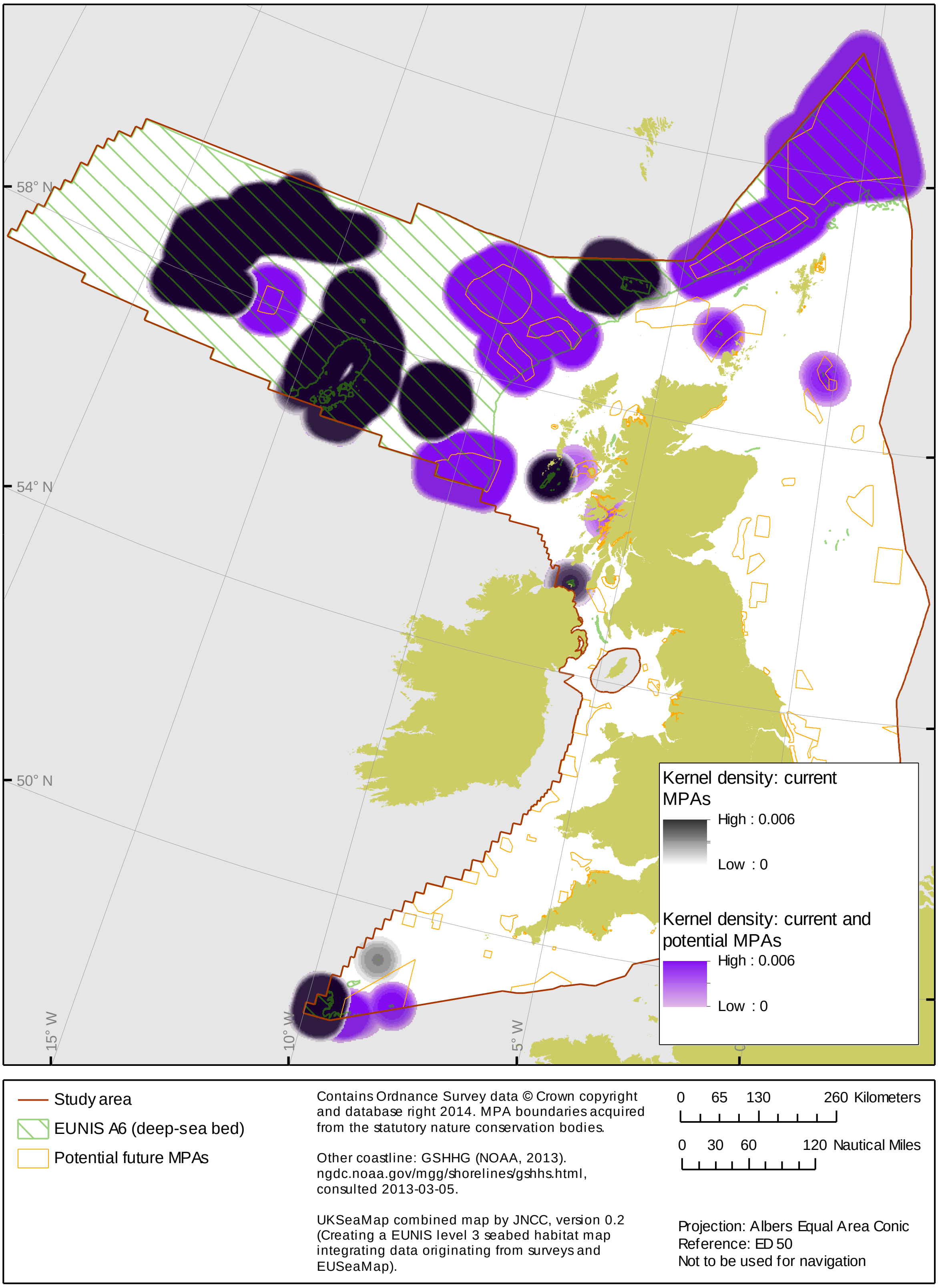

Figure 4.11. Kernel density proximity map for deep sea habitat.

Potential future MPA	EUNIS L2 added
Bideford to Foreland Point (rMCZ)	A2
Compass Rose (rMCZ)	A4
Coquet to St Mary's (rMCZ)	A2, A3
Dover to Deal (rMCZ)	A1
Dover to Folkestone (rMCZ)	A1
East Caithness Cliffs (Scottish pNCMPA)	A3
East of Jones Bank (rMCZ)	A4
Farnes East (rMCZ)	A4
Faroe-Shetland Sponge Belt (Scottish pNCMPA)	A6
Fetlar to Haroldswick (Scottish pNCMPA)	A3
Firth of Forth Banks Complex (Scottish pNCMPA)	A5
Fulmar (RMCZ)	A5
Greater Haig Fras (rMCZ)	A4
Hartland Point to Tintagel (rMCZ)	A1, A2
Holderness Inshore (rMCZ)	A2
North-east Faroe-Shetland Channel (Scottish pNCMPA)	A6
North-west Orkney (Scottish pNCMPA)	A4, A5
North-west sea lochs and Summer Isles (Scottish pNCMPA)	A1, A3
Rosemary Bank Seamount (Scottish pNCMPA)	A6
Small Isles (Scottish pNCMPA)	A3
South-West Deeps (East) (rMCZ)	A5
South-west Sula Sgeir and Hebridean Slope (Scottish pNCMPA)	A6
The Barra Fan and Hebrides Terrace Seamount (Scottish pNCMPA)	A6
West Shetland Shelf (Scottish pNCMPA)	A5

Table 4.16. Potential future MPAs that would improve habitat-based proximity results, selected by visual assessment of the kernel density layers shown in figures 4.6 to 4.11. These sites are mapped in Appendix 1.

4.4 Fine filter mobile species test

The series of maps shown in figures 4.12 to 4.15 display the current and potential future MPAs that include / are being proposed to include the protection of mobile species, together with data layers indicating areas of importance for mobile species.

The areas of Additional Pelagic Ecological Importance data layer (figure 4.12) was produced by the Wildlife Trusts during the UK MCZ process. This layer combines multiple datasets to provide an indication of areas of pelagic biodiversity around the UK. Specifically, the APEI layer combined the following:

- Thermal front data.
- RSPB foraging radius data around seabird colonies.
- Whale and Dolphin Conservation Society data for important areas for marine mammals.
- Cefas and ICES nursery and spawning data based on plankton surveys.
- Marine Conservation Society and Shark Trust basking shark sightings.

The higher scoring components of the APEI layer tend to cluster around the coast. The current MPA network covers some of these areas, particularly around the Welsh and north-east Scottish coasts, though neglects the Northern Irish Sea and much of the south-west where there are large areas with high scores. The Scottish Areas of Search for mobile species cover significant areas with high scores.

Data on the frequency of occurrence of summer sea surface temperature fronts is a significant component of the APEI score. The data on thermal sea surface temperature fronts, which was derived from satellite sea surface temperature data collected over several years (Miller and Christodoulou 2014, Miller *et al.* 2010), is mapped in figure 4.13. As with the APEI layer, many areas where thermal fronts frequently form in the summer months is not covered by current MPAs. Again, the Scottish Areas of Search contribute to this around the Scottish coast, but the south-west and eastern channel lack coverage (though the Wight-Barfleur Reef SAC covers a large area of frontal activity).

Basking shark sightings, which where another component or 'input' data layer for the APEI scores, are shown in figure 4.14. Sightings tend to be clustered around the south-west coast, Isle of Man, western Scottish coast, the Orkneys and Shetland. With the exception of limited parts of the Scottish coast, these sightings fall almost completely outside of the existing MPA network. The Skye to Mull Scottish Area of Search covers an area containing a significant number of sightings.

The European Seabirds at Sea database held by the JNCC is a comprehensive database holding over a million records from ship-based and aerial surveys of offshore seabirds. A comprehensive analysis of the information in this database was beyond the scope of this analysis. Figure 4.15 shows a database extract, filtered on the basis of observations marked as birds displaying foraging behaviour (but not filtered for species, season, or year of survey). It is important to note that these data have not been corrected for survey effort. The majority of the foraging bird sightings extracted from this database are around Eastern England and Scotland, with other areas around the Welsh coast and northern Irish Sea. Significant areas of high foraging count are covered by the existing MPA network, especially the Moray Firth SAC, SPAs around the Solent and the Firth of Forth and other SPAs around the Scottish coast. Potential future MPAs would add coverage to areas with particularly high counts.

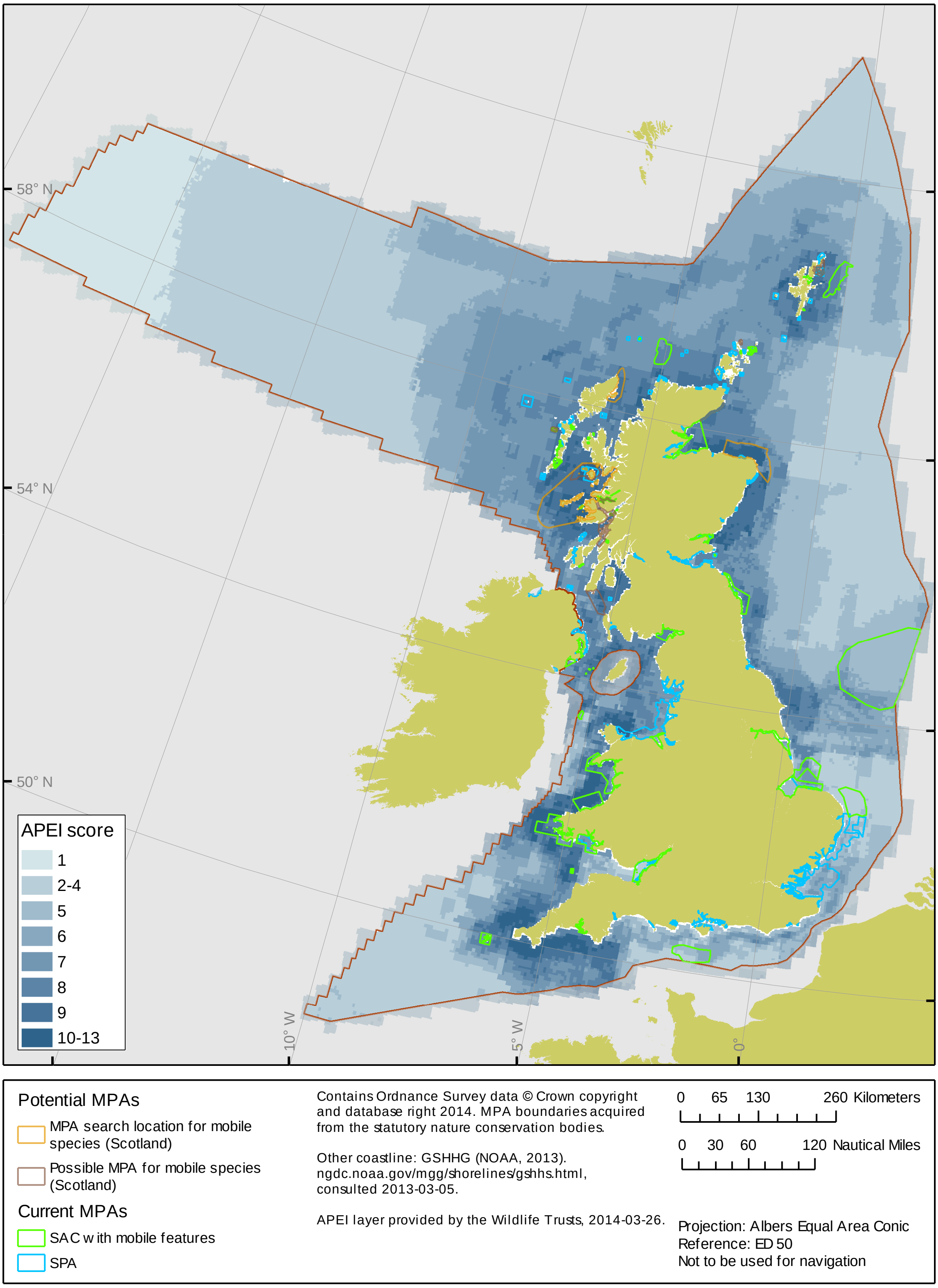

Figure 4.12. Current MPAs with mobile species listed as interest features, mapped with areas of Additional Pelagic Ecological Importance (showing combined information about the spatial distribution of seasonal sea surface temperature fronts, seabird colonies and foraging radiuses of seabirds, spawning and nursery grounds, and mammal sightings).

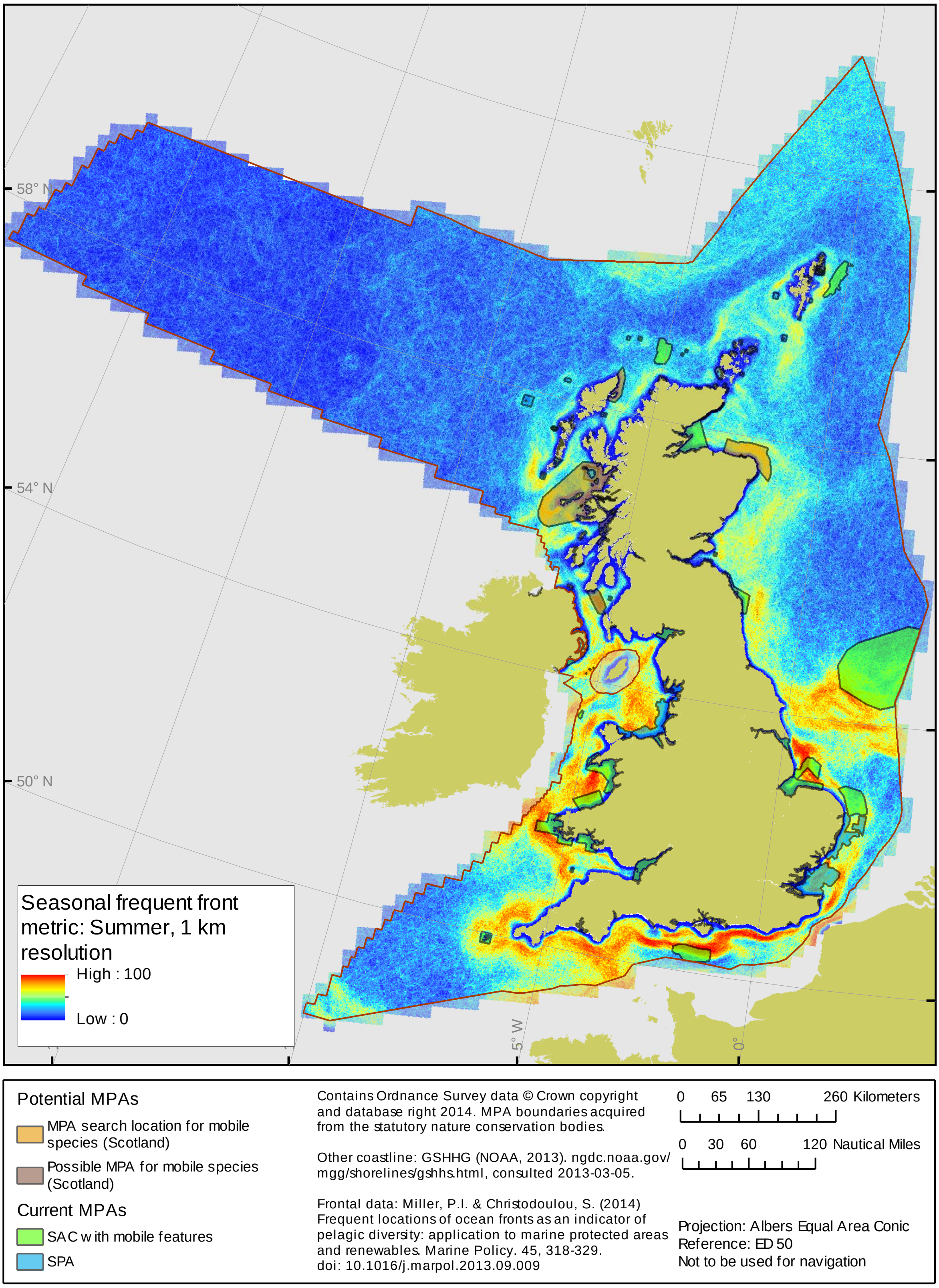

Figure 4.13. Current MPAs with mobile species listed as interest features, mapped with areas where sea surface temperature fronts form frequently (Miller and Christodoulou 2014).

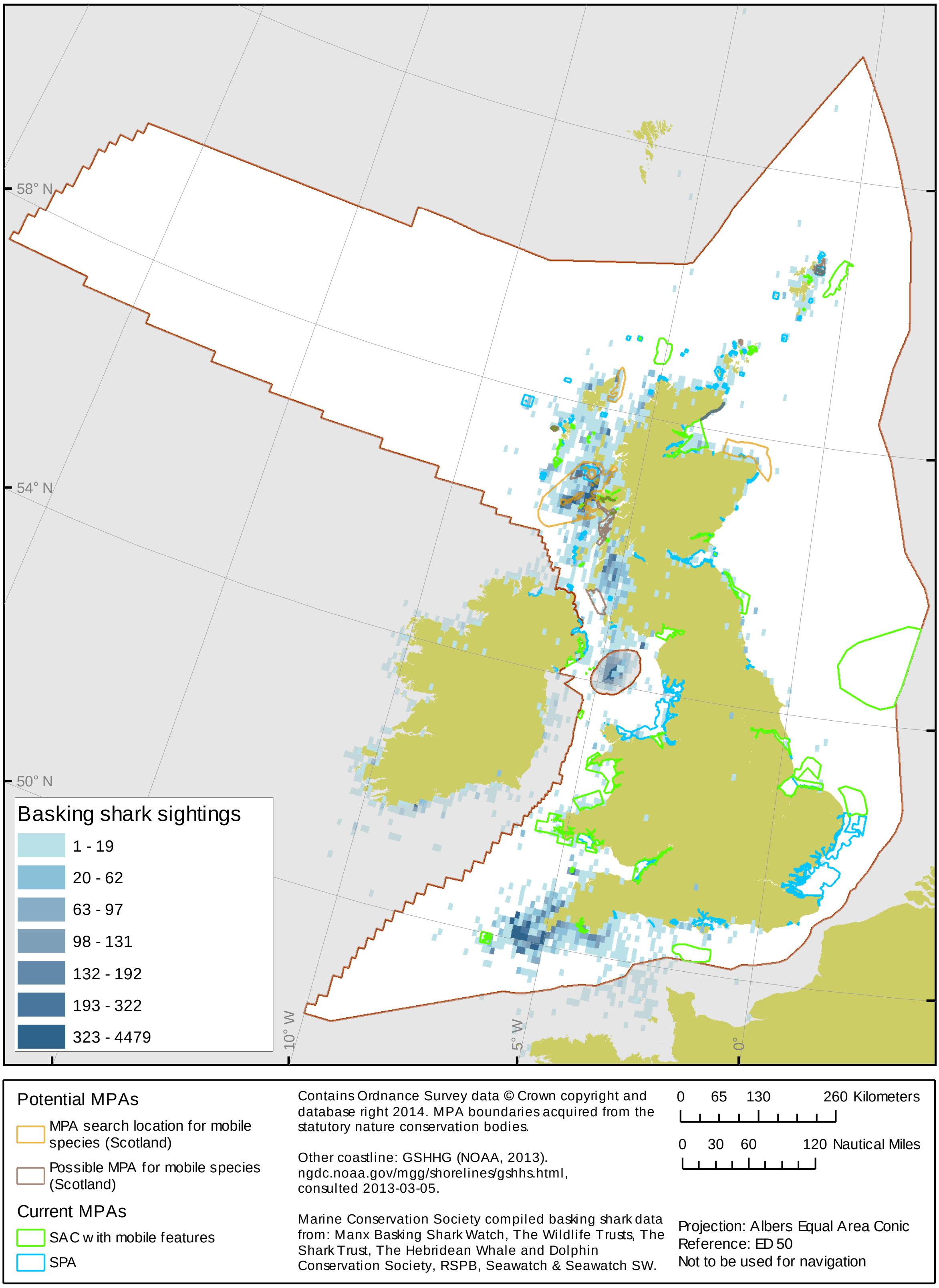

Figure 4.14. Current MPAs with mobile species listed as interest features, mapped with basking shark sightings (Bloomfield and Solandt 2008).

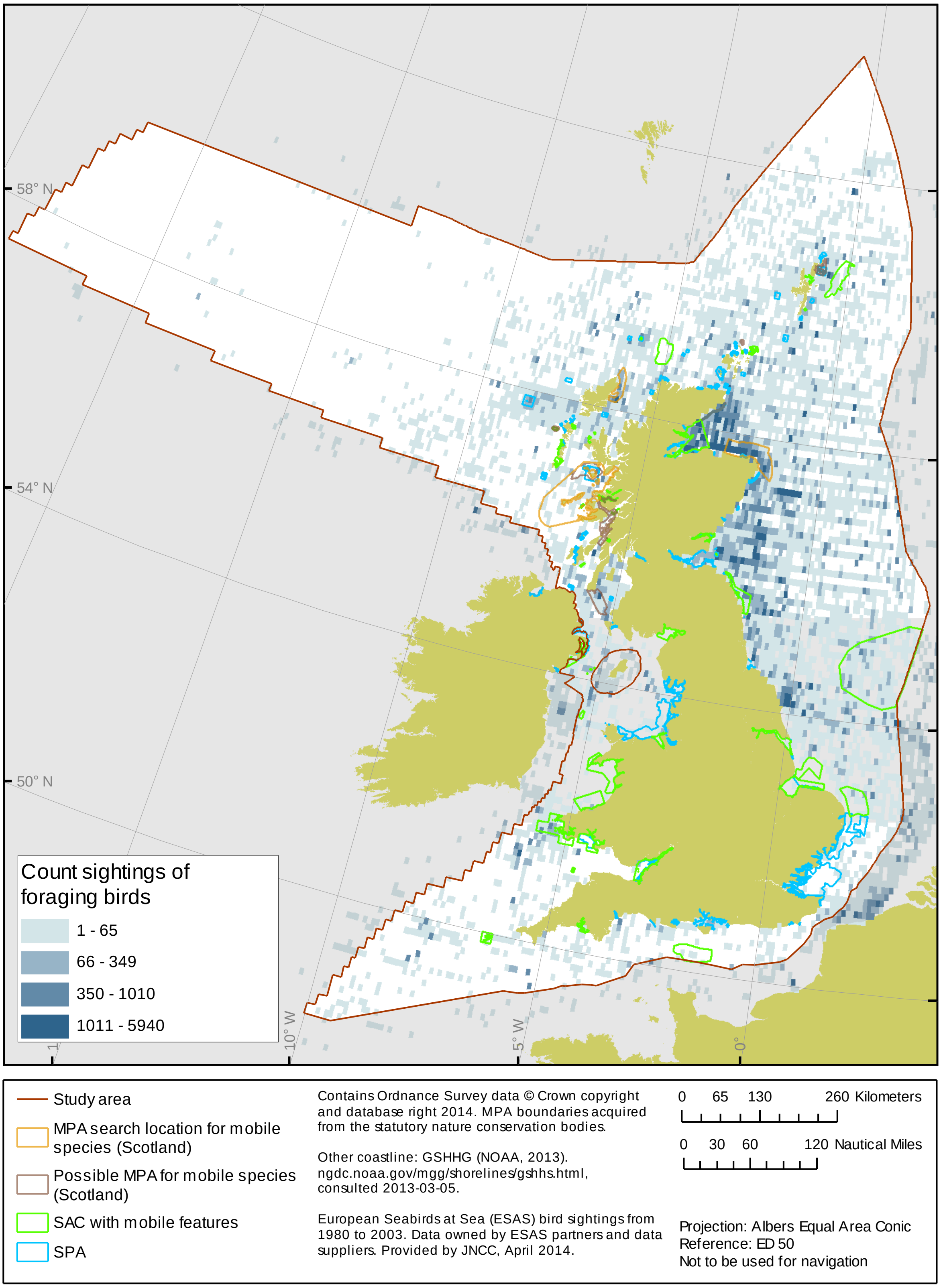

Figure 4.15. Current MPAs with mobile species listed as interest features, mapped with an extract of data from the ESAS database (records of foraging seabirds, all species, all seasons, all years combined).

5. Discussion and recommendations

5.1 Discussion of key results

5.1.1 Gaps identified in the UK's current MPA network

The results of this analysis indicate that the current UK MPA network is not ecologically coherent, as revealed in the coarse filter tests. Given that the coarse filter tests were designed to overestimate the performance of the network, these gaps can be considered significant, irrespective of more detailed considerations and interpretations of ecological coherence principles.

The coarse filter proximity and bathymetric tests revealed significant gaps (spatial and depth), most notably in Scottish waters, and to a lesser degree in offshore areas of the south-west of England. The difference between the southern and northern North Sea is particularly striking, with the existing southern North Sea network performing relatively well against coarse filter measures, whereas the northern North Sea has significant gaps. The deeper shelf, which forms a large proportion of the UK's seabed, is under-represented. This finding dovetails with the offshore gaps identified in Scottish and south-west waters. The coarse filter bathymetry test also revealed that deep sea areas beyond the shelf break are under-represented in the current network.

Some significant gaps (albeit smaller ones) remain present off Scotland even when the potential future sites are included in the coarse filter tests. Bearing in mind that the coarse filter tests are designed to identify only the most significant of gaps, this is a notable finding. The potential future sites in Scotland were selected using guidelines that placed significant emphasis on EBSA-style criteria, and relatively little emphasis on systematic network-level planning principles (Scottish Government 2011). It is therefore perhaps not surprising that the future network performs relatively poorly against a set of tests that focus primarily on network-level principles.

The fine filter tests were designed to test ecological coherence principles in more detail. Given that the coarse filter tests had already revealed gaps, it was inevitable that the fine filter tests would do the same. The replication, percentage habitat coverage, and habitat-based proximity test showed gaps in deep sea habitat coverage in Scottish waters, a finding consistent with the outcomes of the coarse filter tests. In addition, the fine filter tests identified additional gaps, with each test adding progressively more detail relating to different aspects of ecological coherence.

The fine filter tests revealed differences in the performance of the current network between biogeographic regions and between different features. For example, the percentage habitat coverage test revealed that, at the UKCS scale, some of the most widespread sublittoral sediment habitats have some of the lowest percentage coverage figures, with the current network providing proportionally higher coverage for littoral, infralittoral, and (to a lesser degree) circalittoral rock habitats. However, this pattern is not uniform across the UKCS: in the southern North Sea the current network provides comparatively high levels of percentage coverage for sublittoral sediment habitats, while in the adjacent northern North Sea the same habitats have extremely low coverage, and in the Eastern Channel, circalittoral rock suffers a particular shortfall.

The habitat-based proximity test identified gaps of a different sort, including spatial gaps between sites for littoral rock, a broad-scale habitat which the preceding percentage coverage test had characterised as well represented in most regions. This finding illustrates an important consideration to bear in mind when interpreting the results of this analysis, which is that given the multifaceted nature of the ecological coherence concept, no single test can establish that ecological coherence has been fully met, and the absence of gaps identified through any single given test does not automatically mean that there are no gaps present in the network.

5.1.2 Key potential future sites for filling gaps

It might seem desirable to develop a global ranking or prioritisation of sites based on the results of all the ecological coherence tests carried out in this analysis, in order to select those sites which, overall, are most effective at filling gaps. However, this would require the combination of scores from multiple tests, which each have fundamentally different meanings, combining "apples, oranges, and donkeys". A combined scoring system risks yielding results that are difficult to interpret and misleading. The potential pitfalls of using combined scoring approaches in conservation planning have been covered in the literature (e.g. Ferrier and Wintle 2009, Game *et al* 2013, Klein *et al.* 2014), and are explained in box 4.1. In order to avoid generating potentially misleading results, this analysis has not attempted to produce a combined score or global ranking of potential future sites across multiple ecological coherence tests.

Table 5.1 collates the information from tables 4.2, 4.3, 4.4, 4.14, 4.15 and 4.16, which list the sites identified as contributing most significantly towards filling the gaps identified each of the ecological coherence tests included in this analysis (with the exception of the fine filter mobile species test, which is discussed separately below). The table provides a clear indication of the sites that were identified repeatedly as top contributors towards filling gaps. These are predominantly large Scottish pNCMPAs such as the North-East Faroe-Shetland Channel, Rosemary Bank Seamount, and Faroe-Shetland Sponge Belt, i.e. large sites located within some of the largest spatial gaps in the network identified in the coarse filter tests.

Table 5.1 also reflects that as the analysis moved to fine filter tests, the 'top contributing' site list becomes longer, with several English sites appearing, including inshore and coastal sites (particularly in the fine filter habitat-based proximity test). This reflects the greater level of detail of the fine filter tests, which identified a progressively widening variety of gaps for different habitats and features.

Note that in order to maximise its relevance to the current UK MPA planning context, this analysis assessed the potential contribution of sites proposed for possible future designation through the various existing MPA planning processes in the UK. It did not assess the potential contribution that other areas outside the current MPA network would make towards filling the identified gaps, i.e. it did not attempt to identify additional suitable locations for future MPAs. This would require a different analytical approach, and is an additional piece of work that could be carried out in future. At the time of writing, the Welsh and Northern Irish MCZ processes had not yet published specific proposals for future MCZs (previously existing proposals for highly protected Welsh MCZs having been discontinued by the Welsh Government), therefore no potential future sites were assessed for Welsh and Northern Irish territorial waters. This should not be interpreted as an indication that new sites within these areas would add no improvement to the ecological coherence of the UK's MPA network, it is simply a reflection of the approach used and the timing of the analysis.

Potential future MPA	CF area	CF prox	CF b dsh	CF b us	CF b ds	FF rep	FF %	FF prox
NE Faroe-Shetland Channel	26,968	40,233		1,288	13,447	6	3	A6
Rosemary Bank Seamount	7,413	25,067			4,266		2	A6
Faroe-Shetland Sponge Belt	6,379	25,749		2,371	4,008	6	2	A6
Skye to Mull	6,224		4,819					
South-West Deeps East	5,801	9,771	5,623				2	
Barra Fan & Heb. Terr. Seamount	4,701	12,050			2,182	7	2	
North-west Orkney	4,389		4,372				2	A4, A5
West Shetland Shelf	4,047		4,047				2	
East of Gannet & Montrose Fields		14,266	1,838				2	
SW Sula Sgeir & Hebridean Slope		14,049				4	2	
Western Fladen		10,781						
Geikie Slide and Hebridean Slope		10,767		864		5	2	
Central Fladen		10,536						
Fulmar		10,283	2,437				2	A5
Hatton-Rockall Basin		9,936					2	
Greater Haig Fras (rMCZ)			2,032					A4
Southern Trench			1,845					
Firth of Forth Banks Complex			1,609				2	A5
Western Channel (rMCZ)			1,596				2	
North St George's Channel Ext.			1,289					
North St George's Channel			1,231					
Fetlar to Haroldswick						6		A3
Bembridge						4		
Dover to Deal						3		A1
Dover to Folkestone						3		A1
East Caithness Cliffs						3		A3
Bideford to Foreland Point								A2
Compass Rose								A4
Coquet to St Mary's								A2, A3
East of Jones Bank								A4
Farnes East								A4
Hartland Point to Tintagel								A1, A2
Holderness Inshore								A2
NW sea lochs and Summer Isles								A1, A3

Table 5.1. Overview of the potential future MPAs highlighted in the analysis as contributing significantly towards filling gaps identified in the ecological coherence tests. Collated from tables 4.2, 4.3, 4.4, 4.14, 4.15 and 4.16. Green = rMCZ, dark blue = Scottish pNCMPA, light blue = Scottish MPA search area; some site names are abbreviated. Columns marked CF area, CF prox and CF b show areas (in km^2) contributed to filling gaps identified in the coarse filter area coverage, proximity, and bathymetric representation tests, respectively, with the latter divided into figures for deep shelf (dsh), upper slope (us), and deep slope (ds). FF rep and FF % show fine filter replication and habitat percentage cover scores. The final column displays EUNIS A2 habitats for which a site was highlighted as filling a gap identified in the habitat-based proximity test. Blank column cells indicate that a site was not identified as making a particularly significant contribution towards filling gaps for a given test, though this does not signify its contribution would be zero (please refer to the information in the Excel document supplied with this report for details).

5.1.3 Mobile species

Analysing the performance of the network in relation to the protection of mobile species was particularly challenging within this time-limited project. The visual assessment provided in the mobile species test mapped readily available information about areas of potential significance for life history stages for mobile species (i.e. mobile species related EBSAs) against the current UK MPA network (considering solely those sites that are designated to protect one or more mobile species). What the maps show is that the current network does not include several regions which score highly in the combined APEI dataset provided by the Wildlife Trusts. The network also does not include several areas where basking sharks are frequently sighted, or where summer fronts are known to form (areas of frontal activity being associated with high productivity, and high frequency of sightings of feeding seabirds and large marine fauna).

These maps need to be interpreted with circumspection, as it is hard to draw firm conclusions over shortfalls in the mobile species protection of the MPA network from this basic assessment. The challenges of assessing the impacts of MPAs on mobile species are well recognised, and meaningful assessments require much more than spatial tests – they require a detailed understanding of the behaviour, distribution, life history, and ecology of the species in question (Grüss *et al.* 2011). An analysis at this level of detail was beyond the scope of this short project.

In order for MPA networks to be effective at protecting mobile species, it is important that they are well-designed and based on a good level of understanding of the ranges, movement patterns, and life histories of the target species. High levels of mobility can reduce the conservation benefits that static MPAs afford to species, and there is evidence for some species that, in order to yield benefits, MPAs have to cover significant proportions of their ranges (Davies *et al.* 2012, Grüss *et al.* 2011, Le Quesne and Codling 2009). Bearing in mind that some mobile species have ranges that extend well beyond UK waters, this raises practical challenges. Therefore, it may be beneficial to locate MPAs in 'mobile species EBSAS' - specific areas that are of particular importance to the life cycles of given mobile species, such as feeding, breeding, aggregation or nursery areas (e.g. see Louzao *et al.* 2014, Péron *et al.* 2013). In the future, the concept of dynamic ocean management / MPAs could be explored (Game *et al.* 2009, Hobday *et al.* 2014); however, this falls outside to the current static MPA paradigm being considered here.

Further work to assess the performance of the UK's existing MPA network for the protection of mobile species could begin by building on the APEI information, in order to better identify and map mobile species EBSAs in UK waters. This is a considerable task, however, and would require a comprehensive data gathering exercise, the selection of appropriate species and EBSA-like criteria to focus on, research into life histories, behaviours and movement patterns, as well as the addressing of patchy data with uneven distribution of survey effort in time and space, as well as the consideration of seasonal differences. In terms of assessing the performance of the UK's MPA network, however, this would simply constitute a valuable first step. As recognised by the CBD, a differentiation ought to be drawn between the identification of EBSAs, and the design of MPA networks; qualifying as an EBSA does not automatically make a site an optimal location for an MPA within a broader network (see introduction). Any assessment focused on mobile species would ideally assess current and potential future protection afforded through MPAs within the context of existing or potential future wider management measures targeted at the same species, such as noise mitigation requirements for offshore developments, seasonal restrictions on disturbing activities, or modifications to fishing gear to reduce levels of bycatch. While such broader management considerations are relevant for all species and habitats, such considerations are of particular importance for species of high mobility.

5.2 Scope, scale and timing

5.2.1 Scope of the analysis

This project was time-limited, which precluded a comprehensive data gathering exercise, and imposed practical limits on the number and complexity of the analytical tests carried out. Nevertheless, the analysis presented in this report achieved a comprehensive (if broad) assessment of the current MPA network at the UK scale. This was achieved by building on the analytical methods and thresholds developed through previous work carried out under OSPAR and England's MCZ process, and the analysis benefited greatly from data readily available through comprehensive UKCS-scale data stewardship and mapping projects, most notably UKSeaMap.

The tests carried out in this project assessed MPA network characteristics related to each of the principles of ecological coherence outlined in the introduction, albeit to a varying degree of detail. Representativeness was assessed at a broad level (for depth classes) in the coarse filter bathymetric test, and at a more detailed level (for different benthic habitats) in the fine filter replication and habitat percentage coverage and replication tests. The split into CP2 regions allowed an assessment of representativeness across biogeographic regions. Replication was tested as part of the fine filter tests, for EUNIS level 3 habitats, OSPAR threatened and declining features, and ENG FOCI. The habitat percentage coverage test addressed an element of adequacy, by assessing the amount or proportion of coverage for different habitats. Connectivity was addressed through the coarse and fine filter proximity tests. This analysis did not address EBSAs in detail, though the maps created for the mobile species test mapped information layers that would be of relevance to a more detailed EBSA analysis, such as areas of high seasonal frontal frequency, which are known to be areas of particularly high productivity in the summer months.

Given the limited time available for this project, data limitations, and the complex multifaceted nature of the ecological coherence concept, there are inevitably aspects of ecological coherence that this analysis did not cover comprehensively, and which could be addressed through future work building on this project. For example, the adequacy of the size of individual sites was not analysed, and a more in-depth research and analysis project would be needed to comprehensively map EBSAs in the UKCS area (including EBSAs not directly related to mobile species, such as benthic biodiversity hotspots).

Ecological connectivity was considered only through proximity tests. The coarse filter proximity test used a simple 40km buffer around existing MPAs, in order to identify gaps exceeding 80km between sites. The gaps identified on the basis of this simple test indicate that the current UK network has not, by any measure of the principle, achieved ecological connectivity. The kernel density analysis, which was based on a more detailed assessment of the proximity of sites containing varying amounts of similar habitat, identified additional gaps. Following rules of thumb about spacing of MPAs has been advocated as a pragmatic and workable approach in MPA planning, especially in the face of scientific uncertainty and data gaps (California Department of Fish and Game 2008, OSPAR 2008, Ardron 2009, Carr *et al.* 2010).

Filling spatial gaps identified through proximity tests, while very much a step forward that increases the likelihood of ecological coherence, still does not in itself guarantee its achievement. As a subsequent step, tests would have to account for actual ecological pathways (e.g. links between sites through species' life history stages, known patterns of movement and migration, or larval dispersal within predominating water currents). These pathways will vary between species and between areas. For example, it has been suggested that the maximum 80km spacing figure does not adequately take account of the degree of environmental variability and habitat diversity in Scottish waters (Gallego *et al.* 2013).

Further work could be carried out in future to achieve a more detailed assessment of connectivity, e.g. by building on some of the additional tests proposed in OSPAR (2007, 2008). However, at the scale of the entire suite of UK marine species, very little empirical evidence exists to offer clear insight into the 'source and sink' connectivity of the wide variety of UK populations. An in-depth analysis of connectivity pathways would require decisions to be made on which species to focus on, and significant data gathering. Depending on the amount of existing knowledge for a given species within a given area, primary field research and / or modelling of movement and dispersal pathways may be required.

5.2.2 Scale

Any choice of study area is fraught with trade-offs based on issues of scale; some details are lost, while other larger contextual issues are also not considered. The ecological coherence tests in this analysis focused on the UK scale, at which they did not identify significant gaps in the network within Northern Irish and Welsh waters. However, it is important to bear in mind that this is not the same as finding that the existing network in these areas is ecologically coherent. Additional work could be carried out in future to complete finer-scale analyses focused on the territorial waters of Northern Ireland and Wales, using more appropriate benchmarks for these regions (for example, the 40km proximity buffer is arguably not appropriate at the scale of territorial waters that span a width of 12 nautical miles).

It is also worth bearing in mind that this analysis did not consider the wider context within which the UK's MPA network is located, i.e. it did not assess the network at the EU or OSPAR scale, nor did it consider any sites located close to the UKCS boundary within neighbouring waters (including sites in Irish and Manx waters). Other analyses have been completed at a wider scale (e.g. OSPAR 2013, Johnson *et al.* in review), providing important context for this UK-scale analysis. The JNCC analysis (Ridgway *et al.* 2014), though the results are not yet fully published, may also provide valuable insights at a sub-regional scale.

5.2.3 Timing

This assessment was carried out in early 2014. The shape and management of the UK's MPA network will continue to evolve and gaps that are currently present may be closed in future. Furthermore, there are likely to be future improvements in scientific understanding and data availability, as well as shifts in relevant legislation, policy, and governance institutions. There may be a need to adapt the tests and shift the emphasis, scope and scale of any future ecological coherence assessments to adapt to the changing data and context.

5.3 Moving towards ecological coherence

5.3.1 Incremental planning, multiple processes and a multifaceted goal

The introduction highlighted that ecological coherence is a multifaceted concept which meshes together static EBSA-style site selection principles with flexible network-level systematic planning principles. The concept can be applied and interpreted in different ways, and different conservation professionals and scientists place different levels of relative emphasis on the different principles encompassed by the concept, often based on (perfectly reasoned and valid) judgements. Thus, 'ecological coherence' is a potentially malleable policy goal that is open to interpretation. Whilst it is relatively straightforward to establish when it has *not* been achieved, e.g. through failure to meet the coarse filter tests presented in this report, there is no firm set of quantitative benchmarks that establish when it *has* been fully achieved.

To add to the challenge, ecological coherence has not always been an objective in UK MPA planning. As in all other jurisdictions, the UK MPA network did not arise from a clean slate, using systematic planning principles from the outset in order to identify the most efficient possible network configuration. Rather, the design of the network has to build incrementally on existing sites that have been planned and implemented over the course of multiple decades, most notably, the *Natura 2000* process. The EU Habitats and Birds Directives focus on the protection of a limited range of species, habitats, and bird assemblages, defined in within the legislation. Sites are evaluated individually; they either qualify for protection or not, irrespective of their value within the context of a wider network.

When assessed against systematic planning principles, such a site-by-site approach inevitably fares poorly, shown to be 'inefficient' with significant gaps in representativeness. The fine filter tests in this analysis illustrate that some habitats have replication and percentage coverage figures well above the ENG benchmarks in some biogeographic regions, at the same time that others are under-represented. Given the lack of a consistent set of systematic principles to guide the design of the existing set of MPAs in the UK this is not an unexpected finding, and it echoes findings in other parts of the world (e.g. Stewart *et al.* 2003, 2006, Fox and Beckley 2005, Tognelli *et al.* 2009). Whilst the existing network is inefficient at meeting the systematic network principles of representation and replication, this should not be interpreted to mean that there are areas in the current network that are superfluous. So long as criteria and underpinning legal mechanisms (such as the Habitats and Birds Directives) were properly applied to select and designate the existing MPAs, then they remain valid within that regulatory framework.

Considering the various legal frameworks as well as devolution in the UK, it is evident that the *process* of MPA planning at the UK scale lacks 'coherence'. This makes it hard to define one single policy-relevant set of benchmarks for a UK-scale assessment. The approach taken in the analysis presented here is a pragmatic one in the face of these complications, in that the coarse filter tests are broad enough to highlight gaps that will be relevant irrespective of the specific guidance used in any given process.

5.3.2 Prioritising sites for filling gaps in the current network

Whilst the coarse filter gaps constitute a useful 'first cut' of areas that might warrant priority focus for further conservation efforts, filling these big gaps will not automatically guarantee an ecologically coherent network. As noted in the Introduction, systematic reserve planning is, in part, a spatial optimisation problem, where whole alternative configurations need to be assessed, in their entirety, against multiple design criteria. With enough data (and time) available, it is possible to address this challenge using site selection algorithms embedded in conservation planning software tools such as Marxan. This approach was taken by Tognelli *et al.* (2009), who assessed the existing network of MPAs in Chile by locking these areas in to a series of Marxan scenarios, identifying additional sites needed to fill representativeness gaps.

This approach fundamentally differs from the one taken in this analysis, which has focused on the relative utility of future site proposals developed through real-world planning processes. With sufficient time and resources, using Marxan to prioritise sites suitable for filling gaps in the UK network may be an option worth exploring. However, the relative data poverty of the UK's offshore regions render the potential benefits marginal (the Chilean analysis was confined to inshore areas), and whilst Marxan can aid the identification of sites of high utility value for creating a representative network, the tool has limited capacity to address ecological connectivity. Furthermore, using Marxan does not resolve the fundamental incoherence of the planning processes currently underway.

An approach that could be taken to frame the prioritisation of additional sites is to assess shortfalls in meeting specific legal obligations.. Following significant progress in planning inshore and offshore *Natura 2000* sites over the last decade, the existing spatial network configuration performs well against the legal obligations of the Habitats and Birds Directives. These are strong legal mechanisms and failure to comply carries the risk of sanctions from the EU.

The obligations under the MSFD and the MACA (with its equivalents in Scotland and Northern Ireland) go a step further, in that they explicitly require a network that is fully representative of the UK's marine flora and fauna. This analysis highlights that the current network falls short on this obligation to ‘protect a bit of everything’, so a strong argument can be made for prioritising the addition of sites that address shortfalls in achieving the principle of representativeness. It has also been argued that the practical application of the principle of representativeness is more scientifically straightforward than the application of other ecological coherence principles (notably that of connectivity), making the establishment of a representative network a more realistic ambition than the creation of a fully ecologically coherent network (Jones and Carpenter 2009). It is doubtful that a network solely based on representativeness would meet the overarching goals that are encapsulated in the multifaceted concept of ecological coherence; nevertheless, it does suggest a bridging strategy.

5.3.3 Addressing the management gaps: the challenge of feature-based conservation

Arguably the most important gap to address within the UK’s MPA network is not any of the spatial gaps identified in this analysis, but gaps in management. Evidence demonstrates that in order to yield environmental benefits, sites have to be well-managed and enforced (Edgar *et al.* 2014), and the more comprehensive and stringent the protection level, the higher the benefit (Halpern, 2014). Without effective and well-enforced management in place, MPAs are paper parks which, at their worst, squander the societal capital and economic costs associated with their establishment.

The notion of an ‘MPA’ hinges on a geographically delineated area that is managed to protect it from negative impacts. The IUCN defines several protected area categories, depending on the degree of stringency of protection measures, but in order to qualify for any of these categories, the basic definition of ‘protected area’ must be met: “*a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values*” (Day *et al.* 2012).

In the UK (and many other EU jurisdictions as well; e.g. Germany) MPAs are identified and designated before management measures are planned and put in place. This means that for the period in between designation and the implementation of management measures (which spanned several years for marine *Natura 2000* sites and is not yet complete), UK MPAs are temporarily paper parks: designated sites with no management measures in place. The existing MCZs currently fall into this category.

As noted previously, UK MPAs are not designated to protect integral areas of ‘geographical space’, but to protect specific species and habitats which are named in site designations. Conservation objectives are exclusively formulated for these individual ‘designated’ features, which means formal protection is limited to these features. Upfront spatial management measures (exclusions of or limitations on damaging activities) are only put in place for features deemed particularly sensitive, which means that spatial restrictions (e.g. limiting benthic mobile-gear fishing) are often applied only to small proportions of any given MPA.

The feature-based approach created significant challenges for the spatial analysis presented in this report. Inclusively counting all feature occurrences / areas within any given site towards the figures and maps for each test inevitably led to an overestimation of the achievement of thresholds.. Deciding what should ‘count’ towards benchmarks in tests such as the habitat replication and representation tests proved to be difficult. Likewise, the UK’s statutory nature conservation bodies have faced (as yet unresolved) issues in establishing a comprehensive UK-scale inventory of MPAs and features protected within them (Ridgeway *et al.* 2014). Thus, the feature-based approach to the formulation of MPA conservation objectives makes an ecological coherence assessment an extraordinary challenge, not only because of data gaps or technical challenges or complexity in the ecological coherence concept – but because, put simply, it makes it very difficult to decide what the network *is.*

In order to fully assess the true coverage of the UK’s current network, a comprehensive assessment would need to go beyond determining which features are formally protected in each site. It would also need to analyse the coverage of existing spatial protection measures within the network and the levels of protection afforded by these spatial measures. Such a management assessment was beyond the scope of this contract, but would be a valuable additional piece of work to carry out in future.

For England's MCZ process, an in-depth analysis of this problem is provided in Lieberknecht *et al.* (2013) and Lieberknecht and Jones (*in prep.*). There, it is argued that the feature-based approach is at the root of a lot of different kinds of complexity, and a driver of uncertainty, leading to unnecessary costs, fuelling conflicts and limiting environmental benefits of MPAs in the UK. In order to move towards ecologically coherent, well-managed, well-understood MPA network with good levels of support, arguably a more efficient, area-based approach is needed, with conservation objectives formulated for sites as a whole, and management measures that focus on ecological integrity at the site level (Rees *et al.* 2013). Such an approach would be more in line with a wider ecosystem-based approach to management, and would represent a pragmatic way of dealing with scientific uncertainties. Avoiding the dangers of being overly prescriptive in what it sets out to protect, a network-level approach may also provide the flexibility and redundancy that affords a level of resilience against climate change impacts (see Carr *et al.* 2010).

5.3.4 Addressing political and institutional challenges

The above discussion highlights that the establishment of an ecologically coherent MPA network will require more than solving the technical challenge of locating the spatial gaps and identifying suitable candidate sites to fill them. It extends beyond the considerable challenges associated with unpicking the multifaceted concept of ecological coherence and translating it into a set of practical design and evaluation benchmarks, collecting data, and finding the right optimisation tool or GIS analysis to underpin planning decisions.

There are formidable institutional, political, and social challenges that need to be resolved in order to develop effective MPA governance (e.g. see Jones, 2012, Jones *et al.* 2013a, b). Although they are not covered in further detail here, addressing these challenges should be seen as a matter of priority. Gubbay (2009) provides some practical recommendations relating to political and institutional challenges relating to MPAs in Northern Ireland, many of which apply to the UK as a whole. Lieberknecht *et al.* (2013) provide a number of recommendations relating specifically to England's MCZ process, and again, some of these have wider relevance.

5.3.5 MPA networks in the context of ecosystem-based marine spatial planning

Increasingly, marine protected area planning is regarded as an integral element of ecosystem-based, multi-sector marine spatial planning (EBM-MSP). The concept of EBM-MSP places ecosystem protection at the foundation of a wider process of managing multiple human activities across whole oceans and seas (e.g. Ehler and Douvere 2009, Halpern *et al.* 2010, Katsanevakis *et al.* 2011). In reality, EBM-MSP is rarely fully implemented, with stronger drivers towards an approach where environmental conservation is seen as one 'use' of the sea, to be traded off against other uses, rather than being seen as a necessary foundation (Qiu and Jones, 2013).

Emerging marine planning frameworks in different UK administrations mean that increasingly, MPA planning will need to be carried out within the context of planning for multi-use planning. Given the flexibility they offer, systematic reserve network principles are suitable for integration into multi-sector MSP. Since efficient systematic reserve networks can have multiple alternative spatial configurations, it is possible to plan them in a way that reduces negative socio-economic impacts, as part of a wider process of ocean zoning. As the UK MPA network develops, along with the maturing of wider marine planning frameworks, planning tools may be useful in exploring potential trade-offs between ecological coherence benchmarks and socio-economic considerations (Edwards *et al.* 2010, Klein *et al.* 2009, Watts *et al.* 2009). Whether or not such trade-offs are deemed acceptable, understanding them might help formulate inputs into real-world decision-making processes.

5.4 Recommendations for moving towards an ecologically coherent network

Bearing in mind the caveats described throughout this report, a number of recommendations have been formulated for moving towards a more ecologically coherent MPA network. These should be seen as complementary to existing MPA commitments of the UK's administrations under mechanisms such as the Habitats and Birds Directives.

Prioritising conservation efforts

- The coarse filter tests reveal a number of significant gaps in the current UK MPA network configuration. Addressing these larger gaps should be seen as a matter of priority in order to move towards an ecologically coherent MPA network.
- The fine filter tests offer a range of results that should be used to 'fine-tune' the coarse filter tests (e.g. proximity) and identify sites that would help fill additional gaps in the existing network, at a regional and sub-regional scale.
- Effective site management should be considered a conservation priority. Irrespective of how many sites are designated and how well they perform against spatial coherence tests, a network cannot be seen as ecologically coherent unless its constituent areas are genuinely protected on the ground. Given the progress in designating sites in the UK, attention should now turn to their management.

Coherence in policy and governance

- UK marine governance should be analysed with a view towards improving coherence in implementation, and hence improving the likelihood of achieving ecological coherence across the existing fragmented UK MPA processes.
- An agreed-upon list of sites which are seen to constitute the collective UK MPA network, and the features protected in each site (following standard classification nomenclature), would facilitate future analyses and coordination of governance and management.
- An assessment of the efficacy of current management measures in protecting ecosystems as a whole, and their gaps, would aid the transition towards taking an ecosystem-based approach in the UK.

Improving the ecological coherence assessment

- Although the results of the tests in this report provide a lot of material already, a more in-depth set of analytical tests could be developed, if so desired.. However, data limitations would remain a notable constraint. Furthermore, there would be trade-offs to consider between the depth and complexity of tests, and the practical relevance of their outputs. As reflected in OSPAR and other guidance, we believe an iterative approach, starting with simpler tests first, is a defensible and efficient use of resources.
- An in-depth review of the management and protection of mobile species in UK waters could yield valuable insights that would aid the prioritisation of conservation efforts focused on these species (including MPAs, as well as wider measures).
- Given the difficulty of combining multiple ecological coherence criteria into efficient network-level recommendations, one additional approach to consider in future assessments would be to use an optimisation tool like Marxan.
- The challenge of combining EBSA-style site criteria and systematic network-level principles within a single assessment is considerable, warranting the development of information to better link the two constructs. This analysis focused primarily on broad-scale systematic network principles and on the benthos, as it was considered that these would yield the most meaningful and relevant results within the time and data limitations of the project. However, a more in-depth UK-scale EBSA-like mapping exercise would provide a valuable layer of additional information to inform future planning.

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Appendix 1: Maps of potential future MPAs covered in this analysis

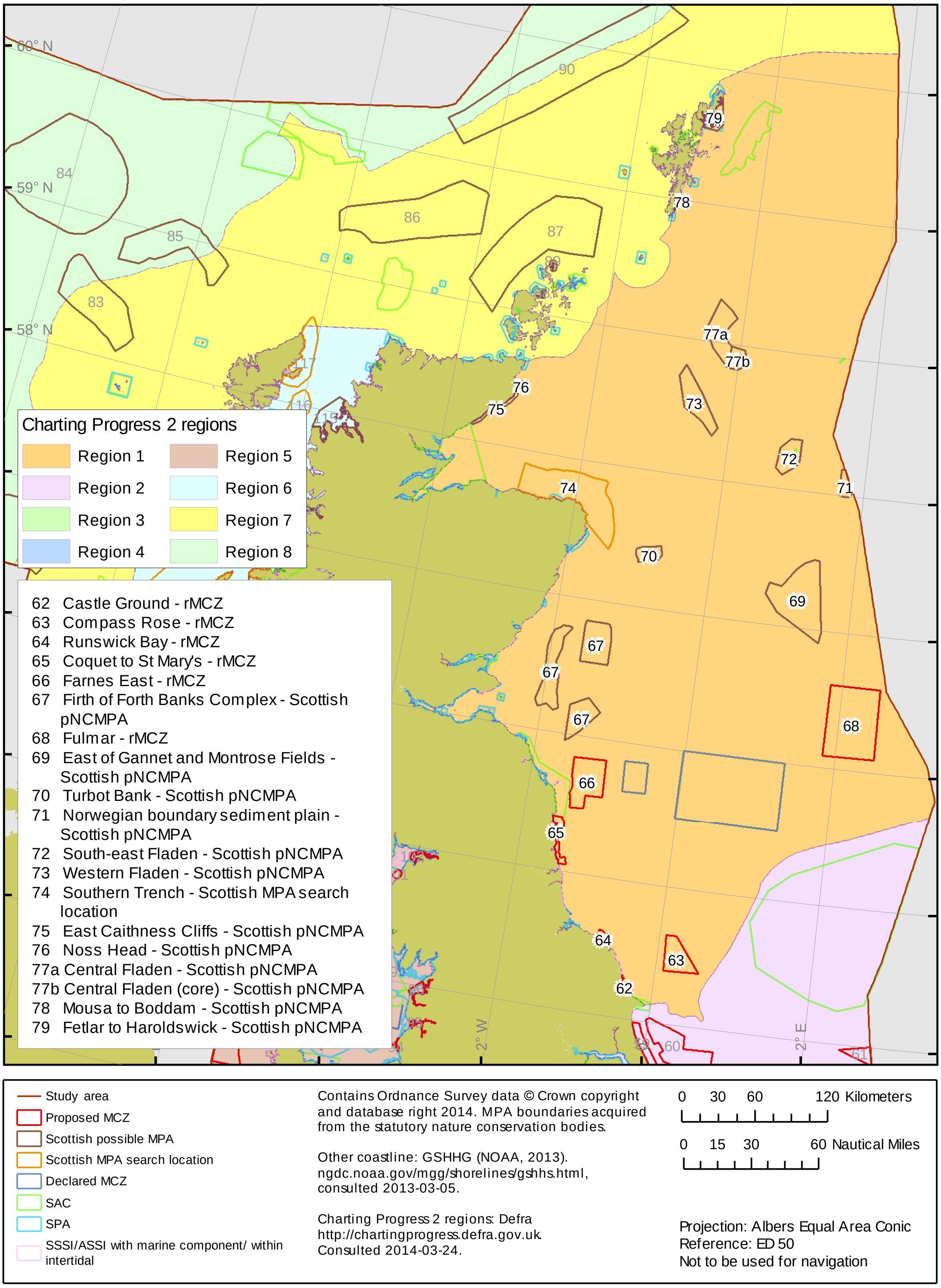

Figure A1.1. Potential future MPAs in Charting Progress 2 region 1.

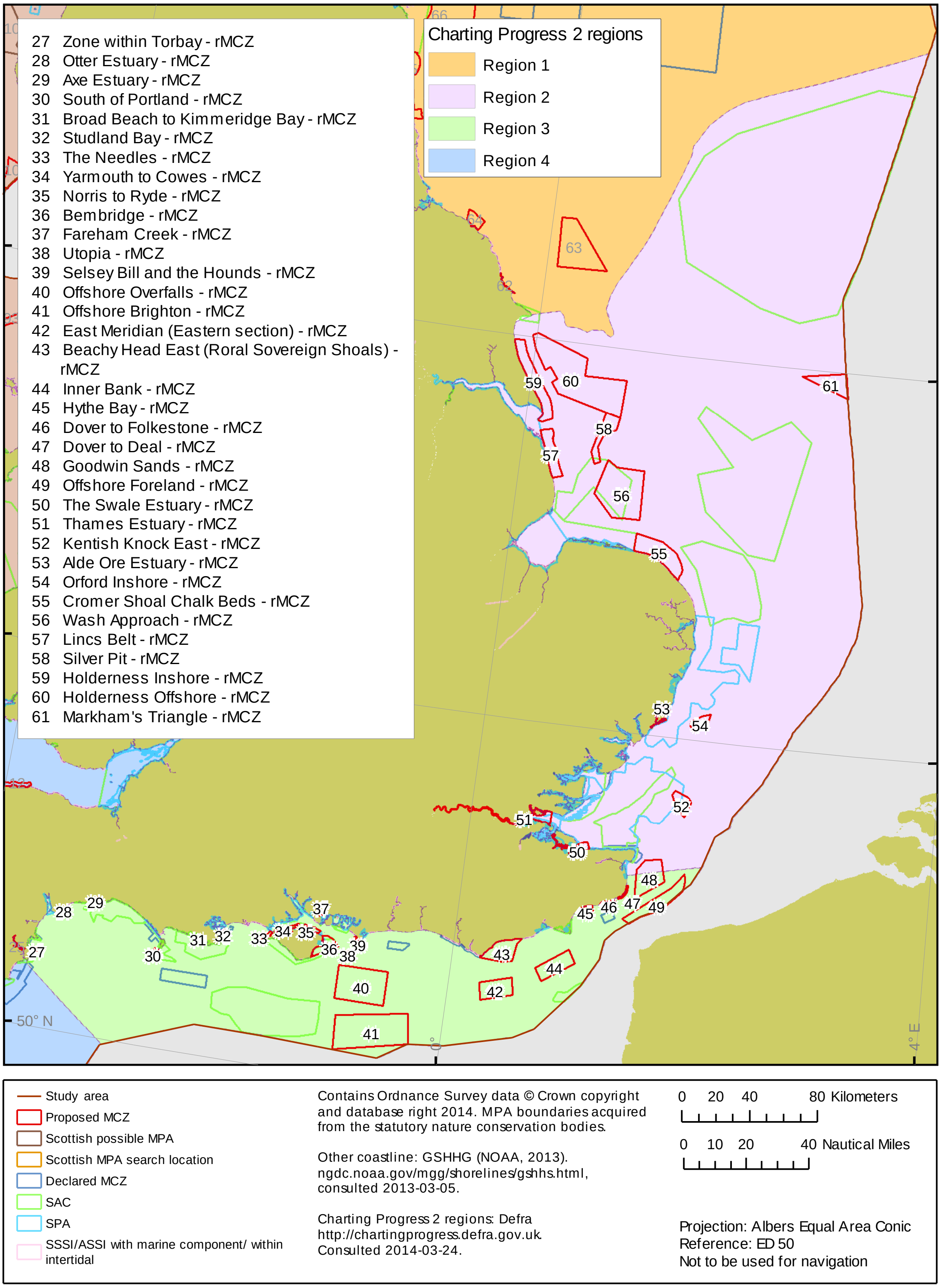

Figure A1.2. Potential future MPAs in Charting Progress 2 regions 2 and 3.

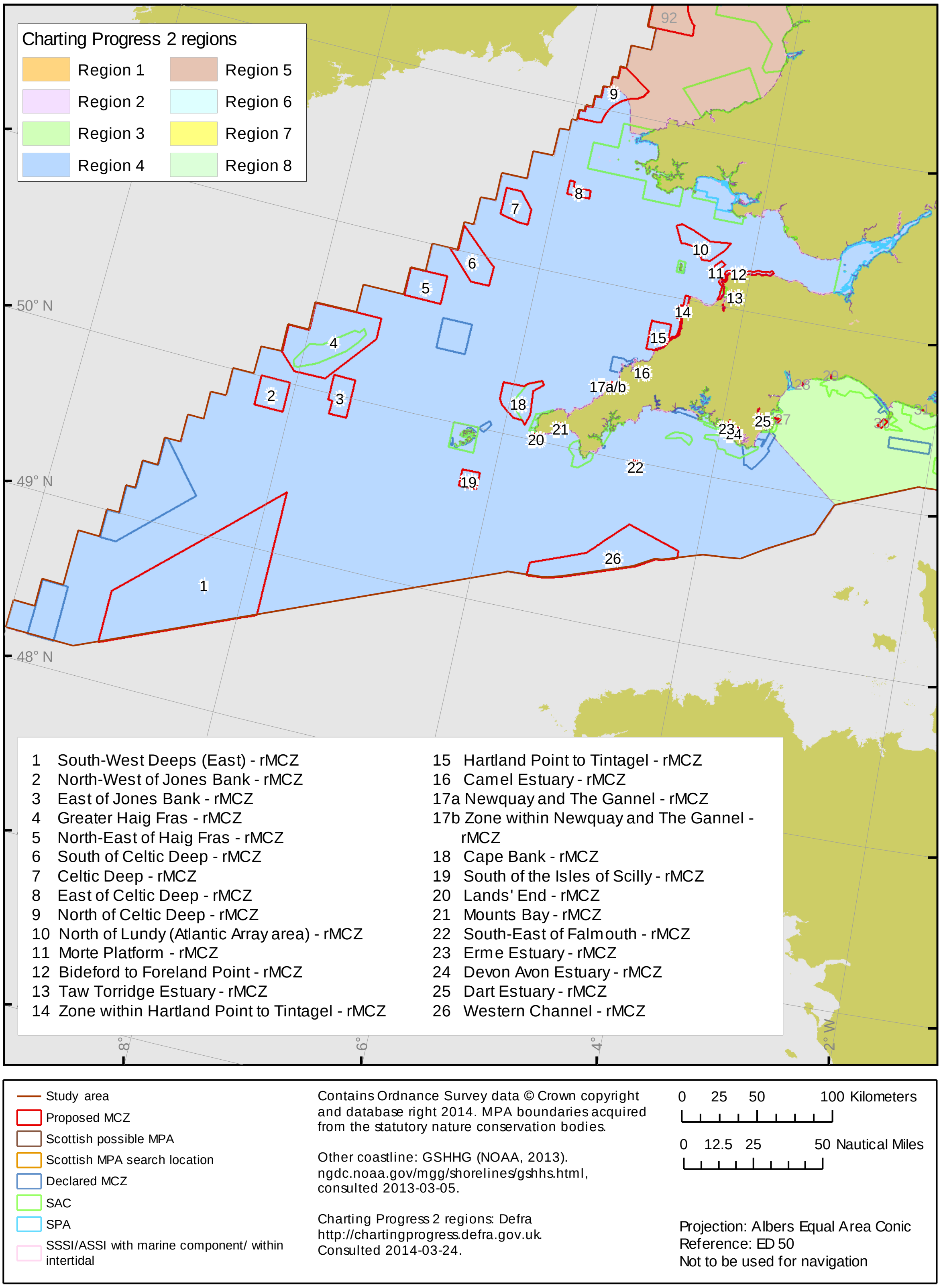

Figure A1.3. Potential future MPAs in Charting Progress 2 region 4.

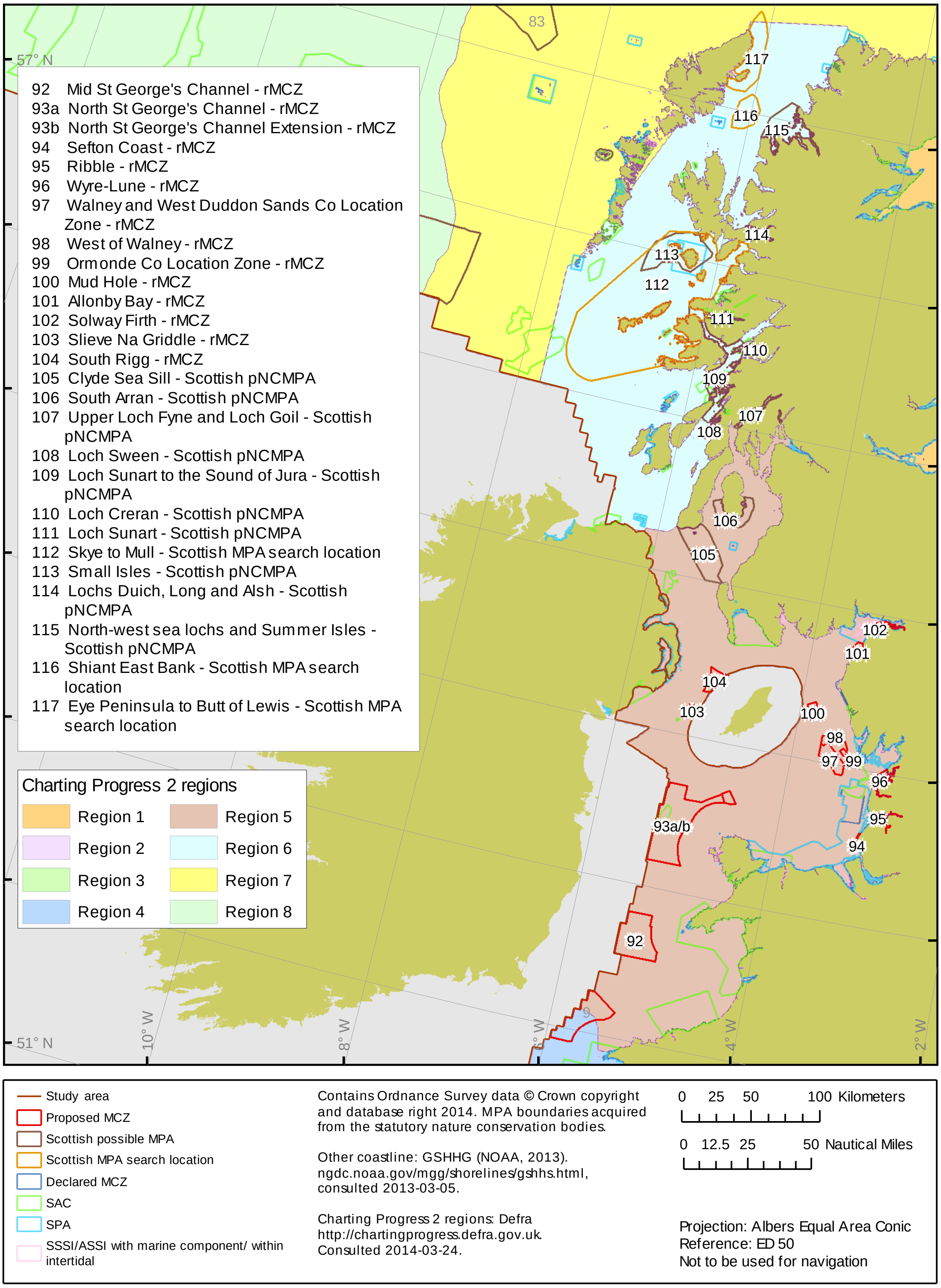

Figure A1.4. Potential future MPAs in Charting Progress 2 regions 5 and 6.

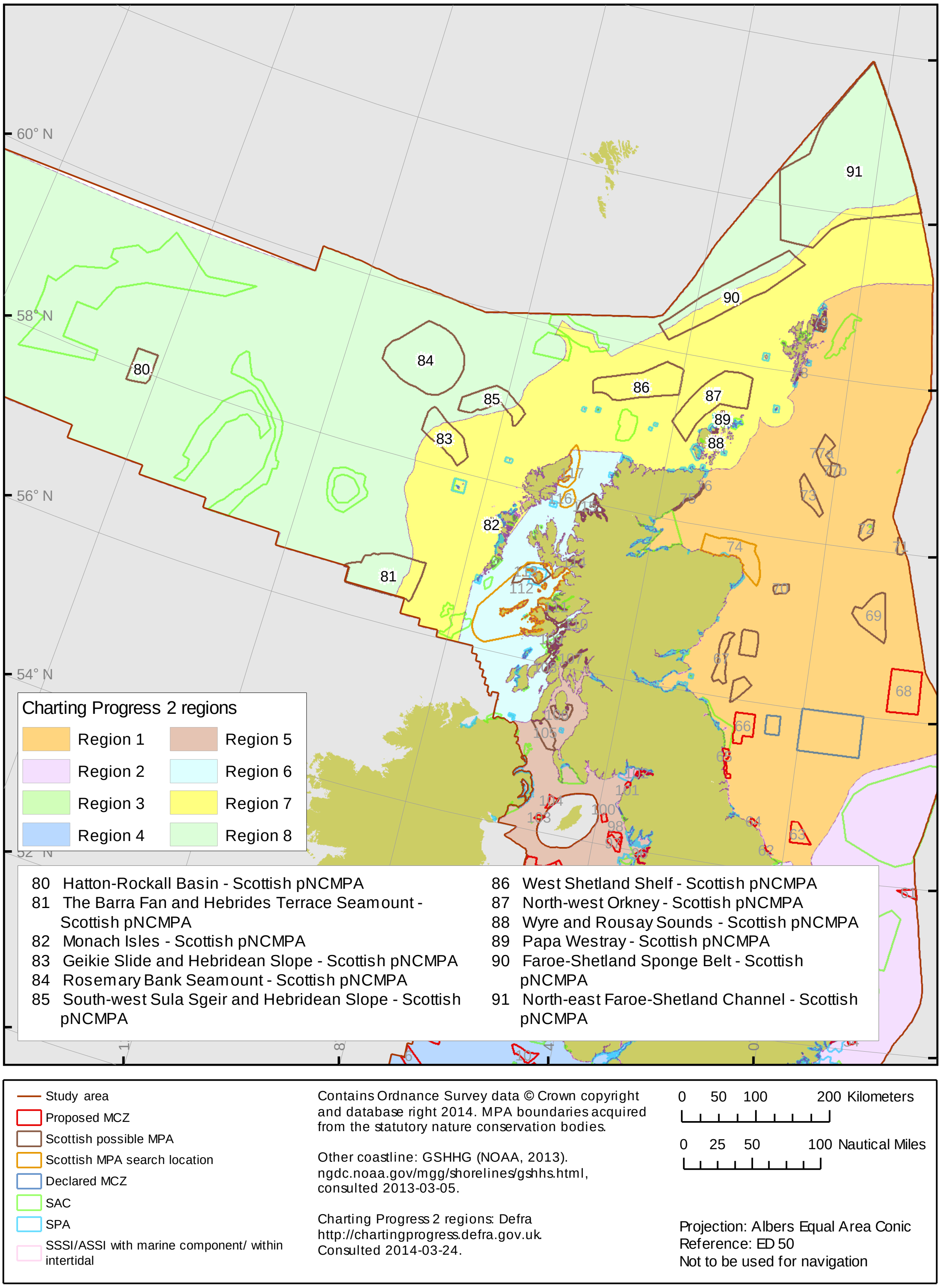

Figure A1.5. Potential future MPAs in Charting Progress 2 regions 7 and 8.

Appendix 2: Northern Ireland Boundaries used in this analysis

There is no internationally agreed maritime boundary between Northern Ireland and the Republic of Ireland[44]. As outlined in the data sources section of this report, this analysis used UKCS boundary data from the UKHO median line data from DECC to define the edge of study area in this analysis, as these were considered to be the most authoritative sources of this data. However, the UKHO's UKCS boundary and the DECC median line do not cover the entire stretch of Northern Ireland's coastline from Lough Foyle to Carlingford Lough as illustrated in figure A2.1. They bisect the Skerries and Causeway SAC, and miss out Carlingford Lough and Lough Foyle. Because the study area polygon was used to clip and extract data during GIS analysis for several of the tests, this means that these two SPAs and the western portion of the Skerries and Causeways SAC were not covered in some of the tests (see table A2.1).

The full inclusion of these three sites would have resulted in slightly different figures and maps for the indicated tests, but would not have yielded substantially different results at the UK scale. Two of the coarse filter tests and the mobile species test (which did not require data to be clipped to the study area polygon) included the sites in full. In the coarse filter bathymetry test, the difference would have been the full inclusion of all three sites. In the fine filter replication, area coverage, and habitat-based proximity tests, the difference would have been that the SAC would have been included in its entirety - the SPAs would have been excluded from these tests in any case, as they focused on benthic features. The tests would have yielded slightly different figures for bathymetric representation, habitat representation and replication, and the kernel density maps would have been affected - but at the UK scale (and even at the CP2 regional scale), the difference would not have led to additional significant gaps being identified.

It seems that there is no consistent way of drawing the 'UK border' in this area for UK-scale marine GIS projects. Figure A2.1 indicates, for example, that the UKSeaMap data layer was clipped to a boundary that does not follow any of the lines shown, and it does not extend into Lough Foyle. To avoid similar issues arising again, future analyses of this kind at the UK scale should consider using the indicative median line shown on figure A2.1 as an alternative to the UKHO / DECC data, even though this is not an officially agreed line, nor from a UK Government source.

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[44] For background information, see the following links:
http://ec.europa.eu/ourcoast/index.cfm?menuID=7&articleID=296
http://www.publications.parliament.uk/pa/cm200405/cmhansrd/vo050113/text/50113w17.htm (Column 635W)

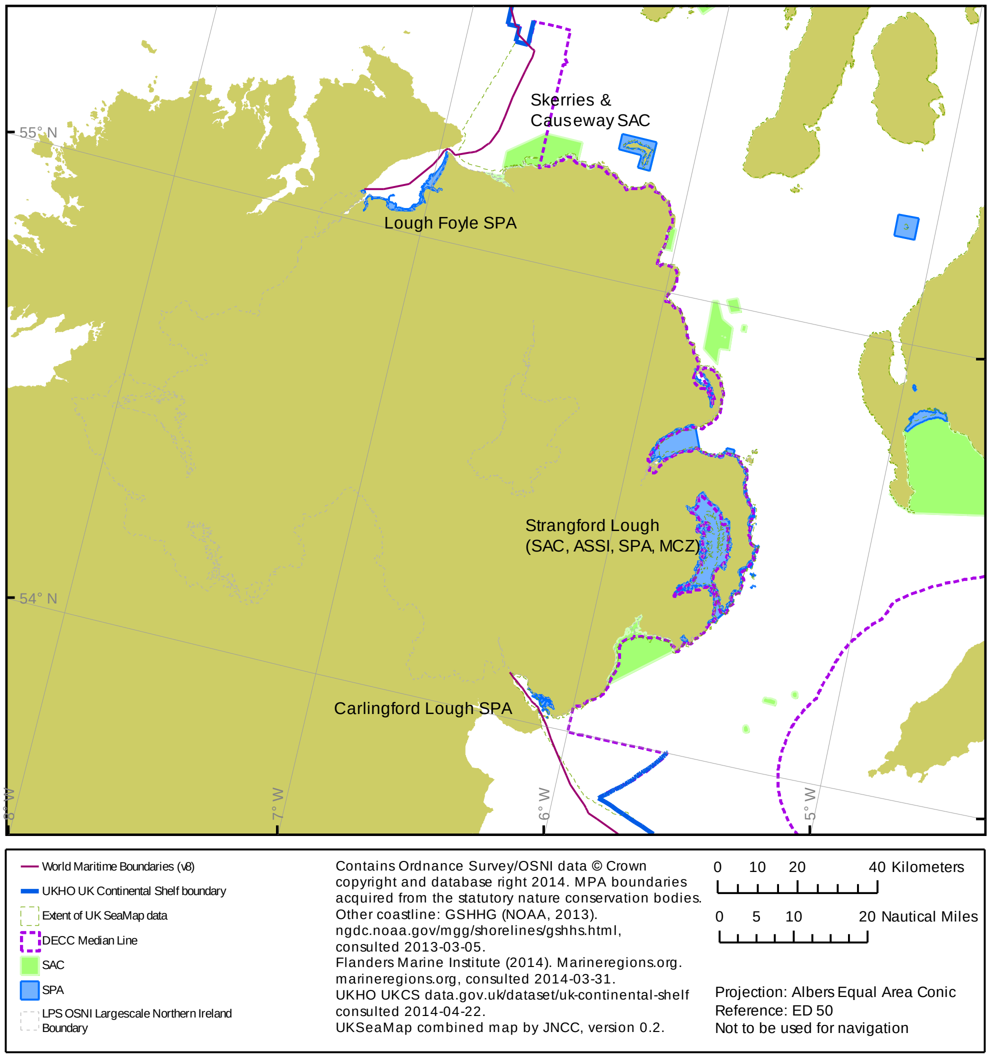

Figure A2.1. Map of the lines used to define the study area boundary for this analysis, focused on Northern Ireland's waters. The UKCS boundary from the UKHO and the DECC median line bisect the Skerries and Causeway SAC, and miss out Carlingford Lough and Lough Foyle. The red line shows an indicative maritime boundary between Northern Ireland and the Republic of Ireland which would have included these areas, had this been used to define the study region boundary – however, this line is not derived from a UK Government source, nor is it an agreed international boundary.

	Coarse filter tests			Fine filter tests			
	area coverage	bathymetry	proximity	replication	% representation	proximity	mobile species
Lough Foyle SPA	included	not included	included	not included*	not included*	not included*	included
Carlingford Lough SPA	included	not included	included	not included*	not included*	not included*	included
Skerries & Causeway SAC	included	western portion excluded	included	western portion excluded	western portion excluded	western portion excluded	included

Table A2.1. Overview of the inclusion and exclusion of Lough Foyle SPA, Carlingford Lough SPA, and the Skerries and Causeway SAC in the network configurations of the ecological coherence tests in this analysis. The asterisk* indicates tests in which no SPAs were included, so even with a different study area boundary, the Carlingford Lough and Lough Foyle SPAs would not have been included.