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The Ecological Coherence and Economic & Social Benefits of the Northern Ireland MPA Network

Report to the Northern Ireland Marine Task Force

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EXECUTIVE SUMMARY

This study develops and applies a novel technique for assessing the ecological coherence of a network of MPAs. In general, the current NI MPA network meets the network design criteria of representativity, replication, connectivity, adequacy and viability, and demonstrates a good level of ecological coherence.

Relative weaknesses in the network are assessed through a gap analysis (focussing on representativity, adequacy, replication and connectivity) identifying areas that, if designated, would further improve the coherence of the network.

The potential benefits to society of this extended network of MPAs are estimated using an established valuation method, previously applied to English and Scottish waters. The present value of the extended Northern Ireland network is estimated to be in the region of £52.8 million to £54.5 million (3.5% discount rate over a 20 years period) depending on the management regimes that are adopted for the network.

The marine environment in Northern Ireland covers approximately 4,500 km^2 and is important in providing wealth and well-being to society by supporting a wide variety of marine life and habitats including seabirds, basking sharks, seals, dolphins and diverse reef habitats. In order to protect the marine environment, the UK Government and the devolved Northern Ireland Government are both committed to the establishment of a Marine Protected Area (MPA) network in Northern Ireland waters. In support of this commitment, the Department of the Environment (DoE, Northern Ireland) released a draft MPA strategy for public consultation in October 2013, outlining its commitment to creating an ecologically coherent network of MPA sites at the Northern Ireland scale, as well as contributing to the broader UK network.

Until recently, protection of the marine environment in Northern Ireland has focussed on species and habitats of European or international importance. With the signing of the Marine Act (Northern Ireland) 2013, DoE is now able to designate a new type of MPA: a Marine Conservation Zone (MCZ). It is likely that MCZs will reflect the conservation needs of species and habitats of importance relative to Northern Ireland, and their designation will augment the existing network of inshore MPA sites, assisting in achieving an ecologically coherent network protecting rare, threatened or nationally important marine habitats, species and geological features. In addition to identifying the ecological characteristics of candidate MCZs, the DoE must consider the social, economic and cultural consequences of designation.

To help inform the development of the Northern Ireland network of MPAs, the Northern Ireland Marine Task Force (NIMTF)[1] has commissioned the University of Hull[2] to undertake an independent study to:

- assess the ecological coherence of the network of Northern Ireland MPA sites in the context of the species, habitats, features and/or areas that are found within Northern Irish waters, and subsequently identify gaps in the MPA network; and to
- assess and review the potential economic and social value associated with this network (considering the value of different levels of MPA protection).

[1] The Northern Ireland Marine Task Force (NIMTF) is a coalition comprising: Northern Ireland Environment Link, Ulster Wildlife, Royal Society for the Protection of Birds, WWF, the National Trust, Wildfowl & Wetlands Trust, Friends of the Earth, the Irish Whale and Dolphin Group, the Marine Conservation Society and Tidy NI. Members of the NIMTF work together to help secure productive and healthy seas and, in this context, are interested in understanding the economic benefits from an ecologically coherent network of sites across Northern Ireland.

[2] Specifically the Institute of Estuarine and Coastal Studies (IECS) at the University of Hull, in collaboration with the Hull University Business School (HUBS).

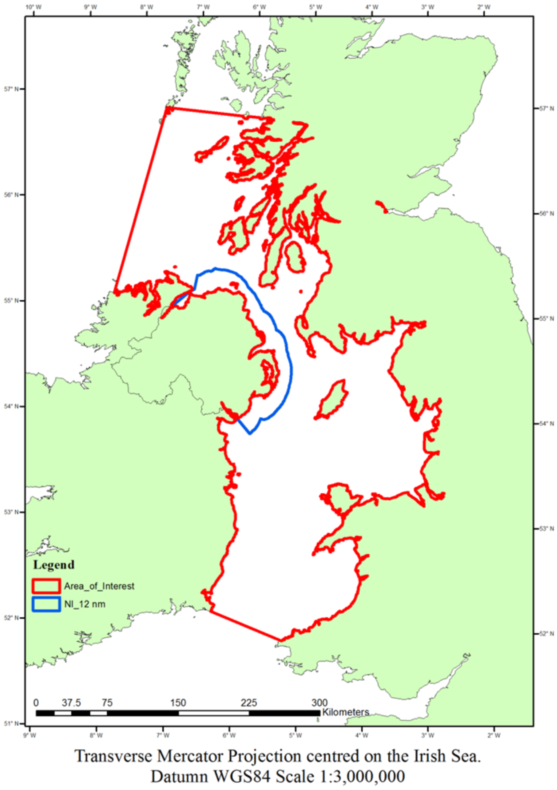


Figure ES1 - Study area: NI inshore area to 12 NM (blue line) and wider Area of Interest (red line).

The geographical scope of the project covers Northern Ireland's inshore waters out to 12 NM, although findings are discussed within the context of a wider 'Area of Interest' to represent a cohesive and ecologically relevant sea area (Figure ES1).

Ecological coherence is a developing concept, and no definitive procedures for its assessment are available. To satisfy the needs of the project, assessments of the fundamental MPA network design criteria (representativity, replication, connectivity, adequacy and viability) were undertaken using both established and novel methods. The findings of these individual assessments, together with an appraisal of the overall ecological coherence of the existing MPA network are discussed. Subsequently, the potential economic and social benefits associated with the designation of an extended coherent MPA network in the territorial waters of Northern Ireland are assessed.

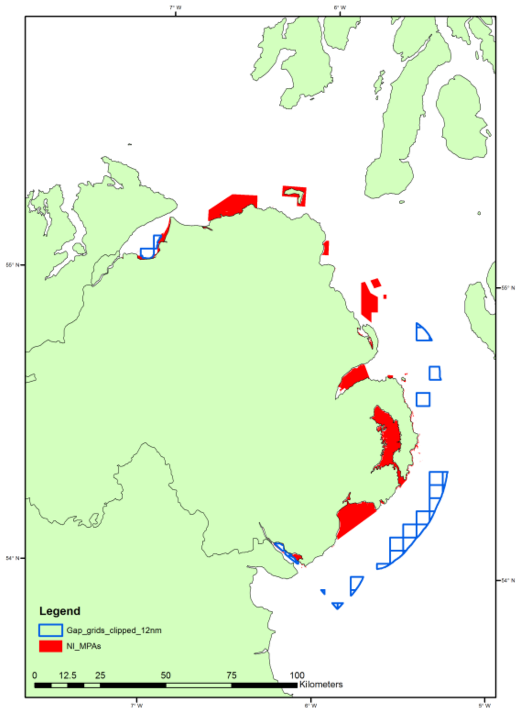
The analyses that were undertaken make extensive use of an extensive data set which was based on the collation of information for species and habitats from a number of different sources. As each of these sources was subject to different data collection strategies, levels of spatial precision and coverage, and sampling intensities (on both temporal and spatial scales) it was necessary to convert the available data into a common format for use in this study. To satisfy this requirement all available data were converted to a grid format based on the presence/absence of each feature within 5 km grid cells.

In total, data for 220 species and habitat features were collated to provide the basis for the ecological coherence assessment. These features (the 'coherence assessment list') were identified from: the Northern Ireland Priority Species List; priority lists produced for the MCZ processes in England and Wales, and for the Scottish MPA project; species and habitats listed in Annex 1 & 2 of the Habitats Directive; species listed in the Birds Directive; species and habitat features recorded on the OSPAR list of threatened and/or declining species and habitats; and the list of marine features (habitats and species) identified by DoE for consideration with respect to new MCZs.

The assessment showed that the network is representative of the broad habitats present in Northern Ireland waters and the constituent MPA sites generally reflected the relative proportions of different habitat types known to be present, although one notable exception is the poor representation of deep water mud habitats. The network provides for a reasonable level of replication, with most of the features sufficiently replicated across MPA sites. Although guidelines for connectivity are available there are a number of other factors that affect the ecological value or importance of between-site distances (e.g. prevailing currents, presence of fronts, and the availability of specific habitat types for key species life-stages). The estimated between-site distances for the MPA network suggested that the degree of connectivity in the network is high. Analyses for adequacy suggest that this element of network design is, in general terms, well met by the existing MPA network. Of all the network design criteria considered it is probably site viability that is weakest, with sites across the

Northern Ireland MPA network being smaller than is generally recommended. However, the network is shown to satisfy each of the design criteria to at least a reasonable extent and it is concluded that the current MPA network demonstrates a good level of ecological coherence.

There are, however, some relative weaknesses in the network and these were assessed through a network gap analysis, focussing on four of the design criteria: representativity, adequacy, replication and connectivity. With the assumption of equal weighting across the design criteria a set of 'priority gap cells' was identified, representing those areas of the Northern Ireland 12 NM zone that, if designated, would further improve the coherence of the network, and which could usefully be considered as providing the basis for areas of search for new MCZs. The existing MPA network in Northern Ireland's inshore area and the proposed (extended) network of MPAs identified by the gap analysis, as shown in Figure ES2.



Transverse Mercator Projection centred on the Irish Sea
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Figure ES2 - Existing MPAs in Northern Ireland's inshore area (red) and the proposed (extended) network of MPAs (blue).

The fundamental purpose of MPAs lies in the conservation of habitats and species, which in turn support the provision of ecosystem services so leading to societal benefits. Ecosystem services are defined here as the link between ecosystems and things that humans benefit from, not the benefits themselves. Identifying and valuing the ecosystem services from MPAs can highlight both the mix and importance of services produced from marine systems in general, whilst identifying the potential for specific services to be enhanced or supported by MPA designation and management. The approach adopted here to estimate the social and economic benefits of the proposed Northern Ireland MPA network follows the methodology developed previously for assessing the MCZ networks in English territorial waters and UK offshore waters[3], and applied to the network of Scottish MPAs[4]. This standardised approach allows subsequent comparisons to be made between the studies. The benefits arising from the proposed MPA network for Northern Ireland inshore waters are associated with a change in the provision of a number of ecosystem services provided by the marine environment. No consideration could be given to off-site benefits that might be derived as a result of site designation within the proposed MPA network, such as the contribution of the additional MPA network to fishery productivity beyond the designated area.

[3] Moran, D., Hussain, S., Fofana, A., Frid, C., Paramor, O., Robinson, L. & Winrow-Giffin, A. (2008) The Marine Bill – Marine Nature Conservation Proposals – Valuing the Benefits. CRO 380 Final Report. London: Defra.

[4] González-Álvarez, J., García-De-La-Fuente, L. & Colina-Vuelta, A. (2012) Valuing the benefits of designating a network of Scottish MPAs In territorial and offshore waters. Scottish Environment Link, 104 pp. Available at: www.scotlink.org [accessed June 2013].

The valuation approach considers two basic scenarios: the current Northern Ireland MPA network and the proposed (extended) Northern Ireland MPA network which is necessary to ensure that the network as a whole is ecologically coherent (Figure ES2). The effects on the provision of ecosystem services at two distinct levels of conservation management are considered: highly restricted MPAs, where the conservation objective is to 'recover'; and maintenance of conservation status MPAs, where the conservation objective is to 'maintain' (Table ES1).

Table ES1 Specification of management regime restrictions.

Conservation Objective:	
'Recover' Management Regime	**'Maintain' Management Regime**
General presumption against fishing of all kinds, and all constructive, destructive and disturbing activities. Recovery measures appropriate to the local situation (enhanced restoration/aftercare measures on expiry of operating licences).	New development activities permitted which are in the public interest (on social or economic grounds). Existing activities to continue if these do not cause the site condition to deteriorate. Restriction of bottom fishing gears either spatially or temporally and technical conservation measures. Recovery measure appropriate to the local situation (enhanced restoration/aftercare measures on expiry of operating licences).

There was no scope within the current project to undertake primary data collection to support economic valuation, and therefore estimates of value were largely based on market analysis and benefit transfer methodologies. Evidence of the total economic value of the UK marine environment was drawn from the literature and the definition of ecosystem services based on an established ecosystem service framework. Despite an increase in ecosystem services research over the last decade or so, there are still a number of ecosystem services for which valuation data at the UK level is not available (e.g. bioremediation of waste, biologically mediated habitat, resilience and resistance, and cultural heritage and identity), and so it is important to regard the total economic value of marine ecosystem services provided here for Northern Ireland waters to be an underestimate of the potential benefits secured from designation. For each ecosystem service category, an estimated total value of UK marine ecosystem services was apportioned between JNCC marine landscapes and the OSPAR Threatened and Declining Habitat types that they represent using a weighting scheme developed within the project. The benefits of designating additional MPA sites in Northern Ireland inshore waters were derived from apportioning the total value estimates to the biophysical changes in landscape/habitat types associated with the implementation of the 'recover' and 'maintain' management regimes.

The main findings are reported as net present values, which is a standard technique used to give allowance for when benefits are distributed over time and, in this case, are estimated to occur over a 20-year period of investigation. All values are presented as 2012 values and inflation is not considered. Present values are calculated using discounting and, based on government guidance, a discount rate of 3.5% was employed. The use of discounting implies that benefits secured earlier in the period have a higher present value than equivalent benefits secured later in the period. It is recognised that there will be benefits beyond the 20 year period but these are not valued. The findings are also presented as undiscounted annual mean values. If values are undiscounted then no allowance in the assessment would be given for the timing of when the benefit is secured.

Overall, the estimated results indicate that potential benefits secured are £52.82 million under the 'maintain' management regime and £54.46 million under the 'recover' management regime. This study has also shown that increasing the proportion of protected area where the recover management regime is applied may be more beneficial. Of course, point estimates of this type suggest a degree of accuracy that is inconsistent with the analysis undertaken and so need to be interpreted as being simply indicative of the scale of benefits that might be secured from the additional proposed MPA network. Undiscounted mean annual benefits range from £4.6 million under the 'maintain' management regime to £4.7 million under the more restrictive 'recover' management regime.

An analysis of the sensitivity of the UK-level valuation estimates was undertaken to assess the impact of using low or high value estimates for those ecosystem services where a range of values were estimated. This analysis was performed to determine the net present values (3.5% discount rate over a 20 year period) under both management regimes. Using low value estimates from the ranges for ecosystem services the net present value provided by the proposed additional Northern Ireland MPA network decreases by 10.75% to £48.1 million for the 'recover' management regime and by 10.48% to £46.8 million for 'maintain' management regime. When the high value estimates in the ranges were applied, the net present value increased by 23.77% to £66.9 million for the 'recover' management regime and by 22.42% to £64.1 million for the 'maintain' management regime.

A number of assumptions and limitations are identified and discussed with respect to the approaches adopted. These relate to the identification of the extent of landscape/habitat types in Northern Irish waters, the estimation of the total value of ecosystem services provided by the UK marine environment, and the disaggregation of the total value to the proposed extended Northern Ireland MPA network. However despite these assumptions and limitations, the methodology is considered to be sufficiently robust to investigate the potential benefits derived from designating an additional MPA network in Northern Ireland's inshore waters.

Given the standardised approach adopted here to estimate the economic and social benefits, comparisons can be made with those obtained from both the English and Scottish MPA studies. The comparative analysis showed that although the present value of the proposed Northern Ireland MPA network (£52.98-£53.31 million) is considerably less than the net present value of the English (£10.29-£10.46 billion) and Scottish networks (£4.29-£4.32 billion), when standardised for spatial extent (per km^2) and for year of study (£ 2012), the net present value per km^2 protected is much greater in the proposed Northern Ireland network (£163,978-£164,991) than the English (£98,463-£100,044) and Scottish (£57,346-£57,808) networks. In the case of Northern Ireland, the majority of the proposed MPA network comprised one landscape/habitat type (shelf mud), and given that this habitat provides a significant contribution to all categories of ecosystem service, this may in part explain the higher valuation of the benefits provided by the extended Northern Ireland MPA network.

ACKNOWLEDGEMENTS

The assistance provided by a number of organisations and individuals, especially with regard to providing data, is gratefully acknowledged. Where it is not open source, all data used in this project has been used under licence and, in this context, the provision of data user agreements in a timely and open manner is greatly appreciated.

In particular the authors would like to thank the NIMTF for their assistance with data provision. The project would not have been possible without access to the Marine Recorder, CEDAR, NBN and Birds at Sea databases, and consequently the authors are indebted to the contributors to, and administrators of, these systems. Data were also kindly provided by DoE and AFBI (The Agri-Food and Biosciences Institute Northern Ireland). The authors would also like to thank the Panache project team at the University of Plymouth for providing reports and literature.

Finally, this report represents an independent piece of work undertaken by the University of Hull. The views expressed herein are those of the authors, and do not necessarily reflect those of the NIMTF.

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TABLE OF CONTENTS

1. INTRODUCTION

1.1 Project Background

There are currently four principal international commitments given by UK Government that relate to the establishment of a Marine Protected Area (MPA) network in Northern Ireland waters:

- the World Summit for Sustainable Development (WSSD) in 2002 - to establish a representative network of MPAs;
- the UN Convention on Biological Diversity - to establish a network of well managed MPAs to enable delivery of WSSD targets;
- OSPAR (the Oslo-Paris Convention for the Protection of the Marine Environment of the North East Atlantic) - to develop an ecologically coherent network of well managed MPAs by 2016; and
- the Ramsar Convention - for the conservation and wise use of wetlands and their resources (NB whilst, under this convention, there is no specific emphasis on the development of a network of sites, it is recognised that Ramsar sites will make an important contribution to the MPA network across the UK).

In March 2011, the UK Government and the Devolved Administrations published the Marine Policy Statement (HM Government *et al.*, 2011). The Statement provides the high-level policy context within which all marine plans in the UK will be developed, implemented, monitored amended and/or withdrawn. It also ensures there is appropriate consistency in marine planning across the whole UK marine area and outlines the national policies for various activities and issues which need to be considered in developing a Northern Ireland Marine Plan (NIMP). It provides transparency to users, guides the development of marine plans, sets out the importance of encouraging co-existence of uses and how impact should be considered.

Each of the devolved administrations within the UK has approached MPA network creation differently (see, for example, Potts *et al.*, 2014). As a consequence there are separate marine programmes across UK waters, affecting English inshore, Welsh inshore, Scottish inshore & offshore and UK offshore regions. In addition, both the Republic of Ireland (RoI) and the Isle of Man have programmes that will potentially interact with the network of sites designated within NI waters. Despite the different approaches that have been used, the devolved administrations are working together to deliver a coherent network of well managed MPAs. In December 2012 they released a joint statement on the UK's contribution to an ecologically coherent MPA network in the North East Atlantic (Defra *et al.*, 2012). This document stated that the UK would be contributing to an ecologically coherent network for the North East Atlantic, and assessing it at the bio-geographic scale; there was also a commitment to link all MPA programmes in the UK.

The Northern Ireland Marine Bill was passed as the Marine Act (Northern Ireland) in September 2013. The Act provides a legislative framework for marine protection and marine planning and provides for the designation of a new type of MPA: Marine Conservation Zones (MCZs). New MCZs that are designated under the auspices of the Marine Act will augment the existing network of MPA sites within inshore Northern Irish Waters (i.e. within the 12 NM limit) to protect rare, threatened or nationally important marine habitats, species and geological features (note that Strangford Lough MNR became a MCZ on enactment of the

Bill). MCZ designation will also help achieve an ecologically coherent network that is representative of the UK marine area and which will conserve or improve the UK marine environment. As noted above, the UK is committed (under the OSPAR convention) to contribute towards an ecologically coherent network of MPAs in the North-East Atlantic. The EU Marine Strategy Framework Directive puts further emphasis on achieving this goal through OSPAR.

Subsequently, and in response to the requirements set out under Section 20(7) of the Marine Act (Northern Ireland), a policy statement was produced by the Northern Ireland Department of Environment (DoE), identifying the principles that the Department intends to follow when designating MCZs to help contribute to the creation of a UK Marine Protected Area network.

In addition to MCZs, DoE intend that the Northern Ireland MPA network will encompass a range of different types of protected area[5] including:

- Special Areas of Conservation (SACs) for habitats of European importance;
- Special Protection Areas (SPAs) for seabirds of European importance;
- Areas of Special Scientific Interest (ASSIs) for nationally important habitats and species; and
- Ramsar sites for wetlands.

DoE (NI) has recently released its draft MPA strategy for public consultation (DoE, 2013) which, *inter alia*, outlines a Northern Ireland Government commitment to creating an ecologically coherent network of sites at the Northern Ireland scale, as well as contributing to the broader UK network. It is intended that an ecologically coherent network of MPAs will also establish appropriate protection and conservation measures for species and habitats designated as ‘Priority Marine Features’ (including the OSPAR List of Threatened and/or Declining Species and Habitats, and other species and habitats, along with some existing Northern Ireland conservation priority species and habitats, which require protection). Appropriate management to enable the achievement of favourable condition status and/or GEnS (Good Environmental Status) through regular monitoring of species and habitats while promoting sustainable use of our seas will then require to be established. There is also a commitment to ensure that relevant stakeholders are involved from an early stage in the development of the MPA network and that, in addition to identifying the ecological characteristics of candidate MCZs, site selection must consider social, economic and cultural consequences from designation.

In specific relation to MCZ designation, the strategy highlights the DoE’s focus on designating sites to complement the existing network of MPAs and improve ecological coherence, and that will conserve and aid the recovery of:

- the range of marine biodiversity in Northern Ireland waters;
- rare or threatened habitats and species;

[5] The fifth type of protected area in Northern Ireland, Marine Nature Reserves (MNRs), has now been replaced by the MCZ designation, with Strangford Lough MNR becoming an MCZ on enactment of the Marine Bill.

- globally or regionally significant areas of geographically restricted habitats or species;
- important aggregations or communities of marine species;
- areas important for specific life-cycle stages of mobile species, such as feeding, spawning and nursery grounds;
- marine ecosystem functioning in Northern Ireland waters, and
- features of particular geological or geomorphological interest[6].

OSPAR in particular requires the development of an ecologically coherent network of sites. Ecological coherence is an evolving concept in the scientific community and, whilst there is no universally accepted definition, guidance has been developed under the OSPAR Convention on the key design principles associated with ecological coherence (see, for example, OSPAR, 2003). In order to ensure that an ecologically coherent network of MPAs is established within the wider OSPAR region, the following OSPAR principles (which have been followed by other UK statutory bodies, e.g. Natural England & JNCC, 2011) are being proposed for adoption within Northern Ireland:

- **Representativity** – the network should represent the range of marine habitats and species present in Northern Ireland's territorial waters;
- **Replication** – ensure replication of habitats with adjacent areas as appropriate to achieve an overall network;
- **Connectivity** – ensure the network has linkages among individual MPAs and between regional networks;
- **Adequacy** – the network should be of adequate size to deliver its ecological objectives and ensure long-term protection and/or recovery;
- **Viability** – the network should be made up of self-sustaining, geographically dispersed component sites of sufficient size;
- **Management** – MPAs should be managed to ensure the protection of the features for which they were selected and to support the functioning of an ecologically coherent network;
- **Best available evidence** – the designation of MPAs should be based on the best information/evidence which is currently available. Where there is a lack of full scientific certainty this should not be used as a reason for postponing decisions on the selection of sites.

The DoE has established or designated a number of areas, given above, with a marine component under international, European and national legislation. These will contribute to the development of an ecologically coherent network of MPAs which will provide added protection to areas of high diversity as required under the OSPAR convention. The

[6] Identification and/or selection of MCZs for protection of geological and geomorphological interest does not stop at the seaward margin of the coast as this can also include marine areas which represent the seaward continuation of terrestrial and inter-tidal sites of geological importance as well as active process sites. Features of interest may include: areas of national geological importance; areas that contain exceptional geological features; or areas that are representative of a geological feature, event or process which is fundamental to understanding Northern Ireland's geological history.

protection provided by this network will be augmented by additional MCZ designation under the auspices of the Marine Act. The network of MPAs in NI currently includes:

- **Special Areas of Conservation** (SACs) designated under the Habitats Directive. Northern Ireland has 54 SACs designated under the Habitats Directive. Six sites have been designated for marine components and two more (The Maidens and Skerries & Causeway) are candidate sites. The SACs have been designated/proposed because of a possible threat to the special habitats or species which they contain and to provide increased protection to a variety of animals, plants and habitats of importance to biodiversity both on a national and international scale. A number of these sites have been damaged and require restoration to favourable conservation status as required under the Habitats Directive.
- **Special Protection Areas** (SPAs) classified under the Birds Directive. There are 15 SPA sites designated in Northern Ireland, nine of which have a marine component. The sites are designated to protect seabirds and waterbirds and cover areas of their migration routes, breeding and aggregation.
- **Ramsar sites** (wetlands of international importance) designated under the Ramsar Convention on Wetlands 1971. There are a total of 21 Ramsar sites designated in Northern Ireland. These sites are areas of wetland recognised as ecosystems that are extremely important for biodiversity conservation in general and for the well-being of human communities.
- **Areas of Special Scientific Interest** (ASSIs) designated under The Environment (Northern Ireland) Order 2002 ; and
- **Marine Conservation Zones** (MCZs) designated under the Marine Act (Northern Ireland) 2013. NI currently has one Marine Conservation Zone (Strangford Lough). Formerly a Marine Nature Reserve (whose purpose was to conserve marine flora and fauna and geological features of special interest, while providing opportunities for the study of marine systems) Strangford Lough became an MCZ following the signing of the Marine (Northern Ireland) 2013.

Augmented by new additional MCZs, the MPA network will be a key tool in contributing to achieving Good Environmental Status (GEnS) as required by the EU Marine Strategy Framework Directive. The network will also help ensure that biodiversity is protected, conserved and where appropriate recovered, and the loss of biodiversity halted as called for at the Conference of the Parties to the Convention on Biological Diversity (COP 10 CBD) which took place in Nagoya, Japan in October 2010.

1.2 Project Objectives

In addition to identifying the ecological characteristics of candidate MCZs, the DoE must consider social, economic and cultural consequences from designation. There is very little academic literature on how Northern Ireland's community values or benefits directly from a healthy inshore area. In comparison, research is more readily available on potential costs of new MPAs to certain industry sectors.

The Northern Ireland Marine Task Force (NIMTF) is a coalition of ten organizations working together to secure productive and healthy seas. The NIMTF (which comprises Northern Ireland Environment Link, Ulster Wildlife, Royal Society for the Protection of Birds, WWF, The National Trust, Wildfowl & Wetlands Trust, Friends of the Earth, the Irish Whale and

Dolphin Group, the Marine Conservation Society and Tidy NI) aims to contribute to the process defined above in understanding the economic benefits from an ecologically coherent network of sites across Northern Ireland.

To support the development of the NI MPA network, NIMTF has commissioned the University of Hull[7] to undertake an independent study:

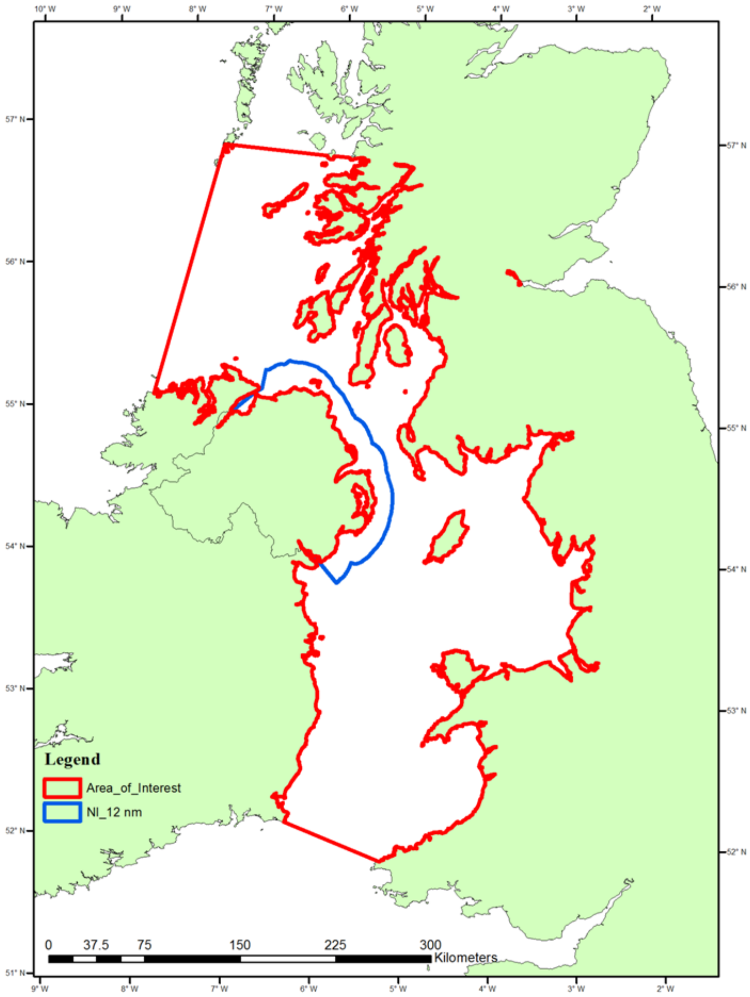
- to assess the ecological coherence of the network of Northern Ireland MPA sites in the context of the species, habitats, features and/or areas that are found within NI waters, and to identify gaps in the MPA network; and
- to assess and review the potential economic and social value associated with this network (considering the value of different levels of MPA protection).

[7] Specifically the Institute of Estuarine and Coastal Studies (IECS) at the University of Hull, in collaboration with the Hull University Business School (HUBS).

2. STUDY AREA

The MPA network within NI waters clearly sits within the wider context of UK and Irish waters. Whilst it is important to assess coherence at the NI level (to help demonstrate that NI is contributing effectively to OSPAR's overall objectives) certain factors (such as connectivity and representativity) can be meaningfully addressed at a wider scale, considering adjacent English, Scottish, Welsh, Isle of Man and Irish waters. Consequently, two marine areas of the marine environment around Northern Ireland (NI) were identified (see Figure 2.1):

- the inshore region (NI waters out to 12 NM); and
- a wider 'Area of Interest' (AoI) – see text below for a further discussion on the inclusion of adjacent marine waters.



Transverse Mercator Projection centred on the Irish Sea.
Datumn WGS84 Scale 1:3,000,000

Figure 2.1 Study area: NI inshore area to 12 NM (blue line) and wider Area of Interest (red line)

The wider AoI was selected to represent a cohesive and ecologically relevant sea area, capturing the Irish Sea and Irish North Coast (Atlantic Coast) biogeographic areas and international boundaries, and was used to restrict analyses to broadly comparable sea areas. The southern limit, extending from Carnsore Point (Republic of Ireland) to St David's

Head (Wales), represents the typical delineation between the Irish Sea and the Celtic Sea. The northern and western limits are set to include a significant block of adjoining seabed. Efforts to align this limit with OSPAR regions, ICES reporting areas or Dinter biogeographic areas (as presented in the OSPAR Quality Status Report, QSR; OSPAR, 2010) generated areas too large for analysis. The northern and western limits were therefore set to coincide with the local geography of the area. The delineation of the Northern Irish 12 NM limit zone used a polygon provided by DoE NI and was used to restrict analyses to the Irish inshore region.

The following description of the physical nature of the wider study area is based extensively on information taken from Hadziabdic & Rickards (2013).

The Irish Sea is open to the Atlantic to both the north and south and can be considered as a channel approximately 300 km long, greatly varying in width. There are numerous islands within the Irish Sea, with Anglesey being the largest, followed by the Isle of Man. The Irish Sea receives freshwater run-off from a large area of land, approximately 43,000 km^2 compared to a sea area of approximately 47,000 km^2. The seabed is predominantly shallow, with approximately two thirds of the area <100 metres deep. It is generally characterised by large tidal energy input from the Atlantic with tidal currents providing much of the energy of the region.

Annual mean temperature in the Irish Sea does not vary much over the area, decreasing from just over 11°C at the southern end of St. George's Channel in the south to 10°C in the North Channel in the north and also decreasing towards the adjacent coasts to the east and west. Winter temperatures are more varied; warm water extends up to the North Channel with temperatures decreasing from the central channel towards the coasts. In summer, conditions are reversed with cool water in St. George's Channel but temperatures exceeding 16°C off the coasts of NW England and North Wales. The rise in temperature towards the Irish coast is much less pronounced.

Salinity is characterised by a decrease from south to north (maximum 34.9 PSU to minimum 34) and from the centre of the channel (34.3-34.9) to the sides (32.0-34.0). This is an indication of a northerly flow of Atlantic water whose salinity is gradually reduced by freshwater from the sides. The salinity minimum is seen in the northeast, between the Solway Firth and Liverpool Bay.

This region also has strong seasonal forcing by surface heating and cooling and high-energy westerly winds. During the heating phase of the seasonal cycle, the stirring of the water column (from tidal and wind forcing) competes with the surface buoyancy input to determine the degree of water column stratification. Most areas are vertically well mixed throughout the year but, where stratification does develop, it is not usually until approximately day 100 in the year, with a surface-bottom water temperature difference <5°C and complete vertical mixing apparent from day 290 or so. The transition between mixed and stratified regions are usually marked by sharp tidal mixing fronts, located between the Isle of Man and the Irish coast or along a line joining Rosslare to Padstow. Residual circulation is generally weak and predominantly barotropic, giving rise to a flushing time of over a year. Outflow from the North Channel (to the north) is predominantly on the eastern Scottish side and inflow is generally weaker on the surface of the Irish side.

Primary productivity in the Irish Sea is promoted by its shallow nature and by the heavy nutrient loading from terrestrial runoff; the Irish Sea contributes a net nutrient flux to the Scottish shelf to the north, enhancing primary production there. While most of the approximately 30-40,000 tonnes of marine species landed per annum in the Irish Sea are shellfish species (see Table 2.1), the most valuable species taken is the Norway lobster (*Nephrops norvegicus).*

Table 2.1 Weight and value of landings from ICES rectangle VIIa (Irish Sea)[8]

	Landings from ICES rectangle VIIa (Irish Sea) landed weight (tonnes) and value (£k)				
	2008	**2009**	**2010**	**2011**	**2012**
Demersal whitefish	2,317 t (£4,041)	1,918 t (£3,023)	1,658 t (£2,788)	1,351 t (£2,446)	1,254 t (£1,885)
Pelagic whitefish	4,908 t (£1,149)	4,608 t (£1,238)	5,004 t (£1,459)	5,238 t (£2,408)	5,698 t (£2,613)
Shellfish	24,588 t (£36,433)	19,502 t (£30,573)	23,429 t (£31,092)	35,487 t (£42,848)	34,143 t (£46,804)
of which: *Nephrops* sp.	3,758 t (£14,753)	3,656 t (£11,184)	3,429 t (£10,802)	3,547 t (£15,581)	3,297 t (£16,682)
Total landings	31,813 t (£41,622)	26,027 t (£34,834)	30,091 t (£35,339)	42,077 t (£47,703)	41,095 t (£51,302)

Inner Seas off the West Coast of Scotland include the waters north of the North Channel and sea area between Scotland and Northern Ireland. The Atlantic North Coast of the Ireland is dominated by the input of warmed Atlantic water and high energy levels, the latter tending to decrease stratification.

Northern Ireland is located at a junction between southern warm water 'Mediterranean Lusitanian' species and cold water 'Arctic Boreal' species. Atlantic oceanic waters influenced by the North Atlantic Drift and the variable water types of the Irish Sea, have contributed to the diverse range of habitats found in these waters (State of the Seas Northern Ireland, 2012).

There are broadly three sediment classes, which are approximately equal in area. They are mixed coarse ground (mixture of bedrock, cobble, pebble and gravel), sands and soft mud. As described above, the north coast tides are moderate and the seabed is mobile sand that is highly sculptured with few epifaunal species. Bedrock and strong currents around Rathlin Island provide excellent rocky reef habitat, rich in a variety of epifaunal species, especially sponges. The North Channel has stronger tides and extensive areas of sand with large ripples and coarse sediment. The rocky outcrops at The Maidens provide additional habitat for a diverse epifaunal community. Off the coast of Down, large areas of muddy sand near the coast are replaced in deeper water with a distinct area of soft mud. The sea loughs contain a wide array of productive seabed habitats, some of which are of international importance for their biodiversity. Each of the sea loughs has distinct physical characteristics

[8] Data taken from http://www.marinemanagement.org.uk/fisheries/statistics/annual.htm

that promote particular biological communities (State of the Seas Northern Ireland: Seabed Integrity, 2012).

Within the study area, the range of MPAs considered included OSPAR sites, SACs, SPAs and Marine ASSIs. The spatial distribution of these different designations, in the context of the NI 12 NM zone, is presented below (Figure 2.2 to Figure 2.5).

The sites that make up the MPA network vary in size; Table 2.2 gives a summary breakdown of the physical aspects of the NI MPA network.

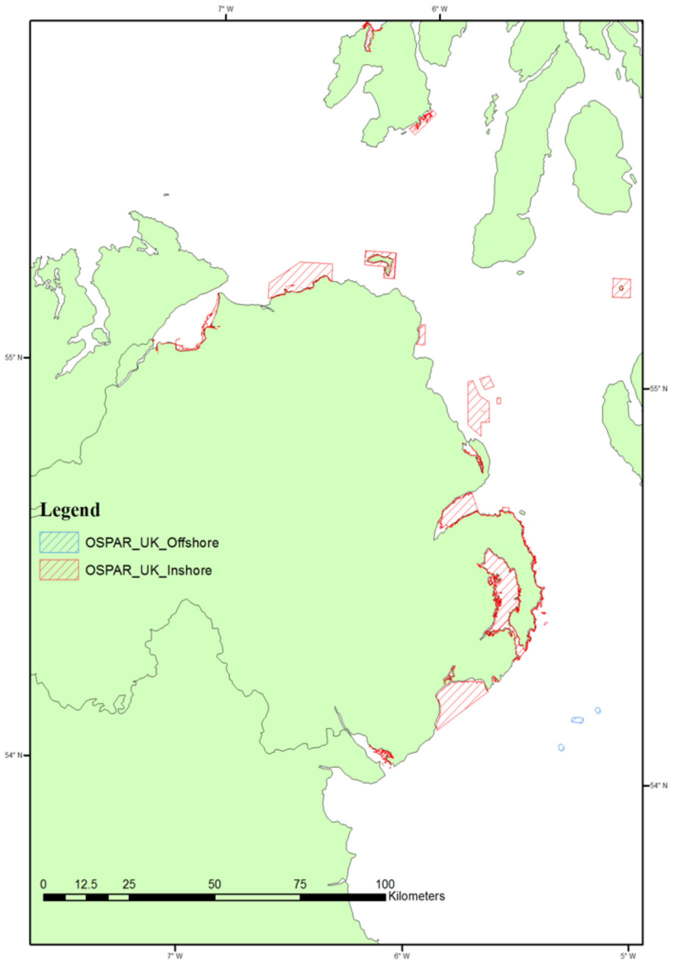
Table 2.2 Composition and area of the components of the NI Marine Protected Area (MPA) network

Component type	Number of discrete components	Size of components (km^2)		
		Smallest	Mean	Largest
SCI*, SAC or cSAC**	8	3.15	63.26	153.89
SPA***	10	0.04	26.76	270.93
Marine ASSI	18	0.06	5.44	20.02

* Red Bay is currently a Site of Community Importance (SCI). SCIs are sites that have been adopted by the European Commission but not yet formally designated by a country's government.

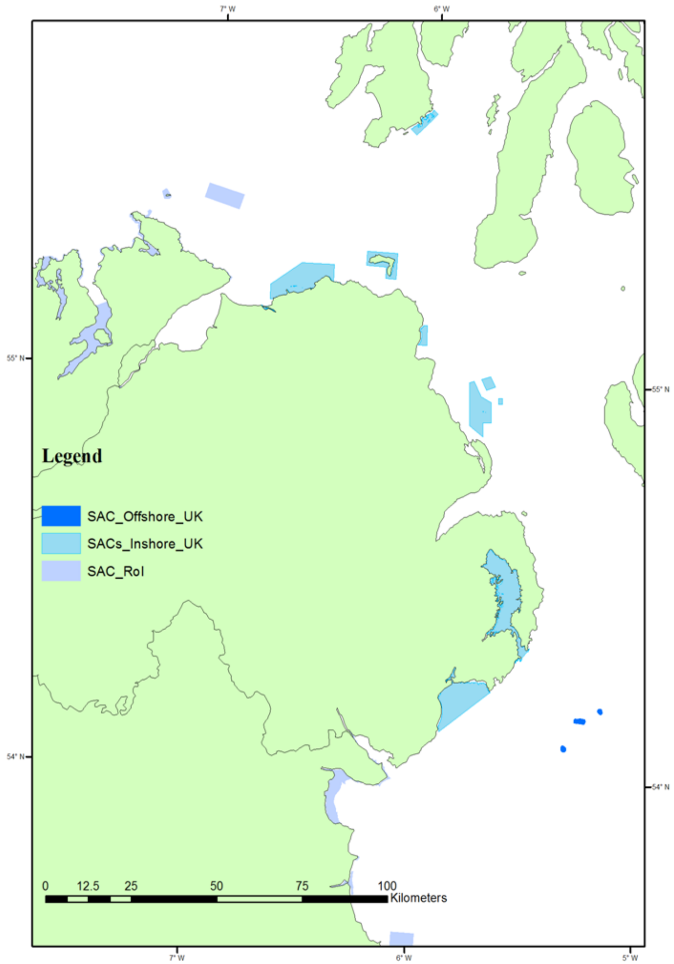
** A candidate SACs (cSAC) is a site that has been submitted to the European Commission, but has not been formally adopted.

*** SPAs cover terrestrial, intertidal and (subtidal) marine areas. Within NI, 47% of the total SPA designated area falls within the inter- and sub-tidal domain. SPAs in NI are Rathlin Island, Sheep Island, Lough Foyle, Larne Lough, Belfast Lough/Belfast Lough Open Water, Copeland Islands, Outer Ards, Strangford Lough, Killough Bay and Carlingford Lough.



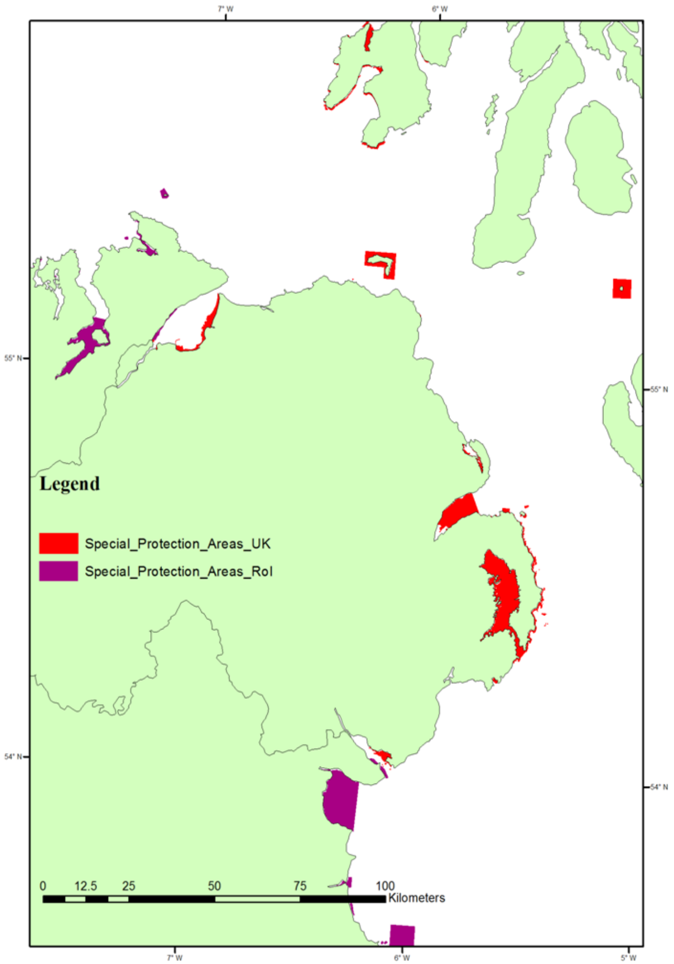
Transverse Mercator Projection centred on the Irish Sea.
Datumn WGS84 Scale 1:1,000,000

Figure 2.2 Spatial distribution of MPAs considered in analysis - inshore and offshore protected OSPAR sites



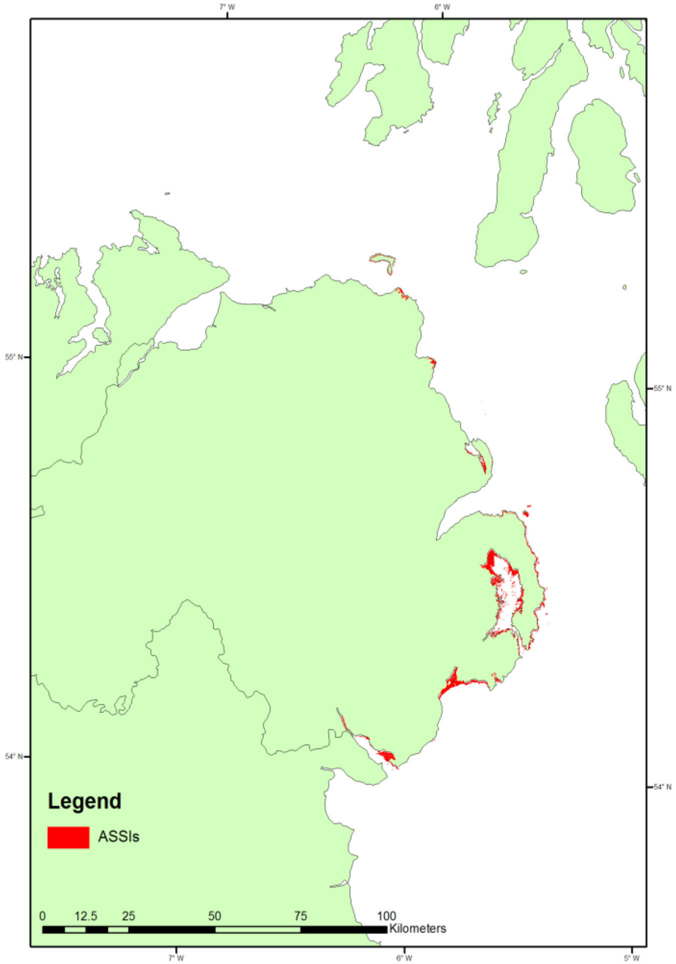
Transverse Mercator Projection centred on the Irish Sea.
Datumn WGS84 Scale 1:1,000,000

Figure 2.3 Spatial distribution of MPAs considered in analysis - Special Areas of Conservation



Transverse Mercator Projection centred on the Irish Sea.
Datum WGS84 Scale 1:1,000,000

Figure 2.4 Spatial distribution of MPAs considered in analysis - Special Protection Areas



Transverse Mercator Projection centred on the Irish Sea.
Datum WGS84 Scale 1:1,000,000

Figure 2.5 Spatial distribution of MPAs considered in analysis - Marine Areas of Special Scientific Investigation

3. ECOLOGICAL COHERENCE OF THE NORTHERN IRELAND MPA NETWORK

3.1 Introduction to Network Coherence

The first set of objectives for the project was addressed through a thorough review of the existing MPA network against the principles that underpin the development of an ecologically coherent network of MPAs, and was supplemented by a spatial gap analysis to identify candidate sites that might help strengthen the existing network.

Ecological coherence is an evolving concept in the scientific community; whilst there is no universally accepted definition, which thus presents a difficulty in determining when coherence is achieved, guidance on site selection to deliver coherence has been developed. In this context a number of principles underpinning network (site) selection have been proposed by UK administrations (see, for example, Natural England & JNCC, 2011). As noted above, a set of seven principles have been proposed by DoE for adoption for this purpose within Northern Ireland (e.g. DoE, 2013), *viz*:

- representativity;
- replication;
- connectivity;
- adequacy;
- viability;
- management; and
- best available evidence.

In addition, the identification and designation of MCZs should take into consideration naturalness, e.g. seeking to (preferentially) protect sites where species and habitats are in a very natural state due to a lack of human induced disturbance or interaction. The naturalness of sites is arguably a factor that might be used in an overall assessment of network coherence.

As noted above, no specific definition for the term ‘ecological coherence’ has been formally agreed upon at an international level (e.g. OSPAR, 2012) although earlier guidance from OSPAR (2006) suggested a number of points that are fundamental to the concept of coherence:

- initially, a network’s constituent parts should be identified on the basis of criteria which aim to support the purpose of the network;
- also, the development of an ecologically coherent network of MPAs should take account of the relationships and interactions between marine species and their environment both in the establishment of its purpose and in the criteria by which the constituent elements are identified; and finally
- a functioning ecologically coherent network of MPAs should interact with, and support, the wider environment as well as other MPAs, although this is dependent on appropriate management to support good ecosystem health and function within and outside the MPAs.

Reflecting this, Ardron (2008) suggested that an ecologically coherent network of MPAs will:

- interact with, and support, the wider environment;
- maintain the processes, functions and structures of the (intended) protected features across their natural range; and
- function synergistically such that individual sites benefit from each other in terms of their achievement of the two foregoing objectives.

Here it is assumed that the degree to which a network satisfies the underlying principles of network design can be used as an indication of overall compliance with the coherence principles (e.g. Ardron, 2008). In effect this is the basis for the Matrix Approach (e.g. OSPAR, 2008a), a feature level assessment that uses compliance with the network design principles to assess network coherence.

The Matrix Approach (as presented by OSPAR, 2008a) uses compliance with six of the seven principles to describe network coherence both within and between OSPAR bioregions. The use of a reporting matrix allows compliance against all of the design principles to be assessed in parallel, although the matrix still requires an accompanying narrative to fully capture the value of the proposed network. In addition, it raises the question as to the relative importance of each of the network design principles in terms of its role in ecological coherence; whilst all are important, there may be an argument for prioritising certain principles ahead of others, AND other factors, such as the degree to which each principle is met, may also be of importance in any evaluation.

In addition, as the matrix approach requires that the elements of the matrix can be easily assimilated and interpreted, there are pragmatic restrictions on the range of its use. For example, in situations where there are few features under consideration (e.g. 10-15 species or a few habitats) the entries within a completed matrix can be relatively easily reviewed and interpreted. Conversely, when the number of entries in the matrix increases, it is no longer possible to easily interpret the resulting information.

There are several alternative approaches that can be used to identify potential constituent sites in a network using the network criteria. For example, a network of sites can be developed on a pragmatic basis, where the ability to implement effective management controls at sites is a prime driver in selecting between different potential options for constituent sites. Alternatively, site selection may be driven primarily from an objective standpoint, developing the network by identifying the set of sites that meet the network design criteria most effectively (for example, minimising the need for designation). Finally, site selection could have an element of subjectivity with the network not only meeting objectives but taking stakeholder concerns/desires into account and attempting to address any resultant issues. In practice, it is likely to be a blend of these three approaches that is used, although all three fundamental principles (pragmatism, objectivity and subjectivity) will need to be considered independently at some stage in the site selection process.

Irrespective of the basis for site selection however, the requirement for the network to address the site selection principles (and so effectively demonstrate ecological coherence) will remain unaltered. One key exception to this is the ability to manage the site(s). Whilst the ability to introduce management measures appropriate to promote the conservation of features within the site is clearly an important principle for the initial identification of sites within a network, the subsequent role of management as a measure of coherence is more problematical. In this context it has been suggested (OSPAR, 2008a) that management sits separately from the other design principles when coherence is assessed. Similarly, whilst it is acknowledged that site selection should be based, *inter alia*, upon the application of 'best available evidence', this might be considered as being a less robust criterion upon which to base an assessment of ecological coherence as it relates not to the value of the network itself but to the information or data used to support site selection.

As noted above, the use of subjectivity in the interpretation of each of the network design principles (for example in terms of which features are selected for an assessment; is one feature 'more important' than another; etc.) potentially confounds any assessment of coherence. One possible exception to this is the consideration of connectivity. Given two versions of a site network, identical in every respect except for the degree of inter-site connectivity; the network version with better connectivity could be argued to be more ecologically coherent. For example, whilst both may provide for sites for juvenile production and subsequent growth/development, if there is no provision for appropriate transport or hydrological connectivity between the sites then neither will function optimally.

However, connectivity is arguably one of the more difficult factors to assess, requiring detailed information on marine currents and fronts and the role that these may play in facilitating (or indeed limiting) inter-site transport of species at different life stages. Nevertheless, it would be reasonable to view a network that meets all of the design principles, but which fails to demonstrate connectivity, as failing to have ecological coherence in its strictest sense. It is suggested that, beyond consideration of the key importance of connectivity, it is not appropriate to, *a priori*, prioritise the importance of any of the principles in terms of assessing ecological coherence but rather to attempt to consider all the principles together, with connectivity being considered as an additional final factor.

This study focuses on MPAs within the NI 12 NM zone, but also considers their regional setting by considering adjacent marine areas. The study has assessed network coherence with reference to the following five network design principles:

- representativity;
- replication;
- connectivity;
- adequacy[9]; and
- viability[10].

Following discussions with NI MTF it was agreed that the sixth and seventh design principles (use of best available evidence, and naturalness) would be excluded. Although it was initially intended to carry out an assessment based on the 'naturalness' of the locations currently designated as constituents of the NI MPA network, such an assessment was identified at an early stage of the project as being likely to be problematic: the intention had been to examine MPA overlap with known activities to provide a potential surrogate of pressure and, by using existing sensitivity matrices, possible impact. However, it very quickly became

[9] 'adequacy' refers to the size of the overall MPA network and its consequent relative coverage of features.

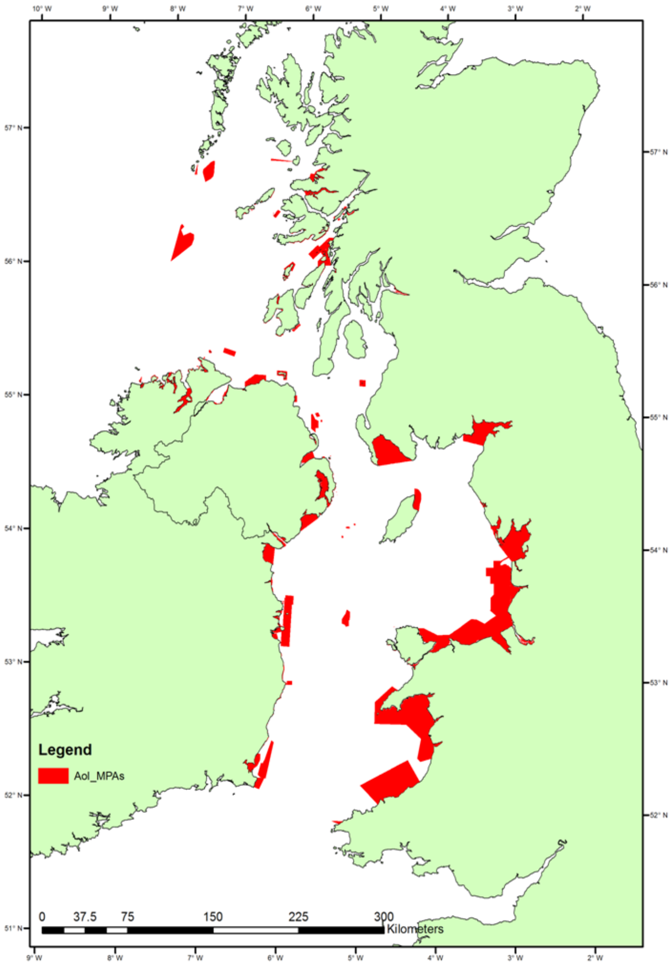
[10] 'viability' refers to the size of individual sites.

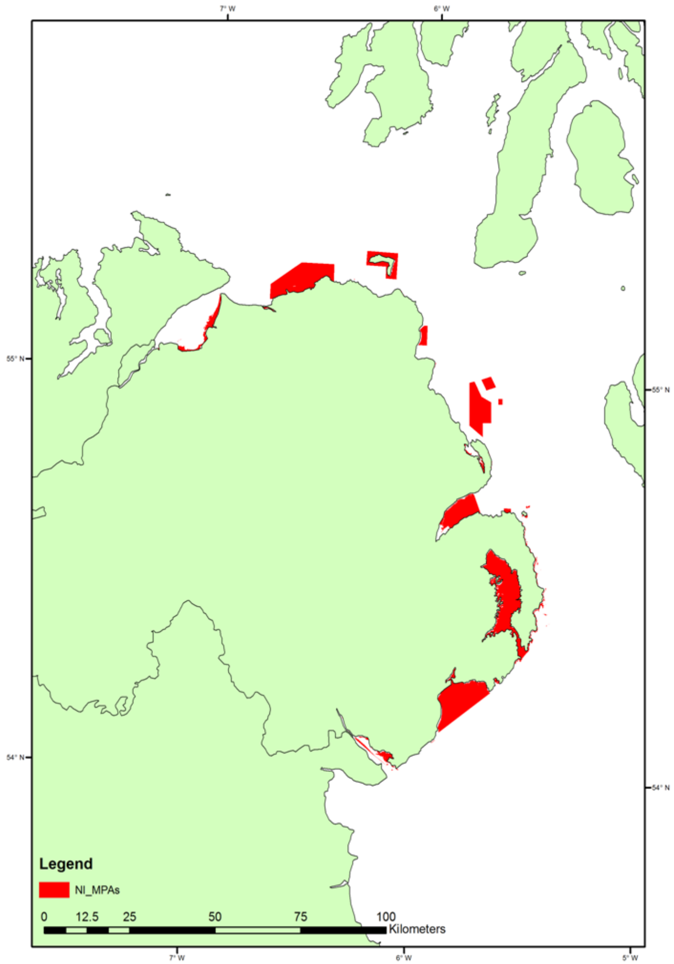
apparent that this would lie outside of the scope of the project due to data deficiencies. Although Vessel Monitoring System (VMS) data were kindly provided by AFBI (the Agri-Food and Biosciences Institute, Northern Ireland), on examination it was found that there was little or no overlap of the MPA network and most of the over 12 m fishing vessels presented in the VMS points. Requests were made to other providers of fishing activity data but no information has been made available for analysis. Furthermore, the assessment of naturalness needs to draw in numerous other data layers to provide for a balanced and complete analysis, and all pressures under consideration would need to be assessed on a habitat-by-habitat basis using established sensitivity and response matrices. Such an analysis was beyond the resources of this project and so it was not possible to undertake a rigorous assessment of the network in the context of human activities. It is thus recommended that this aspect of network analysis is undertaken as a future priority. The accumulation of the current project data with layers of activity and pressure would provide an extremely valuable dataset for the thorough investigation of condition, network gaps and socio-economic considerations.

3.2 Approach

3.2.1 Generation of the MPA network GIS file

Multiple MPA designations display spatial overlap at points across the AoI. Consequently, if the analyses were to account for designation types separately there would be a tendency to significantly overestimate the level of ecological coherence. To eliminate this risk, all designation types were combined into a single MPA network encompassing MPAs from both NI territorial waters (NI MPAs) and from the wider AoI (AoI MPAs) (Figure 3.1). Some adjacent designations that had common boundaries were converted into single units by this process.





A: Overall MPA network across the AoI

B: NI MPA network (sites within the NI 12 NM zone)

Figure 3.1 Derived NI MPA networks as used in analysis (see text for details)

In producing the derived NI MPA and AoI MPA networks there is an assumption that all of the different MPA designations provide a *de facto* level of protection for all features that are present within the MPA. Whilst this is not likely to be strictly applicable in all instances, for the purposes of this analysis it allows a broad scale assessment of ecological coherence to be performed without resorting to a feature-by-feature assessment.

The location of the Northern Ireland/Republic of Ireland boundary through cross-border sea loughs was provided by the Department of the Environment, Northern Ireland and has been used to represent a usable delineation within Carlingford Lough and Lough Foyle. This is acknowledged to be an artificial split as both Loughs are cross-border and it is recognised that both are independently managed by the Loughs Agency. Inclusion of the cross-border sites may have artificially increased the apparent extent of the NI MPA network, whilst exclusion of cross-border areas would potentially under-estimate the value of the network. Pragmatically, for the purposes of this study the sites were artificially split, although connectivity analyses included the cross-border designations within the processing.

3.2.2 SPECIES AND HABITATS

Inherent in the assessment of the ecological coherence of the NI MPA network is the need to define the list of features (habitats and species) that are considered. The scope of the project has necessarily limited the approaches that could be used to determine the membership of such a list.

Conclusions on network coherence that are focused very tightly on specific key features may be criticised, not on the assessment of coherence *per se*, but on the basis for the inclusion of those key features. By broadening the approach to determining the underlying features list, and by assuming equal weighting across all features, it is the underlying structure of the network, as seen in the wider context of overall spatial distribution of species and habitats that becomes more important in the analyses.

Accordingly, this study has focused more on the assessment of the coherence of the NI MPA network (and the subsequent identification of gaps or weak points in this network) rather than on (what may sometimes be) the subjective inclusion of specific features.

The following approach for generating the underlying features list was proposed to, and agreed by, NIMTF:

- the Northern Ireland Priority Species List was amalgamated with the available priority lists for jurisdictions operating in adjacent waters (i.e. the priority lists produced for the MCZ processes in England and Wales, and for the Scottish MPA project; it is our understanding that no such list has been prepared for the Republic of Ireland);
- species and habitats listed in Annex 1 and 2 of the Habitats Directive;
- species listed in the Birds Directive;
- this list was further augmented with species and habitat features recorded on the OSPAR list of threatened and/or declining species and habitats, and by the list of marine features (habitats and species) identified by DoE for consideration with respect to new MCZs (DoE, 2013);
- each element on the resultant list was reviewed against the available spatial data (see Section 3.2.3 below) to develop a revised list that more closely reflected Northern Ireland inshore waters.

This resultant 'coherence assessment list' (CA list) contained some 220 separate features.

3.2.3 DATA SOURCES

The reviews and analyses that form the basis of this report on the ecological coherence of the Northern Irish MPA network were based on data collated from across a large number of discrete sources (Table 3.1).

Table 3.1 Project data sources

Data	Source	Type
ASSI areas (marine)	DoE NI	Designation – polygon (shapefile) data
SAC, SPA and OSPAR designations (UK & IoM)	JNCC	Designation – polygon (shapefile) data
SAC, SPA and OSPAR designations (RoI)	National Parks & Wildlife Service	Designation – polygon (shapefile) data
CEDAR (Center for Environmental Data and Recording)	Ulster Museums	Biological – point data
Marine Recorder (Snapshot 442)	JNCC	Biological – point data
NBN records	NBN Gateway	Biological – point data
Maerl and *Arctica* records	DoE NI	Biological – point data
Elasmobranch position document data	DoE NI	Biological – point data
Ground fish Survey data (1992 – 2005)	AFBI	Biological – point data
Seabirds at Sea database	JNCC	Biological – point data
Whale and dolphin sightings	Irish Whale & Dolphin Group	Biological – gridded at 5 km
Intertidal seagrass	DoE NI	Biological – polygon data
EUSeaMap layers (predicted habitats; interpolated substrata; water column type; and energy environment)[11]	EMDONET portal	Designation – polygon (shapefile) data

[11] Confidence assessment for these data available: Cameron, A. and Askew, N. (eds.) (2011) *EUSeaMap - Preparatory action for development and assessment of a European broad-scale seabed habitat map final report*. Available at http://jncc.gov.uk/euseamap.

3.2.4 DATA MANIPULATION

PROJECTIONS AND DATUM

All spatial data for features on the CA list were projected to a Transverse Mercator projection (WGS84 datum) with the centre point being placed in the middle of the AoI. The use of a Transverse Mercator projection reduced distortion in the grid and allowed accurate measurements of distance between features.

CONSTRUCTION OF SPECIES AND FEATURE PRESENCE/ABSENCE GRIDS

Most of the biological data that were collated are as point data and initially showed that:

- point data were heavily concentrated within existing designations;
- although often containing the same data, some databases had extra records not found elsewhere; and
- the biological data were almost all comprised of point data.

To ensure that all of the records were used effectively in the analyses, species and features with records from multiple databases were merged into one point file. For most species this involved the merging of data from typically three of four databases. Features such as 'maerl beds' included records for individual maerl species and for point and polygon 'maerl bed' records.

To reduce the apparent spatial bias toward designated sites, monitoring stations and traffic lanes that was inherent within the point data, the combined point layers underwent a spatial join with a grid that was set up to cover the range of the AoI. By gridding data to presence/absence, the bias due to high sampling effort for specific areas is partially eliminated. Gridding the data also made more realistic use of the point data (for most species and habitats, it is assumed that features are not exclusively located at the point of sampling but are distributed about that point).

RESOLUTION AND FEATURE-GRID OVERLAP

A very important consideration within the analysis was grid dimensions for the aggregation of species and feature point data. The selection of the grid size was based on the careful balancing of:

- the need to maintain the components of the subsequent analyses across the AoI at a practical size;
- the relative size between MPA footprints and the grid cells;
- an optimum expression of point data at the landscape level; and
- the overall complexity of the analyses based on the use of 220 species and features.

Based on the distribution of many marine species, the use of a 5 km grid (Figure 3.2) was considered a conservative estimate of the local distribution of the species, as well as fulfilling the above criteria. Clearly, for some species and habitats the use of a 5 km grid may over-estimate local presence. However, due to the restrictions of the project scope and involving >220 species and features, it was not possible to select bespoke grids for species and habitats with specific ranges.

For each species or habitat feature under consideration the number of individual records contained with each 5 km grid square was recorded. These data were then transformed to presence/absence values before being analysed. This step eliminated the risk of error due to the inclusion from multiple point data for the same location (for example, data that had inadvertently been replicated through inclusion from separate source databases). This approach also removed some of the bias due to sampling effort that was apparent across the AoI.

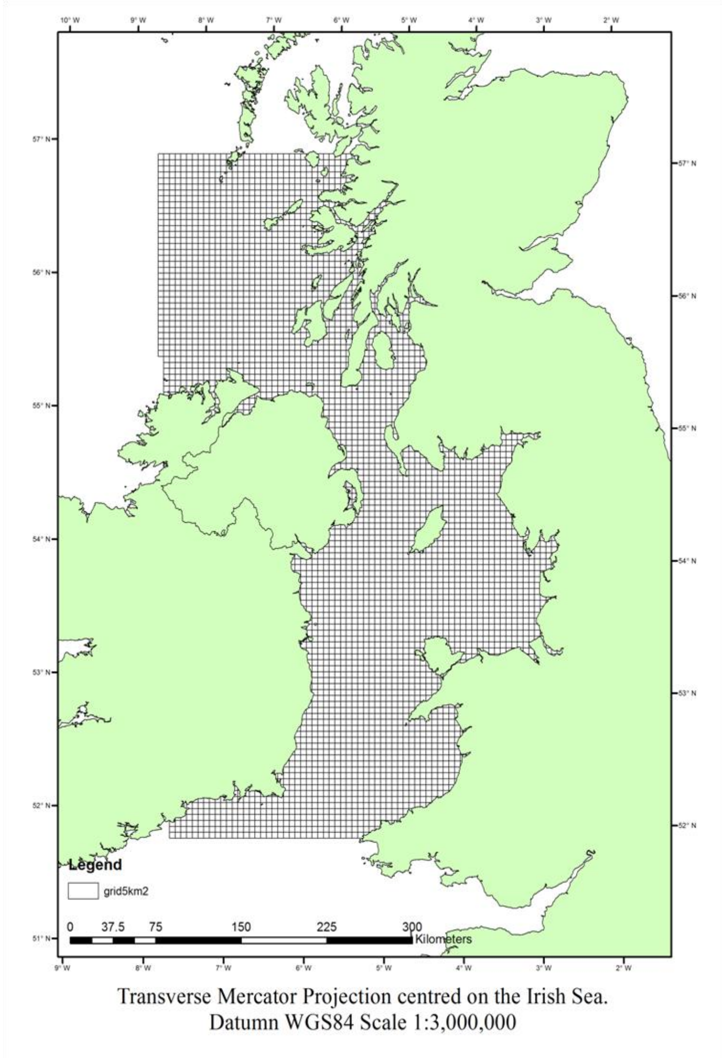


Figure 3.2 5 km x 5 km grid used for summarising biological point data across the range of the AoI

Once complete, the presence/absence grid information for each of the 220 species and habitat features on the CA list was exported from the ESRI ArcMap attribute table and imported into Microsoft Excel for further analysis. Examples of the initial output from this process are provided below, detailing the gridded presence/absence distributions derived from point source data records for:

- Sessile marine species: seapen and burrowing megafauna communities (Figure 3.3), and *Aequipecten opercularis* (queen scallop) (Figure 3.4);
- A highly mobile bird species: *Puffinus griseus* (sooty shearwater) (Figure 3.5); and
- A highly mobile fish species: *Merlangius merlangus* (whiting) (Figure 3.6).

Presence/absence grids showing the spatial distributions for all 220 species and habitat features on the CA list were supplied to NI MTF in the form of an interactive pdf file.

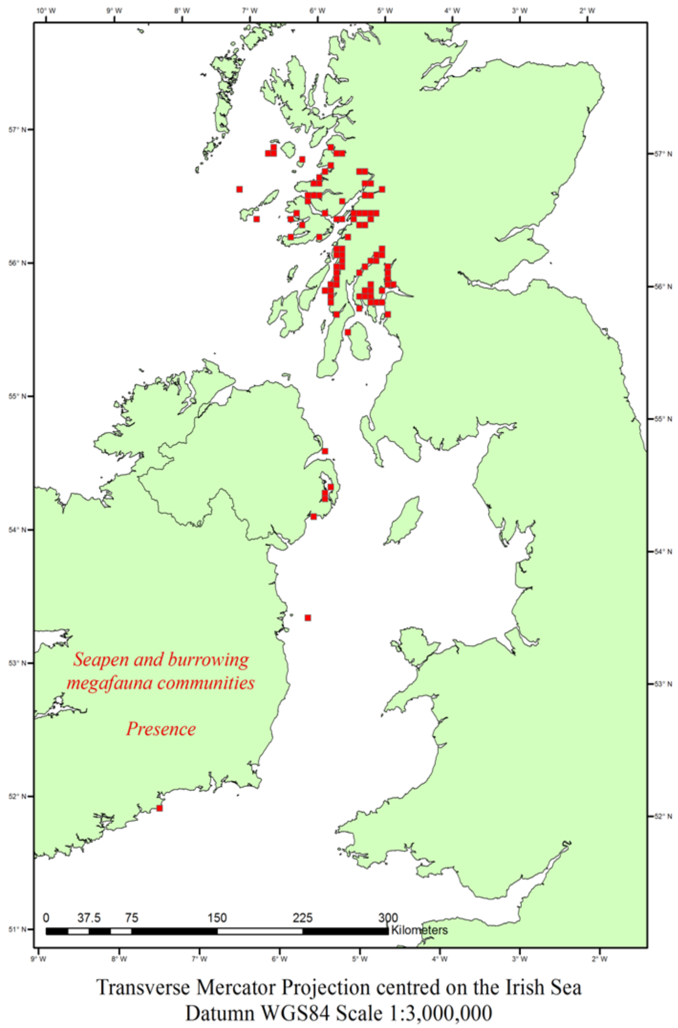


Figure 3.3 Example of 5 km grid populated with derived presence/absence data for seapen and burrowing megafauna communities

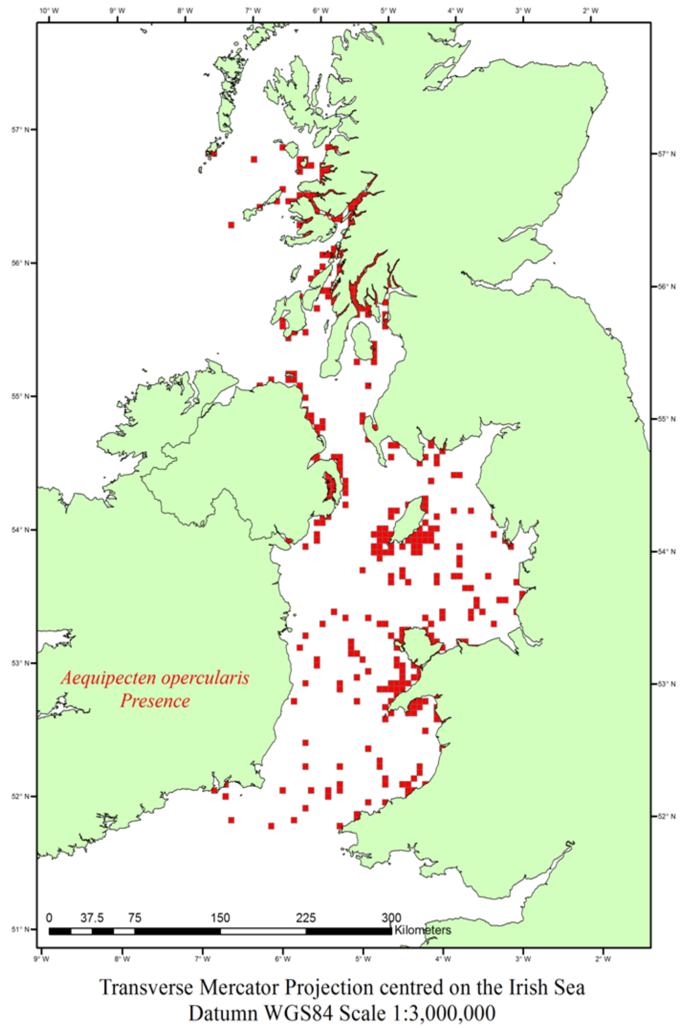


Figure 3.4 Example of 5 km grid populated with derived presence/absence data for *Aequipecten opercularis* (queen scallop)

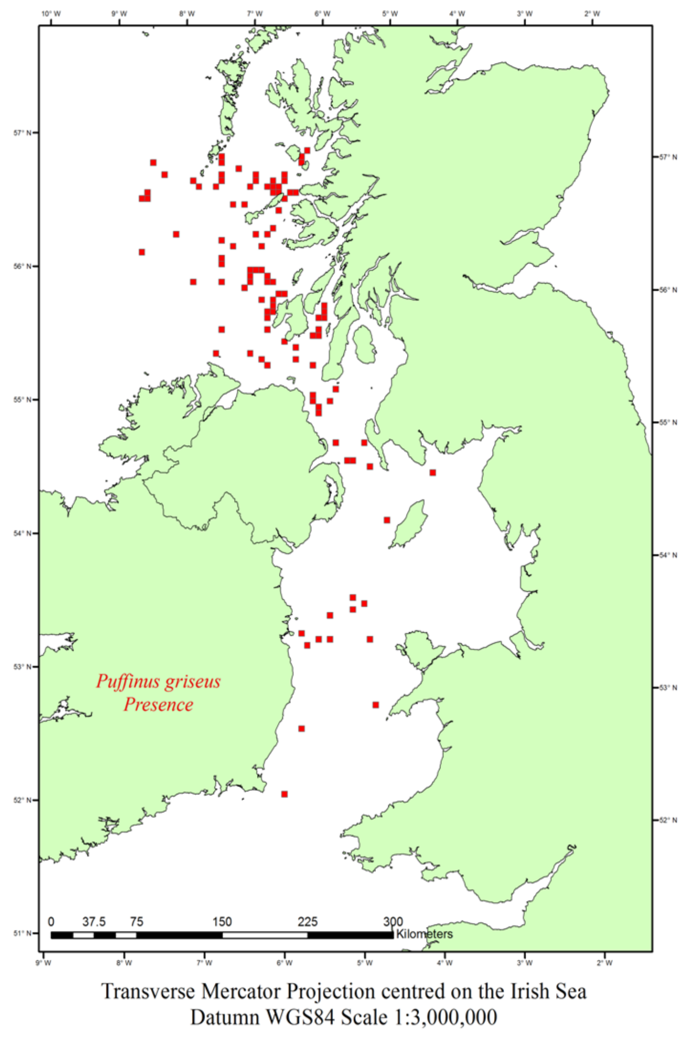


Figure 3.5 Example of 5 km grid populated with derived presence/absence data for *Puffinus griseus* (sooty shearwater)

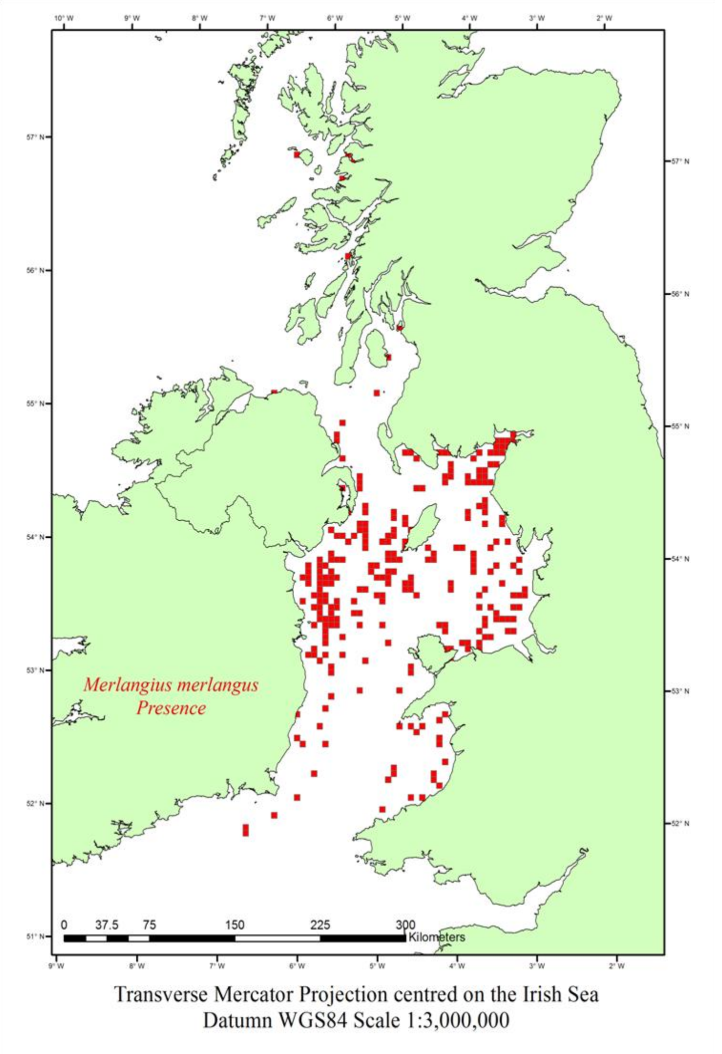


Figure 3.6 Example of 5 km grid populated with derived presence/absence data for *Merlangius merlangus* (whiting)

Having generated the species and features presence/absence grid from point data, and (in so doing) effectively reduced the resolution of some of the data, a number of assumptions regarding the degree of overlap of features with MPAs needed to be made. To underpin this, the ‘species grid output file’ was attributed with data on the degree to which each grid cell was intersected by elements of the MPA network, enabling subsequent analyses to filter data according to the level of apparent grid/MPA overlap (using an Excel-based pivot table analysis).

Figure 3.7 shows the frequency distribution of different level of MPA-grid cell overlap using a 5 km grid. As one would expect, most (>80%) of the cells across the AoI have little or no intersection with the MPA network (i.e. none, or <2.5%, overlap), whilst only 190 of the ~3500 cells used display a significantly high (>80%) degree of overlap with an MPA. The use of grid dimensions greater than 5 km would have significantly decreased the number of non-overlapping cells and thereby increased the perceived level of ecological coherence. Equally, smaller grid cells would reduce the overall amount of intersection and start to re-introduce the bias associated with the highly clustered point data. The differing degrees of MPA-grid cell intersection appear well spread amongst the remaining grid cells throughout the AoI (Figure 3.7).

Figure 3.7 helps put the use of the intersection threshold scenarios into context, and aids the interpretation of the number of extra presence/absence cells that are excluded from the analysis with increasing intersection thresholds.

For the analyses of representativity and replication, the species and feature grids needed to be attributed with:

- land/sea area;
- projected area; and
- membership of the NI 12 NM zone or the AoI.

This information was also exported from the attribute tables from the resulting spatial join layers. As each grid cell has a unique number, this information was combined with the species or feature presence/absence data within an Excel workbook. The resulting Excel workbook was used for multiple subsequent analyses and referred to as the ‘species grid output file’.

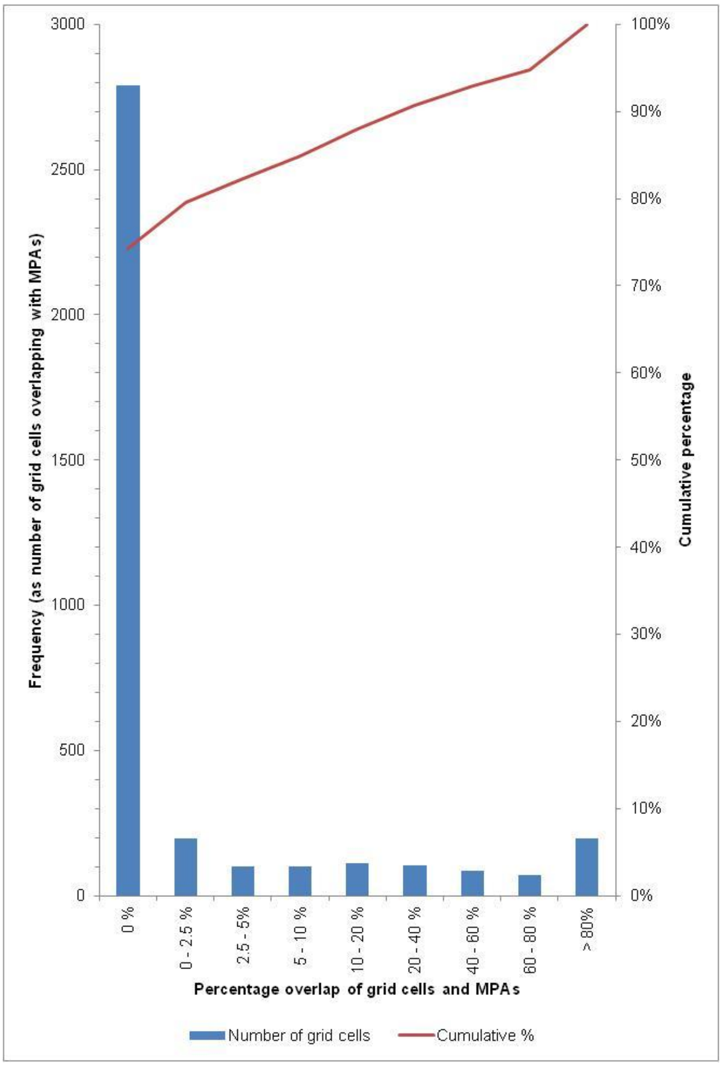
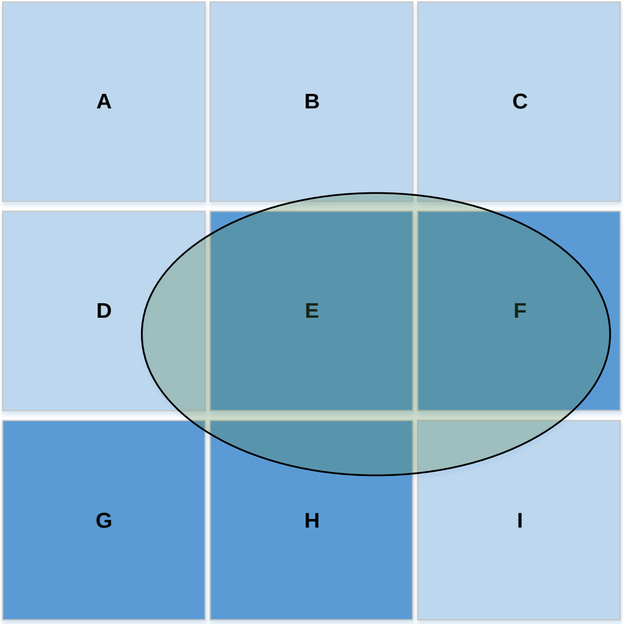


Figure 3.7 Distribution of MPA-grid cell overlap

For the representativity and adequacy analyses the threshold value for degree of intersection was set to 2.5%. By reporting only those grid cells with 2.5% or more potential protection from an MPA small and relatively insignificant boundary overlaps where removed from consideration (by way of example, see Figure 3.8).



In this example a feature has been recorded in four contiguous 5 km grid cells (shown as darker grid cells; E, F, G and H). An MPA that affords a degree of protection to the feature is shown as a green oval. The MPA is coincident with all four grid cells in which the feature has been recorded, but overlaps less than 2.5% of the area of cell G. For the purposes of analysis, therefore, the feature occurs in four cells and is provided protection in three (cells E, F and H).

Figure 3.8 Example of feature presence and coincidence with MPA designations

It should be noted that, in addition to point data, a number of polygon data layers were provided for some species within the study. These were spatially intersected with the grid layer in the same way as the point data, the presence of a polygon area within a grid cell leading to it being flagged as 'present'.

CONFIDENCE

Understanding the levels of confidence inherent in model outputs and derived, aggregated analyses is an important component of any study. However, the understanding and methodologies required to generate meaningful assessments are still undergoing development. Any assessment undertaken in relation to the analysis of representativity or replication relies heavily on the quality of the underlying EUSeaMap classifications made for biological zone, substratum, energy level and EUNIS Level 4 habitat. The EUSeaMap WebGIS portal provides some background on the confidence assessments have been generated during the production of those habitat related inputs and outputs presented on the site. In this context EUSeaMap has explored three methods to display confidence in the maps:

- assessment of source data layers (either quantitative or qualitative);
- quantitative assessment (e.g. using fuzzy classifiers[12]) of the membership of a given location (grid cell) to a particular habitat type based on the conditions at that location in relation to the habitat thresholds; and
- ground-truthing, by comparing modelled seabed habitat maps against recent habitat maps from surveys.

[12] Fuzzy classification is a 'soft' labelling method that, rather than classifying an area or pixel to a single class, attributes the unit with probabilities of membership across several classes.

A broad scale qualitative assessment of source data layers has been included in the GIS project that accompanies this project. However, this confidence assessment is restricted to blocks of existing data used in the production of the predicted maps and does not provide a continuous confidence surface.

The use of fuzzy classifiers in undertaking a quantitative assessment of the a given location's membership of a particular habitat type (an assessment which is based on the conditions at that specific location in relation to predefined habitat thresholds) provides a valuable source of information for a full confidence assessment. However, although they have been produced by the EMODNET project, these confidence layers are not currently available for public download from the JNCC-hosted EMODNET portal. In addition, the final confidence assessment methodology, using a cross tabulation validation of predicted and actual classifications, has only been undertaken in discrete areas that lie outside of the AoI. For reference, the results of this assessment can be found in Cameron and Askew (2011). Other analyses, such as the connectivity calculations undertaken within ESRI ArcMap, do not rely on underlying modelled or interpolated data and the outputs can be considered to be of high confidence.

Examination of similar projects, such as Panache (Sciberras *et al.*, 2013), did not identify any approaches to confidence assessment that could have been applied to this project. Due to the time, complexity and novelty of this project, confidence assessments have not been undertaken as part of the overarching ecological coherence analysis, and assumptions have been made about the confidence of the underlying data layers used for this project. The EUSeaMap layers are a vital source of continuous data for this, and similar, projects. Processes need to be developed where the underlying confidence layers attached to the EUSeaMap products can be incorporated into meaningful confidence assessments within ecological coherence studies. Confidence in underlying data is clearly an important consideration; the development of appropriate methodologies should be recognised and form the focus of future work.

Furthermore, the concept of confidence has many components within an ecological coherence analysis. For example, for clusters of points that fall within a small range of a marine laboratory, there may be high confidence regarding the data's classification and spatial location. However, there are obvious questions around whether the data are sufficiently widespread to be representative of a larger sea area and the level of confidence that can be placed on any assumption regarding how representative they are. These are important concepts, and further work is needed to establish what metrics can be generated and how informative such derived values might be for understanding overall confidence. This work is likely to be novel in its nature as there are no existing approaches that are documented in the literature for understanding confidence in combined ecological coherence analysis studies.

The qualitative assessment of source data layers has been included in the GIS project that accompanies this project. However, this confidence assessment is restricted to blocks of existing data used in the production of the predicted maps and does not provide a continuous confidence surface.

Other analyses, such as the connectivity, do not rely on underlying modelled or interpolated data and the outputs can be considered to be of high confidence.

3.3 Review of ecological coherence

The following sections describe the methods used to undertake the review of ecological coherence of the NI MPA network, and consider each of the network design principles in turn.

3.3.1 REPRESENTATIVITY

In terms of representativity, coherence requires that the network represents the range of marine habitats and species present in Northern Ireland's territorial waters. Analyses to support this assessment were undertaken for: habitats (at EUNIS level 4); substrata; biological zone; and water column classification. Each analysis employed the ESRI ArcMap 'clip' tool, using the EUSeaMap shapefile along with the derived NI MPA network (attributed for 12 NM MPAs and for AoI MPAs outside the 12 NM area).

Subsequently, the attributes table for the clipped EUSeaMap file was exported to Microsoft Excel for pivot table analysis, with data summarised by total area of each seabed class for both the NI 12 NM and AoI MPA networks.

Whilst the EUNIS (Level 4) habitats follow a standard classification, the seabed habitat classes that were considered comprised:

- coarse or mixed sediments;
- muds;
- rock or biogenic reef;
- sands; and
- other.

Analysis of the contribution of depth distribution across MPAs was considered within the biological zone analysis, which considered:

- the infralittoral;
- the circalittoral;
- the deep circalittoral; and
- the upper slope.

The infralittoral zone ranges from the mean low water level to a depth that encompasses the photic zone (where 1% of ambient light reaches the seabed). Within NI waters this lower limit is typically at a depth of 20-30 m. The circalittoral zone ranges from the lower depth limit of the infralittoral to the wave base, which is typically at a depth of 45-55 m. The deep circalittoral band has a depth range from the lower limit of the circalittoral to 200 m, whilst the upper slope areas are regions deeper than 200 m and would include, for example, seabed areas surrounding Rathlin and Maidens.

Finally, consideration of water column stratification considered the extent of shelf water and the region of freshwater influence (ROFI), along with the degree of mixing/stratification.

3.3.2 REPLICATION

To support an assessment of MPA replication within the Panache project (Sciberras *et al*., 2013) it was specified that the size of individual MPA replicates should be sufficient to support the communities of those species the site is intended to protect. HELCOM (2010) set the theoretical minimum of adequate replicates to three, with the minimum size for a landscape patch to be considered a replicate as 24 ha (Piekainen and Korpinen, 2008). The use of a 24 ha threshold within the present study aligns the methodology to with that of other examples (e.g. the BALANCE project, Andersson *et al*., 2008), allowing results to be compared against other ecological coherence studies.

The EUNIS Level 4 habitats contained within the EUSeaMap layer were extracted (using the 'intersection' tool within ESRI ArcMap) to spatially match the layer containing the AoI MPAs, effectively selecting only those landscape patches that occurred within MPAs. The clipped habitats were then given a code that related to each MPA. The 'calculate geometry' tool was used within ESRI ArcMap to attribute each habitat patch with its area. The attribute table for the habitat patches was then exported for analysis within Microsoft Excel where it was converted into a pivot table and the individual patches filtered to remove units <24 ha in size. The pivot table was also designed so that multiple patches of the same habitat within a single MPA were expressed as just one unit (as the objective was to examine the replication of habitat patches between MPAs and not within them). The number of habitat patches and the mean sizes of patches within MPAs were calculated for each habitat type. Finally, the pivot table separated the number and area of replicates within NI MPAs from those in the AoI MPAs.

The analysis of species and feature replication used the 'species grid output file'. The pivot table analysis was limited to reporting the number (count) of MPAs in the 12 NM and AoI that contained records for:

- Habitats Directive Annex 1 and 2 features;
- OSPAR threatened and declining species and habitats; and
- birds listed in the Birds Directive for which records were available showing their presence within the wider AoI.

Unlike the representativity analysis for features, which reported the total number of cells intersected by the MPA network, the replication analysis reports the number of MPAs that contain species of interest. Only one 'presence' grid cell needs to intersect an MPA for a presence flag to be established for that MPA - the absolute number of presence cells within an individual MPA is not important.

Based on the premise that a replicate should be of a sufficient size to support the communities of species it is intended to protect, and that, potentially, the presence within an MPA of just a single cell identified as containing a species is sufficient to flag the MPA as a potential replicate, the threshold for the analysis of MPA and core designation species and features overlap was increased from 2.5% to 10%. By increasing the threshold for the amount of overlap with an MPA required to trigger the reporting of a protected cell the minimum potential area that is assumed to be protected by an MPA is increased (from 62.5 to 250 ha). This higher threshold effectively provides an increased likelihood of the overlap actually providing protection to an area of feature within the overlapping grid cell of size that approaches that which is required to support the communities that it is intended to protect. This also ensured that any reported overlap was substantial and also provided a reasonable reflection of potential redundancy within the network.

3.3.3 CONNECTIVITY

It was originally intended to restrict the MPA connectivity analysis to the MPA network within the NI 12 NM limit. However, an initial run of the connectivity analysis showed that MPAs (e.g. the cross-border sea loughs and some inshore MPAs) had unrealistically low connectivity. In reality, these NI MPAs are ecologically linked to MPAs elsewhere in the wider AoI, especially to those within the RoI. To avoid such obvious edge effects as much as possible, but working within the confines of the project scope, MPAs from adjoining waters (within a 50 km range of the NI 12 NM) were also included in subsequent analyses. This 50 km buffer resulted in the inclusion of an additional ten coastal MPAs in the Republic of Ireland and one UK offshore MPA. It is not possible to totally eliminate the edge-effect for this type of connectivity analysis but the inclusion of neighbouring MPAs through the application of a 50 km buffer substantially reduces it. The selection of 50 km was based on a doubling of the range of shortest distance connections from the first connectivity analysis, and was felt to be appropriate for the biogeographic scales under consideration, reflecting the scale of the network and the between-MPA distances commonly seen within the NI 12 NM limit. In practice, the use of 50 km as a buffer value allowed the nearest connections between NI MPAs and MPAs outside of NI to be fairly assessed. Ultimately, however, the reporting of connectivity was restricted to sites falling within the NI 12 NM area.

The connectivity analysis was based on distances between the centroid (mid-point) of each MPA in the network (defined for each MPA polygon using the ArcMap ‘feature to point’ tool). This approach meant that, for some designations, the centroid was placed inland. In such instances a surrogate mid-point was identified that coincided with the point below mean high water that was closest to the actual centroid.

Where adjacent designations have a partial overlap, or share significant lengths of common boundary, the connection distance is potentially very low and this may lead to bias, effectively overestimating the level of connectivity within the network. To adjust for this, where designations overlapped or shared a common boundary, their respective centroids were deleted and a single new ‘derived’ centroid generated. Examples where this joining of MPAs has occurred includes Strangford Lough, Dundrum and Belfast Lough.

Two different approaches were used when calculating between-site distances: following the marine path and following straight line paths.

Analysis of the marine path connectivity (relevant for species that are only able to move between sites via marine waters) required a land/sea raster to be produced. For each MPA site centroid, the ArcMap ‘cost distance’ tool was used to generate a cost-distance and backlink file (masked to calculations within the sea element of the land/sea raster). The ArcMap ‘cost path’ tool was subsequently used for each MPA. This tool imports the cost distance and backlink file, and plots the shortest marine path to all of the MPAs used in the analysis. The attributes for all of the resulting cost path rasters were exported to Excel so that the descriptive statistics could be extracted for each site and combined for histogram presentation.

For bird species it was felt that a straight line analysis (over-land) was more appropriate. The SPA sites were selected from the MPA network and the ESRI ArcMap tool ‘distance to point’ tool used to calculate straight line distances between all possible combinations of points.

The output from the marine pathway analysis for the MPA centroids consisted of a series of path lengths. Path source and destination locations (start and finish points) were not reported and so it has not been possible to reproduce the inter-MPA pathways as figures.

The analysis of MPA connectivity calculated the connections between MPAs regardless of their composition. As underlying habitat predictions were available for the MPA network, a third connectivity analysis examined the marine pathways between MPAs containing the same habitat features. This used the intersected habitats and MPA layer produced for the replication analysis, i.e. a file containing just the predicted habitats within the MPAs. The habitat polygons within the MPAs were converted from polygons to centroids using the ESRI ArcMap 'feature to point' tool. Some points were manually removed from within MPAs when it contained multiple points for the same habitat – the objective of the analysis was to look at connectivity between the MPA units without connections being made within MPA units.

The points from this file were separated by habitat and exported to separate point files. Following this, each point was also exported to a separate point file. The analysis of the marine pathway for each habitat point to all other points of the same habitat type was undertaken with the ESRI ArcMap distance measurement tool due to the low number of points. Lengths were recorded but source and destinations were not. The resulting distances were exported to Excel so that the descriptive statistics could be extracted for each habitat and combined for histogram presentation.

3.3.4 ADEQUACY

The adequacy analysis also examined the proportion of species/feature presence cells contained within the Northern Irish MPA network. The objective was to understand what proportion of presence cells overlap the MPA network and what additional overlap might be obtained by increasing the MPA footprints.

This analysis used the 'species grid output file'. A pivot table analysis was used to examine the level of protection for the core designation species and features, i.e. the Northern Ireland priority species list, Habitats Directive annex 1 and 2 species and habitats, OSPAR threatened and declining species and habitats and Birds Directive species list. This resulted in a list of 55 species and features present within the Northern Irish 12 NM limit. The intersection used for this analysis was 2.5% (the same as the main species and habitats analysis in the representativity section).

An overview of the level of protection afforded to species and habitats by MPAs across the AoI and within the NI 12 NM limit was undertaken by calculating the extent of protection afforded to each species or feature. For clarity, each of the 220 species and features from the combined features list were assigned to one of four groups:

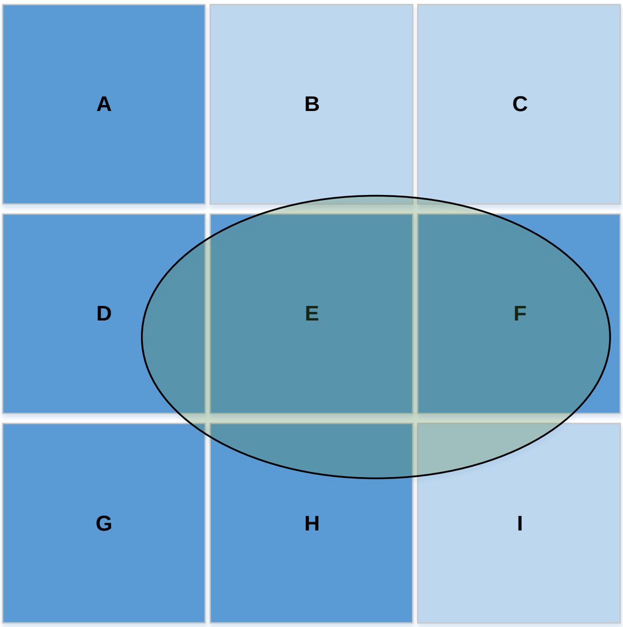
- sessile species;
- mobile (aquatic) species;
- habitats and biotopes; and
- bird species.

For each species or feature, the number of grid cells where the available data implies the feature's presence and which can be assumed to receive some nominal degree of protection from an MPA was evaluated, and expressed as a percentage of the total number of cells where the feature's presence was indicated.

As discussed earlier, a threshold minimum overlap was set to 2.5% of a grid cell (equivalent to an area of overlap of 62.5 ha). By reporting only those grid cells with 2.5% or more potential protection from an MPA small and relatively insignificant boundary overlaps where removed from consideration.

This exercise was repeated for features and MPAs within the AoI and within the NI 12 NM limit (Figure 3.9).

For each species or feature, the analysis considered those grid cells for which the collated data implied presence. The percentage of these cells that were coincident with (overlapped) with an MPA was then calculated. It should be recalled that the overlap threshold has been set at 2.5%, i.e. for a feature's grid cell to be classed as being coincident with an MPA, at least 2.5% of the grid cell should fall within the MPA boundary (for example, see Figure 3.9). Across each of the four broad groupings of features, these percentage values were assigned to 10%-ile bands, and the number of species or features falling within each band was noted.

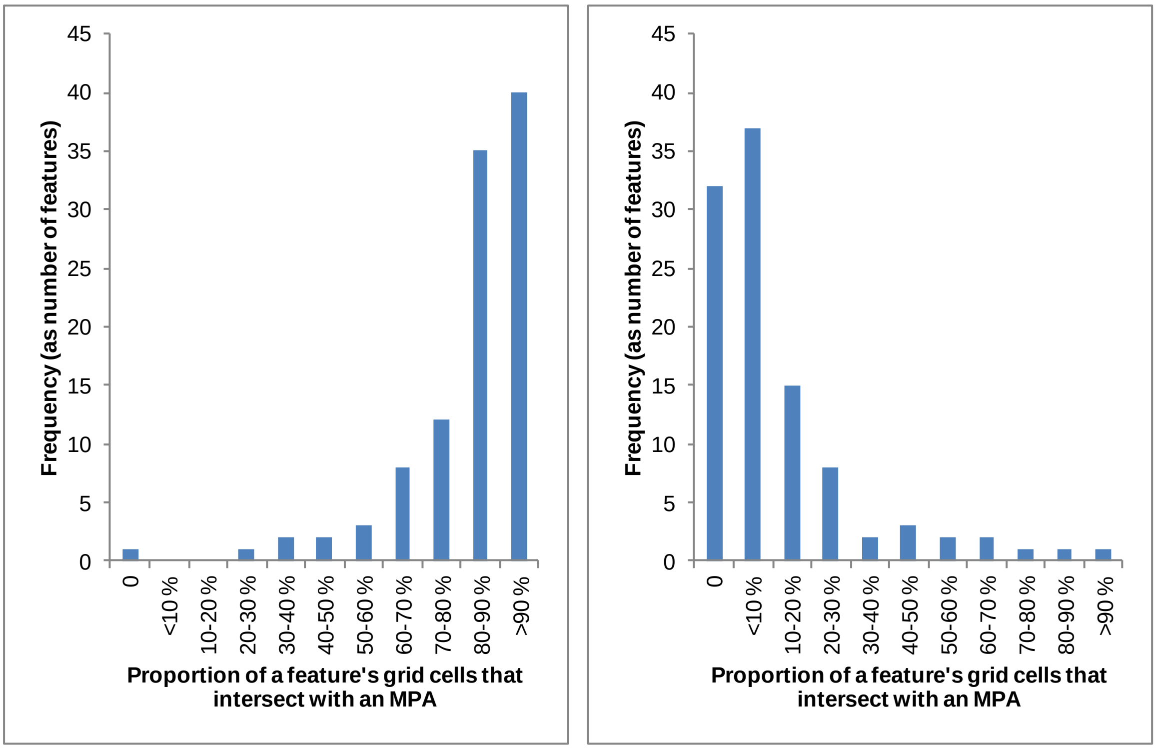


In this example a feature has been recorded in six contiguous 5 km grid cells (shown as the darker grid cells; A, D, E, F, G and H). An MPA is shown as the green oval. The MPA is coincident with five of the grid cells (E, F, G and H) but its overlap with the area of cell G is less than 2.5% of a grid cell.

For the purposes of representativity analysis, the feature is recorded as occurring in six cells and as being afforded protection in four (cells D, E, F and H) – a coverage rate of 67%. This feature would therefore be included within the 50-60% category.

Figure 3.9 Example to show derivation of representativity statistics (see text for further detail)

Figure 3.10 provides an example output of this analysis. The vertical columns show the distribution of differing levels of protection; how many features are afforded each of a series of levels of protection ranging from low (where none of a feature spatial range is coincident with an MPA) through to high (where >90% of a feature spatial range is coincident with an MPA). Instances where the vertical columns cluster to the right of the X-axis therefore represent cases where the distribution of most features typically display a high degree of overlap with MPAs. In such cases it is assumed that the majority of features are protected to a relatively high degree. Conversely, instances where the vertical columns cluster to the left of the X-axis represent cases where the distributions of most features do not overlap with MPAs, and it is assumed that relatively few features are protected to a high degree.



Left hand figure - outputs for a network displaying a good degree of potential feature protection, showing high incidence of feature & MPA overlap;

Right hand figure – outputs for a network displaying a relatively poor degree of potential feature protection, showing a low incidence of feature & MPA overlap

Figure 3.10 Example outputs showing distribution of 'degrees of protection' – see text for details

3.3.5 VIABILITY

Viability as a design principle relates to individual MPAs and is not a network characteristic *per se*. It does not, therefore, strictly figure as part of an assessment of overall network coherence. However, it is useful to be able to place the constituent NI MPAs into context in terms of their individual viability.

Guidance from Natural England and JNCC (2011) suggests that an MPA protecting a broad-scale (EUNIS level 3) habitat should have a minimum diameter of 5 km, and an average size of between 10 and 20 km in diameter (equating to a mean of approximately 20 km^2 and an average size of between 80-315 km^2, assuming circular sites).

The main analysis of viability was based upon an examination of the average size and shape of the component MPA designations. This analysis used Excel sheets provided by JNCC for designations in the UK, and by the National Parks and Wildlife Service for those in the Republic of Ireland. The sites were attributed by region and by sea area, i.e. whether they were in the AoI or the NI 12 NM zone. Once attributed, pivot tables were used to extract the descriptive statistics for designations by region.

The size of NI MPAs was estimated and compared to those in other jurisdictions.

An index of compactness was calculated for all SAC, OSPAR and SPA designations. Compactness, as suggested in OSPAR (2007), numerates MPA shape by the equation:

$C = (4\pi A/p^2)^{0.5}$,

where C is the index of compactness, A is the area of the site, and p the site's perimeter.

A score of unity is achieved by a circle, which is the most compact shape, whilst values of less than one, i.e. lower levels of compactness, indicate longer perimeters, more boundary complexity and a consequent increase in potential edge effects (see, for example Figure 3.11 below).

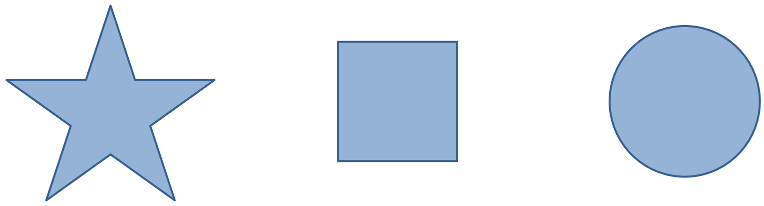
MPA shape			
Area	200 ha	200 ha	200 ha
Perimeter	10.80 km	5.66 km	5.01 km
Index of compactness	0.464	0.886	1.0
Compactness trend	⇨	Increasing compactness (reduced boundary effects)	⇨

Figure 3.11 Changes in compactness for different shaped sites of equal area

In this context, compactness provides a generalised index of the potential for adverse 'edge effect' issues at a site. This is a widely discussed management topic within both marine and terrestrial ecology. Where seabed communities lie at the edge of a protected area they might not be buffered particularly well from the diffuse pressures that exist just outside the boundary of the managed area. This reduction in an effective spatial buffer between communities and sources of local pressures (which may be biotic or anthropogenic) often results in reduced community condition. Compact MPAs maximize interior area, diminish 'edge-effects', and reduce the loss of protected species across borders through migration (Natural England & JNCC, 2011).

Protected areas may be fitted to the natural extent of a habitat type, often reflecting the observed extent of given habitat types. Edges (by definition) occur at the boundary, or interface, between two biological communities or different landscape elements (for example where two types of seabed meet). An ecotone is the zone of transition along the edges of two adjacent ecological communities (Forman, 1995). As such, environmental conditions within ecotones usually differ from those of the immediate surroundings and often have an increased diversity by taking elements from both communities (Basset *et al*., 2013). Some plants and animals benefit from the microclimatic edge effects of the ecotone, and thus the number of different species is generally high in these areas. However, when these species penetrate an adjacent patch, they may compete with species that are dependent on different habitat conditions. Species or communities within adjacent patches may be harmed through the ecological processes of predation, competition, and parasitism, thus increasing 'biotic edge effects'.

Where MPAs are established, it is often management issues around the boundaries that result in reduced levels of protection for features within the site. Consequently, more compact shaped sites, with a shorter boundary for a given area, are likely to provide more robust protection to those habitats and species that they cover (see, for example, NE & JNCC, 2011). Conversely, sites with low values for compactness (i.e. more complex shapes, with longer boundaries for a given area) are likely to provide reduced feature protection as management issues along the site boundaries erode the overall level of protection that the site can provide.

3.4 Gap analysis

3.4.1 General

Following from the ecological coherence assessment, a gap analysis for the MPA network was undertaken considering the existing MPA network at the regional (AoI) scale. Spatial analysis of representativity, replication, connectivity and adequacy were used to identify high priority gaps within the Northern Irish MPA network. Overall, the analysis draws together most of the derivatives from the preceding ecological cohesion analyses and overlays them to calculate an overall 'gap score'.

The principle of viability was not considered as it would necessitate a feature-by-feature assessment of the network. Also, consideration of viability would require access to (polygon) data describing feature extent: these data were not available to the project.

Representativity & Adequacy

Because of similarities in the way that data were processed for these two elements of ecological coherence, representativity and adequacy were considered together in this phase of the gap analysis.

The representativity element of the gap analysis made use of three elements already discussed in the representativity analysis (reported above in Section 3.3.1). These were:

- the derived information for the relative proportions of different biological zones;
- seabed substrata; and
- EUNIS (level 4) habitats covered by the existing MPA network.

In addition, adequacy (in the form of cumulative presence/absence grids for the four habitat and species groups) was also considered.

Classes of each of the three main representativity descriptive groupings (biological zones, seabed substrata and EUNIS habitats) that were poorly represented within the existing MPA network (identified as those where the proportion covered by the NI MPA network represented 10% or less of its occurrence across the whole of the NI 12 NM area) were selectively exported from the main EUSeaMap shapefile. Grid cells representing each of these under-represented classes were attributed with a 'gap code' of 1. This exercise resulted in three sets of layers (one each for biological zones, seabed substrata types and EUNIS habitats) where each cell in the was populated with values of 1 (indicating that the particular zone, substrata or habitat type present at that location was under-represented in the MPA network) or 0 (indicating that the zone, substratum or habitat type at that location was adequately represented in the MPA network). Ultimately, these layers are gridded to be compatible with the connectivity output - the intersection for the overlap between the habitats and grids was set to 50%.

With over 200 species and habitats under consideration, a detailed gap analysis that assesses the spatial distribution of each single feature independently represents a complex undertaking. In addition, a feature-by-feature approach increases the need to ascribe weightings to the importance of each feature. Such a detailed approach was beyond the scope of the current project. Nevertheless, the distribution of key species and habitats within the NI 12 NM area, and the degree to which these are covered by the NI MPA network, is important and efforts were made to capture this information. Rather than attempting to compare across all 220 features, aggregations were made across the four composite groups used previously, *viz*:

- sessile species;
- mobile (aquatic) species;
- habitats and biotopes; and
- bird species.

These composite groups simply combined all of the presence/absence grids together, i.e. each cell reported the number of 'presence' cells. For each group, the presence counts recorded in the individual cells across each of these four grids (i.e. the total number of 'presence' records for each grid cell) were normalised onto a 0-1 scale across the extent of the AoI. This provided four composite grids (one for each of: sessile species, mobile species, habitats, and birds) where the highest scoring cells (those having the highest number of species or biotopes) have values nearer 1. Cells nearer a score of 1 can be viewed as the species hot-spots and areas of higher habitat heterogeneity that should preferentially be included within an MPA network. This process converts the species diversity observed across the entire AoI to a statistic that could be compared with other criteria expressed on a similar relative scale. It would be expected that many of these hot-spots may fall with existing designations but the outputs also highlight areas that are not protected. This approach, best suited to the landscape-scale analysis, aims to capture naturally high areas of species or biotope richness through considering most features rather than specific species or biotopes.

Grids for all three individual representativity components (biological zones, seabed types, and EUNIS habitats) four adequacy components (sessile species, mobile species, habitats & biotopes, and bird species) were combined and summed into a single representativity raster layer, at which point the values in each cell (each of which had a theoretical range of 0-7) were divided by 7 (i.e. the values rescaled onto a 0-1 range) such that that the information held within the resultant 'representativity gap layer' raster had an equal weighting to the connectivity and replication gap layers.

As noted above, a detailed gap analysis that assesses the spatial distribution of each single feature independently represents a complex undertaking. It would also require judgements to be made about the overall value of particular species or habitats for inclusion within the gap analysis, and would need information on the biogeographic extent of each species, the present condition of each feature within NI and the value of particular conservation measures. Recommendations on how the gap analysis might be developed in the future are outlined in the discussion, but it should be noted that particular emphasis would need to be placed on considerations regarding the selection of key species and habitats and the use of weighted elements within the analysis.

REPLICATION

Replication gaps were defined as cells that contained EUNIS level 4 habitats that were replicated less than three times within the existing MPA network. As in Section 3.3.2, a given habitat type was defined as being replicated adequately if at least one grid cell of that habitat was contained within each of at least three separate MPAs. Any habitat types that were under-replicated were selectively exported from the EUSeaMap shapefile, and cells within the grid attributed with a 'gap code' of 1.

CONNECTIVITY

The connectivity gap analysis summed all individual 'cost-distance' layers (produced as an intermediate stage in the 'cost path' analysis undertaken as part of the main connectivity assessment) into one cumulative cost-distance raster for all of the Northern Irish MPAs and those within a 50 km range of the edge of the Northern Irish territorial waters. Only the marine pathways were used (in preference to the direct, straight line pathways) as this provided for more conservative estimates of connectivity. The resultant raster, which effectively records the relative degree of connectivity for any cell within the NI 12 NM zone, was clipped to the NI 12 NM zone and the raster values rescaled onto a 0-1 range. Within the final connectivity raster, values nearer 0 indicate high connectivity, whilst values nearer 1 represent higher levels of geographic isolation (based on a marine pathway between MPAs).

3.4.2 COMBINATION ACROSS COMPONENTS OF ANALYSIS

Finally, the three component layers (representativity & adequacy, replication and connectivity) were summed, providing an overall 'gap raster' with individual cell values with a range from a theoretical minimum of zero up to a theoretical maximum of three. The use of the same 0-1 scale for each criterion (representativity, replication and connectivity) mean that they were all equally weighted in the overall assessment. In practice, as each grid cell was ascribed at least one non-zero value through the course of the process, the observed range of values within the gap raster was less than the theoretical range, with a minimum recorded value of 0.08 and a maximum value of 1.86.

3.4.3 ASSUMPTIONS AND LIMITATIONS

It should be recognised that the overall scope of the agreed objectives for the project was extensive and ambitious. The concept of ecological coherence is a young and developing field, and the collation and analysis of raw species and habitat information required significant data gathering and processing time. Equally, some analysis methods are novel and, as such, are not detailed in existing studies of ecological coherence but have been generated specifically for this project.

The limitations imposed by the availability of data were significant and were a central consideration when designing and interpreting the coherence analyses. The point data used throughout the analysis is not uniformly distributed but is clustered in areas of conservation interest (within designations) or in areas high survey effort (survey effort refers to the amount of observation time or energy that has been spent within an area: areas of high survey effort might include existing monitoring sites, areas of high marine traffic or locations regularly used for scientific investigation). This necessitated the use of an overlaid presence/absence grid. It was not possible to accumulate all the required information into the analysis due to time restraints. Sea-bird records are not contained in the Marine Recorder database. Equally, the CeDAR database output provided also did not contain bird species. The Birds at Sea database did not contain sea bird sightings for Carlingford Lough, Strangford Lough and

Lough Foyle – this deficiency was only noted after the deadline for data provision for the project. Future development of this topic should initially seek to find suitable data for the sea loughs.

Point data for a couple of the species and habitats from the NBN Gateway was provided at a reduced spatial resolution. This was typically done for commercial species with a conservation status, such as the native oyster, *Ostrea edulis*. Due to the reduced spatial accuracy of these points, some species appear to have presence records on land. Any such land-based presence cells were automatically excluded from analyses. However, due to the volume of species and features used in this project it was not possible to remove the land-based presence flags within the database.

Due to the absence of raw survey data, it was not possible to differentiate between 'no data' and recorded absence values. This important distinction means that, for any given feature, grid cells that were not coded as 'present' may be either 'no data' or 'absent'. Furthermore, all of the merged point data, regardless of whether those records contain abundances, are ultimately expressed simply as presence/absence data. When more than one record for the same species occurs within the same grid cell, the number of contributing records is not recorded and the output remains a presence/absence flag.

Another important assumption about the use of point data is that these positions are taken to reflect the habitat within which these species exist. However, within the study area, certain habitats are likely to have greater value than others for specific life history stages. For any given species, the use of presence/absence grids assumes an equal importance for all life history-specific habitats present across the AoI and makes no distinction for potential differences in the relative importance of spawning, nursery or adult (foraging) habitats. Information which would allow researchers to delineate essential habitats for the majority of the species included within this analysis does not currently exist.

The analysis of marine pathway connectivity was lengthy and convolved. As a consequence it was necessary to limit connectivity analysis to NI MPAs and those MPAs within a 50 km radius of cross-border regions and offshore sites. A batch run was possible for this analysis, but distance between habitats within Northern Irish MPAs was undertaken with the measurement tool within ArcMap. The absence of hydrodynamic data from assessments of connectivity in other studies is a recognised weakness, and it was originally intended to include hydrodynamic data within the analysis of connectivity within this project. However, during the processing stage of the project no suitable hydrodynamic data were found for this purpose. Although, in the latter stages of the project, a potential source of information was identified, it was too late to develop the methods, undertake the analysis and include the output for the final report. However, IECS will (outside of the current contract with NI MTF) look to examine the potential of an improved connectivity analysis incorporating the hydrodynamic data after the current project has completed. If successful, the results of this additional work will be made available to NIMTF.

Much of the analysis of representativity and of replication relied heavily on the EUSeaMap surfaces. These surfaces, although modelled and occasionally poor at the finer scale, provided an important source of continuous habitat information. However the EUSeaMap surface does not cover the intertidal zone and, consequently, intertidal habitat coverage is not covered in the representativity, replication or gap analyses. A further problem in terms of accurately assessing the inter-tidal was evident in the absence of a high-resolution 'high shoreline' for the UK and RoI which added substantial difficulty into the analysis. However, where available, presence/absence data for intertidal species and habitats were assessed. Due to their reduced availability, complexity, differing output resolutions and relatively restricted spatial extent, existing modelled habitat maps available from organisations such as AFBI and University of Ulster were not included in the current study.

3.5 Results: MPA network assessment

3.5.1 INTRODUCTION

As discussed above (Section 2) with a significantly large number of target features (i.e. 220 species and habitats) it is not appropriate to consider applying the matrix approach to summarising ecological assessment. Consequently, in terms of assessing the ecological coherence of the NI MPA network, this report is restricted to discussing the degree to which each of the underlying network design principles are addressed:

- Representativity;
- Replication;
- Connectivity;
- Adequacy;
- Viability; and
- Naturalness.

Each of these principles is discussed, in turn, below.

3.5.2 ASSUMPTIONS

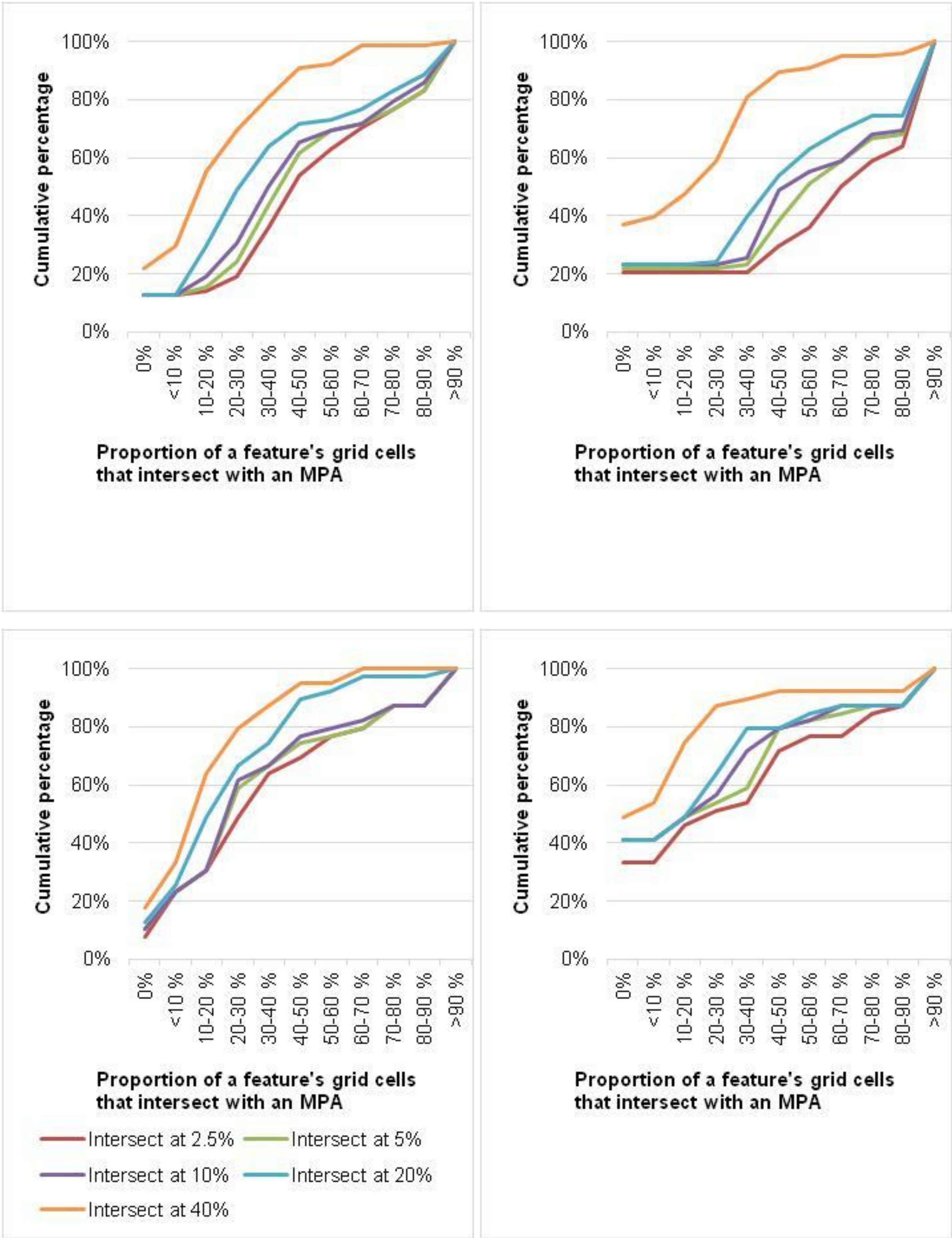
The analyses have made extensive use of a set of derived data held on a GIS. These data were based on the collation of raw data for species and habitats from a number of different sources, and it was necessary early in the project to convert these data into a common format. To satisfy this requirement, and to reduce the potential bias that from repeat sampling at specific locations, the data were converted to a grid format based on the presence/absence of each feature within 5 km grid cells.

Conversion of the collated point source (vector) data to a gridded (raster) format was a straightforward process, but introduced a degree of uncertainty into the data (specific definitive point locations were converted to relatively broad presence/absence cells). Consequently there was less certainty regarding the true coverage of recorded data by existing MPA sites. Although problematical, given the scope of the project coupled with the extensive list of over 200 features, this was thought to be an acceptable compromise. The use of grid dimensions greater than 5 km would have significantly decreased the number of non-overlapping cells and thereby increased the perceived level of ecological coherence. Equally, smaller grid cells would reduce the overall amount of intersection and start to re-introduce the bias associated with the highly clustered point data.

Subsequently, the assessment of whether grid cells with features (species of habitats) recorded as ‘present’ were protected by existing MPA sites required an overlap threshold to be set. Following discussion with NI MTF a threshold value of 2.5% of a 5 km grid cell was selected. A sensitivity analysis was undertaken to assess the effect of selecting different intersection thresholds (of 2.5%, 5%, 10%, 20% and 40%) by considering the effects on combined assessments of sessile species, mobile species, habitats and bird species. First, the percentage of each feature’s ‘presence’ grid cells that overlap with an MPA (assuming a predetermined overlap threshold) was calculated. Each feature was then classified into one of a series of 10-percentile groups. Finally the distinct features in each of the 10-percentile groups were counted, and presented as a percentage of the total number of features considered. For presentation purposes, the change in the total number of features in each 10-percentile group was expressed as a percentage of the total number of features under consideration and shown as the cumulative total.

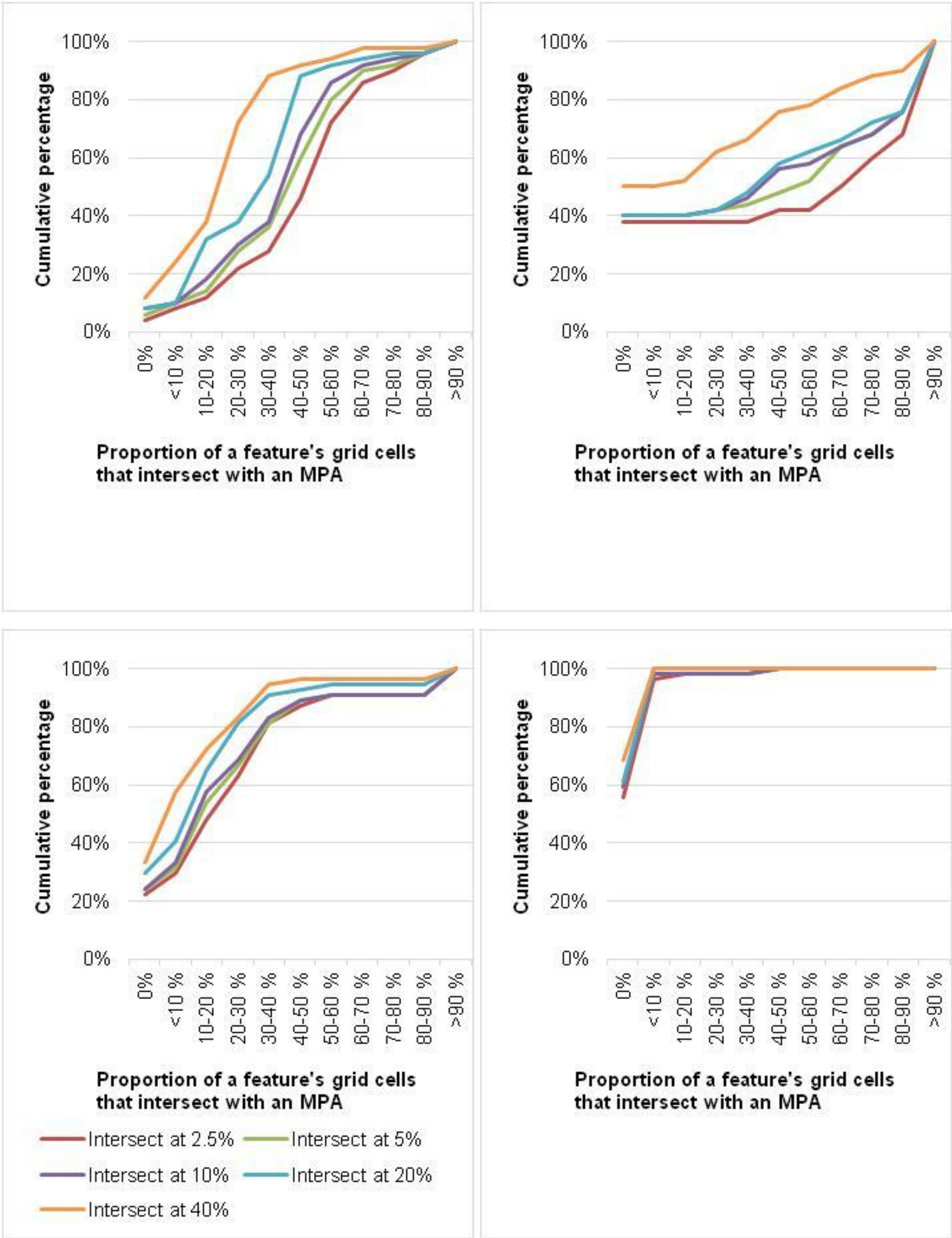
This was intended to provide an indication of the effect that altering the threshold (to a more stringent criterion) might have on the assessment of representativity. Intuitively, as the threshold value is increased the apparent level of representativity seen across the network would decrease.

The following figures (Figure 3.12 and Figure 3.13) show the cumulative percentage curves for each of the five intersection thresholds considered, providing an indication of how the level of protection afforded by the AoI MPA network changes with different overlap criteria.



Sessile species (upper row) and mobile species (lower row)
Features & MPAs from within AoI (left hand figures) and within NI 12 NM limit (right hand figures)

Figure 3.12 Cumulative frequency plots showing effect of altering minimum intersection criterion on indicative level of protection afforded to sessile and mobile species by the MPA network (see text for details)



Habitats (upper row) and bird species (lower row)
Features & MPAs from within AoI (left hand figures) and within NI 12 NM limit (right hand figures)

Figure 3.13 Cumulative frequency plots showing effect of altering minimum intersection criterion on indicative level of protection afforded to habitats and birds by the MPA network (see text for details)

The outputs from this exercise showed the cumulative percentage curves for each of the five intersection thresholds considered. Whether considering the NI 12 NM zone or the wider AoI, all four groups showed only a relatively small effect of increasing the overlap threshold from 2.5% up to 5%, 10% or 20%. It was only when setting the threshold at 40% at a relative stringent that the response was altered to a (visually) significant extent (see Figure 3.12 and Figure 3.13). It was concluded that the 2.5% overlap threshold – which equates to just over 60 ha within each 5 km grid cell – was sufficient to remove what might be 'trivial' or non-significant overlap from further consideration, but was not so robust as to lead to a large number of features' grid cells being classified as being unprotected by the MPA network.

Where a grid cell was deemed to be overlapping with an MPA it was assumed that the MPA provided protection to all of the grid cells features. It is acknowledged that this probably overestimates the actual degree of protection but, in the absence of detailed information on measurement measures for each MPA (the collation and assessment of which was beyond the scope of this project), is accepted as a reasonable and sound pragmatic basis for assessment.

3.5.3 REPRESENTATIVITY

A range of general descriptive outputs are available to describe the degree to which the MPA network reflects the general environmental conditions seen in NI territorial waters. Initially, the geo-spatial extent of the MPA network was considered, examining whether the network was representative of the general extent of the NI marine environment. Table 3.2 summarises the extent of the existing MPA network, whilst Table 3.3 shows the proportions of NI coastline and seabed (below MLWS) that are currently protected.

Table 3.2 Marine area (intertidal and subtidal) protected by region within the Northern Irish 12 NM limit

Sea Region	Total area (km^2)	Number of significantly sized MPA
North Coast (Atlantic)	136.7	3
North Channel	100.2	5
Irish Sea	118.0	4
Sea loughs	225.2	6

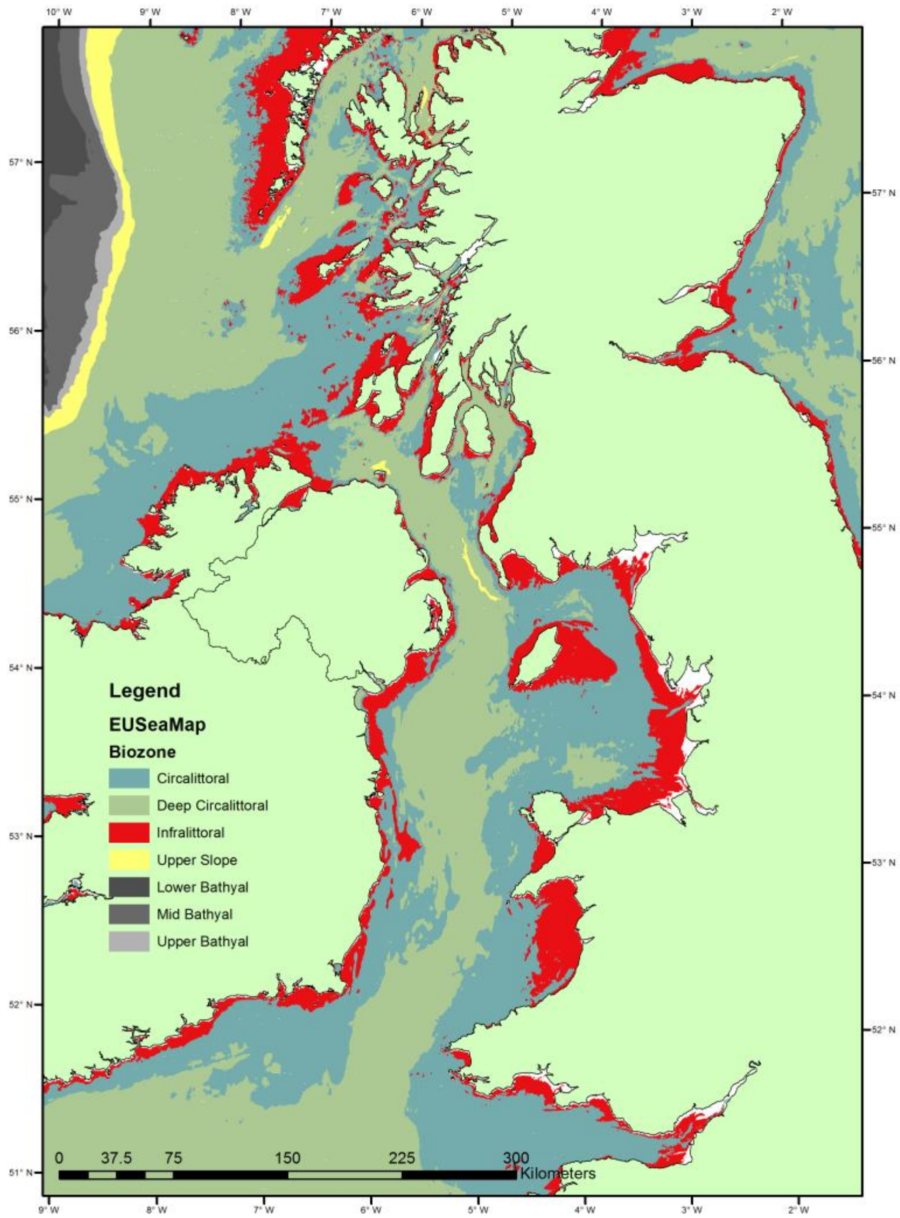
Table 3.3 Protected sea areas within the Northern Irish 12 NM limit

Feature	Occurrence within 12 NM	Amount under designation	Proportion under designation
Coastline (km)*	609 km	353 km	57.9%
Seabed below MLWS (km^2)	4,338 km^2	449 km^2	10.3%

[* Measured at the 1:500,000 scale]

This assessment was extended by reviewing the coverage of the principal biological zones across NI territorial waters, the spatial distribution of which is shown (for the wider AoI) in Figure 3.14.

Figure 3.15 provides an alternative presentation of these data by showing the relative proportions of the different zones within the NI 12 NM zone and the inshore MPA network. In general terms, the more similar the relative proportions shown in this pair of diagrams the more representative the MPA might be considered.



Transverse Mercator Projection centred on the Irish Sea
Datumn WGS84 Scale 1:3,000,000

Data acknowledgement: Cameron & Askew (2011)

Figure 3.14 Spatial distribution of principal biological zones across the AoI

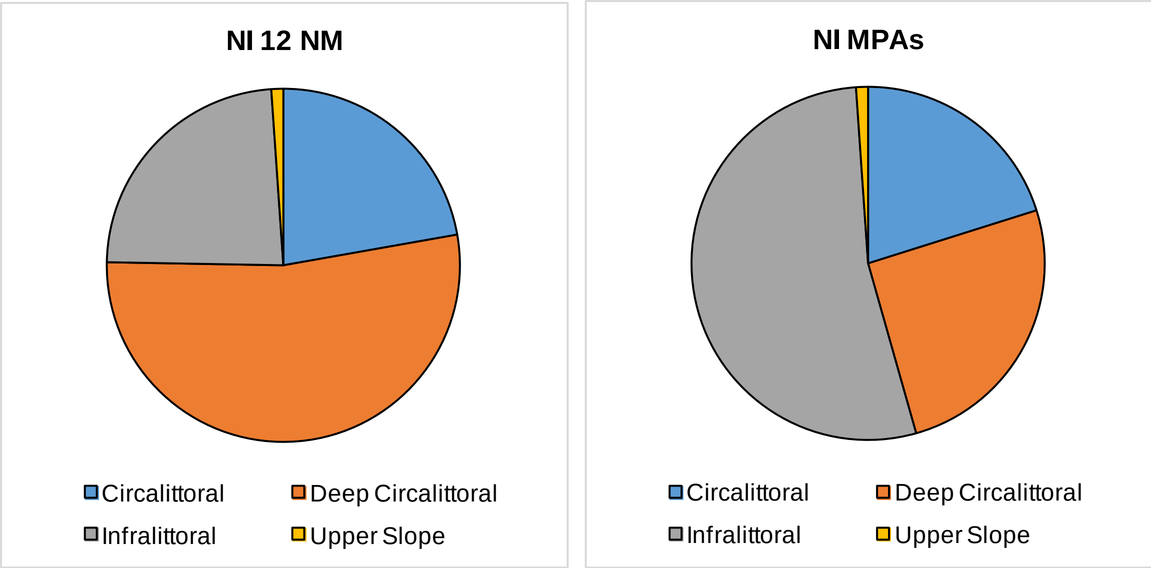
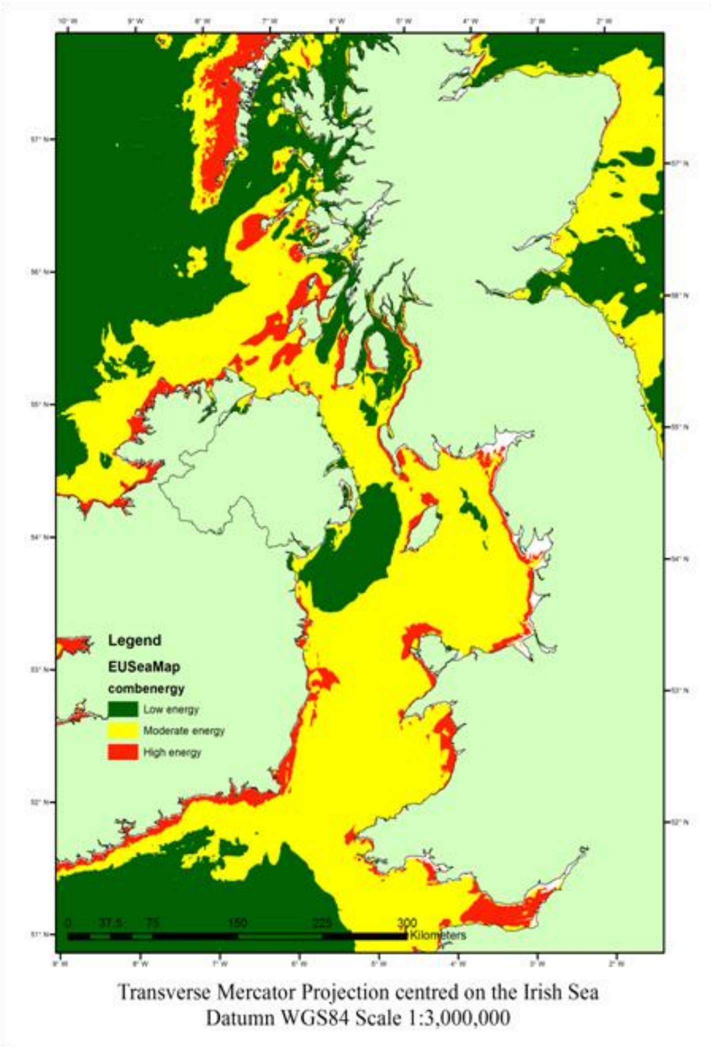


Figure 3.15 Relative proportions of (subtidal) biological zones across NI territorial waters and MPA network

The biological zone analysis shows the depth range of the current NI MPA network in comparison to that of the surrounding seabed. It is clear that the extent of protection for shallower (infralittoral) areas is proportionately higher than that suggested by its distribution across the NI 12 NM zone. It is possible that this increased protection reflects the importance of the photic zone for species diversity, but may also be an artefact arising due to the suitability of this particular depth range band for diver-based survey methods. As depth increases, there is a corresponding decrease in the amount of designated seabed within MPAs. Only within the deepest zone does representativity increase again to just over the 10% threshold.

Similarly, Table 3.16 and Figure 3.17 (below) together provide a summary of the extent to which different wave and tidal energy zones are distributed and represented by the MPA network.



Data acknowledgement: Cameron & Askew (2011)

Figure 3.16 Spatial distribution of principal energy zones across the AoI

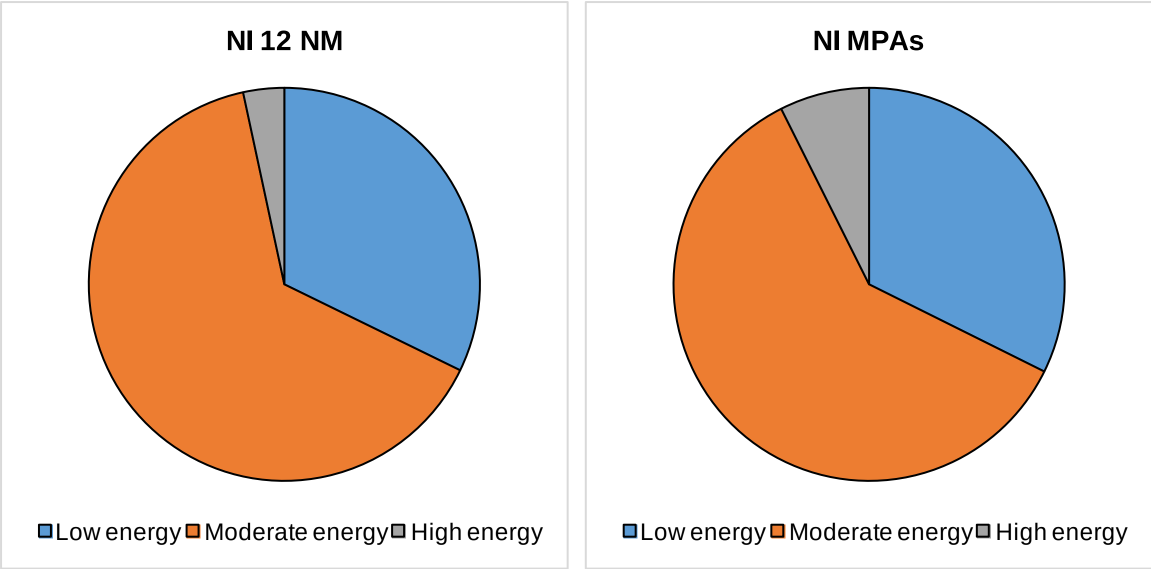
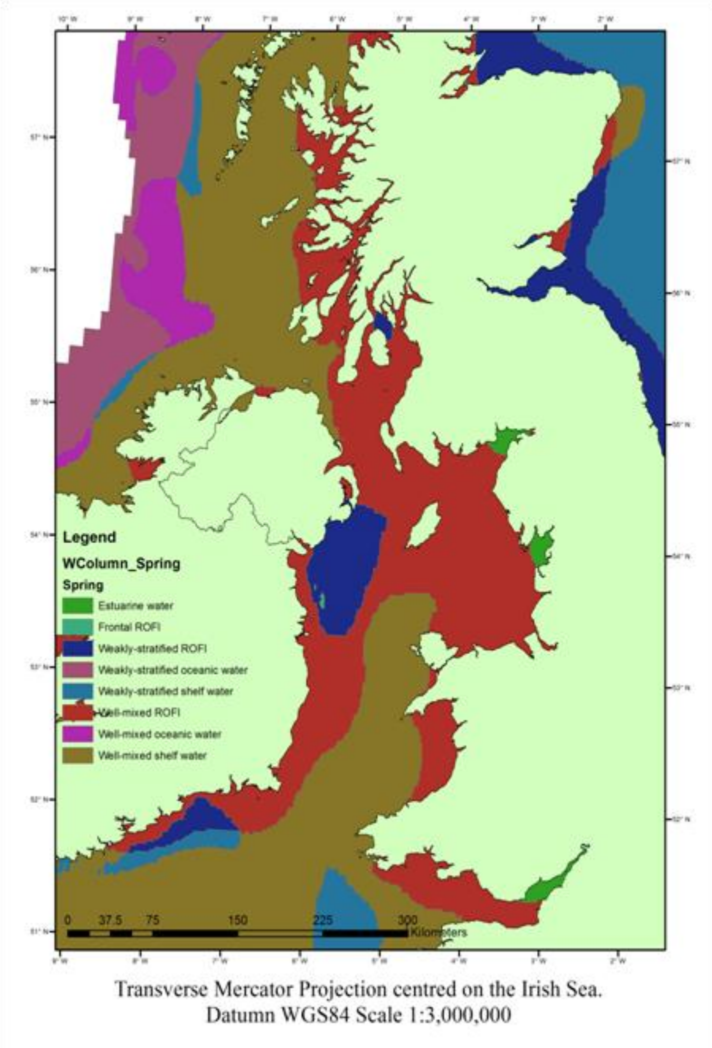


Figure 3.17 Relative proportions of (subtidal) wave and tidal energy zones across NI territorial waters and MPA network

The extent to which different water column stratification structures are represented within the MPA network through the different seasons was also assessed. The underlying data that were used are presented as Figure 3.18 to Figure 3.21 and the data are summarised in Figure 3.22.

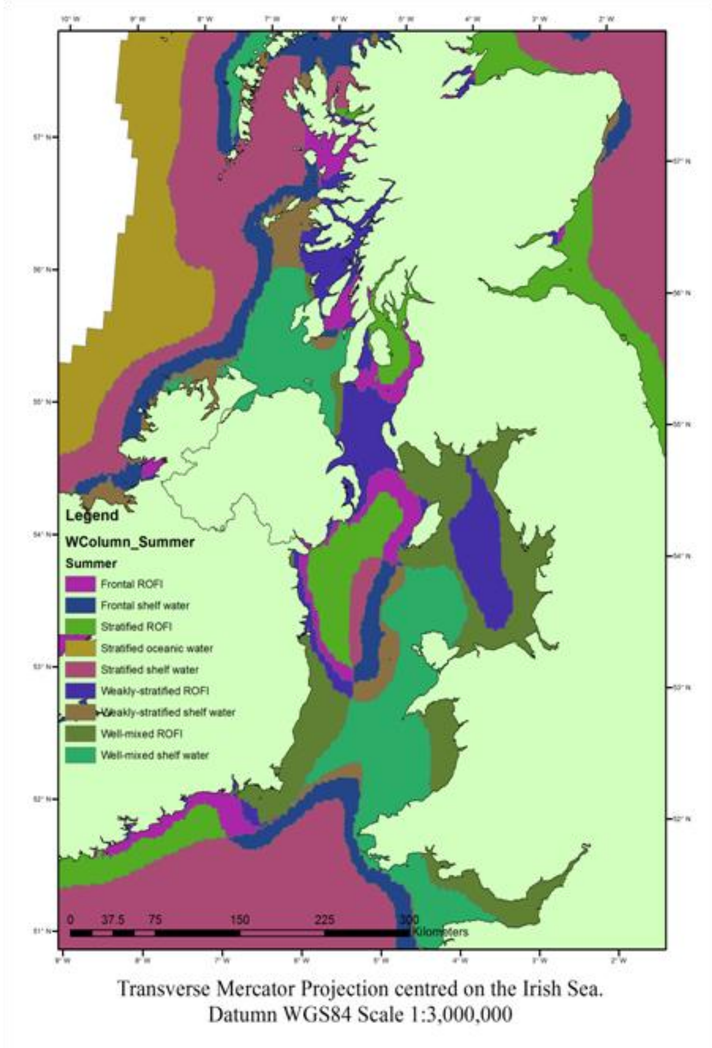
The terminology used for the water column classification is outlined below:

- A **stratified** water body is one which is in which mixing is restricted to the superficial depths less than the overall depth of the water body (e.g. due to the temperature profile of the water column). In such cases, salinity is the same as that in adjacent seawater. Vertical stratification can be pronounced and long-lasting.
- A **weakly stratified** body of water is one that is only partially mixed because the depth of the water body is greater than the depth of mixing. Salinity is the same as that in adjacent seawater.
- A **well mixed** body of water has no vertical stratification apparent.
- **Fronts** are waters characterised by the meeting of two or more differing water bodies and which generally arise through the influence of horizontal gradients.
- A water column which is unmixed, or only partially mixed, because the depth of the water body is greater than the depth of mixing. Fronts can be further classified according to the degree of persistence of stratification and may be ephemeral (e.g. eddies, gyres and upwellings).
- The **region of freshwater influence** (or **ROFI**) is an area where salinity is reduced relative to adjacent (fully marine) seawater; this habitat type is usually found in deeper coastal water situations and is the result of river inflow or ice melt.
- **Shelf water** is fully marine seawater overlying a continental shelf.



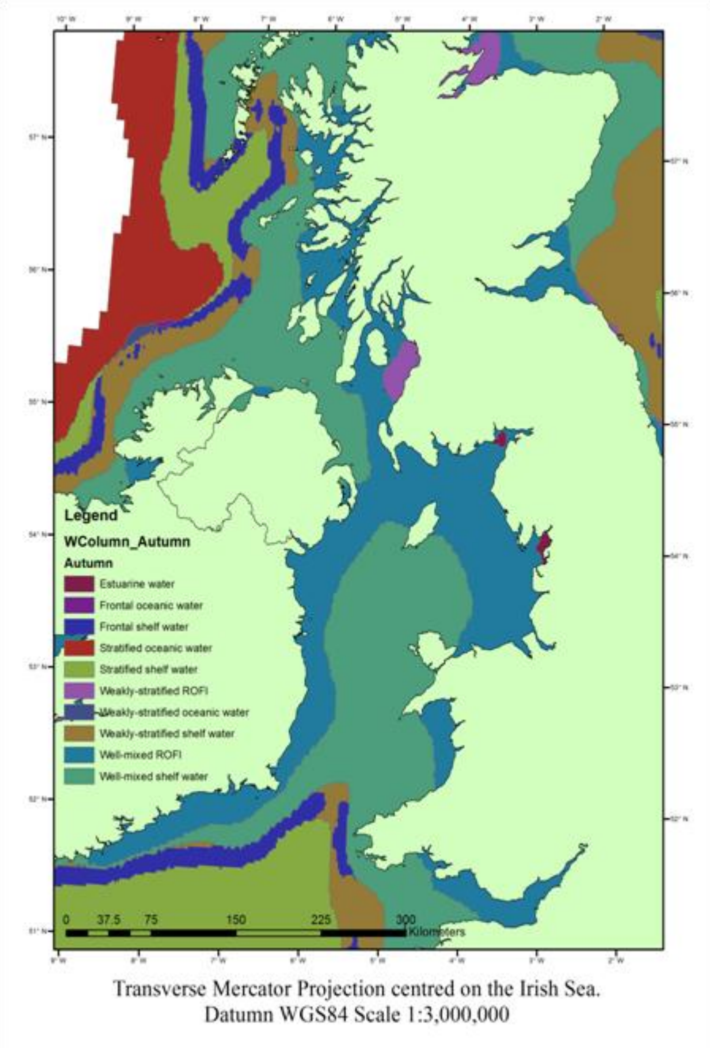
Data acknowledgement: Cameron & Askew (2011)

Figure 3.18 Water column characterisation across western UK waters; spring



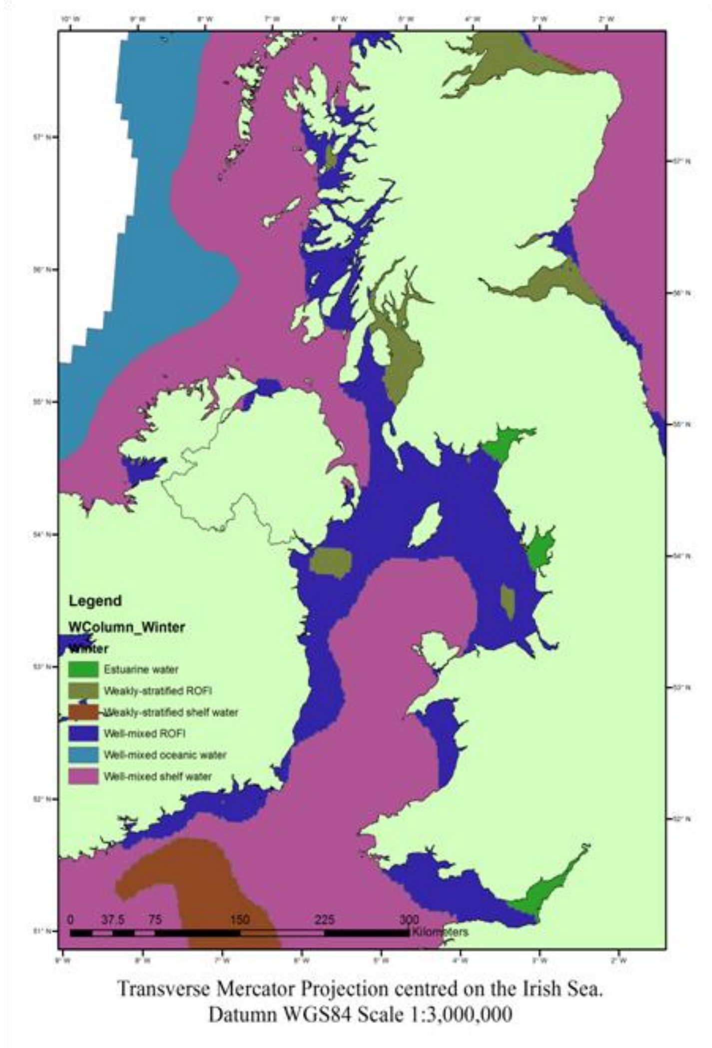
Data acknowledgement: Cameron & Askew (2011)

Figure 3.19 Water column characterisation across western UK waters; summer



Data acknowledgement: Cameron & Askew (2011)

Figure 3.20 Water column characterisation across western UK waters; autumn



Data acknowledgement: Cameron & Askew (2011)

Figure 3.21 Water column characterisation across western UK waters; winter

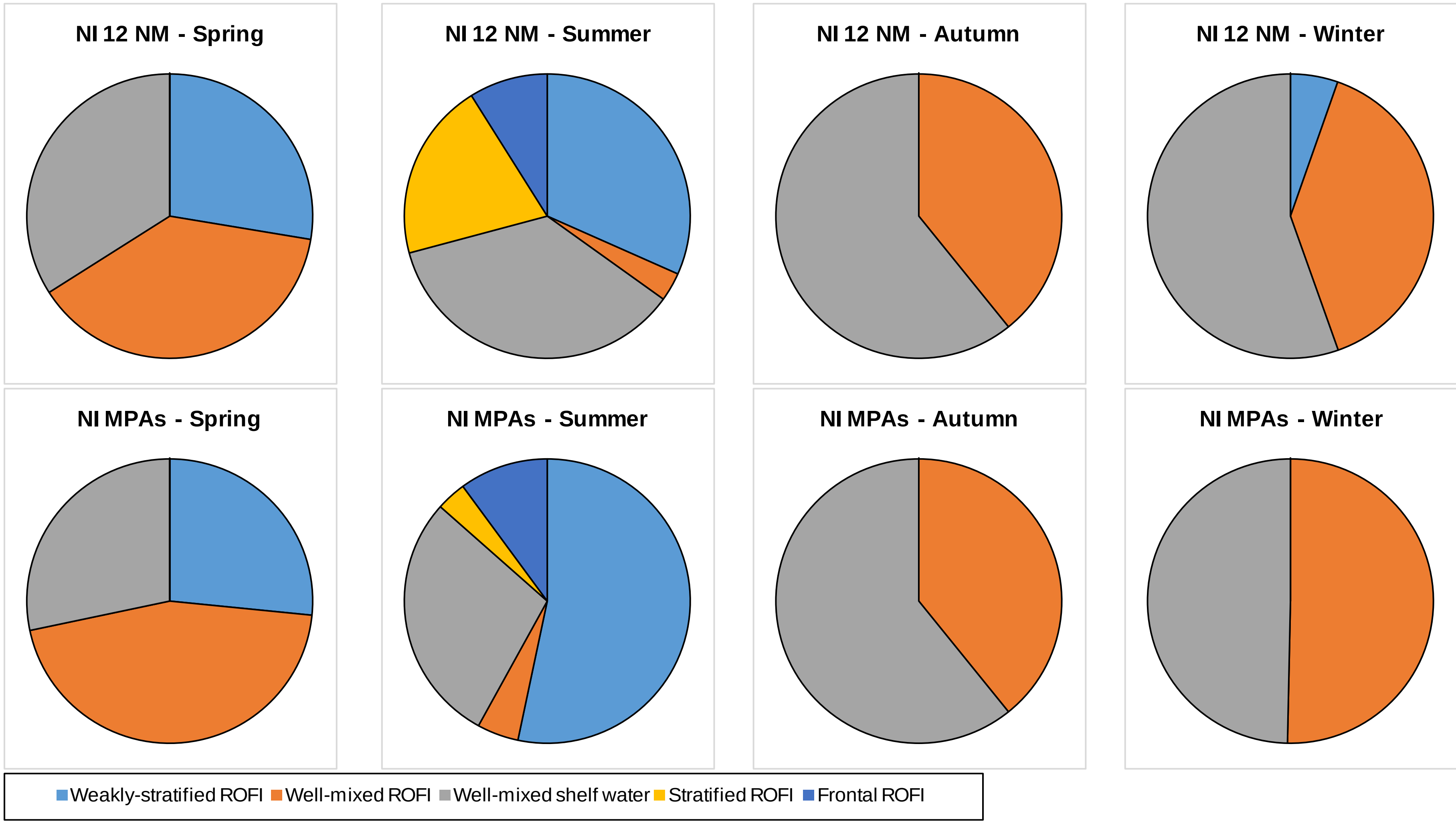
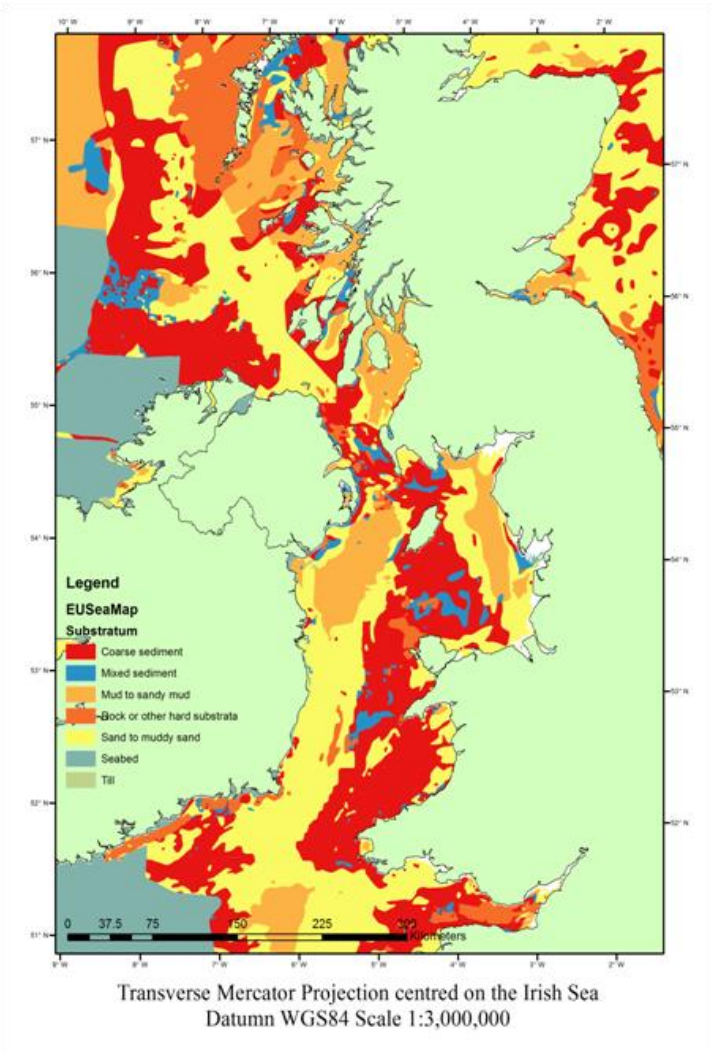


Figure 3.22 Relative proportions of different water column stratification patterns across NI territorial waters and MPA network

Finally, the distribution of different seabed habitat types and their representation within the NI MPA network, both in terms of general substrata (Figure 3.23 and Figure 3.24) and EUNIS level 4 habitats (Figure 3.25 and Figure 3.26) are presented below. For the EUNIS habitats, separate diagrams showing the relative proportions of dominant habitat types and sub-dominant habitat types (making up more than, or less than, 5% of the overall cover within the NI 12 NM zone) are provided as this allows for better visual discrimination of the relative proportions of cover within the 12 NM zone and within the MPA network.



Data acknowledgement: Cameron & Askew (2011)

Figure 3.23 Spatial distribution of principal seabed substrate types across the AoI

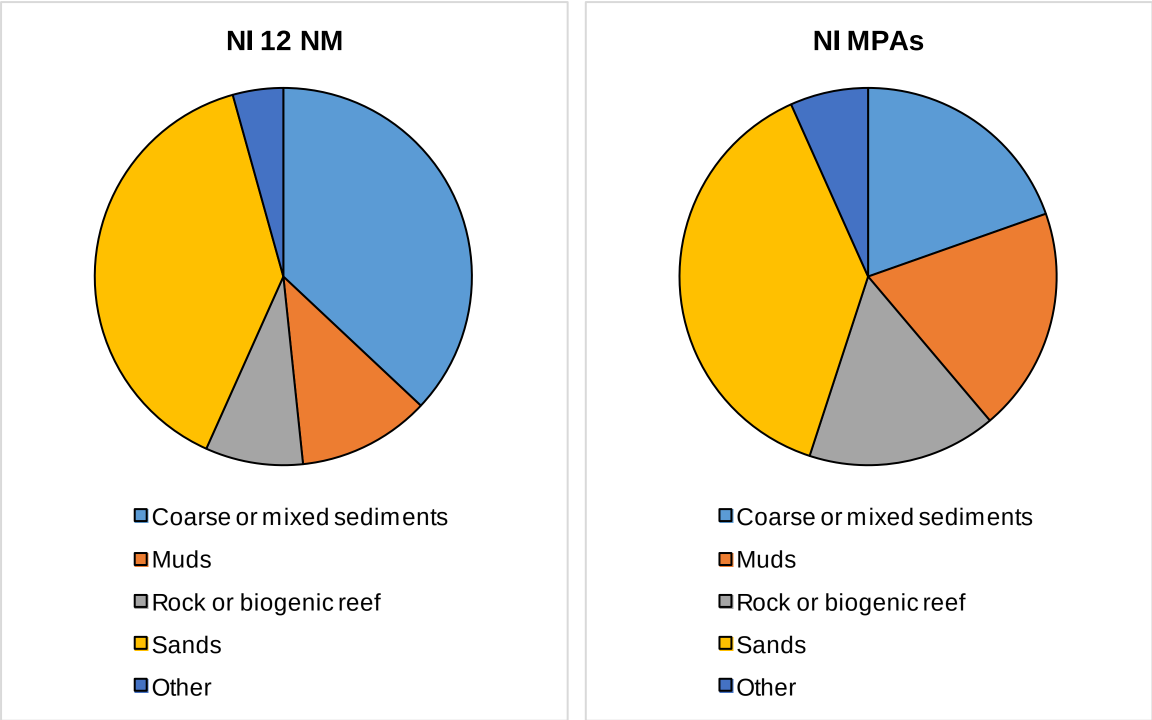
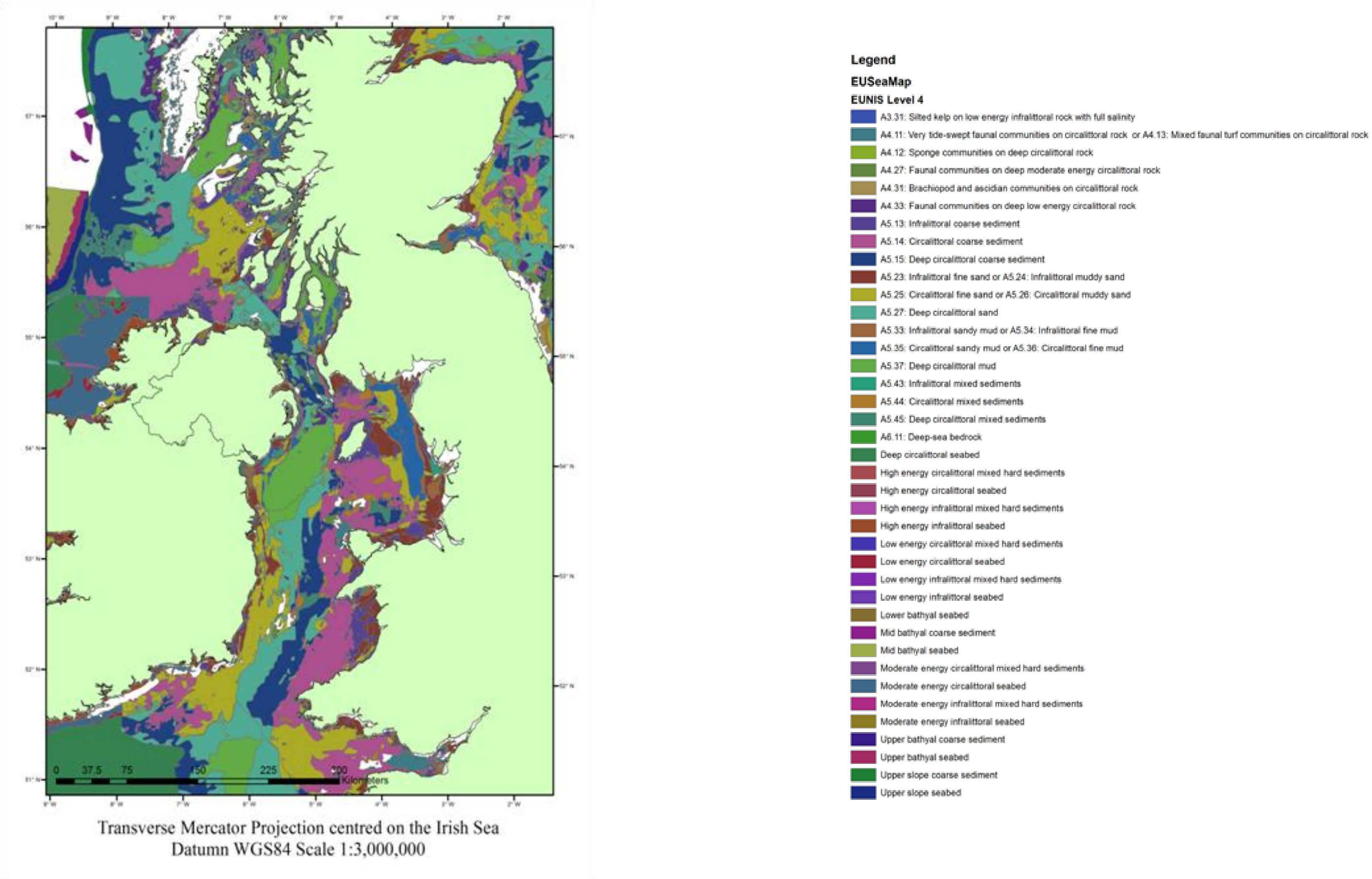


Figure 3.24 Relative proportions of different seabed substrata across NI territorial waters and MPA network



Data acknowledgement: Cameron & Askew (2011)

Figure 3.25 Spatial distribution of EUNIS Level 4 habitat types across the AoI

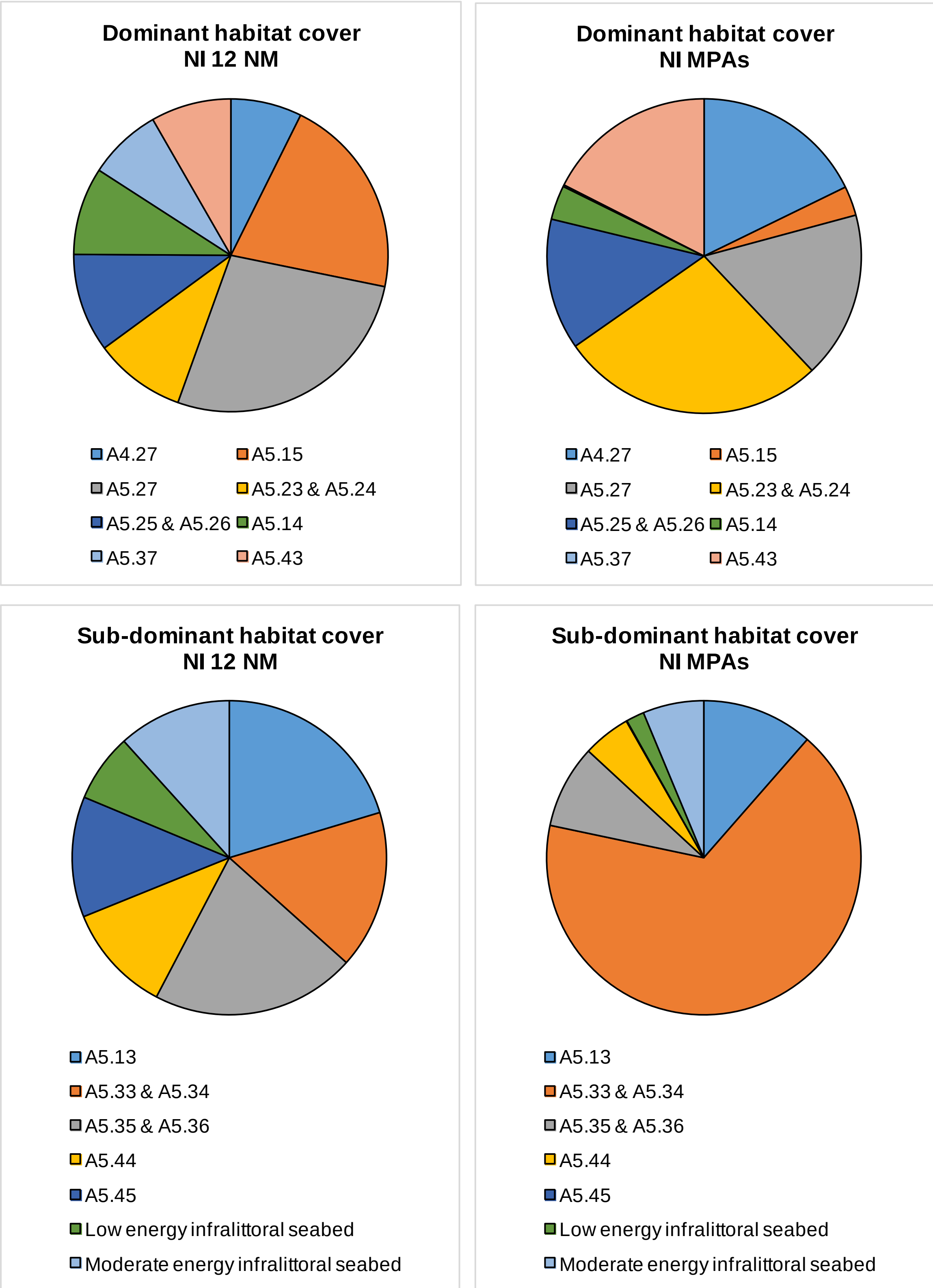
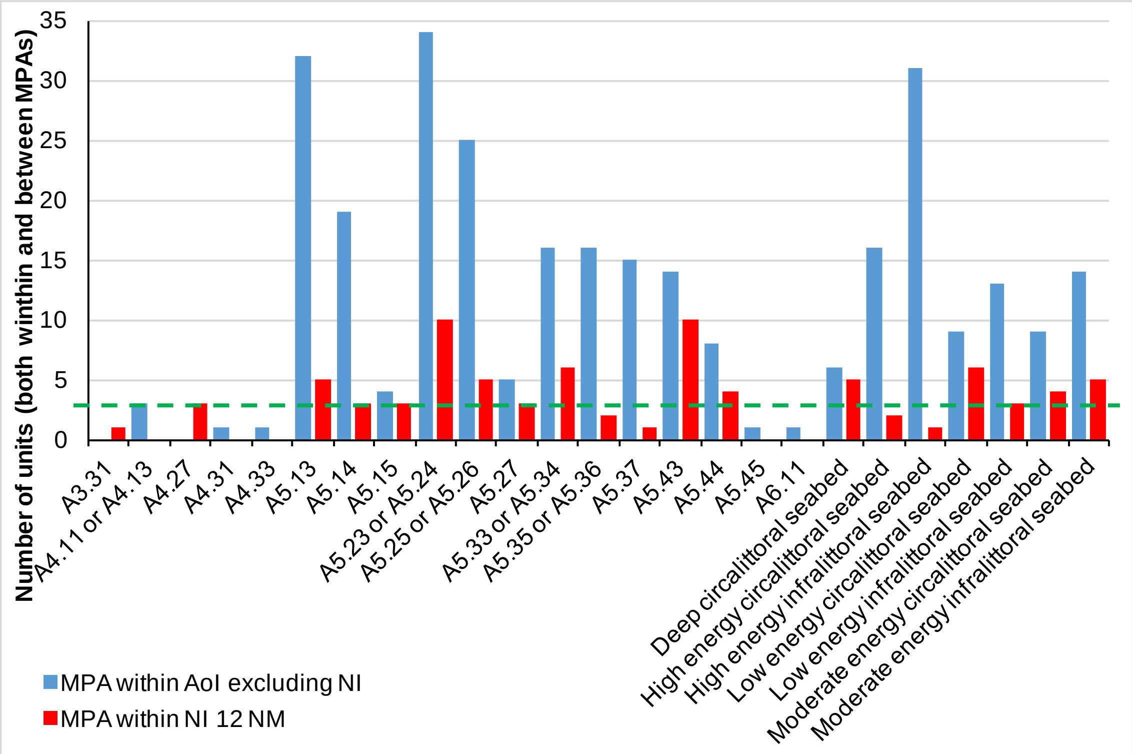


Figure 3.26 Relative proportions of EUNIS habitat categories across NI territorial waters and MPA network – shown separately for dominant (>5%) and sub-dominant (<5%) levels of cover

3.5.4 REPLICATION

Replication of EUNIS level 4 habitats revealed that many common habitat classes are highly replicated both within the AoI MPA network and within the Northern Irish 12 NM MPA network (Figure 3.27). Well-replicated habitats included A4.27 (faunal communities on deep moderate energy circalittoral rock), A5:13 (infralittoral coarse sediment), A5.14 (circalittoral coarse sediment), A5.15 (deep circalittoral coarse sediment), A5.23/A5.24 (infralittoral fine or infralittoral muddy sand), A5.25/A5.26 (circalittoral fine sand or circalittoral muddy sand), A5.33/A5.34 (infralittoral sandy mud or infralittoral fine mud), A5.35/A5.36 (circalittoral sandy mud or circalittoral fine mud), A5.43 (infralittoral mixed sediments), A5.44 (circalittoral mixed sediments), low energy seabeds, moderate energy seabeds and deep circalittoral seabed. These habitats were all represented by at least three units (over 24 ha) in both networks.



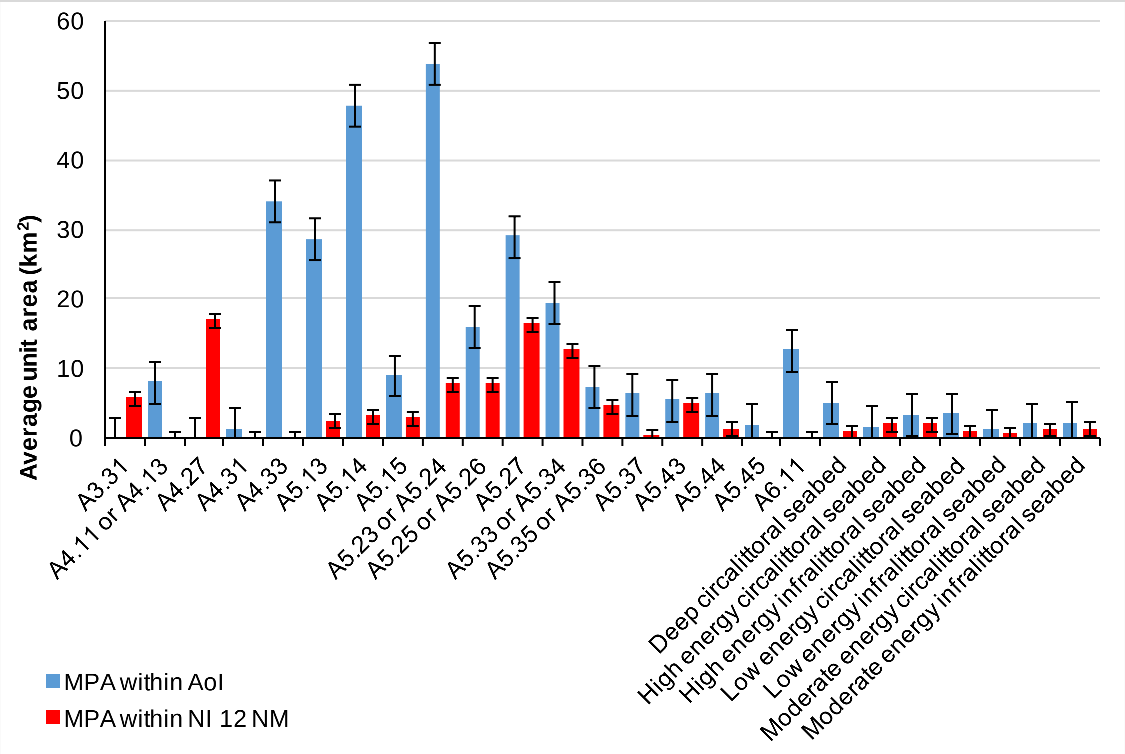
Green dashed line indicates ‘three replicates’ level
See Table 3.4 for EUNIS habitat code definitions

Figure 3.27 Total number of protected habitat units (units of the same habitat within the same MPA combined into 1 unit) within the Area of Interest MPAs and Northern Irish MPAs

For replication, habitats with less than three units within the Northern Irish MPA network were considered under-replicated. These included A3.31 (silted kelp on low energy infralittoral rock with full salinity), A4.11/A4.13 (very tide-swept faunal communities on circalittoral rock or mixed faunal turf communities on circalittoral rock), A4.31 (brachiopod and ascidian communities on circalittoral rock), A4.33 (faunal communities on deep low energy circalittoral rock), A5.37 (deep circalittoral mud), A5.45 (deep circalittoral mixed sediments), A6.11 (deep-sea bedrock) and high energy infralittoral seabed.

Of the eight habitats that were poorly replicated within the Northern Irish MPA network, seven appear to be also rare and poorly replicated within the area of interest. Only one habitat type, namely high energy infralittoral seabed, was well replicated in the area of interest but not within Northern Ireland. This is most likely a reflection of the lack of this type of habitat along the majority of the Irish Sea coastline of Northern Ireland. Only the Skerries SAC covers a substantial area of this habitat; no other MPA along the north coast of Northern Ireland covers over 24 ha of this habitat type within one MPA footprint.

When units of replication were available for a habitat in both networks, replicate size was typically smaller in the Northern Irish 12 NM MPA network when compared to the average within the AoI (Table 3.27). Replicate size was roughly comparable to the AoI sites for units of A5.43 and high energy circalittoral seabed.



See Table 3.4 for EUNIS habitat code definitions

Figure 3.28 Mean area of the protected habitat within the Area of Interest MPAs and Northern Irish MPAs (bars are standard error)

Table 3.4 EUNIS level 4 habitat code definitions

Habitat code (EUNIS Level 4)	Description
A3.31	Silted kelp on low energy infralittoral rock with full salinity
A4.11 or A4.13	Very tide-swept faunal communities on circalittoral rock or Mixed faunal turf communities on circalittoral rock
A4.27	Faunal communities on deep moderate energy circalittoral rock
A4.31	Brachiopod and ascidian communities on circalittoral rock
A4.33	Faunal communities on deep low energy circalittoral rock
A5.13	Infralittoral coarse sediment
A5.14	Circalittoral coarse sediment
A5.15	Deep circalittoral coarse sediment
A5.23 or A5.24	Infralittoral fine sand or Infralittoral muddy sand
A5.25 or A5.26	Circalittoral fine sand or Circalittoral muddy sand
A5.27	Deep circalittoral sand
A5.33 or A5.34	Infralittoral sandy mud or Infralittoral fine mud
A5.35 or A5.36	Circalittoral sandy mud or Circalittoral fine mud
A5.37	Deep circalittoral mud
A5.43	Infralittoral mixed sediments
A5.44	Circalittoral mixed sediments
A5.45	Deep circalittoral mixed sediments
A6.11	Deep-sea bedrock
No code	Deep circalittoral seabed
No code	High energy circalittoral seabed
No code	High energy infralittoral seabed
No code	Low energy circalittoral seabed
No code	Low energy infralittoral seabed
No code	Moderate energy circalittoral seabed
No code	Moderate energy infralittoral seabed

The following tables (Table 3.5 to Table 3.7) show the presence of particular features of conservation importance within the NI 12 NM zone and AoI MPA networks. The first column in each table indicates where the species or habitat is present in Northern Ireland territorial waters. The second column indicates the number of NI 12 NM MPAs with 10% or more intersection with a presence grid cell. The use of the 10% intersect reflects the need to be protecting a significant proportion of the feature in a similar fashion to the use of a 24 ha minimum unit size for the habitats. The final column indicates the number of MPAs within the wider AoI that have and intersection with 10% or more of at least one grid cell where the feature has been recorded.

With regard to those Habitats Directive (Annex 2) species that have been recorded within the NI 12 NM (see Table 3.5, below) all except one - *Alosa alosa*, the allis shad - were covered by at least two MPAs. The records obtained during the data collation exercise for *Alosa alosa*, a highly mobile anadromous species (i.e. one that feeds and matures at sea but which migrates to freshwater for spawning), coincided with just a single MPA. Low replication (where records of presence were coincident with just two MPAs) was evident for *Petromyzon* *marinus* (sea lamprey) and *Salmo salar* (Atlantic salmon). Both of these species are, again, highly mobile and anadromous and were represented by only a very small number of records within the databases queried for this project.

There were no records available for *Alosa fallax* (twaite shad) or *Lampetra fluviatilis* (river lamprey) within the NI 12 NM. Although the status of twaite shad in NI freshwaters is currently unknown (see for example DoE NI, 2006), *L. fluviatilis* is native to NI (e.g. Goodwin *et al*., 2009). Both species are anadromous and it would be reasonable to suggest that they would make use of use the NI 12 NM zone at some point during their life history, suggesting that, certainly as regards *L. fluviatilis*, the absence of available records does not necessarily equate to a true record of absence.

Most of the other Annex 2 species appeared to be well replicated within the NI MPA network (again see Table 3.5). However, of these, four species - *Halichoerus grypus* (grey seal), *Phoca vitulina* (harbour seal), *Phocoena phocoena* (harbour porpoise) and *Tursiops truncates* (bottlenose dolphin) - are both charismatic and highly mobile. These two factors may lead to a higher than averaging reporting frequency (relative to more sedentary or cryptic species) that will, in turn, increase the apparent level of replication across the network for these species.

Table 3.5 Level of (replicated) protection by MPAs for Habitats Directive Annex 2 species

Species	Are records available indicating presence within the NI 12 NM?	Number of NI 12 NM MPAs with feature present	Number of AoI MPAs with feature present
Alosa alosa	Yes	0	0
Halichoerus grypus	Yes	10	19
Petromyzon marinus	Yes	1	2
Phoca vitulina	Yes	10	12
Phocoena phocoena	Yes	11	80
Salmo salar	Yes	1	2
Tursiops truncatus	Yes	8	51
Alosa fallax	No	0	0
Lampetra fluviatilis	No	0	1

NB intersection set to 10% overlap between feature grid squares and MPAs

The available data collated for this project lacked coverage of intertidal features. It was not possible to undertake an independent assessment of the degree of replication afforded to protected intertidal features within the existing MPA network using the EUSeaMap layers. As a way of addressing the shortcoming, the following data on Habitats Directive Annex 1 feature protection and replication (Table 3.6, below) have been sourced from JNCC and indicate the value of, *inter alia*, protection of intertidal features in SACs within NI. This table compares Northern Irish recorded coastal habitat features with records from the UK as a whole. Many coastal habitats, such as the dunes communities, were not covered by this project but are included here for completeness. Poor replication within Northern Ireland of some of these habitats may be due to either a lack of designation or to the fact that these features (e.g. coastal lagoons and submarine structures made by gas seeps) are not found within Northern Irish waters.

The analysis of the amount of intertidal shoreline projected was estimated by measuring the length of shoreline covered by intertidal designations, e.g. SPAs. The distribution of designations that provide intertidal protection within NI is shown in Figure 3.29. The total length of the coastline was extracted from a standard shoreline layer and equalled 609 km. The approximate length of shoreline covered by some form of intertidal designation is 353 km, suggesting 58% of the shoreline of Northern Ireland receives some form of protection.

Table 3.6 Annex 1 habitats (Habitats Directive) protected within the NI SAC network (data from JNCC – see text)

Annex 1 habitats	Units within the NI SAC network	Total units within the full UK SAC network
Annual vegetation of drift lines	3	4
Atlantic decalcified fixed dunes (*Calluno-Ulicetea*)	1	4
Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)	4	15
Coastal lagoons	1	4
Estuaries	1	10
Large shallow inlets and bays	2	7
Mudflats and sandflats not covered by seawater at low tide	3	17
Reefs	4	20
Salicornia and other annuals colonizing mud and sand	1	7
Sandbanks which are slightly covered by sea water all the time	6	16
Spartina swards (*Spartinion maritimae*)	1	6
Submarine structures made by leaking gases	0	1
Submerged or partially submerged sea caves	1	5
Vegetated sea cliffs of the Atlantic and Baltic Coasts	2	4
Fixed coastal dunes with herbaceous vegetation ("grey dunes")	4	9
Shifting dunes along the shoreline with *Ammophila arenaria* ("white dunes")	3	7
Dunes with *Hippopha rhamnoides*	2	3
Dunes with *Salix repens* ssp. *argentea* (*Salicion arenariae*)	0	2

Data available from JNCC at: http://jncc.defra.gov.uk/page-1461

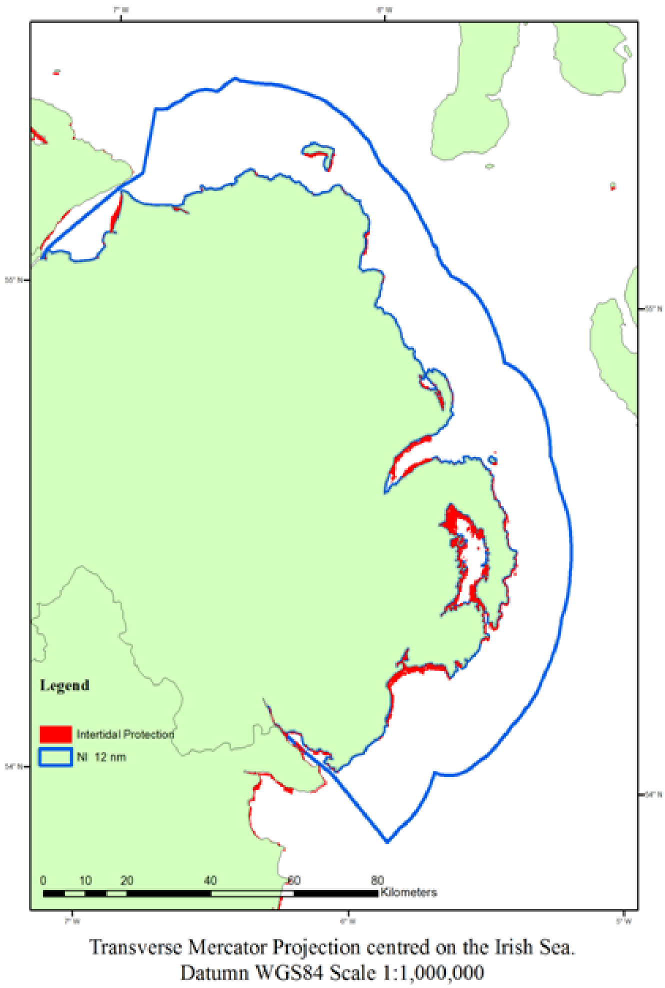


Figure 3.29 Provision of protection to intertidal shoreline

Of the OSPAR threatened and declining species and habitats (Table 3.7), three species - *Alosa alosa, Dipturus batis* (common skate) and *Raja montagui* (spotted ray) - have been recorded as being present within the NI 12 NM zone but are not coincident with sites within the MPA network. The absence of these three species is probably a reflection of their record rarity and their high mobility.

Table 3.7 also indicates that there are no *Mytilus edulis* ‘beds’ within sites comprising the NI 12 NM MPA network. Subsequent re-examination of the species grids revealed that 15 grid cells within the NI 12 NM MPA network contained ‘individuals’ of *M. edulis*. This highlights an important distinction; only records of ‘beds’ (i.e. locations where mussels have accumulated to a point where they form a functional habitat) were included within this analysis. It is possible that reporting of ‘beds’ and ‘individuals’ might have been used interchangeably within survey records and care should be taken when interpreting these results.

As discussed above, low replication was evident for both *Petromyzon marinus* and *Salmo salar*.

One habitat (intertidal mudflats/saltmarsh) was poorly replicated (two incidences of protection by MPAs) whilst protection of the remaining species and habitats appears to be reasonably well replicated (i.e. three or more replicates). Replication for maerl was especially high, with grid cells identified as having maerl present intersected with many of the Northern Irish MPAs. Examination of the point and gridded data indicates extensive reporting of this feature throughout the NI 12 NM zone (although no distinction could be been made as to whether the records identified dead or live maerl, or whether they referred to single locations or maerl in bed form). The high replication stemming from the high number of maerl records and presence grid cells is likely to have been boosted by the number of maerl-related studies conducted by local university researchers.

The NI MPA network also seems to be disproportionally important for some species. For example, 5 of the 7 MPA sites with *Anguilla anguilla* (European eel) records are within the NI 12 NM zone. It is possible that this reflects the local importance of Lough Neigh for the (maturing) population of this (catadromous[13]) species. Records for *Squalus acanthias* (spiny dog fish) were also more prevalent in the NI 12 NM MPA sites when compared to MPAs across the wider AoI. This may be an artefact arising from the use of elasmobranch data for this species which included a relatively high proportion of angler records, which could artificially bias the data to the inshore regions.

[13] Catadromous: a life history strategy where individuals migrate to the marine environment to spawn, but (usually) mature and grow in freshwater habitats.

Table 3.7 Level of (replicated) protection by MPAs for OSPAR threatened and declining species and habitats

Species or feature	Are records available indicating presence within the NI 12 NM?	Number of NI 12 NM MPAs with feature present	Number of AoI MPAs with feature present
Alosa alosa	Yes	0	0
Anguilla anguilla	Yes	5	7
Arctica islandica	Yes	13	27
Cetorhinus maximus	Yes	3	5
Dipturus batis	Yes	0	0
Gadus morhua	Yes	8	22
Intertidal mudflats/Saltmarsh	Yes	2	6
Larus fuscus	Yes	5	36
Maerl beds	Yes	17	27
Modiolus modiolus	Yes	10	33
Mytilus edulis beds	Yes	0	5
Nucella lapillus	Yes	16	55
Ostrea edilus	Yes	14	63
Petromyzon marinus	Yes	1	2
Phocoena phocoena	Yes	11	79
Raja clavata	Yes	4	24
Raja montagui	Yes	0	11
Rissa tridactyla	Yes	10	50
Salmo salar	Yes	1	2
Seapen and burrowing megafauna	Yes	3	9
Squalus acanthias	Yes	5	7
Uria aalge	Yes	11	52
Zostera spp.	Yes	11	36
Lamna nasus	No	0	1
Sabellaria alveolata	No	0	5
Squatine squatina	No	0	2
Sterna dougallii	No	0	2

NB intersection set to 10% overlap between feature grid squares and MPAs

Finally, for species covered by the Birds Directive that were identified as having records falling within NI inshore waters (Table 3.8) there were typically good levels of replication. However, five species (*Anas crecca*, common teal; *Gavia arctica*, black-throated loon; *Haematopus ostralegus*, pied oystercatcher; *Melanitta nigra*, common scoter; and *Oceanodroma leucorhoa*, Leach's storm-petrel) have records for the Northern Irish 12 NM zone but are not represented within the NI 12 NM MPA network. Single occurrences or minimal replication was suggested for four additional species (*Bucephala clangula*, common goldeneye; *Hydrobates pelagicus*, European storm petrel; *Sterna hirundo*, common tern; and *Sterna paradisaea*, Arctic tern). The observed deficiencies in replication may be related to the mobility and seasonality of many of these species. The absence of ornithological records for the sea loughs (except Belfast Lough) may also have biased the analysis and artificially reduced replication for many species.

Table 3.8 Level of (replicated) protection by MPAs for species listed in the Birds Directive

Species	Are records available indicating presence within the NI 12 NM?	Number of NI 12 NM MPAs with feature present	Number of AoI MPAs with feature present
Alca torda	Yes	8	39
Anas crecca	Yes	0	0
Bucephala clangula	Yes	1	1
Fratercula arctica	Yes	4	19
Fulmarus glacialis	Yes	7	37
Gavia arctica	Yes	0	2
Haematopus ostralegus	Yes	0	3
Hydrobates pelagicus	Yes	1	6
Larus argentatus	Yes	10	52
Larus canus	Yes	3	39
Larus fuscus	Yes	5	36
Larus marinus	Yes	7	39
Larus ridibundus	Yes	3	31
Melanitta nigra	Yes	0	18
Oceanodroma leucorhoa	Yes	0	2
Phalacrocora aristotelis	Yes	6	34
Phalacrocorax carbo	Yes	4	31
Puffinus puffinus	Yes	7	29
Rissa tridactyla	Yes	10	50
Somateria mollissima	Yes	4	12
Stercorarius parasiticus	Yes	3	13
Sterna hirundo	Yes	2	19
Sterna paradisaea	Yes	1	8
Sterna sandvicensis	Yes	5	18
Uria aalge	Yes	11	52

Table 3.8 Level of (replicated) protection by MPAs for species listed in the Birds Directive (continued)

Species	Are records available indicating presence within the NI 12 NM?	Number of NI 12 NM MPAs with feature present	Number of AoI MPAs with feature present
Anas acuta	No	0	0
Anas penelope	No	0	2
Anas strepera	No	0	0
Arenaria interpres	No	1	1
Branta bernicla	No	0	0
Calidris alpina	No	0	1
Calidris canutus	No	0	1
Charadrius hiaticula	No	0	0
Clangula hyemalis	No	0	1
Larus melanocephalus	No	0	0
Limosa lapponica	No	0	0
Limosa limosa	No	0	0
Melanitta fusca	No	0	1
Mergus serrator	No	0	2
Numenius arquata	No	0	1
Numenius phaeopus	No	0	0
Phalaropus lobatus	No	0	0
Pluvialis apricaria	No	0	0
Podiceps auritus	No	0	0
Podiceps cristatus	No	0	2
Sterna albifrons	No	0	1
Sterna dougallii	No	0	2
Tadorna tadorna	No	0	1
Tringa totanus	No	0	0
Vanellus vanellus	No	0	0

NB intersection set to 10% overlap between feature grid squares and MPAs

3.5.5 CONNECTIVITY

The locations of the centroids that were used for the MPA network connectivity assessments are shown as Figure 3.30.

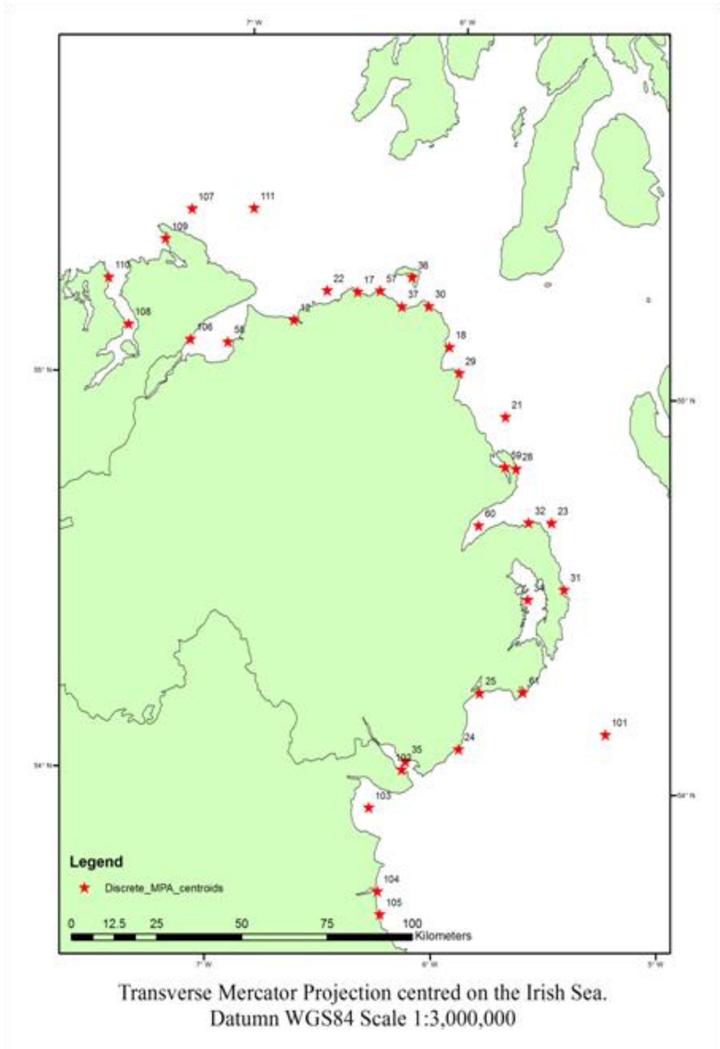


Figure 3.30 Centroid locations for MPAs within NI 12 NM or associated 50 km buffer

The results from the 'marine path' inter-MPA distance analyses are presented below as frequency histograms showing the distribution of minimum and mean distances (Figure 3.31 and Figure 3.32 respectively) between each of the MPAs within the NI 12 NM limit and those MPAs included within the 50 km buffer that was applied (i.e. ten additional MPAs from RoI territorial waters plus one offshore site, Pisces Reef).

The 'straight line' connectivity assessments undertaken for bird species were based on SPA locations. The results from these analyses are presented in Table 3.9.

The third session of connectivity analysis, which considered inter-MPA distances between the calculated centroids of the same habitat feature, is presented in Table 3.10.

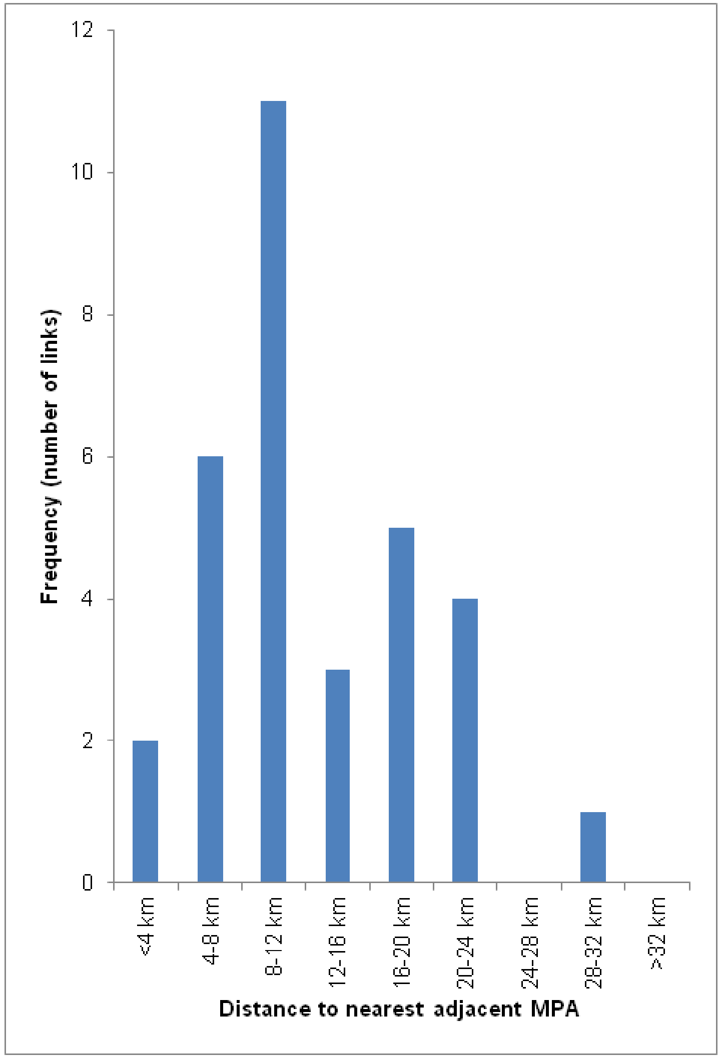


Figure 3.31 Distribution of shortest distance connections (marine route) for each MPA within the NI 12 NM limit

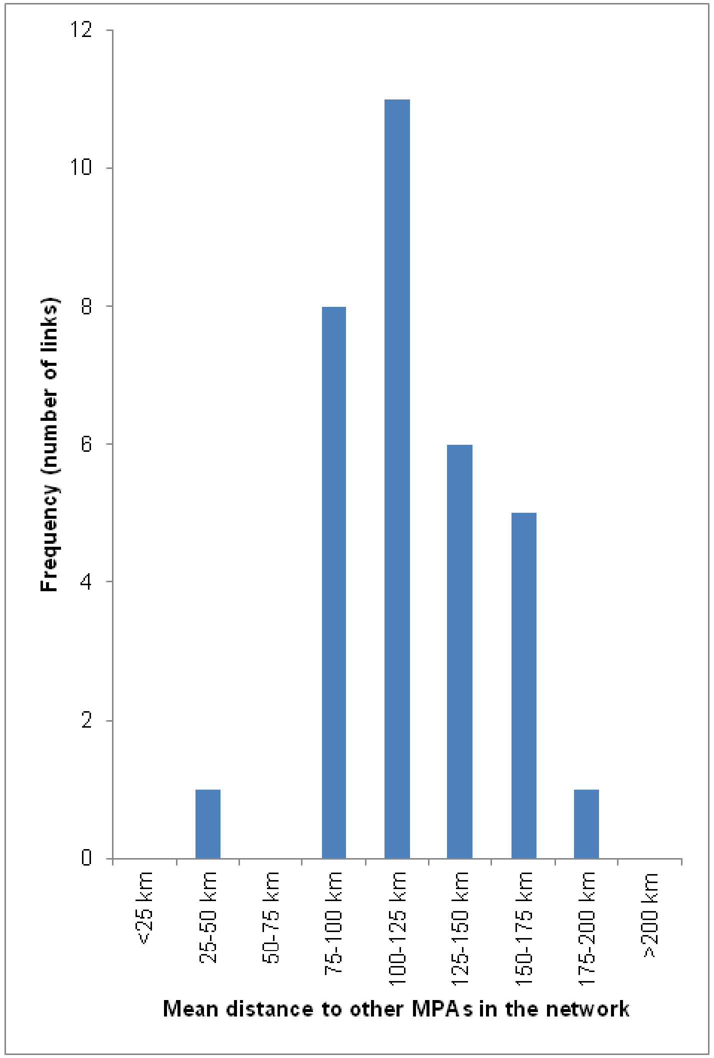


Figure 3.32 Distribution of the mean of all possible connections (marine route), as calculated separately for each MPA within the NI 12 NM limit

Table 3.9 Straight line (overland) connectivity for Northern Irish SPAs.

MPA identification code and name		Connection lengths (km): Shortest	Mean	Longest
12	Bann Estuary	12.8	77.6	169.6
17	North Antrim Coast	6.6	76.3	175.7
18	Red Bay	7.9	72.1	161.3
21	The Maidens	14.2	72.4	145.1
22	Skerries & Causeway	8.9	78.0	176.7
23	Copeland Islands	6.7	77.2	147.3
24	Samuel's Port	15.9	95.2	171.4
25	Murlough	12.8	86.7	160.6
28	The Gobbins	3.3	71.7	131.9
29	Galboly	7.9	70.7	154.4
30	Fair Head and Murlough Bay	7.9	75.3	172.2
31	Outer Ards	11.1	83.2	160.1
32	Ballymacormick Point	6.7	73.9	141.4
34	Strangford Lough	11.1	79.0	153.0
35	Carlingford Lough (N)	2.5	97.0	168.1
36	Rathlin Island	8.8	78.9	180.0
37	Castle Point	7.8	74.1	171.6
57	Sheep Island	6.6	76.0	175.9
58	Lough Foyle (E)	11.0	84.5	167.6
59	Larne Lough	3.3	70.4	131.4
60	Belfast Lough	14.7	69.8	129.2
61	Killough	12.8	90.0	168.9
101	Pisces	27.0	109.0	194.7
102	Carlingford Lough (S)	2.5	98.6	169.8
103	Dundalk Bay	14.4	107.9	176.8
104	Boyne Coast and Estuary	6.6	126.8	200.1
105	River Nanny Estuary and Shore	6.6	132.7	206.6
106	Lough Foyle (W)	11.0	91.1	171.6
107	Inishtrahull	11.4	106.1	206.6
108	Lough Swilly	7.8	100.8	194.3
109	North Inishiwen Head	6.6	105.6	200.8
110	Ballyhoorisky Point to Fanad Head	19.9	113.2	196.6
111	Hemptons Turbot Bank	18.2	98.2	202.6

Table 3.10 Distance between MPAs containing the same habitat type (MPAs within the NI 12 NM limit)

Feature	No of MPAs containing feature	Number of connections	Minimum distance (km)	Mean distance (km)	Maximum distance (km)
A5.4: Sublittoral mixed sediments	10	45	4.3	53.9	125.6
A3.2: Atlantic and Mediterranean moderate energy infralittoral rock	2	1	29.8	29.8	29.8
A3.3: Atlantic and Mediterranean low energy infralittoral rock	0	0	0.0	0.0	0.0
A4.2: Atlantic and Mediterranean moderate energy circalittoral rock	2	1	31.7	31.7	31.7
A4.3: Atlantic and Mediterranean low energy circalittoral rock	0	0	0.0	0.0	0.0
A5.1: Sublittoral coarse sediment	11	55	5.7	115.1	247.6
A5.2: Sublittoral sand	10	45	5.6	137.8	335.3
A5.3: Sublittoral mud	12	66	14.7	67.2	115.8
A6.5: Deep-sea mud	1	0	0.0	0.0	0.0
Deep circalittoral seabed	5	10	4.8	135.1	265.0
High energy circalittoral seabed	7	21	6.1	134.3	274.6
High energy infralittoral seabed	7	21	10.5	165.3	343.9
Low energy circalittoral seabed	3	3	11.8	181.8	260.7
Low energy infralittoral seabed	10	45	12.8	157.8	269.0
Moderate energy circalittoral seabed	8	28	5.9	136.7	342.5
Moderate energy infralittoral seabed	9	36	4.8	143.3	350.5

3.5.6 ADEQUACY

Table 3.11 provides an assessment of the adequacy of coverage of the principal biological zones across NI territorial waters.

Table 3.11 Composition of (subtidal) Northern Irish territorial waters and MPA network by biological zone

Biological zone	Defined limits		Area within the NI 12 NM limit (km^2)	Area within NI MPA network (km^2)	Proportion covered by NI MPA network
	Upper	Lower			
Infralittoral	0 m	1% ambient light reaches the seabed	1,025	239	23.3%
Circalittoral	1% ambient light reaches the seabed	Wave base	964	90	9.9%
Deep circalittoral	Wave base	200 m	2,302	114	5.0%
Upper slope	200 m	750 m	47	5	10.3%

Table 3.12 (below) provides a summary of the adequacy of the NI MPA network in terms of different wave and tidal energy zones.

Table 3.12 Composition of (subtidal) Northern Irish territorial waters and MPA network by wave and tidal energy zones

Energy zone	Area within the NI 12 NM limit (km^2)	Area within NI MPA network (km^2)	Proportion covered by NI MPA network
Low energy	1,398.6	145.2	10.4%
Moderate energy	2,793.5	270.4	9.7%
High energy	146.3	33.2	22.7%

The adequacy of the NI MPA network in terms of its coverage of water column stratification structures is presented below (Table 3.13).

Table 3.13 Composition of (subtidal) Northern Irish territorial waters and MPA network by water column stratification

Season	Water column structure	Area within the NI 12 NM limit (km^2)	Area within NI MPA network (km^2)	Proportion covered by NI MPA network
Spring	Weakly-stratified ROFI*	1268.5	154.5	12.2%
	Well-mixed ROFI	1764.6	262.3	14.9%
	Well-mixed shelf water	1560.7	164.5	10.5%
Summer	Frontal ROFI	410.7	58.7	14.3%
	Stratified ROFI	928.6	19.7	2.1%
	Weakly-stratified ROFI	1453.2	310.0	21.3%
	Well-mixed ROFI	149.3	27.4	18.4%
	Well-mixed shelf water	1652.0	165.6	10.0%
Autumn	Well-mixed ROFI	1799.1	253.2	14.1%
	Well-mixed shelf water	2794.7	328.0	11.7%
Winter	Weakly-stratified ROFI	247.6	0.0	0.0%
	Well-mixed ROFI	1799.1	292.6	16.3%
	Well-mixed shelf water	2547.1	288.7	11.3%

* ROFI = Region of freshwater influence

The adequacy of the NI MPA network in terms of different seabed habitat types (both as general substrata and as EUNIS Level 4 habitats). Note that, for the EUNIS habitats, separate assessments were undertaken for the dominant habitat types and the sub-dominant habitat types (those making up more than, or less than, 5% of the overall cover within the NI 12 NM zone). This was to allow for better discrimination of the relative proportions of cover within the 12 NM zone and within the MPA network (Table 3.14 to Table 3.16).

Table 3.14 Area of seabed substrata within Northern Irish waters (12 NM limit) and proportion within the existing MPA network

Seabed substrata	Area within the NI 12 NM limit (km^2)	Area within NI MPA network (km^2)	Proportion covered by NI MPA network
Coarse or mixed sediments	1604.9	88.0	5.5%
Muds	491.9	86.3	17.5%
Rock or biogenic reef	363.1	72.7	20.0%
Sands	1690.7	171.8	10.2%
Other *	187.7	30.0	16.0%

* ‘Other’ refers to habitats lacking the initial EUNIS Codes; these are areas that, when modelled by the EUSeaMap project, failed to fit within the existing classification, with new categories being generated for their reporting. These newly classified areas are typically small when compared to the area successfully classified with EUNIS level 4 codes

Table 3.15 Area of major (EUNIS Level 4) habitat types within Northern Irish waters (12 NM limit) showing the proportion within the existing MPA network

Habitat (EUNIS level 4)	Area within the NI 12 NM limit (km^2)	Area within NI MPA network (km^2)	Proportion covered by NI MPA network
A3.31: Silted kelp on low energy infralittoral rock with full salinity	40.2	20.5	51.0%
A4.27: Faunal communities on deep moderate energy circalittoral rock	257.7	51.2	19.9%
A5.13: Infralittoral coarse sediment	123.5	13.0	10.5%
A5.14: Circalittoral coarse sediment	316.3	10.1	3.2%
A5.15: Deep circalittoral coarse sediment	730.8	8.7	1.2%
A5.23: Infralittoral fine sand & A5.24: Infralittoral muddy sand	330.6	78.7	23.8%
A5.25: Circalittoral fine sand & A5.26: Circalittoral muddy sand	355.9	38.9	10.9%
A5.27: Deep circalittoral sand	956.8	49.4	5.2%
A5.33: Infralittoral sandy mud & A5.34: Infralittoral fine mud	98.8	76.0	76.9%
A5.35: Circalittoral sandy mud & A5.36: Circalittoral fine mud	127.7	9.7	7.6%
A5.37: Deep circalittoral mud	265.5	0.5	0.2%
A5.43: Infralittoral mixed sediments	291.1	50.5	17.3%
A5.44: Circalittoral mixed sediments	68.0	5.6	8.2%
A5.45: Deep circalittoral mixed sediments	75.3	0.1	0.1%
Deep circalittoral seabed	15.5	4.4	28.1%
High energy circalittoral seabed	5.6	4.1	73.2%
High energy infralittoral seabed	10.9	2.3	20.6%
Low energy circalittoral seabed	20.3	4.6	22.7%
Low energy infralittoral seabed	42.6	2.1	5.0%
Moderate energy circalittoral seabed	21.9	5.5	25.0%
Moderate energy infralittoral seabed	70.9	7.1	10.1%

NB EUNIS categories A4.12, A4.31 and A4.33 each covered less than c.1 km^2 in total within the full extent of the 12 NM zone and are reported separately (see Table 3.16 below)

Table 3.16 Area of uncommon (EUNIS) habitat types within Northern Irish waters (12 NM limit) showing the proportion within the existing MPA network

Habitat (EUNIS level 4)	Area within the NI 12 NM limit (km^2)	Area within NI MPA network (km^2)	Proportion covered by NI MPA network
A4.12: Rock and Biogenic reef*	0.3826	0.0000	0.0%
A4.31: Brachiopod and ascidian communities on circalittoral rock	1.0300	0.1309	12.7%
A4.33: Faunal communities on deep low energy circalittoral rock	0.1311	0.0655	49.9%

* Note that rock and reef is also contained in other habitat codes such as A3.31 (silted kelp on low energy infralittoral rock with full salinity), A4.27 (faunal communities on deep moderate energy circalittoral rock) and other generic codes.

The level of protection afforded each broad group of features (sessile species, mobile (aquatic) species, habitats and biotopes, and bird species) was estimated for features and MPAs within the AoI and within the NI 12 NM limit (see Table 3.17).

Table 3.17 Occurrence of habitats and species across the Area of Interest (AoI), AoI MPA network, Northern Irish waters (12 NM limit) and the Northern Irish MPA network

Subset of features data	Total number of features on the composite feature list	Number of features with a presence in the AoI	Number of features present in at least one cell intersected by MPAs within the AoI	Number of features with a presence in the NI 12 NM limit	Number of features present in at least one cell intersected by MPAs within the NI 12 NM MPA network
Sessile species	78	71	68 (95.8%)	62	62 (100%)
Mobile species	39	38	35 (92.1%)	30	26 (86.7%)
Habitats and biotopes	50	49	48 (98.0%)	31	31 (100%)
Bird species	54	48	43 (89.6%)	31	25 (80.6%)

Table 3.17 shows, for example, that 71 of the 78 sessile species from the combined features list are present to some extent within the AoI. Of these 71, 68 (or 96%) have at least some degree of protection, i.e. the recorded distributions for 68 of the sessile species demonstrate at least one occurrence of an overlap with an MPA (i.e. at least 2.5% of a 5 km grid cell, within which the species has been recorded as being present, is spatially coincident with an MPA).

The relative levels of protection afforded by the MPA network (both within the NI 12 NM limit and the AoI) to each of the four broad groupings of habitats and species (i.e. the percentage of those cells where presence is recorded that are afforded some degree of protection by an MPA designation) is summarised below in Figure 3.33 to Figure 3.40.

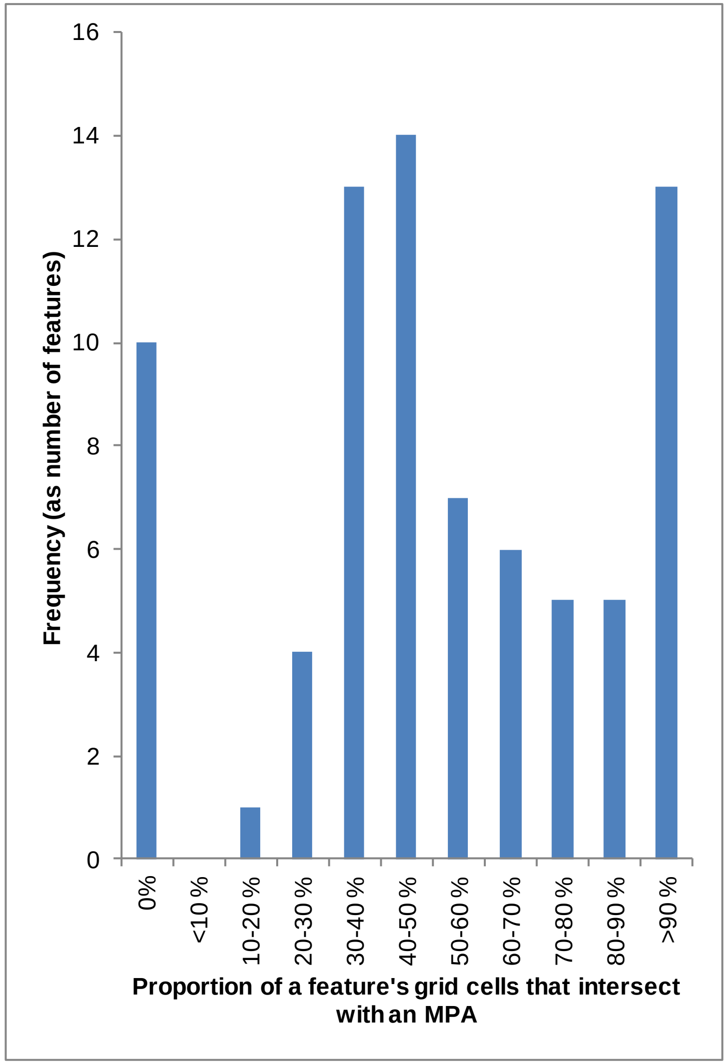


Figure 3.33 Extent of protection afforded to sessile species by MPAs within the AoI

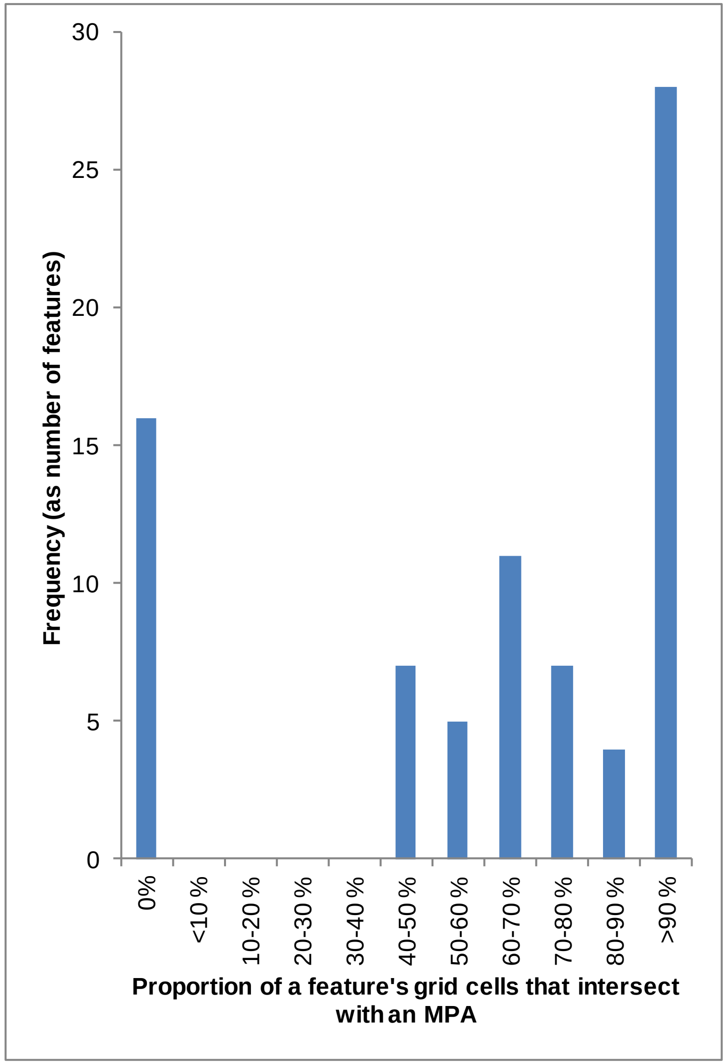


Figure 3.34 Extent of protection afforded to sessile species by MPAs within the NI 12 NM limit

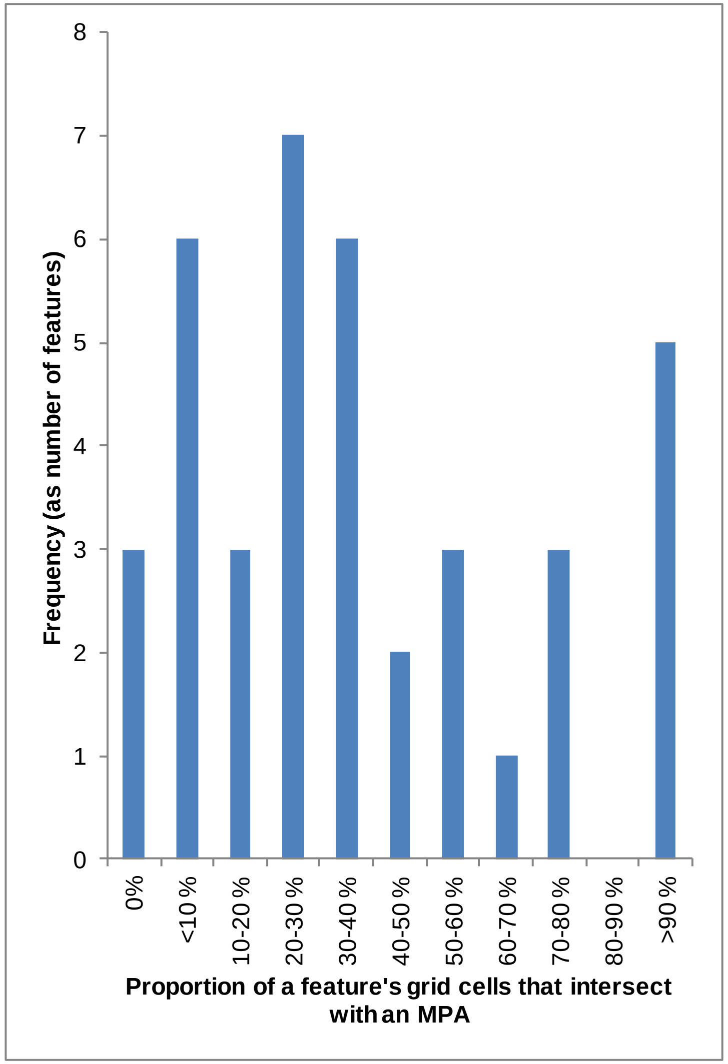


Figure 3.35 Extent of protection afforded to mobile species by MPAs within the AoI

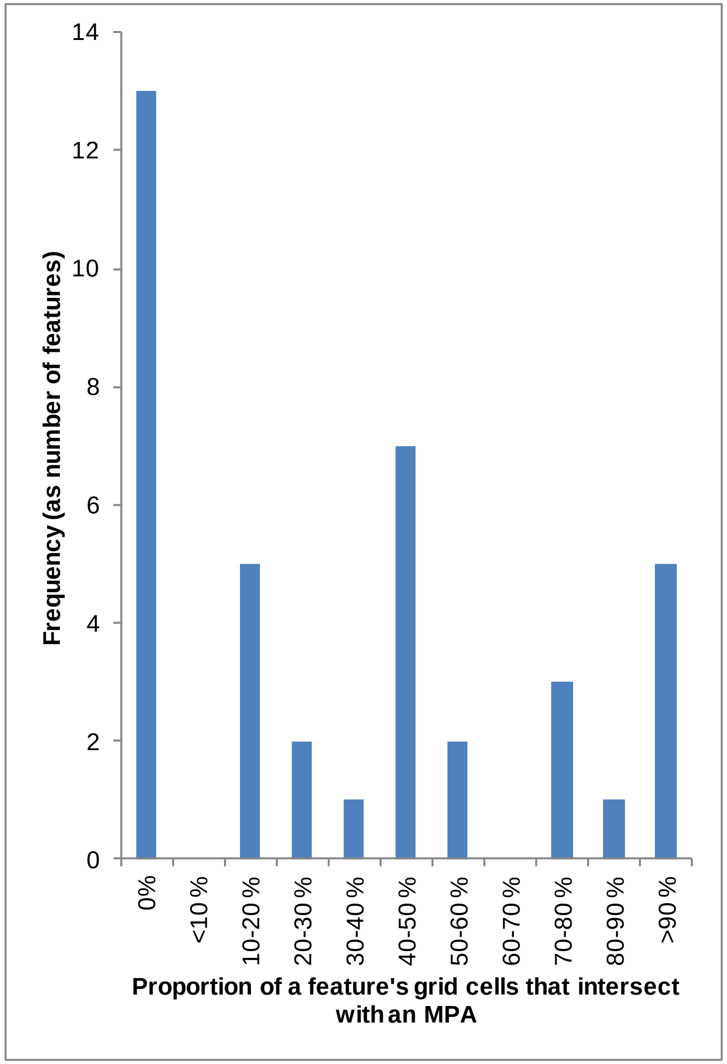


Figure 3.36 Extent of protection afforded to mobile species by MPAs within the NI 12 NM limit

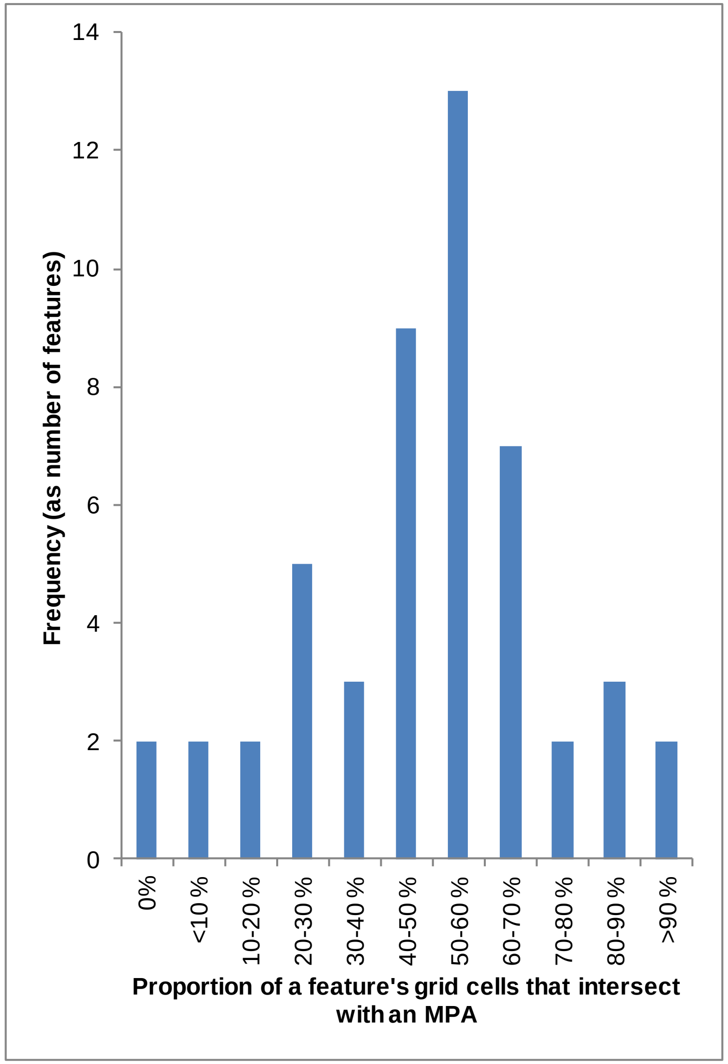


Figure 3.37 Extent of protection afforded to habitats by MPAs within the AoI

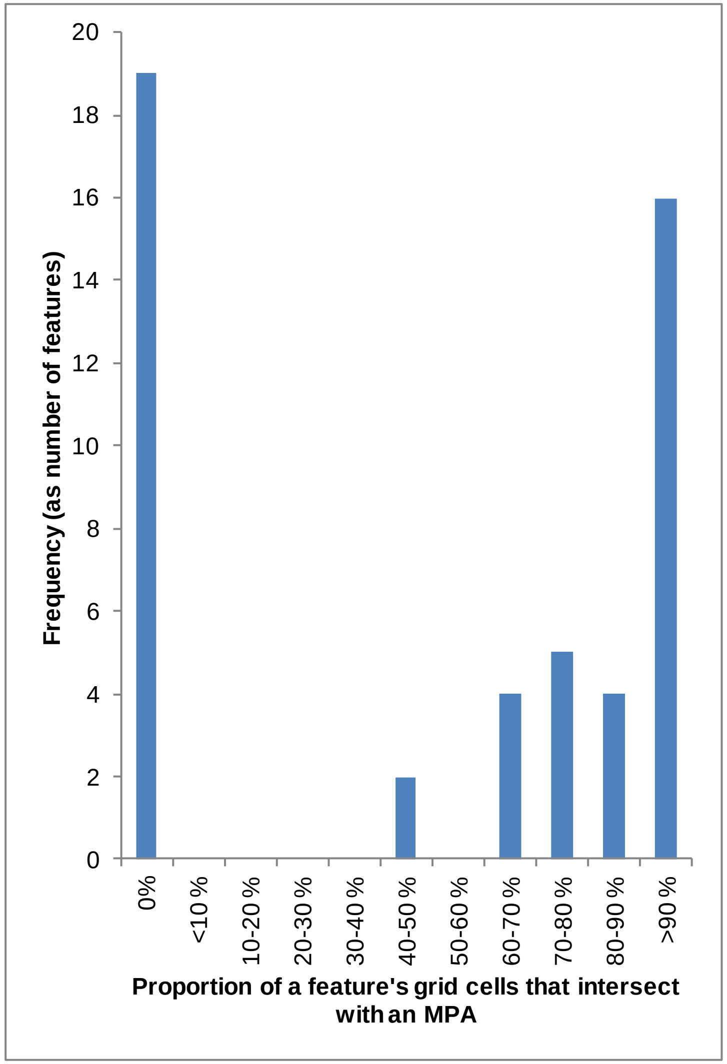


Figure 3.38 Extent of protection afforded to habitats by MPAs within the NI 12 NM limit

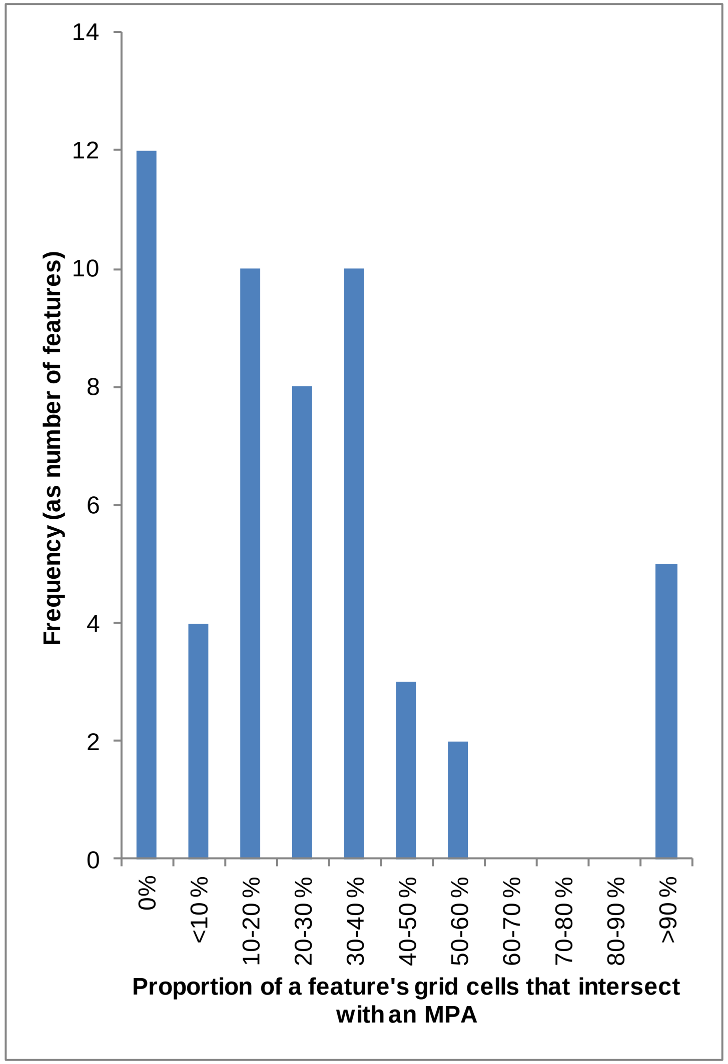


Figure 3.39 Extent of protection afforded to birds by MPAs within the AoI

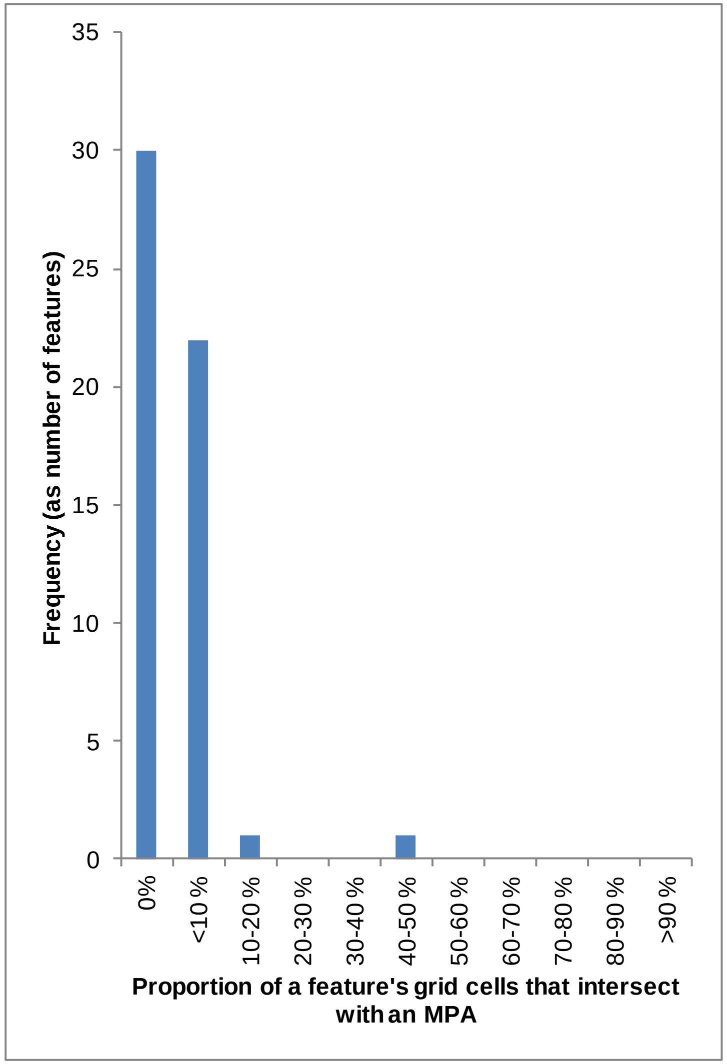


Figure 3.40 Extent of protection afforded to birds by MPAs within the NI 12 NM limit

The adequacy analysis also examined the proportion of species/feature presence cells contained within the Northern Irish MPA network. The objective was to understand what proportion of the 5 km grid cells that are identified as containing one or more records for species and habitats on the core designation list[14] overlap with the MPA network, and what additional overlap might be obtained by increasing the MPA footprints.

Of the 55 species and habitats on the core designation list, the data records collated by the project identify 44 that have a recorded presence within the NI 12 NM limit. Of these, 43 species or features have at least one grid cell of their overall distribution overlapping with an existing MPA within the NI 12 NM limit (assuming a *de minimus* intersection threshold of 2.5%).

3.5.7 VIABILITY

The following tables provide an overview of the physical makeup of constituent elements of the NI MPA network (sizes and degree of compactness), placing them in context with MPAs in adjoining waters (Table 3.18 and Table 3.19).

The average area of SACs in NI is significantly smaller than those found in France and Denmark (the only other two EU countries for which SAC data are available from www.mpaglobal.org), (see Table 3.20). Also, of the European SPA designations summarised in Table 3.21, only the Republic of Ireland and Italy have smaller mean SPA areas than those designated in NI.

However, care must be taken when comparing the sizes of NI MPA designations (which are effectively just constituent elements of a wider UK network) to size summary statistics for entire networks from other countries. There is no suggestion that the sizes of MPAs in NI are so small as to give rise to concern.

[14] The core designation list is defined here as the composite list that combines the Northern Ireland priority species list, Habitats Directive annex 1 and 2 species and habitats, OSPAR threatened and declining species and habitats, and the Birds Directive species list, corrected for occurrence within the project's AoI.

Table 3.18 Viability statistics for SACs by region

Region [1]	Count	Minimum area km^2	Mean area km^2	Regional mean area as a percentage of overall mean [2]	Maximum area km^2	Mean compactness
Northern Ireland	8	3.15	63.26	35%	153.89	0.36
England	33	0.36	208.38	116%	1077.59	0.27
Scotland	10	0.44	114.16	63%	1513.42	0.36
Wales	1	0.43	492.23	274%	1460.23	0.31
Republic of Ireland	41	0.00	20.36	11%	272.67	0.35
Isle of Man [3]	1	-	93.50	52%	-	0.75

[1] Marine areas of less than 1 km^2 were excluded from the analysis; SACs lying across nominal inter-regional boundaries were allocated to one or other of the relevant regions
[2] Overall mean size within the AoI is 179.7 km^2
[3] Isle of Man presented one site composed of five joined sub-components

Table 3.19 Viability statistics for SPAs by region

Region [1]	Count	Minimum area km^2	Mean area km^2	Regional mean area as a percentage of overall mean [2]	Maximum area km^2	Mean compactness
Northern Ireland	10	1.03	26.76	29%	139.70	0.24
England	6	19.51	103.03	111%	316.83	0.24
Scotland	20	1.27	28.28	31%	380.41	0.28
Wales	6	1.63	288.3	311%	1691.22	0.33
Republic of Ireland	31	0.11	17.1	19%	132.41	0.47
Isle of Man [3]	0	-	-	-	-	-

[1] Marine areas of less than 1 km^2 were excluded from the analysis; SPAs lying across nominal inter-regional boundaries were allocated to one or other of the relevant regions
[2] Overall mean size within the AoI is 92.82 km^2
[3] Isle of Man presented no SPAs

Table 3.20 Number, minimum, mean and maximum areas of Special Area of Conservation designations in Denmark and France

Country/Region	Number of SACs	Smallest SAC area (km^2)	Average SAC area (km^2)	Largest SAC area (km^2)
Denmark	73	1.40	118.26	1347.00
France	57	3.41	104.93	1556.00

Source: Wood, L. J. (2007). MPA Global: A database of the world's marine protected areas. Sea Around Us Project, UNEP-WCMC & WWF. www.mpaglobal.org

Table 3.21 Special Protection Area (Birds Directive) designations in Europe

Country/Region	Number of SPAs	Smallest SPA area (km^2)	Average SPA area (km^2)	Largest SPA area (km^2)
Denmark	24	3.74	301.93	1505.00
Finland	8	5.08	91.37	225.70
France	5	20.00	378.00	850.00
Germany	7	6.75	983.84	4550.00
Greece	7	63.02	187.21	336.90
Ireland	22	0.92	15.26	119.10
Italy	19	2.23	18.20	135.00
Netherlands	11	0.23	510.32	2500.00
Norway	20	0.98	41.92	484.00
Portugal	6	14.54	104.13	255.90
UK Channel Islands	1	32.10	32.10	32.10

Source: Wood, L. J. (2007). MPA Global: A database of the world's marine protected areas. Sea Around Us Project, UNEP-WCMC & WWF. www.mpaglobal.org

The mean compactness values for NI MPAs (both SACs and SPAs) suggest that the compactness of NI MPAs does not significantly differ to that seen across England, Scotland, Wales or RoI. In this context, it is not likely that the conformation of sites within the NI MPA network would give rise to any additional edge effects over and above that seen for MPAs in adjoining waters.

The mean size of NI SACs compares favourably with the lower bound of the average range recommended by JNCC (NE & JNCC, 2011).

3.5.8 NATURALNESS

As noted earlier, IECS discussed the assessment of naturalness with NI MTF at the beginning of the project and it was concluded that, due to data deficiencies and the effort required to undertake a rigorous analysis of this nature, it effectively lay outside of the scope of the project. Consequently, no assessment of the contribution of naturalness to network coherence was undertaken.

3.6 Results: Network gap analysis

3.6.1 INTRODUCTION

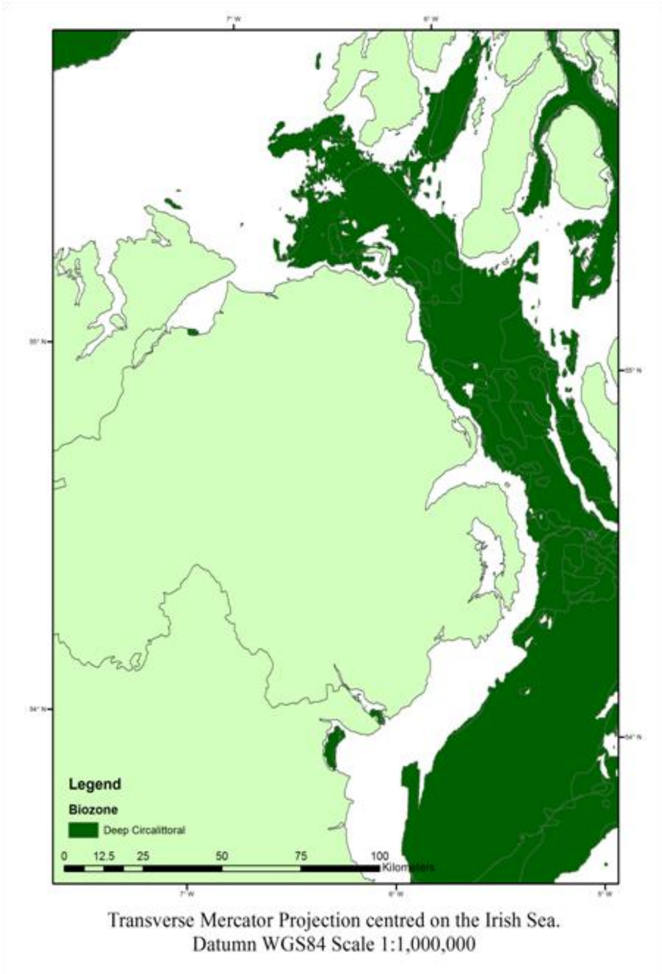
Section 3.5 of this report has provided assessments of the main factors that underpin network design (representativity, replication, connectivity, adequacy, viability and naturalness). As discussed by Ardron (2008) compliance with these network design principles can be used to describe the ecological coherence of an MPA network. However although these different aspects of network design can be seen to contribute to overall network coherence, and can each be presented semi-quantitatively, there is no single derived metric that describes coherence. As regards the identification of gaps in the network it is therefore necessary again to consider these separate network design principles.

It may be feasible to identify where there are gaps in the current network of MPAs for each individual species or habitat under consideration, and then to indicate where additional sites may be required by integrating this spatial information. However the extensive features list that has been used in this study precludes this detailed approach and prohibits any straightforward assessment of where the current network of MPAs fails to protect individual features. Despite this, there is merit in attempting to identify those areas of the marine environment that are less well covered by the existing network.

3.6.2 OUTPUTS

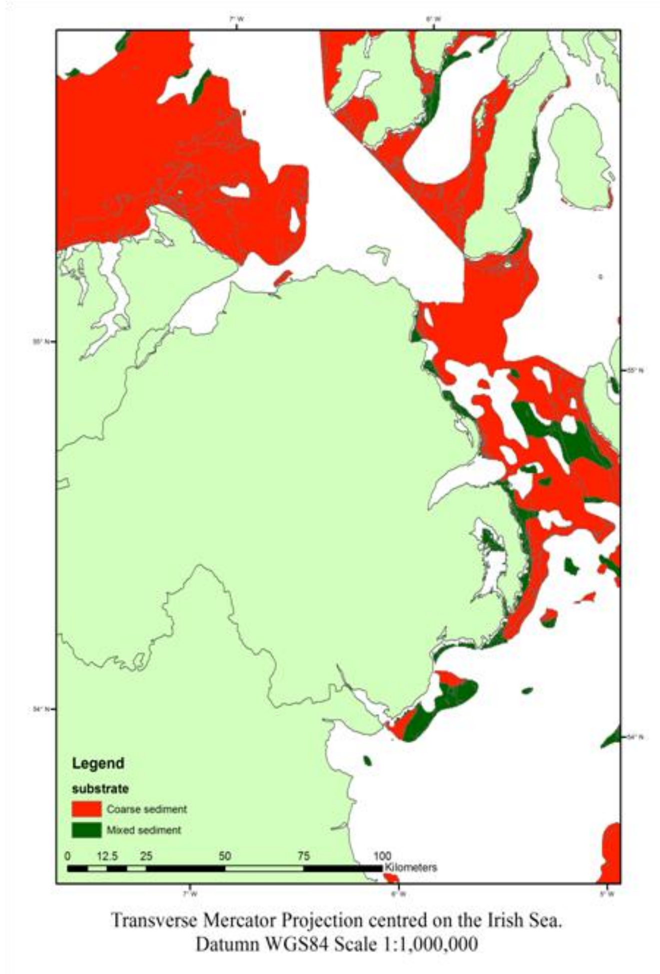
REPRESENTATIVITY & ADEQUACY

The raster outputs for the three composite 'representativity' factors that were considered are shown below (Figure 3.41 to Figure 3.43); the four composite 'adequacy' groups are shown as Figure 3.44 to Figure 3.47.



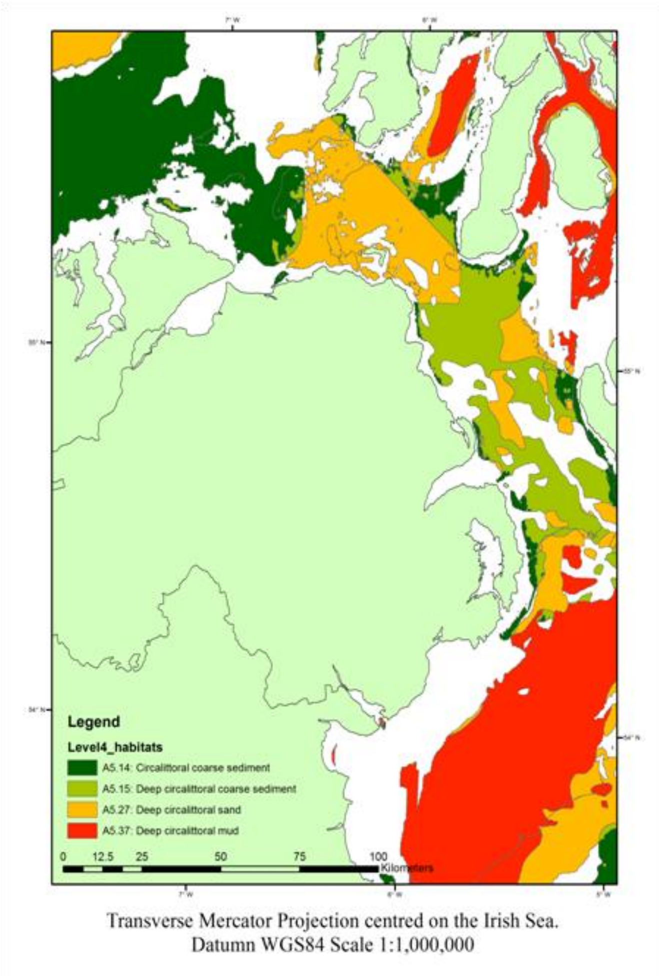
Data acknowledgement: Cameron & Askew (2011)

Figure 3.41 Under-represented EUSeaMap predicted 'biological zones' within NI Territorial waters



Data acknowledgement: Cameron & Askew (2011)

Figure 3.42 Under-represented EUSeaMap substrata within NI Territorial waters



Data acknowledgement: Cameron & Askew (2011)

Figure 3.43 Under-represented EUNIS Level 4 habitats within NI Territorial waters

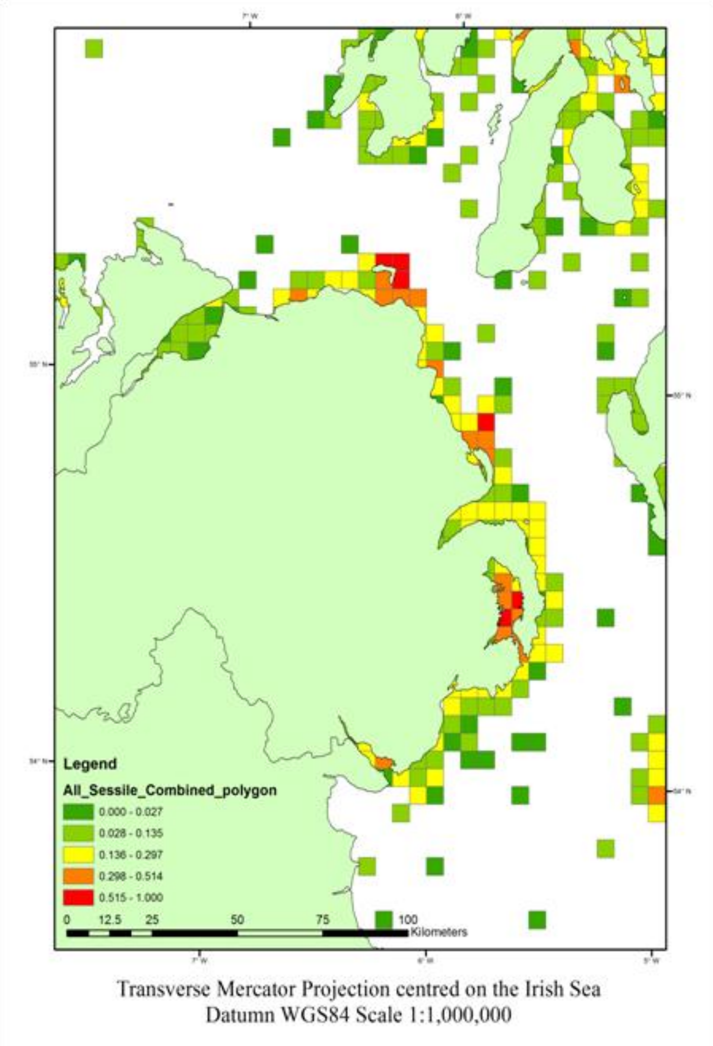


Figure 3.44 Gap analysis intermediate outputs: combined gap scores for sessile species

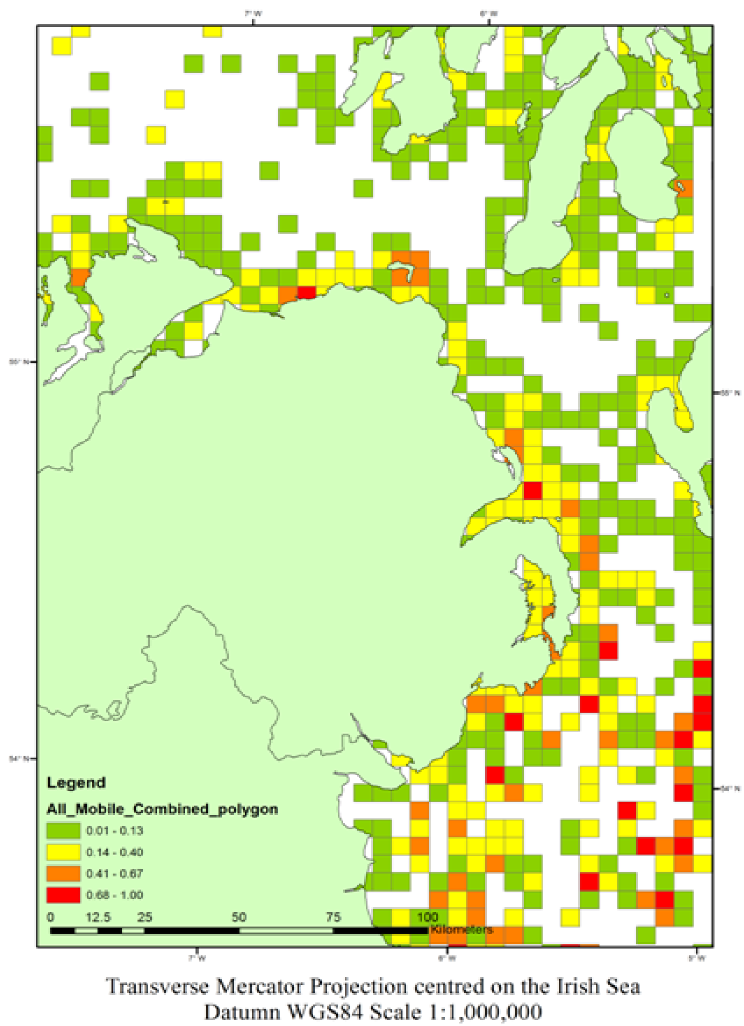


Figure 3.45 Gap analysis intermediate outputs: combined gap scores for mobile species

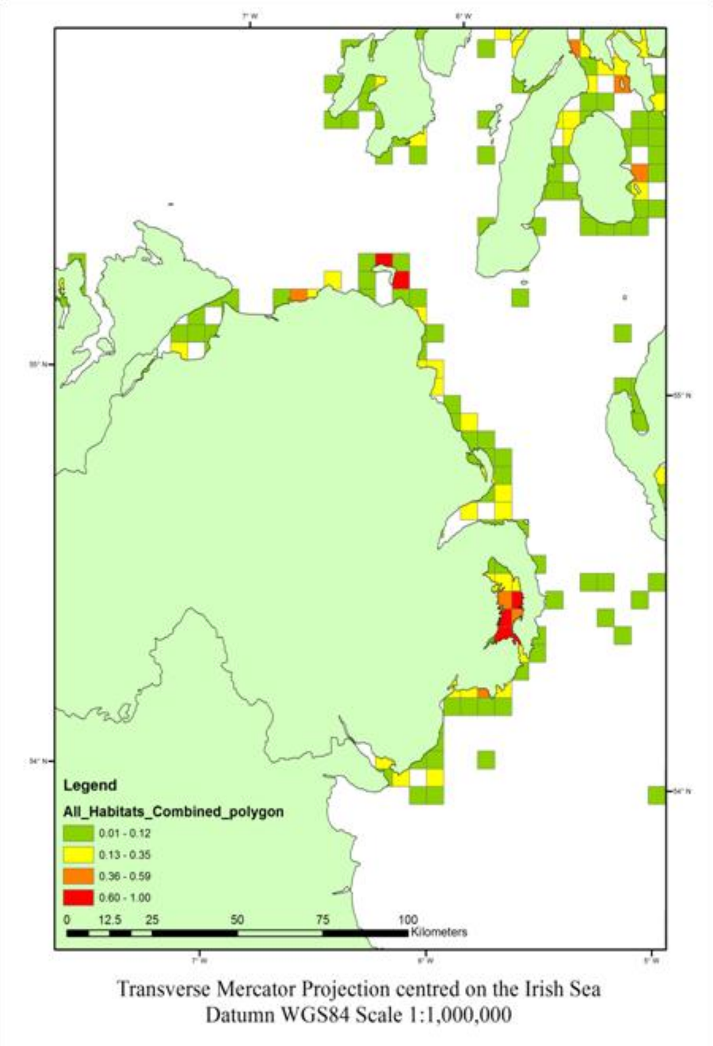


Figure 3.46 Gap analysis intermediate outputs: combined gap scores for habitats/biotopes

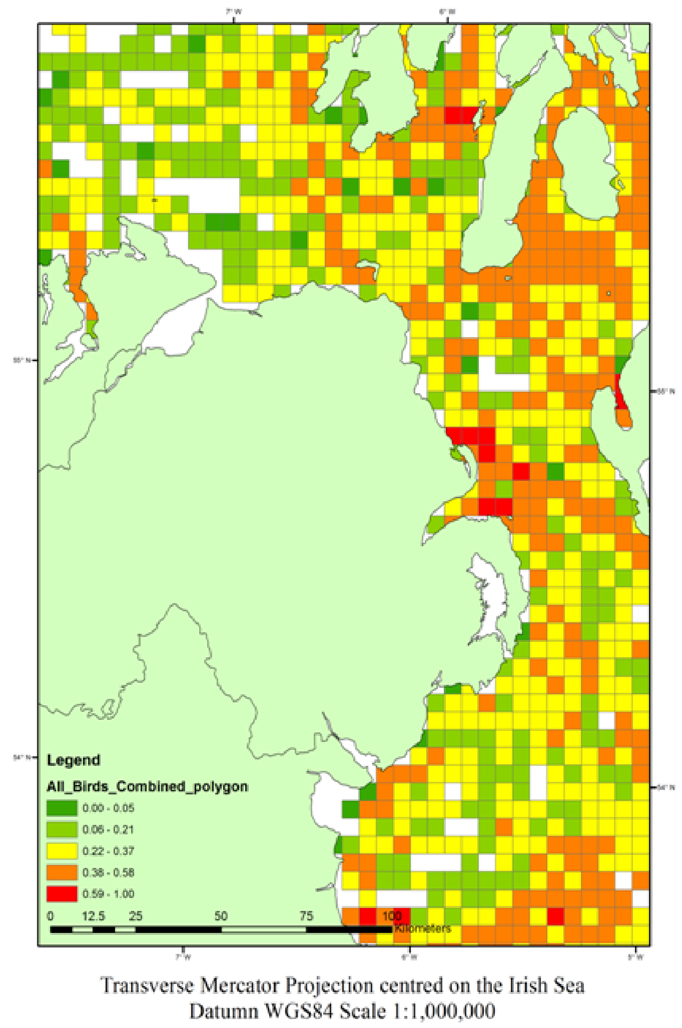
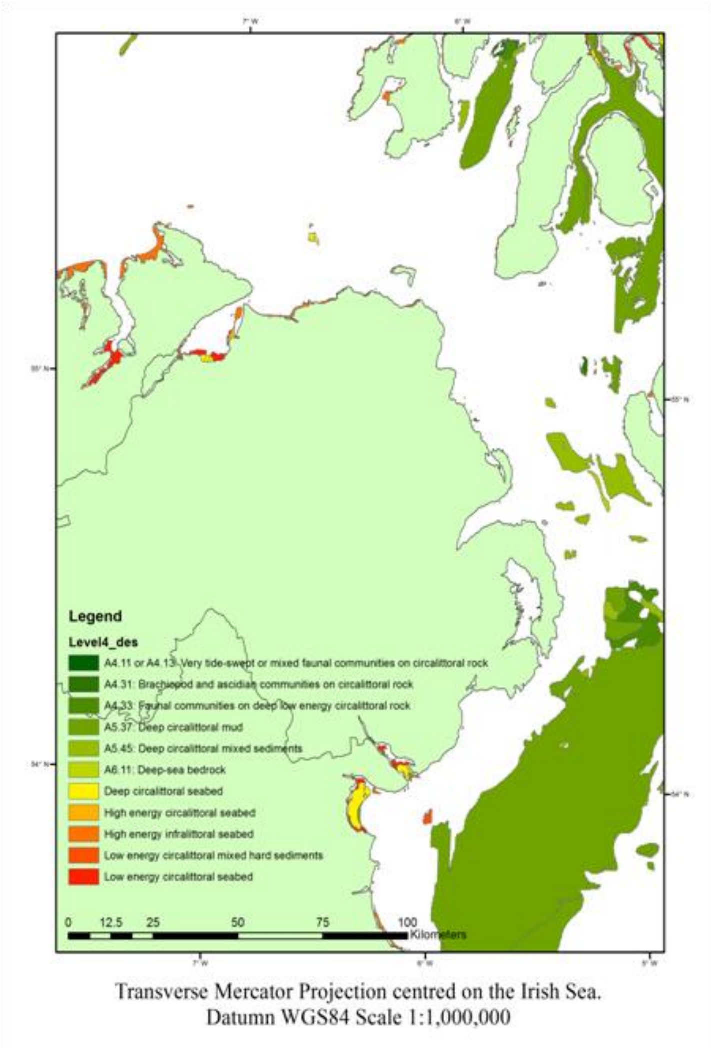


Figure 3.47 Gap analysis intermediate outputs: combined gap scores for bird species

REPLICATION

The raster output showing under-replicated areas of seabed habitat (EUNIS level 4) is provided below as Figure 3.48.

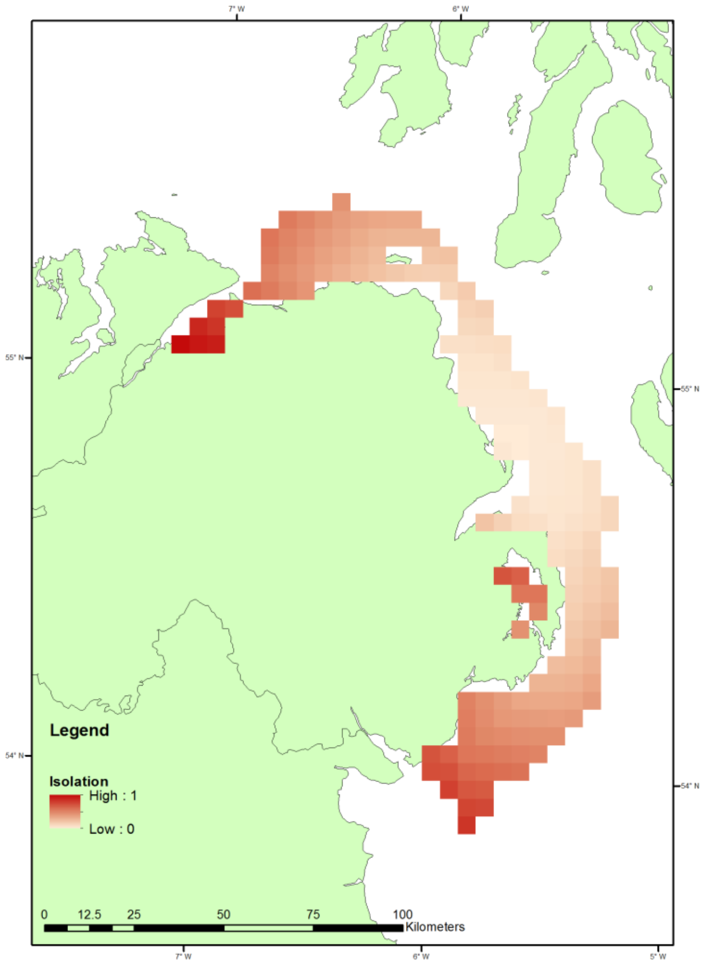


Data acknowledgement: Cameron & Askew (2011)

Figure 3.48 Under-replicated level 4 EUNIS habitats within the Area of Interest

CONNECTIVITY

The raster output for the connectivity element of the gap analysis is shown below in terms of isolation (Figure 3.49). Areas that are well connected in the MPA network show low levels of isolation, whilst areas that are only poorly connected in the MPA network show a high degree of isolation.



Transverse Mercator Projection centred on the Irish Sea.
Datum WGS84 Scale 1:1,000,000

NB: Highly isolated cells (cells that are relatively poorly connected to the existing MPA network) are shown as darker red

Figure 3.49 Derived isolation within the Northern NI 12 NM zone

3.6.3 OVERALL GAP ASSESSMENT

The values held in the three derived rasters (for representativity, replication and connectivity) were then combined to provide a single composite 'gap score' for each 5 km grid square. The distribution of 'gap score' values was classified into quartiles, and into three, four and five classes using Jenks natural breaks[15] within ESRI ArcMap (see Jenks, 1967). The spatial distributions of these various classes are shown as Figure 3.50 to Figure 3.53 (the classifications vary between the figures, but green colours reflect lower scores, whilst red reflects higher scores). Higher scores in this context reflect the intrinsic ‘importance’ or ‘value’ of each grid cell, integrated across the four groups of metrics used.

Details of the break points and class sizes resulting from these analyses are provided as Table 3.22 and Table 3.23. The Jenks method has the advantage over the application of fixed percentile sampling in that, as it tends to identify discontinuities (or regions of rapid change) in the distribution being assessed, the class boundaries that are generated are more meaningful.

From observation of these outputs, it was concluded that the quartile approach would lead to an excessive number of grid cells being identified as priority gap cells. Classification using the Jenks natural break approach provided an output that appeared more discriminating as regards the upper classes (reflecting the detail of the frequency distribution of the gap raster cell values). All three classifications using Jenks natural breaks produced virtually identical class breaks for the highest class (the highest category having 30, 30 and 29 class members for the three class, four class and five class categorisations, respectively) but the four class method was taken forward.

The grid cells belonging to the highest gap code group, as taken from the four way classification using Jenks natural breaks, were exported from the main grid and termed the ‘priority gap cells’. These priority gap cells were ‘clipped’ to the Northern Irish 12 NM limit and by the existing MPA network polygons, producing the spatial distribution shown in Figure 3.54.

[15] The Jenks natural breaks classification method (also known as the Goodness of Variance Fit, or GVF) determines the best arrangement of values into a number of different classes. This is done by seeking to minimise each class’s average deviation from the class mean, while maximising each class’s deviation from the means of the other groups (i.e. minimising within class variance whilst maximising between-class variance).

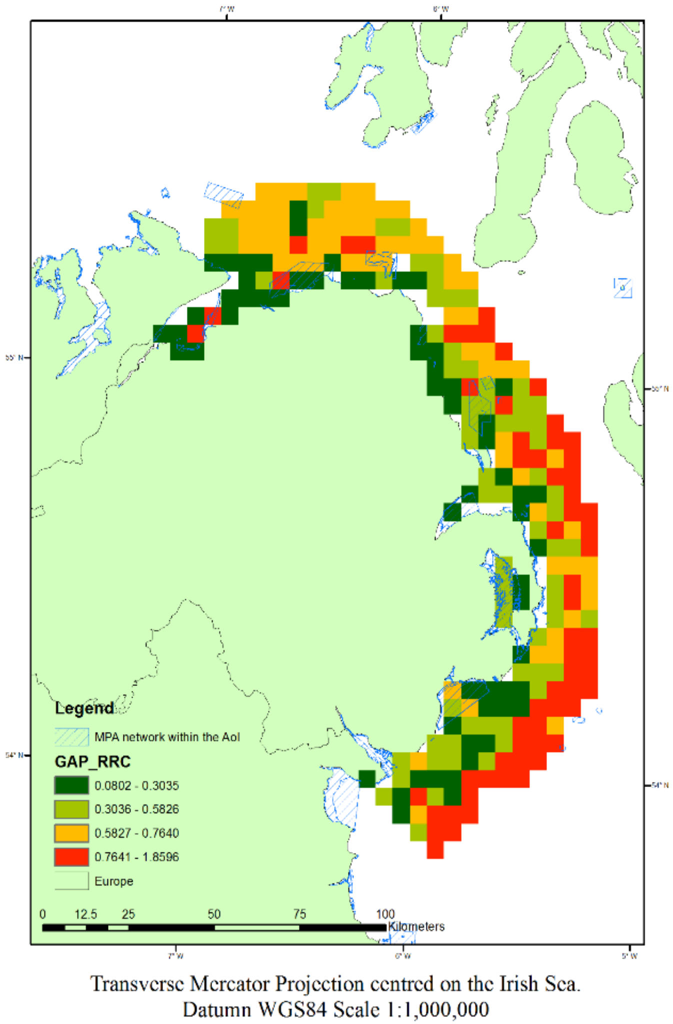


Figure 3.50 Gap analysis outputs with derived composite 'gap scores' classified into quartiles

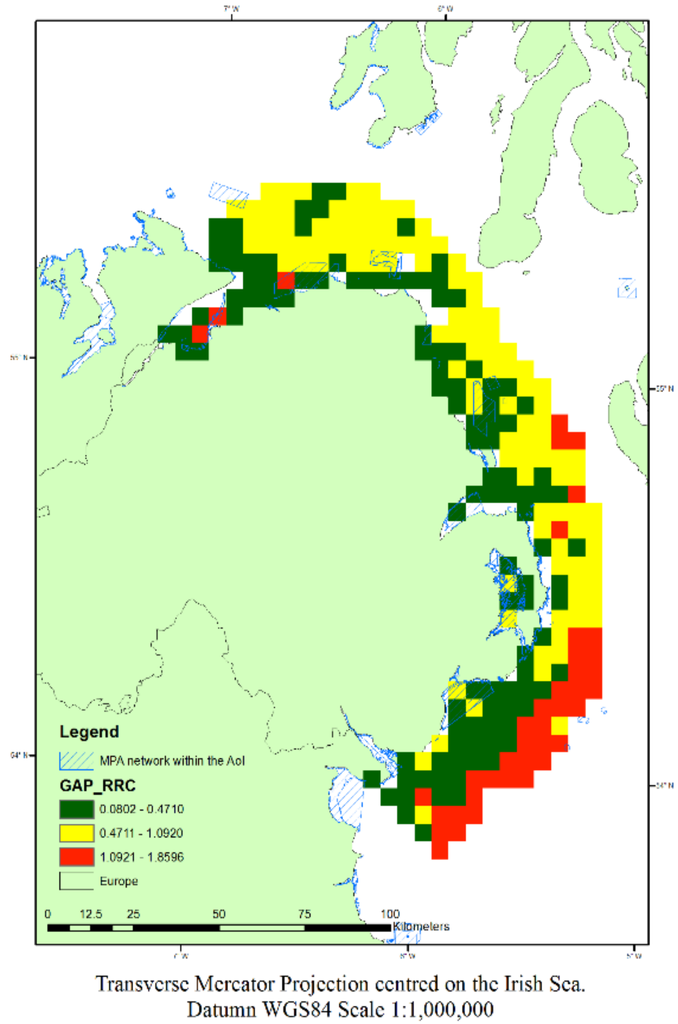
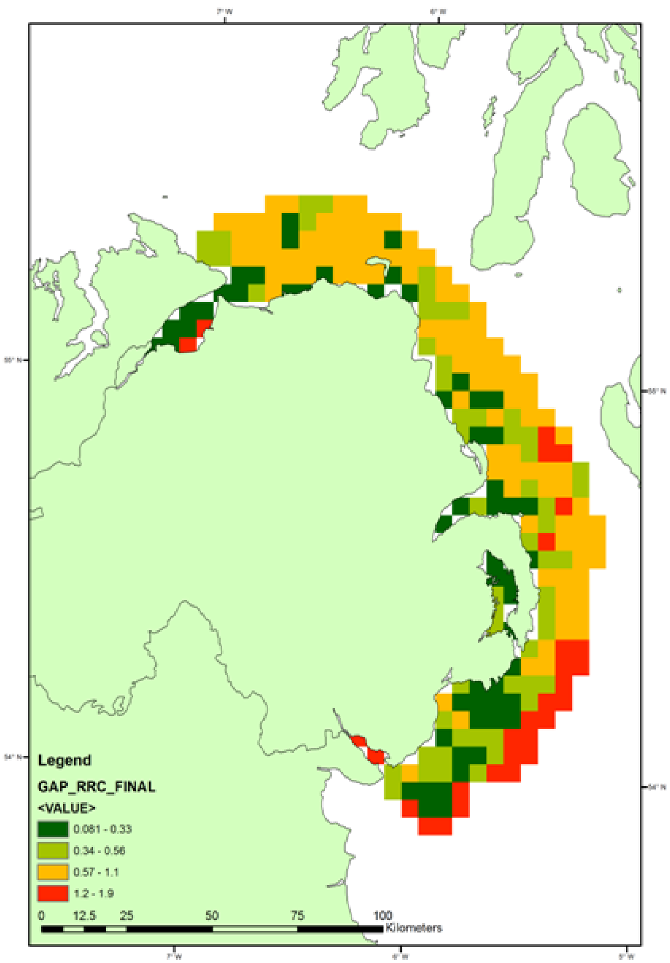
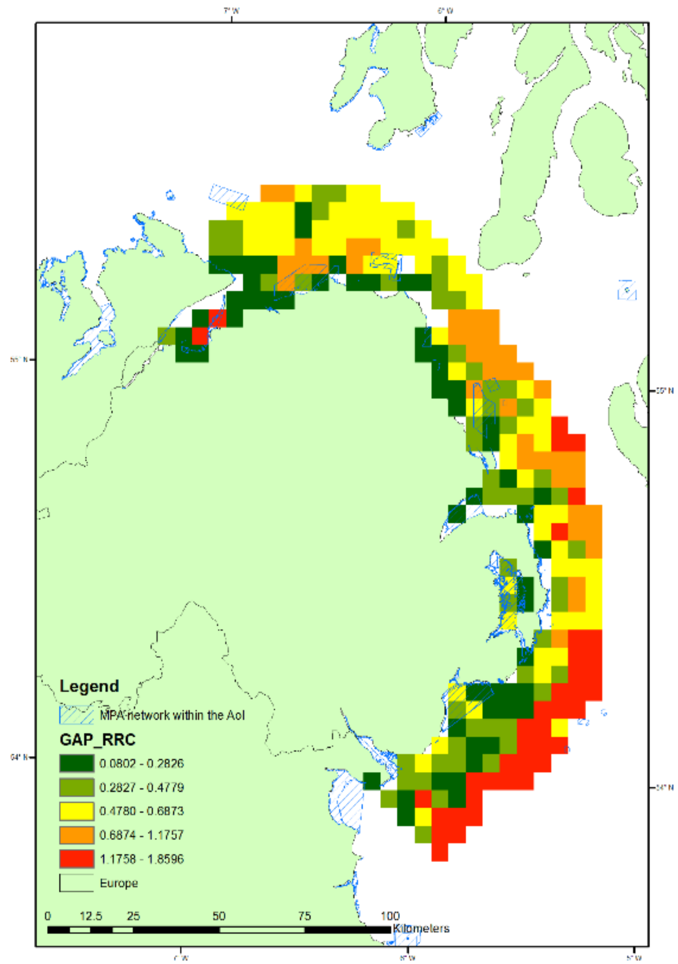


Figure 3.51 Gap analysis outputs with derived composite 'gap scores' classified into three classes using Jenks natural breaks



Transverse Mercator Projection centred on the Irish Sea
Datumn WGS84 Scale 1:1,000,000

Figure 3.52 Gap analysis outputs with derived composite 'gap scores' classified into four classes using Jenks natural breaks



Transverse Mercator Projection centred on the Irish Sea.
Datumn WGS84 Scale 1:1,000,000

Figure 3.53 Gap analysis outputs with derived composite 'gap scores' classified into five classes using Jenks natural breaks

Table 3.22 Class boundaries for quartile classification of derived composite gap codes

Class	Number of grid cells	Class boundary
Lower quartile	59	
		0.339
Second quartile	65	
		0.597
Third quartile	63	
		0.779
Upper quartile	58	

Table 3.23 Class boundaries and class counts for classification of derived composite gap code based on Jenks' natural breaks method within GIS

	Three way classification		Four way classification		Five way classification	
Class	Number of grid cells	Class boundary	Number of grid cells	Class boundary	Number of grid cells	Class boundary
First natural class	97		56		42	
		0.479		0.325		0.283
Second natural class	118		56		55	
		1.092		0.562		0.479
Third natural class	30		103		71	
		-		1.092		0.681
Fourth natural class	-		30		48	
		-		-		1.183
Fifth natural class	-		-		29	

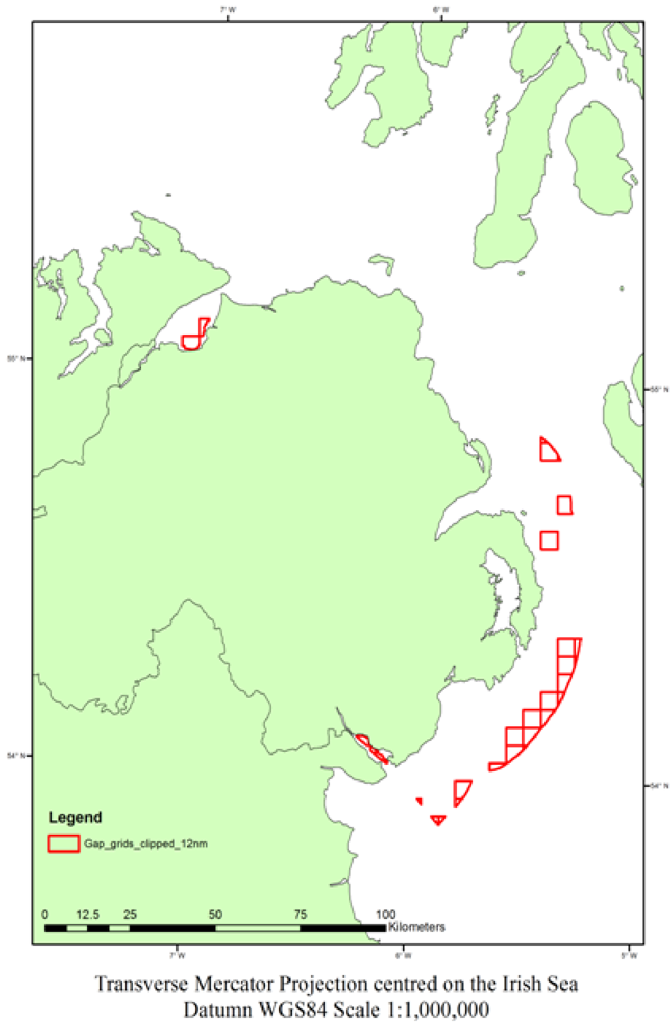


Figure 3.54 Priority gap cells as determined by the four class Jenks natural breaks approach (clipped to NI 12 NM)

The priority gap cells (Figure 3.54) represent those areas that, assuming equal weighting to all factors within the analysis (as outlined above), present the greatest opportunity for improving the overall coherence of the existing network. They can be thought of as providing an indication of the optimum areas of search for additional new or extended MPAs within the NI 12 NM zone. As such, these cells will be used in the associated economic evaluation study that follows from this work.

3.7 Discussion

Examination of the representativity results (using the 10% representation threshold, as outlined above) indicated that, within the 'biological zones', the deep circalittoral was significantly under-represented within the NI 12 NM MPA network. With regard to the substrata, the coarse and mixed sediments appeared to be poorly represented when compared to the composition of the NI 12 NM zone seabed and so was included in the gap analysis. When compared to the predicted regional presence of level 4 EUNIS habitats, A3.31 (silted kelp on low energy infralittoral rock with full salinity), A4.11 (very tide-swept faunal communities on circalittoral rock or A4.13: Mixed faunal turf communities on circalittoral rock), A4.31 (brachiopod and ascidian communities on circalittoral rock), A4.33 (faunal communities on deep low energy circalittoral rock), A5.37 (deep circalittoral mud), A5.45 (deep circalittoral mixed sediments), A6.11 (deep-sea bedrock), and high energy infralittoral were found to fall below the 10% threshold and so were also included in the gap analysis. The distribution of the under-represented EUNIS level 4 habitats is shown as Table 3.4 (above).

The cumulative grid data for the sessile species, mobile species, habitats and birds have been presented (above) as Figure 3.44 to Figure 3.47. For the sessile species, the highest accumulation of species occurred within the inshore area and especially in the sea loughs. For mobile species, there are high diversity cells throughout the inshore area of Northern Ireland. Habitat richness was particularly high in Strangford Lough and surrounding Rathlin Island. Bird richness was widely distributed although areas along the Antrim coast and within Belfast Lough appeared to be particularly rich.

For replication, those habitats with less than three units within the Northern Irish MPA network that were selected for as a priority gap within the analysis raster included: A4.11 (very tide-swept faunal communities on circalittoral rock) or A4.13 (mixed faunal turf communities on circalittoral rock); A4.31 (brachiopod and ascidian communities on circalittoral rock); A4.33 (faunal communities on deep low energy circalittoral rock); A5.37 (deep circalittoral mud); A5.45 (deep circalittoral mixed sediments); A6.11 (deep-sea bedrock); deep circalittoral mixed hard sediments; deep circalittoral seabed; high energy seabeds; and low energy circalittoral mixed hard sediments.

The combined distance layer (representing the degree of isolation from elements of the existing network) is shown above as Figure 3.49. It is apparent that isolation is higher (i.e. connectivity is lower) near the north-western and southern regions of the NI 12 NM zone. Connectivity within some of the sea loughs was also lower than open coastal areas.

The combined gap analysis layer (summed product of the three component layers) classified into four classes with Jenks Natural Breaks analysis highlighted 29 grid cells as being priority gaps within the existing MPA network (Figure 3.54). Most of these grid cells were in deeper water south east of Northern Ireland. Additional scattered cells were found within the cross border loughs of Carlingford and Foyle.

The ‘hotspots’ that were identified for sessile species richness and for habitat richness (i.e. the total number of species or habitats per cell) mostly lie inshore and are covered by the existing NI 12 NM MPA network. Hotspots for bird species richness was also widely distributed but had a greater offshore component, specific hotspots being apparent at the mouth of Belfast Lough, Larne Lough and Rathlin Island.

Whilst noting that the assessment of the overall coherence of the NI MPA network remains subjective, a summary of coherence is provided with reference to each of the underlying network design criteria.

3.7.1 Representativity

With the exception of EUNIS habitats A5.37 (deep circalittoral mud) and A4.12 (rock or biogenic reef) all of the main habitats present within the NI 12 NM limit are represented within the NI MPA network. The rock and biogenic reef habitat is effectively covered by a number of other EUNIS classes that are present, including (for example) A3.31 (silted kelp on low energy infralittoral rock with full salinity) and A4.27 (faunal communities on deep moderate energy circalittoral rock). There is only a very limited occurrence of EUNIS A4.12 (less than 40 ha) within the NI 12 NM limit that is not covered by other rock and reef EUNIS codes, but none of this area is coincident with an MPA.

In addition, the relative proportions of habitats within the NI 12 NM area are generally reflected well across the sites that make up the NI MPA network. One of the principal exceptions is in the coverage of different biological (depth) zones, where the coverage of the deep circalittoral habitat is decreased, and the coverage of infralittoral habitat increased, within the MPAs relative to their overall extent across NI territorial waters.

Coverage of water column characteristics also demonstrated good representativity, with two exceptions. In the summer months the MPA network appears to cover proportionately more of the weakly stratified ROFI and less of the stratified ROFI and well-mixed shelf water areas compared to their occurrence across NI territorial waters as a whole. In the winter months the MPAs fail to cover any of the frontal ROFI that is apparent within the NI 12 NM limit.

Seabed substrata are reasonably well represented, although proportionately less of the coarse or mixed sediment habitat (and more muds and rock/biogenic reef habitat) was covered in the MPAs.

The subtidal wave and tidal energy zones appear to be well represented across the MPA network, with the relative coverage of all classes broadly reflecting the distribution across NI territorial waters.

As might be expected, the greater discrimination that is introduced when the same analysis was applied to EUNIS Level 4 habitat types brings about more apparent discrepancy between the relative coverage of habitats across the 12 NM zone and within the MPA network. However, if the discrimination is reduced from EUNIS Level 4 to Level 3, then the representativity of the MPA network can be seen to be reasonable. For example, Figure 3.55, below, shows the relative composition of the NI 12 NM zone and the MPA network in terms of EUNIS Level 3 habitats (these data are presented in more detail under 'Adequacy' below). On inspection the representation of different habitats within the MPA network appears reasonable although there is some under-representation of A5.1 (subtidal coarse sediments) and a concomitant over-representation of A4.1 (high energy circalittoral rock) and A5.3 (subtidal mud). High energy circalittoral rock (A4.1) is present in the 12 NM but appears to be absent in the MPA network. Similarly, A4.3 (low energy circalittoral rock) – which covers only a small area in the 12 NM zone – covers only a very small area in the MPA network (and so is effectively absent when considered in terms of its proportion of the whole NI 12 NM zone).

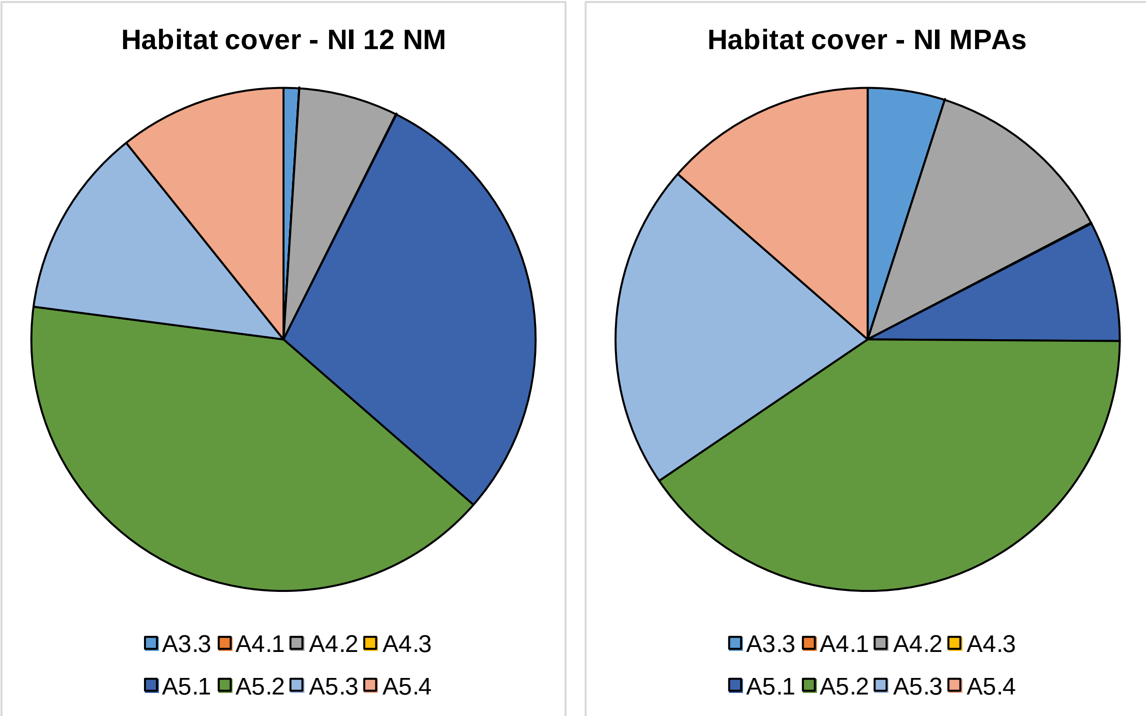


Figure 3.55 Relative proportions of EUNIS Level 3 habitat categories across NI territorial waters and the NI MPA network

Notwithstanding the above, the overall representativity of broad habitats within the NI MPA network is very good with, in general terms, all main habitats covered by the network. The absence of coverage for EUNIS habitat A4.12 (rock or biogenic reef) is a notable exception to this.

3.7.2 Replication

Replicated sites, which should be adequate in size in order to support the communities of species they are intended to protect, should be replicated across the network to provide a measure of resilience to the network. HELCOM (2010) set the theoretical minimum of adequate replicates to three, with the minimum size for a landscape patch to be considered a replicate to 24 ha (Piekäinen and Korpinen, 2008).

Whilst representativity considers the range of habitats covered by the MPA network, replication looks more at the features that are provided with protection by the sites within the network. The occurrence within NI territorial waters of species from the Habitats Directive (Annex 2), the OSPAR Threatened or Declining species list, and the Birds Directive was presented earlier (Table 3.5, Table 3.7 and Table 3.8, respectively). From these, a shortlist can be drawn of species present in NI territorial waters, but which appear not to be covered by fewer than three MPA sites within the NI 12 NM zone. This shortlist is presented below as Table 3.24. Note that, for a species to be flagged as present in an MPA, the assessment procedures adopted for this project require there to be at least 2.5% of a 5 km grid square from the species' distribution coincident with the MPA[16]. This level of overlap equates to 62.5 ha and so the secondary criterion (for replicates to be at least 40 ha in area) is automatically met.

Table 3.24 Species for which there is reduced level of replication across the NI 12 NM MPAs

Species	Common name	Number of NI 12 NM MPAs with feature present	Number of AoI MPAs with feature present
Alosa alosa	Allis shad	0	0
Anas crecca	Common teal	0	0
Bucephala clangula	Goldeneye	1	1
Dipturus batis	Common skate	0	0
Gavia arctica	Black throated diver	0	2
Haematopus ostralegus	Oystercatcher	0	3
Hydrobates pelagicus	Storm petrel	1	6
Melanitta nigra	Common scoter	0	18
Mytilus edulis beds	Blue mussel beds	0	5
Oceanodroma leucorhoa	Leach's storm petrel	0	2
Petromyzon marinus	Sea lamprey	1	2
Raja montagui	Spotted ray	0	11
Salmo salar	Atlantic salmon	1	2
Sterna hirundo	Common tern	2	19
Sterna paradisaea	Arctic tern	1	8

For many species, the lack of coverage by inshore MPAs might be compensated for by their occurrence within MPAs in the wider AoI. In this context there are only three species from the combined Habitats and Birds Directives and OSPAR Threatened or Declining species lists - *Alosa alosa* (allis shad); *Anas crecca* (common teal); and *Dipturus batis* (common skate) – which have been recorded in NI territorial waters but which have no replicated protection whatsoever as regards their coverage by the NI MPA network.

Overall therefore, the network appears to provide a reasonable level of replication.

3.7.3 CONNECTIVITY

Connectivity is measure of the extent to which populations of species in different parts of their range are potentially linked. Such linkages are important for facilitating the movement and exchange of eggs, larvae or other propagules, juveniles or adults (Palumbi, 2003). In this study, connectivity was generally assessed in terms of the shortest marine path between

[16] The analysis also assumes that the presence of a feature within an MPA equates to the protection of that feature by that MPA.

the effective centres of sites. For birds however, the assessment used the shortest straight-line path between SPA sites. It is likely that this approximation is reasonable for most bird species, with the possible exception of gannets and auks (whose flight paths tend to follow the coast rather than crossing inland areas).

As noted earlier, the analysis of connectivity was not limited to sites within the NI 12 NM zone but was extended out to include MPAs in adjacent waters through the incorporation of a 50 km buffer around NI territorial waters. This had the effect of reducing any adverse 'edge effects' for sites at the limits of the NI 12 NM zone and was considered important for a robust analysis.

Guidelines for what constitutes an appropriate level of connectivity are somewhat limited. OSPAR (2008a) define a major gap in a network for coastline and near-shore areas as any gap in excess of 250 km. Clearly this is a valid connectivity target for networks of large sites at a relatively large geographic scale. Its relevance when considering smaller component sites at a relatively local scale is questionable. More appropriate are targets such as those proposed by Roberts *et al*. (2010) who suggest much closer spacing (e.g. 40-80 km between site boundaries)[17]. Where there is replication of protection by MPAs (i.e. the same habitat type occurring in more than one of the NI 12 NM MPAs) the minimum marine path between MPA centroids was estimated as being less than 32 km for all relevant habitats (see Table 3.10, presented earlier). In this context there appears to be a high degree of connectivity between the constituent sites of the NI MPA network.

For the SPAs within the network, the shortest straight line connection between adjacent SPAs was estimated to range between 2.5 and 27.0 km (the latter being for connections to the offshore SPA, Pisces Reef). These results suggest a high degree of connectivity between these elements of the MPA network. This conclusion should be seen in light of the fact that the connectivity analysis for birds was performed on SPAs alone. The majority of SPAs in the NI MPA network are likely to be colony SPAs rather than areas at sea, and so are not likely to provide for the full range of needs and behaviours that are essential for seabird survival. In this context, however, the additional MAPs within the network (SACs and ASSIs) are likely to be able to provide resources to satisfy some of these needs.

It is acknowledged that there are other aspects (other than distance between sites) that can impact on the actual value or quality of connectivity. For example, the prevalence of currents can be important, as can the value or use of different habitats for different life stages of a given species. In addition, it is important to note that throughout these analyses, a record of occurrence for a species or habitat that is coincident with an MPA is taken on face value as being indicative of the feature being afforded a degree of protection. Considering both of these factors it might be considered appropriate to treat the assessment of connectivity as a 'best case'. It is equally important to note that the 40-80 km 'rule of thumb' relates to 'edge to edge' distances (i.e. distances between borders, not centroids). Considering all of the above, the connectivity assessment presented suggests that, in general terms, the network displays a good level of connectivity.

[17] Roberts *et al*. (2010) based their conclusions on information drawn from a number of sources, including: duration of planktonic dispersal; oceanography; modelling; chemistry; population genetics; the spread of invasive species (including algae and invertebrates); and the proximity of known fish spawning and nursery grounds.

3.7.4 ADEQUACY

The use of the concept of adequacy within network design is intended to ensure that a developing network is of adequate size to deliver its ecological objectives and ensure long-term protection and/or recovery. In practice this is usually assessed in terms of the relative proportion of broad habitat types within the waters of interest (e.g. local territorial waters, regional sea, etc.) that are protected by sites within the MPA network (e.g. Defra, 2010).

In terms of this relative coverage, a number of alternative assessment thresholds, outlined in different studies, have been used to report adequacy. The BALANCE project in the Baltic region ('Baltic Sea management – nature conservation and sustainable development of the ecosystem through spatial planning'; a project to develop marine management tools for the Baltic Sea based on spatial planning and cross-sectoral and transnational co-operation) applied the thresholds established by Piekäinen and Korpinen (2008), categorising the proportionate representation of landscape types according to five levels:

- Bad: - <10%;
- Poor: 10-20%;
- Moderate: 20-30%;
- Good: 30-60%; and
- High: >60%,

whilst HELCOM suggest just three levels:

- Inadequate: <20%;
- Questionable: 20-60%; and
- Adequate: >60%.

The Ecological Network Guidance developed for the English MCZ projects (Natural England & JNCC, 2011) also addressed the concept of adequacy and provided a range of (feature-specific) targets to support network design (Table 3.25).

Table 3.25 Adequacy targets for broad-scale habitat types

Broad-scale habitat types (EUNIS Level 3)	Lower target	Upper target
High energy intertidal rock (A1.1)	21%	38%
Moderate energy intertidal rock (A1.2)	21%	38%
Low energy intertidal rock (A1.3)	22%	39%
Intertidal coarse sediments (A2.1)	25%	42%
Intertidal sand and muddy sand (A2.2)	25%	42%
Intertidal mud (A2.3)	25%	42%
Intertidal mixed sediments (A2.4)	25%	42%
High energy infralittoral rock (A3.1)	15%	31%
Moderate energy infralittoral rock (A3.2)	17%	32%
Low energy infralittoral rock (A3.3)	16%	32%
High energy circalittoral rock (A4.1)	11%	25%
Moderate energy circalittoral rock (A4.2)	13%	28%
Low energy circalittoral rock (A4.3)	16%	32%
Subtidal coarse sediment (A5.1)	17%	32%
Subtidal sand (A5.2)	15%	30%
Subtidal mud (A5.3)	15%	30%
Subtidal mixed sediments (A5.4)	16%	32%

Based on the figures shown in Table 3.25 the adequacy of a network to protect broad scale habitats meeting the relevant targets for MCZ network design in England would only range from ‘Poor’ to ‘Good’ on the criteria used for the BALANCE project, or from ‘Inadequate’ to ‘Questionable’ on the HELCOM (2010) criteria. The adequacy figures used for the English MCZ projects would suggest that, even for features that meet the upper target, adequacy would not be described as ‘High’ or ‘Adequate’ according to either of the other sets of criteria reviewed here, highlighting the uncertainties in this area of coherence assessment.

As regards specific (EUNIS) habitat types, Table 3.26 (below) shows the areas of broad scale (Level 3) habitats within the NI 12 NM zone and the NI MPA network.

Table 3.26 Area of broad-scale habitat types (EUNIS Level 3) within Northern Irish waters (12 NM limit) showing the proportion within the existing MPA network

Habitat (EUNIS Level 3)	Area within the NI 12 NM limit (km^2)	Area within NI MPA network (km^2)	Proportion covered (%)
A3.3	40.2	20.5	51.0
A4.1	0.4	0.0	0.0
A4.2	257.7	51.2	19.9
A4.3	1.2	0.2	16.9
A5.1	1170.6	31.8	2.7
A5.2	1643.3	167.0	10.2
A5.3	492.0	86.2	17.5
A5.4	434.4	56.2	12.9
Deep circalittoral seabed	15.5	4.4	28.4
High energy circalittoral seabed	5.6	4.1	73.2
High energy infralittoral seabed	10.9	2.3	21.1
Low energy circalittoral seabed	20.3	4.6	22.7
Low energy infralittoral seabed	42.6	2.1	4.9
Moderate energy circalittoral seabed	21.9	5.5	25.1
Moderate energy infralittoral seabed	70.9	7.1	10.0

On the basis of these figures, and the targets suggested by Natural England and JNCC (2011), the adequacy of the NI MPA network for the main broadscale (EUNIS Level 3) habitats is as shown in the following table (Table 3.27).

Table 3.27 Adequacy of NI MPA network for broadscale (EUNIS Level 3) habitats

Habitat (EUNIS Level 3)	Lower target	Upper target	Proportion covered	Adequacy objective satisfied?
Low energy infralittoral rock (A3.3)	16%	32%	51.00%	✓✓
High energy circalittoral rock (A4.1)	11%	25%	0.00%	×
Moderate energy circalittoral rock (A4.2)	13%	28%	19.87%	✓
Low energy circalittoral rock (A4.3)	16%	32%	16.91%	✓
Subtidal coarse sediment (A5.1)	17%	32%	2.72%	×
Subtidal sand (A5.2)	15%	30%	10.16%	(✓)
Subtidal mud (A5.3)	15%	30%	17.52%	✓
Subtidal mixed sediments (A5.4)	16%	32%	12.94%	(✓)

× - target not met
(✓) – lower target nearly met
✓ - lower target met
✓✓ - upper target surpassed

Whilst the above provides an indication of the adequacy of the network in terms of habitats, the generalized assessments presented as part of the review of adequacy (Section 3.5.6) show that 100% of sessile species, 87% of mobile species and 81% of bird species are present in at least one cell intersected by MPAs within the NI 12 NM MPA network (Table 3.17).

Taken together, the analyses for adequacy suggest that this element of network design is, in general terms, well met by the existing MPA network.

3.7.5 VIABILITY

In terms of network design, viability reflects the need for a network to be made up of self-sustaining, geographically dispersed component sites of sufficient size. In terms of the analyses undertaken here, viability was assessed in terms of MPA size. The average size of individual MPAs that would be needed to meet the principle of viability investigated by Roberts *et al.* (2010) who examined the distances moved by mature adults of 72 species from a wide range of invertebrate, fish and seaweed groups for which data were available. Their results showed that 43% species did not move at all after settlement from the plankton and 38% of species typically moved less than 10 km after reaching maturity, based on which the following rules of thumb were postulated:

- for inshore waters, the average size of MPAs should be no less than 5 km in their minimum dimension, and the average MPA size across the network should be between 10 km and 20 km in their minimum dimension.
- MPAs with a minimum dimension of 1 to 5 km will still be valuable within the network, for example, to protect smaller areas of a habitat FOCI.

Similar rules of thumb have been used in the Great Barrier Reef Marine Park re-zoning (GBRMPA 2002) and California Marine Life Protection Act (MLPA) Initiative (CDFG 2008), and were incorporated into the English MCZ project guidance for MCZ network design (Natural England & JNCC, 2011). Assuming a circular site, the minimum size quoted above (i.e. 5 km across) equates to a site area of just under 20 km^2.

Across the NI MPA network, the minimum area of SAC sites was estimated at 3.15 km^2, whilst the average area was 63.26 km^2. For SPAs the corresponding figures were smaller, with an estimated minimum area of 1.03 km^2 and an associated mean of 26.76 km^2. The mean size of SACs and SPAs within the current MPA network exceeds the minimum suggested size for viability, suggesting that a reasonable proportion of sites are likely to be viable. However, a number of sites will fail even this minimum viability criterion.

Viability is not solely about site area, amongst other factors, compactness and connectivity also contribute (Natural England & JNCC, 2011). The calculated mean compactness of sites within the NI MPA network compares favourably with hat seen across MPA networks in the RoI and the rest of the UK, suggesting that site conformity in NI is not significantly different to that seen in adjacent marine waters.

Overall, the sites that comprise the NI MPA network show reasonable levels of viability.

3.7.6 NATURALNESS

As discussed earlier, it was not possible to assess the naturalness of sites across the NI MPA network.

3.7.7 Gap analysis

The priority gap cells (Figure 3.54) that were identified represent those areas that, assuming equal weighting to all of the factors within the analysis, present the greatest opportunity for improving the overall coherence of the existing network and indicate the optimum areas of search for additional new or extended MPAs within the NI 12 NM zone.

Review of the location of the priority gap cells, and of the underlying gap scores for the individual components of the analysis, provides an indication as to why certain areas have been selected.

The cluster of gap cells to the south-east of County Down appears to be linked to deep circalittoral mud habitats which were identified as being under-represented in the preceding analysis of ecological coherence. The few cells to the east of Belfast Lough appear to have been selected based on the relatively poor representation of coarse- and mixed-substrata within the existing MPA network. Both clusters of gap cells occur within the generally poorly represented deep circalittoral biological zone.

The gap cells in the Foyle and Carlingford sea loughs have moderate levels of sessile species richness and habitat richness but suffer from reduced connectivity. Given the relatively long residence time within many of the sea loughs and the impacts that might have on the spatial dispersal of sessile species it is likely that, in practical terms, the level of connectivity experienced in these areas may be effectively lower than is apparent here. An additional factor that is likely to underpin the selection of all of the identified gap cells is the low incidence of habitat replication. The analysis of these areas may also have been hampered from a lack of seabird data.

The fact that equal weighting was applied to all of the factors included in the gap analysis supports the underlying holistic approach that has been adopted in this assessment of ecological coherence. The equal weighting places more emphasis on the balance of the network and less on the specific contribution of one or two key species. It also helps explain why specific areas, which may be recognised as being good 'candidates' for future designation (perhaps due to their coverage of a particular species), have not necessarily been selected by the gap analysis.

The gap analysis successfully identified a series of priority gap cells that can be used to identify the socio-economic benefits that might accrue from the designation of an extended MPA network in NI.

3.8 Conclusions

The project was able to make use of a number of extensive datasets. Combining data from a range of disparate sources provided a good level of spatial coverage for wide range of habitats and species, but necessitated the adoption of some robust data processing decisions. The requirement to undertake a tranche of pre-analysis processing (e.g. to convert quantitative point-based data records to grid based presence/absence data) resulted in a reduction in the overall quantity (and detail) of information that was available to the project but had the clear advantage of facilitating its subsequent analysis and interpretation. The processed data for all 220 species and habitats that comprised the derived CA list have been collated to an interactive pdf file that has been supplied to NI MTF.

In general, the sites that make up the current NI MPA network meet the network design criteria of representativity, replication, connectivity, adequacy and viability. There are a few minor exceptions to this (for example the network does not encompass any rock or biogenic reef habitat, and three species from the combined Habitats and Birds Directives and OSPAR Threatened or Declining species lists which (despite being recorded in NI territorial waters) have no replicated protection as regards their coverage by the NI MPA network). Of all the network design criteria considered, it is probably site viability that is weakest, with sites across the NI MPA network being (in general terms) smaller than is recommended. However, across the board, the network has been shown to satisfy each of the design criteria to at least a reasonable extent.

As there are no established quantitative methodologies for combining assessments against the individual criteria into a single view of overall network ecological coherence it is necessary to take a qualitative and pragmatic view. In so doing it is important to recognise that, as far as possible, the assessments that have been used have been deliberately holistic, and attempts have been made to move away from the specific and to focus instead on the broad ecological coherence of the network. In this sense, the assessments that have been performed have focussed (intentionally) on the performance of the network rather than on attempting to assess the network's worth for individual species. Given the above the existing network can, overall, be seen to be reasonably ecologically coherent.

There are, however, some relative weaknesses in the network and these were assessed through the network gap analysis. Again, no standard or peer reviewed methodologies are available to perform such an analysis and so a bespoke process was developed to allow the gap analysis to be undertaken. The analysis focussed on three of the design criteria: representativity, replication and connectivity. It was concluded that the addition of further sites (e.g. MCZs designated under the new Marine Act (Northern Ireland) 2013) - identified as 'priority gap cells' - could further improve the coherence of the network, especially providing protection for offshore sites (i.e. sites beyond the 12 NM zone).

The process that was used assumed equal weighting across all of the contributory factors that were considered. This approach could easily be altered should the analysis be re-run in the future but care would need to be taken in identifying any suitable weighting procedure.

3.9 Future work

3.9.1 General

The current work has identified several shortcomings in terms of available data as well as in the handling or processing of data in large scale assessments of ecological coherence, and the subsequent interpretation of assessment outputs. There are, therefore, a number of areas have been identified for potential further work, clustered around:

- Data;
- The coherence assessment process; and
- Approaches to network gap analysis.

3.9.2 Data

Use of point data

Due to the constraints of the project, gridded point data has been used as a surrogate for the potential distribution of the species and features. The use of presence and absence gridding was also used to reduce the influence of survey effort. A time-consuming but superior methodology would be to model the distribution of each species. As modelled environment layers are readily available for a range of potential predictor variables, it should be possible to obtain reasonable predictions for many of the common species using methods such as maximum likelihood classification and generalised additive models. The availability or bias in the records of rarer species may make predictions difficult but the outputs may nevertheless be more informative than gridded point data. This approach may also be more useful for the identification of essential habitat such as nursery or optimum foraging habitats.

SPECIES AND HABITATS USED IN THE ECOLOGICAL COHERENCE ANALYSIS

Assessments of ecological coherence are inevitably heavily influenced by the choice of species and features that are considered. The current MPA network has been developed with reference to several groups of features (including, for example, the NI priority species and habitat list and lists arising from the Habitats and Birds Directives). The network assessment reported in the current project has used these features as well as additional species and habitats that are considered priorities for adjoining waters (the Coherence Assessment, or CA, list). Use of this extended list has provided a robust and wide-ranging analysis.

However, future development of this work should consider refining this list (especially with respect to habitats where there is significant overlap) and considering the inclusion of other species. The consideration of additional species might be made for any of several reasons; for example, it might be appropriate to include species that are disproportionally important for the provision of ecosystem functioning, whilst specific habitats that represent high-value essential fish habitat might be selected. The addition of species that are currently at their distributional limit (both southern and northern edges) may provide useful indicators of climate change and species response. Regardless of which species and habitats are picked, the process for their selection requires significant research and effort to understand their local and regional conservation value, functional ability, ecological traits and population dynamics.

DISTRIBUTION OF MONITORING AND SURVEY DATA

The collation of extensive datasets for species and habitat data provides a useful platform for the subsequent examination of the impact that the distribution of monitoring stations has on the value of survey data. It would be useful to identify a measure of the ease of observation for each data type, as spatial differences across the range of the area of study might influence the confidence that is placed in the reporting of many species and features. For example, data may become less reliable the further offshore one moves. The data accumulated within the current project would provide a useful resource for examining the gaps in current monitoring, based on a similar methodology to that used for the gap analysis in the current study.

3.9.3 COHERENCE ASSESSMENT PROCESS

DEFINING ADEQUACY AND VIABILITY

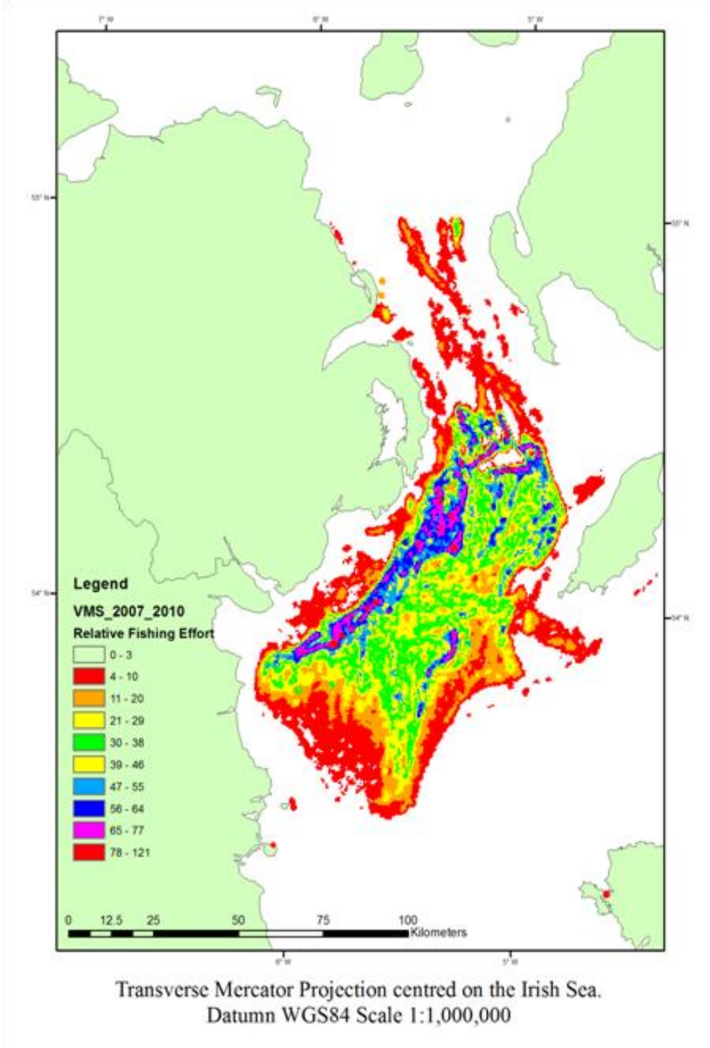
Adequacy is effectively a feature of the network, rather than of individual sites, and is defined in terms of the provision of ‘a network of an adequate size to deliver its ecological objectives and ensure long-term protection and recovery’. Within this project, the emphasis has been on the size of MPA units. However, an adequate size is very much related to the ecological requirements of the species. Adequate areas should be sufficient to capture both a sustainable proportion of the population, sufficient prey availability and foraging habitat.

Further work should be considered to investigate whether there are minimum sizes that capture these aspects of adequacy for particular species groups.

PRESSURES AND CONDITION ANALYSIS

A thorough analysis of condition of the MPA network would require quantitative monitoring data for all of the MPA sites and would involve substantial analysis. Such quantitative data are not available for the majority of sites. A more realistic and pragmatic approach would involve the use of surrogates of environmental degradation based on the spatial intensity of particular pressures. For example, using MPA overlap with known activities as a potential surrogate of pressure and, by using existing feature-specific pressure-sensitivity matrices, infer possible feature impacts. Whilst Vessel Monitoring System (VMS) data were kindly provided by AFBI (Figure 3.56) it was found, on preliminary examination, that most of the over 12 m fishing vessels were presented in the VMS points and that there was little or no spatial overlap of the data with the MPA network. As a consequence, it became apparent that the original proposal surrounding condition assessment was, in fact, beyond the scope of the current project.

Future development of this approach should consider the inclusion of the spatial data generated by Katherine Yates (University of Ulster) during the Diverse Seas project. One hundred and three skippers and owners of NI registered vessels (representing almost half of the active NI fleet) were interviewed about their spatial access priorities. Unlike VMS data, which only covers larger fishing vessels (>12 m), this approach examined a broader cross-section of the fleet, covering both small (inshore) and large (offshore) fishing vessels. Data from these interviews were used to generate spatial access priority maps for both the whole fleet and for each of the main fisheries. These maps provide quantitative data on which parts of the sea are most used by fishermen and potentially the most important in economic terms. Attempts were made during the current project to source this information but access to data was not granted during the analysis period. Based on the breadth of fishing activity contained with the layers from the Diverse Seas project it is likely that they would provide useful surrogates that could be used within a condition/naturalness analysis. Pressures would then need to be assessed on a habitat-by-habitat basis by applying established sensitivity and response matrices. It is recommended here that this analysis is undertaken as a future priority. The accumulation of the current project data with layers of activity and pressure would provide an extremely valuable dataset for the thorough investigation of condition, network gaps and socio-economic considerations.



Data acknowledgement: VMS data provided by AFBI

Figure 3.56 VMS data for the period 2007-2010, showing distribution of relative fishing effort

3.9.4 APPROACHES TO NETWORK GAP ANALYSIS

To support the better identification of shortcomings or gaps within the NI MPA network there are two components of the gap analysis that would benefit from development within one or more separate dedicated project(s). These relate to the selection of species or habitats for use within the analysis (potentially affecting what the gap analysis shows) and to the way in which the relative importance of different factors is addressed in the assessment process (what weightings are applied). Both components require substantial research and consideration.

The selection of species and features for the representativity gap analysis, used to support the current project, provided for the holistic analysis of marine biodiversity at the landscape scale. To refine the gap analysis, it may be appropriate to expand or refine the range of species and features included, with the aim of increasing (for example) relevance of functionally important species within specific habitats; of capturing more charismatic species; of excluding certain economic species; or of sub-sampling species for more detailed gap analyses by specific designation type. Regardless of the species and features selected, carefully background information is required on each species so that aspects of regional importance, functional capabilities, principles of recovery and dispersal capability can be understood.

The other component that requires significant thought, and which would potentially change the outcome of the gap analysis quite substantially, relates to the weighting of input criteria. The current gap analysis used an equal weighting across all of the constituent components of ecological coherence. Weighting becomes important if, for example, the target species list consisted of highly mobile species, and it was agreed that the weighting attached to connectivity could be reduced. Equally, the weighting applied to under-replicated habitats may need to be increased to ensure that habitats that are locally or nationally rare are preferentially considered.

The use of stakeholder workshops or of expert judgement (see for example, Barnard and Boyes, 2013) may help to generate a census as to which aspects of the marine ecosystem are most highly considered and fit within prevailing socio-economic considerations.

The influence of representativity on the overall assessment may also be varied to account for observed redundancy in the provision of key ecosystem functions from particular habitat types. Whilst weightings could be based on the outputs of focussed literature reviews, or on consensus or expert views, any variation should ideally be accompanied by a sensitivity analysis so as to provide for an understanding of the impact of particular weighting strategies.

4. ECONOMIC & SOCIAL BENEFITS OF THE NI MPA NETWORK

4.1 Introduction

The marine environment in Northern Ireland covers approximately 4,500 km^2 and includes parts of both the Irish Sea and Atlantic Ocean (Christie, 2011). The marine waters surrounding Northern Ireland are important in providing wealth and well-being to society by supporting a wide variety of marine life and habitats including basking sharks, seabirds, seals, dolphins and diverse reef habitats. Commercial trawl fishing, for example, is dominated by the *Nephrops* fishery, although it is reported that whitefish and other species make up important additional components (Cappell *et al.*, 2012). In 2010, annual landings by the Northern Ireland trawl fleet totalled 10,299 tonnes of fish (4,306 tonnes were from *Nephrops* landings) which amounted to a value of nearly £10.5 million (£6.7 million were from *Nephrops* landings) (Cappell *et al.*, 2012). The majority of marine biodiversity in Northern Ireland is located within two sites alone, Strangford Lough and Rathlin Island (Christie, 2011). Rathlin Island, for example, is home to Northern Ireland's largest seabird colony, with visitor numbers to the Rathlin Island RSPB Nature Reserve increasing annually since it opened in 1978, growing from 5,000 to 14,500 in the last ten years alone (RSPB, 2010). It was estimated that in 2009 bird watching at this Reserve was worth £115,000 to the local economy predominantly made up of direct employment, reserve expenditures, use of local contractors, and visitor spending on accommodation, subsistence and travel (RSPB, 2010). The waters surrounding Northern Ireland are also popular for recreational angling, from both the shore and sea. This recreational sector was estimated to provide £7.4 million to the local economy in 2005 (PWC, 2007).

Until recently site protection in Northern Ireland has focussed on species and habitats of European or international importance. These are listed in the relevant Annexes of the EC Wild Birds and Habitats Directives or wetlands of international importance under the Ramsar Convention; there are six SACs, nine SPAs and seven Ramsar sites (which have a marine component and are all also SPAs)) (DoE, 2013). In addition, Northern Ireland also has national nature conservation designations in the form of Areas of Special Scientific Interest (ASSIs) designated under The Environment (Northern Ireland) Order 2002 (DoE, 2013) which covers intertidal areas. A new type of MPA, Marine Conservation Zones, (MCZs) will be designated under Part 3 (Marine Protection) of the Marine (Northern Ireland) Act 2013 to protect rare, threatened or nationally important marine habitats, species and geological features and, the first of these has been designated by converting the Marine Nature Reserve in Strangford Lough into an MCZ, although the management objectives have not been developed yet as the strategy and network guidance are still under consultation. Together with existing marine sites, MCZs will assist in achieving an ecologically coherent network. In Northern Ireland, the primary aim of the network is nature conservation of sensitive and ecologically important species and habitats.

Whilst it is acknowledged that the fundamental purpose of MPAs is habitat and species conservation, MPAs provide ecosystem services that are of benefit to society (Potts *et al.*, 2014). Ecosystem services have been defined as the link between ecosystems and things that humans benefit from, not the benefits themselves (Luisetti *et al.*, 2011). In order for society to secure such benefits from ecosystem services, an input of complementary human and man-made capital (such as inputting skills, time, energy, and machinery and equipment) is required (Cooper *et al.*, 2013). Identifying and valuing the ecosystem services from MPAs can highlight the mix and importance of services produced from marine systems in general, whilst there is potential for specific services to be supported or enhanced by the MPA process if designation is achieved and management introduced. Within the context of Northern Ireland, although the Marine (Northern Ireland) Act 2013 does not highlight the protection of ecosystem services *per se*, the DoE's draft strategy for MPAs in Northern Ireland recognises that 'the marine environment has a significant value to society, through the goods and services it provides' (DoE, 2013). The benefits to society arising from the proposed MPA network for Northern Ireland's inshore waters are associated with changes in the provision of a range of ecosystem services provided by the marine environment. Off-site benefits that might be derived as a result of site designation within the proposed MPA network, such as the contribution of the additional MPA network to wider fishery productivity beyond the designated area, while likely to be important are not considered in this report.

A range of techniques are available to assess the value that specific stakeholders and, more generally, society places on marine ecosystem services (see Annex B). In some instances reliance is placed on market prices to value these services. However, as is common to many environmental resources, while market prices may reflect the value of some marine ecosystem services, for other ecosystem services market prices either don't exist or are inadequate. Given such circumstances, recourse to a range of methods to assess the values that are placed on the benefits secured from such services is necessary, including methods based on revealed preferences (e.g. travel cost method, hedonic pricing) and those based on stated preferences (e.g. contingent valuation, choice experiments). Many of the methods are categorised as non-market valuation approaches as they do not rely on market prices, and are advocated by the UK Government for policy evaluations (HM Treasury, 2011).

While there are now quite a large number of UK marine ecosystem service valuation studies, currently the literature provides an incomplete coverage of these services and goods/benefits. Atkins *et al.* (2013) report that in the literature on UK marine waters there is a focus on some key goods and benefits associated with provisioning services, with fish being particularly prominent, and the ecosystem services associated with regulating services and particularly climate regulation, natural hazard reduction, and waste breakdown through improved water quality, and those cultural services associated with recreation and tourism. Other ecosystem services, for example those associated with other cultural services, still defy monetary valuation.

The limited availability of evidence of the value of marine ecosystem services specific to Northern Ireland is a key issue when considering the benefits of extending the number of MPAs. However, the existing UK ecosystem service valuation literature is important as it offers the opportunity to value Northern Ireland marine ecosystem services by employing benefit transfer techniques. Benefit transfer takes pre-existing primary values from a study case to develop a customised estimate of the benefit for a new case. Although the use of primary research to estimate the new case's values is generally preferred, 'the realities of the policy process often dictate that benefit transfer is the only feasible option' for valuation (Johnston & Rosenberger, 2009). In particular, it can be too time-consuming or expensive to directly estimate the monetary worth of an environmental good/benefit in a specific case, such as any proposed MPAs in Northern Ireland's waters. Using benefits transfer, values may be transferred to new geographic sites or transfers may be made involving the same geographic site using past values to assess current situations or predict future outcomes. Two forms of benefit transfer are 'value transfer' which substitutes a point estimate (or mean or mode when based on a range of values) from a previous study and a 'function transfer' which predicts benefits using a previously calibrated function describing how values vary with characteristics of people and places (Kaul *et al.*, 2013). The latter case is often referred to as a 'meta-analysis' or the 'study of studies' which attempts to statistically measure systematic relationships between reported valuation estimates for an environmental good or service and attributes of the study that generated the estimates, including valuation methods, human population and sample characteristics, and characteristics of the good or service itself (Bergstrom & Taylor, 2006). It is unlikely that the existing evidence on the value of ecosystem services in the UK marine environment is sufficient to support function transfer/meta-analysis as a large number of valuation case studies on a given ecosystem service are typically required. However, existing evidence will support the use of value transfer for specific ecosystem services.

4.2 Approach

The approach adopted here to value the benefits provided by additional MPAs in Northern Ireland inshore water follows that developed by Moran *et al.* (2008) to value the benefits provided by proposed MCZ networks in English territorial waters and UK offshore waters. The same approach was also applied to the case of Scottish MPAs by González-Álvarez *et al.* (2012). Employing this approach offers the opportunity for establishing a consistent set of findings across all three regions. In applying the approach to Northern Ireland waters, the methodology of Moran *et al.* has been updated when more recent evidence is available or has been amended where data availability limits its full application in the Northern Ireland context.

The approach adopted here considers two scenarios involving the establishment of a set of MPAs which are managed under two alternative management regimes: (1) maintain and (2) recover. The proposed MPAs must be seen to be additional to the current MPA network and are selected to ensure that the network as a whole is ecologically coherent. We assess the benefit of the proposed MPAs by estimating the economic value of the ecosystem services that are provided by these new MPAs managed under the two regimes.

The approach can be set out as an eight stage process, the first two stages of which define the network scenario and management regimes, whilst the remaining six stages lead to economic valuation estimates:

- Selection of the MPA network scenario and the specification of management regimes for the potential networks.
- Identification of the extent of different marine landscape and habitat types found in the proposed MPA scenario.
- Estimation of the total aggregated value of the different ecosystem services provided by the UK marine environment.
- Division of the total aggregated UK values across the different marine landscape and habitat types.
- Determination of the current status of each marine landscape and habitat type, and their likely state if there were no additional MPA designations (i.e. the *status quo* scenario).

- Consideration of the effects of different management regimes on each of the marine landscape and habitat types by category of ecosystem service in comparison with the *status quo* scenario.
- Economic valuation of the effects of the proposed management regimes by marine landscape and habitat type and ecosystem service category.
- Aggregation of economic values to provide an estimate of the benefits to society of the suite of proposed MPAs.

The flow chart presented in Figure 4.1 illustrates the linkages between these eight stages. The key findings are presented in the main body of the report, whilst the more detailed methodological stages are included in annexes to this report.

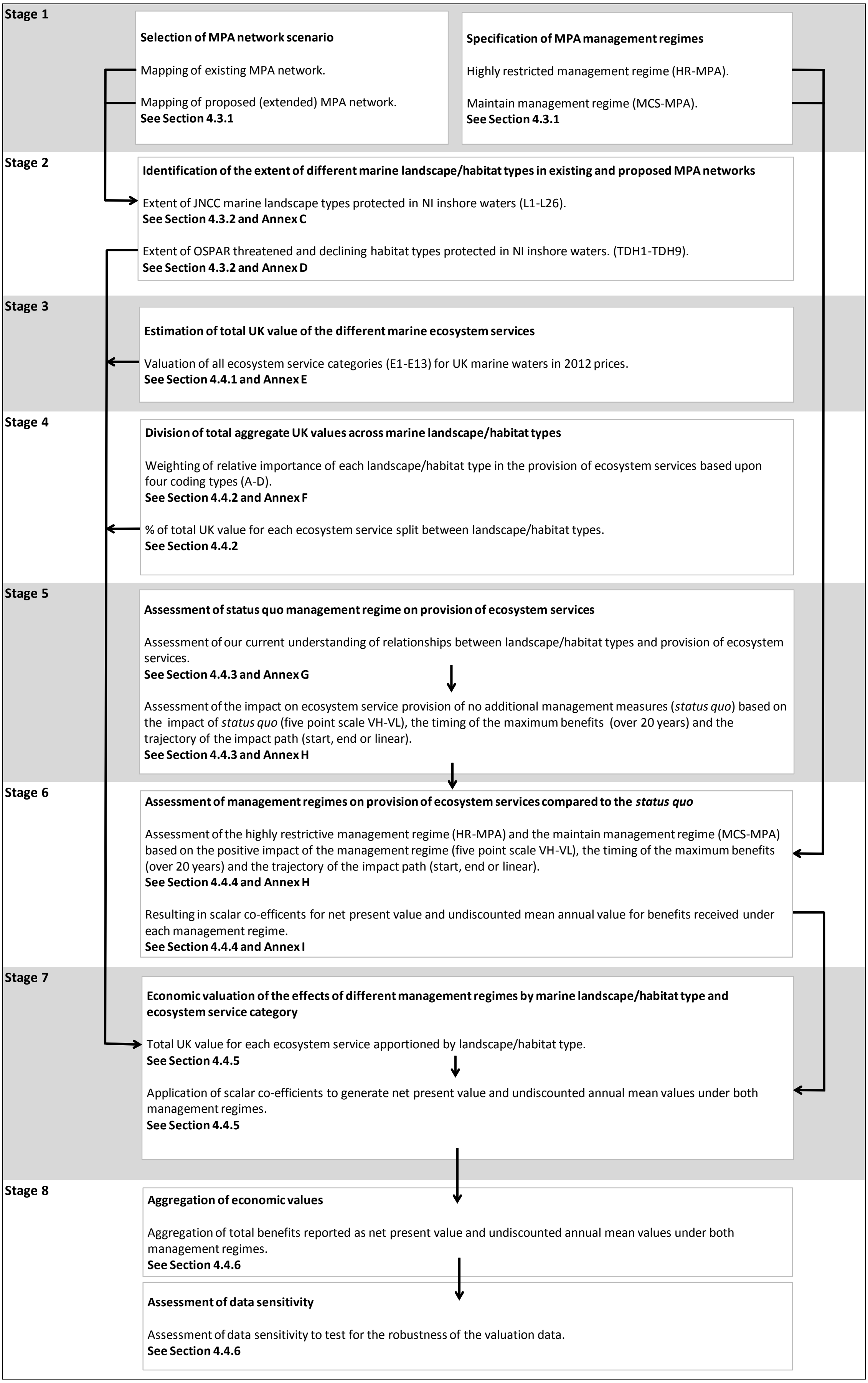


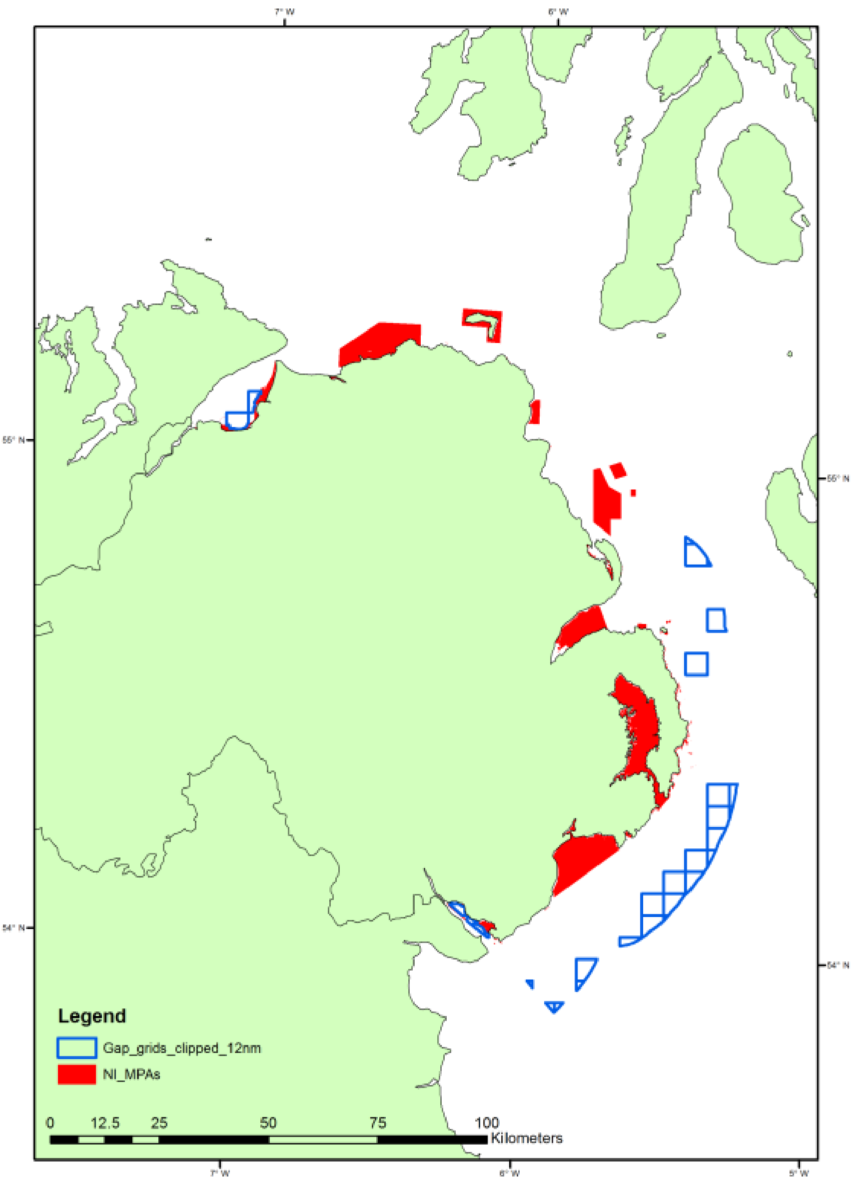
Figure 4.1 Flow chart showing the linkages between the eight stages.

4.3 Definition of MPA Network Scenario and Management Regimes

The first two stages in the methodology involve defining the network scenario and the two management regimes. These two stages build on the outputs from Part 1 of the project which identified the characteristics of the current MPA network in Northern Ireland's inshore waters and which proposed an additional MPA network that was coherent with that network existing already.

4.3.1 Selection of an MPA network scenario and the specification of management regimes for potential networks

The assessment undertaken of network coherence identified a series of 'priority gap cells' which might be used to provide the basis for an (extended) network of MPAs in Northern Ireland (Figure 4.2).



Transverse Mercator Projection centred on the Irish Sea
Datumn WGS84 Scale 1:1,000,000

Figure 4.2 Map of existing MPAs in Northern Ireland's inshore waters (red) and the proposed (extended) network of MPAs (blue).

As a further part of the assessment of the network of MPAs, the effects on the provision of ecosystem services at two levels of conservation management applied to individual MPAs are considered in this report:

- highly restricted MPAs where the conservation objective is to 'recover' (HR-MPA); and
- maintenance of conservation status MPAs where the conservation objective is to 'maintain' (MCS-MPA).

The specification of each of these management regimes is summarised in Table 4.1. It must be noted, however, that while these may not be the only levels of protection which could be given to the additional MPA component of the network, they have been applied here for consistency with Moran *et al.* (2008) and González-Álvarez *et al.* (2012).

Table 4.1 Specification of management regimes (following Moran *et al.*, 2008).

	Conservation Objective	
	'Recover' Management Regime	**'Maintain' Management Regime**
Management regime restrictions	General presumption against fishing of all kinds, and all constructive, destructive and disturbing activities. Recovery measures appropriate to the local situation (enhanced restoration/aftercare measures on expiry of operating licences).	New development activities permitted which are in the public interest (on social or economic grounds). Existing activities to continue if these do not cause the site condition to deteriorate. Restriction of bottom fishing gears either spatially or temporally and technical conservation measures. Recovery measure appropriate to the local situation (enhanced restoration/aftercare measures on expiry of operating licences).

In the Northern Ireland context, the Marine Act (Northern Ireland) 2013 requires that the Department of the Environment must take account of social and economic factors when designating future MPAs/MCZs. However, this does not necessarily mean that the economic and recreational activities in that site will be restricted, as this will depend on the sensitivity of species, habitats and geological/geomorphological features (for which a site is designated) to the activities taking place in that area and on the conservation objectives of those feature(s) (DoE, 2013). Since site-specific management measures are not known until sites have been designated and their conservation objectives set, the economic assessment undertaken here is for the network as a whole rather than on a site-by-site basis. The economic assessment is presented for each of the two management regimes separately and, following Moran *et al.* (2008) which followed Defra advice, on combinations (percentage shares) of the two.

4.3.2 IDENTIFICATION OF THE EXTENT OF DIFFERENT MARINE LANDSCAPE AND HABITAT TYPES CONTAINED IN THE PROPOSED MPA SCENARIO

The existing and proposed MPA networks in Northern Ireland were assessed for the type and extent of habitat that they contained and would be protected. For this purpose, the existing and proposed MPA networks were assessed by estimating the areas they represented of JNCC marine landscapes (L1-L26) (Golding *et al.*, 2004) and the OSPAR Threatened and Declining Habitat types (TDH1-TDH9) (OSPAR, 2008b) (jointly referred to as landscape/habitat types hereafter). Further details on the JNCC landscape and OSPAR habitat classifications are presented in Annex C and Annex D, respectively. The extent of the marine landscape types in Northern Ireland waters are presented below (Figure 4.3). The data were analysed using GIS software (Arc GIS version 10.1) to estimate the area of each landscape/habitat type in the existing MPA network and the additional area of each landscape/habitat type in the proposed MPA network.

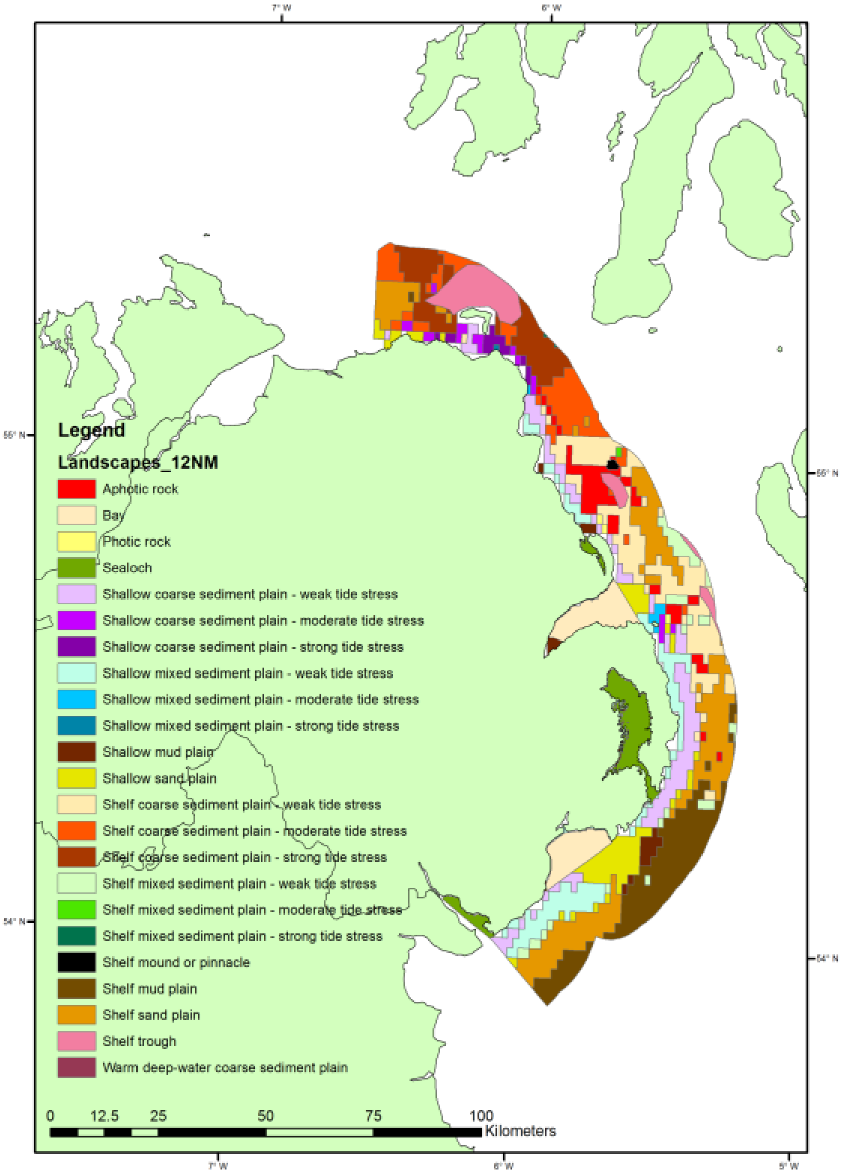
Marine recorder point data were used to initially proportion the existing OSPAR areas to Great Britain and Northern Ireland waters. The percentage of the total points falling within the Northern Ireland MPA network was used to generate a proportion of OSPAR Threatened and Declining Habitat (TDH) types in the existing and proposed MPA networks. For the latter, OSPAR areas were calculated when a present cell coincided with a priority gap cell. The gap analysis has focused exclusively on Northern Ireland waters and not made 'gap' recommendations for the Republic of Ireland's territorial waters. The resulting area was also clipped to the same extent as the gap cell hence areas are within the Northern Ireland 12 NM area and are not already covered by an existing MPA. Both point and grid cell data can be viewed in the interactive pdf that has been produced as an output to this work.

A large proportion of the existing MPA network in Northern Ireland is characterised as being either 'sea loughs' or 'bays'. Such features do not translate directly to JNCC marine landscape categories (Golding *et al.*, 2004), and therefore for the purposes of this assessment these areas were assigned on a proportionate basis to JNCC marine landscape types based on available site-specific evidence (see Table 4.2). Some of the MPA footprints that fell outside the UKSeaMap coverage (after Connor *et al.*, 2006), e.g. Lough Foyle and some areas of the Skerries SAC, were matched from the EUSeaMap layer that had full coverage for the area. The UKSeaMap landscapes 'Sea Lough' and 'Bay' were reclassified into evaluated classes using the AFBI inshore habitat mapping layers and the recent AFBI Strangford Lough multi-beam survey (Strong & Service, *in prep.*). Priority grid cells were also used as a clip feature on the UKSeaMap landscapes layer. All results were exported to Excel and analysed with pivot tables.

Boundary considerations through Carlingford Lough and Lough Foyle were dealt with in the same way as specified in the ecological coherence assessment, i.e. an arbitrary mid-sea lough border was used to separate Northern Ireland and Republic of Ireland designations according to the governing body that originally designated the sites. It is recognised that that Lough Foyle and Carlingford Lough are cross-border water bodies and are managed accordingly by the Loughs Agency.

The areas of each landscape/habitat type for the UK as a whole, for the existing MPA network, and for the proposed MPA network are presented in Table 4.3. The existing MPA network in Northern Ireland includes six SACs, nine SPAs in addition to national nature conservation designations in the form of a single MCZ and ASSIs. The additional network area, based on the 'priority gap cells' identified as part of the network coherence assessment, would consist of a series of MCZs. For valuation purposes our focus here is on the change in the amount of area protected, i.e. the difference between the total area covered by the present MPA network in Northern Ireland's inshore waters and the total area of the proposed MPA network (columns 8 and 9 in Table 4.3 below).

A summary of the proposed Northern Ireland MPA network is presented in Table 4.4, disaggregated by landscape/habitat types, and compared with the UK marine environment.



Transverse Mercator Projection centred on the Irish Sea
Datumn WGS84 Scale 1:1,000,000

Data acknowledgement: Cameron & Askew (2011)

Figure 4.3 JNCC Marine Landscape types in Northern Ireland inshore waters

Table 4.2 Assignment of Sea Loughs and Bays to appropriate JNCC marine landscape types (area below mean low water springs only)

Sea Loughs & Bays	Total Area (km^2)	JNCC Marine Landscape Type					
		Shallow strong tide stress coarse sediment (L11)		Shallow mud (L17)		Shallow sand (L18)	
		Area (km^2)	%	Area (km^2)	%	Area (km^2	%
Belfast Lough (Bay)	90.04	0	0.00	23.69	26.31	66.35	73.69
Strangford Lough	56.31	8.61	15.29	34.52	61.30	13.18	23.41
Dundrum Bay	62.95	0	0.00	10.62	16.87	52.33	83.13
Carlingford Lough	42.81	15.2	35.51	11.23	26.23	16.38	38.26
Larne Lough	5.01	0	0.00	1.46	29.14	3.55	70.86

Table 4.3 Extent of landscape/habitats within existing and proposed NI MPA networks (compared with the UK total). Shaded cells refer to landscape/habitat types not protected in NI waters.

Codes	Marine habitats	UK Total	Present NI MPA Network		Proposed NI MPA Network		Additional MPA Sites	
		Area (km^2)	Area (km^2)	% Protected	Area (km^2)	% Protected	Area (km^2)	% Protected
L1	Aphotic reefs	10,968	52.65	0.48	56.73	0.52	4.08	0.04
L2	Oceanic cold water coarse sediment	386	0.00	0.00	0.00	0.00	0.00	0.00
L3	Oceanic cold water mixed sediment	4,880	0.00	0.00	0.00	0.00	0.00	0.00
L4	Oceanic cold water mud	23,509	0.00	0.00	0.00	0.00	0.00	0.00
L5	Oceanic cold water sand	5,597	0.00	0.00	0.00	0.00	0.00	0.00
L6	Oceanic warm water coarse sediment	3,781	0.10	0.00	0.10	0.00	0.00	0.00
L7	Oceanic warm water mixed sediment	5,407	0.00	0.00	0.00	0.00	0.00	0.00
L8	Oceanic warm water mud	56,327	0.00	0.00	0.00	0.00	0.00	0.00
L9	Oceanic warm water sand	6,076	0.00	0.00	0.00	0.00	0.00	0.00
L10	Photic reef	7,155	3.29	0.05	3.29	0.05	0.00	0.00
L11	Shallow strong tide stress coarse sediment	2,840	4.70	0.17	4.70	0.17	0.00	0.00
L12	Shallow moderate tide stress coarse sediment	16,745	51.37	0.31	51.37	0.31	0.00	0.00
L13	Shallow weak tide stress coarse sediment	33,694	15.86	0.05	21.70	0.06	5.84	0.02
L14	Shallow strong tide stress mixed sediment	952	0.01	0.00	0.01	0.00	0.00	0.00
L15	Shallow moderate tide stress mixed sediment	2,021	0.78	0.04	0.78	0.04	0.00	0.00
L16	Shallow weak tide stress mixed sediment	2,922	10.34	0.35	19.61	0.67	9.27	0.32
L17	Shallow mud	6,893	130.10	1.89	146.52	2.13	16.42	0.24
L18	Shallow sand	48,218	254.71	0.53	263.13	0.55	8.41	0.02
L19	Shelf strong tide stress coarse sediment	2,840	0.50	0.02	0.50	0.02	0.00	0.00
L20	Shelf moderate tide stress coarse sediment	17,433	15.41	0.09	15.41	0.09	0.00	0.00
L21	Shelf weak tide stress coarse sediment	76,492	11.87	0.02	34.27	0.04	22.39	0.03
L22	Shelf strong tide stress mixed sediment	285	0.00	0.00	0.00	0.00	0.00	0.00
L23	Shelf moderate tide stress mixed sediment	2,260	0.00	0.00	0.00	0.00	0.00	0.00
L24	Shelf weak tide stress mixed sediment	3,951	11.87	0.30	41.93	1.06	30.05	0.76
L25	Shelf mud	44,605	0.00	0.00	204.41	0.46	204.41	0.46
L26	Shelf sand	215,215	8.08	0.00	28.55	0.01	20.46	0.01
TDH1	Carbonate mounds	233	0.00	0.00	0.00	0.00	0.00	0.00
TDH2	Lophelia pertusa reefs	1,855	0.00	0.00	0.00	0.00	0.00	0.00
TDH3	Maerl beds	357	11.25	3.15	12.39	3.47	1.14	0.32
TDH4	Modiolus modiolus beds	220	17.27	7.85	17.49	7.95	0.22	0.10
TDH5	Ostrea edulis beds	14	0.92	6.54	0.96	6.84	0.04	0.30
TDH6	Sabellaria spinulosa reefs	105	0.00	0.00	0.00	0.00	0.00	0.00
TDH7	Sea mounts	61	0.00	0.00	0.00	0.00	0.00	0.00
TDH8	Sea-pen and burrowing megafauna communities	3,118	18.71	0.60	18.71	0.60	0.00	0.00
TDH9	Zostera beds	1,217	17.52	1.44	17.89	1.47	0.37	0.03
	TOTAL	**608,632**	**637.30**		**960.42**		**323.12**	

Table 4.4 Summary of the Northern Ireland MPA network statistics (compared with the UK total landscapes/habitat types).

UK Marine Environment	Area (km^2)	%
Total UK Marine Landscape/Habitats	608,632	100.00
UK landscapes/habitats protected by current MPA Network	637	0.10
UK landscapes/habitats protected by proposed MPA Network	960	0.16
Additional habitat protected by proposed MPAs	323	0.05
JNCC Marine Landscapes	**Area (km^2)**	**%**
Total UK Marine Landscape	601,452	100.00
Marine landscapes protected by current MPA network	572	0.10
Marine landscapes protected by proposed MPA network	893	0.15
Additional marine landscapes protected by proposed MPAs	321	0.05
OSPAR Threatened and Declining Habitat (TDH) types	**Area (km^2)**	**%**
Total UK OSPAR TDH	7,180	100.00
TDH types protected by current MPA network	66	0.91
TDH types protected by proposed MPA network	67	0.94
Additional TDH types protected by proposed MPAs	2	0.03

4.3.3 ASSUMPTIONS AND LIMITATIONS

The JNCC marine landscapes are a modelled continuous surface of very broad habitat types. Within the existing economic analysis, it appears that the footprint of the OSPAR habitats has not been deducted from the background landscape, i.e. they both co-exist spatially. At the UK level, OSPAR TDH cover 1% of the total seabed area (not the MPA network). However, as the Northern Irish analysis is focused on the MPA network and this increases the reporting, and hence relative proportion of the OSPAR TDH. For example, the seabed area currently protected in Northern Ireland inshore waters is 637.30km^2, and of this area 65.67km^2 (10.3%) contains OSPAR TDH types. The change in the relative proportion of the OSPAR TDH between the UK seabed and the NI MPA network is based on the differing sea areas, and it being exclusively contained in MPAs in NI. Had the entirety of the Northern Ireland seabed been examined then it would be likely that the OSPAR TDH proportion would have been closer to 1%.

In addition, the OSPAR TDH types, which are based on observational data, have been transposed into area data by Richardson *et al.* (2006). However, since those area data were first produced further observational data have become available. The area data have therefore been updated here using the more recent observational data for UK waters and Northern Ireland inshore waters, and the areas again assigned to each OSPAR TDH on a proportionate basis i.e. based on the number of observations in Northern Ireland's waters as a proportion of those obtained in the UK as a whole. While this method assumes that the areas of each habitat type have remained constant, it now reflects a current assessment of Northern Ireland's contribution to protection of these habitats at a UK level.

Note that while the extended MPA network covers approximately 331km^2, the analysis in this report is for an additional designation of 323km^2. The difference between these two areas (8km^2) is due to the absence of intertidal data in the JNCC marine landscape datasets. This margin appears very small, however this reflects that very few of the gap grid cells identified are adjoining the shore with most of them located further offshore (see Figure 4.2).

4.4 Economic Valuation Estimates

This section covers Stages 3-8 of the methodology associated with the estimation of economic values of the proposed Northern Ireland MPA network for inshore waters as outlined in Figure 4.1, and reports the findings. This section should be read in conjunction with Annexes E - I.

4.4.1 Review of the literature to find estimates for the total aggregated value of the ecosystem services provided by the UK marine environment

The first stage in the economic valuation collates evidence from the literature on the total economic value of the UK marine environment. For consistency with Moran *et al.* (2008) and González-Álvarez *et al.* (2012), the ecosystem service framework applied here follows that of Beaumont *et al.* (2006) which was developed from international literature on ecosystem services such as the Millennium Ecosystem Assessment (MA, 2005) (Table 4.5). It should be noted that the Beaumont *et al.* (2006) framework is not fully consistent with recent ecosystem service frameworks of The Economics of Ecosystems and Biodiversity (TEEB) (Kumar, 2010) and of the UK National Ecosystem Assessment Follow-On Project (Turner *et al.*, 2013). As noted above, there was no scope within the current project to undertake primary data collection and therefore the estimates of value were based on market analysis and benefit transfer methodologies. Given that evidence is limited, economic valuation data was collated from literature at the UK level and then values were inferred for the devolved nations, thus keeping the methodology applied here consistent with that of Moran *et al.* and González-Álvarez *et al.*

Table 4.5 Ecosystem service framework (Beaumont *et al*., 2006).

Code	Good/Service	Definition
E1	Nutrient cycling	The storage, recycling and maintenance of availability of nutrients mediated by living marine organisms
E2	Bioremediation of waste	Removal of pollutants through storage, dilution, transformation and burial
E3	Gas and climate regulation	The balance and maintenance of the chemical composition of the atmosphere and oceans by marine living organisms
E4	Food provision	Plants and animals taken from the marine environment for human consumption
E5	Raw materials	The extraction of marine organisms for all purposes, except human consumption
E6	Biologically mediated habitat	Habitat which is provided by living marine organisms
E7	Resilience and resistance	The extent to which ecosystems can absorb recurrent natural and human perturbations and continue to regenerate without slowly degrading
E8	Disturbance prevention and alleviation	The dampening of environmental disturbance by biogenic structures
E9	Leisure and recreation	The refreshment and stimulation of the human body and mind through the perusal and engagement with living marine organisms in their natural environment
E10	Cultural heritage and identity	The cultural value associated with the marine environment e.g. for religion, folklore, painting, cultural and spiritual traditions
E11	Non-use values - bequest and existence	Value which we derive from marine organisms without using them
E12	Option use values	Currently unknown potential future uses of marine environment
E13	Cognitive values	Cognitive development, including education and research, resulting from marine organisms

A review of the UK economic valuation literature has been presented in Beaumont *et al.* (2006), Moran *et al.* (2008) and González-Álvarez *et al.* (2012). The readers are referred to these reports for a fuller discussion of this literature. Table 4.6 presents a summary of the UK valuation estimates for each of the ecosystems service categories as reported in those three reports, along with additional estimates made as part of the current study. On the current study's estimates, Annex E contains details of the estimations used in the current study to generate UK economic valuation estimates for marine ecosystem services. These values relate to the on-site ecosystem services arising from MPA designation and are based on the similar evidence base as employed in those other reports, with adjustments so that results can be reported in current (2012) prices. Estimated values are reported as point estimates for most services although estimated ranges of values are reported for gas and climate regulation, leisure and recreation, and non-use values. Estimates based on a range of values are common with this type of analysis where data is often reported in different formats and by different sources, giving the analyst some discretion as to which sources of data to employ in the analysis. For the purposes of the valuation estimates, the upper range has been selected (following Moran *et al.*, 2008), with the exception of non-use values where a median 'best estimate' value was applied (following González-Álvarez *et al.*, 2012). The ranges presented here have been used in an analysis to assess the sensitivity of the findings to the choice of valuation data i.e. to examine the impact that changes in the selection of ecosystem service value have on the overall value (see Section 4.4.6). As noted previously, despite an increase in ecosystem services research over the last decade, there are still a number of ecosystem services where valuation data at the UK level is still not available (those services are bioremediation of waste, biologically mediated habitat, resilience and resistance, cultural heritage and identity, and option use values), and so the total economic value of marine ecosystem services provided here for UK waters is considered to be an underestimate of the potential benefits secured.

Table 4.6 An overview of the total aggregated value of ecosystem goods and services provided by the UK environment

Code	Good/Service	Beaumont et al., 2006 Monetary Value (£ 2004)	Moran et al., 2008 Monetary Value (£ 2006)	González-Álvarez et al., 2011 Monetary Value (£ 2011)	Present Study Monetary Value (£ 2012)
E1	Nutrient cycling	£800-£2,320 billion*	£1.3 billion	£1.8 billion	£1.86 billion
E2	Bioremediation of waste	Valuation data not available	Valuation data not available	Valuation data not available	Valuation data not available
E3	Gas and climate regulation	£0.4-8.47 billion	£8.2 billion	£7.1 billion	£7.21-7.23 billion
E4	Food provision	£513 million	£884.9 million	£1.2 billion	£1.12 billion
E5	Raw materials	£81.5 million	£116.5 million	£152.8 million	£0.10 billion
E6	Biologically mediated habitat	Valuation data not available	Valuation data not available	Valuation data not available	Valuation data not available
E7	Resilience and resistance	Valuation data not available	Valuation data not available	Valuation data not available	Valuation data not available
E8	Disturbance prevention and alleviation	£0.3 billion (Maintenance costs) £17-32 billion (Capital costs)	£0.44 billion	£0.54 billion	£0.40 billion (Maintenance costs) £21.3-40.2 billion (Capital costs)
E9	Leisure and recreation	£11.77 billion	£1.4-3.4 billion	£1.8-4.4 billion	£1.68-4.09 billion
E10	Cultural heritage and identity	Valuation data not available	Valuation data not available	Valuation data not available	Valuation data not available
E11	Non-use values - bequest and existence	£0.5-1.1 billion	Not assessed	£0.6-3.9 billion	£0.62-4.01 billion £1.44 billion (Best estimate)
E12	Option use values	Valuation data not available	Valuation data not available	Valuation data not available	Valuation data not available
E13	Cognitive values	£317 million (2002 value)	£453.3 million	£491.1 million	£0.41 billion

4.4.2 Attributing aggregate ecosystem service values across the different marine landscape/habitat types

The total UK annual benefit provided by each marine ecosystem service category is shared between landscape/habitat types (Table 4.7) where the shares reflect the relative importance of the landscape/habitat type to the provision of that particular ecosystem service in the context of the UK as a whole. The detailed methodology for establishing the shares is provided in Annex F. In brief, the individual ecosystem service categories (E1-E13) were linked through expert judgement to one of four coding types (A-D), and each of the four coding types identifies the relative impact (low, medium, high or equal) on the provision of an ecosystem service of a unit area of a given landscape/habitat type (Table 6.9, Annex F). These impact scores were then used to adjust the area share (the '% Area' column in Table 6.10 and 6.11, Annex F) of each landscape/habitat type for their relative impact (the 'multi' columns in Table 6.10 and 6.11, Annex F), so that their share contribution to the value of the aggregate UK ecosystem service could be established (the '%TV' columns in Table 6.10 and 6.11, Annex F). These percentage shares which are presented in full in Table 4.7 below are used in the next stage of the valuation estimation. Since these are percentage shares, the columns for each ecosystem service must sum to 100.

Table 4.7 Proportion of total UK annual benefit from ecosystem service categories (E1-E13) attributed to JNCC landscape (L1-L26) and OSPAR TDH types (TDH1-TDH9) (Shaded cells refer to landscape/habitat types not protected in NI waters).

Code	JNCC Marine Landscape/OSPAR TDH	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		%TV	%TV	%TV	%TV	%TV	%TV	%TV	%TV	%TV	%TV	%TV	%TV	%TV
L1	Aphotic reefs	0.72	0.72	0.72	1.60	4.37	1.80	1.80	1.80	2.86	2.86	2.86	2.86	2.86
L2	Oceanic cold water coarse sediment	0.05	0.05	0.05	0.06	0.05	0.06	0.06	0.06	2.86	2.86	2.86	2.86	2.86
L3	Oceanic cold water mixed sediment	0.64	0.64	0.64	0.71	0.65	0.80	0.80	0.80	2.86	2.86	2.86	2.86	2.86
L4	Oceanic cold water mud	3.07	3.07	3.07	3.43	3.12	3.86	3.86	3.85	2.86	2.86	2.86	2.86	2.86
L5	Oceanic cold water sand	0.73	0.73	0.73	0.82	0.74	0.92	0.92	0.92	2.86	2.86	2.86	2.86	2.86
L6	Oceanic warm water coarse sediment	0.49	0.49	0.49	0.55	0.50	0.62	0.62	0.62	2.86	2.86	2.86	2.86	2.86
L7	Oceanic warm water mixed sediment	0.71	0.71	0.71	0.79	0.72	0.89	0.89	0.89	2.86	2.86	2.86	2.86	2.86
L8	Oceanic warm water mud	7.36	7.36	7.36	8.22	7.48	9.25	9.25	9.24	2.86	2.86	2.86	2.86	2.86
L9	Oceanic warm water sand	0.79	0.79	0.79	0.89	0.81	1.00	1.00	1.00	2.86	2.86	2.86	2.86	2.86
L10	Photic reef	0.94	0.94	0.94	1.04	2.85	1.18	1.18	1.17	2.86	2.86	2.86	2.86	2.86
L11	Shallow strong tide stress coarse sediment	0.37	0.37	0.37	0.41	0.75	0.47	0.47	0.47	2.86	2.86	2.86	2.86	2.86
L12	Shallow moderate tide stress coarse sediment	2.19	2.19	2.19	2.44	4.45	2.75	2.75	2.75	2.86	2.86	2.86	2.86	2.86
L13	Shallow weak tide stress coarse sediment	4.40	4.40	4.40	7.37	8.95	5.54	5.54	5.52	2.86	2.86	2.86	2.86	2.86
L14	Shallow strong tide stress mixed sediment	0.12	0.12	0.12	0.14	0.25	0.16	0.16	0.16	2.86	2.86	2.86	2.86	2.86
L15	Shallow moderate tide stress mixed sediment	0.26	0.26	0.26	0.29	0.54	0.33	0.33	0.33	2.86	2.86	2.86	2.86	2.86
L16	Shallow weak tide stress mixed sediment	0.57	0.57	0.57	0.43	0.78	0.48	0.48	0.48	2.86	2.86	2.86	2.86	2.86
L17	Shallow mud	1.35	1.35	1.35	1.01	0.92	1.13	1.13	1.13	2.86	2.86	2.86	2.86	2.86
L18	Shallow sand	9.45	9.45	9.45	7.03	12.81	7.92	7.92	7.91	2.86	2.86	2.86	2.86	2.86
L19	Shelf strong tide stress coarse sediment	0.37	0.37	0.37	0.21	0.38	0.47	0.47	0.47	2.86	2.86	2.86	2.86	2.86
L20	Shelf moderate tide stress coarse sediment	2.28	2.28	2.28	2.54	2.32	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86
L21	Shelf weak tide stress coarse sediment	10.00	10.00	10.00	16.74	10.16	12.57	12.57	12.54	2.86	2.86	2.86	2.86	2.86
L22	Shelf strong tide stress mixed sediment	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	2.86	2.86	2.86	2.86	2.86
L23	Shelf moderate tide stress mixed sediment	0.30	0.30	0.30	0.33	0.30	0.37	0.37	0.37	2.86	2.86	2.86	2.86	2.86
L24	Shelf weak tide stress mixed sediment	0.77	0.77	0.77	0.58	0.52	0.65	0.65	0.65	2.86	2.86	2.86	2.86	2.86
L25	Shelf mud	8.74	8.74	8.74	9.76	5.93	7.33	7.33	7.31	2.86	2.86	2.86	2.86	2.86
L26	Shelf sand	42.19	42.19	42.19	31.40	28.60	35.36	35.36	35.29	2.86	2.86	2.86	2.86	2.86
TDH1	Carbonate mounds	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	2.86	2.86	2.86	2.86	2.86
TDH2	*Lophelia pertusa* reefs	0.12	0.12	0.12	0.27	0.25	0.30	0.30	0.30	2.86	2.86	2.86	2.86	2.86
TDH3	*Maerl* beds	0.05	0.05	0.05	0.05	0.09	0.06	0.06	0.06	2.86	2.86	2.86	2.86	2.86
TDH4	*Modiolus modiolus* beds	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.04	2.86	2.86	2.86	2.86	2.86
TDH5	*Ostrea edulis* beds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	2.86	2.86	2.86	2.86
TDH6	*Sabellaria spinulosa* reefs	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	2.86	2.86	2.86	2.86	2.86
TDH7	Sea mounts	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	2.86	2.86	2.86	2.86	2.86
TDH8	Sea-pen and burrowing megafauna communities	0.61	0.61	0.61	0.68	0.41	0.51	0.51	0.51	2.86	2.86	2.86	2.86	2.86
TDH9	*Zostera* beds	0.24	0.24	0.24	0.09	0.16	0.20	0.20	0.40	2.86	2.86	2.86	2.86	2.86
	TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

4.4.3 THE CURRENT STATUS OF EACH MARINE LANDSCAPE/HABITAT TYPE AND THEIR FATE IF THERE WERE NO ADDITIONAL MPA DESIGNATIONS

An assessment of the *status quo* scenario is used as a baseline from which to assess the potential impacts of both the 'recover' (HR-MPA) and 'maintain' (MCS-MPA) management regimes in the Northern Ireland context. This follows the two stage procedure established by Moran *et al.* (2008).

First, related to the methodological approach outlined in Section 4.4.2 and Annex F, a combination of evidence derived from a literature review and expert opinion was applied by Moran *et al.* to assess the level of current understanding of the relationship, depicted as a matrix, between marine landscape/habitat types and their relative provision of ecosystem services. The supporting evidence comprising specific explanations for each landscape/habitat type is presented in Annex G. The assessment showed that of the full matrix of 455 cells there was a high level of understanding relating to 166 cells (36.5%), a medium level of understanding relating to 203 cells (44.6%) and a low understanding relating to 86 cells (18.9%) as identified in Table 4.8.

Secondly, Moran *et al*. investigated how the provision of ecosystem services by the marine landscape/habitat types change under the *status quo* scenario where management of the existing MPA network continues but no additional MPAs are designated. A 20-year period was selected for determining the benefits that are secured over time by the MPAs with the choice of 20-years following from the guidelines of the UK Cabinet Office for undertaking impact assessments. The trajectory of the impact path determining when the benefit was realised over the 20 year period was also allowed to vary between cells, alternatively allowing the benefits to be realised at the start, at the end and, as is most frequently the case, linearly throughout the period. The assessment comprises the identification of three main elements:

- The impact of the management regime and categorised by the percentage loss of each ecosystem service over a 20-year period. The impacts were categorised as very high (VH, 90-100% loss), high (H, 50-89% loss), medium (M, 10-49% loss), low (L, 1-9% loss) or very low (VH, <1% loss).
- The timing that the maximum benefit is realised in the 20-year period.
- The trajectory of the impact path. That is, whether the benefits were realised at the start (S), end (E) or linearly (L) throughout the 20 year period.

A detailed methodology is presented in Annex H, with the results presented in Table 6.12, (Annex H). For the impact of the *status quo* scenario, very high or high impacts were identified within 123 cells (27%) which are shaded red, medium impacts were identified within 198 cells (44%) shaded amber, and low or very low impacts were identified within 134 cells (29%) shaded green.

Table 4.8 Summary of the extent of knowledge of the link between marine landscape/habitat type and the delivery of ecosystem services.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	H	H	H	H	M	H	H	H	H	M	M	M	M
L2	Oceanic cold water coarse sediment	L	L	L	L	L	L	L	H	M	L	L	L	M
L3	Oceanic cold water mixed sediment	L	L	L	L	L	L	L	H	M	L	L	L	M
L4	Oceanic cold water mud	L	L	L	L	L	L	L	H	M	L	L	L	M
L5	Oceanic cold water sand	L	L	L	L	L	L	L	H	M	L	L	L	M
L6	Oceanic warm water coarse sediment	L	L	L	L	L	L	L	H	M	L	L	L	M
L7	Oceanic warm water mixed sediment	L	L	L	L	L	L	L	H	M	L	L	L	M
L8	Oceanic warm water mud	L	L	L	L	L	L	L	H	M	L	L	L	M
L9	Oceanic warm water sand	L	L	L	L	L	L	L	H	M	L	L	L	M
L10	Photic reef	H	H	H	H	M	H	H	H	H	M	M	M	M
L11	Shallow strong tide stress coarse sediment	M	M	M	H	M	H	H	H	H	M	M	M	M
L12	Shallow moderate tide stress coarse sediment	M	M	M	H	M	H	H	H	H	M	M	M	M
L13	Shallow weak tide stress coarse sediment	M	M	M	H	M	H	H	H	H	M	M	M	M
L14	Shallow strong tide stress mixed sediment	M	M	M	H	M	H	H	H	H	M	M	M	M
L15	Shallow moderate tide stress mixed sediment	M	M	M	H	M	H	H	H	H	M	M	M	M
L16	Shallow weak tide stress mixed sediment	M	M	M	H	M	H	H	H	H	M	M	M	M
L17	Shallow mud	H	H	H	H	M	H	H	H	H	M	M	M	M
L18	Shallow sand	H	H	H	H	M	H	H	H	H	M	M	M	M
L19	Shelf strong tide stress coarse sediment	M	M	M	H	M	M	M	H	H	M	M	M	M
L20	Shelf moderate tide stress coarse sediment	M	M	M	H	M	M	M	H	H	M	M	M	M
L21	Shelf weak tide stress coarse sediment	M	M	M	H	M	M	M	H	H	M	M	M	M
L22	Shelf strong tide stress mixed sediment	M	M	M	H	M	M	M	H	H	M	M	M	M
L23	Shelf moderate tide stress mixed sediment	M	M	M	H	M	M	M	H	H	M	M	M	M
L24	Shelf weak tide stress mixed sediment	M	M	M	H	M	M	M	H	H	M	M	M	M
L25	Shelf mud	H	H	H	H	M	H	H	H	H	M	M	M	M
L26	Shelf sand	H	H	H	H	M	H	H	H	H	M	M	M	M
TDH1	Carbonate mounds	L	L	L	M	M	H	H	H	M	M	H	M	H
TDH2	Lophelia pertusa reefs	L	L	L	M	M	H	H	H	M	M	H	M	H
TDH3	Maerl beds	M	M	M	H	H	H	H	H	H	M	H	M	H
TDH4	Modiolus modiolus beds	M	M	M	H	M	H	H	H	H	M	H	M	H
TDH5	Ostrea edulis beds	M	M	M	H	M	H	H	H	H	H	H	M	H
TDH6	Sabellaria spinulosa reefs	M	M	M	M	M	H	H	H	H	M	H	M	H
TDH7	Sea mounts	M	M	M	M	M	H	H	H	M	M	H	M	H
TDH8	Sea-pen and burrowing megafauna communities	M	M	M	M	M	H	H	H	H	M	H	M	H
TDH9	Zostera beds	H	H	H	H	H	H	H	H	H	H	H	M	H

H = High, M=Medium, L=Low

4.4.4 CONSIDERATION OF THE EFFECTS OF DIFFERENT MANAGEMENT REGIMES ON EACH LANDSCAPE/HABITAT TYPE BY CATEGORY OF ECOSYSTEM SERVICES IN COMPARISON WITH THE STATUS QUO SCENARIO.

The coding scheme developed for assessing the impacts of the *status quo* regime is also employed to assess the effects of the two management regimes to enable comparison with the *status quo* regime. A detailed methodology and the results of the analysis for both the recover (HR-MPA) and maintain (MCS-MPA) management regimes are presented in Annex H. Table 6.13 and Table 6.14 indicate the differences in the impacts of the management regimes which are reflected by the different cell codes that result. In the case of the recover management regime, 58% of cells (262 out of 455) were predicted to have a high or very high positive impact on ecosystem service provision under the recover option (shaded red), 9% of cells (43 out of 455) to have a medium positive impact (shaded amber), whilst the remaining 33% of cells (150 out of 155) were considered to provide a low or very low impact (shaded green). In the case of the maintain management regime, 49% of cells (222 out of 455) predicted to have a high or very high positive impact on ecosystem service provision (shaded red), 18% of cells (81 out of 455) to have a medium positive impact (shaded amber), and 33% of cells (152 out of 455) to provide a low or very low positive impact under the MCS-MPA option (shaded green).

4.4.5 ECONOMIC VALUATION OF THE EFFECTS OF PROPOSED PROTECTION MEASURES (MANAGEMENT REGIMES) BY LANDSCAPE/HABITAT TYPE AND ECOSYSTEM SERVICE CATEGORY.

The next stage in the procedure is to estimate the value of the impact of the management regimes on the additional proposed MPAs in Northern Ireland waters net of the value of the *status quo* regime.

The main findings are presented below as net present values. Present values have been calculated for benefits to account for when they occur over the 20-year period of investigation. All values are presented as 2012 values and inflation is not considered. Present values are calculated using discounting and a discount rate of 3.5% was employed, based on government guidance (HM Treasury, 2011). The use of such discounting implies that benefits secured in earlier periods have a higher present value than equivalent benefits secured later in the period. It is recognised that there will be benefits beyond the 20 year period. The findings are also presented as undiscounted annual mean values. If values are undiscounted then no allowance in the assessment would be given for the timing of when the benefit is secured.

This stage of the methodology involves three main tasks which were undertaken for each of the ‘recover’ and ‘maintain’ management regimes. A more detailed explanation of the tasks is presented in Annex I. Briefly:

1. An appropriate share of the total value of UK marine ecosystem services is assigned to each landscape/habitat type and ecosystem service pairing for the additional proposed MPA network in Northern Ireland waters. The relative share is assigned by combining the ‘area change’ evidence for the additional proposed MPA network presented in Table 4.3 with the evidence on ‘percentage share of total value’ presented in Table 4.7. This procedure allows due allowance to be made for the fact that Northern Ireland waters are only a part of the UK marine environment. The results are presented in Table 6.17, Annex I.

2. The present value of the benefits of each landscape/habitat type and ecosystem service pairing is derived for the proposed MPA network in Northern Ireland waters under the two management scenarios, net of the equivalent values associated with the *status quo* regime. The present value of benefits is established by calculating the product of the 'scalar coefficients' presented in Table 6.18 and the 'percentages of total economic value' given in Table 6.17, with the results presented in Table 6.19.
3. Finally, we establish the present value of each ecosystem service across all landscape/habitat types for the additional proposed MPA network in Northern Ireland waters under two management scenarios, net of the equivalent values associated with the *status quo* regime. This is based on summing for each ecosystem service the present values for each landscape/habitat type (column totals in Table 6.19, Annex I) and then multiplying this by the proportion (%) of the total UK value of that ecosystem service (see Table 4.10).

The net present value results disaggregated by ecosystem service type for both management regimes are presented in Table 4.9 and Table 4.10. Most of the additional benefits secured under both management regimes is associated with the 'gas and climate regulation' service, with this service accounting for 59% and 61% of the total additional benefits under the 'recover' and 'maintain' management regimes, respectively. The benefits secured from extractive activities, reflecting 'food provision' and 'raw materials' services, are greater under the 'maintain' management regime than under recovery. This finding follows from the characteristics of the 'recover' management regime where all constructive, destructive and disturbing activities would be restricted. It may be expected that under the recover management regime that the benefits from provisioning services would be driven to zero, however as noted by Moran et al., in reality this would be achieved over a period of time through the withdrawal of activities, non-awarding of new permits/licences etc., hence some benefits will still be observed under this management regime. Both 'non-use' and 'cognitive values' are greater under the 'recover' management option.

When the findings are presented as undiscounted annual mean values under the 'recover' and 'maintain' management options (Table 4.11 and Table 4.12), similar differences can be observed. Again, the majority of additional benefits are secured from the 'gas and climate regulation' service. However, it is interesting to note that when the data are presented as undiscounted annual mean values, there are no additional benefits received from the provisioning services ('food provision' and 'raw materials') under the 'recover' management regime, with only a slight increase in benefit from 'food provision' under the maintain management regime reflecting in part the magnitude of the scalar co-efficients.

Table 4.9 Net present value of protecting the additional proposed MPA sites under the 'recover' management regime.

Code	Ecosystem Service	Total UK Value (£)	% of Total UK Value	Total benefit from additional NI MPA network(£)
E1	Nutrient cycling	1,859,468,111	0.4564	**8,487,297**
E3	Gas and climate regulation	7,229,567,022	0.4564	**32,998,407**
E4	Food provision	1,116,935,000	0.0006	**7,157**
E5	Raw materials	102,290,816	0.0005	**484**
E8	Disturbance prevention and alleviation	396,656,424	0.0011	**4,498**
E9	Leisure and recreation	4,087,976,540	0.0989	**4,043,709**
E11	Non-use values - bequest and existence	1,439,799,331	0.4823	**6,944,062**
E13	Cognitive values	408,710,692	0.4823	**1,971,186**

Table 4.10 Net present value of protecting all proposed additional Northern Ireland MPA sites under the 'maintain' management regime.

Code	Ecosystem Service	Total UK Value (£)	% of Total UK Value	Total benefit from additional NI MPA network(£)
E1	Nutrient cycling	1,859,468,111	0.4460	**8,293,537**
E3	Gas and climate regulation	7,229,567,022	0.4460	**32,245,071**
E4	Food provision	1,116,935,000	0.0065	**72,968**
E5	Raw materials	102,290,816	0.0025	**2,594**
E8	Disturbance prevention and alleviation	396,656,424	0.0013	**4,984**
E9	Leisure and recreation	4,087,976,540	0.0995	**4,068,369**
E11	Non-use values - bequest and existence	1,439,799,331	0.4400	**6,335,169**
E13	Cognitive values	408,710,692	0.4400	**1,798,342**

Table 4.11 Undiscounted mean annual values (£) for protecting the entire Northern Ireland MPA network under the 'recover' management regime.

Code	Ecosystem Service	Total UK Value (£)	% of Total UK Value	Total benefit from additional NI MPA network (£)
E1	Nutrient cycling	1,859,468,111	0.0381	**708,857**
E3	Gas and climate regulation	7,229,567,022	0.0381	**2,756,020**
E4	Food provision	1,116,935,000	0.0000	**0**
E5	Raw materials	102,290,816	0.0000	**0**
E8	Disturbance prevention and alleviation	396,656,424	0.0001	**543**
E9	Leisure and recreation	4,087,976,540	0.0094	**384,841**
E11	Non-use values - bequest and existence	1,439,799,331	0.0454	**654,115**
E13	Cognitive values	408,710,692	0.0454	**185,681**

Table 4.12 Undiscounted mean annual values (£) for protecting the additional proposed Northern Ireland MPA network under the 'maintain' management regime.

Code	Ecosystem Service	Total UK Value (£)	% of Total UK Value	Total benefit from additional NI MPA network (£)
E1	Nutrient cycling	1,859,468,111	0.0372	**692,291**
E3	Gas and climate regulation	7,229,567,022	0.0372	**2,691,611**
E4	Food provision	1,116,935,000	0.0002	**1,927**
E5	Raw materials	102,290,816	0.0000	**0**
E8	Disturbance prevention and alleviation	396,656,424	0.0001	**543**
E9	Leisure and recreation	4,087,976,540	0.0099	**406,405**
E11	Non-use values - bequest and existence	1,439,799,331	0.0419	**602,934**
E13	Cognitive values	408,710,692	0.0419	**171,153**

4.4.6 AGGREGATION OF TOTAL ECONOMIC VALUES

The total economic value estimated for the sum of all ecosystem services are presented below (Table 4.13). Overall, the estimated results indicate that potential benefits secured are £52.8 million under the 'maintain' management regime and £54.5 million under the 'recover' management regime. Of course, point estimates of this type suggest a degree of accuracy that is inconsistent with the analysis undertaken and so need to be interpreted as being simply indicative of the scale of benefits that might be secured from the additional proposed MPA network (some assumptions and limitations of the methodology are discussed further below). Undiscounted mean annual benefits range from £4.6 million under the 'maintain' management regime to £4.7 million under the more restrictive 'recover' management regime.

The results suggest the value differs with management regime, being £1.64 million greater when the 'recover' management regime is applied across the entire additional MPA network than when the 'maintain' regime is applied. To assess the impact on the totals economic value of the network being subject to the greatest protection (i.e. HR-MPA), the aggregate values were re-estimated assuming different proportions of the two management regimes. The range presented in the table comprises between 10% and 30% of the network being managed using a 'recover' regime (HR-MPA) with the remainder of the network (90-70% respectively) being managed by the 'maintain' (MCS-MPA) regime (Table 4.13). Net present values increase slightly from £52.98 million to £53.31 million when the proportion of the network managed by the 'recover' management regime increases from 10% to 30%. When analysing changes in the undiscounted mean annual benefits, a slight increase from £4.58 million to £4.60 million is observed for a similar change in management regimes.

Table 4.13 Summary of the net present value and undiscounted mean annual benefit of five different management scenarios.

% Maintain	% Recover	Net present values (£) (3.5% discount rate)	Undiscounted mean annual benefits (£)
100	0	52,821,034	4,566,863
90	10	52,984,610	4,579,182
80	20	53,148,187	4,591,502
70	30	53,311,763	4,603,821
0	100	54,456,800	4,690,057

Sensitivity analysis can be used for a number of purposes including testing for the robustness of the results and to increase our understanding of the relationship between the input and output variables of a system or model. The methodological approach developed by Moran *et al.* (2008) and applied here may lead to outcomes that are sensitive to the assumptions made at different methodological stages of the analysis. One of the areas of sensitivity relates to the UK aggregate benefit estimates. For a number of ecosystem services (gas and climate regulation, leisure and recreation, and non-use value), a range of values were estimated. These ranges were further investigated for the sensitivity analysis. The estimations of net present value under both management options were re-calculated to provide a low and high total value (Table 4.14 and Table 4.15). Comparisons with the study findings (Table 4.16) show that using the lower estimates results in an overall decrease in total value of around 10-11%, whereas using the higher estimates results in an overall increase in total value of 22-24%. Taking the lower estimates as a ‘worst case scenario’ still provides net values at the present time of £48.1 million and £46.8 million for the ‘recover’ and ‘maintain’ management regimes respectively.

Table 4.14 Comparison of net present value under the ‘recover’ management regime using low and high estimates of total UK values.

Code	Ecosystem Service	Total UK Value (£) Low	Total UK Value (£) High	% Total UK Value	Low Total (£)	High Total (£)
E1	Nutrient cycling	1,859,468,111	1,859,468,111	0.4564	**8,487,297**	**8,487,297**
E3	Gas and climate regulation	7,218,734,187	7,229,567,022	0.4564	**32,948,962**	**32,998,407**
E4	Food provision	1,116,935,000	1,116,935,000	0.0006	**7,157**	**7,157**
E5	Raw materials	102,290,816	102,290,816	0.0005	**484**	**484**
E8	Disturbance prevention and alleviation	396,656,424	396,656,424	0.0011	**4,498**	**4,498**
E9	Leisure and recreation	1,683,284,457	4,087,976,540	0.0989	**1,665,057**	**4,043,709**
E11	Non-use values - bequest and existence	617,056,856	4,010,869,565	0.4823	**2,976,026**	**19,344,172**
E13	Cognitive values	408,710,692	408,710,692	0.4823	**1,971,186**	**1,971,186**
Total					**48,060,667**	**66,856,910**

Table 4.15 Comparison of net present value under the 'maintain' management regime using low and high estimates of total UK values.

Code	Ecosystem Service	Total UK Value Low	Total UK Value High	% Total UK Value	Low Total (£)	High Total (£)
E1	Nutrient cycling	1,859,468,111	1,859,468,111	0.4460	**8,293,537**	**8,293,537**
E3	Gas and climate regulation	7,218,734,187	7,229,567,022	0.4460	**32,196,754**	**32,245,071**
E4	Food provision	1,116,935,000	1,116,935,000	0.0065	**72,968**	**72,968**
E5	Raw materials	102,290,816	102,290,816	0.0025	**2,594**	**2,594**
E8	Disturbance prevention and alleviation	396,656,424	396,656,424	0.0013	**4,984**	**4,984**
E9	Leisure and recreation	1,683,284,457	4,087,976,540	0.0995	**1,675,211**	**4,068,369**
E11	Non-use values - bequest and existence	617,056,856	4,010,869,565	0.4400	**2,715,072**	**17,647,970**
E13	Cognitive values	408,710,692	408,710,692	0.4400	**1,798,342**	**1,798,342**
Total					**46,759,462**	**64,133,835**

Table 4.16 Comparison of net present values for both management regimes using high and low valuation estimates compared with the study findings.

	Recover Management Regime		Maintain Management Regime	
	Net Present Value (£)	% Difference	Net Present Value (£)	% Difference
Present Study	54,456,800		52,821,034	
Low Estimates	48,060,667	-10.75	46,759,462	-10.48
High Estimates	66,856,910	23.77	64,133,835	22.42

4.4.7 ASSUMPTIONS AND LIMITATIONS WITH ECONOMIC VALUATION ESTIMATES

There are a number of assumptions employed and other limitations associated with the approach applied here which should be noted.

- All sites were treated as being 'typical', for example, in the sense that one hectare of aphotic reef was assumed to deliver exactly the same amount of each ecosystem service irrespective of its location. This assumption was necessary given the limited scientific evidence on the economic valuation of systemic MPA network effects.
- Given the lack of scientific evidence on the relationships between the landscape/habitat types and the provision of ecosystem services, and on the impact of management regimes on the provision of ecosystem services then a combination of literature review and expert judgement was employed by Moran *et al.* (2008) in order to assign appropriate weightings for the analysis. Specific relationships that result from this approach may be contested.
- Estimates for the annual benefit of UK marine ecosystem service provision relied on benefit transfer methods. The limited number of UK-level studies prohibited a meta-analysis and therefore the majority of estimates were based upon a single estimate or on a range of estimates all derived using a similar methodology. Confidence in the results would be stronger if the UK valuation data were more extensive.

- Non-use value estimates based on findings from McVittie and Moran (2010) were assumed to hold. The aggregate value used to apportion the benefits arise from a stated preference approach based on a UK sample asked about their WTP to halt the loss of biodiversity loss resulting from the designation of a UK MPA network. Applying these findings in this way assumes that the respondents WTP was proportional to the size/extent of the present network.
- UK-level value estimates were not available for all ecosystem service categories and therefore it is likely that the economic benefits of designating the proposed MPA network in Northern Ireland inshore waters are understated here.
- The assessment has been undertaken for the additional proposed Northern Ireland MPA network as a whole, and this allows little discretion in the choice of management measures at a site-specific level. In reality, management regimes would be designed for individual MPAs taking local circumstances into consideration. Initial economic valuations were presented with the two management regimes applied across the entire network. However, looking at altering the mix of management scenarios has shown how potential benefits may change.

Overall, the approach developed by Moran *et al*. (2008) and applied to both the Scottish MPA network (González-Álvarez *et al.*, 2012), and here to the Northern Ireland MPA network, is considered to be sufficiently robust approach to investigate the potential benefits derived from designating a MPA network in UK waters.

4.5 Discussion

Economic and Social Benefits of MPAs

This study has estimated the economic and social benefits arising from the designation of a theoretical MPA network in Northern Ireland’s inshore waters.

An additional MPA network has been proposed which would increase the area of seabed protected in Northern Ireland to 960.42 km^2, offering protection to 17 out of 26 JNCC marine landscapes and five out of nine OSPAR TDH types. The majority of the proposed additional MPA network area (63.7%) comprises ‘shelf mud’. Protecting shelf mud has been shown to be important in establishing a coherent MPA network since this habitat is not currently protected within Northern Ireland’s inshore waters. Thus, the composition of the additional proposed MPA network should be interpreted within the context of the wider MPA network as the intention is to ensure that an appropriate range of habitats and species is protected in order to enhance the provision of the full range of ecosystem services within Northern Irish waters.

One of the key discussions surrounding the creation of an ecologically coherently network of MPAs in the UK is related to the management regime to be adopted. This study has investigated the impact of two management regimes, ‘recover’ (HR-MPA) and ‘maintain’ (MCS-MPA), on the economic and social benefits of the Northern Ireland MPA network. Given that this study has only assessed the benefits of the network as a whole, then discussion of management measures will be limited as they will be applied on a site-by-site basis following designation.

The results of the economic valuation have demonstrated that designating such additional MPAs in Northern Ireland inshore waters may provide significant levels of benefit for society. Despite only accounting for eight out of 13 ecosystem service benefits that are secured over a 20 year period, net present values of £52.8-£54.5 million (3.5% discount rate) may be realised depending on the management regime adopted. These point estimates need to be interpreted with some caution as they suggest a degree of accuracy that is inconsistent with the type of analysis undertaken. However, they are indicative of the scale of benefits that might be realised from the additional proposed MPA network. While these results are based on an approach which is widely recognised as being applicable for social analysis, undiscounted mean annual benefits has also been estimated and these amounted to £4.56-£4.69 million. The economic valuation focussed on on-site benefits only, and therefore off-site benefits such as the potential for spill-over effects to local commercial fisheries are not included within these estimations. This study has also shown that increasing the proportion of protected area where the recover management regime is applied may be more beneficial.

The impact of using low or high value estimates for those ecosystem services where a range of values are available was assessed. The net present value (3.5% discount rate over a 20 year period) provided by the proposed additional Northern Ireland MPA network decreases to £48.1 million (a 10.75% decrease) and £46.8 million (a 10.48% decrease) for the 'recover' and 'maintain' management regimes respectively. When the high value estimates were applied, the net present value increased to £66.9 million (a 23.77% increase) and £64.1 million (a 22.42% increase) for the 'recover' and 'maintain' management regimes respectively. These results demonstrate the sensitivity of the valuation to changes in the value of specific ecosystem services.

Using a consistent approach to estimate the value of the economic benefits of potential additional MPA networks in Northern Ireland waters as that adopted for English and Scottish waters allows for comparisons to be made between the studies. For purposes of comparison the findings of the three studies have been standardised to 2012 prices. However when estimating the values of ecosystem services for the UK as a whole, Table 4.6 above has demonstrated differences between these studies. A number of network scenarios were presented for both the English and Scottish studies, following the earlier work of Richardson *et al.* (2006); only one of these scenarios (Scenario A) is presented here as this was considered by the authors to be most similar to the Northern Ireland network scenario as it relates solely to the protection of JNCC marine landscapes and OSPAR species and habitat types, with no additional management criteria (see Richardson *et al.*, 2006 for further details). However it is recognised that the 'gap analysis' methodology applied to defining an extended MPA network scenario in the present study was novel (see Section 3.4) and thus differed in approach to the earlier work of Richardson *et al*.

The comparative analysis shows that although the total net present value of the proposed Northern Ireland MPA network is considerably less than the net present value of the English and Scottish networks, when standardised for spatial extent (per km^2) and for year of study (£ 2012), the net present value per km^2 protected is much greater in the proposed Northern Ireland network (Table 4.17). It is suggested here that such differences may reflect the particular ecosystem services protected by the network scenarios. In the case of Northern Ireland, the proposed MPA network was dominated by one habitat type (shelf mud), and given that this habitat provides a significant contribution to all categories of ecosystem service, as reflected by the percentage of total value shown in Table 4.7, this may in part explain the higher valuation of the benefits provided by the extended Northern Ireland MPA network. However further comparative analysis of the three studies would be required to draw any firm conclusions.

Table 4.17 A comparison of net present value estimations (£ 2012) for proposed MPAs in England, Scotland and Northern Ireland.

% Maintain	% Recover	Size of Area Protected (km^2)	Net Present Value (£)	Net Present Value (£ 2012)	Net Present Value (£ 2012) per km^2 Protected
England (scenario A)					
90	10	125,700	10,293,879,066	12,376,804,742	98,463
80	20	125,700	10,376,511,366	12,476,157,361	99,253
70	30	125,700	10,459,143,667	12,575,509,981	100,044
Scotland (scenario A)					
90	10	76,900	4,288,044,000	4,409,944,916	57,346
80	20	76,900	4,305,284,000	4,427,675,017	57,577
70	30	76,900	4,322,524,000	4,445,405,117	57,808
Northern Ireland					
90	10	323	52,984,610	52,984,610	163,978
80	20	323	53,148,187	53,148,187	164,484
70	30	323	53,311,763	53,311,763	164,991

Advances in Marine Ecosystem Service Research

While consistency with previous studies is important, future research of this type might consider recent developments in our understanding of marine ecosystem services and their valuation. One area which has developed significantly in the UK (and Europe) since this approach was first applied by Moran *et al.* (2008) relates to ecosystem service frameworks. Under the Defra-funded UK National Ecosystem Assessment (UK NEA, 2011), a generic ecosystem services framework was developed which recognised the importance of distinguishing between basic processes, intermediate services and final services, and goods/benefits. The UK NEA defines intermediate ecosystem services as '*those whose ecological processes and functions support all life, and, by definition all other services*' and final services as '*the outcomes from ecosystems that directly lead to good(s) that are valued by people' and good(s) as 'all the use and non-use, material and non-material outputs from ecosystems that have value for people*' (UK NEA, 2011). This framework recognises that it is not appropriate to value intermediate services without identifying explicitly the associated final services and goods/benefits which have human welfare implications, and as such using such a framework will avoid double counting in the valuation of ecosystem services (Fisher & Turner, 2008). The UK NEA framework was designed to be generically applicable across ecosystems however the requirement for a coastal and marine specific framework became apparent[18]. A marine-specific ecosystem services framework was proposed by the UK NEAFO project and recognises the importance of complementary capital, in the form of human and man-made capital, in order for society to obtain the goods and benefits (see Figure 6.2 in Annex J). For example, in order to catch fish for human consumption, a fisherman has to invest in resources such as labour, fishing gear, fuel, etc. in order to obtain the benefit from landing species of commercial interest (Atkins *et al.*, 2013).

When comparing the UK NEAFO framework with the Beaumont *et al.* (2006) framework used in the present study, a number of key issues become apparent. The distinction between components and processes, intermediate and final services, and goods and benefits eliminates the potential for double counting when it comes to economic valuation; issues associated with double counting may be considered a weakness of the framework proposed by Beaumont *et al.* (2006). For example, within the UK NEAFO framework nutrient cycling is defined as a supporting intermediate service, and therefore this service is not valued directly, as the value of nutrient cycling within the system is partially captured within the values attributed to all of the other goods/benefits identified. In a further example, the UK NEAFO framework does not consider resilience and resistance to be an ecosystem service, and thus no attempt is made to value it; its value is captured from the inherent benefit generated from a combination of all the other components and processes and ecosystem services that they provide. These differences in the definition and identification of ecosystem services, and their subsequent valuation, should therefore be taken into account in future assessments. Unfortunately, there was not sufficient time or resources available within the current study to incorporate ecosystem service framework changes into the existing methodology however in doing so this would update the methodology and keep it in line with other ecosystem service projects within the UK.

There have also been a number of recent studies which have attempted to link the provision of ecosystem services to particular features currently protected within UK MPAs (e.g. eftec, 2010; Fletcher *et al.*, 2012a, 2012b; Potts *et al.*, 2014). For example, in Potts *et al.* (2014), following the work of Fletcher *et al.* (2012a), matrices were developed showing the relative importance of ecosystem service provision by each of the features (both habitats and species) currently protected by English, Welsh and Scottish MPAs (see Figure 6.3 in Annex J). Their study used expert judgement (the NERC-funded Valuing Nature Network) to identify the relative importance of these relationships and to provide a measure of our confidence in these judgements. Such evidence has been used within the ongoing English and Scottish MPA processes, and elsewhere in Europe, and work is currently underway to further develop this approach using the UK NEAFO framework and to extend its coverage to Northern Irish features (Saunders *et al.*, in prep.). Such evidence could therefore be used to improve our underlying knowledge of the link between ecosystem service provision and MPA management in the future.

[18] This was initially addressed under the NERC-funded Valuing Nature Network (VNN) coastal management programme (Turner *et al.*, 2013a), and subsequently under the Defra-funded UK National Ecosystem Assessment Follow-on-Project WP3b (marine economics) (Turner *et al.*, 2013b).

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6. ANNEXES TO MAIN REPORT

ANNEX A OCCURENCE OF INDIVIDUAL FEATURES ACROSS THE AOI, AND THEIR COINCIDENCE WITH MPA SITES

Table 6.1 Occurrence of sessile species presence cells within the AoI and NI 12 NM sea areas and their respective MPA networks

Species	Total number of presence cells identified within the AoI	Number of presence cells outside of NI 12 NM zone		Number of presence cells within NI 12 NM zone	
		Not intersecting an MPA	Intersecting an MPA	Not intersecting an MPA	Intersecting an MPA
Aequipecten opercularis	423	270	107	14	32
Ahnfeltia plicata	53			20	33
Ahnfeltiopsis devoniensis	1	1			
Amphianthus dohrnii	6	2	4		
Anotrichium barbatum	3		3		
Anseropoda placenta	57	43	7	1	6
Antho brattegardi	5			1	4
Antho granditoxa	2				2
Arachnanthus sarsi	3		1		2
Arctica islandica	225	127	52	17	29
Ascophyllum nodosum	342	162	103	23	54
Ascophyllum nodosum mackaii	22	8	14		
Astropecten irregularis	302	186	100	7	9
Atalecyclus rotundatus	114	85	10	8	11
Atractophora hypnoides	6		3		3
Atrina fragilis	8	6	1		1
Callista chione					
Caryophyllia inornata	13	1	10	1	1
Cerastoderma glaucum	8	4	3		1
Cestopagurus timidus	1				1
Chlamys varia	176	106	46	4	20
Clathria barleei	5				5
Cruoria cruoriaeformis	10	1	2		7
Cumanotus beoumonti	4			2	2
Dasya ocellata	1	1			
Desmarestia dresnayi	12	8	2		2
Diazona violacea	42	21	17	2	2

		Number of presence cells outside of NI 12 NM zone		Number of presence cells within NI 12 NM zone	
Species	**Total number of presence cells identified within the AoI**	**Not intersecting an MPA**	**Intersecting an MPA**	**Not intersecting an MPA**	**Intersecting an MPA**
Diphasia alata	7		2		5
Diphasia nigra	9	1	5		3
Edwardsia timida	9	4	3		2
Erato voluta	3				3
Eubranchus doriae	2			1	1
Eunicella verrucosa	13	9	4		
Eurypon coronula	2	1			1
Gammarus insensibilis					
Glossus humanus	5	5			
Haliclystus auricula	40	7	7	12	14
Hymedesmia cohesiba	3				3
Hymedesmia rathlinia	5			1	4
Hymerhabdia typica	3				3
Inachus leptochirus	46	23	4	9	10
Labidoplax media	9	2	5		2
Leptometra celtica	44	22	21		1
Leptopsammia pruvoti					
Leptosynaapta bergensis	25	11	13		1
Lissodendoryx jenjones	4				4
Lucernariops cruxmelitensis	1		1		
Lucernariopsis campanulata	6	3	1	1	1
Lytocarpis myriophyllum	48	26	10	7	5
Maerl	135	33	23	27	52
Melarhaphe neritoides	151	65	55	12	19
Modiolus modiolus	366	244	68	17	37
Munida rugosa	271	174	66	11	20
Mycale contarenii	9	4	1		4
Mytilus edulis	83	1		26	56
Nematostella vectensis					
Nucella lapillus	425	210	138	24	53
Ocnus planci	26	11	10		5

Species	Total number of presence cells identified within the AoI	Number of presence cells outside of NI 12 NM zone		Number of presence cells within NI 12 NM zone	
		Not intersecting an MPA	Intersecting an MPA	Not intersecting an MPA	Intersecting an MPA
Ostrea edilus	496	243	186	17	50
Padina pavonica					
Palinurus elephas	53	29	19	2	3
Palio dubia	2	1	1		
Paracucumaria hyndmani	42	29	10		3
Parazoanthus axinellae	11	3	4		4
Pentapora fascialis	81	30	40		11
Polyplumaria flabellata	8	1	2		5
Porania pulvillus	154	114	25	8	7
Pycnoclavella stolonialis	11			3	8
Pyura microcosmus	48	14	21	5	8
Solaster endeca	173	101	48	7	17
Somateria mollissima					
Spanioplon armaturum	12	1	1	1	9
Tenellia adspersa					
Tethya hibernica	2				2
Thyonidium drummondii	29	12	11		6
Tonicella marmorea	103	52	30	8	13
Virgularia mirabilis	50	18	7	7	18
Zostera	231	132	60	7	32

Table 6.2 Occurrence of mobile species presence cells within the AoI and NI 12 NM sea areas and their respective MPA networks

Species	Total number of presence cells identified within the AoI	Number of presence cells outside of NI 12 NM zone		Number of presence cells within NI 12 NM zone	
		Not intersecting an MPA	Intersecting an MPA	Not intersecting an MPA	Intersecting an MPA
Alosa alosa	2	1			1
Alosa Fallax	4	3	1		
Ammodytes marinus	5	2	1		2
Anguilla anguilla	35	14	6	11	4
Balaenoptera acutorostrata	220	136	54	14	16
Balaenoptera borealis	7	2	5		
Balaenoptera musculus					
Caretta caretta	1				1
Cetorhinus maximus	38	21	3	10	4
Clupea harengus	9	5	4		
Delphinus delphis	134	87	32	8	7
dipturus batis	10	8		1	1
Gadus morhua	226	165	30	14	17
galeorhinus galeus	67	58	3	1	5
Globicephala melas	52	22	30		
Gobius couchi	2		2		
lamna nasus	4	1	3		
Lampetra fluviatilis	2		2		
Leucoraja naevus	174	151	12	2	9
Lophus piscatorius	105	68	22	12	3
Megaptera novaeangliae	18	5	12	1	
Merlangius merlangus	260	178	55	7	20
Merluccius merluccius	104	84	4	2	14
Molva molva	101	63	16	11	11
Orcinus orca	44	24	12	1	7
Petromyzon marinus	2		1	1	
Phoca vitulina	52	16	4	26	6
Phocoena phocoena	923	536	278	46	63
Pleuronectes platessa	426	252	106	33	35

Species	Total number of presence cells identified within the AoI	Number of presence cells outside of NI 12 NM zone		Number of presence cells within NI 12 NM zone	
		Not intersecting an MPA	Intersecting an MPA	Not intersecting an MPA	Intersecting an MPA
Raja clavata	274	195	64	7	8
Raja montagui	233	180	42	2	9
Raja undalata	3	1	1	1	
Raja undulata	6	4	1	1	
Salmo salar	3		2	1	
Solea solea	209	143	57	3	6
Squalus acanthias	127	106	4	5	12
Squatine squatina	3		3		
Trachurus trachurus	121	100	6		15
Tursiops truncatus	271	110	119	22	20

Table 6.3 Occurrence of habitats and biotopes presence cells within the AoI and NI 12 NM sea areas and their respective MPA networks

Habitat or biotope	Total number of presence cells identified within the AoI	Number of presence cells outside of NI 12 NM zone		Number of presence cells within NI 12 NM zone	
		Not intersecting an MPA	Intersecting an MPA	Not intersecting an MPA	Intersecting an MPA
Blue Mussel beds	13	5	8		
Coastal saltmarshes and saline	48	9	20	16	3
Estuarine rocky habitats	26	18	8		
Flame file shell beds	17	6	11		
Fragile sponge anthozoan communities	11	5	2	4	
High energy circalittoral rock	32	15	13	3	1
High energy infralittoral rock	30	13	9	7	1
High energy intertidal rock	6	5		1	
Honeycomb worm Sabellaria alveoata	12	1	11		
Inshore deep mud with burrowing	10	9	1		
Intertidal chalk	1		1		
Intertidal coarse sediment	19	7	12		
Intertidal mixed sediments	33	13	19	1	
Intertidal mud	16	5	8	3	
Intertidal mudflats AND Saltmarsh	16	5	8	3	
Intertidal sand and muddy sand	25	12	12	1	
Intertidal sediments dominated					
Intertidal under boulder communities	86	23	27	22	14
Kelp and seaweed communities on sublittoral sediments	60	26	27	7	
Littoral chalk communities	22	2	4	7	9
Low energy circalittoral rock	27	19	4	4	
Low energy infralittoral rock	26	15	8	3	
Low energy intertidal rock	26	18	8		
Low or variable salinity habitat	23	4	16	3	
Maerl	135	33	23	52	27
Moderate energy circalittoral rock	32	16	13	2	1

Habitat or biotope	Total number of presence cells identified within the AoI	Number of presence cells outside of NI 12 NM zone		Number of presence cells within NI 12 NM zone	
		Not intersecting an MPA	Intersecting an MPA	Not intersecting an MPA	Intersecting an MPA
Moderate energy intertidal rock	15	12	3		
Modiolus modiolus	366	244	68	37	17
Mud habitats in deep water	5	2	3		
Northern sea fan and sponge communities	34	17	13	4	
Offshore subtidal sands and gravel	17	13	4		
Peat and clay exposures	6	1	5		
Ross worm *Sabellaria spinulosa*	11	4	7		
Saline lagoons	11	5	6		
Seapen and burrowing megafauna	82	63	14	4	1
Sediment habitats with long lived bivalves	157	108	32	12	5
Shallow tideswept coarse sands	17	9	8		
Sheltered muddy gravels	86	34	40	11	1
Stable sand with associated fauna	12	11	1		
Sublittoral sand and mud	70	33	29	7	1
Subtidal chalk	4	2	2		
Subtidal coarse sediment	215	121	68	19	7
Subtidal macrophyte dominated sediment	15	3	10	1	1
Subtidal mixed sediments	32	14	17	1	
Subtidal rock with *Pentapora*	7	4	2	1	
Subtidal sands and gravels	105	46	48	10	1
Tideswept algal communities	1	1			
Tideswept algal communities *Laminaria*	32	6	23	3	
Tideswept channels	11	4	3	3	1
Zostera	231	132	60	32	7

Table 6.4 Occurrence of bird species presence cells within the AoI and NI 12 NM sea areas and their respective MPA networks.

Species	Total number of presence cells identified within the AoI	Number of presence cells outside of NI 12 NM zone		Number of presence cells within NI 12 NM zone	
		Not intersecting an MPA	Intersecting an MPA	Not intersecting an MPA	Intersecting an MPA
Alca torda	1287	1028	148	25	86
Anas acuta					
Anas crecca	2	1			1
Anas penelope	3		3		
Anas strepera					
Arenaria interpres	1			1	
Branta bernicla					
Bucephala clangula	3	2			1
Calidris alpina	3	2	1		
Calidris canutus	1		1		
Cepphus grylle	131	89	24	10	8
Charadrius hiaticula	1	1			
Clangula hyemalis	4	3	1		
Fratercula arctica	554	451	43	5	55
Fulmarus glacialis	2058	1685	186	34	153
Gavia arctica	8	4	3		1
Gavia stellata	104	67	35	1	1
Grampus griseus	24	13	10		1
Haematopus ostralegus	10	5	4		1
Hydrobates pelagicus	416	365	19	2	30
Lagenorhynchus albirostris	37	23	14		
Larus argentatus	1448	1085	224	37	102
Larus canus	364	218	121	8	17
Larus fuscus	1019	828	142	13	36
Larus marinus	948	751	136	14	47
Larus ridibundus	177	98	68	2	9
Limosa lapponica	1	1			
Limosa limosa					
Melanitta fusca	1		1		

Species	Total number of presence cells identified within the AoI	Number of presence cells outside of NI 12 NM zone		Number of presence cells within NI 12 NM zone	
		Not intersecting an MPA	Intersecting an MPA	Not intersecting an MPA	Intersecting an MPA
Melanitta nigra	103	43	59		1
Mergus serrator	12	9	2	1	
Numenius arquata	8	7	1		
Numenius phaeopus	2	2			
Oceanodroma leucorhoa	11	8	2	1	
Phalacrocora aristotelis	388	261	88	16	23
Phalacrocorax carbo	180	87	79	4	10
Phalaropus lobatus					
Pluvialis apricaria	1		1		
Podiceps auritus	13	12	1		
Podiceps cristatus	5	3	2		
Puffinus griseus	95	79	7		9
Puffinus puffinus	1542	1230	157	29	126
Rissa tridactyla	2102	1654	275	40	133
Somateria mollissima	101	73	15	7	6
Stercorarius parasiticus	112	84	17	3	8
Sterna albifrons	2	1	1		
Sterna dougallii	13	9	4		
Sterna hirundo	148	96	42	3	7
Sterna paradisaea	96	72	17	3	4
Sterna sandvicensis	66	21	25	10	10
Tadorna tadorna	4	3	1		
Tringa totanus					
Uria aalge	2092	1635	278	40	139
Vanellus vanellus	1	1			

ANNEX B ECONOMIC VALUATION TECHNIQUES

Table 6.5 Economic valuation techniques – from Cooper *et al.*, 2013

Economic Valuation Method	Description	Relevance to Ecosystem Services
Choice Experiment Method (CEM)	Discrete choice model which assumes the respondent has perfect discrimination capability. Uses experiments to reveal factors that influence choice.	Applicable to all ecosystem services.
Contingent Valuation Method (CVM)	Construction of a hypothetical market by direct surveying of a sample of individuals and aggregation to encompass the relevant population. Problems of potential bias.	Applicable to all ecosystem services.
Cost-of-Illness (COI)	The benefits of pollution reduction are measured by estimating the possible savings in direct out-of-pocket expenses resulting from illness and opportunity costs.	Applicable to: clean water and sediments; and immobilisation of pollutants.
Damage Avoidance Costs (DAC)	The costs that would be incurred if the ecosystem good or service were not present.	Applicable to: healthy climate; prevention of coastal erosion; sea defence; clean water and sediments; and immobilisation of pollutants.
Defensive Expenditure Costs (DEC)	Costs incurred in mitigating the effects of reduced environmental quality. Represents a minimum value for the environmental function.	Applicable to: healthy climate; prevention of coastal erosion; and sea defence.
Hedonic Pricing (HP)	Derive an implicit price for an environmental good from analysis of goods for which markets exist and which incorporate particular environmental characteristics.	Applicable to: tourism/nature watching.
Market Analysis (MA)	Where market prices of outputs (and inputs) are available. Marginal productivity net of human effort/cost. Could approximate with market price of close substitute. May require shadow pricing where prices do not reflect social valuations.	Applicable to: food; fish feed; ornamentals; medicine; aggregates; healthy climate; prevention of coastal erosion; and sea defence.
Net Factor Income (NFI)	Estimates changes in producer surplus by subtracting the costs of other inputs in production from total revenue and ascribes the remaining surplus as the value of the environmental input.	Applicable to: food, fish feed, medicines, aggregates, clean water and sediments; and immobilisation of pollutants.
Production Function Analysis (PFA)	An ecosystem good or service treated as one input into the production of other goods: based on ecological linkages and market analysis.	Applicable to: food; fish feed; ornamentals; medicine; aggregates; healthy climate; prevention of coastal erosion; and sea defence.
Productivity Gains and Losses (PGL)	Change in net return from marketed goods: a form of (dose-response) market analysis.	Applicable to: healthy climate; prevention of coastal erosion; and sea defence.
Replacement / Substitution Costs (R/SC)	Potential expenditures incurred in replacing the function that is lost; for instance by the use of substitute facilities or ‘shadow projects’.	Applicable to all provisioning and regulating services but with limited role for cultural services.
Restoration Costs (RC)	Costs of returning the degraded ecosystem to its original state. A total value approach; important ecological, temporal and cultural dimensions.	Applicable to: healthy climate; prevention of coastal erosion; sea defence; clean water and sediments; and immobilisation of pollutants.
Shadow Price of Carbon (SPC)	A price that reflects the social cost of carbon consistent with the damage experienced under an emissions scenario such that e.g. a specific policy goal can be achieved (the precautionary principle might support a further adjustment to the price).	Applicable to: healthy climate.
Social Cost of Carbon (SCC)	Damage costs of an incremental unit of carbon (or equivalent amount of other greenhouse gas emissions) imposed over the whole of its time in the atmosphere.	Applicable to: healthy climate.
Travel Cost Method (TCM)	Cost incurred in reaching a recreation site as a proxy for the value of recreation. Expenses differ between sites (or for the same site over time) with different environmental attributes.	Applicable to: tourism/nature watching.

ANNEX C JNCC MARINE LANDSCAPE TYPES

The concept of marine landscapes classification of the sea and seabed was developed with the aim of enabling action to be taken to benefit nature conservation in circumstances where marine biological data are limited (Golding *et al.*, 2004). The classification is based on the assumption that geophysical and hydrographical information (for which there is generally better broad-scale coverage than biological information) can be used *in lieu* of biological information to classify medium scale marine habitats and to set marine nature conservation priorities. Following the methodology of Moran *et al.* (2008), Northern Irish waters were assessed for extent of 26 marine landscape types (Table 6.6, below). Those landscape types shaded in grey are not currently protected by the existing or proposed Northern Ireland MPA network.

Table 6.6 JNCC Marine landscape type

Codes	Marine habitats
L1	Aphotic reefs
L2	Oceanic cold water coarse sediment
L3	Oceanic cold water mixed sediment
L4	Oceanic cold water mud
L5	Oceanic cold water sand
L6	Oceanic warm water coarse sediment
L7	Oceanic warm water mixed sediment
L8	Oceanic warm water mud
L9	Oceanic warm water sand
L10	Photic reef
L11	Shallow strong tide stress coarse sediment
L12	Shallow moderate tide stress coarse sediment
L13	Shallow weak tide stress coarse sediment
L14	Shallow strong tide stress mixed sediment
L15	Shallow moderate tide stress mixed sediment
L16	Shallow weak tide stress mixed sediment
L17	Shallow mud
L18	Shallow sand
L19	Shelf strong tide stress coarse sediment
L20	Shelf moderate tide stress coarse sediment
L21	Shelf weak tide stress coarse sediment
L22	Shelf strong tide stress mixed sediment
L23	Shelf moderate tide stress mixed sediment
L24	Shelf weak tide stress mixed sediment
L25	Shelf mud
L26	Shelf sand

ANNEX D OSPAR THREATENED OR DECLINING HABITAT TYPES

The OSPAR Biological Diversity and Ecosystems Strategy sets out that the OSPAR Commission will assess which species and habitats need to be protected (OSPAR, 2008). This work is to guide the setting of priorities by the OSPAR Commission for its activities in implementing Annex V to the Convention ("On the Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area"). The OSPAR List of Threatened and/or Declining Species and Habitats (Table 6.7) has been developed to fulfil this commitment. Of relevance to the current project is the list of Threatened and Declining Habitats, nine of which occur in UK waters: carbonate mounds; *Lophelia pertusa* reefs; Maerl beds; *Modiolus modiolus* beds; *Ostrea edulis* beds; *Sabellaria spinulosa* reefs; Sea mounts; Sea-pen and burrowing megafauna communities; *Zostera* beds.

Table 6.7 OSPAR Threatened and/or Declining Species and Habitats

PART II - HABITATS

DESCRIPTION	OSPAR Regions where the habitat occurs	OSPAR Regions where such habitats are under threat and/or in decline
HABITATS		
Carbonate mounds	**I, V**	**V**[1]
Coral Gardens	**I, II, III, IV, V**	**All where they occur**
Cymodocea meadows	**IV**	**All where they occur**
Deep-sea sponge aggregations	**I, III, IV, V**	**All where they occur**
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	**II, III**	**All where they occur**
Intertidal mudflats	**I, II, III, IV**	**All where they occur**
Littoral chalk communities	**II**	**All where they occur**
Lophelia pertusa reefs	**All**	**All where they occur**
Maerl beds	**All**	**III**
Modiolus modiolus beds	**All**	**All where they occur**
Oceanic ridges with hydrothermal vents/fields	**I, V**	**V**
Ostrea edulis beds	**II, III, IV**	**All where they occur**
Sabellaria spinulosa reefs	**All**	**II, III**
Seamounts	**I, IV, V**	**All where they occur**
Sea-pen and burrowing megafauna communities	**I, II, III, IV**	**II, III**
Zostera beds	**I, II, III, IV**	**All where they occur**

ANNEX E UK ECONOMIC VALUATION ESTIMATES

E1 Nutrient cycling

The valuation estimate for nutrient cycling presented in Beaumont *et al*. (2006) was deemed by Moran *et al*. (2008) to be too high and would therefore dominate any valuation study. Moran *et al*. therefore adopted a more conservative approach following Costanza *et al*. (1997) valuation of $118 (1994) per ha per year. JNCC calculated the UK 12nm zone to be 161,200km^2 which equates to 16,120,000 ha and results in an annual benefit of £1.3 billion (2006 prices).

For the present study, the appropriate US CPI was used to adjust 1994 $ prices into 2012 $ prices (see the US CPI table below) before using the 2012 $/£ exchange rate resulting in an estimate of £1.86 billion:

[($118*16,120,000 ha)*(229.594/148.2 US CPI 1994 to 2012)*0.6310 (2012 $/£ exchange rate) = 1,859,468,111].

E2 Bioremediation of waste

At present there is no suitable valuation data for this service which could be transferred to the UK marine environment.

E3 Gas and climate regulation

Beaumont *et al*. (2006) reported annual primary production by phytoplankton of 70,000,000 tons of carbon per year. To convert carbon into CO_2 equivalents you need to divide by 0.2727 as carbon comprises 12/44 the mass of CO_2. Beaumont *et al*. (2006) used the shadow price to value the CO_2 sequestered by phytoplankton.

The present study used the same methodology but applied the 2012 shadow price of carbon (£28.1/tCO_2)

[£28.1 / 0.2727 * 70,000,000 = £7,213,054,100].

In addition, the present study also incorporated literature on carbon sequestration of other marine habitats including seagrass, saltmarsh and sand dunes, recognising that carbon sequestration in the marine environment is undertaken by more than phytoplankton alone.

Luisetti *et al*. (2013) report the carbon sequestration rate of seagrass communities as 1.91 tCO_2/ha/yr. In the UK there are 4,887 hectares of seagrass. The SPC in 2012 is £28.1/tCO_2.

[£28.1*1.91*4887)=£262,290]

Saltmarsh sequesters carbon at a rate of 0.64-2.19 t C/ha/yr (Beaumont *et al.*, 2010). There is a total area of 44,512 ha of saltmarsh in the UK (Beaumont *et al.*, 2010). The 2012 SPC is £103.04.

Low - [(£28.1/0.2727)*0.64*44,512=£2,935,474]

High - [(£28.1/0.2727)*2.19*44,512=£10,044,824]

Sand dunes sequester carbon at a rate of 0.34-0.85 t C/ha/yr (Beaumont *et al.*, 2010). There are 70,853 ha of sand dune in the UK (Beaumont *et al.*, 2010). The 2012 SPC is £103.04.

Low - [(£28.1/0.2727)*0.34*70,853=£2,482,323]

High - [(£28.1/0.2727)*0.85*70,853=£6,205,808]

E4 Food provision

The MMO (2013) report that 627,000 tonnes of fish were landed by UK vessels in the UK and abroad in 2012 at a total value of £770.3 million (ex-vessel prices). This price does not reflect the true value of this resource and therefore a value-added factor of 0.45 was applied (following Pugh & Skinner, 2002) to take account of value added activities along the marketing chain.

[£770,300,000*1.45=£1,169,350,000]

E5 Raw materials

Beaumont *et al*. (2006) reported values of raw materials of £81.5 million in 2004.

The present study used the appropriate CPI to convert the 2004 price of £81.5 million to 2012 price giving a total of £102 million (see UK CPI table below).

[£81,500,000*(123/98) = £102,290,816]

E6 Biologically mediated habitat

At present there is no suitable valuation data for this service which could be transferred to the UK marine environment.

E7 Resilience and resistance

At present there is no suitable valuation data for this service which could be transferred to the UK marine environment.

E8 Disturbance prevention and alleviation

King & Lester (1995) recognise the importance of saltmarsh as a natural form of sea defence. They report annual maintenance cost savings of £7,100 per hectare per year as opposed to maintaining man-made sea defences. In the UK there are 44,512 ha of saltmarsh in UK (UK NEA 2011).

The present study therefore used appropriate the CPI to adjust 2004 price of £0.3 billion to 2012 price.

[7,100*(123/98)*44,512=396,656,424].

In addition, Beaumont *et al*. (2006) also report capital costs of £17-32 billion (2004 prices). The present study adjusted these values using the appropriate CPI into 2012 prices (see UK CPI table below).

The present study also reports capital costs of £21.3-40.2 billion (2012 prices).

E9 Leisure and recreation

Beaumont *et al*. (2006) reported leisure and recreation to be worth £11.77 billion but recognised that this is likely to be an overestimate. Moran *et al*. (2006) reported a range of values for this ecosystem service from £1.4-3.4 billion.

The present study used appropriate UK RPI to adjust the Moran *et al.* 2006 price of £1.4-3.4 billion to 2012 prices (see UK RPI table below).

Low - [1,400,000,000*(123/102.3)=1,683,284,457]

High - [3,400,000,000*(123/102.3)=4,087,976,539]

E10 Cultural heritage and identity

At present there is no suitable valuation data for this service which could be transferred to the UK marine environment.

E11 Non-use values - bequest and existence

Beaumont *et al*. reported non-use values as £0.5-1.1 billion (2004 prices). Moran *et al*. (2008) did not include non-use values in their study. González-Álvarez *et al*. (2012) reported values of £0.6-3.9 billion and a best estimate of £1.4 billion – these values were based on more recent literature (e.g. McVittie & Moran, 2010).

The present study adjusted the findings of González-Álvarez *et al*. (2012) into 2012 prices using the appropriate UK CPI (see UK CPI table below).

Low - [600,000,000*(123/119.6)=£617,056,800]

High - [3,900,000,000*(123/119.6)=£4,010,869,200]

Best estimate - [1,400,000,000*(123/119.6)=£1,439,799,200]

E12 Option use values

At present there is no suitable valuation data for this service which could be transferred to the UK marine environment.

E13 Cognitive values

Used appropriate UK CPI to adjust 2002 price of £317 million to 2012 price.

[£317,000,000*(123/95.4) = £408,710,692]

The table below provides a summary of the UK consumer price index (1997-2012) and retail price index (1994-2012) and the US consumer price index (1994-2012). This information has been sourced from the UK Office of National Statistics and the US Bureau of Labor Statistics. These indices have been used in the calculation above to adjust prices as follows:

Consumer Price Index (CPI) = Base Price x (Current CPI / Base Year CPI)

Retail Price Index (RPI) = Base Price x (Current RPI / Base Year RPI)

Table 6.8 Summary of the annual UK and US consumer price index and UK retail price index used to adjust economic valuations into 2012 prices.

Year	UK Annual Average CPI* (2005 = 100)	UK Annual Average RPI* (1987 = 100)	US Annual Average CPI** (1982-84=100)
1994		144.1	148.2
1995		149.1	152.4
1996		152.7	156.9
1997	89.7	157.5	160.5
1998	91.1	162.9	163
1999	92.3	165.4	166.6
2000	93.1	170.3	172.2
2001	94.2	173.3	177.1
2002	95.4	176.2	179.9
2003	96.7	181.3	184
2004	98.0	186.7	188.9
2005	100.0	192.0	195.3
2006	102.3	198.1	201.6
2007	104.7	206.6	207.3
2008	108.5	214.8	215.303
2009	110.8	213.7	214.537
2010	114.5	223.6	218.056
2011	119.6	235.2	224.939
2012	123.0	242.7	229.594

* Source: UK Office of National Statistics

** Source: US Bureau of Labor Statistics

ANNEX F SPLITTING OF TOTAL AGGREGATED VALUES ACROSS THE DIFFERENT MARINE LANDSCAPE/HABITAT TYPES

For each ecosystem service category the total value of UK marine ecosystem services was split between the landscape/habitat types following the methodology of Moran *et al.* (2008). The relative importance of the provision of each ecosystem service by landscape/habitat type was determined and an appropriate weighting applied to each landscape/habitat type. The total value was apportioned according to four coding types:

- Coding Type A: Impact of one unit area of the landscape/habitat type relative to one unit of other landscape/habitat (L=1 (low), M=2 (medium), H=3 (high)).
- Coding Type B: Unit area is used to split aggregate impact score, with no weighting for particular landscape/habitat types.
- Coding Type C: Economic impact depends on distance from shore (L=1 (low), M=2 (medium), H=3 (high)).
- Coding Type D: No scientific rationale available for splitting aggregate values.

This scoring system reflects the extent to which there is a biological basis to partition the total contribution from the UK seas between individual habitats. Further details are provided in Moran *et al.* (2008). Scoring for the landscape/habitat types is presented in Table 6.9.

Coding Type A

Five ecosystem service categories were coded ‘A’: nutrient cycling (E1), bioremediation of waste (E2), gas and climate regulation (E3), food provision (E4) and biologically mediated habitat (E5). A score was assigned to each landscape/habitat type with high benefit categories scoring 3, medium categories scoring 2 and low benefit categories scoring 1. These are cardinal scores and thus a score of 3 implies that, per unit area, that landscape/habitat type has three times the impact on a given ecosystem service category as compared to a landscape/habitat type which scores 1. The calculations for all five ecosystem service categories coded ‘A’ are presented in Table 6.10.

Coding Type B

Two ecosystem services were coded ‘B’: biologically mediated habitat (E6) and resilience and resistance (E7). No weighting are applied to these categories and therefore the relative % area (column three in Table 6.11) is used to directly calculate the % of the total value assigned to these categories.

Coding Type C

Only one ecosystem service was coded ‘C’: disturbance prevention and alleviation (E8). A similar approach was undertaken as the one for coding type A but differs in that the economic benefit depends on the distance from the shore. Only *Zostera* beds (TDH9) were considered to be of medium importance (with a score of 2), with the distance from shore for all other ecosystem services being considered of low importance (with a score of 1). The calculations for disturbance prevention and alleviation are presented in Annex E.

Coding Type D

Five ecosystem services were coded ‘D’: leisure and recreation (E9), cultural heritage and identity (E10), non-use/bequest values (E11), option use values (E12) and cognitive benefits (E13). Given that there was no rationale available for splitting aggregate values across these ecosystem services, then the total value was divided equally across each service (i.e. 1/35 of the total value) (see Table 4.7).

Table 6.9 Scoring for landscape/habitat types (Moran *et al.*, 2008).

Coding Type		A	A	A	A	A	B	B	C	D	D	D	D	D
		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
Code	Landscape/habitat type	Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	L	L	L	M	H			L					
L2	Oceanic cold water coarse sediment	M	M	M	M	L			L					
L3	Oceanic cold water mixed sediment	M	M	M	M	L			L					
L4	Oceanic cold water mud	M	M	M	M	L			L					
L5	Oceanic cold water sand	M	M	M	M	L			L					
L6	Oceanic warm water coarse sediment	M	M	M	M	L			L					
L7	Oceanic warm water mixed sediment	M	M	M	M	L			L					
L8	Oceanic warm water mud	M	M	M	M	L			L					
L9	Oceanic warm water sand	M	M	M	M	L			L					
L10	Photic reef	M	M	M	M	H			L					
L11	Shallow strong tide stress coarse sediment	M	M	M	M	M			L					
L12	Shallow moderate tide stress coarse sediment	M	M	M	M	M			L					
L13	Shallow weak tide stress coarse sediment	M	M	M	H	M			L					
L14	Shallow strong tide stress mixed sediment	M	M	M	M	M			L					
L15	Shallow moderate tide stress mixed sediment	M	M	M	M	M			L					
L16	Shallow weak tide stress mixed sediment	H	H	H	M	M			L					
L17	Shallow mud	H	H	H	M	L			L					
L18	Shallow sand	H	H	H	M	M			L					
L19	Shelf strong tide stress coarse sediment	M	M	M	L	L			L					
L20	Shelf moderate tide stress coarse sediment	M	M	M	M	L			L					
L21	Shelf weak tide stress coarse sediment	M	M	M	H	L			L					
L22	Shelf strong tide stress mixed sediment	M	M	M	M	L			L					
L23	Shelf moderate tide stress mixed sediment	M	M	M	M	L			L					
L24	Shelf weak tide stress mixed sediment	H	H	H	M	L			L					
L25	Shelf mud	H	H	H	H	L			L					
L26	Shelf sand	H	H	H	M	L			L					
Total for marine landscapes		**57**	**57**	**57**	**54**	**37**			**26**					
TDH1	Carbonate mounds	L	L	L	M	L			L					
TDH2	Lophelia pertusa reefs	L	L	L	M	L			L					
TDH3	Maerl beds	M	M	M	M	M			L					
TDH4	Modiolus modiolus beds	H	H	H	M	L			L					
TDH5	Ostrea edulis beds	M	M	M	L	L			L					
TDH6	Sabellaria spinulosa reefs	L	L	L	L	L			L					
TDH7	Sea mounts	L	L	L	M	L			L					
TDH8	Sea-pen and burrowing megafauna communities	H	H	H	H	L			L					
TDH9	Zostera beds	H	H	H	L	L			M					
Total for habitats		**17**	**17**	**17**	**16**	**10**			**10**					
Total for landscapes and habitats		**74**	**74**	**74**	**70**	**47**			**36**					

Coding Type A: Impact of one unit area of the habitat/landscape type relative to one unit of other habitats/landscapes (L=1, M=2, H=3)
Coding Type B: Unit area is used to split aggregate impact score, with no weighting for particular habitats/landscapes
Coding Type C: Economic impact depends on distance from shore (L=1, M=2, H=3)
Coding Type D: No scientific rationale available for splitting aggregate values

Table 6.10 Proportions of total values attributed to each landscape/habitat type for ecosystem services assigned Code A.

Landscape/habitat type		Area (km^2)	% Area	E1_E3	Multi	%TV	E4	Multi	%TV	E5	Multi	%TV
L1	Aphotic reefs	10,968	1.80	1	1.80	0.72	2	3.60	1.60	3	5.41	4.37
L2	Oceanic cold water coarse sediment	386	0.06	2	0.13	0.05	2	0.13	0.06	1	0.06	0.05
L3	Oceanic cold water mixed sediment	4,880	0.80	2	1.60	0.64	2	1.60	0.71	1	0.80	0.65
L4	Oceanic cold water mud	23,509	3.86	2	7.73	3.07	2	7.73	3.43	1	3.86	3.12
L5	Oceanic cold water sand	5,597	0.92	2	1.84	0.73	2	1.84	0.82	1	0.92	0.74
L6	Oceanic warm water coarse sediment	3,781	0.62	2	1.24	0.49	2	1.24	0.55	1	0.62	0.50
L7	Oceanic warm water mixed sediment	5,407	0.89	2	1.78	0.71	2	1.78	0.79	1	0.89	0.72
L8	Oceanic warm water mud	56,327	9.25	2	18.51	7.36	2	18.51	8.22	1	9.25	7.48
L9	Oceanic warm water sand	6,076	1.00	2	2.00	0.79	2	2.00	0.89	1	1.00	0.81
L10	Photic reef	7,155	1.18	2	2.35	0.94	2	2.35	1.04	3	3.53	2.85
L11	Shallow strong tide stress coarse sediment	2,840	0.47	2	0.93	0.37	2	0.93	0.41	2	0.93	0.75
L12	Shallow moderate tide stress coarse sediment	16,745	2.75	2	5.50	2.19	2	5.50	2.44	2	5.50	4.45
L13	Shallow weak tide stress coarse sediment	33,694	5.54	2	11.07	4.40	3	16.61	7.37	2	11.07	8.95
L14	Shallow strong tide stress mixed sediment	952	0.16	2	0.31	0.12	2	0.31	0.14	2	0.31	0.25
L15	Shallow moderate tide stress mixed sediment	2,021	0.33	2	0.66	0.26	2	0.66	0.29	2	0.66	0.54
L16	Shallow weak tide stress mixed sediment	2,922	0.48	3	1.44	0.57	2	0.96	0.43	2	0.96	0.78
L17	Shallow mud	6,893	1.13	3	3.40	1.35	2	2.27	1.01	1	1.13	0.92
L18	Shallow sand	48,218	7.92	3	23.77	9.45	2	15.84	7.03	2	15.84	12.81
L19	Shelf strong tide stress coarse sediment	2,840	0.47	2	0.93	0.37	1	0.47	0.21	1	0.47	0.38
L20	Shelf moderate tide stress coarse sediment	17,433	2.86	2	5.73	2.28	2	5.73	2.54	1	2.86	2.32
L21	Shelf weak tide stress coarse sediment	76,492	12.57	2	25.14	10.00	3	37.70	16.74	1	12.57	10.16
L22	Shelf strong tide stress mixed sediment	285	0.05	2	0.09	0.04	2	0.09	0.04	1	0.05	0.04
L23	Shelf moderate tide stress mixed sediment	2,260	0.37	2	0.74	0.30	2	0.74	0.33	1	0.37	0.30
L24	Shelf weak tide stress mixed sediment	3,951	0.65	3	1.95	0.77	2	1.30	0.58	1	0.65	0.52
L25	Shelf mud	44,605	7.33	3	21.99	8.74	3	21.99	9.76	1	7.33	5.93
L26	Shelf sand	215,215	35.36	3	106.08	42.19	2	70.72	31.40	1	35.36	28.60
TDH1	Carbonate mounds	233	0.04	1	0.04	0.02	2	0.08	0.03	1	0.04	0.03
TDH2	Lophelia pertusa reefs	1,855	0.30	1	0.30	0.12	2	0.61	0.27	1	0.30	0.25
TDH3	Maerl beds	357	0.06	2	0.12	0.05	2	0.12	0.05	2	0.12	0.09
TDH4	Modiolus modiolus beds	220	0.04	3	0.11	0.04	2	0.07	0.03	1	0.04	0.03
TDH5	Ostrea edulis beds	14	0.00	2	0.00	0.00	1	0.00	0.00	1	0.00	0.00
TDH6	Sabellaria spinulosa reefs	105	0.02	1	0.02	0.01	1	0.02	0.01	1	0.02	0.01
TDH7	Sea mounts	61	0.01	1	0.01	0.00	2	0.02	0.01	1	0.01	0.01
TDH8	Sea-pen and burrowing megafauna communities	3,118	0.51	3	1.54	0.61	3	1.54	0.68	1	0.51	0.41
TDH9	Zostera beds	1,217	0.20	3	0.60	0.24	1	0.20	0.09	1	0.20	0.16
Total		**608,632**	**100**	**74**	**251**	**100**	**70**	**225**	**100**	**47**	**124**	**100**

Table 6.11 Proportions of total values attributed to each landscape/habitat type for ecosystem services assigned Code C.

Landscape/habitat type		Area (km^2)	% Area	E8	Multi	%TV
L1	Aphotic reefs	10,968	1.80	1	1.80	1.80
L2	Oceanic cold water coarse sediment	386	0.06	1	0.06	0.06
L3	Oceanic cold water mixed sediment	4,880	0.80	1	0.80	0.80
L4	Oceanic cold water mud	23,509	3.86	1	3.86	3.85
L5	Oceanic cold water sand	5,597	0.92	1	0.92	0.92
L6	Oceanic warm water coarse sediment	3,781	0.62	1	0.62	0.62
L7	Oceanic warm water mixed sediment	5,407	0.89	1	0.89	0.89
L8	Oceanic warm water mud	56,327	9.25	1	9.25	9.24
L9	Oceanic warm water sand	6,076	1.00	1	1.00	1.00
L10	Photic reef	7,155	1.18	1	1.18	1.17
L11	Shallow strong tide stress coarse sediment	2,840	0.47	1	0.47	0.47
L12	Shallow moderate tide stress coarse sediment	16,745	2.75	1	2.75	2.75
L13	Shallow weak tide stress coarse sediment	33,694	5.54	1	5.54	5.52
L14	Shallow strong tide stress mixed sediment	952	0.16	1	0.16	0.16
L15	Shallow moderate tide stress mixed sediment	2,021	0.33	1	0.33	0.33
L16	Shallow weak tide stress mixed sediment	2,922	0.48	1	0.48	0.48
L17	Shallow mud	6,893	1.13	1	1.13	1.13
L18	Shallow sand	48,218	7.92	1	7.92	7.91
L19	Shelf strong tide stress coarse sediment	2,840	0.47	1	0.47	0.47
L20	Shelf moderate tide stress coarse sediment	17,433	2.86	1	2.86	2.86
L21	Shelf weak tide stress coarse sediment	76,492	12.57	1	12.57	12.54
L22	Shelf strong tide stress mixed sediment	285	0.05	1	0.05	0.05
L23	Shelf moderate tide stress mixed sediment	2,260	0.37	1	0.37	0.37
L24	Shelf weak tide stress mixed sediment	3,951	0.65	1	0.65	0.65
L25	Shelf mud	44,605	7.33	1	7.33	7.31
L26	Shelf sand	215,215	35.36	1	35.36	35.29
TDH1	Carbonate mounds	233	0.04	1	0.04	0.04
TDH2	Lophelia pertusa reefs	1,855	0.30	1	0.30	0.30
TDH3	Maerl beds	357	0.06	1	0.06	0.06
TDH4	Modiolus modiolus beds	220	0.04	1	0.04	0.04
TDH5	Ostrea edulis beds	14	0.00	1	0.00	0.00
TDH6	Sabellaria spinulosa reefs	105	0.02	1	0.02	0.02
TDH7	Sea mounts	61	0.01	1	0.01	0.01
TDH8	Sea-pen and burrowing megafauna communities	3,118	0.51	1	0.51	0.51
TDH9	Zostera beds	1,217	0.20	2	0.40	0.40
Total		**608,632**	**100**	**36**	**100**	**100**

ANNEX G RELATIONSHIPS BETWEEN MARINE LANDSCAPE/HABITAT TYPES AND THEIR RELATIVE PROVISION OF ECOSYSTEM SERVICES

The following supporting evidence has been reproduced from Moran *et al.* (2008).

For many of the landscape units the information derives from the same sources. For example the ecological functioning of all shallow sedimentary habitats, their response to impacts and dynamics are similar and derived from a comprehensive body of studies, many of which provide information relevant to more than one landscape type. This in part is the result of key ecological principles being expressed in all the systems with similar ecological outcome and in part derives from the fact that the studies forming the information base consider ecological units that in many cases do not simply map, one for one, on to the JNCC landscapes. The extent of knowledge is thus described for each habitat type but they are grouped where the assessment is the same.

Assessment of JNCC Marine Landscape Types

Aphotic reef (L1)

For all of the goods and services the extent of knowledge was considered high or medium.

Oceanic sedimentary landscapes (L2-L9)

For all the oceanic sedimentary landscapes, the majority of the goods and services the extent of knowledge was considered low. A 'medium' score was given for 'cognitive values' as the landscape has research value but the educational aspect of it is unknown. A high level of knowledge was attributed to 'disturbance prevention and alleviation', as it is definitively known that oceanic sedimentary landscapes have little value for this service.

Photic reef (L10)

For all of the goods and services the extent of knowledge was considered high or medium.

Shallow sedimentary landscapes (L11-L16)

The extent of knowledge is considered as either high or medium for all the shallow sedimentary landscapes types. However, the authors rarely define their study sites in terms of JNCC landscape types thus we have had to use the available information and some interpretation to derive accounts for these landscape types.

Shallow mud (L17)

For all of the goods and services the extent of knowledge was considered high or medium.

Shallow sand (L18)

For all of the goods and services the extent of knowledge was considered high or medium.

Shelf sedimentary landscapes (L19-L24)

For all of the goods and services of the sedimentary landscape types the extent of knowledge was considered high or medium.

Shelf mud and shelf sand (L25-L26)

For the majority of the goods and services for the shelf sand and mud landscapes the extent of knowledge was considered high or medium due to the extensive demersal and *Nephrops* fisheries that occur on these landscapes.

Assessment of extent of knowledge for each TDH

All the TDHs are well-studied, as this is a prerequisite to their being assigned TDH status.

Carbonate mounds and *Lophelia pertusa* reefs (TDH1-TDH2)

These two OSPAR TDHs were considered to have the same level of knowledge due to their tendency to occur in similar areas in deep waters. For the majority of the goods and services there was considered to be a high or medium, with the exception of 'nutrient cycling', 'gas and climate regulation' and 'bioremediation of waste' where there is little literature on how the actual habitats deliver these processes.

Maerl beds (TDH3)

There was considered to be a high level of knowledge overall of how maerl beds affect the provision of ecological goods and services.

***Modiolus modiolus* beds (TDH4)**

The level of knowledge for the majority of goods and services was considered to be either high or medium for this habitat.

***Ostrea edulis* beds (TDH5)**

For the majority of goods and services there was deemed a high level of knowledge of how they provided the specific ecological goods and services.

***Sabellaria spinulosa* reefs (TDH6)**

There was judged to be either a high or medium level of knowledge of how the habitat provides ecological goods and services.

Sea mounts (TDH7)

The level of knowledge for sea mounts and their provision of ecological goods and services was considered to be of a high or medium level.

Sea-pen and burrowing megafauna communities (TDH8)

The level of knowledge for this habitat was judged to be of a high or medium level.

***Zostera* beds (TDH9)**

For the majority of the ecological goods and services that this habitat can deliver there was deemed to be a high level of knowledge.

ANNEX H CONSIDERATION OF THE EFFECTS OF DIFFERENT MANAGEMENT REGIMES

The results of the assessment of impact of human activities if no additional management measures were put in place ('*status quo*') and the impact of the two management regimes ('recover' and 'maintain') in comparison with the *status quo* scenario are presented in Table 6.12, Table 6.13, and Table 6.14, respectively.

Table 6.12 Impact of human activities for marine landscapes/habitat types under a *status quo* management scheme.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	M 0/20L	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L2	Oceanic cold water coarse sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 10/20E
L3	Oceanic cold water mixed sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 10/20E
L4	Oceanic cold water mud	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 10/20E
L5	Oceanic cold water sand	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 10/20E
L6	Oceanic warm water coarse sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 10/20E
L7	Oceanic warm water mixed sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 10/20E
L8	Oceanic warm water mud	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 10/20E
L9	Oceanic warm water sand	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 10/20E
L10	Photic reef	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	M 0/20L	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L11	Shallow strong tide stress coarse sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	M 0/20L	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L12	Shallow moderate tide stress coarse sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	M 0/20L	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L13	Shallow weak tide stress coarse sediment	H 0/20L	H 0/20L	H 0/20L	H 0/20L	L 0/20L	H 0/20L	H 0/20L	VL 0/20S	H 0/20L	VL 0/20S	H 0/20L	H 0/20L	H 0/20L
L14	Shallow strong tide stress mixed sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	M 0/20L	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L15	Shallow moderate tide stress mixed sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	M 0/20L	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L16	Shallow weak tide stress mixed sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	M 0/20L	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L17	Shallow mud	M 0/20L	M 0/20L	M 0/20L	M 0/20L	VL 0/20L	M 0/20L	M 0/20L	VL 0/20S	L 0/20L	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L18	Shallow sand	M 0/20L	M 0/20L	M 0/20L	M 0/20L	VL 0/20L	M 0/20L	M 0/20L	VL 0/20S	M 0/20L	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L19	Shelf strong tide stress coarse sediment	L 0/20L	L 0/20L	L 0/20L	L 0/20L	L 0/20L	L 0/20L	L 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	L 0/20L	L 0/20L	L 0/20L
L20	Shelf moderate tide stress coarse sediment	L 0/20L	L 0/20L	L 0/20L	L 0/20L	L 0/20L	L 0/20L	L 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	L 0/20L	L 0/20L	L 0/20L
L21	Shelf weak tide stress coarse sediment	VH 0/20L	VH 0/20L	VH 0/20L	VH 0/20L	L 0/20L	VH 0/20L	VH 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	VH 0/20L	VH 0/20L	VH 0/20L
L22	Shelf strong tide stress mixed sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L23	Shelf moderate tide stress mixed sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	M 0/20L
L24	Shelf weak tide stress mixed sediment	M 0/20L	M 0/20L	M 0/20L	M 0/20L	L 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 0/20L
L25	Shelf mud	M 0/20L	M 0/20L	M 0/20L	H 10/10E	VL 0/20L	M 0/20L	M 0/20L	VL 0/20S	VL 0/20S	VL 0/20S	M 0/20L	M 0/20L	H 10/20E
L26	Shelf sand	M 0/20L	M 0/20L	M 0/20L	M 0/20L	M 0/20L	M 0/20L	M 0/20L	VL 0/20S	M 0/20L	VL 0/20S	M 0/20L	M 0/20L	H 5/20E
TDH1	Carbonate mounds	H 0/20L	H 0/20L	H 0/20L	H 0/20L	L 0/20L	H 0/20L	H 0/20L	VL 0/20S	VL 0/20S	H 0/20L	H 0/20L	H 0/20L	H 0/20L
TDH2	Lophelia pertusa reefs	H 0/20L	H 0/20L	H 0/20L	H 0/20L	L 0/20L	H 0/20L	H 0/20L	VL 0/20S	VL 0/20S	H 0/20L	H 0/20L	H 0/20L	H 0/20L
TDH3	Maerl beds	H 0/20L	H 0/20L	H 0/20L	H 0/20S	H 0/20L	H 0/20L	H 0/20L	VL 0/20S	L 0/20S	H 0/20L	H 0/20L	H 0/20L	H 0/20L
TDH4	Modiolus modiolus beds	H 0/20L	H 0/20L	H 0/20L	H 0/20S	L 0/20L	H 0/20L	H 0/20L	VL 0/20S	L 0/20S	H 0/20L	H 0/20L	H 0/20L	H 0/20L
TDH5	Ostrea edulis beds	H 0/20L	H 0/20L	H 0/20L	H 0/20S	L 0/20L	H 0/20L	H 0/20L	VL 0/20S	L 0/20S	H 0/20L	H 0/20L	H 0/20L	H 0/20L
TDH6	Sabellaria spinulosa reefs	H 0/20L	H 0/20L	H 0/20L	H 0/20S	VL 0/20S	H 0/20L	H 0/20L	VL 0/20S	L 0/20S	H 0/20L	H 0/20L	H 0/20L	H 0/20L
TDH7	Sea mounts	H 0/20L	H 0/20L	H 0/20L	H 0/20L	L 0/20L	H 0/20L	H 0/20L	VL 0/20S	VL 0/20S	H 0/20L	H 0/20L	H 0/20L	H 0/20L
TDH8	Sea-pen and burrowing megafauna communities	H 0/20L	H 0/20L	H 0/20L	H 0/20S	L 0/20L	H 0/20L	H 0/20L	VL 0/20S	L 0/20S	H 0/20L	H 0/20L	H 0/20L	H 0/20L
TDH9	Zostera beds	H 0/20L	H 0/20L	H 0/20L	H 0/20L	H 0/20L	H 0/20L	H 0/20L	M 0/20L	H 0/20L	H 0/20L	H 0/20L	H 0/20L	H 0/20L

Table 6.13 Positive impact of HR-MPA management regime for landscapes/habitat types as compared to the status quo scenario.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	H 10/20E	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	H 10/20E	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L2	Oceanic cold water coarse sediment	H 15/20E	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	H 15/20E
L3	Oceanic cold water mixed sediment	H 15/20E	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	H 15/20E
L4	Oceanic cold water mud	H 15/20E	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	H 15/20E
L5	Oceanic cold water sand	H 15/20E	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	H 15/20E
L6	Oceanic warm water coarse sediment	H 10/20E	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L7	Oceanic warm water mixed sediment	H 10/20E	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L8	Oceanic warm water mud	H 10/20E	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L9	Oceanic warm water sand	H 10/20E	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L10	Photic reef	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	H 5/20E	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L11	Shallow strong tide stress coarse sediment	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	M 5/20E	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L12	Shallow moderate tide stress coarse sediment	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	M 5/20E	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L13	Shallow weak tide stress coarse sediment	VH 8/20E	VH 8/20E	VH 8/20E	VL 0/20S	VL 0/20S	VH 8/20E	VH 8/20E	VL 0/20S	H 5/20E	VL 0/20S	VH 8/20E	VH 8/20E	VH 8/20E
L14	Shallow strong tide stress mixed sediment	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	M 5/20E	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L15	Shallow moderate tide stress mixed sediment	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	M 5/20E	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L16	Shallow weak tide stress mixed sediment	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	M 5/20E	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L17	Shallow mud	M 5/20E	M 5/20E	M 5/20E	VL 0/20S	VL 0/20S	M 5/20E	M 5/20E	VL 0/20S	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L18	Shallow sand	M 5/20L	M 5/20L	M 5/20L	VL 0/20S	VL 0/20S	M 5/20L	M 5/20L	VL 0/20S	M 5/20L	VL 0/20S	M 5/20L	M 5/20L	M 5/20L
L19	Shelf strong tide stress coarse sediment	M 5/20E	M 5/20E	M 5/20E	VL 0/20S	VL 0/20S	M 5/20E	M 5/20E	VL 0/20S	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L20	Shelf moderate tide stress coarse sediment	M 5/20E	M 5/20E	M 5/20E	VL 0/20S	VL 0/20S	M 5/20E	M 5/20E	VL 0/20S	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L21	Shelf weak tide stress coarse sediment	VH 8/20E	VH 8/20E	VH 8/20E	VL 0/20S	VL 0/20S	VH 8/20E	VH 8/20E	VL 0/20S	L 8/20E	VL 0/20S	VH 8/20E	VH 8/20E	VH 8/20E
L22	Shelf strong tide stress mixed sediment	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	L 5/20E	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L23	Shelf moderate tide stress mixed sediment	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	L 8/20E	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L24	Shelf weak tide stress mixed sediment	H 8/20E	H 8/20E	H 8/20E	VL 0/20S	VL 0/20S	H 8/20E	H 8/20E	VL 0/20S	L 8/20E	VL 0/20S	H 8/20E	H 8/20E	H 8/20E
L25	Shelf mud	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L26	Shelf sand	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
TDH1	Carbonate mounds	VH 20/20E	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VH 20/20E	VH 20/20E
TDH2	Lophelia pertusa reefs	VH 20/20E	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VH 20/20E	VH 20/20E
TDH3	Maerl beds	VH 20/20E	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VL 0/20S	M 20/20E	VH 20/20E	VH 20/20E	VH 20/20E	VH 20/20E
TDH4	Modiolus modiolus beds	VH 15/20E	VH 15/20E	VH 15/20E	VL 0/20S	VL 0/20S	VH 15/20E	VH 15/20E	VL 0/20S	M 15/20E	VH 15/20E	VH 15/20E	VH 15/20E	VH 15/20E
TDH5	Ostrea edulis beds	VH 15/20E	VH 15/20E	VH 15/20E	VL 0/20S	VL 0/20S	VH 15/20E	VH 15/20E	VL 0/20S	M 15/20E	VH 15/20E	VH 15/20E	VH 15/20E	VH 15/20E
TDH6	Sabellaria spinulosa reefs	VH 5/20E	VH 5/20E	VH 5/20E	VL 0/20S	VL 0/20S	VH 5/20E	VH 5/20E	VL 0/20S	M 5/20E	VH 5/20E	VH 5/20E	VH 5/20E	VH 5/20E
TDH7	Sea mounts	VH 20/20E	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VH 20/20E	VH 20/20E
TDH8	Sea-pen and burrowing megafauna communities	VH 10/20E	VH 10/20E	VH 10/20E	VL 0/20S	VL 0/20S	VH 10/20E	VH 10/20E	VL 0/20S	M 10/20E	VH 10/20E	VH 10/20E	VH 10/20E	VH 10/20E
TDH9	Zostera beds	VH 10/20E	VH 10/20E	VH 10/20E	VL 0/20S	VL 0/20S	VH 10/20E	VH 10/20E	H 10/20E	VH 10/20E	VH 10/20E	VH 10/20E	VH 10/20E	VH 10/20E

Table 6.14 Positive impact of MCS-MPA management regime for landscapes/habitat types as compared to the status quo scenario.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	H 10/20E	H 10/20E	H 10/20E	M 6/20E	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	H 10/20E	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L2	Oceanic cold water coarse sediment	H 15/20E	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	H 15/20E
L3	Oceanic cold water mixed sediment	H 15/20E	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	H 15/20E
L4	Oceanic cold water mud	H 15/20E	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	H 15/20E
L5	Oceanic cold water sand	H 15/20E	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 15/20E	H 15/20E	H 15/20E
L6	Oceanic warm water coarse sediment	H 10/20E	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L7	Oceanic warm water mixed sediment	H 10/20E	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L8	Oceanic warm water mud	H 10/20E	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L9	Oceanic warm water sand	H 10/20E	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 10/20E	H 10/20E	H 10/20E
L10	Photic reef	H 5/20E	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	VL 0/20S	H 5/20E	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L11	Shallow strong tide stress coarse sediment	M 5/20E	M 5/20E	M 5/20E	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	VL 0/20S	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L12	Shallow moderate tide stress coarse sediment	M 5/20E	M 5/20E	M 5/20E	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	VL 0/20S	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L13	Shallow weak tide stress coarse sediment	H 8/20E	H 8/20E	H 8/20E	L 8/20E	VL 0/20S	H 8/20E	H 8/20E	VL 0/20S	H 8/20E	VL 0/20S	H 8/20E	H 8/20E	H 8/20E
L14	Shallow strong tide stress mixed sediment	M 5/20E	M 5/20E	M 5/20E	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	VL 0/20S	M 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L15	Shallow moderate tide stress mixed sediment	M 5/20E	M 5/20E	M 5/20E	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	VL 0/20S	M 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L16	Shallow weak tide stress mixed sediment	M 5/20E	M 5/20E	M 5/20E	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	VL 0/20S	M 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L17	Shallow mud	M 5/20E	M 5/20E	M 5/20E	VL 5/20L	VL 5/20L	M 5/20E	M 5/20E	VL 0/20S	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L18	Shallow sand	M 5/20E	M 5/20E	M 5/20E	VL 5/20L	VL 5/20L	M 5/20E	M 5/20E	VL 0/20S	L 5/20E	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L19	Shelf strong tide stress coarse sediment	M 5/20E	M 5/20E	M 5/20E	VL 5/20L	VL 5/20L	M 5/20E	M 5/20E	VL 0/20S	L 5/20L	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L20	Shelf moderate tide stress coarse sediment	M 5/20E	M 5/20E	M 5/20E	VL 5/20L	VL 5/20L	M 5/20E	M 5/20E	VL 0/20S	L 5/20L	VL 0/20S	M 5/20E	M 5/20E	M 5/20E
L21	Shelf weak tide stress coarse sediment	VH 8/20E	VH 8/20E	VH 8/20E	VL 5/20L	VL 5/20L	VH 8/20E	VH 8/20E	VL 0/20S	L 5/20L	VL 0/20S	VH 8/20E	VH 8/20E	VH 8/20E
L22	Shelf strong tide stress mixed sediment	H 5/20E	H 5/20E	H 5/20E	VL 5/20L	VL 5/20L	H 5/20E	H 5/20E	VL 0/20S	L 5/20L	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L23	Shelf moderate tide stress mixed sediment	H 5/20E	H 5/20E	H 5/20E	VL 5/20L	VL 5/20L	H 5/20E	H 5/20E	VL 0/20S	L 5/20L	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L24	Shelf weak tide stress mixed sediment	H 8/20E	H 8/20E	H 8/20E	VL 5/20L	VL 5/20L	H 8/20E	H 8/20E	VL 0/20S	L 5/20L	VL 0/20S	H 8/20E	H 8/20E	H 8/20E
L25	Shelf mud	H 5/20E	H 5/20E	H 5/20E	VL 5/20L	VL 5/20L	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
L26	Shelf sand	H 5/20E	H 5/20E	H 5/20E	VL 5/20L	VL 5/20L	H 5/20E	H 5/20E	VL 0/20S	VL 0/20S	VL 0/20S	H 5/20E	H 5/20E	H 5/20E
TDH1	Carbonate mounds	VH 20/20E	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VH 20/20E	VH 20/20E
TDH2	Lophelia pertusa reefs	VH 20/20E	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VH 20/20E	VH 20/20E
TDH3	Maerl beds	VH 20/20E	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VL 0/20S	M 20/20E	VH 20/20E	VH 20/20E	VH 20/20E	VH 20/20E
TDH4	Modiolus modiolus beds	VH 15/20E	VH 15/20E	VH 15/20E	VL 0/20S	VL 0/20S	VH 15/20E	VH 15/20E	VL 0/20S	M 15/20E	VH 15/20E	VH 15/20E	VH 15/20E	VH 15/20E
TDH5	Ostrea edulis beds	VH 15/20E	VH 15/20E	VH 15/20E	VL 0/20S	VL 0/20S	VH 15/20E	VH 15/20E	VL 0/20S	M 15/20E	VH 15/20E	VH 15/20E	VH 15/20E	VH 15/20E
TDH6	Sabellaria spinulosa reefs	VH 5/20E	VH 5/20E	VH 5/20E	VL 0/20S	VL 0/20S	VH 5/20E	VH 5/20E	VL 0/20S	M 5/20E	VH 5/20E	VH 5/20E	VH 5/20E	VH 5/20E
TDH7	Sea mounts	VH 20/20E	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VL 0/20S	VL 0/20S	VH 20/20E	VH 20/20E	VH 20/20E	VH 20/20E
TDH8	Sea-pen and burrowing megafauna communities	VH 10/20E	VH 10/20E	VH 10/20E	VL 0/20S	VL 0/20S	VH 10/20E	VH 10/20E	VL 0/20S	M 10/20E	VH 10/20E	VH 10/20E	VH 10/20E	VH 10/20E
TDH9	Zostera beds	VH 10/20E	VH 10/20E	VH 10/20E	VL 0/20S	VL 0/20S	VH 10/20E	VH 10/20E	H 10/20S	VH 10/20E	VH 10/20E	VH 10/20E	VH 10/20E	VH 10/20E

Following the methodologies of Moran *et al.* (2008), the impact codes for each management regime were transformed into scalar coefficients which convert the three element codes into single numbers that can be used for valuation purposes.

The extent of positive impact in the *status quo*, MSC-MPA and HR-MPA scenarios was determined using one of five categories (Table 6.15). The mid-point was used as a 'best estimate' of positive impact.

Table 6.15 Interpretation of impact coding for valuation estimates

Coding	% range	Mid-point (%)	High value (%)	Low value (%)
VH (very high)	90-100	95	100	90
H (high)	50-89	70	89	50
M (medium)	10-49	30	49	10
L (low)	1-9	5	9	1
VL (very low)	<1	0.5	1	0

The second part of the coding includes two numbers. The first number indicates when the maximum benefit is received (i.e. at 0, 5, 6, 8, 10, 15 or 20 years) and the second number is the number of years (in this case 20 year). These values were used for discounting purposes. The coding has been converted into a second scalar factor (that is then multiplied by the first scalar factor derived of the extent of the impact) for both present value and undiscounted mean annual value.

Scalar coefficients are calculated for both net present values and undiscounted mean values and are presented in the following section. Net present values determine the present value of a stream of benefits that are secured over a period of time. In this case the benefits are assumed to be secured within the 20 year period, although it is recognised that there will likely be benefits beyond this period. If the discount rate is positive (e.g. 3.5%) then benefits secured in earlier periods have a higher value than equivalent benefits secured later in the period. A 3.5% discount rate was chosen as this is the UK Government recommended rate for discounting (HM Treasury, 2011). If values are undiscounted then the present value of a benefit is not affected by the timing of when the benefit is secured.

For example, consider Figure 6.1 below that pertains to the calculation for 10 years. The top curve represents a coding for 10/20S, the middle for 10/20L and the bottom for 10/20E. For the undiscounted mean annual benefits, the total areas under the respective curves are calculated and divided by the 20 year period. For net present values, the calculation is made with a continuous discount rate of 3.5% (Table 6.16). The figures that arise for 10/20 are given in Table 6.16 below. NPV_2 refers to the area from 10 years to 20 years i.e. the rectangle in Figure 6.1, as illustrated by the dashed light blue box. NPV_2 is calculated separately merely for mathematical ease of analysis, and is then added to the area under each respective curve (NPV_1) to give the net present value (NPV_{total}).

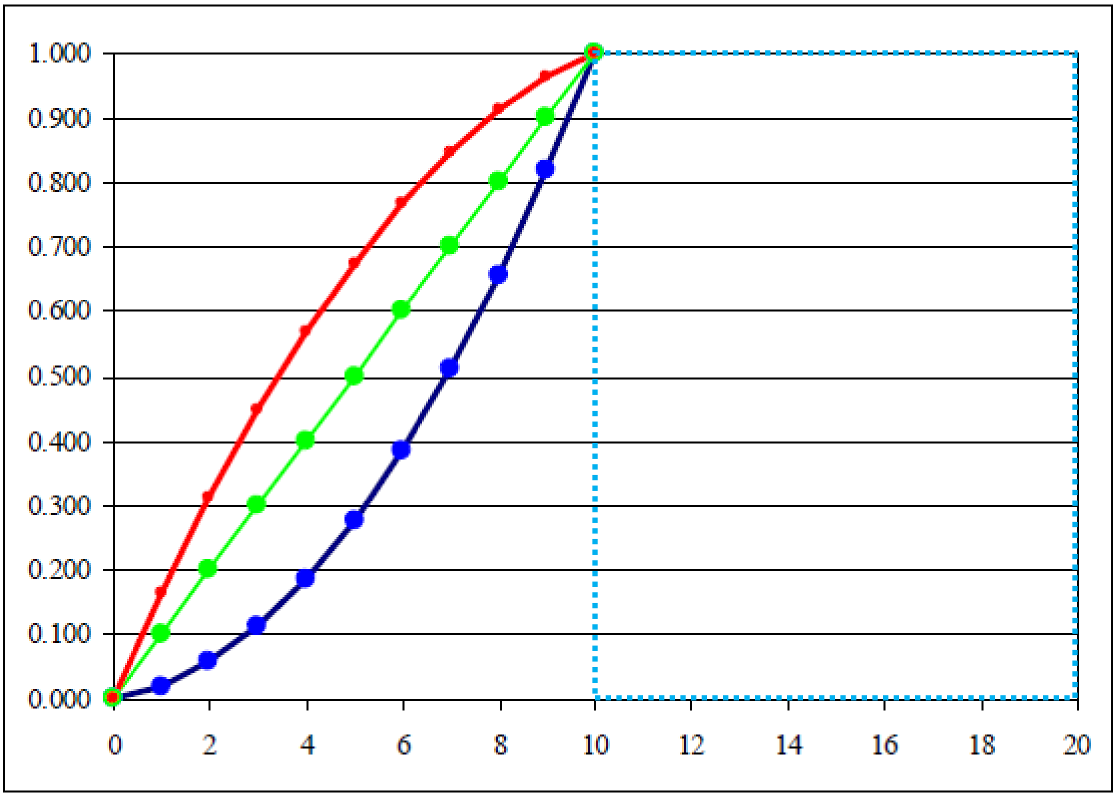

Figure 6.1 Trajectories for benefit paths for 10/20 coding where maximum benefits are recieved after 10 years. Maximum benefits (0.000-1.000) on y-axis and number of years (0-20) on x-axis.

Table 6.16 Net present values and discounted means for 10/20 coding.

	End (E)	Linear (L)	Start (S)
Area	13.5	15.0	16.2
NPV_1	2.7	4.0	5.0
NPV_2	5.9	5.9	5.9
NPV_{total}	8.7	9.9	10.9

ANNEX I ECONOMIC VALUATION OF THE EFFECTS OF PROPOSED PROTECTION MEASURES (MANAGEMENT REGIMES) BY HABITAT TYPE AND ECOSYSTEM SERVICE CATEGORY.

To demonstrate this stage of the process, only one application of the three tasks will be described, that pertaining to net present value under the 'recover' management regime. However, the supporting tables for the other scenarios are provided here for completeness.

NET PRESENT VALUE UNDER THE 'RECOVER' MANAGEMENT REGIME

The first stage of the economic valuation process uses the area change data for the proposed (extended) Northern Ireland MPA network contained in Table 4.3, and combines this with the % total value data contained in Table 4.7, to assign on a consistent basis the proportion of the UK value for each landscape/habitat and ecosystem service combination (see Table 6.17). For example, taking cell E1 (nutrient cycling)/L1 (aphotic reefs), the % total value (0.72%) is multiplied by the proportion of aphotic reefs in the proposed MPA network (0.04%) to give a percentage for the total aggregate value for nutrient cycling apportioned to aphotic reefs by the MPA scenario (0.0003%).

The second stage of the economic valuation process takes the scalar co-efficients which are generated from the assessment in the previous section as given in Table 6.18, and combines these with the data in Table 6.17 to generate a final summary table for net present value/'recover' with the impact factor and present value coefficients both applied (at a 3.5% discount rate) (Table 6.19). Following the example above (E1/L1), 0.0003% is multiplied by the net present value scalar coefficient of 6.06 to give a percentage contribution of 0.016%.

The final stage of the economic valuation process sums the column totals for each ecosystem service, which generates a percentage value for the total UK value of that ecosystem service (Table 6.21). This information is then multiplied by the total value of that service within the UK (Table 4.10). For example, with respect to nutrient cycling (E1), the total at the bottom of column E1 (0.4564%) is then multiplied by the total UK value for nutrient cycling (£1.86 billion) to give the net present value for nutrient cycling as a result of 'recover' management of £8.49 million. Those ecosystem services for which benefit values have not been found were omitted from this final analysis (biologically mediated habitat, resilience and resistance, disturbance prevention and alleviation, cultural heritage and identity and option use value).

Table 6.17 Percentage of the total aggregate value for ecosystem services apportioned to landscape/habitat types protected by the proposed MPA scenario. Shaded cells refer to landscape/habitat types not protected in NI waters.

		Additional MPA Area	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		%	Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	0.04	0.0003	0.0003	0.0003	0.0006	0.0016	0.0007	0.0007	0.0007	0.0011	0.0011	0.0011	0.0011	0.0011
L2	Oceanic cold water coarse sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L3	Oceanic cold water mixed sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L4	Oceanic cold water mud	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L5	Oceanic cold water sand	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L6	Oceanic warm water coarse sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L7	Oceanic warm water mixed sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L8	Oceanic warm water mud	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L9	Oceanic warm water sand	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L10	Photic reef	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L11	Shallow strong tide stress coarse sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L12	Shallow moderate tide stress coarse sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L13	Shallow weak tide stress coarse sediment	0.02	0.0008	0.0008	0.0008	0.0013	0.0016	0.0010	0.0010	0.0010	0.0005	0.0005	0.0005	0.0005	0.0005
L14	Shallow strong tide stress mixed sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L15	Shallow moderate tide stress mixed sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L16	Shallow weak tide stress mixed sediment	0.32	0.0018	0.0018	0.0018	0.0014	0.0025	0.0015	0.0015	0.0015	0.0091	0.0091	0.0091	0.0091	0.0091
L17	Shallow mud	0.24	0.0032	0.0032	0.0032	0.0024	0.0022	0.0027	0.0027	0.0027	0.0068	0.0068	0.0068	0.0068	0.0068
L18	Shallow sand	0.02	0.0016	0.0016	0.0016	0.0012	0.0022	0.0014	0.0014	0.0014	0.0005	0.0005	0.0005	0.0005	0.0005
L19	Shelf strong tide stress coarse sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L20	Shelf moderate tide stress coarse sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L21	Shelf weak tide stress coarse sediment	0.03	0.0029	0.0029	0.0029	0.0049	0.0030	0.0037	0.0037	0.0037	0.0008	0.0008	0.0008	0.0008	0.0008
L22	Shelf strong tide stress mixed sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L23	Shelf moderate tide stress mixed sediment	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L24	Shelf weak tide stress mixed sediment	0.76	0.0059	0.0059	0.0059	0.0044	0.0040	0.0049	0.0049	0.0049	0.0217	0.0217	0.0217	0.0217	0.0217
L25	Shelf mud	0.46	0.0401	0.0401	0.0401	0.0447	0.0272	0.0336	0.0336	0.0335	0.0131	0.0131	0.0131	0.0131	0.0131
L26	Shelf sand	0.01	0.0040	0.0040	0.0040	0.0030	0.0027	0.0034	0.0034	0.0034	0.0003	0.0003	0.0003	0.0003	0.0003
TDH1	Carbonate mounds	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH2	Lophelia pertusa reefs	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH3	Maerl beds	0.32	0.0001	0.0001	0.0001	0.0002	0.0003	0.0002	0.0002	0.0002	0.0091	0.0091	0.0091	0.0091	0.0091
TDH4	Modiolus modiolus beds	0.10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0029	0.0029	0.0029	0.0029
TDH5	Ostrea edulis beds	0.30	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0086	0.0086	0.0086	0.0086	0.0086
TDH6	Sabellaria spinulosa reefs	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH7	Sea mounts	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH8	Sea-pen and burrowing megafauna communitie	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH9	Zostera beds	0.03	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0009	0.0009	0.0009	0.0009	0.0009

Table 6.18 Present value (3.5% discount rate) scalar coefficients for 'recover'. Shaded cells refer to landscape/habitat types not protected in NI waters.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	6.06	6.06	6.06	0.01	0.01	6.06	6.06	0.01	6.06	0.01	6.06	6.06	6.06
L2	Oceanic cold water coarse sediment	4.48	4.48	4.48	0.01	0.01	4.48	4.48	0.01	0.01	0.01	4.48	4.48	4.48
L3	Oceanic cold water mixed sediment	4.48	4.48	4.48	0.01	0.01	4.48	4.48	0.01	0.01	0.01	4.48	4.48	4.48
L4	Oceanic cold water mud	4.48	4.48	4.48	0.01	0.01	4.48	4.48	0.01	0.01	0.01	4.48	4.48	4.48
L5	Oceanic cold water sand	4.48	4.48	4.48	0.01	0.01	4.48	4.48	0.01	0.01	0.01	4.48	4.48	4.48
L6	Oceanic warm water coarse sediment	6.06	6.06	6.06	0.01	0.01	6.06	6.06	0.01	0.01	0.01	6.06	6.06	6.06
L7	Oceanic warm water mixed sediment	6.06	6.06	6.06	0.01	0.01	6.06	6.06	0.01	0.01	0.01	6.06	6.06	6.06
L8	Oceanic warm water mud	6.06	6.06	6.06	0.01	0.01	6.06	6.06	0.01	0.01	0.01	6.06	6.06	6.06
L9	Oceanic warm water sand	6.06	6.06	6.06	0.01	0.01	6.06	6.06	0.01	0.01	0.01	6.06	6.06	6.06
L10	Photic reef	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	7.91	0.01	7.91	7.91	7.91
L11	Shallow strong tide stress coarse sediment	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	3.39	0.01	7.91	7.91	7.91
L12	Shallow moderate tide stress coarse sediment	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	3.39	0.01	7.91	7.91	7.91
L13	Shallow weak tide stress coarse sediment	9.14	9.14	9.14	0.01	0.01	9.14	9.14	0.01	7.91	0.01	9.14	9.14	9.14
L14	Shallow strong tide stress mixed sediment	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	3.39	0.01	7.91	7.91	7.91
L15	Shallow moderate tide stress mixed sediment	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	3.39	0.01	7.91	7.91	7.91
L16	Shallow weak tide stress mixed sediment	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	3.39	0.01	7.91	7.91	7.91
L17	Shallow mud	3.39	3.39	3.39	0.01	0.01	3.39	3.39	0.01	0.56	0.01	3.39	3.39	3.39
L18	Shallow sand	3.61	3.61	3.61	0.01	0.01	3.61	3.61	0.01	3.61	0.01	3.61	3.61	3.61
L19	Shelf strong tide stress coarse sediment	3.39	3.39	3.39	0.01	0.01	3.39	3.39	0.01	0.56	0.01	3.39	3.39	3.39
L20	Shelf moderate tide stress coarse sediment	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	0.56	0.01	7.91	7.91	7.91
L21	Shelf weak tide stress coarse sediment	9.14	9.14	9.14	0.01	0.01	9.14	9.14	0.01	0.48	0.01	9.14	9.14	9.14
L22	Shelf strong tide stress mixed sediment	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	0.56	0.01	7.91	7.91	7.91
L23	Shelf moderate tide stress mixed sediment	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	0.56	0.01	7.91	7.91	7.91
L24	Shelf weak tide stress mixed sediment	6.73	6.73	6.73	0.01	0.01	6.73	6.73	0.01	0.48	0.01	6.73	6.73	6.73
L25	Shelf mud	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	0.01	0.01	7.91	7.91	7.91
L26	Shelf sand	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	0.01	0.01	7.91	7.91	7.91
TDH1	Carbonate mounds	4.23	4.23	4.23	0.01	0.01	4.23	4.23	0.01	0.01	4.23	4.23	4.23	4.23
TDH2	Lophelia pertusa reefs	4.23	4.23	4.23	0.01	0.01	4.23	4.23	0.01	0.01	4.23	4.23	4.23	4.23
TDH3	Maerl beds	4.23	4.23	4.23	0.01	0.01	4.23	4.23	0.01	1.34	4.23	4.23	4.23	4.23
TDH4	Modiolus modiolus beds	6.07	6.07	6.07	0.01	0.01	6.07	6.07	0.01	1.92	6.07	6.07	6.07	6.07
TDH5	Ostrea edulis beds	6.07	6.07	6.07	0.01	0.01	6.07	6.07	0.01	1.92	6.07	6.07	6.07	6.07
TDH6	Sabellaria spinulosa reefs	10.73	10.73	10.73	0.01	0.01	10.73	10.73	0.01	3.39	10.73	10.73	10.73	10.73
TDH7	Sea mounts	4.23	4.23	4.23	0.01	0.01	4.23	4.23	0.01	0.01	4.23	4.23	4.23	4.23
TDH8	Sea-pen and burrowing megafauna communitie	8.22	8.22	8.22	0.01	0.01	8.22	8.22	0.01	2.60	8.22	8.22	8.22	8.22
TDH9	Zostera beds	8.22	8.22	8.22	0.01	0.01	8.22	8.22	5.04	8.22	8.22	8.22	8.22	8.22

Table 6.19 Final summary table for present value/'recover' with Impact Factors and PV coefficients both applied (3.5% discount rate). Shaded cells refer to landscape/habitat types not protected in NI waters.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	0.0016	0.0016	0.0016	0.0000	0.0000	0.0041	0.0041	0.0000	0.0064	0.0000	0.0064	0.0064	0.0064
L2	Oceanic cold water coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L3	Oceanic cold water mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L4	Oceanic cold water mud	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L5	Oceanic cold water sand	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L6	Oceanic warm water coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L7	Oceanic warm water mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L8	Oceanic warm water mud	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L9	Oceanic warm water sand	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L10	Photic reef	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L11	Shallow strong tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L12	Shallow moderate tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L13	Shallow weak tide stress coarse sediment	0.0070	0.0070	0.0070	0.0000	0.0000	0.0088	0.0088	0.0000	0.0039	0.0000	0.0045	0.0045	0.0045
L14	Shallow strong tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L15	Shallow moderate tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L16	Shallow weak tide stress mixed sediment	0.0144	0.0144	0.0144	0.0000	0.0000	0.0121	0.0121	0.0000	0.0307	0.0001	0.0717	0.0717	0.0717
L17	Shallow mud	0.0109	0.0109	0.0109	0.0000	0.0000	0.0091	0.0091	0.0000	0.0038	0.0001	0.0231	0.0231	0.0231
L18	Shallow sand	0.0060	0.0060	0.0060	0.0000	0.0000	0.0050	0.0050	0.0000	0.0018	0.0000	0.0018	0.0018	0.0018
L19	Shelf strong tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L20	Shelf moderate tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L21	Shelf weak tide stress coarse sediment	0.0267	0.0267	0.0267	0.0000	0.0000	0.0336	0.0336	0.0000	0.0004	0.0000	0.0076	0.0076	0.0076
L22	Shelf strong tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L23	Shelf moderate tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L24	Shelf weak tide stress mixed sediment	0.0396	0.0396	0.0396	0.0000	0.0000	0.0332	0.0332	0.0000	0.0104	0.0002	0.1463	0.1463	0.1463
L25	Shelf mud	0.3170	0.3170	0.3170	0.0004	0.0003	0.2657	0.2657	0.0003	0.0001	0.0001	0.1036	0.1036	0.1036
L26	Shelf sand	0.0317	0.0317	0.0317	0.0000	0.0000	0.0266	0.0266	0.0000	0.0000	0.0000	0.0021	0.0021	0.0021
TDH1	Carbonate mounds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH2	Lophelia pertusa reefs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH3	Maerl beds	0.0006	0.0006	0.0006	0.0000	0.0000	0.0008	0.0008	0.0000	0.0123	0.0387	0.0387	0.0387	0.0387
TDH4	Modiolus modiolus beds	0.0003	0.0003	0.0003	0.0000	0.0000	0.0002	0.0002	0.0000	0.0055	0.0173	0.0173	0.0173	0.0173
TDH5	Ostrea edulis beds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0165	0.0520	0.0520	0.0520	0.0520
TDH6	Sabellaria spinulosa reefs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH7	Sea mounts	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH8	Sea-pen and burrowing megafauna communities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH9	Zostera beds	0.0006	0.0006	0.0006	0.0000	0.0000	0.0005	0.0005	0.0006	0.0070	0.0070	0.0070	0.0070	0.0070
Total		**0.4564**	**0.4564**	**0.4564**	**0.0006**	**0.0005**	**0.3997**	**0.3997**	**0.0011**	**0.0989**	**0.1156**	**0.4823**	**0.4823**	**0.4823**

NET PRESENT VALUE UNDER THE 'MAINTAIN' (MCS-MPA) MANAGEMENT REGIME

Table 6.20 Present value (3.5% discount rate) scalar coefficients for MCS-MPA. Shaded cells refer to landscape/habitat types not protected in NI waters.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	6.06	6.06	6.06	2.73	0.01	6.06	6.06	0.01	6.06	0.01	6.06	6.06	6.06
L2	Oceanic cold water coarse sediment	4.48	4.48	4.48	0.01	0.01	4.48	4.48	0.01	0.01	0.01	4.48	4.48	4.48
L3	Oceanic cold water mixed sediment	4.48	4.48	4.48	0.01	0.01	4.48	4.48	0.01	0.01	0.01	4.48	4.48	4.48
L4	Oceanic cold water mud	4.48	4.48	4.48	0.01	0.01	4.48	4.48	0.01	0.01	0.01	4.48	4.48	4.48
L5	Oceanic cold water sand	4.48	4.48	4.48	0.01	0.01	4.48	4.48	0.01	0.01	0.01	4.48	4.48	4.48
L6	Oceanic warm water coarse sediment	6.06	6.06	6.06	0.01	0.01	6.06	6.06	0.01	0.01	0.01	6.06	6.06	6.06
L7	Oceanic warm water mixed sediment	6.06	6.06	6.06	0.01	0.01	6.06	6.06	0.01	0.01	0.01	6.06	6.06	6.06
L8	Oceanic warm water mud	6.06	6.06	6.06	0.01	0.01	6.06	6.06	0.01	0.01	0.01	6.06	6.06	6.06
L9	Oceanic warm water sand	6.06	6.06	6.06	0.01	0.01	6.06	6.06	0.01	0.01	0.01	6.06	6.06	6.06
L10	Photic reef	7.91	7.91	7.91	0.01	0.01	7.91	7.91	0.01	7.91	0.01	7.91	7.91	7.91
L11	Shallow strong tide stress coarse sediment	3.39	3.39	3.39	0.56	0.01	3.39	3.39	0.01	0.56	0.01	3.39	3.39	3.39
L12	Shallow moderate tide stress coarse sediment	3.39	3.39	3.39	0.56	0.01	3.39	3.39	0.01	0.56	0.01	3.39	3.39	3.39
L13	Shallow weak tide stress coarse sediment	6.73	6.73	6.73	0.40	0.01	6.73	6.73	0.01	6.73	0.01	6.73	6.73	6.73
L14	Shallow strong tide stress mixed sediment	3.39	3.39	3.39	0.56	0.01	3.39	3.39	0.01	3.39	0.01	3.39	3.39	3.39
L15	Shallow moderate tide stress mixed sediment	3.39	3.39	3.39	0.56	0.01	3.39	3.39	0.01	3.39	0.01	3.39	3.39	3.39
L16	Shallow weak tide stress mixed sediment	3.39	3.39	3.39	0.56	0.01	3.39	3.39	0.01	3.39	0.01	3.39	3.39	3.39
L17	Shallow mud	3.39	3.39	3.39	0.06	0.06	3.39	3.39	0.01	0.56	0.01	3.39	3.39	3.39
L18	Shallow sand	3.39	3.39	3.39	0.06	0.06	3.39	3.39	0.01	0.56	0.01	3.39	3.39	3.39
L19	Shelf strong tide stress coarse sediment	3.39	3.39	3.39	0.06	0.06	3.39	3.39	0.01	0.60	0.01	3.39	3.39	3.39
L20	Shelf moderate tide stress coarse sediment	7.91	7.91	7.91	0.06	0.06	7.91	7.91	0.01	0.60	0.01	7.91	7.91	7.91
L21	Shelf weak tide stress coarse sediment	9.14	9.14	9.14	0.06	0.06	9.14	9.14	0.01	0.60	0.01	9.14	9.14	9.14
L22	Shelf strong tide stress mixed sediment	7.91	7.91	7.91	0.06	0.06	7.91	7.91	0.01	0.60	0.01	7.91	7.91	7.91
L23	Shelf moderate tide stress mixed sediment	7.91	7.91	7.91	0.06	0.06	7.91	7.91	0.01	0.60	0.01	7.91	7.91	7.91
L24	Shelf weak tide stress mixed sediment	6.73	6.73	6.73	0.06	0.06	6.73	6.73	0.01	0.60	0.01	6.73	6.73	6.73
L25	Shelf mud	7.91	7.91	7.91	0.06	0.06	7.91	7.91	0.01	0.01	0.01	7.91	7.91	7.91
L26	Shelf sand	7.91	7.91	7.91	0.06	0.06	7.91	7.91	0.01	0.01	0.01	7.91	7.91	7.91
TDH1	Carbonate mounds	4.23	4.23	4.23	0.01	0.01	4.23	4.23	0.01	0.01	4.23	4.23	4.23	4.23
TDH2	*Lophelia pertusa* reefs	4.23	4.23	4.23	0.01	0.01	4.23	4.23	0.01	0.01	4.23	4.23	4.23	4.23
TDH3	Maerl beds	4.23	4.23	4.23	0.01	0.01	4.23	4.23	0.01	1.34	4.23	4.23	4.23	4.23
TDH4	*Modiolus modiolus* beds	6.07	6.07	6.07	0.01	0.01	6.07	6.07	0.01	1.92	6.07	6.07	6.07	6.07
TDH5	*Ostrea edulis* beds	6.07	6.07	6.07	0.01	0.01	6.07	6.07	0.01	1.92	6.07	6.07	6.07	6.07
TDH6	*Sabellaria spinulosa* reefs	6.07	6.07	6.07	0.01	0.01	6.07	6.07	0.01	3.39	6.07	6.07	6.07	6.07
TDH7	Sea mounts	4.23	4.23	4.23	0.01	0.01	4.23	4.23	0.01	0.01	4.23	4.23	4.23	4.23
TDH8	Sea-pen and burrowing megafauna communities	8.22	8.22	8.22	0.01	0.01	8.22	8.22	0.01	2.60	8.22	8.22	8.22	8.22
TDH9	*Zostera* beds	8.22	8.22	8.22	0.01	0.01	8.22	8.22	6.06	8.22	8.22	8.22	8.22	8.22

Table 6.21 Final summary table for present value/'maintain' with Impact Factors and PV coefficients both applied (3.5% discount rate). Shaded cells refer to landscape/habitat types not protected in NI waters.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	0.0016	0.0016	0.0016	0.0016	0.0000	0.0041	0.0041	0.0000	0.0064	0.0000	0.0064	0.0064	0.0064
L2	Oceanic cold water coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L3	Oceanic cold water mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L4	Oceanic cold water mud	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L5	Oceanic cold water sand	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L6	Oceanic warm water coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L7	Oceanic warm water mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L8	Oceanic warm water mud	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L9	Oceanic warm water sand	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L10	Photic reef	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L11	Shallow strong tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L12	Shallow moderate tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L13	Shallow weak tide stress coarse sediment	0.0051	0.0051	0.0051	0.0005	0.0000	0.0065	0.0065	0.0000	0.0033	0.0000	0.0033	0.0033	0.0033
L14	Shallow strong tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L15	Shallow moderate tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L16	Shallow weak tide stress mixed sediment	0.0062	0.0062	0.0062	0.0008	0.0000	0.0052	0.0052	0.0000	0.0307	0.0001	0.0307	0.0307	0.0307
L17	Shallow mud	0.0109	0.0109	0.0109	0.0001	0.0001	0.0091	0.0091	0.0000	0.0038	0.0001	0.0231	0.0231	0.0231
L18	Shallow sand	0.0056	0.0056	0.0056	0.0001	0.0001	0.0047	0.0047	0.0000	0.0003	0.0000	0.0017	0.0017	0.0017
L19	Shelf strong tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L20	Shelf moderate tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L21	Shelf weak tide stress coarse sediment	0.0267	0.0267	0.0267	0.0003	0.0002	0.0336	0.0336	0.0000	0.0005	0.0000	0.0076	0.0076	0.0076
L22	Shelf strong tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L23	Shelf moderate tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L24	Shelf weak tide stress mixed sediment	0.0396	0.0396	0.0396	0.0003	0.0002	0.0332	0.0332	0.0000	0.0130	0.0002	0.1463	0.1463	0.1463
L25	Shelf mud	0.3170	0.3170	0.3170	0.0027	0.0016	0.2657	0.2657	0.0003	0.0001	0.0001	0.1036	0.1036	0.1036
L26	Shelf sand	0.0317	0.0317	0.0317	0.0002	0.0002	0.0266	0.0266	0.0000	0.0000	0.0000	0.0021	0.0021	0.0021
TDH1	Carbonate mounds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH2	*Lophelia pertusa* reefs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH3	Maerl beds	0.0006	0.0006	0.0006	0.0000	0.0000	0.0008	0.0008	0.0000	0.0123	0.0387	0.0387	0.0387	0.0387
TDH4	*Modiolus modiolus* beds	0.0003	0.0003	0.0003	0.0000	0.0000	0.0002	0.0002	0.0000	0.0055	0.0173	0.0173	0.0173	0.0173
TDH5	*Ostrea edulis* beds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0165	0.0520	0.0520	0.0520	0.0520
TDH6	*Sabellaria spinulosa* reefs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH7	Sea mounts	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH8	Sea-pen and burrowing megafauna communities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH9	*Zostera* beds	0.0006	0.0006	0.0006	0.0000	0.0000	0.0005	0.0005	0.0007	0.0070	0.0070	0.0070	0.0070	0.0070
Total		**0.4460**	**0.4460**	**0.4460**	**0.0065**	**0.0025**	**0.3902**	**0.3902**	**0.0013**	**0.0995**	**0.1156**	**0.4400**	**0.4400**	**0.4400**

UNDISCOUNTED MEAN VALUE UNDER THE 'RECOVER' MANAGEMENT REGIME

Table 6.22 Undiscounted mean annual value scalar coefficients for 'recover'. Shaded cells refer to landscape/habitat types not protected in NI waters.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	0.54	0.54	0.54	0.00	0.00	0.56	0.56	0.00	0.56	0.00	0.56	0.56	0.56
L2	Oceanic cold water coarse sediment	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.51	0.51	0.51
L3	Oceanic cold water mixed sediment	0.50	0.50	0.50	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.57	0.57	0.57
L4	Oceanic cold water mud	0.50	0.50	0.50	0.00	0.00	0.52	0.52	0.00	0.00	0.00	0.53	0.53	0.53
L5	Oceanic cold water sand	0.43	0.43	0.43	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.50	0.50	0.50
L6	Oceanic warm water coarse sediment	0.58	0.58	0.58	0.00	0.00	0.56	0.56	0.00	0.00	0.00	0.58	0.58	0.58
L7	Oceanic warm water mixed sediment	0.33	0.33	0.33	0.00	0.00	0.67	0.67	0.00	0.00	0.00	0.60	0.60	0.60
L8	Oceanic warm water mud	0.56	0.56	0.56	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.55	0.55	0.55
L9	Oceanic warm water sand	0.55	0.55	0.55	0.00	0.00	0.56	0.56	0.00	0.00	0.00	0.56	0.56	0.56
L10	Photic reef	0.62	0.62	0.62	0.00	0.00	0.63	0.63	0.00	0.64	0.00	0.64	0.64	0.64
L11	Shallow strong tide stress coarse sediment	0.60	0.60	0.60	0.00	0.00	0.67	0.67	0.00	0.26	0.00	0.63	0.63	0.63
L12	Shallow moderate tide stress coarse sediment	0.63	0.63	0.63	0.00	0.00	0.64	0.64	0.00	0.27	0.00	0.64	0.64	0.64
L13	Shallow weak tide stress coarse sediment	0.82	0.82	0.82	0.00	0.00	0.83	0.83	0.00	0.63	0.00	0.83	0.83	0.83
L14	Shallow strong tide stress mixed sediment	0.67	0.67	0.67	0.00	0.00	0.50	0.50	0.00	0.27	0.00	0.64	0.64	0.64
L15	Shallow moderate tide stress mixed sediment	0.56	0.56	0.56	0.00	0.00	0.64	0.64	0.00	0.27	0.00	0.64	0.64	0.64
L16	Shallow weak tide stress mixed sediment	0.71	0.71	0.71	0.00	0.00	0.67	0.67	0.00	0.27	0.00	0.65	0.65	0.65
L17	Shallow mud	0.28	0.28	0.28	0.00	0.00	0.27	0.27	0.00	0.05	0.00	0.26	0.26	0.26
L18	Shallow sand	0.26	0.26	0.26	0.00	0.00	0.26	0.26	0.00	0.26	0.00	0.26	0.26	0.26
L19	Shelf strong tide stress coarse sediment	0.29	0.29	0.29	0.00	0.00	0.22	0.22	0.00	0.04	0.00	0.26	0.26	0.26
L20	Shelf moderate tide stress coarse sediment	0.65	0.65	0.65	0.00	0.00	0.65	0.65	0.00	0.05	0.00	0.63	0.63	0.63
L21	Shelf weak tide stress coarse sediment	0.82	0.82	0.82	0.00	0.00	0.82	0.82	0.00	0.03	0.00	0.81	0.81	0.81
L22	Shelf strong tide stress mixed sediment	1.00	1.00	1.00	0.00	0.00	0.50	0.50	0.00	0.05	0.00	0.64	0.64	0.64
L23	Shelf moderate tide stress mixed sediment	0.67	0.67	0.67	0.00	0.00	0.63	0.63	0.00	0.05	0.00	0.65	0.65	0.65
L24	Shelf weak tide stress mixed sediment	0.67	0.67	0.67	0.00	0.00	0.63	0.63	0.00	0.03	0.00	0.60	0.60	0.60
L25	Shelf mud	0.64	0.64	0.64	0.00	0.00	0.64	0.64	0.00	0.00	0.00	0.65	0.65	0.65
L26	Shelf sand	0.64	0.64	0.64	0.00	0.00	0.64	0.64	0.00	0.00	0.00	0.63	0.63	0.63
TDH1	Carbonate mounds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.58	0.58	0.58
TDH2	*Lophelia pertusa* reefs	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.67	0.67	0.67	0.67
TDH3	Maerl beds	0.50	0.50	0.50	0.00	0.00	0.50	0.50	0.00	0.19	0.60	0.60	0.60	0.60
TDH4	*Modiolus modiolus* beds	1.00	1.00	1.00	0.00	0.00	0.50	0.50	0.00	0.22	0.70	0.70	0.70	0.70
TDH5	*Ostrea edulis* beds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.71	0.71	0.71	0.71
TDH6	*Sabellaria spinulosa* reefs	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.28	0.87	0.87	0.87	0.87
TDH7	Sea mounts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.60	0.60	0.60
TDH8	Sea-pen and burrowing megafauna communities	0.82	0.82	0.82	0.00	0.00	0.70	0.70	0.00	0.24	0.76	0.76	0.76	0.76
TDH9	*Zostera* beds	0.75	0.75	0.75	0.00	0.00	0.71	0.71	1.14	0.77	0.77	0.77	0.77	0.77

Table 6.23 Final summary table for undiscounted mean benefits/'recover' with Impact Factors and PV coefficients both applied. Shaded cells refer to landscape/habitat types not protected in NI waters.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	0.0001	0.0001	0.0001	0.0000	0.0000	0.0004	0.0004	0.0000	0.0006	0.0000	0.0006	0.0006	0.0006
L2	Oceanic cold water coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L3	Oceanic cold water mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L4	Oceanic cold water mud	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L5	Oceanic cold water sand	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L6	Oceanic warm water coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L7	Oceanic warm water mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L8	Oceanic warm water mud	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L9	Oceanic warm water sand	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L10	Photic reef	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L11	Shallow strong tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L12	Shallow moderate tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L13	Shallow weak tide stress coarse sediment	0.0006	0.0006	0.0006	0.0000	0.0000	0.0008	0.0008	0.0000	0.0003	0.0000	0.0004	0.0004	0.0004
L14	Shallow strong tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L15	Shallow moderate tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L16	Shallow weak tide stress mixed sediment	0.0013	0.0013	0.0013	0.0000	0.0000	0.0010	0.0010	0.0000	0.0024	0.0000	0.0059	0.0059	0.0059
L17	Shallow mud	0.0009	0.0009	0.0009	0.0000	0.0000	0.0007	0.0007	0.0000	0.0003	0.0000	0.0018	0.0018	0.0018
L18	Shallow sand	0.0004	0.0004	0.0004	0.0000	0.0000	0.0004	0.0004	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001
L19	Shelf strong tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L20	Shelf moderate tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L21	Shelf weak tide stress coarse sediment	0.0024	0.0024	0.0024	0.0000	0.0000	0.0030	0.0030	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007
L22	Shelf strong tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L23	Shelf moderate tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L24	Shelf weak tide stress mixed sediment	0.0039	0.0039	0.0039	0.0000	0.0000	0.0031	0.0031	0.0000	0.0007	0.0000	0.0130	0.0130	0.0130
L25	Shelf mud	0.0256	0.0256	0.0256	0.0000	0.0000	0.0215	0.0215	0.0000	0.0000	0.0000	0.0085	0.0085	0.0085
L26	Shelf sand	0.0026	0.0026	0.0026	0.0000	0.0000	0.0022	0.0022	0.0000	0.0000	0.0000	0.0002	0.0002	0.0002
TDH1	Carbonate mounds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH2	*Lophelia pertusa* reefs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH3	Maerl beds	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0017	0.0055	0.0055	0.0055	0.0055
TDH4	*Modiolus modiolus* beds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0020	0.0020	0.0020	0.0020
TDH5	*Ostrea edulis* beds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0061	0.0061	0.0061	0.0061
TDH6	*Sabellaria spinulosa* reefs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH7	Sea mounts	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH8	Sea-pen and burrowing megafauna communities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH9	*Zostera* beds	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0007	0.0007	0.0007	0.0007	0.0007
Total		**0.0381**	**0.0381**	**0.0381**	**0.0000**	**0.0000**	**0.0332**	**0.0332**	**0.0001**	**0.0094**	**0.0142**	**0.0454**	**0.0454**	**0.0454**

UNDISCOUNTED MEAN VALUE UNDER THE 'MAINTAIN' MANAGEMENT REGIME

Table 6.24 Undiscounted mean annual value scalar coefficients for 'maintain'. Shaded cells refer to landscape/habitat types not protected in NI waters.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	0.54	0.54	0.54	0.29	0.00	0.56	0.56	0.00	0.56	0.00	0.56	0.56	0.56
L2	Oceanic cold water coarse sediment	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.51	0.51	0.51
L3	Oceanic cold water mixed sediment	0.50	0.50	0.50	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.57	0.57	0.57
L4	Oceanic cold water mud	0.50	0.50	0.50	0.00	0.00	0.52	0.52	0.00	0.00	0.00	0.53	0.53	0.53
L5	Oceanic cold water sand	0.43	0.43	0.43	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.50	0.50	0.50
L6	Oceanic warm water coarse sediment	0.58	0.58	0.58	0.00	0.00	0.56	0.56	0.00	0.00	0.00	0.58	0.58	0.58
L7	Oceanic warm water mixed sediment	0.33	0.33	0.33	0.00	0.00	0.67	0.67	0.00	0.00	0.00	0.60	0.60	0.60
L8	Oceanic warm water mud	0.56	0.56	0.56	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.55	0.55	0.55
L9	Oceanic warm water sand	0.55	0.55	0.55	0.00	0.00	0.56	0.56	0.00	0.00	0.00	0.56	0.56	0.56
L10	Photic reef	0.62	0.62	0.62	0.00	0.00	0.63	0.63	0.00	0.64	0.00	0.64	0.64	0.64
L11	Shallow strong tide stress coarse sediment	0.20	0.20	0.20	0.00	0.00	0.33	0.33	0.00	0.05	0.00	0.26	0.26	0.26
L12	Shallow moderate tide stress coarse sediment	0.29	0.29	0.29	0.05	0.00	0.27	0.27	0.00	0.04	0.00	0.27	0.27	0.27
L13	Shallow weak tide stress coarse sediment	0.61	0.61	0.61	0.00	0.00	0.61	0.61	0.00	0.60	0.00	0.60	0.60	0.60
L14	Shallow strong tide stress mixed sediment	0.33	0.33	0.33	0.00	0.00	0.25	0.25	0.00	0.27	0.00	0.27	0.27	0.27
L15	Shallow moderate tide stress mixed sediment	0.22	0.22	0.22	0.00	0.00	0.27	0.27	0.00	0.27	0.00	0.27	0.27	0.27
L16	Shallow weak tide stress mixed sediment	0.29	0.29	0.29	0.00	0.00	0.33	0.33	0.00	0.27	0.00	0.27	0.27	0.27
L17	Shallow mud	0.28	0.28	0.28	0.00	0.00	0.27	0.27	0.00	0.05	0.00	0.26	0.26	0.26
L18	Shallow sand	0.28	0.28	0.28	0.00	0.00	0.28	0.28	0.00	0.04	0.00	0.27	0.27	0.27
L19	Shelf strong tide stress coarse sediment	0.29	0.29	0.29	0.00	0.00	0.22	0.22	0.00	0.04	0.00	0.26	0.26	0.26
L20	Shelf moderate tide stress coarse sediment	0.65	0.65	0.65	0.00	0.00	0.65	0.65	0.00	0.05	0.00	0.63	0.63	0.63
L21	Shelf weak tide stress coarse sediment	0.82	0.82	0.82	0.00	0.00	0.82	0.82	0.00	0.03	0.00	0.81	0.81	0.81
L22	Shelf strong tide stress mixed sediment	1.00	1.00	1.00	0.00	0.00	0.50	0.50	0.00	0.05	0.00	0.64	0.64	0.64
L23	Shelf moderate tide stress mixed sediment	0.67	0.67	0.67	0.00	0.00	0.63	0.63	0.00	0.05	0.00	0.65	0.65	0.65
L24	Shelf weak tide stress mixed sediment	0.67	0.67	0.67	0.00	0.00	0.63	0.63	0.00	0.06	0.00	0.60	0.60	0.60
L25	Shelf mud	0.64	0.64	0.64	0.00	0.00	0.64	0.64	0.00	0.00	0.00	0.65	0.65	0.65
L26	Shelf sand	0.64	0.64	0.64	0.00	0.00	0.64	0.64	0.00	0.00	0.00	0.63	0.63	0.63
TDH1	Carbonate mounds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.58	0.58	0.58
TDH2	*Lophelia pertusa* reefs	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.67	0.67	0.67	0.67
TDH3	Maerl beds	0.50	0.50	0.50	0.00	0.00	0.50	0.50	0.00	0.19	0.60	0.60	0.60	0.60
TDH4	*Modiolus modiolus* beds	1.00	1.00	1.00	0.00	0.00	0.50	0.50	0.00	0.22	0.70	0.70	0.70	0.70
TDH5	*Ostrea edulis* beds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.71	0.71	0.71	0.71
TDH6	*Sabellaria spinulosa* reefs	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.28	0.87	0.87	0.87	0.87
TDH7	Sea mounts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.60	0.60	0.60
TDH8	Sea-pen and burrowing megafauna communities	0.82	0.82	0.82	0.00	0.00	0.70	0.70	0.00	0.24	0.76	0.76	0.76	0.76
TDH9	*Zostera* beds	0.75	0.75	0.75	0.00	0.00	0.71	0.71	1.14	0.77	0.77	0.77	0.77	0.77

Table 6.25 Final summary table for undiscounted mean benefits/'maintain' with Impact Factors and PV coefficients both applied. Shaded cells refer to landscape/habitat types not protected in NI waters.

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
		Nutrient cycling	Bioremediation of waste	Gas and climate regulation	Food provision	Raw materials	Biologically mediated habitat	Resilience and resistance	Disturbance prevention and alleviation	Leisure and recreation	Cultural heritage and identity	Non-use values - bequest and existence	Option use values	Cognitive values
L1	Aphotic reefs	0.0001	0.0001	0.0001	0.0002	0.0000	0.0004	0.0004	0.0000	0.0006	0.0000	0.0006	0.0006	0.0006
L2	Oceanic cold water coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L3	Oceanic cold water mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L4	Oceanic cold water mud	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L5	Oceanic cold water sand	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L6	Oceanic warm water coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L7	Oceanic warm water mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L8	Oceanic warm water mud	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L9	Oceanic warm water sand	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L10	Photic reef	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L11	Shallow strong tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L12	Shallow moderate tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L13	Shallow weak tide stress coarse sediment	0.0005	0.0005	0.0005	0.0000	0.0000	0.0006	0.0006	0.0000	0.0003	0.0000	0.0003	0.0003	0.0003
L14	Shallow strong tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L15	Shallow moderate tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L16	Shallow weak tide stress mixed sediment	0.0005	0.0005	0.0005	0.0000	0.0000	0.0005	0.0005	0.0000	0.0024	0.0000	0.0024	0.0024	0.0024
L17	Shallow mud	0.0009	0.0009	0.0009	0.0000	0.0000	0.0007	0.0007	0.0000	0.0003	0.0000	0.0018	0.0018	0.0018
L18	Shallow sand	0.0005	0.0005	0.0005	0.0000	0.0000	0.0004	0.0004	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
L19	Shelf strong tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L20	Shelf moderate tide stress coarse sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L21	Shelf weak tide stress coarse sediment	0.0024	0.0024	0.0024	0.0000	0.0000	0.0030	0.0030	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007
L22	Shelf strong tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L23	Shelf moderate tide stress mixed sediment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L24	Shelf weak tide stress mixed sediment	0.0039	0.0039	0.0039	0.0000	0.0000	0.0031	0.0031	0.0000	0.0013	0.0000	0.0130	0.0130	0.0130
L25	Shelf mud	0.0256	0.0256	0.0256	0.0000	0.0000	0.0215	0.0215	0.0000	0.0000	0.0000	0.0085	0.0085	0.0085
L26	Shelf sand	0.0026	0.0026	0.0026	0.0000	0.0000	0.0022	0.0022	0.0000	0.0000	0.0000	0.0002	0.0002	0.0002
TDH1	Carbonate mounds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH2	*Lophelia pertusa* reefs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH3	Maerl beds	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0017	0.0055	0.0055	0.0055	0.0055
TDH4	*Modiolus modiolus* beds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0020	0.0020	0.0020	0.0020
TDH5	*Ostrea edulis* beds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0061	0.0061	0.0061	0.0061
TDH6	*Sabellaria spinulosa* reefs	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH7	Sea mounts	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH8	Sea-pen and burrowing megafauna communities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TDH9	*Zostera* beds	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0007	0.0007	0.0007	0.0007	0.0007
Total		**0.0372**	**0.0372**	**0.0372**	**0.0002**	**0.0000**	**0.0325**	**0.0325**	**0.0001**	**0.0099**	**0.0142**	**0.0419**	**0.0419**	**0.0419**

ANNEX J SUPPLEMENTARY ECOSYSTEM SERVICE MATERIAL

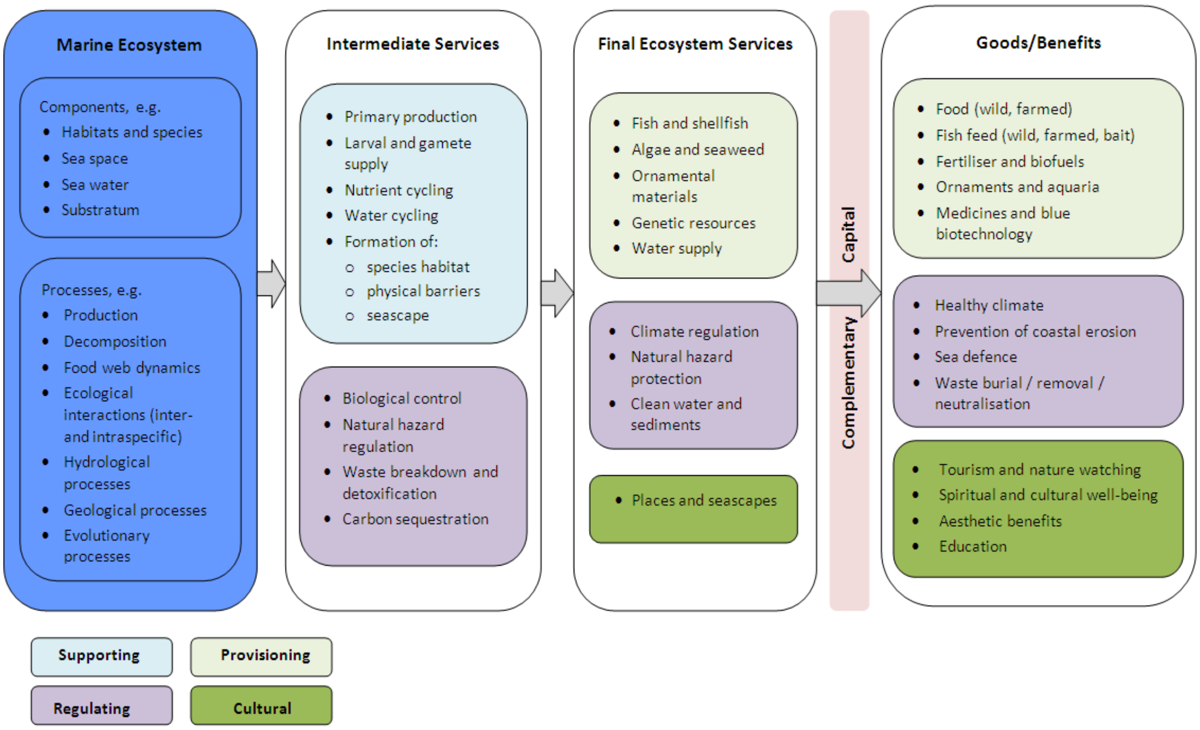

Figure 6.2 Ecosystem services framework for the coastal and marine environment (Turner *et al.*, 2013b)

Feature Type†	EUNIS code	Feature	Intermediate services											Goods/Benefits													
	Note: Eunis codes were identified using the JNCC EUNIS translation matrix. Some habitats do not have a direct relationship to the EUNIS code and this column should only be used as a guide.		Supporting services							Regulating services				from Provisioning services					from Regulating services					from Cultural services			
			Primary production	Larval / Gamete supply	Nutrient cycling	Water cycling	Formation of species habitat	Formation of physical barriers	Formation of seascape	Biological control	Natural hazard regulation	Regulation of water & sediment quality	Carbon sequestration	Food	Fish feed	Fertiliser	Ornaments (incl. aquaria)	Medicine & blue biotechnology	Healthy climate	Prevention of coastal erosion	Sea defence	Clean water and sediments	Imobilisation of pollutants	Tourism / Nature watching	Spiritual / Cultural wellbeing	Aesthetic benefits	Education
Broad Scale Habitat																											
E,W	A1.1	High energy intertidal rock	3	2	3		2	1	1		1		2	3					2	1	1			1	1	1	1
E,W	A1.2	Moderate energy intertidal rock	3	2	3		2	1			1		2	3					2	1	1			1	1	1	1
E,W	A1.3	Low energy intertidal rock	3	2	3		2	1			1		2	3					2	1	1			1	1	1	1
E,W	A2.1	Intertidal coarse sediment	1	3	1		3	1	1		3			1						3	3			1	1	1	1
E,W	A2.2	Intertidal sand and muddy sand	3	3	3		3	1	3		3		2	1					2	3	3			1	1	3	1
E,EU	A2.4	Intertidal mixed sediments	3	3	3		3	1	1		3		2	1					2	3	3			1	1	1	1
E,W	A2.3	Intertidal mud	3	3	3		1		1		3	3	3	3					3	3	3	3	3	1	1	1	1
E	A2.5	Coastal saltmarshes and saline reedbeds	2	3	3		3	3	3		3	3	3	3		3			3	3	3	3	3	3	1	3	1
E,EU,W	A2.6	Intertidal sediments dominated by aquatic angiosperms	2		3		2	1	1		1	3	1	3		3			1	1	1	1	1	1	1		1
E,EU,W	A2.7	Intertidal biogenic reefs	1	1	2		3		1		2	1	1	2					1	2	2	2	2	1	1		1
E,W	A3.1	High energy infralittoral rock*	2	2			2	1			1			3						1	1			1	1		1
E,W	A3.2	Moderate energy infralittoral rock*	2	2			2	1			1			3						1	1			1	1		1
E,W	A3.3	Low energy infralittoral rock*	2	2			2	1			1									1	1			1	1		1
E,W	A4.1	High energy circalittoral rock**	2	2			2	1			1			1						1	1			1	1		1
E,W	A4.2	Moderate energy circalittoral rock**	2	2			2	1			1			1						1	1			1	1		1
E,W	A4.3	Low energy circalittoral rock**	2	2			2	1			1			1						1	1			1	1		1
E,W	A5.1	Subtidal coarse sediment	3	3	3		3				3	1		2	3					3	3	3	1		1		1
S	A5.1, A5.2	Offshore subtidal sands and gravels	1	1	1		1	1		1	1	1		1	3	1	1	1	1	1	1	1	1	1	1		1
E,W	A5.2	Subtidal sand	3	3	3		3				3	1		2	3					3	3	3	1		1		1
E,W	A5.3	Subtidal mud	3	3	3		3				3	1		2	3					3	3	3	3		1		1
E,EU,W	A5.4	Subtidal mixed sediments	3	3	3		3				3	1		2	3					3	3	3	3		1		1
W	A5.4, A5.3	Subtidal mixed muddy sediments	3	3	3		3				3	1		2	3					3	3	3	3		1		1
E,EU,W	A5.5	Subtidal macrophyte-dominated sediment	3	2	2		2				1	2	2	3		3			2	1	1	2	2	1	1		1
E,EU,W	A5.6	Subtidal biogenic reefs	1	2	3		2				3	3	1	3			1		1	2	2	3	1	1	1		1
S	A7.4, A7.7	Salinity fronts	1	1	1		1	1		1	1	1	1	1		1	1	1	1	1	1	1	2	1	1		1
S	Various	Low or variable salinity habitats	1	1	1		1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	3
EU	X02	Saline lagoons		3	3		3		1					1										1	1		1
Habitats																											
E	A1.32	Estuarine rocky habitats	1	1			2		1		1			1						1	1			1	1	1	1
E,W	A1.2142, A3.2112	Intertidal under boulder communities	1	1			2				1			2						1	1			1	1	1	1
E	A1.127, A1.223, A4.231	Peat and clay exposures		1			2																	1	1		1
S	A1.325	Sea loch egg wrack beds	1	1	1		1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1		1
E	A1.441, B3.114, B3.115	Littoral chalk communities	1	1			3																	1	1		1
EU	A1.44	Submerged or partially submerged sea caves					1		1															1	1		1
E,S,W	A2.2, A2.7, A5.6	Blue Mussel beds	1	1	1		1	1	1	1	1	3	1	2		2	1	1	1	1	1	1	1	1	1		1
E,W	A2.71	Honeycomb worm *Sabellaria alveolata* reef		1	1		3	1		1	2	1	1	1					1	1	1	1	1	1	1		1
S	A3.126, A3.213	Tide-swept algal communities (Laminaria hyperborea, Halidrys siliquosa)	1	1	1		1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1
S	A3.126, A3.213, A1.15	Tide-swept algal communities	1	1	1		1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1
E,W	A4.12, A4.12	Fragile sponge&anthozoan communities on subtidal rocky habitats		1			3			1				3									1	3	1		1
W	A4.131, A4.2122	Subtidal rock with Ross 'coral' Pentapora foliacea		1			2			1				1									1	3	1		1
S	A4.133, A4.211	Northern sea fan and sponge communities					1		1														1			1	
E	A4.22	Ross worm *Sabellaria spinulosa* reefs		1	1		3	1		1	1	1	1	1					1	1	1	1	1	1	1		1
E	A4.23	Subtidal chalk		1			2																	1	1	1	1
E	A5.12, A5.13	Subtidal sands and gravels	1	1	1		2					1		2	3							1		1	1		1
S	A5.133	Shallow tide-swept coarse sands with burrowing bivalves (Morella sp.)			1		1					1		1								1			1		1
E,S	A5.361	Sea-pen and burrowing megafauna communities	1	1	2		3	1	1	1	1	1	1	2		1	1	1	1	1	1	1	1	1	1	1	1
S	A5.371	Inshore deep mud with burrowing heart urchins	3	3	3		3				3	1		2						3	3	3	3		1		1
W	A5.371	Mud habitats in deep water	3	3	3		3				3	1		2	3					3	3	3	3		1		1
E,W	A5.43, A2.41, A2.42	Sheltered muddy gravels		1	1		2					1	1	2					1			1	1	1	1		1
E,S	A5.434	Flame/ File shell beds	1	1	3		3		1	1	3		1	3					1	1	1		1	1	1	1	1
E,S,W	A5.435	Native Oyster *Ostrea edulis* beds		1	1		1		1	1	1	1	1	3					1	1	1	1	1	1	1	1	1
All	A5.51	Maerl beds	3	1	1		3	1	1	1				3		1	1							1	1	1	1
S	A5.5112	Maerl or coarse shell gravel with burrowing sea cucumbers	3	1	1		3	1	1	1				3		1	1							1	1		1
S	A5.52	Kelp and seaweed communities on sublittoral sediment	1	1	1		1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
All	A5.53, A5.545, A2.61	Seagrass beds	2	1	2		3	1	1	2	1	2	2	3		2	2	1	2	2	2	2	2	2	1	2	1
E,S,W	A5.62	Horse mussel (Modiolus modiolus) beds	1	1	1		3	1	1	1	1	1	1	1		1	1	3	1	1	1	1	1	1	1	1	1
E	A5.63	Cold-water coral reefs		1	1		2	3					1	1					1					1	1	2	1
EU	A5.71	Submarine structures made by leaking gases			1		3							1				1							1		1
E,S	A6.61	Coral Gardens	1	1	1		3	1	1	1	1	1	1	1		1	3	1	1	1	1	1		1	1	1	1
S	A6.75	Carbonate mound communities	1	1	1		1	1		1	1	1	1	1		1	1	1	1	1	1	1		1	1		1
E,W	Various	Tide-swept channels		1			1																	1	1		1
W	Various	Sediment habitats with long lived bivalves			2		1	1		1		1		1								1	1	1	1		1
E	N/A	Areas of high planktonic primary productivity	3	1	3		1	1		1	1		2	2	3				2	1	1	1	1	1	1		1

Scale of ecosystem service supplied relative to other features

- # (black) Significant contribution
- # (dark grey) Moderate contribution
- # (light grey) Low contribution
- # (white) No or negligible ESP
- (empty) Not assessed

Confidence in evidence

- 3 UK-related, peer-reviewed literature
- 2 Grey or overseas literature
- 1 Expert opinion
- (empty) Not assessed

Feature type†

- S Scottish MPA search feature
- E English MCZ feature
- W Welsh HP MCZ feature
- EU EU Habitats Directive Annex 1 feature or sub-feature

Figure 6.3 Relative importance of designated habitats in providing intermediate ecosystem services and goods/benefits (Potts *et al.*, 2014).