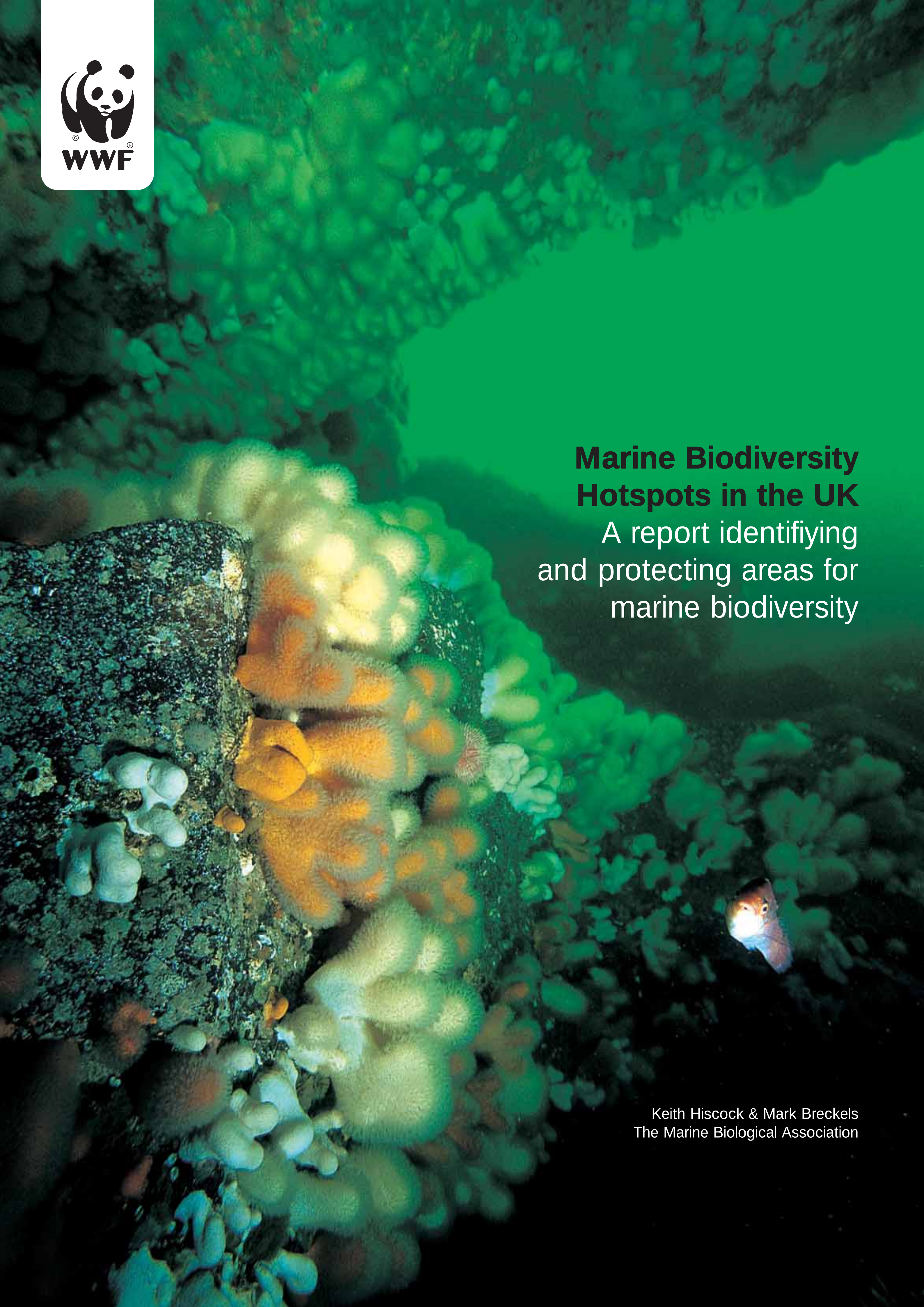

Marine Biodiversity Hotspots in the UK

A report identifiying and protecting areas for marine biodiversity

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Marine Biodiversity Hotspots in the UK: their identification and protection

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Contents

Marine Biodiversity Hotspots in the UK: their identification and protection

EXECUTIVE SUMMARY

Marine biodiversity hotspots are areas of high species and habitat richness that include representative, rare and threatened features.

The idea of identifying biodiversity hotspots, where conservation effort can be concentrated to get best 'value for money', is an attractive one. In this report, we explore the concept of biodiversity hotspots contributing to the identification of marine protected areas and we look at the potential threats to those hotspots.

We use six different measures of 'richness' including species, biotopes (habitats and their associated community of species), and Nationally Important Marine Features. By using the most comprehensive data set currently available for seabed species at 120 well-surveyed locations, we conclude that:

1 The results broadly match the locations that are believed to be of high interest.
2 The wide range of types of data maintained requires that 'minimum standards' are applied to identify acceptability. However, that is currently a large manual task. It would be helpful when applying hotspot measures if existing and incoming data sets were 'tagged' with type and quality.
3 The measures developed (in which the number of survey events at a location are taken into account when identifying hotspot status) require more development, as naturally rich areas tend to be downgraded if they are very well surveyed. In the exercise described here, a 'weighting' has been applied to such sites.
4 Some locations are naturally low in species and biotope richness and their low scores need to be seen in that context.
5 The identification of the number of Nationally Important Marine Features in an area is an important measure, but the current list of Features needs to be further moderated to correct anomalies, especially arising from the strict application of criteria.
6 Hotspot measures are one of several tools for assessing the importance of an area's marine natural heritage.

There was insufficient survey data for offshore areas to make comparisons of richness between these and other areas.

Information on species that live in the water column and at the surface is often less well collated than for seabed species, although hotspot locations are known. There is little offshore data that can be analysed in a comparative way to identify hotspots. This report is about biodiversity hotspots, but productivity hotspots and single species hotspots also occur.

A descriptive approach to assessing the ‘quality’ of a location is outlined. The maintenance or recovery of quality is threatened by a range of human activities, which are briefly described.

The results of the review and analyses described in the report, together with other aspects of the marine biodiversity hotspots concept, were discussed at a workshop on 24 July 2006. The results of that workshop are taken into account in the report.

We conclude that the measures we have tested should all be used to inform the site selection process and we demonstrate, in a series of dossiers for case study sites, how such scientific information can be used to support proposals for protection and management.

INTRODUCTION

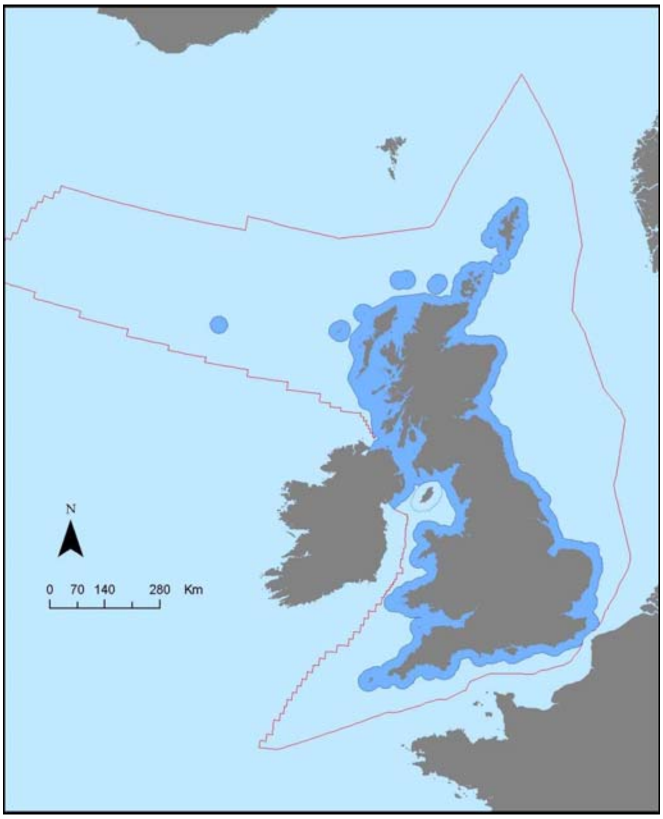


Figure 1. UK continental shelf and (dark blue) 12-mile limit of territorial seas. Map courtesy of JNCC.

A fantastic variety of marine habitats and species exist along the UK’s 20,000km coastline and within the 710,100 square kilometres of its sea and seabed, which descends to depths in excess of 2,000m over the UK continental shelf. Human activities have already had a great effect on those habitats and species and, as our seas get more and more ‘busy’, we are urgently seeking ways to protect biodiversity. Some of that protection is required to safeguard the ‘goods and services’ that the sea provides, and some is to ensure that areas survive that are not damaged by human activities: areas that enable us to understand how ecosystems function and how they should look. The idea that we can get greatest benefits for limited resources by concentrating conservation effort at 'hotspots', where diversity is greatest, has been an important part of conservation on land and this report explores how we can apply the hotspots principle to the seas around the UK.

Identifying and protecting marine biodiversity hotspots should contribute to the ecosystem-based approach to the management of our seas, through identifying which are the most valuable areas for biodiversity and where protection will yield benefits for the maintenance of ecosystem structure and functioning, including the biotic processes that drive them. Such benefits are achieved through the resilience that diverse communities may provide, although biodiversity conservation is as much to do with protecting sensitive and rare or scarce species as those that confer some functional role. The identification of areas worthy of special protection for their biodiversity has to be supported by other aspects of the ecosystem approach, especially the development of management measures that take account of species biology and the maintenance of structure and functioning in those places.

Box 1. The ecosystem approach

"The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. The application of the ecosystem approach will help to reach a balance of the three objectives of the Convention: conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources."
Convention on Biological Diversity, 2000

"The ecosystem approach is the comprehensive integrated management of human activities, based on best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of the marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity."
EU Marine Strategy Stakeholder Workshop, Denmark, 4-6 December 2002

In this report, we identify what has already been done in the UK to protect marine life through the designation of marine protected areas (MPAs), what could be achieved by using the criteria and processes now available to identify representative areas for conservation, and what sort of management tools must be adopted to ensure effective conservation. We use the described principles to demonstrate how a small selection of hotspot locations could protect some precious examples of our marine biodiversity.

We have trialled the analysis of data to identify hotspots using a readily available and very large data set, which predominantly covers inshore waters and seabed species – the Marine Recorder database, which is maintained by the UK National Biodiversity Network (see www.searchnbn.net).

We have been helped in developing the hotspot concept, and especially in understanding where the approach developed might (and might not) fit within current marine conservation actions, by the contributors to a workshop held in Bristol on 25 July 2005. The main conclusions of that workshop are summarised in Appendix 1.

The analysis that we have undertaken has been a 'proof of concept' exercise and we have not produced a list of candidate MPAs as an outcome of the study. There is much good work that has been done and is being done in the UK to develop protection of marine biodiversity. This report is a contribution to that work, using data and incorporating the main principles developed by others in the context of 'hotspot' theory. The locations that we have chosen are examples rather than definitive, but we hope to provide a good picture of the range of diversity around our shores.

WHAT IS A BIODIVERSITY 'HOTSPOT'?

Biodiversity includes richness at all levels from landscapes to genes (see, for instance, Gaston & Spicer, 2004). Within that range of attributes, species richness and variety of habitats are the most practical measures to identify hotspots. Endemism (where a species is restricted to a particular area) is an important criterion to identify hotspots on land and in fresh water but is an unusual feature in the marine environment of the north-east Atlantic: there are no marine species believed endemic to anywhere in the UK. However, hotspots should include rare or threatened species and habitats (which have been identified as 'Nationally Important Marine Features' in the UK: see Connor *et al.*, 2002), and the more present at a particular location, the better 'value for money'.

Box 2. Nationally Important Marine Features are:

Areas that best represent the range of seascapes, habitats and species present in the UK – the UK's marine biodiversity heritage.

Seascapes, habitats and species for which we have a special responsibility in a national, regional or global context.

Seascapes, habitats and species that have suffered significant decline in their extent or quality, or are threatened with such decline, and can thus be defined as being in poor status.

Based on: Connor *et al*., 2002. See Appendix 2 for identification criteria.

'Biodiversity hotspots' is shorthand for a more complicated concept than species richness alone. In the next section, we investigate what characteristics a marine hotspot should have and conclude that:

"Marine biodiversity hotspots are areas of high species and habitat richness that include representative, rare and threatened features."

Where hotspots are identified, they can be protected from potentially damaging activities. Those hotspots that include sensitive species and habitats (those that, once lost, are unlikely, or will take a long time, to recover) should have the highest priority for protection.

In this report, we have not included 'single species', 'ecosystem services' or 'productivity' hotspots. Single species hotspots are locations where a particular species congregates, probably for feeding or reproduction. We also appreciate there may be a view that there are other elements of marine ecosystems that might be called ‘hotspots’. For instance, an ‘ecosystem services hotspot’ might be a ‘biodiversity coldspot’ because it is dominated by one species, such as a suspension feeder, that is critically important to the health of an area. Productivity hotspots may be important in maintaining a high abundance of species but not necessarily species richness or the occurrence of rare and threatened species.

HISTORICAL PERSPECTIVES AND MARINE CONSERVATION SITES ALREADY DESIGNATED IN THE UK

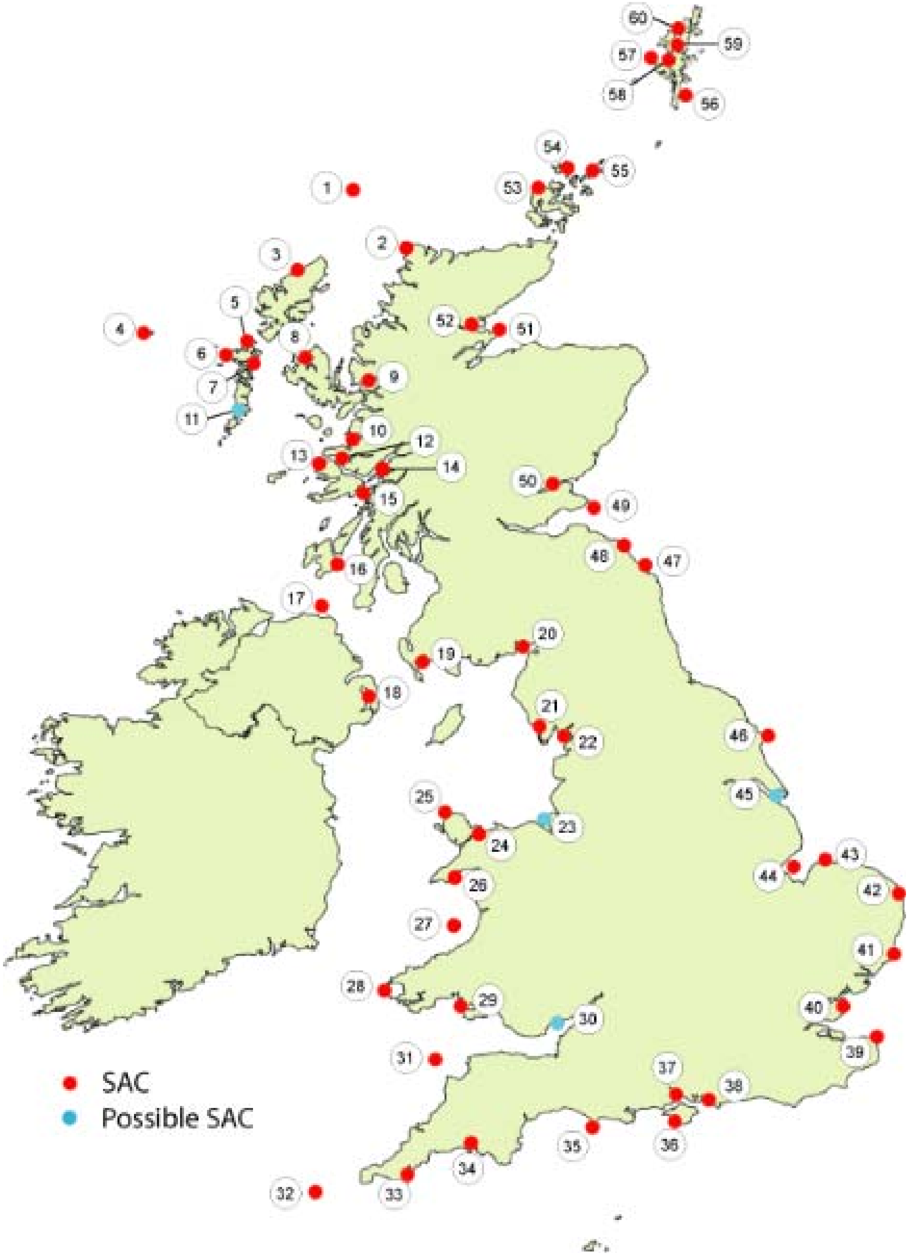


Figure 2. The location of UK Special Areas of Conservation (SACs) for marine habitats and species, including possible SACs. The Darwin Mounds pSAC is not shown. Additionally, the following are draft offshore SACs: Braemer Pockmarks;

Dogger Bank; Haig Fras; North Norfolk Sandbanks and Saturn reef; Scanner Pockmark; Stanton Banks; and Wyville Thomson Ridge. Information derived from www.jncc.gov.uk/page-1458. Appendix 3 shows the names of each of the SAC locations.

The history of marine conservation in the UK goes back to the mid-1960s when a group of marine biologists and scientific divers suggested three possible sites for underwater reserves: Skomer Island in south-west Wales, St Anthony Head near Falmouth, and the Farne Islands and Holy Island in north-east England (see Mitchell & Hiscock, 1996).

Plate 1. Lundy. Britain's first voluntary and first statutory marine nature reserve. Image: Nicola Saunders.

In the late 1960s there was a great deal of activity worldwide in establishing marine parks and reserves. Inevitably, questions were asked about the possibility of such areas being established in Britain but despite consideration by UK government advisers, it was determined that, in the absence of strong evidence that a marine conservation problem existed owing to controllable factors, proposals should not be pursued at that time. However, by 1971, the island authorities at Lundy in the Bristol Channel had accepted the proposal for Britain's first voluntary marine nature reserve to be established around the island (Hiscock *et al.*, 1973).

The designation of intertidal areas as Sites of Special Scientific Interest (SSSIs) (Areas of Special Scientific interest – ASSI – in Northern Ireland) seemed a way to protect intertidal areas, but very few of those established cited marine biology to be of importance. (In 1994, before SSSI designations were made for any candidate SAC with intertidal area, there were 83 that mentioned marine biological interest in the citation, out of the 744 that included intertidal areas in Britain.) SSSIs extend only to low water level and are predominantly a planning measure. However, the criteria are well thought through and provide the basis for selection of a meaningful series of locations for the conservation of biodiversity. Provisions for the establishment of marine nature reserves were included in the Wildlife and Countryside Act 1981 for Great Britain, and the Nature Conservation and Amenity Lands (NI) Order 1985 in Northern Ireland. However, the provisions for Marine Natures Reserves are weak and only three have been designated (Lundy at the entrance to the Bristol Channel; Skomer in west Wales; and Strangford Lough in Northern Ireland).

Box 3. SSSI guideline criteria

Guidelines and criteria for assessment and selection of intertidal and saline lagoon biological Sites of Special Scientific Interest in England, Scotland and Wales (extracts)

Summary of aims:
Within each Area of Search (AOS), a minimum aim of SSSI selection is to include examples (and preferably the best) of the full range of habitats and associated communities which satisfy the guidelines for selection.

Particular care is taken to ensure that habitats and their associated communities and species which have a restricted national or international distribution are included in SSSIs.

[AOS are defined by coastal cell boundaries]

The criteria for assessment and selection are:
- Size (extent)
- Diversity (species richness and habitat diversity)
- Naturalness
- Rarity (the scarcer the habitat or community or the species occurring there, the greater the percentage that needs to be protected)
- Fragility (used as a synonym for ‘sensitivity’ and encompassing ‘vulnerability’)

‘Selection units’ (different shore or lagoon types for description and comparison) are defined.

Extracts from: Joint Nature Conservation Committee. 1996. *Guidelines for selection of biological SSSIs: intertidal marine habitats and saline lagoons*. Peterborough

Plate 2. The Menai Strait. One of the few Sites of Special Scientific Interest established for the importance of its marine biological features. Image: Keith Hiscock.

Throughout the early days of identifying and establishing both voluntary and statutory MPAs, it was expert knowledge of locations and not quantitative, objective analysis of data sets that led to designations. Practical and pragmatic criteria were also important.

Plate 3. Surveys of inshore marine habitats commissioned by the nature conservation agencies provide the bulk of information used to identify marine biodiversity hotspots in this report. Image: JNCC.

The Intertidal Survey of Great Britain, the Marine Nature Conservation Review of Great Britain, and similar surveys in Northern Ireland were the first government-funded programmes to collect the information that would be needed to undertake objective comparisons of different areas and to identify protected areas based on scientific criteria. The data that those surveys collected provides the bulk of information used to identify marine biodiversity hotspots in this report. Unfortunately, the surveys were incomplete at the time that the European Commission Habitats Directive had to be implemented and, in any case, the selection criteria in the Directive were not compatible with the sort of scientific criteria that had been developed in the UK. Nevertheless, the Habitats Directive has led to the establishment of 56 SACs for marine habitats and species in the UK (see Figure 2, above) that are managed to protect wildlife habitats.

European initiatives have further contributed to identifying areas that are important for their high marine biodiversity. BIOMARE was an EC-funded Concerted Action, involving 21 organisations from the EU and associate countries, to "implement and network large-scale, long-term Marine Biodiversity Research in Europe," under the reference terms of the European Science Plan on Marine Biodiversity of the European Science Foundation. The Primary Sites identified and, to an extent, the Reference Sites are relevant to consider as marine biodiversity hotspots. (See: Warwick *et al*., 2003 and www.biomareweb.org/wp1.html)

BIOMARE Primary Sites fulfil the criteria:

1. To be pristine with respect to both anthropogenic and natural stresses – relative to the conditions dominant in the region.
2. To contain a representative array of habitat types present in the region.
3. To already have available information on local marine biodiversity.
4. To be protected by legislation, thereby offering some guarantee that they will remain relatively pristine in the future.
5. To offer facilities to conduct research on marine biodiversity.

Reference Sites (about 100 in Europe), fulfil the criteria (2), (3) and (5) above and should be directly connected with marine research institutes.

BIOMARE Primary and reference sites identified in the UK were:

- Isles of Scilly (a Primary Site)
- Flamborough Head
- Plymouth Sound and estuaries
- The Farne Islands
- Filey Brigg and Filey Bay
- Robin Hood's Bay
- Esk Estuary

Candidate sites were:

- Sullom Voe
- Beadnell to Craster
- Buckton and Bempton Cliffs

- Cornelian Bay
- Menai Strait
- Firth of Lorn and Loch Linnhe complex including Mull

Candidate sites are listed because several were not progressed only because relevant forms were not completed.

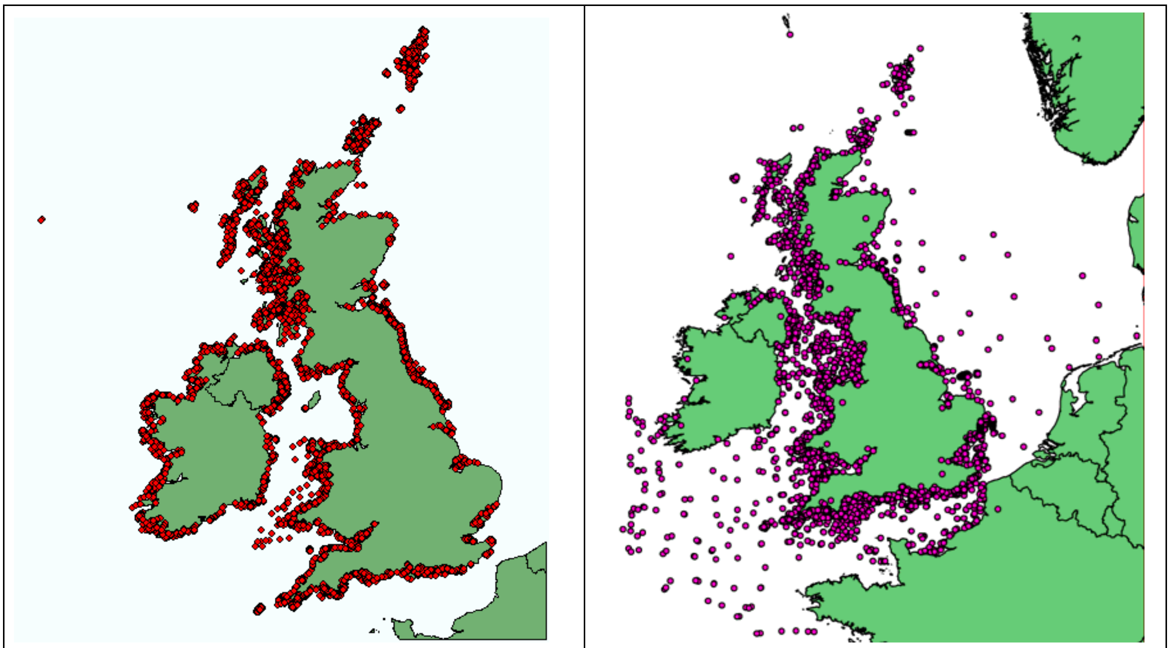
As a contribution to the marine biodiversity hotspots exercise, 20 experienced field marine biologists were contacted by e-mail and asked to apply the hotspot definition and identify which of the 120 areas we selected they would describe as ‘hotspots’. There were seven responses in which the following locations were identified by three or more experts:

- Loch Maddy (Uist)
- South Uist
- Rathlin Island
- Strangford Lough
- Menai Strait
- Tremadog Bay
- Lleyn Peninsula and Bardsey
- Pembrokeshire islands
- Milford Haven
- Lundy
- Falmouth – Helford
- Plymouth Sound – Wembury
- Salcombe – Start Point
- Lyme Bay, Chesil and the Fleet
- Lulworth Cove – Kimmeridge Bay

Now, 40 years after the idea of establishing protected areas for marine conservation was first suggested, we are well-equipped to use data resources to identify locations that can best represent the range of habitats that exist around our shores, including those that are important because of the presence of rare or endangered species and habitats. In particular, we have:

- results from a wide range of surveys in inshore areas;
- criteria to identify MPAs (most recently, OSPAR and the RMNC); and
- criteria to identify rare, threatened or vulnerable species and habitats (most recently, Nationally Important Marine Features – NIMF – criteria).

In this report, we have trialled the use of the extensive data sets to identify marine biodiversity hotspots.



Survey information collected or brought together by the MNCR 1987-1998.	Survey information accessed by the *MarLIN* programme.

Figure 3. Locations where data is available to identify seabed marine biological features. The data is now held by the UK National Biodiversity Network (NBN).

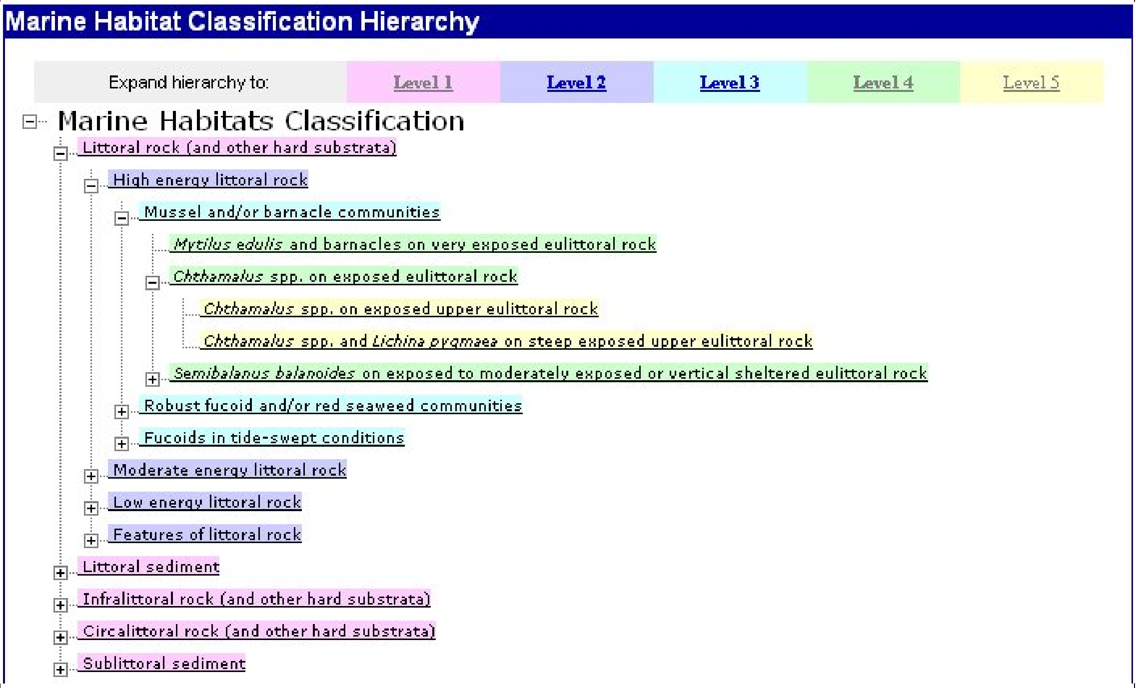
INFORMATION RESOURCES TO IDENTIFY HOTSPOTS

The main data resource available to identify biodiversity hotspots is the UK National Biodiversity Network (NBN) database. The inshore marine biological data in NBN is most significantly from the Marine Nature Conservation Review (MNCR) surveys and associated data access work undertaken from 1987 to 1998 around Great Britain. Data from Northern Ireland is from intertidal and subtidal survey programmes that followed similar methods to the MNCR. The aims of MNCR and associated surveys were to record the range of different habitats and communities of species in an area, often surveying according to physiographic features. Surveys included both recording of epibiota through *in situ* survey and some remote sampling of sediment fauna. Supporting data from other surveys and scientific literature, especially of infaunal sediment benthos, was added to the MNCR database wherever possible. However, the data from MNCR and associated surveys for a particular area is often biased towards epibiota and hard substrata, which needs to be taken into account as far as possible when interpreting data sets. The NBN data resource is being added to on an almost daily basis as more data sets are identified and incorporated by various data centres and especially through the *MarLIN* programme at the Marine Biological Association and now by the Defra-funded Data Archive for Seabed Species and Habitats (DASSH). Access to the NBN database has enabled the analysis of species occurrence data using a variety of approaches to identify hotspots.

Another way of expressing biodiversity is as the variety of different habitats as biotopes in an area. The Britain and Ireland marine biotopes classification (see Box 4, below) was developed by the MNCR as a contribution to the EU-funded BioMar programme. Biotopes are a pragmatic approach to identifying distinctive recurring species assemblages in particular physical and chemical habitats. As a part of the MNCR, survey data from all around Britain was analysed and the biotopes represented by the data from a site identified. While not a comprehensive exercise, in the areas surveyed by the MNCR, the biotopes catalogue for defined areas enables an indication of the number and range of biotope diversity in an area. Particular biotopes occur under particular physical, chemical and biological conditions and can be used to identify the character of a site so that sites of similar character can be compared to identify representative examples based on best examples (usually the richest in species).

Box 4. The biotopes classification

A biotope is: The smallest geographical unit of the biosphere or of a habitat that can be delimited by convenient boundaries and is characterized by its biota (Lincoln *et al*., 1998).



The seabed biotopes classification for Britain and Ireland (Connor *et al.* 2004) includes 262 biotopes at Level 4 and 370 at Level 5. The full classification is shown at Level 1, then portions at Levels 2-5. See www.jncc.gov.uk/page-1584.

Box 5. Criteria to identify nationally rare, scarce and uncommon seabed species (from Sanderson *et al*., 1996)

Nationally rare benthic marine species are those species that occur in eight or fewer of the 10km x 10km squares (of the Ordnance Survey national grid) containing sea within the three-mile territorial limit for Great Britain.
Nationally scarce species are those that occur in 9-55 such squares.
Uncommon species occur in 56 to 150 such squares.

The importance of a site for the conservation of biodiversity is elevated if species that are rare or scarce are present. Identifying which those species are again depends on pragmatic criteria developed as a part of the MNCR (Sanderson, 1996) (see Box 5). However, ‘rarity’ is often a natural feature of a species and some species are only ‘rare’ because they are cryptic or difficult to identify and have simply not been recorded. Nevertheless, the rarity criteria are a useful indicator especially for macrofauna and flora.

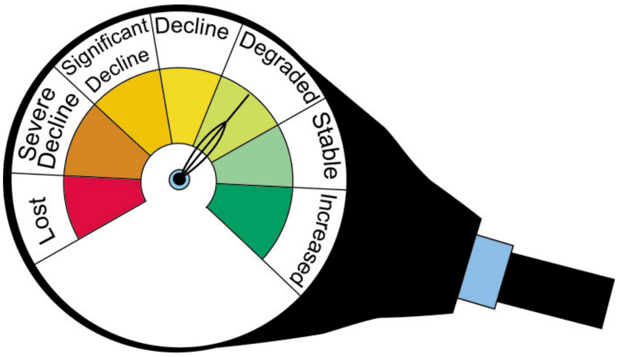


Figure 4. The ‘Health’ gauge from the WWF-UK *Marine Health Check 2005*. The measures are explained in Appendix 4.

The importance of protecting a location is increased if there are species there that are threatened with damage by human activities and may already have been adversely affected. Registering the degree of ‘threat’ or ‘decline’ for a species or biotope is especially difficult because so little historical information is available on numbers or distribution of species and biotopes. Quantitative measures are usually required (for instance, the IUCN Red Data Book criteria). However, the particular difficulties in assessing decline and threat in the marine environment were recognised in the identification of Biodiversity Action Plan Habitats and Species in 1997 and have been further refined and assisted by the work of the RMNC to be incorporated into criteria for Nationally Important Marine Features (NIMF) (see Box 6, below). The concept of decline of species and degradation of habitats is an important one and was central to the WWF-UK *Marine Health Check 2005* (Hiscock *et al.*, 2005). The health status measures developed in that report rely on information from scientific studies but not the degree of quantification employed for many terrestrial species and habitats.

CRITERIA TO IDENTIFY AREAS FOR CONSERVATION

The criteria for and practical methods of identifying where MPAs for the conservation of biodiversity can best represent the UK’s marine habitats are well-established (see Mitchell, 1987) and are essentially those used as a part of the process of identifying intertidal Sites of Special Scientific Interest in Great Britain (Box 3, above) (see JNCC, 1996). Those criteria have been little used – in part because marine nature conservation has been driven since 1992 by the EC Habitats Directive (see McLeod *et al.*, 2005), which includes very broad marine habitats, few marine species that are not charismatic megafauna, and has poorly developed criteria to identify marine sites. At a meeting held in 1994, the criteria for identifying marine areas were improved by the addition of further ‘principles’. In particular, ‘rarity’ was added. These principles were developed by the UK as ones that could be used by other Member States, but they have not been formally added to the selection criteria in Annex III to the Directive nor in guidance elsewhere.

Box 6. Criteria in the UK for identifying Nationally Important Marine Features (species and habitats)*

SPECIES

CRITERION 1: Proportional importance
A high proportion of the (global or regional) populations of a species or of a habitat occurs within the UK.

CRITERION 2: Rarity
Marine species that are sessile or of restricted mobility and habitats are considered nationally rare if distribution is restricted to eight or fewer 10km squares (0.5%) within the three-mile territorial seas limit of UK waters.

CRITERION 3: Decline
An observed, estimated, inferred or suspected significant decline (exceeding expected or known natural fluctuations) in numbers, extent or quality (in terms of life history parameters) of a marine species or habitat in the UK. Species decline should be at least 25% in the past 25 years where figures are available. For habitats, a decline of 10% or more of its former natural extent in the UK, or distribution in the UK has become significantly reduced, or loss of typical or natural components.

CRITERION 4: Threat of decline
It is estimated, inferred or suspected that a species or habitat will suffer a significant decline (as defined in Criterion 4) in the foreseeable future as a result of human activity.

* Summarised for this box. Definitions are given in Appendix 1.

However, much good work to establish relevant criteria for marine habitats and species has been undertaken in the past 10 years or so by the OSPAR Commission and by the UK, especially through its Joint Nature Conservation Committee. Conclusions have most recently been brought together in the Review of Marine Nature Conservation (Defra, 2004). Those efforts have further developed criteria suitable for use in identifying MPAs and Nationally Important Marine Features (which are the starting point to identify Biodiversity Action Plan species and habitats) (see Box 6). Furthermore, good thinking has gone into identifying which are the most vulnerable species and habitats in terms of their sensitivity to natural factors and human activities (Hiscock & Tyler-Walters, 2006). These newly developed or updated criteria are applied to survey information from particular landscape features within the Regional Seas identified around the UK.

Whatever scientific criteria are applied to identify suitable candidate locations to establish MPAs, there has also to be a final selection based on practical or pragmatic criteria which include socio-economic considerations. Guidance of where the most suitable locations might be for MPAs may come from the use of computer programs such as Marxan. This supports identification of MPAs by evaluating planning units (which might be on a grid or might be physiographic types) against costs and conservation targets (see Possingham *et al.*, 2000). One part of Marxan that would benefit a hotspots approach is the ‘summed irreplacibility’ output.

The hotspots work described here supports a ‘biodiversity-led’ approach to identifying potential MPAs. Starting with areas that have high biodiversity scores, we have taken a descriptive approach to assessing the reasons for proposing areas for protection. We have demonstrated in the case study dossiers how the RMNC criteria (see Box 7, below) can be used to support the identification of candidate MPAs.

When scientific criteria are applied to survey data and moderated by practical criteria, the sites identified are, in many cases, likely to fall within existing scheduled sites. Here, we advocate the stronger application of protective measures in locations where the greatest range of representative as well as vulnerable features can be protected.

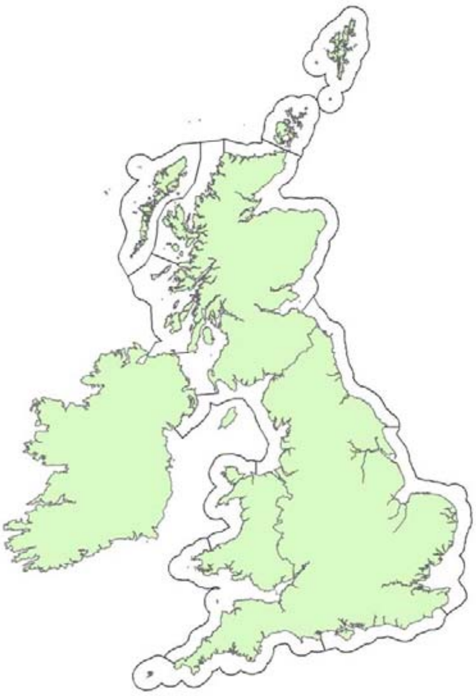
Applying selection criteria is greatly assisted if scientifically sound structures are in place to organise data – for instance, to assess rarity and degree of threat, and to classify biotopes so that the same biotopes from different locations can be compared.

Box 7. OSPAR Convention on the Protection of the Marine Environment of the North-East Atlantic criteria and Review of Marine Nature Conservation criteria.

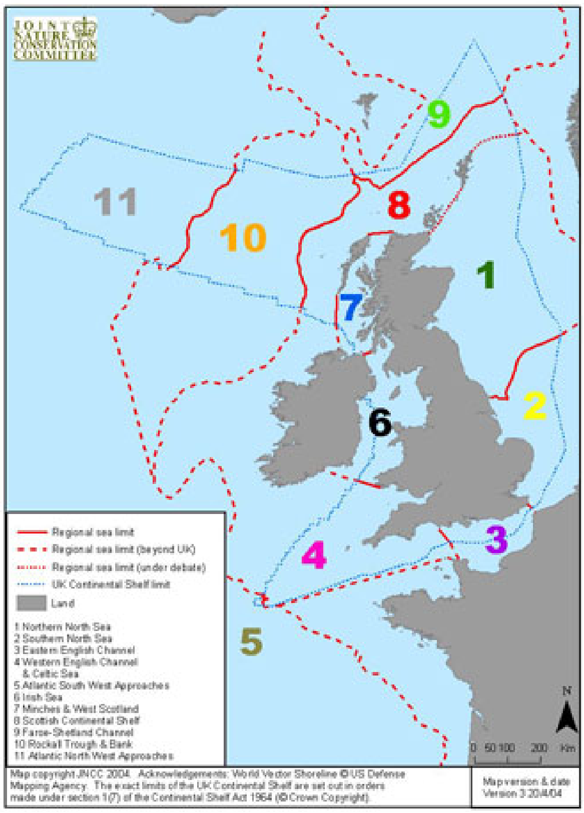
OSPAR criteria. The criteria are interpreted as described in Hiscock (2004).	**RMNC 'Criteria for the identification of important marine areas' equivalents (See Appendix 5)**
Ecological criteria/considerations	
1. THREATENED OR DECLINING SPECIES AND HABITATS/BIOTOPES. [Include 'Rarity' as information on decline is often lacking.]	AREA IMPORTANT FOR A PRIORITY MARINE FEATURE
IMPORTANT SPECIES AND HABITATS/ BIOTOPES. [Refers to global ('Proportional importance') and UK ('Regional importance') distribution and population numbers.]	AREA IMPORTANT FOR A PRIORITY MARINE FEATURE
ECOLOGICAL SIGNIFICANCE. [Includes 'Dependency'.]	CRITICAL AREA
HIGH NATURAL BIOLOGICAL DIVERSITY	BIOLOGICAL DIVERSITY
REPRESENTATIVITY	TYPICALNESS
SENSITIVITY	[AREA IMPORTANT FOR A PRIORITY MARINE FEATURE]
NATURALNESS	NATURALNESS
Practical criteria/considerations	
SIZE (meaning extent of the feature being considered – usually, the bigger the better)	SIZE
POTENTIAL FOR RESTORATION	
DEGREE OF ACCEPTANCE	
POTENTIAL FOR SUCCESS OF MANAGEMENT MEASURES	
POTENTIAL DAMAGE TO THE AREA BY HUMAN ACTIVITIES. [Degree of threat.]	
SCIENTIFIC VALUE.	

HOTSPOTS IN THE CONTEXT OF EXISTING APPROACHES TO MARINE CONSERVATION

Maintaining high species and biotope richness (biodiversity) is essential in sustaining a wide range of ecosystem functions, goods and services that are crucial to humans (Costanza *et al.*, 1997). Three main criteria have been used in terrestrial ecology to identify and describe biodiversity hotspots: species richness, threatened species richness and endemic species richness. Marine systems have fewer and weaker barriers to dispersal and tend to be more open than terrestrial systems and, as a consequence, there are no known endemic marine species in UK waters. Furthermore, diversity at high taxonomic levels is much greater in the sea where nearly all known phyla are represented and there are 14 phyla found only in marine ecosystems (Warwick & Clarke 2001). Comparing diversity measures between sites may therefore be facilitated by the higher-level diversity in marine ecosystems.



MNCR Sectors. Map courtesy of JNCC.



UK Regional Seas. Map courtesy of JNCC.

Figure 5. Areas within which biogeographically similar species assemblages can be compared. Data in the NBN database used to identify hotspots in this report is identified to MNCR Sectors (see Hiscock, 1996). The UK Regional Seas are likely to be the divisions used in the future.

Areas of high species or habitat richness should be identified in different biogeographical areas: the species in a reef area in south-west England will be very different from those of a reef area in Shetland. On a global scale, biodiversity hotspots have been searched for on a grid of 1° of latitude by 1° of longitude (e.g. Orme *et al*. 2005) (approximately 100km x 100km in temperate latitudes). However, in terms of marine biogeography around the UK, it is most sensible to identify biogeographically similar areas as Areas of Search. The MNCR identified 15 coastal sectors (see Figure 2) based on locations where the physiographic character of the coastline changed markedly, on the presence of distributional barriers such as expanses of sea between land masses, and on locations of known biogeographical separation (Hiscock, 1996). Survey data from the MNCR is identified to those sectors and so comparisons can be made between them. Changes have been made to some of the sector positions in various iterations of the concept and the latest 'Regional Seas' map (Defra, 2005) is shown in Figure 5.

As well as biogeographical differences, certain landscape features such as fjordic sea lochs or offshore sediment banks will have species and communities of species that are typical of those features and do not or may not occur in other landscape types. It is therefore important to identify hotspots according to geography and to landscape so that a series of protected areas adequately represents the variety of marine habitats associated with physiographic features in the UK. However, not all 'estuaries', 'sea lochs', etc. are the same in character and comparison of like-with-like may need a finer level of classification.

Offshore, the availability of maps of seabed types and of water masses is rapidly improving and should enable the comparison of hydrographically and geologically similar areas in the future. However, biological survey data is mainly very sparse offshore and different approaches to the 'data-hungry' ones described in this report may be needed.

Some of the OSPAR criteria for areas for conservation lend themselves to the use of the quantifiable features that have already been mentioned (number of species present, number of biotopes present, number of regionally important features, number of rare or scarce features, number of threatened features), perhaps offering a 'formulated' decision. However, others are more descriptive. For example, 'representativity' or 'typicalness' is an important ecological consideration when defining a priority area for conservation.

Representativity is a term used to determine if a given location or physiographic feature has the sub-set of species that would be expected, thus if it were to be protected it would provide a 'textbook' example of the species that you might expect to find in that particular ecosystem. In this way, representativity almost infers 'average-ness' (although the guidelines for the identification of intertidal SSSIs – JNCC, 1996 – refer to "representative and preferably the best").

When trying to establish a biodiversity hotspot, average-ness is counterintuitive. A biodiversity hotspot, by definition, does not have an average selection of species but is highly species rich. At this point it is worth detailing that species richness is the number of species found at any site, while species diversity takes into consideration species richness and the evenness with which individuals in the assemblage are distributed among the species present (Begon, Harper & Townsend 1996). It is also important to realise that quantifiable criteria provide useful tools for conservation management but are dependent on the quality of data available and the ease of interpretation. With the primary aim of trialling the biodiversity hotspot concept across UK using available data, rather than to produce a categorical list of the level of UK biodiversity, all

UK regions were analysed together. Clearly, some physiographic features will be intrinsically more biodiverse than others and, in order to establish which locations could be considered ‘hotspots’ for each physiographic feature, future studies should focus on a sub-set of physiographic types to allow like-with-like comparisons to be made. However, by analysing all UK locations together across regional and physiographic boundaries it may be possible to establish which areas stand out as hotspots.

When trying to establish which areas in UK coastal waters qualify as biodiversity hotspots, it is crucial that the primary objective of practical conservation management is not overlooked. Therefore, the search for hotspots was focused on areas that could potentially become manageable ‘units’. Here we chose to focus attention on physiographic features, rather than on predetermined areas as Orme *et* al. (2005) did. There are associated advantages and disadvantages with this approach. By selecting defined physiographic units it is possible to focus on an area of coastline than can be thought of as a potentially manageable unit, rather than predefined grid squares that may dissect interesting physiographic features. Additionally, if future studies aim to find the best examples of a particular physiographic feature, this approach may be favoured.

However, physiographic features will vary in spatial scale, which may have inbuilt species area effects. The five major physiographic features selected from around the UK coastal waters for analysis were islands, embayments, estuaries, linear coastlines and sealochs. Others, such as straits, rias and voes and mixed feature physiographic units were also included. There are further statistical and ecological reasons for selecting these manageable units. Sampling methods and sampling effort will vary markedly depending on the physiographic feature being studied. Equally, two locations with the same physiographic features are more likely to have a similar sub-set of species and biotopes than another location within a different physiographic type.

The RMNC ‘criteria for the identification of important marine areas’ should be used in the process to identify where MPAs are to be established. Analysis of data as described here to identify various hotspot measures can contribute significantly to the assessment of locations. Where different hotspot measures contribute (and do not contribute) to the identification of MPAs and to biodiversity conservation is summarised in Box 8, below. The quality assessment descriptions given later address the RMNC “naturalness” criterion.

Box 8. What the identification of marine biodiversity hotspots will and will not do*

Will:
Identify locations where the number of species present is higher than would be expected ("High natural biodiversity" in RMNC criteria).

Identify locations where the number of biotopes present is higher than would be expected ("High natural biodiversity" in RMNC criteria).

Provide a representation of where there is a high intensity of rare, declining and/or threatened species and habitats (areas that score highly for NIMF species or biotopes).

Contribute information to the RMNC criterion "Area important for a priority marine feature" (areas that score highly for NIMF species or biotopes).

Will not:
Identify single species hotspots.

Identify the actions needed to manage a location, especially in relation to ecosystem structure and functioning.

* The summary in this box refers to the approach described and tested here which is for inshore seabed habitats. The summary benefits from the contributions made at the workshop held on 24 July 2006 (Appendix 1).

DATA ANALYSIS FOR HOTSPOTS

The full NBN Marine Recorder database was made available for analysis in March 2006. Each species and biotope record was plotted using its exact latitudinal and longitudinal coordinates onto a map of the UK using GIS software. Once all the data was uploaded on to the map it was possible to establish regional differences in sampling intensity. From around the UK inshore area approximately 120 example locations (see Figure 6) with an adequate level of sampling intensity that were associated with a distinctive physiographic unit were selected. These 120 selected locations are not an exhaustive list of all the areas with adequate sampling intensity to allow analysis, but provide an example of how the methods may be employed.

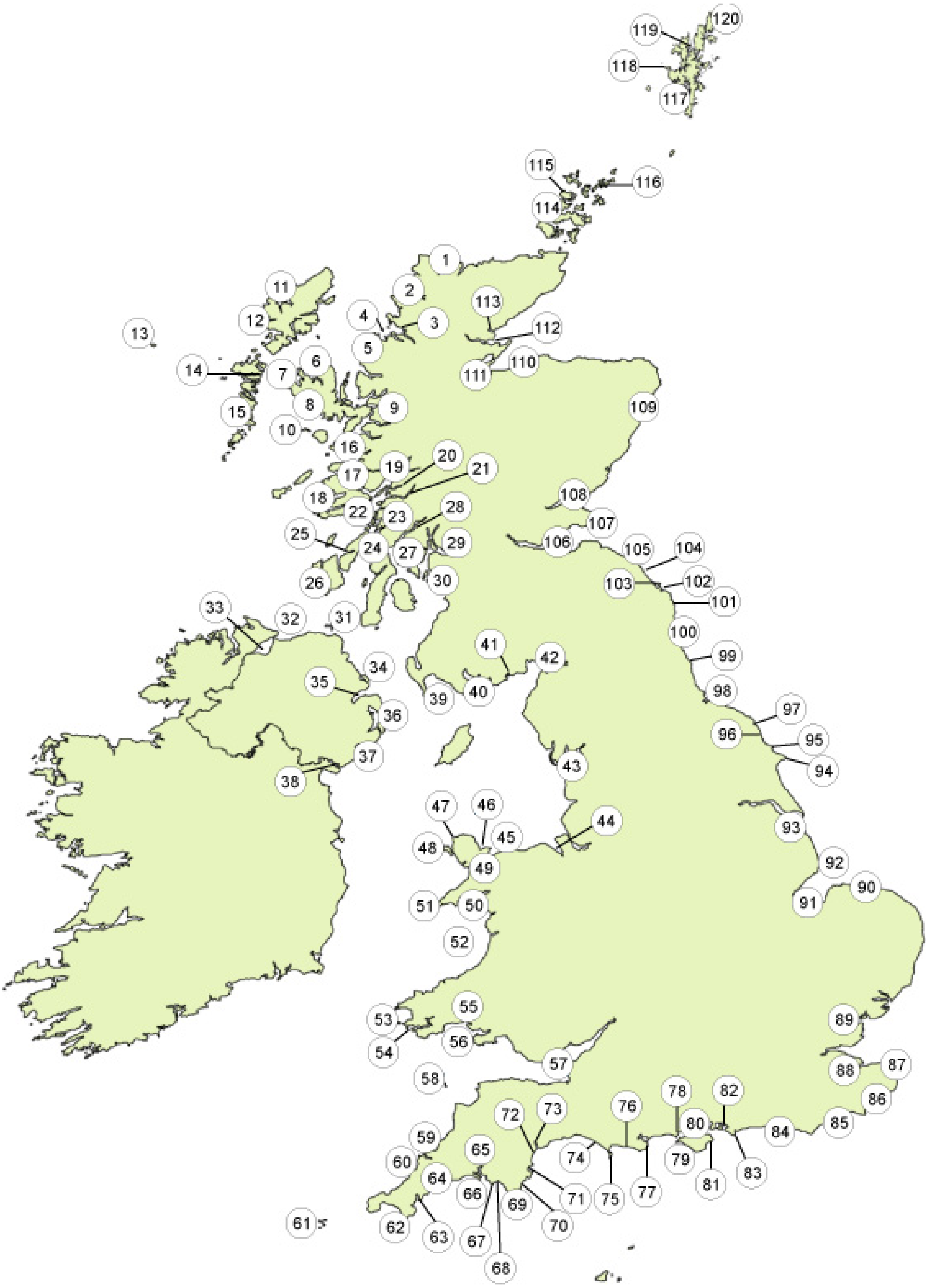


Figure 6. Sample locations from around the UK coastal waters selected for hotspot analysis. The names of locations are given in Appendix 6.

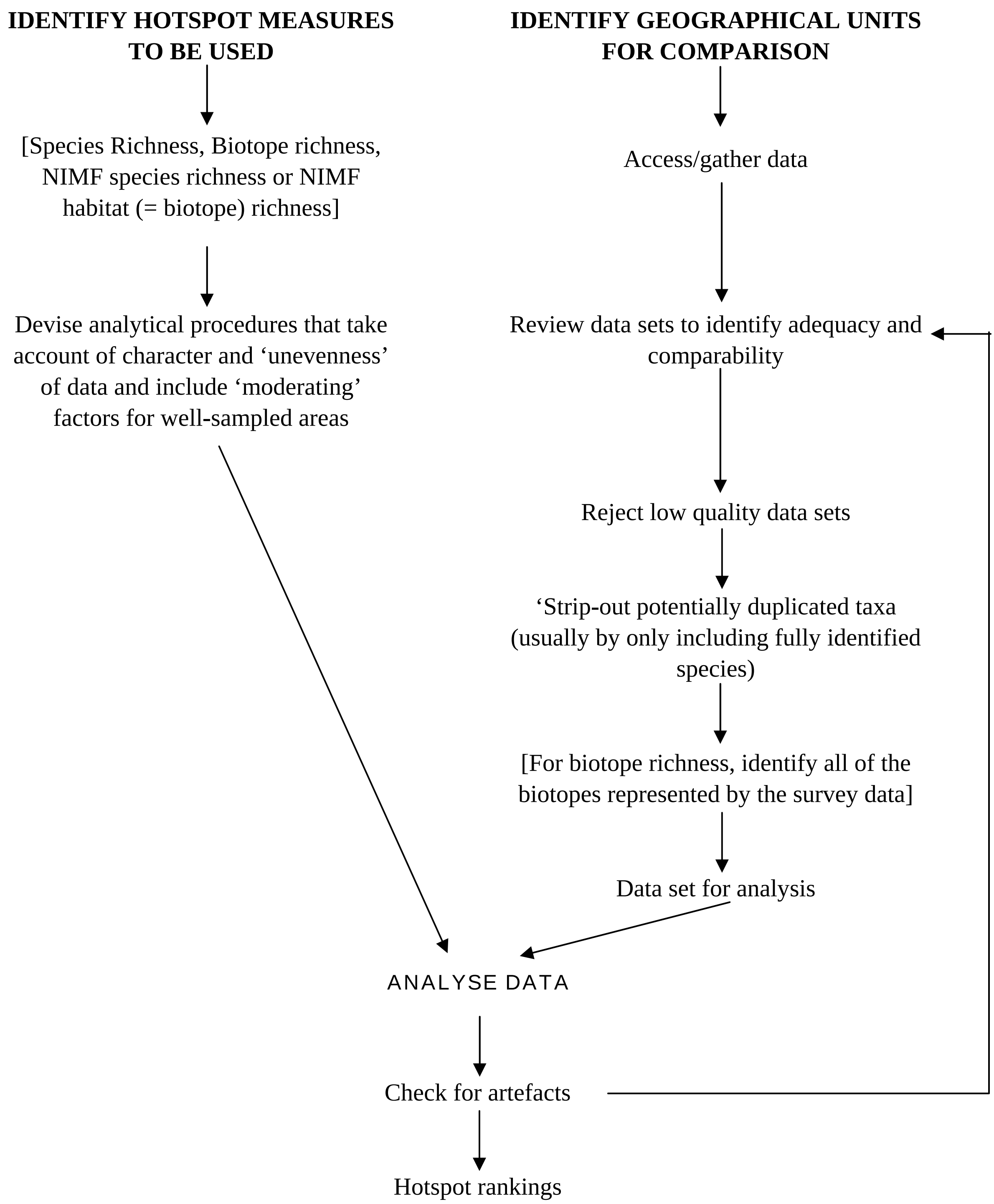


Figure 7. Procedure for identifying Marine Biodiversity hotspots from survey data

Figure 7 summarises the data analysis procedure.

Data was sought for offshore areas and, in particular, areas of the North Sea. However, as Figure 3 shows, offshore data points in the database are very sparsely distributed and are not sufficient to undertake comparative analysis with the criteria of this study in mind.

Six measures of diversity were analysed in this study: species richness, biotope richness, number of Nationally Important Marine Feature (NIMF) species and biotopes, average taxonomic distinctness and average biotope distinctness. To be able to compare results for all measures of diversity, each location was assigned a score from 1-3 for each diversity measure analysed, where 1 was lower than expected or poor, 2 was expected and 3 was high or greater than expected diversity for that given measure.

The way in which 'expected' diversity was identified is described below and in more detail in Appendix 7. After all six measures where analysed it was possible to find a location's average score. In future studies it would be possible to weight the scores for each measure differently or use different measures depending on the specifications of the study.

Species richness

GIS was used to plot all species records by latitudinal and longitudinal coordinates on to a map of the UK. Information about each taxa record at the 120 locations was then uploaded. Many of the species records were only accurate to genus level, which can cause artificial inflation of species richness because, for example, a database query would identify *Gibbula* sp. and *Gibbula umbilicalis* as two different species from the genus *Gibbula* when only one may be present in a sample. Therefore only records accurate to species level were included in the analysis.

Measures of species richness provide an instantly comprehensible expression of diversity so long as care is taken with sample size (Magurran, 1996). However, a data set compiled from surveys carried out at locations around the whole of the UK coastline will have spatial variances in sample intensity and sampling procedures. Thus, methods have to be adopted to counter these variances in sampling, as the phenomenon that 'the more you look the more you find' will transcend into the data. The NBN database has a huge amount of available data and records have been made, and continue to be made, by a range of different people from professional marine taxonomists to amateur biologists; thus there is a huge amount of variability in the quality of the data. Without stringent prior filtering of the database, statistical transformations of the data to attempt to standardise for differences in sampling and an appreciation on the nature of the species accumulation curves at each location, statistically robust quantitative comparisons are not achievable. However, using the full set of data available, it is possible to obtain semi-quantitative species richness figures.

Once the full species lists for each location had been compiled they were plotted against sampling effort. A simple regression was performed to allowing species richness to be related to sampling intensity (see Appendix 7) this allowed each location to be given a score from 1-3, where 1 indicates lower than expected species richness, 2 indicates expected species richness and 3 indicates higher than expected species richness based on the level of sampling intensity for any given location.

Some areas were subjected to *post hoc* modification (see Appendix 7) as it was concluded that a large sampling effort was responsible for a lower than anticipated species richness value. These areas included Milford Haven with 1,197 species, Strangford Lough (with 635 species) and the Isles of Scilly (with 767 species).

Nationally Important Marine Feature (NIMF) species

The list of Nationally Important Marine Features (NIMF) was still in draft at the time that research for this report was being undertaken (Hiscock *et al.*, 2006) but the draft list provided a useful indication of the numbers of important species found at any given location. The NIMF species draft lists were compared to a full list of species found at each location. The number of candidate NIMF species found at each location was recorded. NIMF species richness is not independent of sampling intensity – standardisations for sampling intensity were not performed, instead actual numbers were favoured. The top 10% of locations with the highest number of recorded NIMF species were assigned hotspot status and given a score of 3. Locations with the number of NIMF species richness in the lowest 10% were regarded as being poor for that criterion and given a score of 1. Because the list of NIMF species used for analysis was a draft list, the results are illustrative only.

Biotope richness

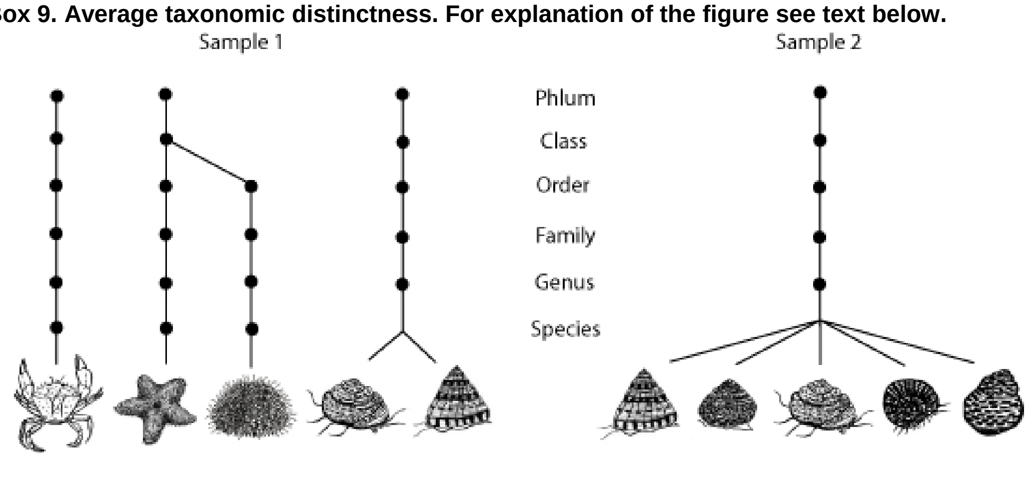
A biotope is the smallest geographical unit of the biosphere or of a habitat that can be delimited by convenient boundaries and is characterised by its biota (Lincoln *et al.*, 1998)**.** Biotope recording did not occur during all surveys and there are fewer biotope records than survey stations on the database. However, all the biotope data available was plotted on GIS, and the number of biotopes recorded at each location established. Biotope richness was standardised for sampling intensity and allocated a score from 1-3 using the same method used for species richness.

Nationally Important Marine Feature (NIMF) biotopes

As well as nationally important marine species, there are nationally important marine habitats. The final NIMF biotope list is still under review and here we used the recommended list to ascertain which locations had important habitats present. The number of NIMF biotopes recorded at each location was scored in the same way as NIMF habitats, with the top 10% of locations assigned a score of 3 and the lowest 10% assigned a score of 1; the rest were given a score of 2. Because the list of NIMF biotopes used for analysis was a draft list, the results are illustrative only.

Average taxonomic distinctness

Box 9. Average taxonomic distinctness. For explanation of the figure see text below.



Average taxonomic distinctness calculates the average taxonomic distance apart of all the pairs of species in a sample, based on branch lengths of a hierarchical Linnaean taxonomic tree (Warwick & Clarke, 2001). The illustration above shows the principle of average taxonomic distinctness. Both Sample 1 and Sample 2 have the same species richness, with five species present. However, Sample 2 has five species from the same genus, while Sample 1 has five species from four different genera and three different phyla. Therefore, species from Sample 1 are separated by longer branch lengths in the taxonomic tree and have a greater average taxonomic distinctness.

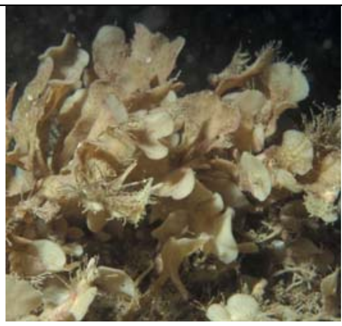
 Cnidarians (the stalked jellyfish *Lucernariopsis campanulata*)	 Annelids (a *Nephtys* species of worm)	 Molluscs (the sea slug *Greilada elegans*)
 Crustaceans (the barnacle *Solidobalanus fallax*)	 Bryozoans (hornwrack, *Flustra foliacea*)	 Echinoderms (sea potato urchin *Echinocardium cordatum*)

Plate 4. Focus was restricted to the numbers of species in six major marine phyla to identify average taxonomic distinctiveness. Images: Keith Hiscock.

The methods already described allow comparisons of several biological features to be made between locations. But, although species richness is widely used in the literature to describe biodiversity hotspots, it does not give the full picture (see Purvis & Hector, 2000). In particular, the measures do not address the range of different taxonomic groups that are represented (see Box 9). Thus, in addition to species richness, taxonomic distinctness was also calculated. ‘taxonomic distinctness’ is measured according to the major taxonomic groups in which species are classified. Therefore, it is possible to calculate how taxonomically distinct (distant) two species are from one another. Several methods have been developed to allow diversity measure on the relatedness of species to be calculated. Not all the species data was used in the analysis as different sampling methods employed at spatially distinct locations can result in different species being observed. Therefore, only species from six phyla were analysed (annelids, bryozoans, crustaceans, cnidarians, echinoderms and molluscs), as these phyla are widely distributed and have full taxonomic classifications.

Average biotope distinctness

For the purpose of this study, a new system was developed to analyse biotope distinctness based on the biotope classification hierarchy. This method works in the same way as Average Taxonomic Distinctness and allows insights into the variety of biotopes present at any particular location. All biotopes fit within a hierarchical classification (see Box 4) similar in principle to the Linnaean tree for species taxonomy. Therefore it is possible to determine how distantly related two biotopes are by determining the branch lengths between them, as you can for species (see Box 9). It may be preferable to target conservation on locations that have a high level of different habitat types as well as being highly species rich or taxonomically distinct. Locations were given a score from 1-3 for average biotope distinctness under the same selection criteria as for average taxonomic distinctness.

RESULTS OF DATA ANALYSIS

By identifying several different diversity criteria it is possible to obtain a fuller picture of the biodiversity in a region. Several of the diversity indices were not synonymous, and areas that were 'hot' for some aspects of biodiversity were average or even poor for others. Of all the locations analysed, 46% achieved hotspot status for at least one of the six measurements analysed. Three locations (the Menai Strait, Salcombe to Start Point, and Plymouth Sound) stood out as biodiversity hotspots, with Plymouth Sound SAC and Salcombe to Start Point achieving hotspot status for four of the six measures investigated. As found in previous studies, areas that achieved hotspot status for one criteria were not necessarily congruent across criteria; 13% of locations achieved hotspot status for three criteria, 24% of hotspot areas met two criteria while 60% were idiosyncratic. This does not detract from the importance of identifying biodiversity hotspots, but highlights the significance as stated by Orme *et al*. (2005) for identifying several criteria, especially as some locations that met hotspot status for one measure were poor for others.

Species richness

The south-west of England had several species rich areas (see Figure 8) with Falmouth and Helford, Plymouth Sound SAC having over 800 recorded species, and Salcombe, Lyme Regis, Chesil and the Fleet all achieving hotspot status. Other species rich areas included the Menai Strait, which boasted nearly 950 species, the Pembrokeshire islands with 1,270 species, Cardigan Bay, Wigtown Bay, and mainland Orkney.

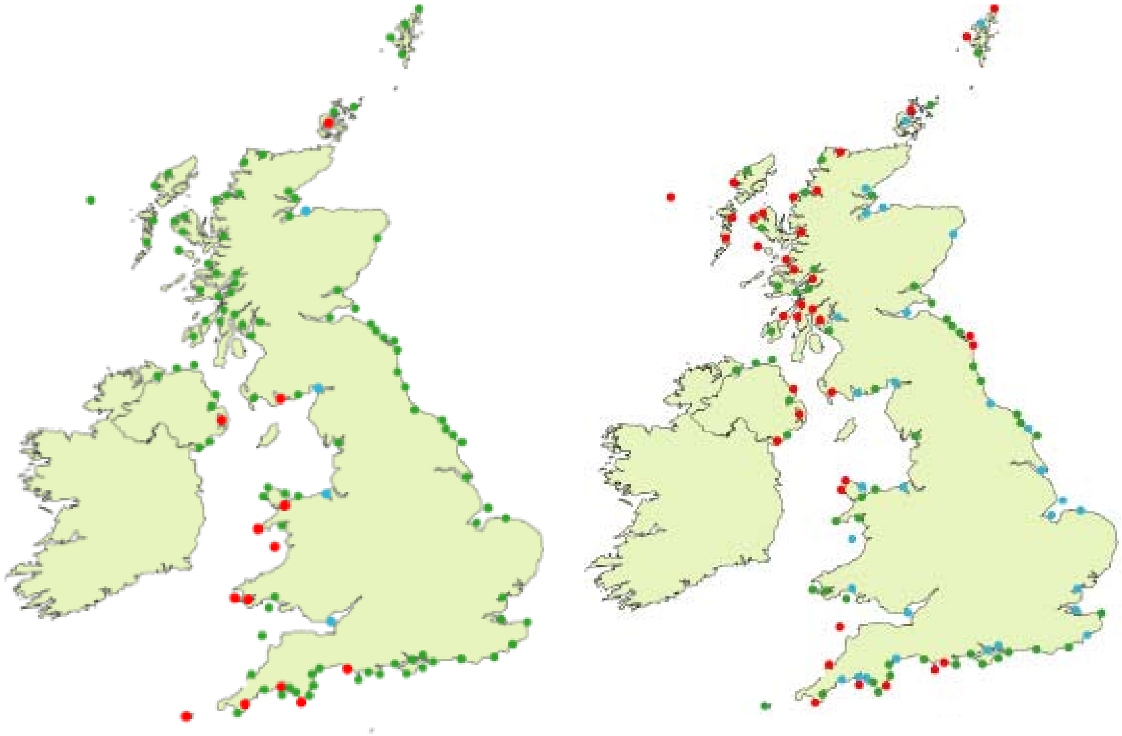


Figure 8. a) Species richness; and b) Average taxonomic distinctness for all physiographic features for six major phyla for coastal locations around the UK. Red dots represent 'hot' areas or high diversity, green dots represent areas of expected diversity and blue dots show areas with lower than expected diversity.

Average taxonomic distinctness

A funnel plot (see Appendix 7) shows the average taxonomic distinctness (AvTD) for each location. All locations are then given a score from 1-3, where 1 indicates lower than expected AvTD, 2 shows expected taxonomic distinctness and 3 is higher than expected AvTD based on the regional species pool.

When all physiographic features were analysed together it was clear that sealochs and islands were the physiographic features with the highest AvTD. The north-west coast of Scotland has a high proportion of these physiographic features and is shown to be a 'hot' area in terms of AvTD on the illustration (see Figure 8). The island of Unst in the far north of the UK coastal waters had a high value for AvTD. The western channel also had a large number of locations with high AvTD indicating a varied range of species. The species rich Menai Strait had an average AvTD in the upper part of the expected range. Strangford Lough in Northern Ireland had a high AvTD value and a large species list, indicating a large taxonomic breadth among the many species present.

The sealochs were the most taxonomically distinct physiographic feature and, when analysed against each other, Loch Craignish, Loch Riddon and Striven (to the north of Bute) and Loch Resort on Lewis had higher than expected AvTD values. Loch Fleet on the east coast of Scotland had a very low value for average taxonomic distinctness in comparison to the other sealochs. Estuaries in the Western Channel attained the highest AvTD when estuaries were analysed with the Camel, Dart, Erme, Teign and Fal estuaries, all having high AvTD values.

Holyhead on Anglesey, the Lizard in Cornwall and Amble Farm on the north-east coast of England were the linear coast sites with a higher than expected AvTD. Luce Bay, Lulworth Cove and Larne in Northern Ireland where the bays with the greatest AvTD values.

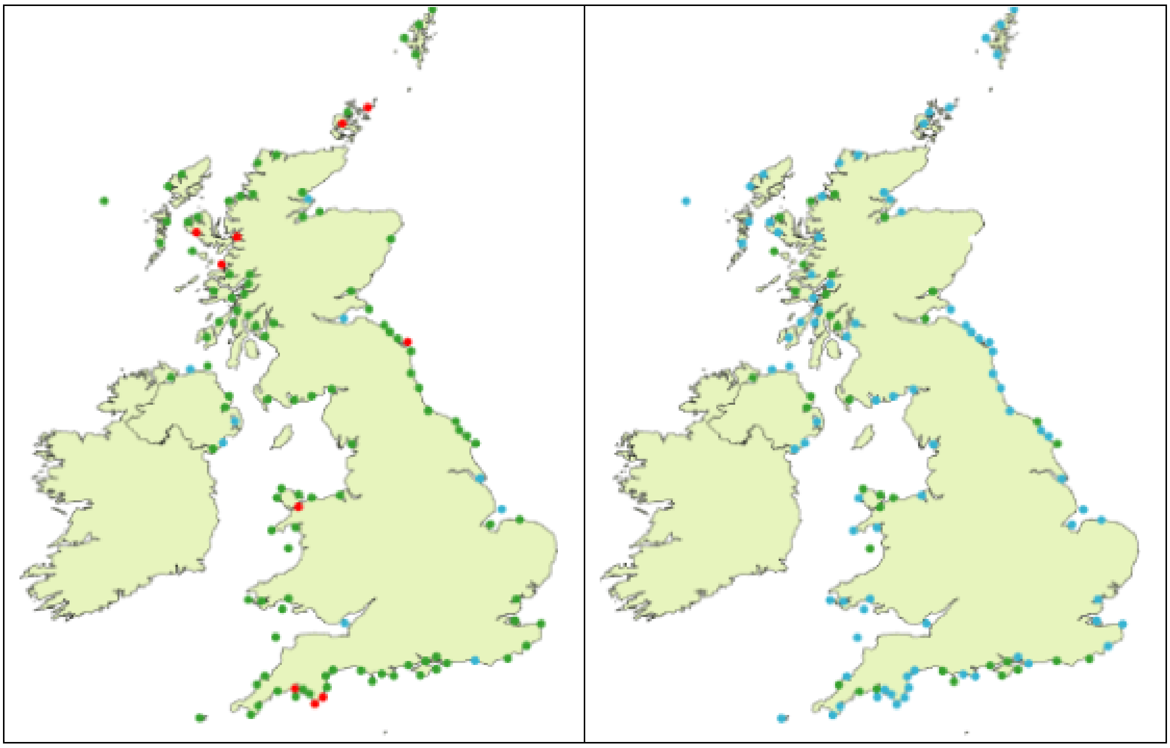


Figure 9. a) Biotope richness for coastal locations around the UK; and b) Average biotope distinctness for all biotopes and physiographic features. Red dots represent 'hot' areas or high diversity, green dots represent areas of expected diversity and blue dots show areas with lower than expected diversity.

Average biotope distinctness

When average biotope distinctness analysis was performed, the frequency default was selected to test allowing rare biotopes to have an effect on the funnel plot. When all physiographic types were analysed together the majority fell below the expected range. This is not highly surprising, as each physiographic type may be expected to have its own sub-set of biotopes and therefore when compared to the full regional biotope list it will not have the same range of biotopes.

However, when each physiographic group was analysed separately there were still no locations above the expected range. For the purpose of analysis, all physiographic features will be tested together as the hypothesis is about which areas support the greatest average distinctness of biotopes and therefore answers questions about which locations have the largest range of biotopes. Several areas with high biotope richness also fell within the expected range for average biotope distinctness, including the Sound of Arisaig, the Menai Strait and Plymouth Sound.

Biotope richness

The total number of recorded biotopes did not always correspond to areas with the greatest distinctness of biotopes. For example, two locations in the Western Channel, Salcombe and the Dart estuary had higher than predicted biotope richness for the sampling effort, but lower than expected average biotope distinctness indicating a large number of closely related biotopes being observed. A similar situation can be seen for the Farne islands, the Loch Duich, Long and Alshe system, mainland Orkney, Sanday and Loch Bracadale on Skye where biotope richness is high but biotope distinctness is low. Locations with higher than expected biotope richness included Plymouth Sound, Salcombe and the Dart estuary in the Western Channel, the Menai Strait in Wales, the Farne Islands in north-east England, mainland Orkney and Sanday, the Sound of Arisaig, Loch Bracadale on Skye and lochs Duich, Long and Alsh.

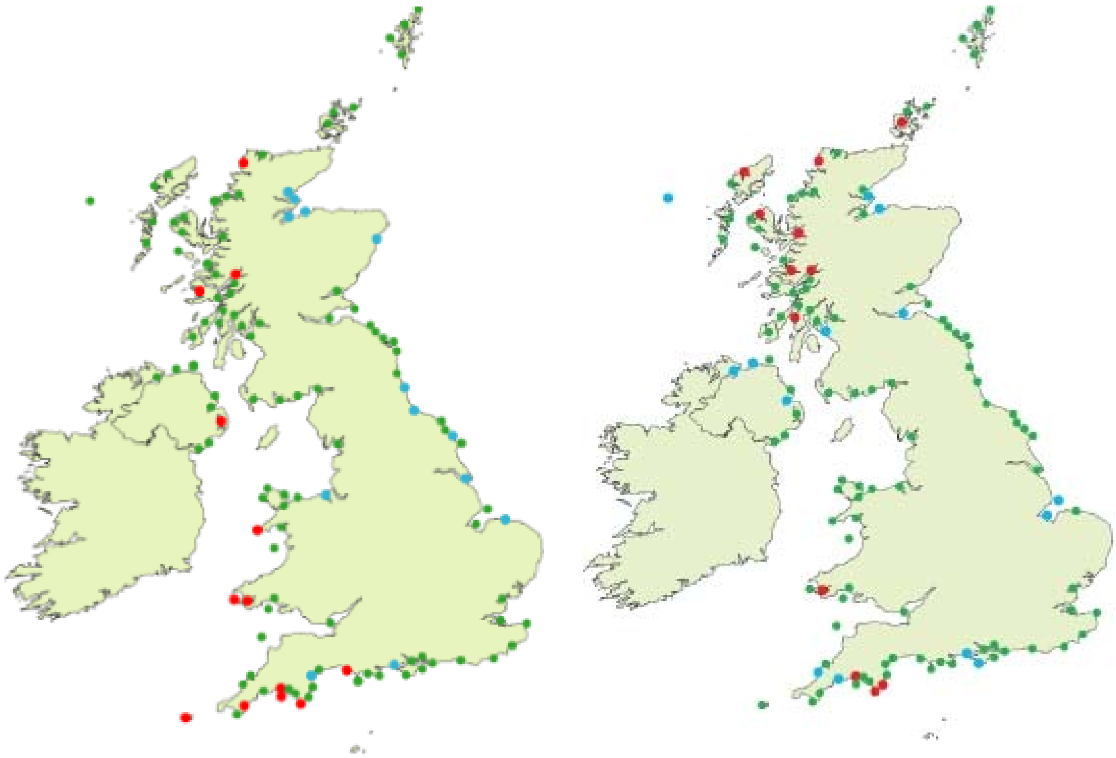


Figure 10. a) NIMF candidate species richness; and b) NIMF candidate biotope richness for coastal locations around the UK. Red dots represent 'hot' areas or higher than expected diversity, green dots represent areas of expected diversity and blue dots show areas with lower than expected diversity.

It is particularly important to focus conservation efforts towards areas with a high number of Nationally Important Marine Feature (NIMF) species. Figure 10 shows the distribution of areas that have a high richness of candidate NIMF species: the Western Channel including the Isles of Scilly, and the Plymouth reefs have several locations with a higher number of candidate NIMF species. North-west Scotland, Mull, the Sound of Arisaig, Strangford Lough and the Pembrokeshire region are all rich in NIMF species.

Loch Laxford, the Loch Linnhe system, Salcombe, Plymouth Sound and Milford Haven are rich in candidate NIMF habitats as well as candidate NIMF species. The western coast of Scotland and the Outer Hebrides are rich in NIMF habitats as are Orkney and the Menai Strait.

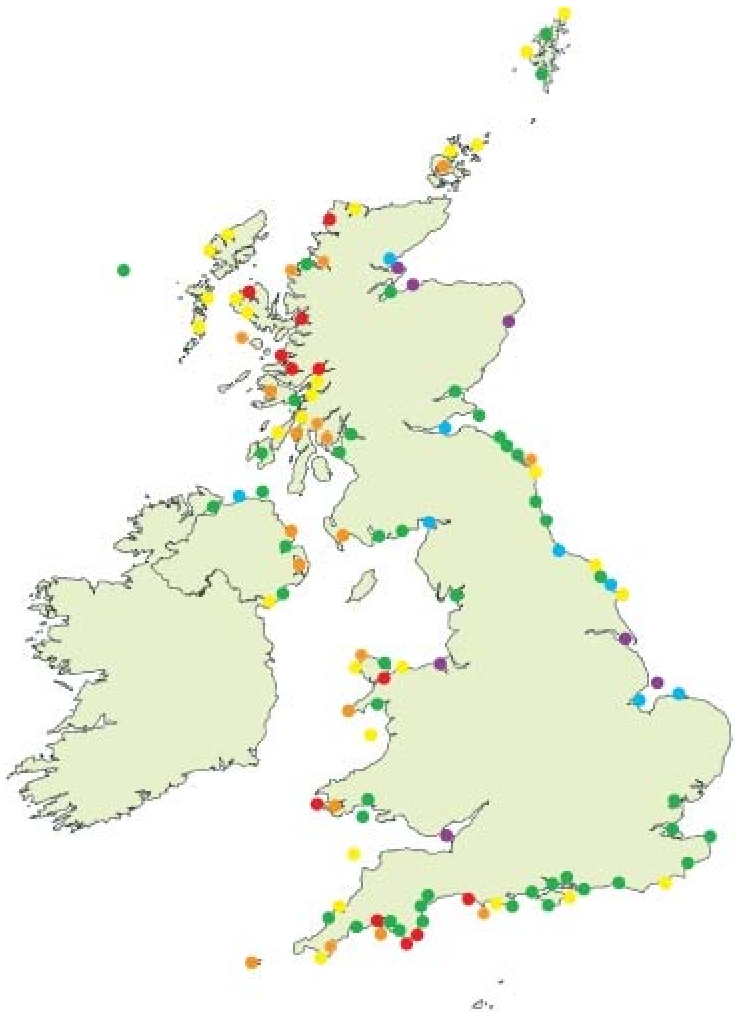


Figure 11. The 'hotspot' locations around the UK, based on averages from the six diversity measures investigated. *All physiographic types have been compared together so this illustration does not show the richest of each physiographic type, but the richest locations when all areas are compared. Thus, the colours on the map should not be considered as a reflection of intended conservation effort.* The 'hottest' locations are shown in red, then orange, yellow, green, blue and purple for the areas with the lowest averages for the measures investigated.

Figure 11, above, shows the overall results for the six biodiversity criteria this study investigated. Salcombe to Start Point and Plymouth Sound to Wembury were the highest scored locations, followed in alphabetical order by: Chesil and The Fleet; the Dart Estuary; the Loch Linnhe system; Lochs Duich, Alsh and Long; Loch Snizort; Loch Sunart; the Menai Strait; Milford Haven; north-west Scotland lochs; and the Sound of Arisaig. There is an apparent biodiversity bias, with locations in the south west of England, Wales and western Scotland obtaining higher hotspot status than locations on the North Sea coast, most likely due to the expected lower number of species in colder waters with less habitat complexity.

ASSESSMENT OF ANALYSES AND RESULTS

The main aim of the work reported here was to see how the concept of biodiversity hotspots could be applied to the marine environment and to demonstrate approaches by analysing UK data sets. While the principles that we established are meaningful and sound, data analysis revealed difficulties in reaching firm conclusions.

The UK is fortunate in Europe in having access to a very large data set for marine seabed species distributions. However, a very apparent feature of the data set that can be seen in Figure 3 is that the data available is not continuous around the coastline and there are large variances in regional data availability. The north and north-east coast of Scotland suffer from a lack of sampling, as do some areas in East Anglia. Critically, the data is mainly restricted to inshore areas and there was insufficient data to compare offshore locations.

In this study we used physiographic features as units for comparison. There is other work being undertaken (by Andrew Blight and colleagues at Queens University Belfast) to explore approaches to identifying marine biodiversity hotspots in the UK including using grid squares of data, reducing the range of species groups analysed and checking species listed by field work. Such studies will further inform the application of marine biodiversity hotspot measures.

The six measures that we selected to analyse for are, we feel, the most meaningful in the context of identifying seabed biodiversity hotspots relevant to wildlife conservation. However, the methods used could be applied to other units of measurement. For example, NIMF species (included in this study) could readily be replaced with Biodiversity Action Plan species.

Many diversity measures, especially the number of recorded species, are highly dependent on the sampling regime and are complicated to compare unless sampling methods are universal (see, for instance, Clarke & Warwick, 1998). Attempting to standardise for sampling regimes and sampling effort across physiographic features using data collected from a range of different workers and over large timescales, such as the data on the NBN database, would be a hugely demanding exercise and well beyond the scope of this study. Although we selected locations as having been ‘well sampled’, the ‘species richness’ values used in this study to compare locations are not statistically robust but provide an indicative representation of the species present at any given location. It would not be feasible to attempt to use such a data set as a basis for statistically robust large scale comparisons between sites. Here, in the analyses a very simple method was used to identify areas with high numbers of species but several caveats are discussed in Appendix 7.

For data collected by different workers over large timescales it has to be established that only certain aspects of diversity, such as average taxonomic distinctness, may be compared with any validity (Clarke & Warwick, 1998). Average taxonomic distinctness is independent of sample size, and is an invaluable tool in the analysis of marine biodiversity based on species relatedness. Average taxonomic distinctness has one caveat in that workers with different taxonomic identification skills may fail to identify some species, but as long as they do so at random across the species pool the results are not affected (Clarke & Warwick, 1998). There is much scope for the use of average taxonomic distinctness in studies of diversity, especially when sound statistical measures for other diversity indices are unavailable. Having worked to make best use of often uneven data sets in the study described here, it is felt that, in the absence of fully comparable data sets, average taxonomic distinctness provides the most comparatively robust measure of biodiversity.

Average biotope distinctness is a new approach that could be very useful in combination with other diversity measures as, while independent of sample size, it gives a measure of the breadth of habitats present at any given location based on the regional biotope list. 'Biotope richness' suffers from the same sampling problems as species richness, and average biotope distinctness could potentially resolve some of these problems. In future studies, if the questions being addressed included where to find the 'best' example of a particular marine landscape or physiographic feature, the regional biotope master list could easily be modified to match the biotopes present in that feature and analyses could identify the locations with the highest habitat breadth. In combination with average taxonomic distinctness these two methods could become powerful tools and, with regards to the data analysed in this study, they are the most valid diversity measures.

An aspect of data collected over time that must be considered is the possibility that some species may no longer be present in an area and so should not be included in analysis. However, discovering what those species are is virtually impossible and, to have a large enough data set to analyse, we needed to use all of the sources available.

The concept of marine biodiversity hotspots and the results of data analysis were presented and discussed at a workshop held in Bristol on 24 July 2006. Main points from the assessment given above and feedback during the workshop are summarised as advantages and disadvantages in Appendix 8.

In summary, the data used here to identify marine biodiversity hotspots has shortcomings in relation to making analytical comparisons but can give a semi-quantitative exploratory insight into several measures of diversity. It is apparent that combinations of diversity measures are required to appreciate the status of a location, as several of the measures analysed were not congruent.

QUALITY ASSESSMENT

All areas of our coasts and seas have inevitably been affected by human activities. Some of those activities will have changed areas for ever – for instance, through land claim, port construction and habitat homogenisation (due to bottom fishing activity). Other adverse activities can be reversed or at least reduced – for instance, discharge of contaminants, species depletions due to over-fishing and physical disturbance, and unregulated species movements leading to the import of non-native species.

Quality assessment is a major issue for the implementation of the Water Framework Directive in UK waters and the status classes are shown in Box 10. Our aim here has been to produce a descriptive identification of status that will help in identifying the condition that an area is in and to track in the future whether that condition is improving or getting worse.

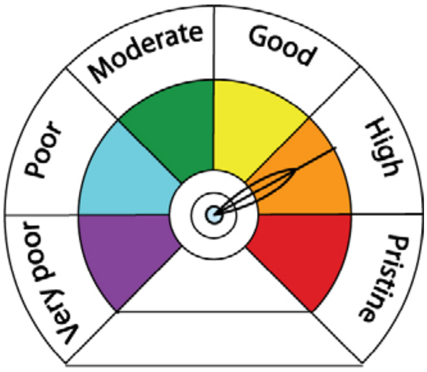
There are complex principles involved in identifying what the species numbers should be in a particular habitat or physiographic feature and there is a danger that degradation will have proceeded a long way before species numbers fall below recorded natural variability. For instance, the adverse effects of TBT antifouling paint on the fauna of enclosed areas was for a long time seen as causing shell thickening in oysters and imposex in dog whelks. It is now clear that TBT had a much wider effect on marine life and that species diversity in enclosed areas was probably devastated: for instance, Matthiessen *et al.* (1999) provide an account of changes in the Crouch Estuary following the prohibition of TBT use on small vessels in 1987. While a definite link to TBT could not be established, the increase in number of infaunal taxa from 15 in 1987 to 40 in 1991 and 47 in 1997 (and from 29 in 1987 to 39 in 1997 for epifauna) at the most inland site suggests that a considerable pressure on sensitive species had been significantly reduced.

Also, identifying meaningful indicators of biodiversity that are easy to relate to is not easy. The issue is addressed by Hiscock *et al.* (2005) for hard substrata and refers to a review of indicator species (see www.marlin.ac.uk/indicatorspp). It seems most likely that, for a particular location, 'quality' can best be assessed by an index that takes account of the expected number of species in that habitat as assessed by the particular survey method used and/or the proportion of sensitive species against species that are favoured by disturbance or pollution.

Box 10. The Water Framework Directive uses the following status classes:

High quality. The composition of animal taxa is consistent with undisturbed conditions and disturbance sensitive taxa are present. There are no disturbance-favoured species found and no non-native species.
Good quality. The composition of animal taxa is consistent with undisturbed conditions although species diversity (as number of species) may be below expected. Most of the disturbance sensitive taxa are present and/or there are some disturbance-favoured taxa present and/or non-native species.
Moderate quality. The composition of animal taxa is predominantly consistent with undisturbed conditions although species diversity (as number of species) may be below expected and/or disturbance-sensitive taxa are absent and/or significant numbers of the disturbance-favoured taxa are present and/or non-native species dominate in places.
Poor quality. Taxonomic diversity is low. The substratum is dominated by disturbance-favoured taxa and disturbance sensitive taxa are absent and/or the hard substratum is dominated by non-native species.
Bad quality. Taxonomic diversity is very low. The substratum is occupied only by disturbance-highly-favoured or neutral taxa.

From: Prior *et al.*, 2004. *Development of a classification scheme for the marine benthic invertebrate component*, Water Framework Directive. Environment Agency, unpublished.



The descriptive assessment for quality that we have used is:

1. **Pristine.** The area will include the range and abundance of native species that would be expected according to geographical location and physiographic features. Expected sensitive species are present and may be abundant while disturbance-favoured species are only present in naturally perturbated habitats. There are no non-native species present. The area will have no significant sources of contaminants and would not be subject to extractive or damaging human activities. The area would have no coastal development. [Such a definition might be found to apply to a strictly protected marine reserve although the abundance of mobile exploited species will never be at 'pristine' levels and climate change effects will be widespread.]
2. **High.** The area will include the range and abundance of native species that would be expected according to geographical location and physiographic features. Expected sensitive species are present and disturbance-favoured species are only present in naturally perturbated habitats. There may be some non-native species present but they do not dominate any habitats. The area would have no significant sources of contaminants and would not be subject to damaging human activities, although environmentally benign fisheries may be pursued. The area would have small coastal developments (villages, jetties, slipways etc.). [Such a definition might be found to apply to a remote area of coast distant from sources of contamination where small-scale fisheries occur that are not destructive to non-target wildlife.]
3. **Good.** The composition of species in natural habitats is consistent with undisturbed conditions although species diversity (as number of species) may be below expected. Disturbance sensitive species are present but there may also be some disturbance-favoured species present and several non-native species may occur. There may be fisheries but they use equipment that causes minimal disturbance. Levels of contaminants are strictly controlled and unlikely to have a significant effect. The area may include coastal developments such as towns or cities where there has not been extensive habitat modification (not affecting, say, more than 10% of the area). [Such a definition might be found to apply to an area where there is urban but not significant industrial development and some destructive fisheries.]
4. **Moderate.** The composition of species is predominantly consistent with undisturbed conditions although species diversity (as number of species) may be below expected. Although fisheries may have caused habitat homogenisation and continue to disturb the seabed, it is over areas that are capable of rapid recovery. Disturbance-sensitive species are

absent and/or significant numbers of the disturbance-favoured species are present and/or non-native species dominate in places. The area may include coastal developments such as towns or cities where there has been significant habitat modification (not affecting, say, more than 20% of the area) or offshore areas subject to frequent passes of heavy mobile fishing gear. [Such a definition might be found to apply to an area where there is urban but not significant industrial development and some destructive fisheries or other destructive activities such as channel dredging or aggregate extraction.]

5. **Poor.** Species diversity is lower than would be expected in the geographical area and physiographic situation. The substratum is dominated by disturbance-favoured species and disturbance sensitive species are absent and/or the substratum is dominated by non-native species. [Such a definition be found to apply to an area that is heavily industrialised and subject to effluents contaminated with harmful chemicals or high nutrient levels or an area that is heavily fished or subject to extensive habitat modification, including removal of habitats.]
6. **Very poor.** Species diversity is very low compared with would be expected in the geographical area and physiographic situation. The substratum is occupied only by disturbance-highly-favoured or neutral species and there are probably some areas that are azoic. [Such a definition might apply to an area which is heavily modified and subject to damaging contaminants or frequent habitat disturbance.]

Another way of describing areas that are 'pristine' or 'high' quality is 'Good news areas' (*sensu* Myers *et al*., 2000) – areas that appear undamaged or largely undamaged by human activities. However, we cannot select a series of representative MPAs on the basis that they are hardly affected by human activities. By selecting a full range of different habitat types, estuarine and sediment areas that require restorative action to make them high quality sites will also be included.

TAKING ACCOUNT OF CONNECTIONS IN THE MARINE ENVIRONMENT: THE CONCEPT OF 'NETWORKS'

Maintenance of the richness and special features (especially of rare species and fragile habitats) in an area needs an understanding of how species propagate themselves and how species recruit into the community. Biodiversity hotspots, in terms of high species richness, are most likely to be present in relation to high habitat diversity and to the presence of a wide variety of small niches – perhaps as result of the presence of key structural species such as horse mussels. But from where and how far do new recruits come?

A high proportion (perhaps almost all algae and half the invertebrate species, based on Kinlan & Gaines, 2003) of algae and sessile invertebrates have spores or larvae that are likely to travel less than 10 km with water currents before settling. Some have spores or larvae that fall to the seabed adjacent to adults, spending seconds in the water column. If currents take larvae and spores away from an MPA but there is no input of larvae and spores from outside the boundaries, the site is likely to become impoverished. Indeed, species rich areas may be 'sinks' for larvae rather than 'sources'. The health of the seas and of habitats as a whole (and not just in MPAs) is therefore of critical importance.

However, we do not know enough. Some nationally rare species with very short-lived larvae occur at distant locations – are those locations refugia from previously much more widespread distributions or, for instance, are there occasional ‘jet stream’ currents that bring larvae from distant locations? Most significantly, many of the species that are unlikely to recover if damaged by human activities are the ones with a short larval life where other MPAs are unlikely to be close enough to provide new recruitment. It is therefore of critical importance not to lose species populations and the habitats on which they depend wherever they occur.

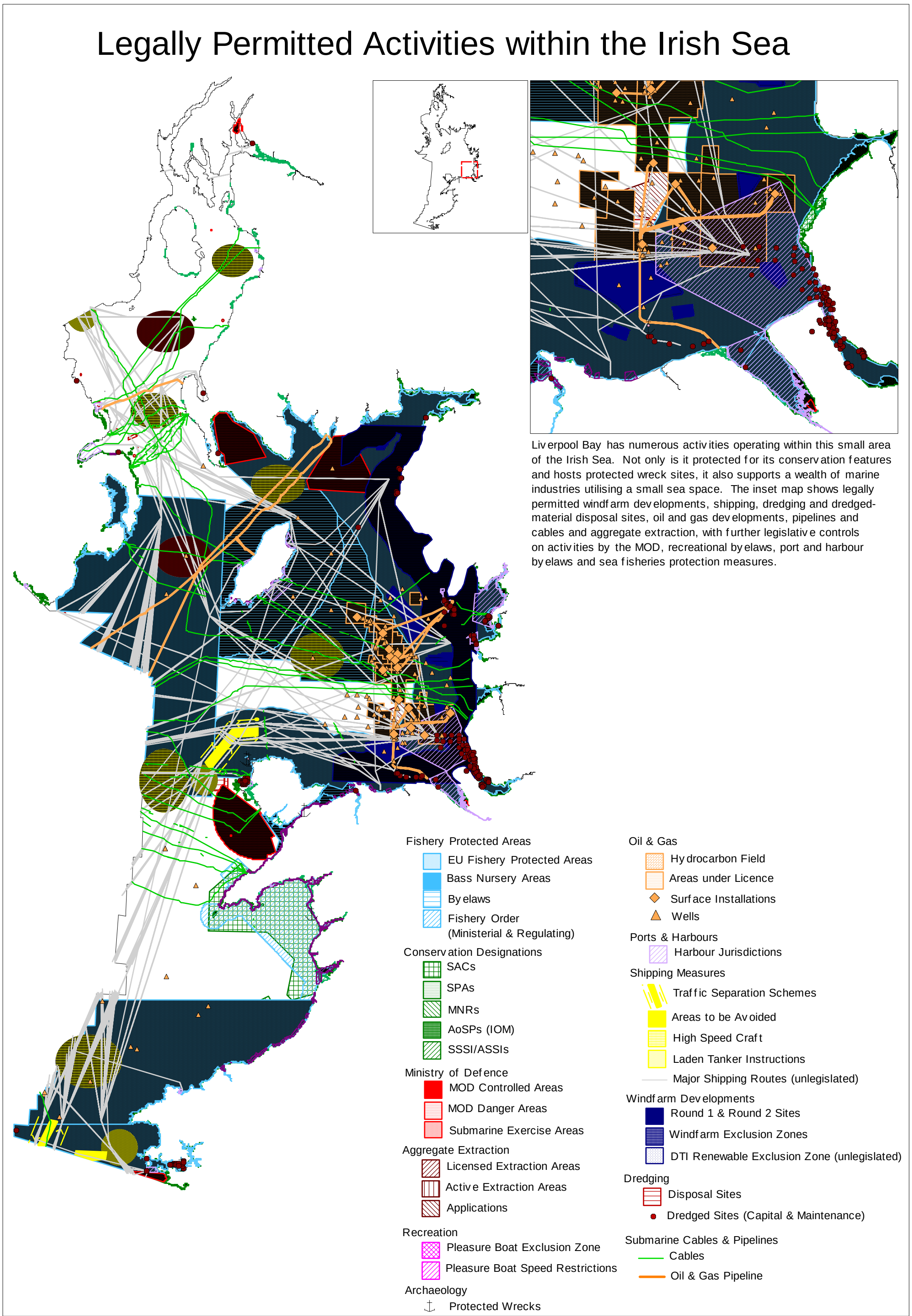


Figure 12. Legally permitted activities and designations in the Irish Sea. An illustration of how busy our seas are becoming. Copyright: © IECS, SNH, EN & CCW, 2005. Based on data from various sources.

Our seas are becoming busier than ever before. Legislation has led to reductions in the use of the sea to dispose of waste, but there seems little or no halt to destructive fishing practices that are destroying fragile structures and threatening the balance of food webs. Climate change is already having an effect on species distributions and may significantly change the species at a location; while another effect of increasing carbon dioxide levels – the increasing acidification of our seas – may also be catastrophic in the long-term for marine life. Non-native species continue to arrive in UK waters and some are already having an adverse effect on native biodiversity while we still cannot predict when a devastating species will arrive.

Box 11. Some human activities likely to damage marine species and communities. A more comprehensive list is available at www.marlin.ac.uk/PDF/activities3.pdf

Fisheries – mobile gear
Fisheries – fixed gear
Fisheries – gathering
Release of greenhouse gases, especially CO_2, resulting in climate change and ocean acidification
Coastal developments (ports, coastal defence, land claim etc)
Collecting – educational/scientific/curio
Dredging (capital and maintenance)
Dumping (non-toxic)
Eutrophication (nutrient enrichment)
Introduction of non-native species
Mariculture (oyster trays, mussel ropes, caged fish)
Offshore construction (oil/gas rigs, wind farms, artificial reefs)
Oil pollution
Pollution by persistent chemicals
Production of greenhouse gases – climate change
Sand and gravel extraction
Shipping

Box 11 lists some of the human activities that put 'pressure' on marine habitats and species. Those pressures may degrade or change the character of a hotspot, perhaps destroying features that made the location special. Some examples of vulnerable species and habitats are given in Appendix 9. If the irreplaceable features of sites are to be protected, it is important to remove damaging pressures. Assessing 'degree of threat' requires information on the intolerance of species and habitats and their likely recoverability if damaged, together with a measure of the likelihood of an event happening.

Many human activities have a transitory adverse effect on marine communities and their richness, especially where those communities are subject to naturally stressful environmental conditions such as in intertidal habitats, where immersion and emersion regimes occur, or in sediments mobilised every so often by storms. Damaging activities are particularly those that are irreversible (such as construction or dredging), that are poisonous (such as disposal of contaminants), or that destroy structural features of the seabed (such as through mobile fishing gear removing horse mussel beds). It is much less easy to predict consequences in other cases, such as climate change and the introduction of non-native species these impacts are likely to be irreversible and significant. The following sections are brief examples of the results of human activities most likely to damage biodiversity hotspots.

Plate 5. Extensive areas of estuarine habitat have been replaced by docks and harbours, losing natural habitat and gaining a variety of new surfaces for colonisation, possibly increasing biodiversity. Image: Harvey Tyler-Walters.

Loss of habitats as a result of construction

Some of the richest marine habitats are in enclosed waters that are also much sought-after for harbour developments. Communities such as those supported by maerl beds or sea grass beds, which are rich in species, may be replaced by concrete or by jetty piles and the seabed dredged to maintain shipping channels. While the introduction of hard substrata into otherwise sedimentary habitats may be considered to increase habitat and therefore species diversity, it is natural communities that are valued.

Coastal defence, usually by concrete embankments, together with sea level rise brought about by global warming, causes ‘coastal squeeze’ which reduces the extent of shore available for colonisation.

Fishing

Fishing impacts both stock size for commercial species and the ecosystem as a whole, including seabed habitats and species. Much attention has been paid to the changes that occur in the nature of seabed communities where fisheries can reduce infaunal diversity and cause loss of large and fragile species, favouring scavenging and predatory species. The most vulnerable areas include structurally diverse feature such as biogenic reefs, where damage by mobile gear reduces species richness as a result of:

- mortality of fragile species;
- loss of habitat-specific species (where habitat is destroyed);

- loss of refuges among structurally complex habitats; and
- impossibility of replacement where long-lived, slow-growing species with direct development or benthic larvae have been destroyed.

All in all, diversity is likely to be reduced and some long-lived species lost for ever. Hotspots of diversity, such as the horse mussel reefs in Strangford Lough, have been severely degraded by mobile fishing gear.

Contaminants and water quality

Contaminants from industrial discharges, including mine wastes and from shipping, especially from antifouling paint, have severely degraded the biology of locations and are a threat to the continued richness of hotspots. Fortunately, measures such as the Water Framework Directive should continue the improvement in water quality that has been proceeding for some years now.

A demonstration of how devastating contaminants can be to species richness is provided by the impacts of tributyl tin (TBT) antifouling paints. The use of TBT brought about one of the greatest 'disasters' to hit marine life, at least in enclosed areas of coast (for example, see Bryan *et al*., 1986). Possible 'signals' (indicators) that the ecosystem was suffering in some way (for instance, the lack of late stage oyster larvae in the plankton, and imposex and localised extinction of the dog whelk) were not spotted, and only when severe impacts such as shell thickening in oysters occurred were investigations commenced. What scientists failed to realise was that TBT was having a widespread and disastrous impact on benthic biodiversity with a large number of species adversely affected, especially at their larval stage. In the upper Crouch estuary, over the 10 years following the banning of use of TBT on small vessels, the number of seabed species present there doubled (Rees *et al.*, 2001).

Climate change and ocean acidification

The production of greenhouse gases and consequent climate change is having an effect on marine biodiversity, and we need to consider whether climate change will alter the location and nature of hotspots. Since it is the range of different habitats and their structural nature within an area that is most often important in determining high species richness, climate change may shift species occurrence. But, provided that locations have been protected from physical disturbance, chemical contamination and other local impacts, it might be expected that they will remain as hotspots.

However, there are more insidious effects of climate change that might occur and some that we have not yet worked out. For instance, warmer surface waters are likely to increase the strength of thermal stratification. In enclosed areas, such stratification can lead to the isolation of deeper waters and consequent de-oxygenation at the seabed. On the open coast, stronger stratification might 'block' the supply of nutrients from deeper water and reduce primary productivity that is the starting point for food chains. In southern California, species richness in mussel beds has declined by about 60% since the 1960s and has been linked to a decline by 80% in zooplankton biomass which, in turn, has been linked to increased stratification of coastal waters that may be the result of seawater warming (Smith *et al.*, 2006).

The acidity of the oceans is increasing as a result of increased carbon dioxide from the atmosphere being absorbed by seawater and forming carbonic acid. Although there would have to be a significant rise for that acidity to affect organisms (especially marine life with calcium carbonate skeletons or structures), some predictions suggest that it might happen (see Royal Society, 2005). Very many marine organisms have calcium carbonate skeletons and, if those skeletons cannot be maintained, the impact on marine ecosystems will be catastrophic.

Box 12. Likely impacts of climate change on marine biodiversity and hotspot status

Warming seawater temperatures:
Increase in number and abundance of southern species at locations (through migration, enhanced reproductive ability and enhanced survival). Species richness and possibly abundance of rare species may be enhanced. 'New' areas may become important for previously rare species.

Decrease in numbers and abundance of northern species at locations (through migration, reduced reproductive ability and reduced survival). Locations important for occurrence of northern species may no longer be important.

Non-native species introduced as not reproductively viable in colder-than-native climes become viable and reproduce to threaten native species.

Increasing extent and stronger stratification of waters leading to:
- De-oxygenation and mortality of species in enclosed areas. Hotspots may be lost.
- Blocking of nutrients, reducing productivity and therefore food availability and species survival.

Species richness may decline and hotspots may be lost.

Warming air temperatures leading to:
Increase in number and abundance of southern species and decrease in northern species as described for seawater temperature rise.

'Overheating' of rockpools leading to unsuitability for some species.

Rising sea level causing 'coastal squeeze':
Reduced extent of specifically intertidal biotopes and possible loss of some special features such as rockpools.

Increased storminess:
Increased likelihood of fragile species being damaged and 'wash-out' of seabed organisms.

Plate 6. The non-native Pacific oyster *Crassostrea gigas*, helped by warmer temperatures, has taken over areas of shore in parts of Europe, and is becoming abundant in some locations in the UK. Noss Mayo, South Devon. Image: Keith Hiscock.

Plate 7. Decaying brittlestars killed as a result of a bloom of a non-native dinoflagellate alga in Killary Harbour, Ireland. Image: Rohan Holt.

Non-native species

The possible impact of non-native species on biodiversity hotspots is difficult to predict, in part because we do not know what species will arrive next, but it could be devastating in some locations and habitats. For instance, the non-native dinoflagellate alga *Karenia mikimoto* (previously *Gymnodinium aureolum*) occurring in high concentrations can result in fish kills, de-oxygenation and the widescale death of benthic organisms (see Silke *et al.*, 2005). Another species, the slipper limpet *Crepidula fornicata* is now dominant on some areas of seabed in the English Channel, displacing native species. In sheltered inlets, its pseudofaeces can change the character of the seabed and may change a biodiversity hotspot to one that is species poor and dominated by opportunistic and a non-native species. For instance, slipper limpets becoming dominant on a maerl bed would be a disaster for species richness there and rare and threatened species would be lost.

Another species to watch out for is the Pacific oyster *Crassostrea gigas*, which was introduced for mariculture and is now occurring as wild populations. The species can become dominant (as has happened in the Netherlands and parts of France), reducing local diversity and changing the character of the shore. Our biosecurity is very poor and the next species to enter UK waters may be disastrous for native species and destroy the importance of current hotspots.

POLICY LINKS

Being able to assess the status of an area in terms of species richness, biotope richness, NIMF species and biotope richness, and taxonomic or biotope distinctness (the biodiversity hotspot measures) informs the identification of areas that can best represent the diversity of marine habitats and species in our seas and which should be protected. The identification of effective MPAs is a recommendation of the Review of Marine Nature Conservation (RMNC) (Defra, 2004) and featured in the consultation for a Marine Bill early in 2006. Box 8 indicates where hotspot measures can be used to support application of the assessment criteria developed as apart of the RMNC. Policy makers may see a value in identifying areas where biodiversity hotspot measures are high on the basis that such areas will provide best ‘value for money’ in terms of the range of species and habitats protected. However, care is needed: hotspot measures can be artificially inflated by intensive survey by expert biologists. An approach to comparing sites at the level of species richness beyond which a 100% increase in sampling effort will produce only 10% more species may be a pragmatic solution.

CASE STUDIES

Eight contrasting locations have been selected to demonstrate how objective scientific information can be used to identify the importance of an area for biodiversity, to demonstrate the factors that might adversely affect the area and identify any special features of those areas. The locations are either existing protected areas or may, for a variety of reasons outlined in the case studies, be considered for protection in the future. Only the inshore locations have sufficient information to assess hotspot measures, and all of those score highly for at least one measure. The areas are:

- Rathlin Island, Northern Ireland
- The Menai Strait, north Wales
- Plymouth reefs, south Devon
- The Blackwater Estuary, Essex
- The Dogger Bank

- Mull area, western Scotland
- Unst, Shetland
- The Hatton Bank

For each location, a dossier of information has been produced (see Appendix 10). Figures from the detailed analysis of the data set are included in the dossiers. Where NIMF biotopes are referred to, we have taken the biotopes that were listed in Hiscock *et al.* (2006) but moderated them according to the criteria suggested in that report.

The special features of each area and the variety of measures that they achieved are discussed briefly below.

Rathlin Island is highly regarded as a location where there is an exceptional variety of species, including rare and scarce species, often in habitats that are rarely observed elsewhere in the UK. Of the species recorded off Rathlin Island in 1983, 26 are listed as being nationally important in the draft list. Of these 26 species, nine are scarce and two are rare. The 2005 and 2006 surveys have identified further rare species, including the burrowing sea anemone *Halcampoides* '*abyssorum*', and have especially revealed the very high richness of sponge species, with about 150 species recorded (about one third of the total sponge fauna recorded for Britain and Ireland) (Bernard Picton, personal communication).

In the analysis for hotspot measures, Rathlin ranks highly for NIMF species richness. Although not ranking highly for other measures, it is important to consider that the survey results used in the exercise described here were from surveys in 1983 predominantly on rock habitats. Surveys undertaken in 2005 and 2006 will no doubt increase the species richness ranking. Inevitably, the restricted range of habitats surveyed in 1983 has also led to a low biotope richness measure.

The Menai Strait is a 'hotspot' because of high species and biotope richness and because of the presence of well-developed examples of rare habitats. The area ranks highly for species and biotope richness but is average/expected for presence of NIMF species and biotopes and for taxonomic distinctiveness in species and biotopes. The area has been highly sampled (which might be considered to skew species and biotope richness measures upwards), but it is considered that the high species richness is a result of high variety of habitats in a small area (a central consideration in identifying hotspots) and that the 'special' features (communities typical of extremely strong currents, rich underboulder communities, rich muddy gravel communities) are of importance.

Plymouth Reefs rank highly for NIMF species richness and for taxonomic distinctness. The habitats in the vicinity and offshore of Plymouth present a very wide variety of open coast hard substratum and sediment habitats. Those habitats have been studied for over 100 years, albeit using dredges and grabs for most of the period, and their fauna and flora are well documented. However, the data available for analysis did not include data from the fauna (Marine Biological Association, 1957) and flora (Anonymous, 1952) lists for the area or from various sediment fauna surveys undertaken up to the 1980s. The case study is therefore for reefs.

The Dogger Bank includes North Sea sediment communities capable of some restoration towards natural communities. The case study by Gubbay *et al.* (2002) identifies characteristics and threats. However, more sampling information is required to identify any special features that might be present, including any Nationally Important Marine Features. Also, the possibility that an SAC would be established for ‘shallow sandbanks slightly covered by seawater all the time’, with boundaries determined so that the SAC is mainly shallower than the 20m depth contour, would not make ecological sense and boundaries should be determined according to maintaining integrity of representative biotopes and of structure and functioning. The issues surrounding a possible transboundary MPA for the Dogger Bank are explored by Unger (2004).

Mull ranks highly for NIMF species richness and has generally high scores for other measures. The variety of habitats and associated species makes the area of Mull of high value and, if combined with adjacent high scoring areas (Loch Sunart, Loch Linnhe and Loch Creran), the area is outstanding for most hotspot measures.

Unst ranks highly for taxonomic distinctness and, considering its northern location and comparatively small number of sample sites, has generally high scores for other measures. The highest value for Unst is not identified directly in the hotspot measures: the area is important as the northernmost outpost of the UK and has significant populations of arctic-boreal species that only occur in the far north. The marine habitats are adjacent to terrestrial sites of natural heritage importance, especially the National Nature Reserve at Hermaness and the area attracts large mammals including killer whales.

The Hatton Bank is highly regarded for its deep water hard substratum habitats, including coral structures and associated species. The area includes pristine deep water habitats, although some areas are no doubt damaged by trawling. The area is representative of the topographical rises from the deep sea to the north-west of Britain and seems to include some, if not the best, examples of hard substratum deep water communities in UK waters. Very little is known of the biology of deep sea habitats and so it is difficult to identify species that are rare or threatened. What is certain is that the coral habitats in particular are highly susceptible to physical damage.

CONCLUSIONS

We have demonstrated what can be done to identify and document marine biodiversity hotspots. We have found that the data sources for inshore areas around the UK are good for much of the inshore area and allow semi-quantitative measures to be applied. However, the data sets are a mixture of many surveys that range in quality and the quantity of species or taxa recorded, and are uneven in relation to the range of habitats surveyed and sampled in an area, and regarding whether or not biotopes have been identified from survey data.

We are also aware that there are important data sets from surveys that had not yet been submitted to the NBN at the time we started analysis, so such surveys have not been included in the exercise described here. Such difficulties prevented full application of objective comparative analysis – leading to the restricted analysis described in the text. Results from the analyses that are possible with the datasets available are therefore indicative and a contribution to identifying the highest value locations for conservation. Work can be done, and must be a part of future data gathering, to identify the quality of data sets so that only relevant ones are used in analysis.

Ideally, future surveys should ensure ‘evenness’ in sampling within the landscapes or physiographic features being surveyed so that comparison is possible. Especially where data is lacking, the ever-dwindling number of scientists with field experience can provide guidance and wisdom about the importance of areas. Training will be needed to initiate new survey teams able to use appropriate *in situ* survey techniques and able to identify species and biotopes. The range and type of data that is required to undertake hotspot analysis is outlined in Box 13. The categories listed are essentially those identified for MNCR surveys (see Hiscock, 1996) and a survey programme to achieve them fully is greatly reliant on good weather during survey events.

Box 13. The range and type of data required to undertake biodiversity hotspot analysis for a location. The specification takes account of types of data already available so that comparative studies are facilitated

Requirements for comparative assessments of species richness, NIMF species richness, biotope richness and NIMF biotope richness:

1. Inventory of conspicuous fully identified species on hard substrata (collected by *in situ* survey including identification of collected specimens. Usually recorded as semi-quantitative abundance).*
2. Inventory of fully identified species from sediments collected by specified minimum sample areas per habitat and sieved over a 0.5 or 1mm mesh (usually undertaken by remote sampling and abundance of individuals recorded as semi- or fully quantitative abundance).*
3. Samples to be collected from all of the major habitats present (i.e. zonal habitats and habitats related to wave exposure, tidal stream strength and the range of different substrata in an area).
4. All data sets interpreted to list the biotopes represented in the area.

* If biotopes only are being identified, detailed species lists will not be needed.

Data that can additionally be used for taxonomic distinctness but not species richness (see text):

1. Taxa records not identified to genus and species.

Data that is likely to be too specialist to be included in comparative analysis:

1. Meiofauna data.
2. Kelp holdfast fauna data
3. ‘Weed washing’ data.

Nationally Important Marine Features (NIMF) (species and biotopes) provide a means of testing datasets for levels of ‘importance’ in nature conservation terms, but the species and biotopes identified in the most recent candidate lists by application of criteria still need some common sense applied. For instance, species such as ross worm *Sabellaria spinulosa*, the common sea urchin *Echinus esculentus*, the Devonshire cup coral *Caryophyllia smithii*, and the sand goby *Pomataschistus minutes* (from OSPAR lists) should not be included as they are widespread in the UK and recruit (recover) readily.

Some species, such as maerl species, did not achieve the criteria requirements but should be included. Some biotopes assessed as threatened (and therefore qualifying as NIMF) are nevertheless widespread and it is questionable whether they should be included. The ‘Grouped Action Plan’ for commercial fish was very unhelpful as many common species are exploited and should not separately qualify as NIMF (they have been excluded from the case studies).

Nevertheless, the concept behind NIMF is sound, and NIMF species richness and NIMF biotope richness, when based on finally moderated lists of species and biotopes, should be of great value in assessing the importance of an area in relation to the degree of conservation required.

"In practical decision-making, the use of total professional experience (including any existing detailed data) is the essential approach in any important matter, such as the selection of marine areas for special treatment."
Dr Bill Ballantine

Cautions
"The hotspot approach protects a tiny sample of the Earth. Meanwhile you could be ignoring ecosystems that are hugely important to mankind."
Dr Peter Kareiva

WHAT TO DO NOW

We need to know what and where the marine conservation 'resource' is and how it is changing. Monitoring studies in SACs and in relation to assessing 'quality' for implementation of the Water Framework Directive will help to understand how our seas are changing, but studies are often not targeted on the rare and threatened species and habitats or on aspects of the biology of those species relevant to conservation. There are major gaps in our knowledge of what marine wildlife is where, which can be filled by:

- accessing many more of the available data sets (see www.dassh.ac.uk);
- ensuring that the quality and type of data sets is identified so that they can be screened for appropriate use; and
- initiating major new surveys to continue the work of the Marine Nature Conservation Review which was finished prematurely in 1998.

'Unevenness' of survey coverage has been a significant problem in analysing data sets from locations identified in this hotspots exercise; in future, such exercises would benefit from balanced (i.e. evenly across different habitats) sampling – as much as the weather during sampling periods allows.

ACKNOWLEDGEMENTS

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APPENDIX 1. SUMMARY FROM THE MARINE BIODIVERSITY HOTSPOTS WORKSHOP HELD ON 24 JULY 2006

Following introductory presentations, workshop participants contributed to developing the hotspots concept through four themed breakout sessions. The following is a summary of the main points made, including several points that are overarching. They are not conclusions.

The concept

1 Marine biodiversity 'hotspots' is a new name for an old concept, i.e. identifying representative areas and 'the best examples' for conservation. [In fact, biodiversity hotspots are intended to encompass areas with a wide variety of habitats and therefore species, so the concept is different to representativeness.]

2 'Hotspots' is an attractive influencing/publicity term.

3 The identification of hotspots based on available survey data is just one 'tool in the box' and should be used with other measures of importance.

4 Single species hotspots (for instance breeding and spawning locations) have not been included in the MBA exercise.

5 Simplistic application of hotspots to identification of locations for protection is potentially misleading because the data used is uneven in coverage and completeness.

6 Areas that are not 'hot' may be considered not worthwhile.

7 The units for comparison (physiographic features) might seem similar but may be vastly different in size and structure; for instance 'estuary'.

Information needs

8 Biotope diversity may be a useful surrogate for species diversity where broad scale survey methods are used.

9 However, sparse offshore survey data to identify biotopes and lack of information about species richness where broad scale methods are used makes biotope diversity a poor surrogate for hotspots.

10 Hotspots focus on species and biotope richness, and other features such as the presence of structural species or species particularly important for productivity are ignored.

11 Hotspots that are based on **presence-absence** data for rare and scare or threatened species will not indicate locations where those species are abundant.

12 Old data may not be valid and might add species no longer present to recent survey data so that a spuriously high richness is indicated. However, we do not have enough datasets to disregard old data.

13 Knowledge of natural fluctuations is needed to help interpret the available data sets.

14 The hotspot methodology developed in the project is 'data hungry' and there is a danger that only data rich areas will rank highly with intuitively worthwhile areas being ignored.

15 The north and north-east of the UK is naturally more poor in species than the west and south-west and lower scores may need to be adopted as cut-offs. Hotspots should therefore be identified using a regional seas approach.

16 'Quality' descriptions [referring to the six quality ranks described] are a useful tool for reporting.

Marine nature conservation measures to manage hotspots

17 As a starting point, it needs to be clear where hotspots fit with other conservation measures, and to articulate their role clearly to policy advisers.

18 It needs to be acknowledged that the current legislative and enforcement framework is weak for marine biodiversity conservation.

19 'Measures' must include robust enforcement, including consideration of jurisdictional and governance matters.

20 There must be stakeholder engagement from an early stage in developing measures.

21 Measures include monitoring of features present and quality – including to assess change with time.

22 Care will be needed to ensure that any focus on hotspots does not lessen the value of sites of marine natural heritage importance for other reasons.

23 If measures include no-go areas for fishing especially, consideration will need to be given to effects of effort displacement.

24 Hotspots may be the basis for the identification of nationally important sites.

25 Hotspots should be managed for their role as reference areas, for their potential for fish stock enhancement and raising awareness.

The role of marine protected areas for the management of hotspots

26 The management of hotspots is, as for any area identified as important for its biological diversity, a matter of having clear objectives and robust enforcement measures.

27 It is important to understand why an area has been identified as a hotspot in order to establish management objectives: i.e. what species or biotopes are driving the hotspot status? What is their importance or sensitivity?

28 MPAs should be a key tool for managing hotspots.

29 But, what is an 'ecologically coherent network' of MPAs? We need to better understand connectivity in marine systems to see if the concept makes sense.

30 MPAs suffer from 'shifting baselines' and some may need to be de-notified in the future.

31 Public views are important and need to be considered.

32 The burden of proof (of whether or not damage is likely to a location as a result of some human activity) needs to be reversed and (in line with EC case law for Special Areas of Conservation) fall to the developer to prove that biodiversity interest will not be damaged.

33 Marxan [a computer program that supports identification of MPAs] can be used to 'lock-in' hotspot areas when determining an MPA series.

Hotspots in the context of the management of the wider seas

[Several points raised under this workshop theme have already been included above and are not repeated.]

34 Identification of hotspots will contribute to zoning in the context of Marine Spatial Planning.

35 Hotspots will not deliver the Ecosystem Based Approach (EBA) but could provide locations used to monitor change including as reference sites.

36 Identification of hotspots might encourage public interest but other stakeholders, especially public representatives, need to be mobilised.

37 The hotspots approach needs to be linked to ecosystem-based objectives.

38 Thinking is needed on the role of hotspots within Marine Spatial Planning.

39 If hotspots are protected from impacts, especially fishing, shifting those damaging activities could extend the areas damaged.

40 Conservation can have major economic value [as well as consumptive/exploitive activities].

41 Governance structure is a major issue and it is unclear who will manage protective measures.

42 Whatever we do to identify worthy sites for conservation, ownership and jurisdiction is a difficult problem.

43 It is unclear where hotspots fit in the scheme of nature conservation needs and uses and clarity is needed.

44 Biodiversity ‘coldspots’ may be important for ecosystem functioning and that importance needs to be taken into account in management (hotspots may not be congruent with areas important for ecosystem functioning).

45 The identification of hotspots, as undertaken in the MBA exercise, ignores fish populations.

46 There are questions of where boundaries should be in hotspot-based MPAs – are buffer zones needed?

47 Ancestral evidence needs to be taken into account – especially where areas that were once rich are now damaged.

48 Understanding why an area is a hotspot (is it physical structures or what?) is important for management.

49 Because of the influence of sampling intensity on hotspot identification, the presence of high diversity (i.e. hotspot) of an area should not be the sole reason for designating an MPA.

50 The identification of hotspots can be informed by public participation in collecting data – especially in relation to identifying hotspots for Nationally Important Features.

All of the above points need to be taken into account to ensure organisational and personal buy-in, which means that we have to understand their needs and concerns.

APPENDIX 2. SUMMARISED CRITERIA IN THE UK FOR IDENTIFYING NATIONALLY IMPORTANT MARINE FEATURES

Criteria were developed by the Marine List Review Group contributing to the UK BAP Priority Species and Habitat Review and are given in full in Appendix 1 and 2 of Hiscock *et al.* 2006.

Species

CRITERION 1: Proportional importance

A high proportion of the populations of a species occurs within the UK. Species are categorised as follows:

Global importance: a high (>25%) proportion of the global population of a species occurs within the UK.

Regional importance: a high (>30%) proportion of the regional (north-east Atlantic within the OSPAR area) population of a species.

CRITERION 2: Rarity

Marine species that are sessile or of restricted mobility are considered nationally rare if distribution is restricted to eight or less 10km squares (0.5%) within the three-mile territorial seas limit of UK waters. A mobile species qualifies as nationally rare if the total population size is known, inferred or suspected to be fewer than 250 mature individuals. Outside of inshore areas, sparse survey data makes it difficult to apply quantitative criteria and expert judgement is used.

CRITERION 3: Decline

An observed, estimated, inferred or suspected significant decline (exceeding expected or known natural fluctuations) in numbers, extent or quality of a marine species in the UK (quality refers to life history parameters).

CRITERION 4: Threat of decline

It is estimated, inferred or suspected that a species will suffer a significant decline in the foreseeable future as a result of human activity. This assessment will need to take into account inherent sensitivity, and expected degree of exposure to the effects of human activity.

Habitats

CRITERION 1: Proportional importance

A high proportion of the marine habitat occurs within the UK. This may be related to either global or regional extent of the feature. Habitats are categorised as follows:

Global importance: a high proportion of the global extent of a marine habitat occurs within the UK. ‘High proportion’ is considered to be more than 25%.

Regional importance: a high proportion of the regional extent of a marine habitat occurs within the UK. ‘Regional’ refers to the north-east Atlantic (OSPAR) area. ‘High proportion’ is considered to be more than 30%.

CRITERION 2: Rarity

Marine habitats are considered nationally rare if distribution is restricted to a limited number of locations. For pragmatic reasons, habitats are considered rare if recorded in eight or less 10km squares (0.5%) within the three-mile territorial seas limit of UK waters. (The figure is calculated for the UK as a whole and with the Isle of Man so that rarity is assessed in a relevant geographical area and for a distance offshore that includes most of the variable habitats before the level sediment plain is reached. See Sanderson (1996) for an explanation with regard to species.)

CRITERION 3: Decline

An observed, estimated, inferred or suspected significant decline (exceeding expected or known natural fluctuations) in extent or quality of a marine habitat in the UK. The decline may be historic, recent or current. Alternatively, a decline at a global or regional level, where there is cause for concern that the proportional importance criteria will be met within the foreseeable future. Decline in extent and quality of habitats at different scales should be assessed as follows:

Extent:

- A marine habitat that has declined in extent to 90% or less of its former natural extent in the UK (i.e. there has been a decline of 10% or more); or
- Its distribution within the UK has become significantly reduced (e.g. lost from several sub-regions).

Quality: A marine habitat for which quality, based on change from natural conditions caused by human activities, is negatively affected by:

- A change of its typical or natural components over a significant part of its UK distribution; or
- The loss of its typical or natural components in several sub-regions.

Such judgement is likely to include aspects of biodiversity, species or habitat composition, age composition, productivity, biomass per area, reproductive ability, non-native species and the abiotic character of the habitat.

CRITERION 4: Threat of decline

It is estimated, inferred or suspected that a habitat will suffer a significant decline (as defined under the "decline" criterion) in the foreseeable future as a result of human activity. This assessment will need to take into account inherent sensitivity, and expected degree of exposure to the effects of human activity. A habitat may also qualify under this criterion if there is real cause for concern that it would fulfil the proportional importance criterion in the near future due to threat of global or regional decline.

[Full criteria are available from: Lieberknecht, L.M., Vincent, M.A., & Connor, D., 2004. *The Irish Sea Pilot – Report on the identification of nationally important marine features in the Irish Sea.* Joint Nature Conservation Committee, Peterborough.]

APPENDIX 3. MARINE SACS AROUND THE UK COASTLINE. THE LIST INCLUDES PROPOSED AND POSSIBLE SACS

Table 1. Special Areas of Conservation notified or being considered for submission under the Habitats Directive for Annex I and Annex II marine features. The primary reasons for notification are given, followed (after "Also") by any secondary reasons. Some Annex I habitat titles are abbreviated. Otter are included where they appear to be using the sea for habitat. Information is derived from that given on www.jncc.gov.uk/page-1458.

Number on map	Name	Area (ha)	Status
1	North Rona (Grey seal. Also, Reefs, Sea caves)	628.53	SAC
2	Loch Laxford (Large shallow inlets and bays. Also, Reefs)	1221.33	SAC
3	Loch Roag Coastal lagoons (Coastal lagoons)	43.62	SAC
4	St Kilda (Reefs)	25467.58	SAC
5	Obain Loch Euphoirt (Coastal lagoons)	348.59	SAC
6	Monarch Islands (Grey seals)	3646.58	SAC
7	Loch nam Madadh Euphoirt (Coastal lagoons, Large shallow inlets and bays, Otter. Also, Sandbanks, Mudflats and sandflats, Reefs)	2320.38	SAC
8	Ascrib, Isay and Dunvegan (Common seal)	2585	SAC
9	Lochs Duich, Long and Alsh Reefs (Reefs)	2380.86	SAC
10	Sound of Arisaig (Loch Ailort to Loch Ceann Traigh) (Sandbanks)	4556.65	SAC
11	Sound of Barra (Bottlenose dolphins)	5279	Possible
12	Sunart (Otter. Also Reefs)	10246.72	SAC
13	Treshnish Isles (Grey seal)	1962.66	SAC
14	Loch Creran (Reefs)	1226.39	SAC
15	Firth of Lorn (Reefs)	20975.01	SAC
16	South-east Islay Skerries (Common seal)	1498	SAC
17	Rathlin Island (Reefs, Sea caves)	3344.62	SAC
18	Strangford Lough (Mudflats and sandflats, Coastal lagoons, Large shallow inlets and bays, Reefs. Also, common seal)	15398.54	SAC
19	Luce Bay and Sands (Large shallow inlets and bays. Also, Sandbanks, Mudflats and sandflats, Reefs)	48759.28	SAC
20	Solway Firth (Sandbanks, Estuaries, Mudflats and sandflats, Sea lamprey, River lamprey. Also, Reefs)	43636.72	SAC
21	Drigg Coast (Estuaries. Also, Mudflats and sandflats)	1397.44	SAC
22	Morecambe Bay (Estuaries, Mudflats and sandflats,	61506.22	SAC

Number on map	Name	Area (ha)	Status
	Shallow inlets and bays. Also Sandbanks, Coastal lagoons, Reefs)		
23	Dee Estuary/Aber Dyfrdwy	15754.93	Possible
24	Y Fenai a Bae Conwy/Menai Strait and Conwy Bay (Sandbanks, Mudflats and sandflats, Reefs. Also, Large shallow inlets and bays, Sea caves)	26482.67	SAC
25	Bae Cemlyn/Cemlyn Bay (Coastal lagoons)	43.43	SAC
26	Pen Llyn a`r Sarnau/Lleyn Peninsula and the Sarnau (Sandbanks, Estuaries, Coastal lagoons, Large shallow inlets and bays, Reefs. Also, Mudflats and sandflats, Sea caves)	146023.48	SAC
27	Cardigan Bay/Bae Ceredigion (Sandbanks, Reefs, Sea caves, Bottlenose dolphin. Also, Sea lamprey, River lamprey, Grey seal)	95860.36	SAC
28	Pembrokeshire Marine/Sir Benfro Forol (Estuaries, Bays, Reefs, Grey seal. Also, Sandbanks, Mudflats and sandflats, Coastal lagoons, Sea caves, Sea lamprey, Allis shad, Twaite shad, Otter)	138069.45	SAC
29	Carmarthen Bay and Estuaries/ Bae Caerfyrddin ac Aberoedd (Sandbanks, Estuaries, Large shallow inlets and bays, Twaite shad. Also, Sea lamprey, River lamprey, Allis shad)	66101.16	SAC
30	Severn Estuary / Môr Hafren	73487.75	Possible
31	Lundy (Reefs. Also Sandbanks, Sea caves, Grey seals)	3064.53	SAC
32	Isles of Scilly Complex (Sandbanks, Mudflats and sandflats, Reefs. Also, grey seal.)	26850.95	SAC
33	Fal and Helford (Sandbanks, Mudflats and sandflats, Large shallow inlets and bays. Also, Estuaries, Reefs)	6387.8	SAC
34	Plymouth Sound and Estuaries (Sandbanks, Large shallow inlets and bays, Estuaries, Reefs. Also Mudflats and sandflats, Allis shad)	6402.03	SAC
35	Chesil and the Fleet (Coastal lagoons)	1631.63	SAC
36	South Wight Maritime (Reefs, Sea caves)	19862.71	SAC
37	Solent and Isle of Wight Coastal lagoons (Coastal lagoons)	36.24	SAC
38	Solent Maritime (Estuaries. Also, Sandbanks, Mudflats and sandflats, Coastal lagoons	11325.09	SAC
39	Thanet Coast (Reefs, Sea caves)	2803.84	SAC
40	Essex Estuaries (Estuaries, Mudflats and sandflats. Also		SAC

Number on map	Name	Area (ha)	Status
	Sandbanks)		
41	Alde, Ore and Butley Estuaries (Estuaries. Also, Mudflats and sandflats)	1561.53	SAC
42	Benacre to Easton Bavents Lagoons (Coastal lagoons)	366.93	SAC
43	North Norfolk Coast (Coastal lagoons)	3207.37	SAC
44	The Wash and North Norfolk Coast (Sandbanks, Mudflats and sandflats, Large shallow Inlets and bays, Reefs, Common seal. Also, Coastal lagoons)	107761.28	SAC
45	The Humber Estuary	39492.89	Possible
46	Flamborough Head (Reefs, Submerged or partially submerged sea caves)	6311.96	SAC
47	Berwickshire and North Northumberland Coast (Mudflats and sandflats, Large shallow inlets and bays, Reefs, Sea caves, Grey seals)	65045.5	SAC
48	Tweed Estuary (Estuaries, Mudflats and sandflats. Also, River lamprey, Sea lamprey).	155.93	SAC
49	Isle of May (Grey seal)	356.75	SAC
50	Firth of Tay and Eden Estuary (Estuaries, Common seal. Also, Sandbanks, Mudflats and sandflats)	15412.53	SAC
51	Moray Firth (Sandbanks, Bottlenose dolphin)	151341.67	SAC
52	Dornoch Firth and Morrich More (Estuaries, Mudflats and sandflats, Common seal. Also, Sandbanks, Reefs)	8700.53	SAC
53	Loch of Stenness (Coastal lagoons)	791.87	SAC
54	Faray and Holm of Faray (Grey seal)	785.68	SAC
55	Sanday (Reefs, Common seal. Also, Sandbanks, Mudflats and sandflats)		SAC
56	Mousa (Common seal. Also, Reefs, Sea caves)	530.6	SAC
57	Papa Stour (Reefs, Sea caves)	2076.69	SAC
58	The Vadills (Coastal lagoons)	62.43	SAC
59	Sullom Voe (Large shallow inlets and bays. Also, Coastal lagoons, Reefs)	2698.55	SAC
60	Yell Sound Coast (Otter, Common seal)	1540.55	SAC

APPENDIX 4. CATEGORIES OF DECLINE USED IN THE WWF-UK MARINE HEALTH CHECK

For the purposes of this report, we have adopted the following descriptive terms which are based on work undertaken by OSPAR, by *MarLIN* and in the EU 6th Framework project European Lifestyles and Marine Ecosystems (ELME: www.elme-eu.org). Reference is made to the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List categories (see: www.redlist.org/info/categories_criteria2001.html).

Seabed habitats

Rank	Scenario
Lost	**Extent:** the habitat and its associated community is destroyed or removed. There is no evidence to suggest it still exists. **Degradation:** the 'quality' or 'structure' of the habitat is so severely degraded that it can no longer support its typical community or characteristic species.
Severe decline	**Extent:** over 75% of the spatial extent (or density of key structural[1] or key functional[2] species) of the habitat is lost, OR the majority[3] of the habitat has been lost. Where its overall extent remains, the habitat is reduced to widely dispersed, small fragments. **Degradation:** the habitat has experienced a severe reduction (over 75%) in the abundance of associated key structural or key functional species, and the species richness or biodiversity is minimal. Further degradation is likely to result in loss of the habitat.
Significant decline	**Extent:** the spatial extent (or density of key structural or key functional species) of the habitat has declined by over 25 to 75% of prior distribution OR the spatial extent (or density) has declined 'considerably'[4]. The habitat has either shrunk in spatial extent or been fragmented. **Degradation:** The population(s) of species important for the structure and/or function of the habitat may be reduced or degraded by the factor under consideration, the habitat may be partially destroyed, or the viability of a species population, species richness and biodiversity, and function of the associated community may be reduced. Further degradation may result in severe decline (above).

[1] Key structural – the species provides a distinct habitat that supports an associated community. Loss/degradation of this species population would result in loss/degradation of the associated community.

[2] Key functional – the species maintains community structure and function through interactions with other members of that community (for example, predation, grazing, competition). Loss/degradation of this species population would result in rapid, cascading changes in the community.

[3] The term 'majority' is used to denote a 'major' (or 'mostly') loss, fragmentation or mass mortality.

[4] The term 'considerable' is used to denote a change in status that indicated that the habitat is (or was) under threat and action needed. Similar terms might include 'significant', 'much', 'large scale', or 'a lot'.

Decline	**Extent:** the spatial extent (or density or key structural or functional species) has reduced by 25% or less OR the habitat has suffered a 'minor'[5] but 'noticeable' reduction in spatial extent (or density). The majority of the habitat remains but has either shrunk in extent, exhibits cleared or disturbed patches or shows signs of erosion or encroachment at its edges. **Degradation:** species important for the structure and/or function of the habitat are still present but their abundance is reduced. Especially sensitive, rare or scarce species are missing, especially those species sensitive to environmental change and disturbance. The viability of a species population or the biodiversity/functionality in a community is reduced. Further degradation may result in significant decline (above).
Degraded	The spatial extent (or density or key structural or functional species) is not reduced. However, the habitat demonstrates signs of degradation, change in function or stress. Further degradation may result in decline (above). Symptoms will depend on the habitat in question. For example, especially sensitive, rare or scarce species are missing or reduced in abundance, especially those species sensitive to environmental change and disturbance. Biodiversity and species richness are reduced. Opportunistic species or species tolerant of disturbance may be increasing in abundance. Key structural or functional species may exhibit disease or reduced viability (growth or reproduction rates).
Stable	No change in status (spatial extent, abundance or community function) reported or expected.
Increased	The spatial extent (or density of key structural or functional species) has increased over that expected or observed due to natural variability.

Species

Rank	**Scenario**
Lost	The population of the species is no longer present or there is a high probability that the last individuals have died or moved away, or if surveys in the study area have repeatedly failed to record a living specimen.
Severe decline	The population demonstrates a high[6] and rapid[7] decline in numbers in the study area[4], or the species has already disappeared from the major part of its former range in the area, or population numbers are at a severely low level due to a long[8], continuous decline in the past.

[5] The terms 'minor' or 'noticeable' are used to suggest a measurable change in status that causes concern. Similar terms might include 'chronic change', 'mild', 'some reduction', 'somewhat reduced', 'reduced', 'smaller than'.

[6] 'High' might be quantified as an over 70% reduction in the population, using IUCN categories of 'Critically Endangered, and 'Endangered' as a guide.

[7] 'Rapid' means 'within a year or less'.

[8] 'Long' in environmental management terms might be quantified as 'over 10 years'.

Significant decline	The population has undergone a 'considerable'[9] decline in numbers, range, and distribution beyond that expected by natural variability.
Decline	The population has suffered a 'minor'[10] but 'noticeable' reduction in numbers or distribution, or evidence suggests that there is a high probability of significant decline (above) due to reduced recruitment and/or reproductive individuals, or continued unsustainable extraction.
Stable	The population is believed to occur in similar numbers and/or extent, range and distribution to either: 1. historical times before human activities or natural catastrophes adversely affected populations; or 2. over a defined time period. (The time period against which the assessment is made is to be stated.)
Increased	The population has undergone an increase in numbers, range, and distribution beyond that expected by natural variability. 'Increased' includes recovery towards pre-existing numbers and/or extent.

Application of the scales is undertaken using best available knowledge and expert judgement – precise figures for population size and habitat extent will very rarely be available.

[9] The term 'considerable' is used to denote a change in status that indicated that the habitat is (or was) under threat and action needed. Similar terms might include 'significant', 'much' 'large scale' or 'a lot'.

[10] The terms 'minor' or 'noticeable' are used to suggest a measurable change in status that causes concern. Similar terms might include 'chronic change', 'mild', 'some reduction', 'somewhat reduced', 'reduced', 'smaller'.

APPENDIX 5. CRITERIA FOR THE IDENTIFICATION OF IMPORTANT MARINE AREAS

1. **Typicalness:** the area contains examples of marine landscapes, habitats and ecological processes or other natural characteristics that are typical of their type in their natural state.

2. **Naturalness:** the area has a high degree of naturalness, resulting from the lack of human-induced disturbance or degradation; marine landscapes, habitats and populations of species are in a near-natural state. This is reflected in the structure and function of the features being in a near-natural state to help maintain full ecosystem functioning.

3. **Size:** the area holds large examples of particular marine landscapes and habitats or extensive populations of highly mobile species. The greater the extent, the more the integrity of the feature can be maintained and the higher the biodiversity it is likely to support.

4. **Biological diversity:** the area has a naturally high variety of habitats or species (compared to other similar areas).

5. **Critical area:** the area is critical for part of the life cycle (such as breeding, nursery grounds/juveniles, feeding, migration, resting) of a mobile species. The assessment needs to evaluate the relative importance of the area for the species. An area for which a species has no alternative should receive a greater weighting than an area where a species has a range of alternatives for the aspect of its life cycle (e.g. is a given gravel bank the only one for a herring population to spawn on?). This will vary according to species and the part of the life cycle in question.

6. **Area important for a priority marine feature:** features that qualify as special features or which are declined or threatened should contribute to the identification of these areas. The assessment should consider whether such features are present in sufficient numbers (species), extent (habitat) or quality (habitats, marine landscapes) to contribute to the conservation of the feature.

From: www.defra.gov.uk/wildlife-countryside/ewd/rmnc/pdf/rmnc-report-0704.pdf

See: Connor *et al*., 2002. *Rationale and criteria for the identification of nationally important marine nature conservation features and areas in the UK. Version 02.11*. Unpublished. Joint Nature Conservation Committee, Peterborough. Available from: www.jncc.gov.uk/PDF/sg341.pdf

APPENDIX 6. NAMES OF LOCATIONS IN FIGURE 6 (THE LOCATIONS USED FOR ANALYSIS OF HOTSPOTS)

Location number	Location	Physiographic type
1	Durness Lochs	Sea loch
2	Loch Laxford area	Sea loch
3	Loch Broom	Sea loch
4	Little Loch Broom and Gruinard	Sea loch
5	Loch Ewe	Sea loch
6	Loch Snizort	Sea loch
7	Loch Dunvegan (Skye)	Sea loch
8	Loch Bracadale (Skye)	Sea loch
9	Lochs Duich, Long and Alsh	Sea loch
10	Canna Island (nr Skye)	Island
11	Loch Roag (Lewis)	Sea loch
12	Loch Resort	Sea loch
13	St Kilda	Island
14	Loch Maddy – Uist	Sea loch
15	South Uist	Island
16	Sound of Arisaig	Strait / Sound
17	Loch Sunart	Sea loch
18	Mull	Island
19	Linnhe system	Sea loch
20	Loch Creran	Sea loch
21	Loch Etive	Sea loch
22	Firth of Lorne	Island
23	Loch Craignish	Strait / Sound
24	Loch Sween	Sea loch
25	Loch Tarbert (Jura)	Sea loch
26	Islay	Island
27	Loch Striven and Loch Riddon (north of Bute)	Sea loch
28	Loch Fyne	Sea loch
29	Upper Firth of Clyde	Estuary
30	Great Cumbrae Island area	Island
31	Rathlin Island	Island
32	Portrush area	Open coast
33	Lough Foyle	Sea loch
34	Larne	Open coast
35	Belfast Lough	Sea loch
36	Strangford Lough	Sea loch
37	Newcastle – Killough Harbour (N.I.)	Open coast
38	Carlingford Lough	Sea loch
39	Luce Bay	Bay
40	Wigtown Bay – Abbeys Head	Bay
41	Auchencairn Bay	Bay
42	Solway Firth	Bay
43	Morecambe Bay	Bay

44	River Dee	Estuary
45	Conwy Bay	Bay
46	Red Wharf Bay – Moelfre	Bay
47	Carmel Head and Skerries (Anglesey)	Island
48	Holyhead, Anglesey	Open coast
49	Menai Straits	Strait / Sound
50	Tremadoc Bay	Bay
51	Lleyn Peninsula and Bardsey	Open coast / Island
52	Cardigan Bay	Open coast
53	Pembrokeshire islands	Island
54	Milford Haven	Bay / Ria
55	Towy, Taf, Gwendraeth estuary	Estuary
56	Carmarthen Bay and Burry Inlet	Bay
57	Severn Estuary to Bridgend	Estuary
58	Lundy	Island
59	Camel Estuary	Estuary
60	Gannel Estuary – Newquay	Estuary
61	Isles of Scilly	Island
62	South Lizard	Open coast
63	Falmouth – Helford	Ria / Estuary
64	Fowey Estuary	Ria / Estuary
65	Plymouth Sound – Wembury	Open coast
66	Plymouth offshore reefs (incl. Eddystone reefs)	Open sea / Open coast
67	Yealm Estuary	Ria / Estuary
68	Erme estuary	Estuary
69	Salcombe – Start Point	Estuary / Open coast
70	Dart Estuary	Estuary
71	Torbay – Torquay	Bay
72	Teign Estuary	Estuary
73	Exe Estuary	Estuary
74	Lyme Bay and Chesil Beach and the Fleet	Open coast
75	Portland Harbour	Bay
76	Lulworth Cove – Kimmeridge Bay	Bay
77	Purbeck and Swanage	Open coast
78	Christchurch Harbour	Bay
79	South Wight Maritime	Open sea
80	Solent lagoons	Estuary
81	Bembridge Harbour and East Solent	Bay / Open sea
82	Chichester Harbour	Bay
83	Selsey Head	Open coast
84	Brighton	Open coast
85	Beachy Head to Dungeness	Open coast
86	East Wear Bay	Bay
87	Thanet	Open coast
88	Medway and Swale Estuary	Estuary
89	Blackwater Estuary and River Colne	Estuary
90	Blakeney to Brancaster	Open coast

91	The Wash	Bay
92	Offshore Skegness	Open coast
93	Humber Estuary	Estuary
94	Flamborough Head	Open coast
95	Scarborough	Open coast
96	Robin Hood's Bay	Open coast
97	Sandsend Esk Estuary	Estuary
98	Tees Estuary	Estuary
99	Tyne Estuary	Estuary
100	Newbiggin – Blyth	Open coast
101	Amble Farm	Open coast
102	Farne Islands	Island
103	Holy Island (Lindisfarne)	Island
104	Berwick-upon-Tweed	Estuary
105	St Abb's	Open coast
106	Firth of Forth	Bay / Estuary
107	Isle of May	Island
108	Firth of Tay	Estuary
109	North Aberdeen	Open coast
110	Nairn and Findhorn Bay	Bay
111	Inner Moray Firth	Estuary
112	Dornoch Firth	Bay
113	Loch Fleet	Sea loch
114	Mainland Orkney	Island
115	Rousay (and Eynhallow Sound)	Island / Sound-Strait
116	Sanday	Island
117	Easter – Scalloway – Kettla ness	Ria/Voe
118	Papa Stour	Island
119	Sullom Voe	Ria/Voe
120	Unst	Island / Sound-Strait

APPENDIX 7. DATA ANALYSIS FOR BIODIVERSITY HOTSPOTS

Species and biotope richness measures

Species richness measures provide an instantly comprehensible expression of diversity provided that care is taken with sample size (Magurran, 1996). To approximately standardise for variances in sampling intensity at all the locations around the UK coastline analysed, regression analysis was performed. Along with the regression, 80% prediction intervals were plotted. Prediction intervals (confidence intervals of the population) show the range where (here) 80% of the data would fall if measurements were repeated. Eighty per cent prediction intervals were used, allowing more data points to fall outside the predicted range. Locations were given a score of 1-3 depending on their position relative to the prediction intervals. If a location fell within the prediction intervals (the green area on the graph below) it was assigned a score of 2; if it fell below the prediction intervals (blue shaded area) it was considered to be poor for that richness measure and assigned a score of 1. Locations above the 80% prediction intervals (red shaded area) were considered to have high values for the particular richness measure and were assigned a score of 3. This provides an easy to use answer but does have some shortcomings, especially in areas with a high level of sampling intensity. These problems are discussed below.

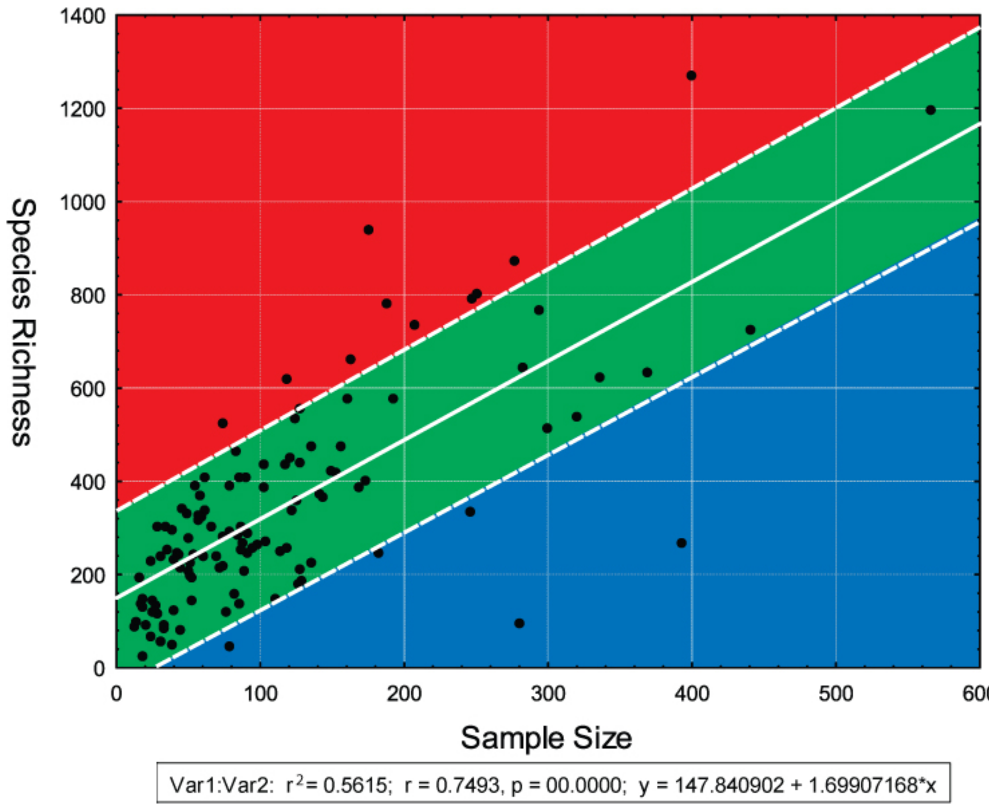


Figure 13. The linear-relationship between species richness and sample size (n = 120). The box below the graph shows that over 56% of the variance (r^2) in species richness can be explained by the sample size alone and that the relationship is highly significant ($p < 0.0001$). The data points within the dashed 80% prediction intervals are shaded green and represent the area in which 80% of the data would be predicted to fall if repeat measures were taken. Data points in the area shaded in red have more species per sample effort than would be predicted, while data points in the blue area have fewer species than would be predicted.

The methods outlined above provide a relatively simple way of comparing species richness between sites while roughly attempting to standardise for sampling intensity. However, there are some circumstances where these methods fall down. In some areas where a huge level of sampling intensity has been carried out the standardisation procedure may cause a location to obtain an unduly low score. In the report we have taken into account this problem and looked carefully at the data sets. In several locations it was felt that there was a large number of species and a large amount of sampling effort had caused the location to score lower than anticipated. This is due to the point of diminishing returns illustrated in the species accumulation graph below. After a certain level of sampling, each sample will record fewer and fewer new species.

Depending on the shape of the species accumulation curve at any given location, extra sampling effort may start to cause a reduction in the number of species per sample. Scores have been adjusted accordingly. However, as a part of future methods standardisation in site comparisons, it is advised that every data set from a specified area should be subject to the construction of a species accumulation graph and the number of species representing a point at which a doubling of sample effort produces 10% more species should be used as the representative species number.

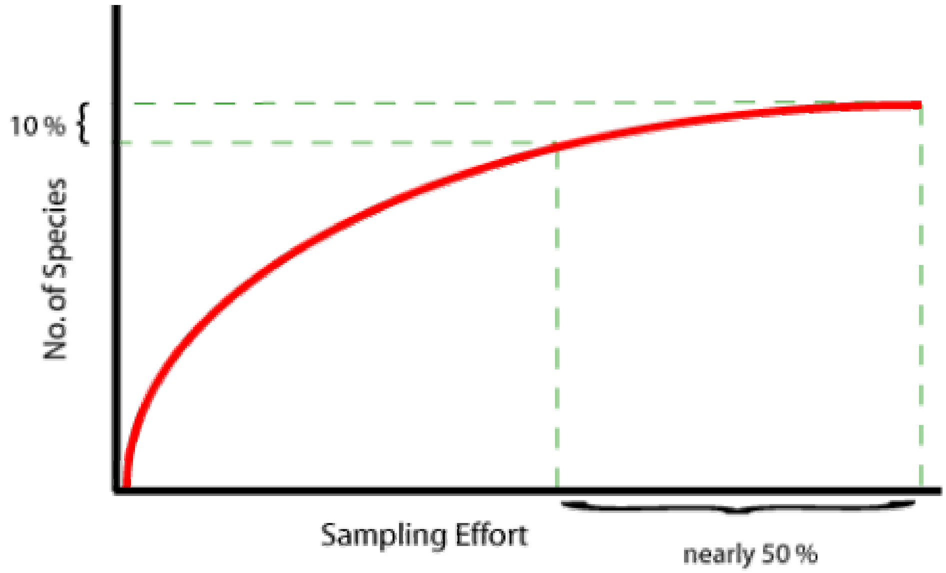


Figure 14. A species accumulation curve for a hypothetical location, showing that initially species number increases rapidly with each additional sample but then begins to plateau. In this example, the final 10% increase in the number of observed species requires a near doubling in sampling effort.

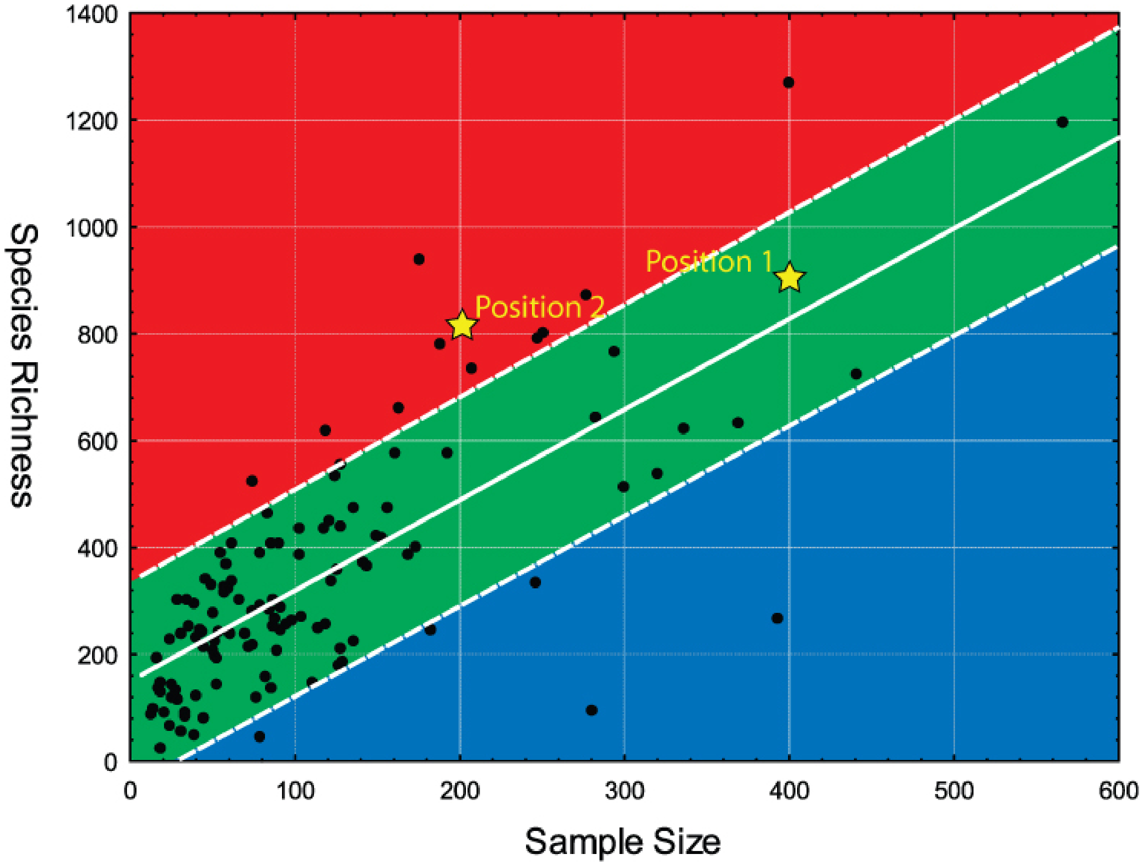


Figure 15. The figure shows how the hypothetical location with a high level of sampling intensity may move from an expected number of species, in Position 1, to a higher than expected number of species, in Position 2, if 90% of the observed species were plotted against the level of sampling intensity, where 100% additional sampling yields 10% more species.

Distinctness measures

Undisturbed benthic communities existing in a late stage of succession are likely to host a wider range of more distantly related species belonging to many different phyla and will have a high taxonomic distinctness (Warwick & Clarke, 2001). Taxonomic distinctness measures the features of an assemblage's taxonomic spread. The measure is based to a large part on equal branch lengths between hierarchical levels of Linnaean classifications and, although some would argue that such classifications are arbitrary, many are based on cladistic principles, which marine biologists have accepted to be realistic phylogenetic representations (Warwick & Clarke, 2001).

In this study we analysed the average taxonomic distinctness (see Box 9) of all the 120 locations around the UK coastline. Initially, all phyla present at the 120 study locations were assembled into a regional species list and analysed in Primer 6.15. However, this caused problems as differences in sampling methods around the UK coastline will result in different species being observed. Therefore, our study focused on six phyla: annelids, bryozoans, crustaceans, cnidarians, echinoderms and molluscs, as these phyla are widely distributed easily sampled and have good taxonomic classification records allowing a full aggregate regional species list to be compiled. The species records data was transformed to presence/absence and all physiographic types were analysed using a funnel plot with 95% confidence intervals.

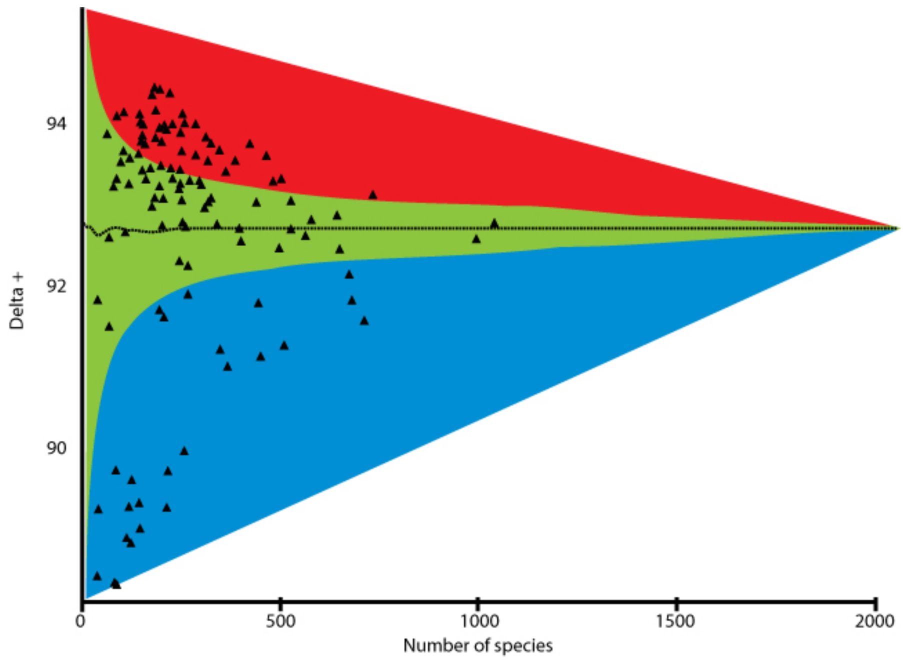


Figure 16. Average taxonomic distinctness funnel plot showing the data points for all physiographic types for six major phyla. The green area shows the 95% confidence intervals for random ‘expected’ distinctness based on 1,000 random permutations of the same number of species from a regional species master list. Data points outside the green area depart significantly from random expectation (Clarke & Warwick, 1998).

Points that fall within the expected green area on the funnel plot conform to the expected range from the regional master species list and were assigned a score of 2. Locations that fell in the red area of the funnel plot where assigned a score of 3 as they were significantly higher than expected. Locations in the blue area of the plot were assigned a score of 1 as they had lower than expected average taxonomic distinctness.

APPENDIX 8. 'ADVANTAGES' AND 'DISADVANTAGES' OF IDENTIFYING MARINE BIODIVERSITY HOTSPOTS AND THE METHODS USED

The following summary takes account of outcomes of the workshop held in Bristol on 24 July 2006 and the issues raised as a result of analysing available survey data.

Concept and approaches	Advantages	Disadvantages	Notes
1. Biodiversity hotspots give the highest species richness including of rare and threatened species in protected areas.	1. Best 'value for money'. 2. Fewer areas will be needed to represent the range of biodiversity. 3. Easier to convince the public of importance.	1. Rich areas may not include (a significant number of) NIMF (rare and threatened species and habitats). 2. Areas with a significant number of NIMF may not be species/biotope rich. 3. Measures based on or reduced to analysis of presence/absence records will ignore locations where rare or threatened species are abundant. 4. Some geographical areas are naturally poorer than others.	1. Different hotspot measures (rarity, richness, degree of threat) often do not occur in the same areas. 2. Biodiversity hotspot measures are just one 'tool in the box'. 3. Naturally poorer geographical areas can be accommodated by a Regional Seas approach.
2. Biodiversity hotspots can be based on the locations with highest number of biotopes.	1. Biotopes include different species and are easier to inventory than full species assessment. Therefore the number of biotopes is a surrogate for the number of species likely.	1. Survey data has been unevenly analysed to identify biotopes and some locations have incomplete lists of biotopes. 2. Surveys may not have covered all habitats in an area. For instance, predominantly diving surveys will not have adequately included sediments.	
3. Hotspots include a high number of 'special' features.	1. Public can perceive value. 2. Locations with endangered (because rare or vulnerable) features are identified.	1. 'Representativeness' is a key requirement of MPAs – but especially rich or endangered features may not be 'representative'.	Hotspots of special features may not correspond to locations of high species richness.

Concept and approaches	Advantages	Disadvantages	Notes
4. Hotspots should be identified based on gridded searches (e.g. 0.1 x 0.1 minute of latitude and longitude/ 20km x 20km squares)	1. Comparisons are ‘like with like’ areas in size (offshore only?).	1. In inshore areas, grids will include variable lengths of coastline and variable proportions of land and sea (i.e. not comparing like with like). 2. Offshore, survey data is likely to be too sparse except in areas where EIAs have been required.	The problem of different lengths of coastline in the same size grid units can be adjusted for.
5. Hotspots should be identified based on comparison of physiographically similar areas.	1. Comparing like with like.	1. Not like with like in terms of size and therefore areas not quantitatively comparable. 2. Physiographic features such as an ‘estuary’ encompass a range of types and sizes and therefore not comparing like with like.	

Concept and approaches	Advantages	Disadvantages	Notes
6. Use all data available for an area to identify species richness.	1. Best estimate of richness.	1. Very well-sampled areas will (almost) inevitably rank highly. 2. Old data may include species that no longer occur in an area.	"Well sampled" means that all of the major habitats have been sampled according to standard procedures. However, sampling is often uneven. For instance, at Lundy, sublittoral hard substrata are well sampled but sediments and intertidal areas are not. The area therefore appears species poor. A robust moderation process is needed to ensure that sheer volume of sampling does not overwhelm an assessment of species richness.
7. Use moderated data to identify species richness.	1. Potentially provides comparative figures even where some locations have been thoroughly ('over-') sampled.	1. Difficult to establish what the moderation process should be. 2. Moderation by a species-area curve approach does not allow for some habitats (e.g. sediments) not having been sampled at all. 3. Moderation processes may be seen as a 'fudge factor'.	'Moderation' will be by assessment of a point at which further sampling will bias results heavily to be a 'hotspot' but without punishing areas that really are very species rich.

Concept and approaches	Advantages	Disadvantages	Notes
8. Use ‘Expert judgement’ to indicate where hotspots are.	1. Biologists with experience of a wide range of locations will ‘know’ a rich area or area special for rarities. 2. The public may have more faith in an ‘expert’ than in mathematical formulae.	1. ‘Experts’ may have a bias towards their favourite locations – which might be local to them. 2. ‘Experience’ may not compete with ‘objective’ mathematical approaches in the eyes of policy advisers.	There is inherent distrust of ‘experts’ in some quarters but a willingness to accept complex and impressive mathematical approaches which the policy adviser doesn’t actually understand.

APPENDIX 9. CONSEQUENCES OF HUMAN ACTIVITIES AND EXAMPLES OF SPECIES AND BIOTOPES UNDER THREAT FROM THOSE ACTIVITIES

The identification of 'degree of threat' is through interrogation of the *MarLIN* Biology and Sensitivity Key Information Database. The methods used and definition of terms are described in Hiscock *et al.*, 2006. The example species and biotopes are ones that are key to ecosystem structure and function and/or nationally rare and scarce. Only a selection of species and biotopes is given and not a full list. A list of species and biotopes sensitive to activities can be accessed on www.marlin.ac.uk/search/humanactivity.php

Example human activities	**Example resulting environmental effects**	**Examples of likely effects on ecosystem structure and functioning**	**DEGREE OF THREAT** **Examples of species and biotopes that are 'significantly' or 'severely' threatened**
Harbour dredging; Sand and gravel extraction	Substratum loss	The habitat with any associated structure (such as natural and biogenic reef structure) is removed. The remaining substratum may no longer be suitable to support the species and communities previously present	Lagoon sandworm (*Armandia cirrhosa*); DeFolin's lagoon snail (*Caecum armoricum*); lagoon sea slug (*Tenellia adspersa*); fan mussel (*Atrina fragilis*); maerl (all species); sea grass *(Zostera marina*); maerl biotopes (IGS.Phy.HEc, IGS.Lgla)
Harbour dredging; spoil dumping	Smothering	Feeding and respiration adversely affected. Loss of filtering function if filter feeders are smothered and cannot feed	Sunset coral (*Leptopsammia pruvoti*); native oyster (*Ostrea edulis*); branching axinellid sponge (*Axinella dissimilis*); maerl biotopes (IGS.Phy.HEc, IGS.Lgla)
	Increased turbidity	Less light for primary productivity resulting in reduced micro- and macroalgal growth	Maerl (all species); sea grass (*Zostera marina*); sea grass *Zostera marina* biotopes (IMS.Zmar); maerl biotopes (IGS.Phy.HEc, IGS.Lgla)

Example human activities	Example resulting environmental effects	Examples of likely effects on ecosystem structure and functioning	DEGREE OF THREAT Examples of species and biotopes that are 'significantly' or 'severely' threatened
Harbour dredging; Towed fishing gear; Anchoring; Sand and gravel extraction	Abrasion and physical disturbance	Loss of important physical structure including habitats, such as biogenic reefs, and change of sediment structure. Destruction of fragile organisms	Horse mussels (*Modiolus modiolus*); fan mussel (*Atrina fragilis*); northern hatchet shall (*Thyasira gouldi*); knotted wrack (*Ascophyllum nodosum*); maerl (all species); maerl biotopes (IGS.Phy.HEc, IGSLgla); *Serpula vermicularis* reefs on very sheltered circalittoral muddy sand (CMS.Ser); *Ostrea edulis* beds on shallow sublittoral muddy sand (IMX.Ost); *Lophelia* reefs (COR.Lop)
Construction of causeways (barrages)	Decrease in water flow	Supply of suspended food blocked, suspended matter is deposited causing smothering	Maerl (all species); maerl biotopes (IGS.Phy.HEc, IGSLgla)
Disposal of industrial waste; antifoulant use	Synthetic chemicals	Recruitment reduced due to poisoning of larvae. Mortality in adults. Reproductive function adversely affected leading to population decline	Native oyster (*Ostrea* edulis), horse mussels (*Modiolus* modiolus); dog whelks (*Nucella lapillus*)
Oil pollution	Hydrocarbons	Direct mortality. Loss of grazers from intertidal areas leading to increased macroalgal abundance	Lagoon sand shrimp (*Gammarus insensibilis*). (Few species with high sensitivity because of rapid recovery capabilities.)

Example human activities	**Example resulting environmental effects**	**Examples of likely effects on ecosystem structure and functioning**	**DEGREE OF THREAT Examples of species and biotopes that are 'significantly' or 'severely' threatened**
Agricultural runoff	Increase in nutrients	Phytoplankton blooms resulting in increased turbidity and reduced sediment oxygen levels	Sea grass (*Zostera marina*); maerl (all species); all sea grass *Zostera* spp) biotopes (IMS.Zmar; LMS.Znol)
Climate change	Increased temperature	Extended spawning period for some species. Increase in impacts of disease or exacerbation of de-oxygenation events. Tolerances for reproduction exceeded	*Styela gelatinosa* and others solitary ascidians on very sheltered deep circalittoral muddy sediment (COS.Sty); *Lithothamnion glaciale* maerl beds in tide-swept variable salinity infralittoral gravel (IGSLgla); *Lophelia* reefs (COR.Lop)
Aquaculture, shipping	Introduction of non-native species	Displacement of native species through competition for space	Seaweeds in sediment (sand or gravel)-floored eulittoral; rockpools (LR.SwSed); Fucoids and kelps in eulittoral rockpools (LR.FK); *Ostrea edulis* beds on shallow sublittoral muddy sand (IMX.Ost)
Fisheries	Extraction of species (targeted and non-targeted)	Loss of significant part of the population (especially relevant for long-lived low fecundity species)	*Dipturus batis* (common skate); *Zostera noltii* beds in upper to mid shore muddy sand (LMS.Znol); *Modiolus modiolus* beds with hydroids and red seaweeds on tideswept circalittoral mixed substrata (MCR.ModT); *Ostrea edulis* beds on shallow sublittoral muddy sand (IMX.Ost)

APPENDIX 10. CASE STUDY DOSSIERS FOR SELECTED LOCATIONS

The case study areas are selected to represent a range of different types of locations that might be assessed for 'hotspot' status. The case studies reveal a range of interpretation requirements particularly centred around the uneven nature of data available, but also that some areas (such as estuaries and reefs in northern Britain) might not be expected to have high species richness (and therefore might be considered to have 'failed'). The summary conclusion has been added to the body of the report.

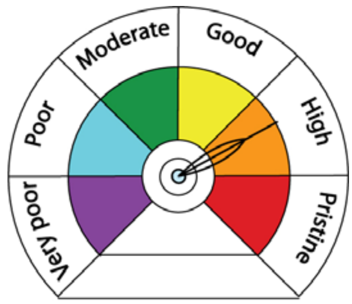
CASE STUDY SITE: RATHLIN ISLAND, NORTHERN IRELAND

Location: 55° 18.00'N 6° 13.00' W
Existing designations for marine areas: SAC, SPA
SAC established for Habitats Directive Annex 1 marine habitats: reefs; submerged or partly submerged sea caves
Physiographic type: Island

Species and biotopes

Recorded taxa*: 521 from 141 survey stations
Hotspot measures (rank):
Species richness*: 374 (2)
Candidate NIMF species: 26 (2)
Taxonomic distinctness 93.25 (2)
Biotope richness 36 (2)
Candidate NIMF biotopes: 6 (2)
Biotope distinctness 88.85 (1)

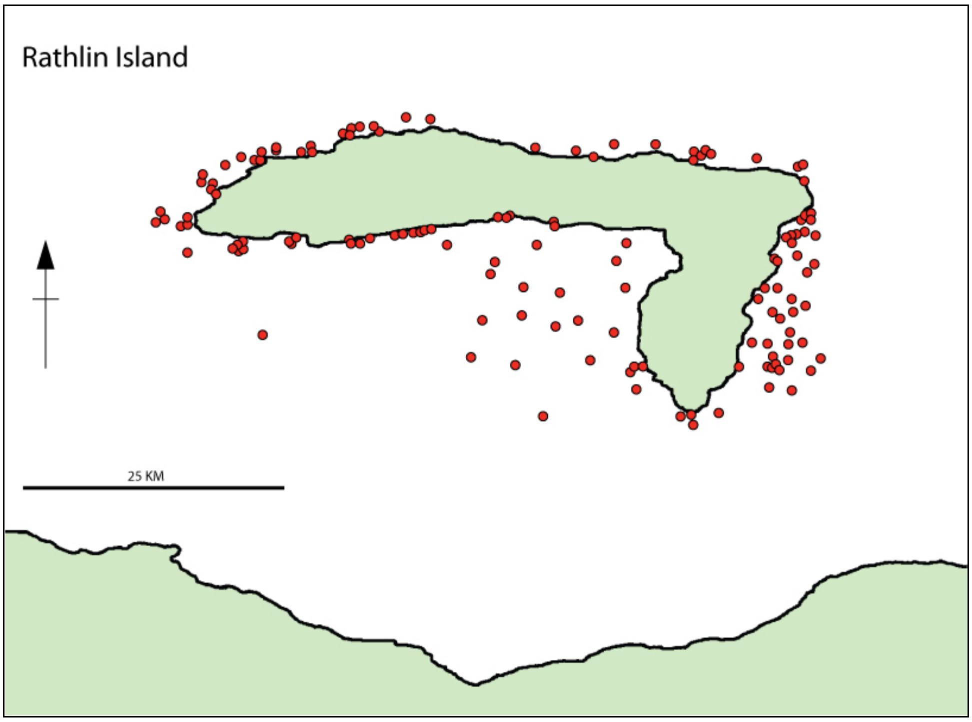
Site quality



See the text for definitions

(Data is from 1983 surveys)

* "Taxa" refers to all entities recorded including incomplete identifications. "Species" includes only entities identified to genus and species.



Survey sites included in analyses from around Rathlin Island

Description of Site/Criteria for selection:
(See Appendix 5 for definitions of Review of Marine Nature Conservation criteria.)

Typicalness: Marine habitats near to the coast are predominantly typical of rocky habitats and are exposed to a wide range of conditions of wave action and strengths of tidal streams creating a wide range of habitats and associated communities of species. Rathlin is also exceptional in having steeply sloping rocky or underwater cliff habitats that extend to depths in excess of 100m, making the site important for such deep rocky habitats. The cave habitats present are also notable. Biotopes representative of tide-swept habitats and of caves are particularly notable.

Naturalness: Cliff and cave habitats that are not accessible to mobile fishing gear can be considered close to natural. However, rock habitats adjacent to sand have been damaged by heavy mobile fishing gear including damage to boulder communities with populations of long-lived and slow growing sponges. Sediment areas are fished and thus there is disturbance to communities. The area is distant from mainland sources of pollution.

Size: The island is ‘self-contained’ for the habitats and many of the species present there. Many of the species that are of importance for the conservation of biodiversity most likely recruit from local populations around the island and do not rely on mainland sources of larvae.

Biological diversity: The wide range of habitats is reflected in a wide range of species and biotopes present around Rathlin. However, the greatest importance may be in the richness of particular habitats as demonstrated by the extremely wide range of sponge species present. Habitat complexity is important to species richness and the limestone rock at Rathlin can be highly fissured and bored by species, giving a wide range of niches for a wide range of species.

Critical area: Many of the species that are rare or scarce and occur at Rathlin are dependent on the particular conditions there and may occur at few other locations which most likely means that there are few other locations suitable for their occurrence.

Area important for a priority marine feature

There are a significant number of candidate Nationally Important Marine Features for which Rathlin is a location. It is considered that survey data from 2005 and 2006 will significantly add to the NIMF species listed.

While the number of candidate NIMF biotopes is not high, it is considered that data has not been fully analysed for biotope identification and further NIMF biotopes will be identified.

Activities/Threats

The Rathlin area is used for both recreational and commercial fishing, especially potting for lobsters. In areas of sediment, scallop dredging is a threat to adjacent rock communities and damage has been done to the communities of sponges, which are unlikely to recover.

Summary conclusion

Rathlin Island is highly regarded as a location where there is an exceptional variety of species including rare and scarce species often in habitats that are rarely observed elsewhere in the UK.

Of the species recorded off Rathlin Island in 1983, 26 are listed as being nationally important in the draft list. The 2005 and 2006 surveys have identified further rare species including the burrowing sea anemone *Halcampoides* '*abyssorum*' and have especially revealed the very high richness of sponge species with a total of about 150 species recorded (about one third of the total sponge fauna recorded for Britain and Ireland) (Bernard Picton, personal communication).

Although not ranking highly for hotspot measures, it is important to consider that the survey results used in the exercise described here were from surveys in 1983 on predominantly rock habitats. Surveys undertaken in 2005 and 2006 will no doubt increase the species richness ranking. Inevitably, the restricted range of habitats surveyed in 1983 have also led to a low biotope richness measure.

Images

Plate 8. The spectacular cliffs of Rathlin Island continue underwater. Image: Kate Reeves.

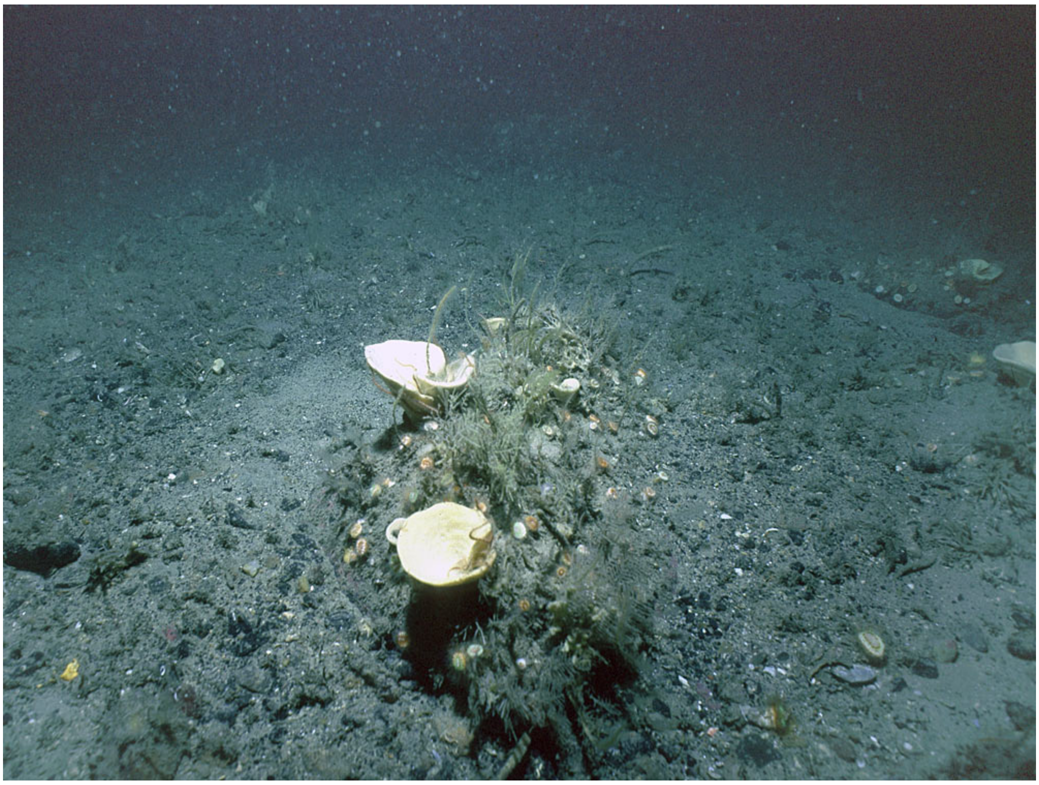


Plate 9. Nationally scarce sponges *Axinella infundibuliformis* in 1984 on frequent scattered boulders in poorly sorted coarse gravel sediment. Such sponges are very long-lived, slow growing and seem to recruit very infrequently (Bernard Picton, Ulster Museum).

Plate 10. Damaged sponge communities on a righted boulder turned by dredging, including *Axinella infundibuliformis* in 1989, the black patches are where the sponge has gone anaerobic and died. Other boulders in the area had lines indicating where they had been previously embedded in the sediment, but were on their sides, having been rolled out of the sediment. In a 2005 survey there were no boulders present in this area (Bernard Picton, Ulster Museum, pers. comm.).

CASE STUDY SITE: THE MENAI STRAIT, NORTH WALES

Location: 53° 13.13'N, 4° 10.24'W
Existing designations for marine areas: SSSI, SAC
SAC established for Habitats Directive Annex 1 marine habitats: sandbanks; mudflats and sandflats; large shallow inlets and bays; reefs; submerged or partly submerged sea caves.
Physiographic type: Strait

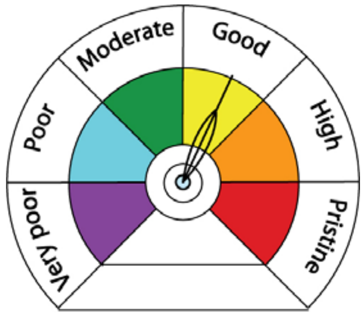
Species and biotopes

Recorded taxa*: 1359 from 175 survey stations

Hotspot measures (rank):

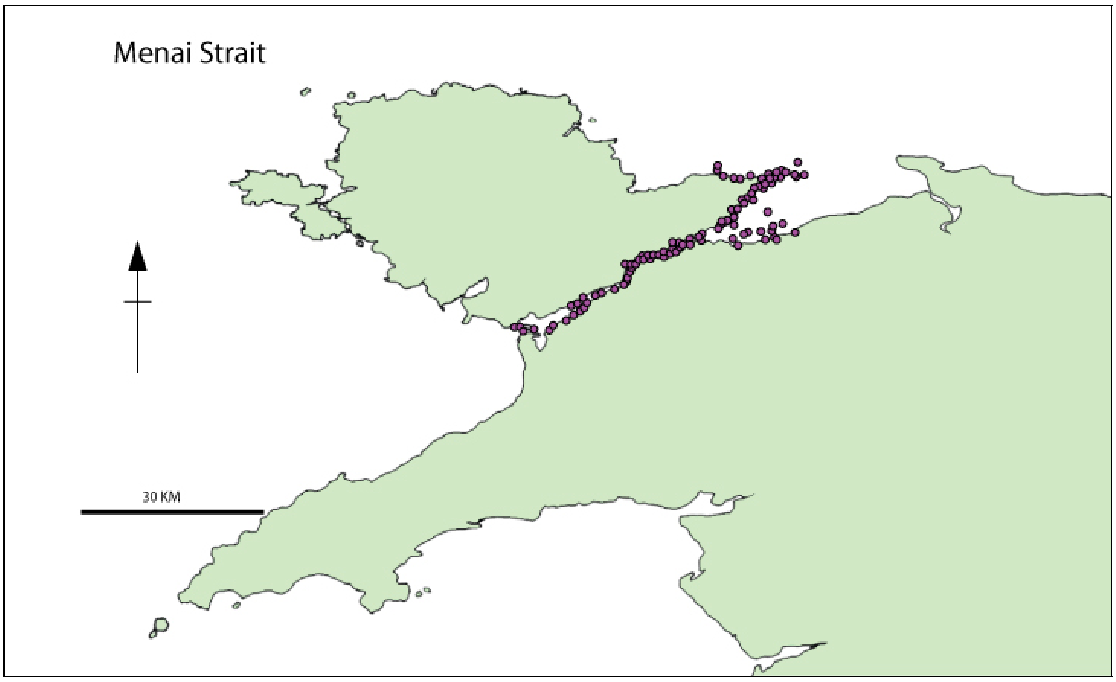
Species richness*: 941 (3)
Candidate NIMF species: 24 (2)
Taxonomic distinctness 93.11 (2)
Biotope richness 84 (3)
Candidate NIMF biotopes: 25 (3)
Biotope distinctness 92.98 (2)

Site quality



See the text for definitions

* "Taxa" refers to all entities recorded including incomplete identifications. "Species" includes only entities identified to genus and species.



Survey sites included in analyses from the Menai Strait and adjacent areas.

Description of Site/Criteria for selection:
(See Appendix 5 for definitions of Review of Marine Nature Conservation criteria.)

Typicalness: The range of habitats present in the Menai Strait and adjacent areas near to Puffin Island is very large. To the east, limestone reefs occur but with a limited range of species probably resulting from the high turbidity and variable salinity condition prevailing in the east basin of the Irish Sea. Those communities are typical of such turbid, variable salinity and wide temperature range. However, the limestone rock creates a habitat for boring and nestling species which, with sediment dwelling species, may be rich in areas at the eastern entrance. Sandflat and mudflat habitats with typical associated fauna occur at the western and eastern ends of the Strait but the richest communities, typical of rarely occurring habitats occur especially between the two bridges. Here, tidal currents are very strong and the communities are characteristic of such conditions. Flowing water also creates very rich underboulder communities in the intertidal. Further west, strong tidal currents are generally less vicious and suspension feeding communities typical of strong currents but negligible wave action thrive.

Naturalness: The habitats present in the Menai Strait are mainly natural but significantly modified in places by human activities. That modification is particularly in the form of hard substrata being introduced as causeways, walls and piers. Some of those walls have broken down and boulders are displaced onto the shore. Contamination by sewage effluents has been a significant concern in the past and, although sewage effluent continues to be discharged, it is now tertiary treated. Nevertheless, that effluent and most likely agricultural runoff increases nutrient levels in the Straits so that species may be affected. Mussel and oyster farming are both activities that change the ecosystem including introduction of non-native species.

Biological diversity: The wide range of habitats is reflected in a wide range of species and biotopes present in the Menai Strait. In some of those habitats, especially the extremely strong tidal flow areas, the number of species that can survive is restricted but those that do are abundant. Wave sheltered conditions where tidal flow is moderate are the richest and the underboulder communities in the vicinity of Church Island on the north shore between the bridges is outstanding.

Critical area: The extremely tideswept habitats that occur between the bridges and the rich underboulder communities at Church Island are rare features for which the Menai Strait is of critical importance.

Area important for a priority marine feature

The number of candidate NIMF species and biotopes is moderately high in the Menai Strait and the area is particularly important for the tide exposed, wave sheltered biotopes and associated species as well as some rich examples of sediment and underboulder communities.

Activities/Threats

The Menai Strait has extensive boat moorings and marina facilities and demand for those may increase, compromising the remaining naturalness of the area and increasing input of antifouling contaminants. Also, any proposals for new causeways, slipways, jetties and piers would need to be carefully considered especially in relation to changing water flow. Marina facilities have an ongoing requirement for maintenance dredging, which raises questions over the sustainability and environmental impact of different disposal methods (e.g. water injection dredging).

Increased nitrification in such an enclosed area, and taking account of likely elevated input from Liverpool Bay, is likely to pose a threat, although tidal flushing is generally good. Two pollution events in the Menai Strait, including one in June 2006 were the result of oil contamination of the marine environment from land-based sources, highlighting the vulnerability of the Strait to such pollution sources. The mussel and oyster lays already have an effect in changing the biotopes present and increasing extent may affect some critical habitats – especially where biodiversity is high on coarse sediment shores. Such extensive aquaculture operations also have the potential to impact on marine habitats and species remote to the actual lays themselves, for example through nutrient depletion or creation of sediment plumes during harvesting operations. Certain areas within the Menai Strait are heavily used for bait collection. For example, muddy gravel areas are targeted by lug and rag worm collectors, while boulder shores are targeted for peeler crab collection. It is likely that novel fisheries will continue to be a threat to inshore marine areas, such as the Menai Strait, where an unregulated commercial fishery for shore crab has developed in recent years.

Summary conclusion

Inspection of the survey data suggests several anomalies that would reduce the number of species present in the area. For instance, the soft coral *Alcyonium glomeratum* is recorded but is believed to be a misidentification of brown *Alcyonium digitatum*. Crawfish *Palinurus elephas* are recorded but records are likely to be old and the species no longer occurs there. However, the number of anomalies is likely to be small.

The Menai Strait is a ‘hotspot’ because of high species and biotope richness and because of the presence of well-developed examples of rare habitats. The area ranks highly for species and biotope richness but is average/expected for presence of NIMF species and biotopes and for average taxonomic distinctiveness in species and biotopes. The area has been highly sampled (which might be considered to skew species and biotope richness measures upwards) but it is considered that the high species richness is a result of high variety of habitats in a small area (a central consideration in identifying hotspots) and that the ‘special’ features (communities typical of extremely strong currents, rich underboulder communities, and rich muddy gravel communities) are of importance.

Images

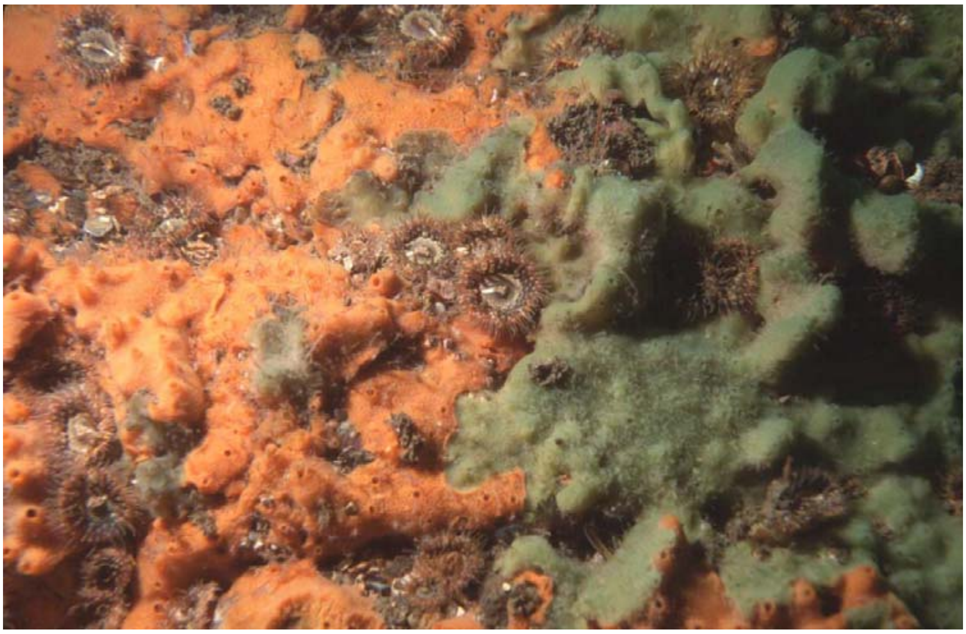


Plate 11. Mosaics of sponges and sea anemones covered in swarms of caprellid amphipods characterise areas subject to strong tidal currents in the Menai Strait. Below the Telford Bridge. Image: Jon Moore/CCW.

Plate 12. Muddy gravel sediments in wave-sheltered locations are often rich in species and are extensive in the Menai Strait. Fryar's Road, near Beaumaris, Anglesey. Image: Krysia Mazik/CCW.

Plate 13. Under boulder habitats provide shelter from desiccation and predation and are colonised in the Menai Strait by a wide range of species. Britannia Bridge. Image: Krysia Mazik/CCW.

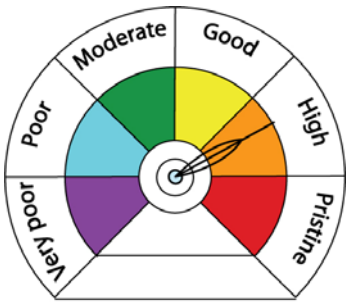
UK MARINE BIODIVERSITY HOTSPOTS

CASE STUDY SITE: PLYMOUTH REEFS

Location: Plymouth Reefs
Existing designations for marine areas: The area considered is almost entirely outside the Plymouth Sound and Estuaries SAC
Physiographic type: Open coast

Species and biotopes	Site quality

Recorded taxa*: 774 from 168 survey stations
Hotspot measures (rank):
Species richness*: 388 (2)
Candidate NIMF species: 30 (3)
Taxonomic distinctness 94.11 (3)
Biotope richness 42 (2)
Candidate NIMF biotopes: 10 (2)
Biotope distinctness 89.90 (1)



See text for definitions

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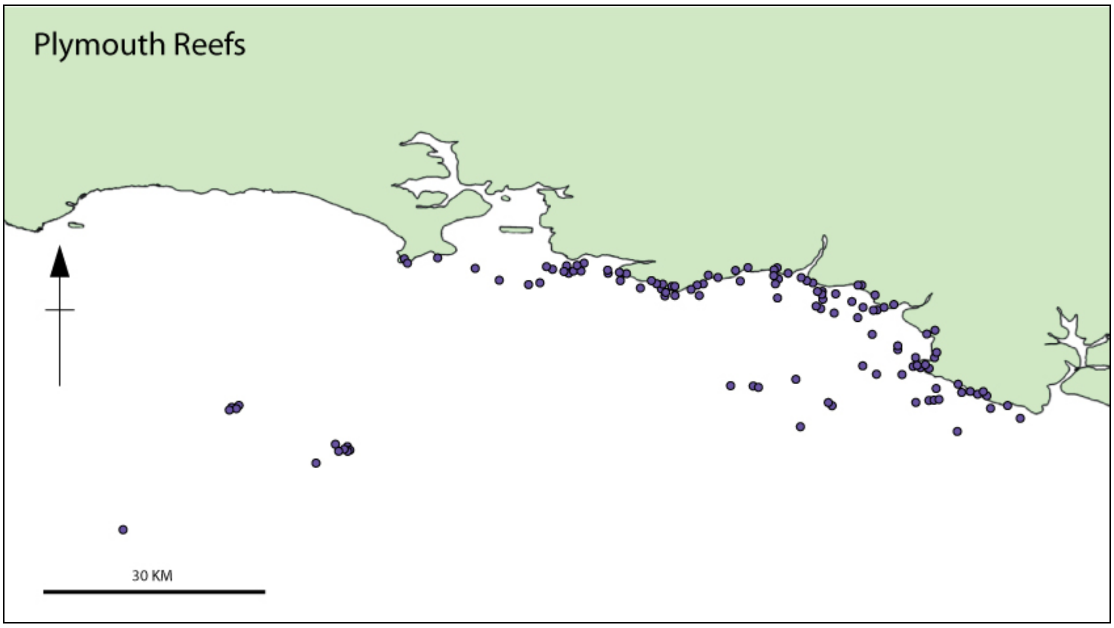


Survey sites included in analyses from Plymouth Reefs.

Description of Site/Criteria for selection:
(See Appendix 5 for definitions of Review of Marine Nature Conservation criteria.)

Typicalness: Reef habitats are predominantly typical of wave-exposed rocky habitats although on deeper areas, wave action is reduced. Shallow parts of reefs are dominated by algae including extensive kelp forests while, below a depth of about 20m, animals predominate. Tidal streams are moderate or strong. Reefs are broken with shale reefs especially having extensive overhangs. The marine species present are typically southern species and, in places, sea fans are abundant. The southern character of the communities makes the area representative of the extreme south-west or Lusitanean-Atlantic biogeographical area of the UK. The submerged cliff line – at between about 25m and 35m below chart datum and about 2km south of the Plymouth sound breakwater – is a geological feature that is an important habitat for many rare and scarce species as well as being spectacularly colourful. Both inshore and offshore reefs, while different in character, include many nationally rare or scarce species.

Naturalness: Communities on reef habitats are considered to be mainly natural in character and comparisons with descriptions made in the 1950s suggest little change since then (see Hiscock, 2005). Very few non-native species occur on the open coast reefs and are rare there. However, the area is subject to potentially damaging fishing activities and the outflow of the Tamar and Plym estuaries in particular contains contaminants that may have reduced diversity compared to pristine conditions.

Biological diversity: Inshore reefs that are generally contiguous with the coast have a very high species richness made most important by the presence of nationally rare and scarce species such as the alga *Carpomitra costata*, the football sea squirt *Diazona violacea*, the corals *Leptopsammia pruvoti* (sunset cup coral), *Hoplangia durotrix* (carpet coral) and *Caryophyllia inornata*, the sponge *Adreus fascicularis*, and pink sea fingers *Parerythropodium hibernicum*. Offshore, the reefs are not so rich, probably because they are dominated by species characteristic of wave and tide exposed conditions including jewel anemones *Corynactis viridis* and dead men's fingers *Alcyonium digitatum*. However, species that are rarely encountered in south-western waters occur on the offshore reefs such as the cushion star *Porania pulvillus*, the slipper lobster *Scyllarus arctus* and the sea fan anemone *Amphianthus dohrnii*.

Critical area: Plymouth Reefs include the most extensive and most dense beds of the scheduled sea fan *Eunicella verrucosa* and probably the most extensive and widespread colonies of the nationally rare sunset coral *Leptopsammia pruvoti*. The integrity of the reefs is of critical importance for the survival of several nationally rare or scarce species and may be a source of larvae for their survival elsewhere.

Area important for a priority marine feature

The number of species from the candidate Nationally Important Marine Features list is especially high in the area. There are many nationally rare or scarce species present on the extensive reefs and many that are considered to be in threat of significant decline. While the number of biotopes identified as candidate Nationally Important Marine Features is not high, some are very extensive and especially well-developed examples. The low number of NIMF biotopes is also influenced by the lack of intertidal habitats surveyed in the area defined.

Activities/Threats:

Inshore reefs are located 'downstream' of the estuaries of the Plym and Tamar, both of which include large facilities for commercial and recreational vessels and numerous effluents, risking contamination with chemicals which may have an effect on species abundance and health. Fishing in the area includes potting, netting and trawling as well as recreational angling. Many locations are subject to recreational diving pressure which may displace species. Inshore habitats were most likely affected by TBT antifoulants, in the 1980s especially, although offshore locations should be remote from significant contamination. Netting, which often occurs over reefs, is likely to result in snagging and causing detachment of erect attached species. Lost nets are likely to 'ghost fish'. Seabed mobile fishing gear sometimes 'encounters' reefs and may cause damage to attached species.

Summary conclusion

Plymouth Reefs rank highly for species and biotope richness, for NIMF species richness and for taxonomic distinctness. The habitats in the vicinity and offshore of Plymouth present a very wide variety of open coast hard substratum and sediment habitats. Those habitats have been studied for over 100 years, albeit using dredges and grabs for most of the period, and their fauna and flora are well documented. However, the data available for analysis did not include data from the fauna (Marine Biological Association, 1957) and flora (Anonymous, 1952) lists for the area or from various sediment fauna surveys undertaken up to the 1980s. The case study is therefore for reefs.

References

Anonymous 1952. *Flora of Devon. Volume II, Part 1. The Marine Algae*. The Devonshire Association, Torquay.

Hiscock, K. 2005. A re-assessment of rocky sublittoral biota at Hilsea Point Rock after fifty years. *Journal of the Marine Biological Association of the United Kingdom*, **55**, 1009-1010.

Marine Biological Association 1957. *Plymouth Marine Fauna. Third Edition.* Marine Biological Association of the UK, Plymouth.

Images

Plate 14. Sea fan anemone *Amphianthus dohrnii*, a nationally rare species often seen on some Plymouth reefs. Image: Keith Hiscock

Plate 15. Plymouth Reefs are popular with recreational divers. The Mew Stone. Image: Keith Hiscock

Plate 16. Gill nets for catching sea bass are often set over reef areas risking entanglement with and loss of attached species. Plymouth Reefs Drop-off (submerged cliff line). Image: Keith Hiscock

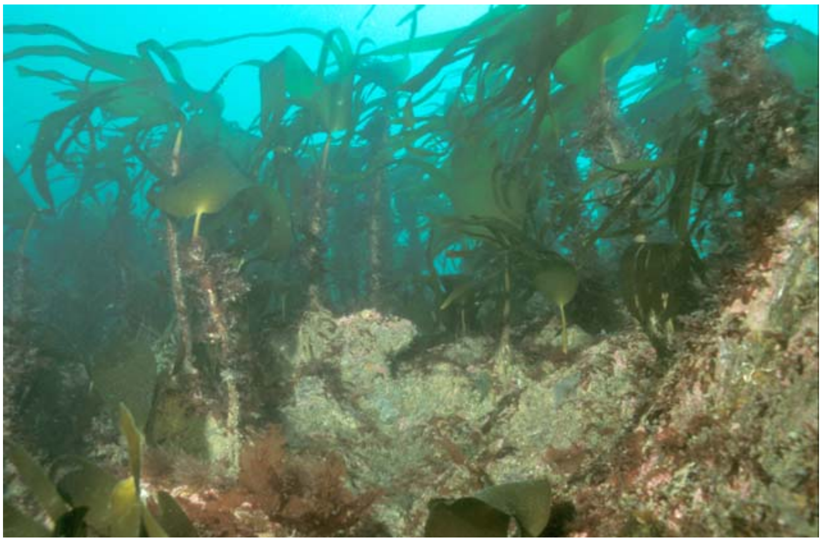


Plate 17. Kelp forests are high productivity systems and occur to depths of about 15m on Plymouth Reefs. Gara Point. Image: Keith Hiscock

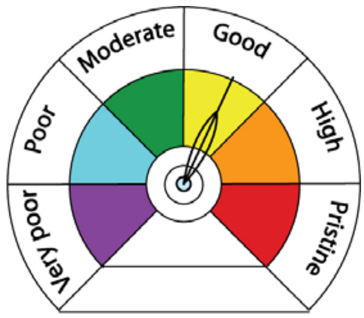
CASE STUDY SITE: BLACKWATER ESTUARY, ENGLAND

Location: 51° 45.56 ‘N 0° 56.26’ E
Existing designations for marine areas: SAC, SPA
SAC established for Habitats Directive Annex 1 marine habitats: Estuaries, mudflats and sandflats, shallow sandbanks slightly covered by seawater all the time
Physiographic type: Estuary

Species and biotopes

Recorded taxa*: 362 from 91 survey stations
Hotspot measures (rank):
Species richness*: 247 (2)
Candidate NIMF species: 6 (2)
Taxonomic distinctness 89.68 (1)
Biotope richness 29 (2)
Candidate NIMF biotopes: 7 (2)
Biotope distinctness 81.82 (1)

Site quality



See the text for definitions

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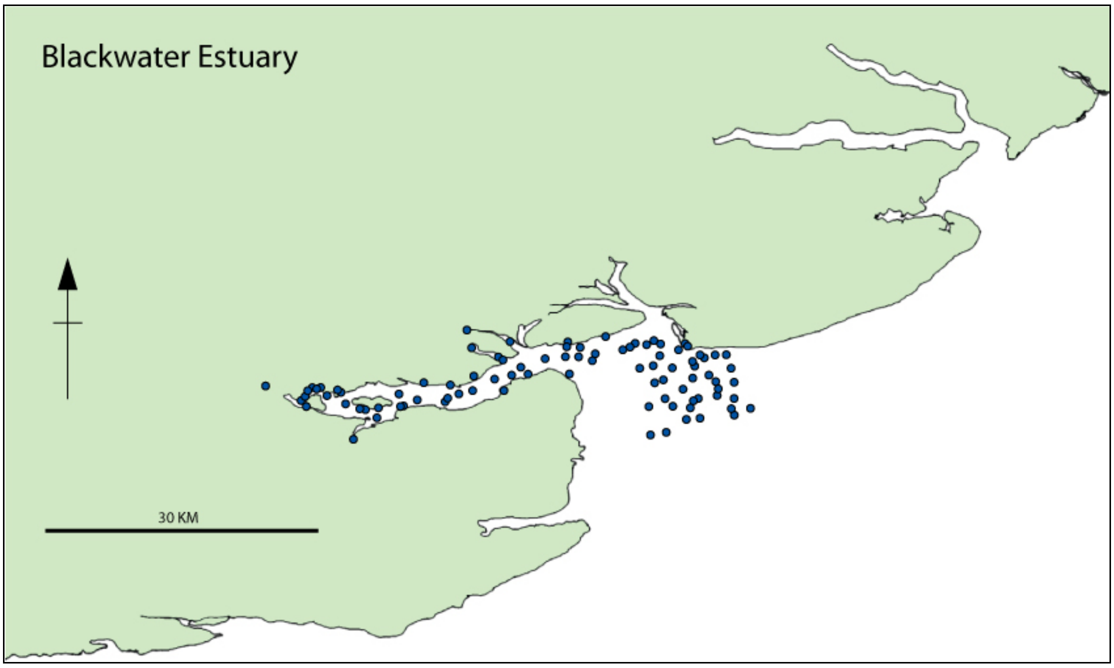


Survey sites included in analyses from around the Blackwater Estuary

Description of Site/Criteria for selection:
(See Appendix 5 for definitions of Review of Marine Nature Conservation criteria.)

Typicalness: Marine habitats in the Blackwater Estuary are representative of the system of creeks, mudflats, saltmarshes and shallow subtidal habitats found in transitional waters of coastal plain estuaries.

Naturalness: There are areas of the Blackwater Estuary that are built on, or where sea defences have been established but a high proportion of the area can be considered natural habitats, albeit affected by diffuse pollutants. The Blackwater and Chelmer rivers collectively receive wastes from a population of about 400,000. Moorings, pontoons and other structures associated with leisure boating are also extensive in the estuary. Some human influences are ancient: the remains of Saxon fish weirs can still be found. Non-native species occur and some, such as the slipper limpet (*Crepidula fornicata*) may be dominant in places.

Size: The Blackwater Estuary is the largest estuary in Essex: it is some 23km in length with creeks, river channels and an island all increasing the coastal length.

Biological diversity: In the context of estuarine habitats, species richness and habitat diversity is high. The Blackwater has rich intertidal and subtidal mixed sediment biotopes.

Critical area: The highly productive mudflats are of critical importance as feeding areas for wading birds.

Area important for a priority marine feature:
The range of species and biotopes in estuarine conditions are not expected to be large and those that are identified as candidate NIMF are mainly ones that characterise variable or low salinity conditions.

Activities/Threats
The extensive nature of mudflats and saltmarshes in the Blackwater Estuary makes the area particularly vulnerable to rising sea level and, because of coastal defences, to ‘coastal squeeze’ which would reduce the extent of intertidal habitats and saltmarsh. At Tollesbury, work has been done on the re-creation of intertidal habitats for nature conservation and flood defence by facilitating ‘managed retreat’, in which flood defences are breached allowing areas to flood.

The report by Chesman *et al*. (2006) addresses issues of contaminants in the Blackwater and suggests: “At present there is little unequivocal evidence from chemical data indicating that modifications to biota of the European Marine Site have occurred or would be expected to occur, due to toxic contaminants. The potential *combined* threat from multiple inputs of nutrients, selected metals (Cu, Zn, Hg, Ag), residual TBT and episodic pesticide inputs is probably of most concern.”

Summary conclusion
The Blackwater Estuary was identified as a case study location in part because, in an unpublished comparative study of English east coast estuaries undertaken in 1998 by the Joint

Nature Conservation Committee, the Blackwater ranked most highly for species and biotope richness and for nationally scarce species and habitats.

Estuaries are characterised by high biological productivity and abundance of organisms, but low diversity. Therefore numbers of species and biotopes identified are low compared to open coast areas with reefs and sediments. Estuarine areas do not generally have significant numbers of rare and scarce or threatened species and, although six NIMF species were identified from the data set, most are species that are widespread. Similarly, the NIMF biotopes that were identified are mainly widespread but threatened by such activities as land claim.

References

Chesman, B.S., Burt, G.R. & Langston, W.J. 2006. *Characterisation of the European Marine Sites: Essex Estuaries European Marine Site*. Marine Biological Association of the United Kingdom Occasional Publication 17. Marine Biological Association, Plymouth.

Images

Plate 18. Mudflats are generally populated by a low diversity of species but are important feeding grounds supporting a wide range of other species Salcott Creek on the Blackwater Estuary. Image: JNCC/David Connor.

Plate 19. The upper reaches of estuaries are habitats for species that can withstand low and variable salinity. Maldon Bridge, Blackwater Estuary. Image: JNCC/Roger Covey.

CASE STUDY SITE: DOGGER BANK

Location: 54° 81.00'N 2° 00' E
Existing designations for marine areas: (Possible SAC)
SAC proposed for Habitats Directive Annex 1 marine habitats: Shallow sandbanks slightly covered by seawater all the time
Physiographic type: Offshore

Species and biotopes

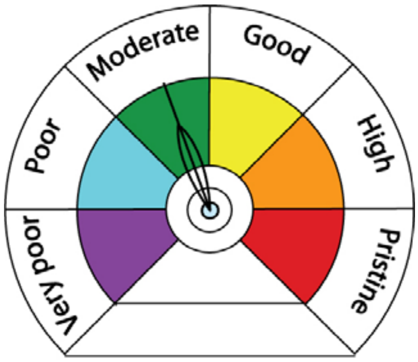
Recorded taxa: incompletely sampled

Hotspot measures (rank):

Incompletely sampled. None of the biotopes identified qualify as candidate NIMF species or biotopes.

Rank: not relevant

Site quality



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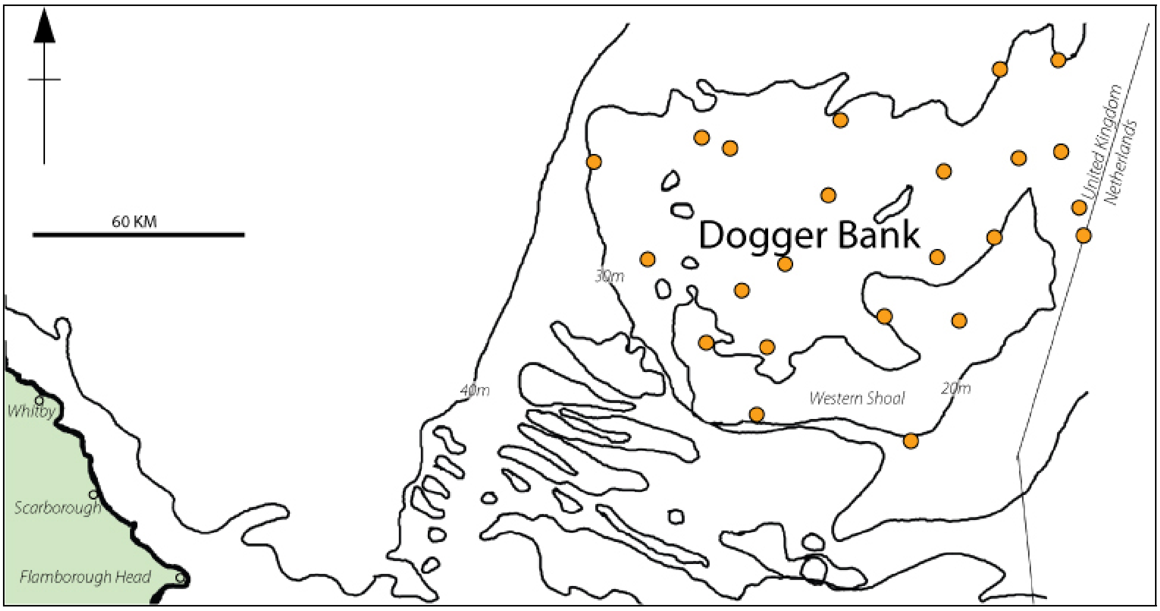


The Dogger Bank showing approximate locations of biological survey points within the UK sector

Description of Site/Criteria for selection:
(See Appendix 5 for definitions of Review of Marine Nature Conservation criteria.)

Typicalness: The Dogger Bank is an area of shallow sediments extending between 18m to more than 40m depth in a central region of the North Sea. The Dogger Bank is up to about 300km across and spans the territorial seas of Denmark, Germany, the Netherlands and the UK. JNCC has assessed the biological communities in the UK sector of the Dogger Bank and within the possible SAC as being typical of fine sand and muddy sand sublittoral sediments with the following biotopes being present:

- *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand (SS.SSA.IFiSa.NcirBat).
- Sparse fauna on highly mobile sublittoral shingle (cobbles and pebbles) (SS.SCS.ICS.SSh).
- *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand (SS.SSa.CFiSa.EpusOborApri).
- *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand (SS.SSA.IMuSa.FfabMag).
- *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud (SS.SMU.CSaMu.AfilMysAnit).

The Dogger Bank is considered untypical of North Sea habitats by Krönke & Knust (1995), being probably affected by eutrophication as well as fishing. The area proposed as a SAC by the JNCC would be representative of shallow Dogger Bank habitats, where sediments are probably mobile. Deeper than the area that qualifies as a Habitats Directive Annex 1 ‘Shallow sandbank’, sediments are more stable and communities are likely to be richer (see Krönke & Knust, 1995).

Naturalness: Seabed communities on the Dogger Bank are not in a natural state. The area has been extensively trawled for over 100 years and any architecturally complex structural features that may have been present before then will have been lost. However, in its current condition, the shallow seabed sediments are mobile and subject to some natural disturbance, so today’s fishery impacts assessed against a baseline of, say, 50 years ago are probably similar to natural disturbance. There are a small number of oil and gas installations and licence applications for aggregate extraction have been sought. Significantly, Krönke & Knust (1995) consider the communities of the Bank to show characteristics of areas affected by eutrophication.

Size: The Dogger Bank as a whole is a very large area, being about 300km across. The UK sector of the Dogger Bank proposed as an SAC is 13,405 sq km.

Biological diversity: Diversity of sediment communities is difficult to assess in view of the limited survey data currently available. The area is currently unlikely to be a ‘hotspot’ for species richness or the variety of habitats present but may prove to be a representative site for North Sea sediment habitats. If the area were to be strictly protected, it is likely that species diversity, particularly in deeper areas not subject to storm disturbance, would increase and communities would become closest to a natural state.

Critical area: The Dogger Bank is highly productive, with year-round phytoplankton production (see Krönke & Knust, 1995). It has been an important spawning ground for herring and may be regaining that importance. The bank may also represent an important area for harbour porpoise and is a feeding area for seabirds (see Unger, 2004).

Area important for a priority marine feature:

There were no candidate NIMF species or biotopes identified from the limited survey data available for the Dogger Bank.

Activities/Threats

The Dogger Bank is already subject to extensive physical disturbance as a result of bottom fishing. There is also potential vulnerability as a result of pipeline laying, oil and gas platforms and possibly offshore wind farm development. Aggregate extraction is not currently carried out but would be an issue if proposed. Although the area is subject to a considerable amount of shipping, those activities are unlikely to affect seabed communities. However, there may be disturbance to cetaceans and birds. Enhanced nutrient levels (eutrophication) may affect offshore areas – for example, phytoplankton production may be enhanced (see Krönke & Knust, 1995).

Summary conclusion

The Dogger Bank includes North Sea sediment communities capable of some restoration towards natural communities. The case study by Gubbay *et al.* (2002) identifies characteristics and threats. However, more sampling information is required to identify any special features that might be present, including any Nationally Important Marine Features. Also, the possibility that an SAC would be established for ‘shallow sandbanks slightly covered by seawater all the time’, with boundaries determined so that the SAC is mainly shallower than the 20m depth contour, would not make ecological sense and boundaries should be determined according to maintaining integrity of representative biotopes and of structure and functioning. The issues surrounding a possible transboundary MPA for the Dogger Bank are explored by Unger (2004).

References

Gubbay, S., Baker, C.M. & Bett, B.J. 2002. *The Darwin Mounds and the Dogger Bank. Case studies of the management of two potential Special Areas of Conservation in the offshore environment.* WWF-UK, Godalming.

Krönke, I. & Knust, R. 1995. The Dogger Bank: a special ecological region in the central North Sea. *Helgölander Meeresunters,* **49**, 335-353.

Unger, S. 2004. *Managing across boundaries. The Dogger Bank – a future international marine protected area.* WWF-Germany, Bremen.

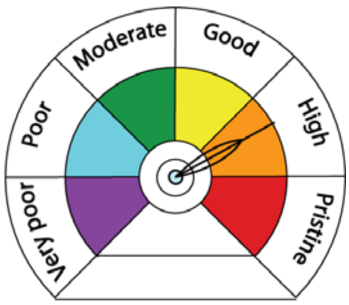
UK MARINE BIODIVERSITY HOTSPOTS

CASE STUDY SITE: MULL

Location: Mull and adjacent coast
Existing designations for marine areas: The area is not currently within any designation.
Physiographic type: Island

Species and biotopes	Site quality

Recorded taxa*: 943 from 192 survey stations
Hotspot measures (rank):
Species richness*: 579 (2)
Candidate NIMF species: 30 (3)
Taxonomic distinctness 93.02 (2)
Biotope richness 91 (2)
Candidate NIMF biotopes: 22 (2)
Biotope distinctness 93.12 (2)



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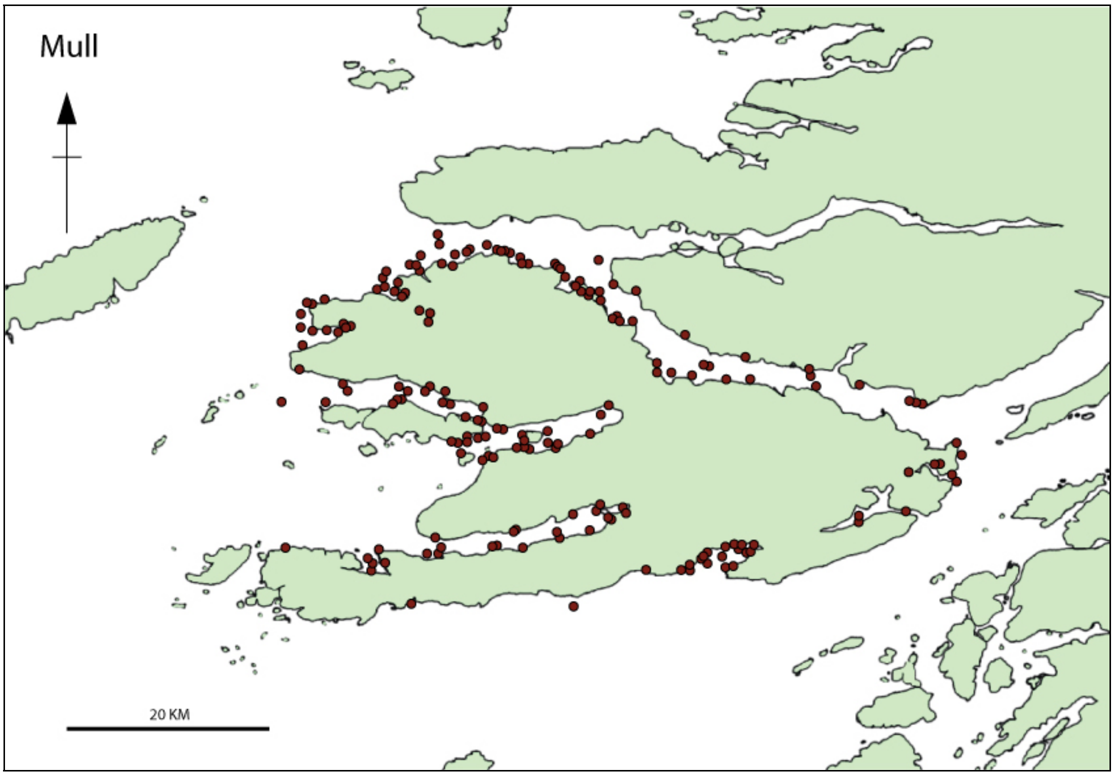


Survey sites included in analyses around Mull.

Description of Site/Criteria for selection:
(See Appendix 5 for definitions of Review of Marine Nature Conservation criteria.)

Typicalness: The area is predominantly reefs, which are typical of a wide range of conditions from extremely exposed to wave action to extremely sheltered from wave action, and from areas with gentle tidal currents to ones where currents are strong. The marine species present are typically northern and west coast species and include many that are Mediterranean-Atlantic and extend to the west coast of Scotland.

Naturalness: The area is considered to be highly natural in character.

Biological diversity: The Mull area supports a wealth of species diversity. Six species found here are rare, including the sea fan anemone (*Amphianthus dohrnii*), worm anemone (*Scolanthus callimorphus*), cup coral (*Caryophyllia inornata*), the hydroid *Obelia bidentata* and the bryozoan *Bugula purpurotincta*.

Mull is an important area for whale and dolphin watching excursions, with 23 species of cetacean recorded in the coastal waters. Common seals (*Phoca vitulina*), grey seals (*Halichoerus grypus*) and European otters (*Lutra lutra*) add to Mull's mammal fauna. Basking sharks are also seasonal visitors to the waters around Mull.

Critical area

Area important for a priority marine feature
The area of Mull holds many species identified as candidate NIMF, including both northern and southern species. Biotopes identified as candidate NIMF are especially sediment ones including maerl.

Activities/Threats
There is a large amount of fishing activity around Mull, with crustaceans and scallops being targeted. Scallop dredging is highly damaging to seabed communities, especially where reefs are incidentally impacted. Fish farming in the sea lochs introduces waste food and faeces, which can smother seabed life and cause de-oxygenated conditions. There are high levels of recreational diving in the Mull area, particularly targeting wrecks. The wildlife watching industry is particularly active around Mull and care is required to minimise disturbance.

Summary conclusion
Mull ranks highly for NIMF species richness and has generally high scores for other measures. The variety of habitats and associated species makes the area of Mull of high value and, if combined with adjacent high scoring areas (Loch Sunart, Loch Linnhe and Loch Creran), the area is outstanding for most hotspot measures.

CASE STUDY SITE: UNST (INCLUDING BLUEMULL SOUND), SHETLAND

Location: 60° 44.55'N, 0°53.25'W
Existing designations for marine areas: none
SAC established for Habitats Directive Annex 1 marine habitats: none
Physiographic type: Island

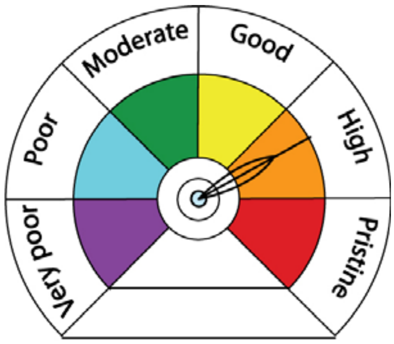
Species and biotopes

Recorded taxa*: 428 from 54 survey stations

Hotspot measures (rank):

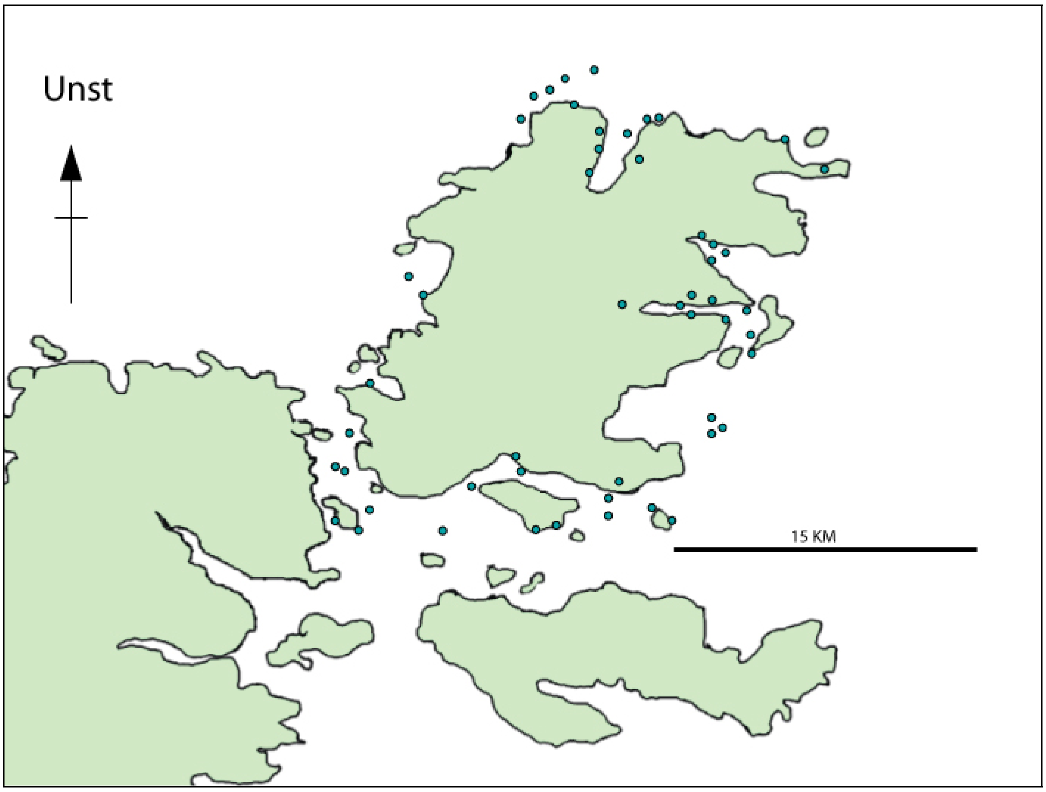
Species richness*: 243(2)
Candidate NIMF species: 10 (2)
Taxonomic distinctness 93.95 (3)
Biotope richness 64 (2)
Candidate NIMF biotopes: 21 (2)
Biotope distinctness 89.45 (1)

Site quality



See text for definitions

* "Taxa" refers to all entities recorded including incomplete identifications. "Species" includes only entities identified to genus and species.



Survey sites included in analysis for Unst.

Description of Site/Criteria for selection:
(See Appendix 5 for definitions of Review of Marine Nature Conservation criteria.)

Typicalness: The area is the most northern part of the UK and, as such, the species and biotopes present are characteristic of cold water temperatures and include Arctic-boreal species such as the sea urchin *Strongylocentrotus droebachiensis* and the sea cucumber *Cucumaria frondosa*, as well as species that particularly thrive in northern waters such as the stone crab *Lithodes maia*, the tortoishell limpet *Tectura testudinalis*, the snail *Margarites helicinus* and the brachiopod (lamp shell) *Neocrania anomala*. Broken beds of horse mussels *Modiolus modiolus* are present and maerl beds are also well developed in wave-sheltered tide-swept areas, especially at the southern entrance of Bluemull Sound. There are cave systems, although there is little information on how representative they are. Unusually for such northern waters, wave and tide exposed locations include communities dominated by jewel anemones *Corynactis viridis* which, nevertheless are typical of such exposed conditions. There are other biotopes present that are typical of exposed conditions, including those that occur in surge gullies.

Naturalness: There are few man-made structures that impinge on the marine environment – mainly slipways and jetties. The area is distant from mainland sources of pollution, and local sources of domestic effluent are mainly led to septic tanks. However, farmed fish cages will produce organic effluents and potentially chemicals including antifoulants and pharmaceutical products.

Size: The island is 'self-contained' for the habitats and many of the species present there. Many of the species that are of importance for the conservation of biodiversity are most likely to recruit from local populations around the island and do not rely on adjacent island sources of larvae.

Biological diversity: Biological diversity in terms of species richness decreases to the north of the UK and so high species counts would not be expected for Unst. Nevertheless, the location comes out as moderate species richness and the range of taxonomic groups is high. Unst has a very wide range of habitats: from extremely exposed to wave action and tidal streams to very sheltered conditions in voes and the sound between islands. Bluemull Sound is particularly notable as tidal streams are so strong there and, as they reduce to the south, the maerl beds are a special feature of the area. It is the wide range of habitats that makes the area so rich (for a northern site) in species.

Cetaceans including killer whales are frequently cited off Unst, especially in the Blumull Sound area.

Critical area: While no information has been found regarding critical importance for mobile species, some nationally rare or scarce species occur around Unst and, although they are 'outliers' of large populations in Scandinavia, they are important in a UK context.

Area important for a priority marine feature:
The main features for which Unst is important include northern species for which Shetland is the only location or main location in the UK, and some habitats, especially maerl.

Activities/Threats

Wave sheltered areas, especially south of Unst, have become extensively developed for salmon and now cod farms in the past 20 years and, while it has not be possible to assess impacts for this report, it is felt that such activities are bound to reduce water quality. Potting for crustaceans is an important activity. Oyster culture has the potential to import non-native species. Proposals for a tidal generator in Bluemull Sound could lead to disruption of communities (during construction and including potential damage by jack-up rigs) and through the presence of the generator.

Summary conclusion

Unst ranks highly for taxonomic distinctness and, considering its northern location and comparatively small number of sample sites, has generally high scores for other measures. The highest value for Unst is not identified directly in the hotspot measures: the area is important as the northernmost outpost of the UK and has significant populations of arctic-boreal species that only occur in the far north. The marine habitats are adjacent to terrestrial sites of natural heritage importance, especially the National Nature Reserve at Hermaness, and the area attracts large mammals including killer whales.

Images

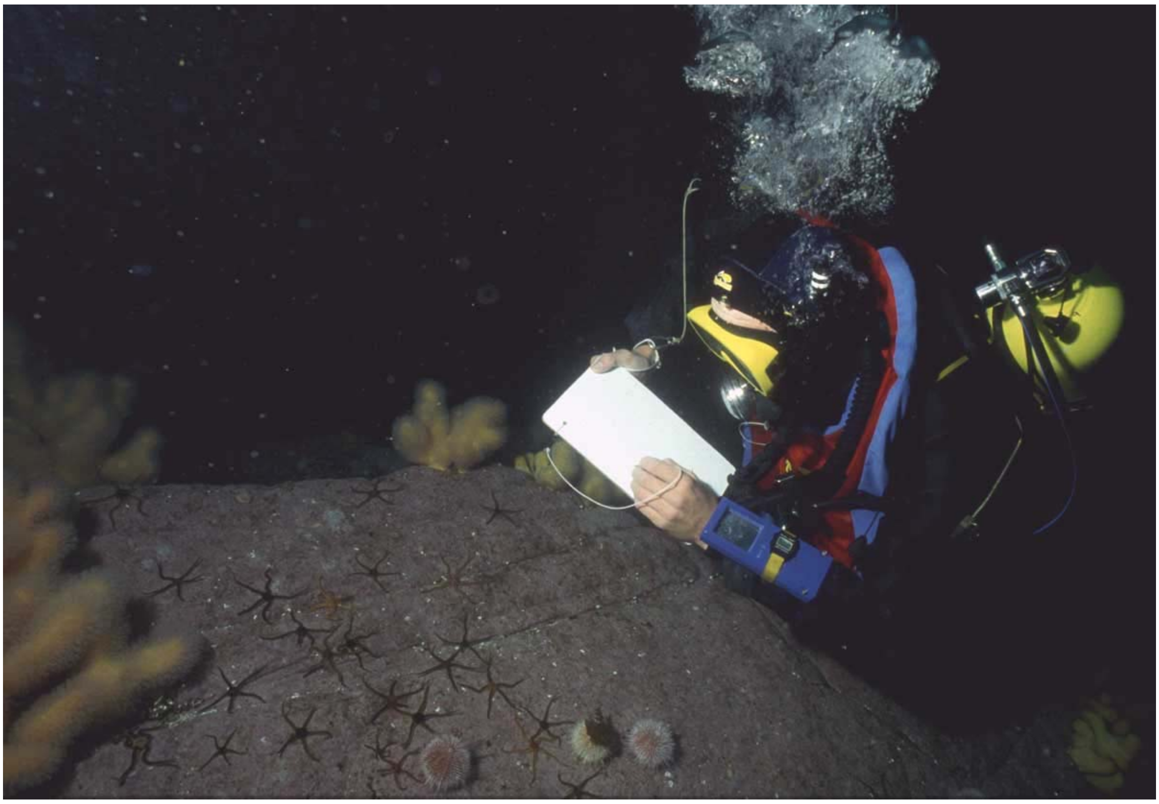


Plate 20. Surveying in Shetland. Open coast rocky areas are heavily grazed by sea urchins *Echinus esculentus*. Also visible are dead men's fingers *Alcyonium digitatum* and black brittle stars *Ophiocomina nigra*. Image: JNCC/Sue Scott.

Plate 21. Muckle Flugga and Out Stack off Unst in Shetland – the most northerly islands in Britain. Image: JNCC/David Connor.

Plate 22. The northern sea urchin *Strongylocentrotus droebachiensis* is recorded from Shetland and Orkney in the British Isles. Image: JNCC/Sue Scott.

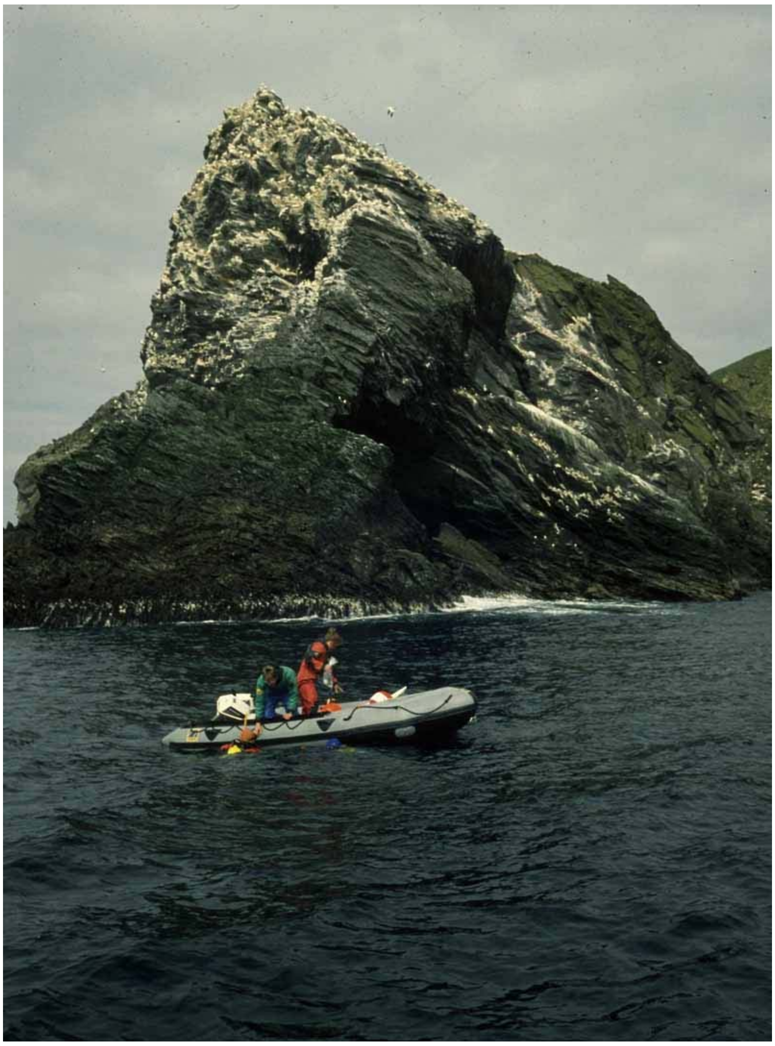


Plate 23. Hermaness, on the north-west of Unst – an important location for breeding sea birds. Photographed during Marine Nature Conservation Review surveys in Shetland. Image: JNCC/Keith Hiscock.

CASE STUDY SITE: HATTON BANK

Location: 59° 00'N, 17° 00'W
Existing designations for marine areas: None. The Hatton Bank is currently being investigated by the UK Joint Nature Conservation Committee for possible protection under the EU Habitats Directive.
Physiographic type: Deep sea reefs

Species and biotopes

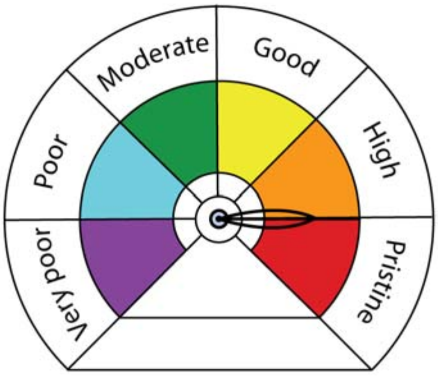
Recorded taxa: incompletely sampled

Hotspot measures (rank):

Incompletely sampled.

Rank: not relevant

Site quality



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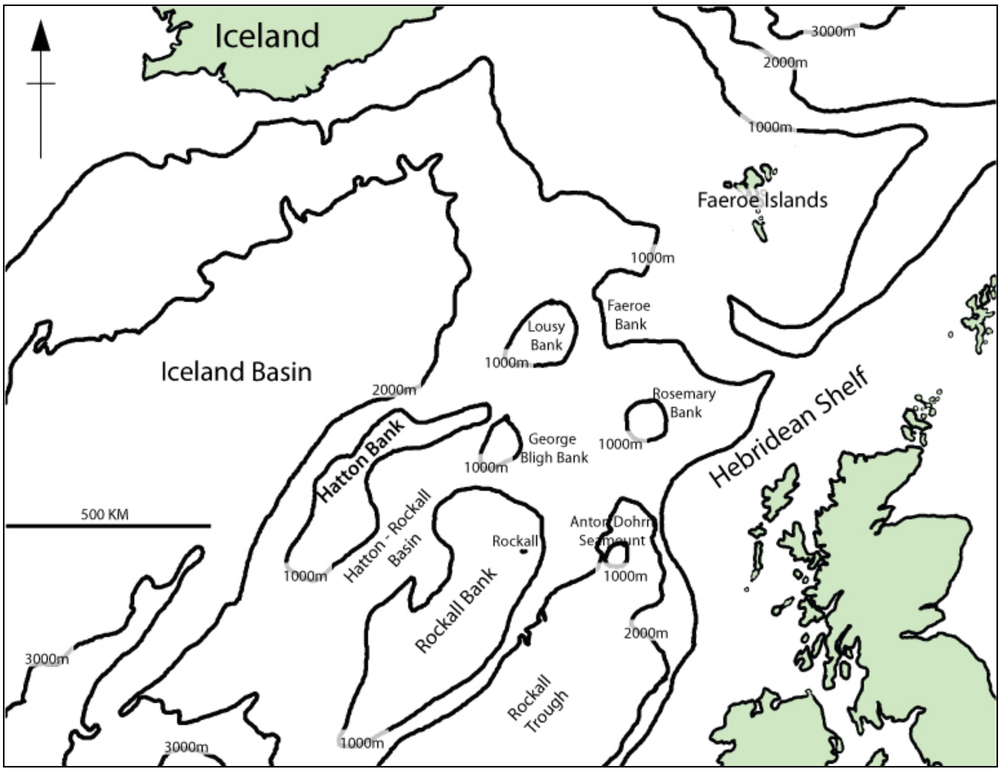

Location of the Hatton Bank

Description of Site/Criteria for selection:
(See Appendix 5 for definitions of Review of Marine Nature Conservation criteria.)

Typicalness: The Hatton Bank is one of the topographical features that rise out of deep (>1,500m) water to the north-west of Britain. The shallow parts of the Hatton Bank are less than 500m deep. Sparse survey data suggests that the Hatton Bank is populated by similar habitats and communities to George Bligh and NW Rockall Banks.

Naturalness: A high proportion of the Hatton Bank is most likely to be in pristine condition. However, some areas have been subject to extractive and damaging human activities (bottom trawling) so that areas of coral reef have been damaged.

Size: The Hatton Bank extends over 400km from 56° to 59° N, with shallow areas being about 50-80km across.

Biological diversity:
During photographic surveys (Narayanaswamy *et al*. in preparation; Long *et al.* unpublished), visible megafaunal diversity was found to be high on Hatton Bank (as well as the George Bligh and NW Rockall Banks). Extensive areas of reef framework created by the scleractinian corals *Lophelia pertusa* and *Madrepora oculata* were found at 500-900m on the Hatton Bank where coral-dominated areas supported a rich associated sessile epifauna. Sampling has mainly been by video survey, revealing coral structures a variety of epifauna including the large sea anemone *Phelliactis* sp., the black coral (antipatharian) *Stichopathes* sp., hydroids and bryozoans and with a variety of crustaceans, echinoderms and fish. Steep slopes, ledges and rock overhangs at 470-730m are often colonised by stylasterid corals (probably *Pliobothrus* sp.), antipatharia coral (*Leiopathes* sp. and *Stichopathes* sp.), scleractinian and bamboo corals and the holothurian *Psolus squamatus*. There are extensive sediment areas.

Critical area: The area is little known and any critical attributes for mobile species such as importance for spawning are not yet known.

Area important for a priority marine feature:

Species. None listed but knowledge of species on deep water reefs is very poor.

Biotopes. The Hatton Bank supports *Lophelia pertusa* coral reefs, which are a BAP habitat.

Activities/Threats
The Hatton Bank is fished for deep water species and it is known that vessels dredge live coral from the area (Frederiksen, 1992; Wilson, 1979).

Summary conclusion
The Hatton Bank is highly regarded for its deep water hard substratum habitats, including coral structures and associated species. The area includes pristine deep water habitats, although some areas are no doubt damaged by trawling. The area is representative of the topographical rises from the deep sea to the north-west of Britain and seems to include some, if not the best,

examples of hard substratum deep water communities in UK waters. Very little is known of the biology of deep sea habitats and so it is difficult to identify species that are rare or threatened. What is certain is that the coral habitats in particular are highly susceptible to physical damage.

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Images

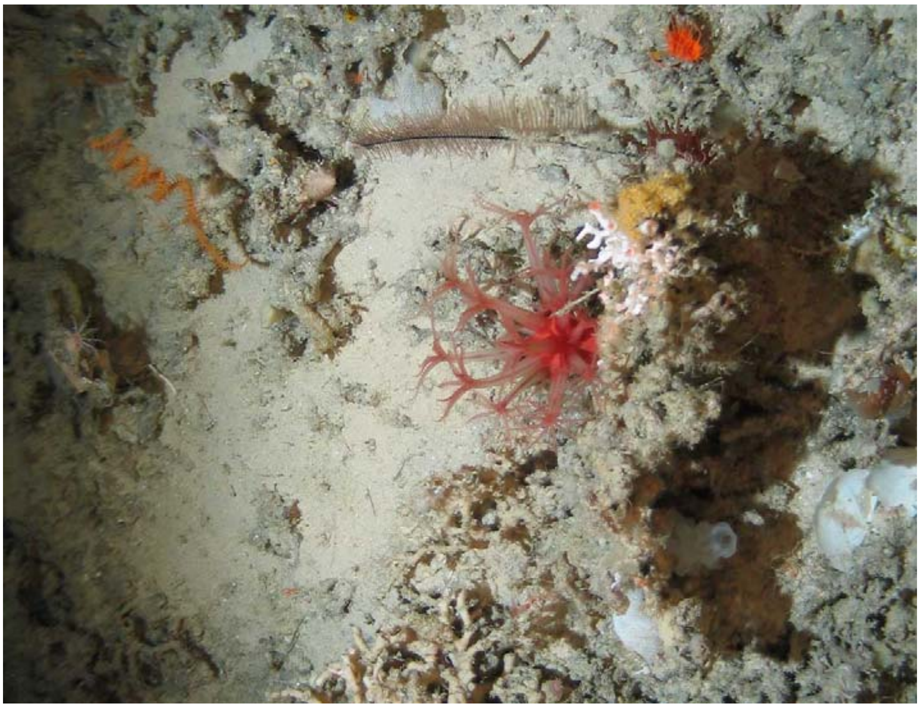

Plate 24. Deep water fauna on the Hatton Bank. The red zoanthid anemone *Anthomatus grandifloris* with (left) the black coral *Sticopathes* sp. and (right) a small colony of the coral *Lophelia pertusa*. Image: Crown Copyright.

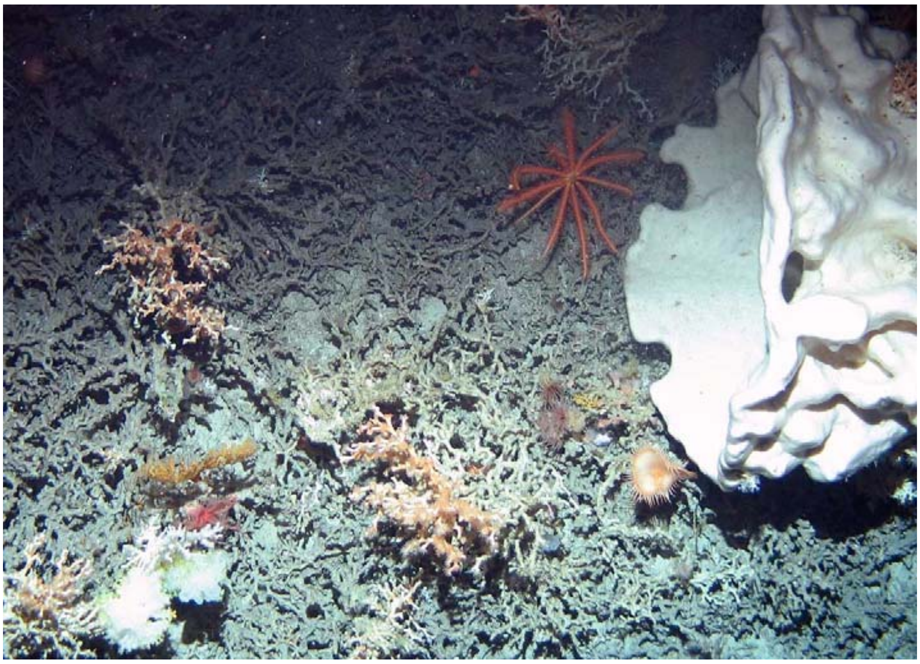

Plate 25. Deep water fauna on the Hatton Bank. Colonies of the coral *Lophelia pertusa* with a large *Aphrocalistes* sp. sponge, the anemone *Phellactinia* sp. and a brisingid sea star. Image: Crown Copyright.

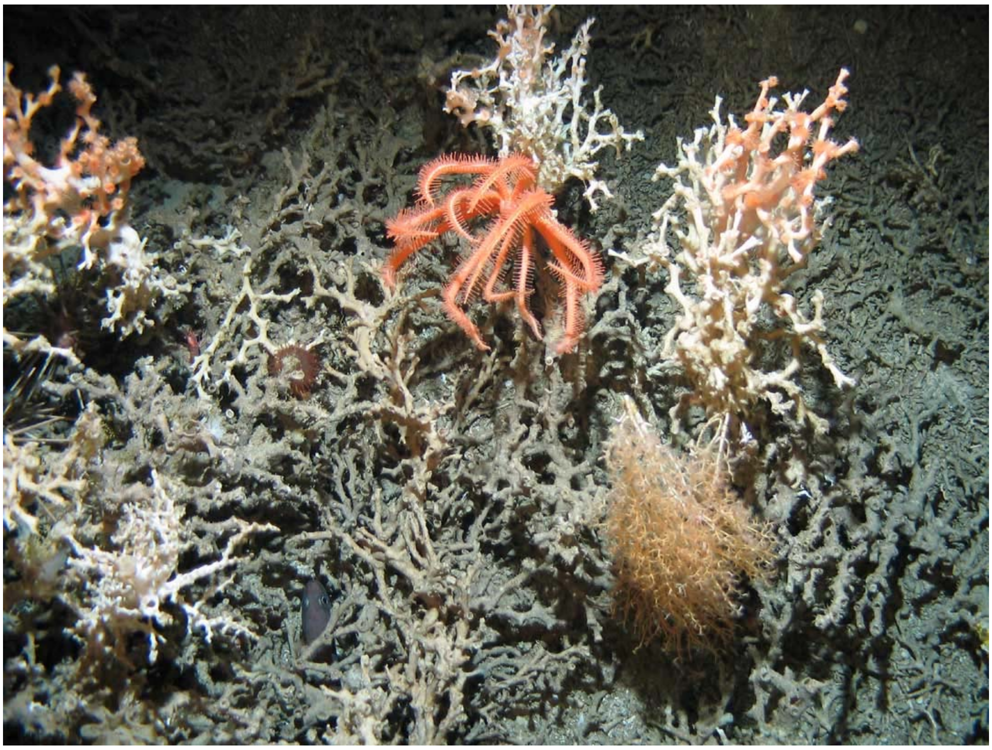

Plate 26. Deep water fauna on the Hatton Bank. Colonies of the coral *Lophelia pertusa* with a brisingid sea star and ?*Acanella* bamboo coral. Image: Crown Copyright.

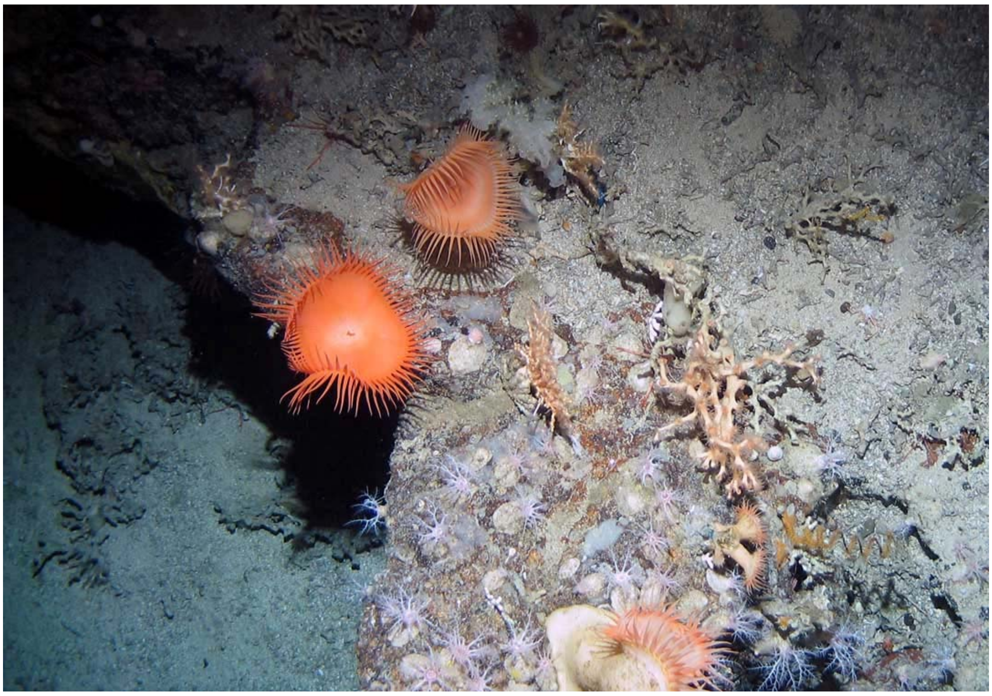

Plate 27. Deep water fauna on the Hatton Bank. The red anemone *Phellactinia* sp., sea cucumbers, *Psolus* sp., the black corkscrew-like coral *Sticopathes* sp. and a small colony of the coral *Lophelia pertusa*. Image: Crown Copyright.

APPENDIX 11. GLOSSARY OF TECHNICAL TERMS

Average taxonomic distinctness Average taxonomic distinctness calculates the average taxonomic distance apart of all the pairs of species in a sample, based on branch lengths of a hierarchical Linnaean taxonomic tree, making it possible to calculate how taxonomically distinct (distant) two species occurring in an area or sample are from one another (based on Warwick & Clarke 2001).

Biodiversity "The variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." (UN Convention on Biological Diversity, 1992.)

Biotope 1. The physical 'habitat' with its biological 'community'; a term which refers to the combination of physical environment (habitat) and its distinctive assemblage of conspicuous species. MNCR uses the biotope concept to enable description and comparison. 2. The smallest geographical unit of the biosphere or of a habitat that can be delimited by convenient boundaries and is characterised by its biota (Lincoln *et al*., 1998).

Ecosystem Approach The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. (Convention on Biological Diversity, 2000.)

Epifauna Animals living on the surface of the seabed.

Imposex An abnormality of the reproductive system in female gastropod molluscs, by which male characteristics are superimposed onto female individuals (Smith, 1980), resulting in sterility or, in extreme cases, death. This may be caused by hormonal change in response to pollution from organotin antifoulants, even at low concentrations.

Infauna Benthic animals that live within the seabed.

Marine Biodiversity Hotspot Area of high species and habitat richness that include representative, rare and threatened features. [Definition developed for this report.]

Marine Nature Reserve A statutory marine protected area declared in Great Britain by the Nature Conservancy Council and its successor agencies under the Wildlife and Countryside Act 1981 for the purpose of conserving marine flora or fauna or geological or physiographical features in the area and providing opportunities for study and research (from Anon., 1994). Voluntary MNRs are non-statutory protected areas agreed by local sea-users and other interested parties.

Monitoring The process of repetitive observation, for defined purposes, of one or more elements of the environment, according to prearranged schedules in space and time and using comparable methods for environmental sensing and data collection. Monitoring provides factual information concerning the present state and past trends in environmental behaviour (based on UNEP definition). The term is also applied to compliance monitoring against accepted standards to ensure that agreed or required measures are followed.

Nationally Important Marine Features 1. Areas that best represent the range of seascapes, habitats and species present in the UK – the UK's marine biodiversity heritage. 2. Seascapes, habitats and species for which we have a special responsibility in a national, regional or global context. 3. Seascapes, habitats and species that have suffered significant decline in their extent or quality, or are threatened with such decline, and can thus be defined as being in poor status. (Connor *et al.* 2002.)

Nationally rare (species) For marine conservation purposes, these are regarded as species of limited national occurrence (q.v. rarity). By analogy with the approach adopted in British Red Data Books but referring to sea areas within the three-mile limit of territorial seas, they are defined as those species known to occur in 0.5% or less (eight or fewer) of the 10km x 10km squares containing sea within the three-mile limit of territorial seas for Great Britain (Sanderson, 1996).

Nationally scarce (species) For marine conservation purposes, these are regarded as species of limited national occurrence (q.v. rarity). By analogy with the approach adopted in British Red Data Books but referring to sea areas within the three-mile limit of territorial seas, they are defined as those species known to occur in 0.5 to 3.5% (9-55) of the 10km x 10km squares containing sea within the three-mile limit of territorial seas for Great Britain (Sanderson, 1996).

Physiographic feature Referring to physical geography and landform features (various references via www.dictionary.com).

Pristine Having original purity, unaffected by human activities (based on definitions in www.dictionary.com)

Propagule A structure with the property to give rise to a new plant (spores, seeds, vegetative growths etc.) (based on definitions in www.dictionary.com)

Refugia An area that has escaped ecological changes occurring elsewhere and so provides a suitable habitat for relict species. (www.dictionary.com).

Ria A drowned river valley in an area of high relief; most have resulted from the post-glacial rise in relative sea-level (based on Allaby & Allaby, 1990). As defined for the EC Habitats Directive, 'rias and voes' are "drowned river valleys (not of glacial origin) with relatively deep narrow well-defined channels which are predominantly marine throughout".

Sites of Specific Scientific Interest (SSSI) An area of land that is of special interest by reason of its flora, fauna or geological or physiographic features and that is notified under the provisions of the Wildlife and Countryside Act 1981. In the marine environment, SSSI can be notified to Mean Low Water in England and Wales and Mean Low Water of Spring Tides in Scotland. In Northern Ireland, Areas of Special Scientific Interest have similar status. (Based on the Wildlife & Countryside Act 1981.)

Strait Any deep (>5m) tidal channel between two bodies of open coastal water. Strictly, a strait is the stretch of water between an island and its mainland (or adjacent islands) (from Earll & Pagett, 1984).

Taxon (pl. taxa) A taxonomic group of any rank, including all its subordinate groups; may be a single species or a group of related species, e.g. genus, class, order, etc., considered to be sufficiently distinct from other such groups to be treated as a separate unit (based on Lincoln & Boxshall, 1987 and Fitter & Manuel, 1986).

Taxonomy The branch of biology concerned with the classification of organisms into groups (taxa) based on similarities of structure, origin, etc.

Voe A ria (q.v.) (in Shetland).

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APPENDIX 12. ACRONYMS AND NAMES

BAP Biodiversity Action Plans

BioMar (not an acronym) Marine coastal zone management: identification, description and mapping of biotopes (an EU-LIFE-funded project)

BIOMARE Implementation and networking of large scale, long term **MAR**ine **BIO**diversity research in **E**urope

DASSH Data Archive for Seabed Species and Habitats

EUNIS European Nature Information System

GIS Geographical Information Systems

MarLIN Marine Life Information Network for Britain and Ireland

Marxan A marine nature reserve system selection tool

MNCR Marine Nature Conservation Review of Great Britain

MPA Marine Protected Area

NBN UK National Biodiversity Network

NIMF Nationally Important Marine Feature

OSPAR Oslo-Paris Commission for the Protection of the Marine Environment of the North-East Atlantic

RMNC Review of Marine Nature Conservation

SSSI Site of Special Scientific Interest

TBT Tributyl tin (a now banned ingredient of anti-fouling paint)

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The Marine Biodiversity Hotspots report was prepared by the Marine Biological Association of the UK.

The MBA promotes scientific research into all aspects in the sea and disseminates to the public the knowledge gained. The *MarLIN* programme is a part of the MBA supporting marine environmental management protection and education. www.mba.ac.uk, www.marlin.ac.uk

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