

THE IRISH SEA PILOT

Report on the development of a Marine Landscape classification for the Irish Sea.

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1. Introduction

The Department of the Environment, Transport and the Regions (DETR) (now Defra), established a working group to undertake a Review of Marine Nature Conservation (RMNC) in the UK. One of the key recommendations in the interim report of the RMNC Working Group, submitted to Ministers in March 2001, was the promotion of a pilot scheme, at the regional sea scale, to demonstrate the application of the regional seas concept.

The Irish Sea Pilot scheme was established in 2002, with the aim of trialling a 'framework for marine conservation' (Laffoley *et al.*, 2000), addressing the ecological requirements of marine wildlife at an appropriate range of spatial scales. In doing so, the Irish Sea Pilot has examined the degree to which this framework can contribute to wider sustainable development for the whole of the marine environment. In particular, the trial investigated the manner in which nature conservation objectives could be integrated into the objectives of other marine interest sectors (fisheries, oil and gas, shipping etc.) in practice. The 'framework for marine conservation' proposed the use of marine landscapes as part of an ecosystem-based approach to marine conservation.

The concept of marine landscapes was developed for Canadian waters by Roff and Taylor (2000), and is further discussed in a UK context by Laffoley *et al.*, (2000). The concept is a broad-scale classification of the marine environment based on geophysical features, recognising that these are important in determining the nature of biological communities. This approach is potentially well suited for areas away from the coastline where biological information is likely to be lacking, and/or where the regulation of human activity needs to be addressed at the relatively large scale.

Roff and Taylor (2000) considered that the concept could be applied to the water column (using factors such as water temperature, depth/light, and stratification/mixing regime), and also to the seabed (using factors such as water temperature, depth/light, substratum type, exposure and slope). Using these parameters, they developed a classification, the resultant components of which were termed 'seascapes'.

However, as the term 'seascapes' has already been used in other contexts in the UK and its use could lead to confusion, the RMNC Working Group has adopted the term 'marine landscapes' for this concept.

The 'framework for marine nature conservation' envisages conservation action at a range of scales, from measures taken at the scale of the UK continental shelf and adjacent waters, down to measures taken to conserve individual marine protected areas and individual species (Laffoley *et al.*, 2000). In summary, these scales can be summarised as follows:

- The wider sea: This includes all territorial waters, the continental shelf under UK jurisdiction and adjacent waters. At this scale, conservation action will address wider issues such as pollution, water quality and the protection of wide ranging marine species, as well as reporting on environmental change.

- **Regional Seas:** This level is based on ecologically meaningful sub-divisions of the wider sea (Turnbull, 2004). This approach will provide a framework within which to map and describe marine biodiversity, identify conservation priorities, assess the marine resource and engage with industry (Laffoley et al., 2000).
- **Marine Landscapes:** This level represents an intermediate scale between regional seas and habitats, which have consistent physical and ecological character and provide a sensible scale to relate to the management of certain human activities such as fishing. Conservation action will be aimed at regulating such human activities in a way which is tailored to the relative sensitivity to damage of the seabed substratum, and also to the relative sensitivity to alteration or disturbance of particular water column characteristics (such as frontal systems).
- **Habitats/Species:** Here, conservation action will be aimed at ensuring that areas which are of high value for biodiversity are maintained in this condition for the future, and to regulate human activity which could harm important species, including mobile species, whose needs are not met by action taken under the other scales. At this level, conservation action will include the establishment of marine protected areas, i.e. areas protected within a tightly defined legal framework; for example as provided for under the Habitats Directive (EC, 1992).

The classification of marine landscapes has been based on readily available broad-scale geophysical and hydrographical data to define and map a series of marine landscape types for the seabed and water column. For each of these, it was expected that it would be possible to ascertain (or predict) the biological communities characteristic of the particular type and thus use them for conservation and management purposes, particularly in the absence of ground-truthed biological data. These marine landscape features are defined at a scale which is both ecologically relevant and applicable to the management of human activities.

The work that was undertaken on marine landscapes under the Pilot can be summarised as follows:

- The collation and analysis of essential geophysical information to identify and map the main types of marine landscape occurring in the Irish Sea.
- The characterisation of the marine landscapes identified, to summarise their characteristic biological communities, insofar as this can be ascertained from available data.
- An evaluation of the marine landscapes in relation to their susceptibility to harm as a result of human activities.
- The setting of conservation objectives appropriate to the various marine landscapes and the identification of management measures necessary to protect, recover and maintain their contribution to marine ecosystem structure and function, and our sustainable use of them.

This paper reports on the work undertaken to collate and analyse geophysical information and identify marine landscapes for the Irish Sea, and also identify their characteristic

biological communities. Work to evaluate the susceptibility of marine landscapes to human activities (Tyler-Walters *et al.*, 2003), and to 'score' each coastal (physiographic) and seabed marine landscape using a simple measure of relative biological diversity, is also reported in this paper. Work on the setting of conservation objectives for marine landscapes is reported in Lumb *et al.* (2004a).

2. Methods

2.1 Background

The advantage of using marine landscapes is that they are based on physical data, i.e. their definition does not require detailed biological data. As part of the Irish Sea Pilot, marine landscapes were characterised and ‘validated’ using available biological data to assess their robustness and further test the theory outlined in Roff and Taylor (2000), who stated that marine landscaped may be used as surrogates for detailed biological data.

2.2 Coastal (physiographic) and seabed marine landscapes

The coastal (physiographic) marine landscapes such as Estuaries and Sea lochs were based on a derivation from the Marine Nature Conservation Review (MNCR) classification of physiographic types (Connor et al., 1997). The estuaries and inlets were mapped onto a Geographical Information System (GIS), on the basis of definitions applied in the UK according to the EC Habitats Directive definitions of Annex I types (EC, 1999). However, within the marine landscape classification, types for linear coasts, bays and embayments were excluded, as it was considered that these units could overcomplicate the marine landscape classification. In addition, they would have been much more difficult to define compared to units such as estuaries, which are a recognisable ‘ecosystem unit’.

For the development of the seabed marine landscapes, datasets from several sources were compiled and integrated onto a Geographical Information System (GIS) to develop the seabed marine landscapes. The data collation process has been well documented in Lumb *et al.*, (2004b). Datasets and sources are detailed in table 2.1.

Table 2.1: Data types and sources used for marine landscape derivation and characterisation.

Data type	Data source
Seabed sediments (DigSBS250)	British Geological Survey (BGS)
Bathymetry (DigBath)	BGS
Slope (derived from DigBath)	BGS
Generalised bedforms (1:250,000 series)	BGS
Gas seeps	BGS
Maximum bed stress	Proudman Oceanographic Laboratory
Biological Data	Various

BGS Seabed sediment data was simplified from 15 sediment classes to six, modified after the Folk classification system (James *et al.*, 2002)(figure 2.1). It should be noted that the coarse sediment marine landscape units included ‘gravelly muddy sand’ and ‘gravelly sand’, as these categories contained more than 5% gravel.

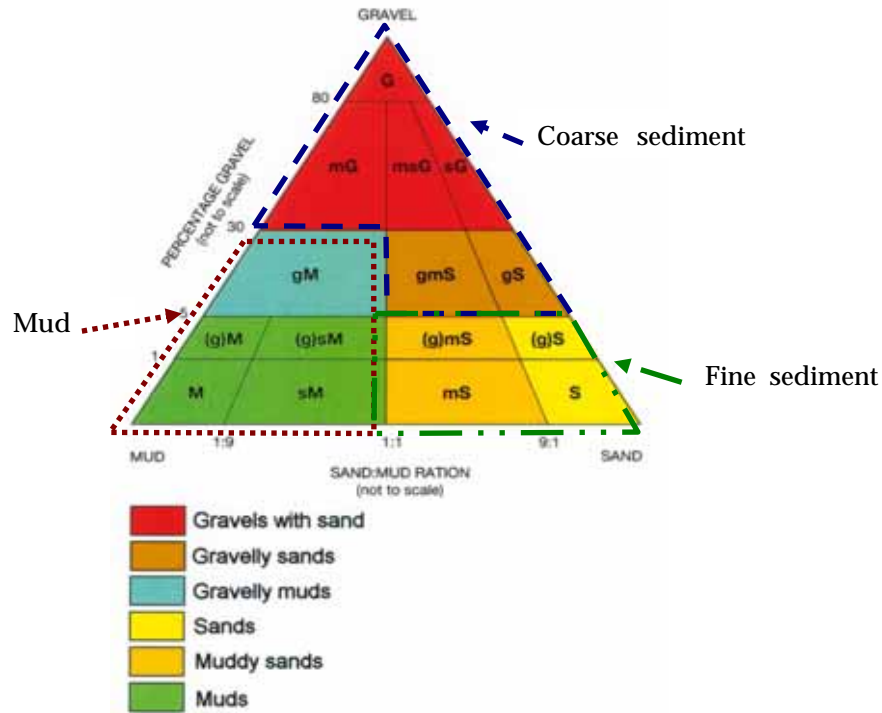


Figure 2.1: Modified version of the Folk classification for seabed sediments (James *et al.*, 2002), showing the groupings of sediments within *Mud basin*, *Fine sediment plain* & *Coarse sediment plain* marine landscape types.

Bathymetry and seabed sediment data, once converted from polyline to polygon format, were merged with the derived slope dataset in a GIS using a process called ‘union’. This process combines the attributes of each dataset into one, allowing easier querying within the GIS. Other datasets, including generalised bedforms, maximum bed stress and gas seeps were overlaid on this ‘union’ layer. The bedform dataset was compiled from paper charts, which were scanned and geo-referenced within the GIS. Maximum bed stress data was supplied by Proudman Oceanographic Laboratory as a grid, and required converting to polygon data within the GIS. Gas seep data was supplied by BGS as a standard GIS file and needed no further manipulation. The bathymetry and seabed sediment data (DigBath250 and DigSBS250 respectively) were provided at the scale of 1:250,000.

From the resulting ‘union’ layer, bedform-derived marine landscape types such as *Sediment wave/megaripple fields* were identified. For other units, practical criteria were developed to assist in the separation of marine landscapes into distinct types. Depth, substratum type, slope/topography and bed-stress were key among these criteria. For example, *Sand/gravel banks* were selected by identifying all polygons consisting of sandy/gravel sediment, bounded by a slope of at least 1-4%, and with a water depth shallower than 50m below Mean Sea Level.

A limitation of the BGS data was that sediment data did not extend to shallow coastal waters and some estuaries. Areas adjacent to the coast, where BGS sediment data was unavailable, were considered in the light of the datasets on benthic communities, and allocated to *Photic reef* or *Coastal sediment* marine landscape types on the basis of these communities.

Biological characterisation of the coastal and seabed marine landscapes was carried out by linking available biological data to each marine landscape, using the 'spatial-join' function within the GIS. All biological data made available for the characterisation process was classified and 'tagged' to the biotope complex level of the National Marine Habitat Classification for the UK and Ireland (Connor *et al.*, 2003). This level in the marine habitat classification was used, as it was detailed enough to test the validity of the marine landscape types, which are broad-scale in nature.

A preliminary study on the sources of additional biological data was carried out by Dipper (2002). Biological data from these sources was then collated onto Marine Recorder (a data capture and editing tool) by Northen (2003). Where it was known that biological data within individual marine landscapes was sparse, or indeed absent, further surveys were commissioned. Two such research cruises were commissioned; one cruise utilised the RV Prince Madog and targeted the *Aphotic reefs* and *Coarse sediment plains* off the north-west coast of Anglesey. The other research cruise utilised the RV Lough Foyle looking at the north-west Irish Sea and targeting the *(Irish) Sea Mounds & Deep-Water Channel* marine landscape types, where no biological data were available. A variety of remote-sampling techniques were used, including grab sampling, Acoustic Ground Discrimination System (AGDS), Multibeam and video ground-truthing. Summaries of the RV Lough Foyle and RV Prince Madog research cruises can be found in Appendix I and II. These surveys also had the added benefit of 'testing' whether the marine communities observed reflected those that had been predicted for that particular marine landscape.

2.3 Water column marine landscapes

For the development of the water column marine landscapes, an 'interpolation procedure' was carried out on two 'model derived', gridded datasets; salinity and stratification data. These datasets were supplied by Proudman Oceanographic Laboratory. Stratification data was produced using a derivation of the difference between sea surface and bottom temperature. These datasets, once converted from grid to polygon format, were merged using the 'union' process described earlier in the methods. Data on the location of fronts was supplied by Proudman Oceanographic Laboratory and the Sir Alister Hardy Foundation for Ocean Science (SAHFOS)(Edwards and Johns, 2003).

Data supplied by SAHFOS were used to biologically characterise the water column marine landscapes, using the same process described earlier in the methods. The biological data were supplied in the form of gridded distribution maps for five key features of the plankton community from Irish Sea continuous plankton recorder tows; i. *Dinophysis* spp., ii. *Coscinodiscus wailesii*, iii. Decapod larvae, iv. Fish larvae and v. total adult *Calanus*. *Dinophysis* spp. are a group of dinoflagellates which cause harmful algal blooms, and have been linked with Diarrhetic Shellfish Poisoning. *Coscinodiscus wailesii* is an important member of the phytoplankton assemblage, but is a non-indigenous diatom, originating from the Pacific. Decapod larvae are representative of the benthic component of the plankton assemblage. Fish larvae are representative of a higher trophic component in the plankton. Total adult *Calanus* comprises one of the most important components of the zooplankton community (a principal food source for higher trophic levels) (Edwards and Johns, 2003). SAHFOS used all available data when

compiling the aforementioned distribution maps, and did not separate data seasonally, so seasonal determinations could not be carried out. Further details of the data supplied by SAHFOS can be found in Annex III.

2.4 Assessing marine landscape diversity

Work was carried out to 'score' each seabed marine landscape for the number of biotope complexes that were found and/or were predicted to occur within it, to provide a simple measure of relative biological diversity. In addition, the numbers of marine landscape types occurring in 20 by 20 km grid cells (grid is shown in figure 3.4) were determined in order to assess whether any regions within the Irish Sea Pilot area were particularly rich in marine landscape types (Lieberknecht *et al.*, 2004b).

2.5 Sensitivity of coastal and seabed marine landscapes

The Marine Biological Association, through its MarLIN programme, has collated information on the sensitivity of marine species and biotopes to the effects of human activities (www.marlin.ac.uk). The Pilot commissioned the Marine Biological Association to evaluate methodologies for assessing and mapping the sensitivity of the marine landscapes within the Irish Sea Pilot area (Tyler-Walters *et al.*, 2003). A sensitivity assessment was made for each of the coastal (physiographic) and seabed marine landscapes for which sufficient information on their physical characteristics and biotopes was available. The assessments were made against three main factors: substratum loss, smothering and physical disturbance. Sensitivity was assessed on the basis of whether the biotope complexes characteristic of the marine landscape would survive a one-off impact.

However, this sensitivity assessment did not take account of actual, likely or potential patterns of exposure to human activities, and the results of the sensitivity work were subjected to a vulnerability assessment which took account of the likely relative exposure of the marine landscape to specific human activities. A matrix of relative vulnerability (following Gilliland, 2001) was used to combine sensitivity and exposure data in order to calculate relative vulnerability.

3. Results

3.1 Background

Three main groups of marine landscapes were identified for the Irish Sea (as an example of a 'Regional Sea'). These are:

- Coastal (physiographic) marine landscapes such as Rias and Estuaries where the seabed and water body are closely interlinked. In this group, both the seabed and the overlying water are included within the marine landscape.
- Seabed marine landscapes which occur away from the coast, i.e. the seabed of open sea areas. In this group, the marine landscapes comprise the seabed and the water at the substrate/water interface.
- Water column marine landscapes of the open sea areas, such as mixed and stratified water bodies and frontal systems. In this group, the marine landscapes comprise the water column above the substrate/water interface.

3.2 Coastal and seabed marine landscape types

In total, 18 coastal and seabed marine landscapes were identified for the Irish Sea. These are listed in table 3.1, which also displays a summary of the criteria developed to define each marine landscape type. The distribution of these 18 types can be seen in figure 3.1. Table 3.5 shows the extent of each marine landscape in square kilometres and as a percentage of the total Irish Sea Pilot study area.

Figure 2.1 shows three seabed sediment definitions used to define marine landscape types, derived from the modified Folk classification: *Mud basins*, *Fine sediment plains* and *Coarse sediment plains*. It should be noted that *Coarse sediment plains* were further split using the value of near-bed stress; *Low bed-stress coarse sediment plains* with values from 0-10 Nm⁻² and *High bed-stress coarse sediment plains* with values ≥ 11 Nm⁻².

A summary of the biological characterisation of coastal and seabed marine landscapes can be seen in table 3.2. Only those biotope complexes that contributed greater than 5% to each marine landscape were listed. The biotope complex codes shown in table 3.2 are those found in Connor *et al.*, (2003).

The results of the two research cruises proved interesting. The survey undertaken by the RV Prince Madog found that there was a good correlation between survey results and the marine landscapes identified from the geophysical and hydrographic data with respect to *Sediment wave/megaripple fields*, and the *Coarse sediment plain* types. *Aphotic Reef* was validated in general but, in some areas, the actual substrate was more complex than the marine landscapes map indicated, with some admixture and overlay of gravel and finer sediments. Summaries of the various sections of the RV Prince Madog cruise are attached in Appendix I. The survey undertaken by the RV Lough Foyle validated the (*Irish*) *Sea mounds* as substantial rocky outcrops, but indicated that for at least some of the mounds surveyed (two of the four), a veneer of fine sediment of variable thickness was present on the rock in places. A summary of the RV Lough Foyle cruise is attached in Appendix II.

In general, the predictions of biotope complexes were validated by the surveys, but, the nature of the communities present often depended on the fine structure of the habitat. For example, gravel areas contained protruding boulders, reef areas were partly obscured by sediment veneers, and boulder fields contained sand and shell in the interstices between the boulders. There is, therefore, a good level of confidence that the marine landscape types are ecologically relevant, although some aspects warrant further investigation.

3.3 Water column marine landscapes

In total, four water column marine landscapes were identified. The geographical distribution of these is shown in figure 3.2. The hydrographical and physical conditions of each are shown in table 3.3.

The biological characterisation used the same method of spatial joining as the coastal and seabed marine landscapes. Point values from the gridded distribution data (see Appendix III) were spatially joined to the underlying water column type, giving a set of abundance values for each water column type. For each dataset, an average abundance was calculated, to give mean abundance per 3m³. The results can be seen in table 3.4.

The *Mixed and High Salinity* type is characteristic of waters found in the area of the central Irish Sea. Compared to the other types, it has an impoverished plankton community and has the fewest number of phytoplankton taxa. There are no plankton taxa specific to this type.

The *Mixed and Low Salinity* water column type, in particular around Liverpool Bay, is regularly an area of *Phaeocystis* bloom formation. In addition to *Phaeocystis*, two other species form exceptional blooms in this area: the dinoflagellate *Gyrodinium aureolum* (which produces 'red tides' and occurs in the inshore waters of south-east Liverpool Bay and the Solway Firth) and the luminescent *Noctiluca scintillans*. The 'red tides' caused by *Gyrodinium aureolum* are of particular importance to coastal managers as they have been linked to invertebrate mortalities (Edwards & Johns, 2003).

The *Stratified and High Salinity* type has plankton communities indicative of higher salinity waters and possesses the most diverse zooplankton community of the four types. The plankton community contained numerous oceanic species, such as *Calanus helgolandicus* and the area-specific taxon Cocolithaceae, particularly in the south of the Pilot area where the assemblage reflects oceanic inflow from the warmer southern waters.

The *Stratified and Low Salinity* type has the highest mean abundance of *Dinophysis* spp., which is associated with Diarrhetic Shellfish Poisoning.

In addition to the four water column types, the data indicate a number of areas of water mixing or 'frontal zones', where there is evidence of higher than normal productivity. These include seasonal fronts, resulting from the stratification of the water column in summer, and a salinity front in the Liverpool Bay area which is a permanent feature throughout the year (Edwards and Johns, 2003). The approximate position of these fronts is shown in figure 3.2.

The Liverpool Bay front has the highest phytoplankton biomass and zooplankton abundance of all the four water column types (Edwards and Johns, 2003). Its phytoplankton colour

index value (an assessment of total phytoplankton biomass), and copepod abundance value (an assessment of secondary biomass), were both about twice those of the other types.

The north-east basin of the Irish Sea which incorporates the Liverpool Bay front zone, the *Mixed and Low Salinity* and the *Stratified and Low Salinity* water column types, is an area with a high benthic component to the zooplankton assemblage (including Decapod larvae). Another important aspect of the zooplankton assemblage within the three water column types in this area is that it contains the eggs/larvae of many commercially exploited species.

The Pilot reviewed the distribution data for a range of pelagic vertebrates, including seabirds, cetaceans and basking shark, but was unable to identify clear correlations with the water column marine landscape types. This may be a result of inadequacies of the data, but may also be due to weak effects of the different water column types on adult vertebrate populations, at least in the Irish Sea. An exception to this general conclusion is that there is some evidence that seabird numbers in summer are concentrated in the vicinity of the seasonal western Irish Sea front (Stone *et al.*, 1994). However, full consideration of the correlation between fronts and vertebrate distribution patterns, and indeed between fronts and water column marine landscapes, requires further consideration.

3.4 Assessing marine landscape diversity

The results of the work to ‘score’ individual coastal and seabed marine landscapes against the number of biotope complexes they contained is shown in figure 3.3. It should be noted that, although these scores are a measure of biotope richness, they also partly reflect survey effort, so should be used cautiously when making judgements with respect to nature conservation value. To give a true picture of the latter, other factors such as the relative rarity of individual marine landscapes, and the conservation value of the species and habitats they support, would also need to be taken into consideration.

Figure 3.4 shows the number of marine landscape types, as shown in figure 3.1, recorded within 20km by 20km grid cells in the Irish Sea Pilot study area. Due to the coarseness of both the grid and the marine landscape classification, the results are highly dependent upon the positioning of the grid, which is arbitrary. By shifting the anchor point for the grid by a few kilometres, the results are significantly altered. It was therefore considered that this method of assessing marine landscape diversity is not robust enough to be used with any degree of confidence. Furthermore, the BGS data on which the seabed classification is largely based is too coarse a scale in nature to allow an assessment at this level of detail. The concept of marine landscape diversity is discussed further in Lieberknecht *et al.*, (2004b).

3.5 Sensitivity of coastal and seabed marine landscapes

Table 3.6 summarises the results of the work discussed in the methods to assess the sensitivity and vulnerability of coastal and seabed marine landscapes.

It should be emphasised that Table 3.6 assesses only the widespread biological components of marine landscapes. While, therefore, it can be used for assessing the likely impacts of human activities at the broad scale, it does not have regard to smaller scale habitats of high

conservation value (e.g. eelgrass beds or horse mussel beds), nor to factors relevant to maintaining population biomass or food webs, nor to the needs of nationally important features (Lieberknecht *et al.*, 2004a). For local spatial planning purposes, therefore, particularly in coastal areas where there is a high degree of habitat complexity, these other aspects of biological importance will also need to be taken into account. Similarly, when taking regulatory decisions, all available information needs to be taken into consideration, including information from environmental impact assessments.

Nonetheless, the application of sensitivity and vulnerability assessments at the marine landscape scale is potentially very useful, particularly in offshore waters, and the further development and refinement of assessment methods is likely to prove very worthwhile

Table 3.1: Summary of physical characteristics of each Marine Landscape

Marine Landscape	Depth (m)	Substratum	Bed-stress/ current	Topography/ slope & additional criteria
<i>Estuary</i>	0-30m	Mixed	Variable	Variable
<i>Ria</i>	Shallow: 0-20m	Typically rocky with sediment	Variable	A drowned river valley; often v-shaped in cross section
<i>Saline Lagoon</i>	V Shallow: 0-5m	Mixed	Weak currents	Parallel to coast, limited water exchange, large surface area: volume ratio
<i>Sea loch</i>	0-200m	Rocky with sediment basins	Variable	Includes fjords (have shallow sill & deep basins) & fjards (generally shallower)
<i>Sound</i>	0-30m	Gravels & sands	Strong currents	Narrow channel, open at both ends
<i>Gas structures</i>	Variable	Mixed	Very weak currents	Pockmarks/ depressions (hard structures)
<i>Photic Reefs</i>	Within photic zone (generally <10-20m in Irish Sea)	Bedrock, boulders & cobbles	Variable	Rough/uneven topography Contains Littoral Rock and Infralittoral Rock
<i>Aphotic Reefs</i>	Generally in aphotic zone (generally >10-20m in Irish Sea)	Rock/biogenic	Variable	Rough topography (not as pronounced as Sea Mounds)
<i>(Irish) Sea Mounds</i>	Rising >20m above surrounding seabed	Rock, often with sediment veneer	Variable	Sea Mound slope > 1-8%
<i>Sand/ gravel banks</i>	Variable	Sands & gravels	Strong currents	Bank slope >1-8%
<i>Coastal sedimentDef</i>	Intertidal -50m (& no BGS sediment data)	Muds, sands & gravels	Variable	Adjacent to coastline N.B. "Bucket" category, where no BGS data was available.
<i>Shallow-water mud basin</i>	0-50m	Muds	Very weak currents	Depression
<i>Deep-water mud basin</i>	Deeper than 50m	Muds	Very weak currents	Depression
<i>Fine sediment plain</i>	Variable	Sands & muddy sands	Weak currents	Negligible slope
<i>Sediment wave/ megaripple field</i>	Variable	Sands	Moderate/strong currents	Waves/ripples ¹
<i>Low bed-stress coarse sediment plain</i>	Variable	Cobbles, pebbles & muddy gravels	Low bed-stress	Negligible slope Evidence of fines in sediment
<i>High bed-stress coarse sediment plain</i>	Variable	Boulders, cobbles, pebbles & gravels	High bed-stress	Negligible slope No fines within sediment
<i>Deep-water channel</i>	Deeper than 150m	Cobbles, gravels & mixed sediments	Variable	Channel slope > 1-8%

¹ Definition of sandwaves and megaripples taken from BGS Seabed Sediments Sheet 51°N-08°W: Nympe Bank

Table 3.2: Summary of biological characterisation for each Marine Landscape

Marine Landscape	Characteristic biology (biotope complexes² with > 5% contribution)	Corresponding codes from previous column
Estuary	Fucoids on sheltered rocky shores; Fucoids in variable salinity conditions; Upper estuarine mud shores; mid estuarine mud shores; Mobile sandy shores; Muddy sandy shores:	LR.LLR.F; LR.LLR.FVS; LS.LMu.UEst; LS.LMu.MEst; LS.LSa.MoSa; LS.LSa.MuSa
Ria	Fucoids on sheltered rocky shores; Barnacles/fucoids on moderately exposed rocky shores; Mussels and barnacles on exposed rocky shores; Lichens; Tideswept kelp; Upper estuarine mud shores:	LR.LLR.F; LR.MLR.BF; LR.HLR.MusB; LR.FLR.Lic; IR.MIR.KT; LS.LMu.UEst
Saline lagoon	Upper estuarine mud shores; mid estuarine mud shores; Muddy sand shores; Infralittoral sandy mud; Sublittoral seagrass beds: (characteristic biology for a typical saline lagoon, from Bamber <i>et al</i> , 2001)	LS.LMu.UEst; LS.LMu.MEst; LS.LSa.MuSa; SS.SMu.IFiMu; SS.SMp.SSgr
Sea loch	Fucoids on sheltered rocky shores; Silted kelp; Brachiopod & ascidian communities; Circalittoral fine muds; circalittoral sandy muds; Circalittoral mixed sediments; Sublittoral mussel beds:	LR.LLR.F; IR.LIR.K; CR.LCR.BrAs; SS.SMu.CFiMu; SS.SMu.CSaMu; SS.SMx.CMx; SS.SBR.SMus
Sound	Fucoids on sheltered rocky shores; Tideswept kelp; Circalittoral mixed faunal turf; Echinoderm and crustose communities; Infralittoral fine sands; Circalittoral coarse sediments; Infralittoral mixed sediments:	LR.LLR.F; IR.MIR.KT; CR.HCR.XFa; CR.MCR.EcCr; SS.SSa.IFiSa; SS.SCS.CCS; SS.SMx.IMx
Gas structures	Offshore Mud;	SS.SMu.OMu
Photic reef	Mussels and barnacles on exposed rocky shores; Barnacles/fucoids on moderately exposed rocky shores; Fucoids on sheltered rocky shores; Lichens; Rockpools; Kelp with cushion fauna/foliose red seaweeds/coralline crusts; Sand/gravel affected kelp communities; Kelp with red seaweeds	LR.HLR.MusB; LR.MLR.BF; LR.LLR.F; LR.FLR.Lic; LR.FLR.Rkp; IR.HIR.KFaR; IR.HIR.KSed; IR.MIR.KR
Aphotic reef	Circalittoral tideswept fauna; Circalittoral mixed faunal turf; Echinoderm and crustose communities; Circalittoral vertical rock communities	CR.HCR.FaT; CR.HCR.XFa; CR.MCR.EcCr; CR.FCR.FaV;
(Irish) Sea Mounds	Offshore coarse sediments; Offshore mixed sediments; Circalittoral sandy mud; Offshore mud; Sublittoral polychaete reefs	SS.SCS.OCS; SS.SMx.OMx; SS.SMu.CSaMu; SS.SMu.OMu; SS.SBR.PoR
Sand/ gravel banks	Infralittoral fine sands; Infralittoral muddy sands; Infralittoral coarse sediment; Circalittoral coarse sediment; Circalittoral mixed sediment; Offshore mixed sediment; Sublittoral mussel beds:	SS.SSa.IFiSa; SS.SSa.IMuSa; SS.SCS.ICS; SS.SCS.CCS; SS.SMx.CMx; SS.SMx.OMx; SS.SBR.SMus
Coastal sediment	Fine sandy shores; Mobile sand shores; Muddy sand shores; Sublittoral estuarine mud; Infralittoral sandy mud	LS.LSa.FiSa; LS.LSa.MoSa; LS.LSa.MuSa; SS.SMu.EstMu; SS.SMu.ISaMu
Shallow-water mud basin	Circalittoral sandy mud;	SS.SMu.CSaMu
Deep-water mud basin	Offshore mud; Circalittoral sandy mud:	SS.SMu.OMu; SS.SMu.CSaMu
Fine sediment plain	Circalittoral sandy mud; Infralittoral sandy mud; Circalittoral muddy sand; Infralittoral fine sands; Infralittoral muddy sands; Infralittoral coarse sediments:	SS.SMu.CSaMu; SS.SMu.ISaMu; SS.SSa.CMuSa; SS.SSa.IFiSa; SS.SSa.IMuSa; SS.SCS.ICS
Sediment wave/ megaripple field	Circalittoral sandy mud; Circalittoral muddy sand; Infralittoral fine sands; Circalittoral fine sands; Circalittoral coarse sediments; Infralittoral coarse sediments:	SS.SMu.CSaMu; SS.SSa.CMuSa; SS.SSa.IFiSa; SS.SSa.CFiSa; SS.SCS.CCS; SS.SCS.ICS
Low bed-stress coarse sediment plain	Circalittoral mixed faunal turf; Infralittoral fine sands; Infralittoral muddy sands; Circalittoral coarse sediment; Infralittoral coarse sediment; Circalittoral mixed sediment; Offshore mixed sediment:	CR.HCR.XFa; SS.SSa.IFiSa; SS.SSa.IMuSa; SS.SCS.CCS; SS.SCS.ICS; SS.SMx.CMx; SS.SMx.OMx
High bed-stress coarse sediment plain	Circalittoral mixed faunal turf; Circalittoral Coarse sediments; Offshore mixed sediment	CR.HCR.XFa; SS.SCS.CCS; SS.SMx.OMx
Deep-water channel	Offshore mixed sediment:	SS.SMx.OMx

² Refers to biotope complexes within Connor *et al.*, (2003)

Table 3.3: Physical and hydrographical definitions of each water column marine landscape. Water column marine landscapes physical/hydrographical definitions

Water Column marine landscapes	Number of days stratified (annual)	Salinity (Dec-Feb)
'Mixed & high salinity'	< 40 days	> 34‰
'Mixed & low salinity'	< 40 days	≤ 34‰
'Stratified & high salinity'	≥ 40 days	> 34‰
'Stratified & low salinity'	≥ 40 days	≤ 34‰

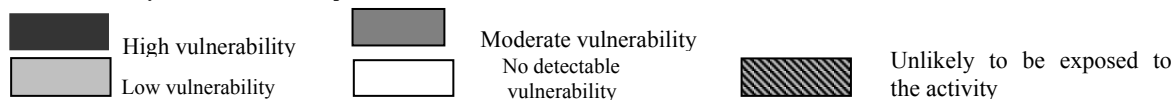
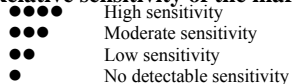
Table 3.4: Mean abundance (per 3m³) of key plankton community features in the Irish Sea

	Water Column Units			
	Mixed & High Salinity	Mixed & Low Salinity	Stratified & High Salinity	Stratified & Low Salinity
Key Plankton Community Features	Mean abundance per 3m ³			
Fish Larvae	1.19	1.24	1.17	1.23
<i>Dinophysis</i> spp.	1.13	1.38	1.52	1.61
Decapod larvae	1.98	2.80	2.14	3.07
Total adult <i>Calanus</i>	1.91	1.44	2.32	1.45
<i>Coscinodiscus wailesii</i>	1.06	1.23	1.08	1.31

Table 3.5: The extent of marine landscapes in the Irish Sea Pilot study area.

Marine landscape	Area within the Irish Sea Pilot study area (km ²)	% of total Irish Sea Pilot study area
<i>Estuary</i>	939	1.6
<i>Ria</i>	49	0.1
<i>Saline lagoon</i>	8	<0.1
<i>Sea loch</i>	600	1.0
<i>Sound</i>	69	0.1
<i>Gas structures</i>	58	0.1
<i>Photic reef</i>	278	0.5
<i>Aphotic reef</i>	1,237	2.0
<i>(Irish) Sea Mounds</i>	74	0.1
<i>Sand/ gravel banks</i>	540	0.9
<i>Coastal sediment</i>	3,606	6.0
<i>Shallow-water mud basin</i>	980	1.6
<i>Deep-water mud basin</i>	5,024	8.3
<i>Fine sediment plain</i>	13,218	21.9
<i>Sediment wave/megaripple field</i>	6,630	11.0
<i>Low bed-stress coarse sediment plain</i>	15,186	25.1
<i>High bed-stress coarse sediment plain</i>	11,760	19.4
<i>Deep-water channel</i>	234	0.4

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Relative vulnerability of the marine landscape							Relative sensitivity of the marine landscape			
										
Categories of activity which may cause deterioration or disturbance	Examples of human activities	Estuary	Ria	Saline Lagoon	Sea loch	Sound	Photic reefs	Aphotic reefs	Shallow-water mud basins	Deep water mud basins
Substratum loss	Coastal development	●●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●●●
	Offshore development	●●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●●●
	Aggregate extraction	●●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●●●
	Capital dredging	●●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●●●
	Maintenance dredging	●●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●●●
	Tractor dredging for shellfish	●●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●●●
Smothering	Suction dredging for shellfish	●●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●●●
	Disposal of dredged spoil	●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●	●
Physical disturbance or abrasion	Maintenance dredging	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●
	Suction dredging for shellfish	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●
	Tractor dredging for shellfish	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●
	Beam trawling	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●
	Scallop dredging	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●
	Demersal otter trawling	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●
	Anchoring	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●
	Mussel harvesting	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●
Recreational activities	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●	
Categories of activity which may cause deterioration or disturbance	Examples of human activities	Coastal sediment	Fine sediment plains	LBS coarse sediment plain	HBS coarse sediment plain	Sediment wave/megaripple field	Sand/gravel banks	Sea mounds	Deep water channel	Gas structures
Substratum loss	Coastal development	●●●	●●●	●●●	●●●	●●	●●●	●●●	*3	*
	Offshore development	●●●	●●●	●●●	●●●	●●	●●●	●●●	*	*
	Aggregate extraction	●●●	●●●	●●●	●●●	●●	●●●	●●●	*	*
	Capital/maintenance dredging	●●●	●●●	●●●	●●●	●●	●●●	●●●	*	*
	Tractor dredging for shellfish	●●●	●●●	●●●	●●●	●●	●●●	●●●	*	*
Smothering	Suction dredging for shellfish	●●●	●●●	●●●	●●●	●●	●●●	●●●	*	*
	Disposal of dredged spoil	●●	●●	●●	●●	●	●	●●●	*	*
	Capital/maintenance dredging	●●●	●●●	●●●	●●●	●	●●	●●●	*	*
	Suction dredging for shellfish	●●●	●●●	●●●	●●●	●	●●	●●●	*	*
	Tractor dredging for shellfish	●●●	●●●	●●●	●●●	●	●●	●●●	*	*
	Beam trawling	●●●	●●●	●●●	●●●	●	●●	●●●	*	*
	Scallop dredging	●●●	●●●	●●●	●●●	●	●●	●●●	*	*
	Demersal otter trawling	●●●	●●●	●●●	●●●	●	●●	●●●	*	*
	Anchoring	●●●	●●●	●●●	●●●	●	●●	●●●	*	*
	Mussel harvesting	●●●	●●●	●●●	●●●	●	●●	●●●	*	*
Recreational activities	●●●	●●●	●●●	●●●	●	●●	●●●	*	*	

³ Insufficient information on seabed habitats to assess sensitivity

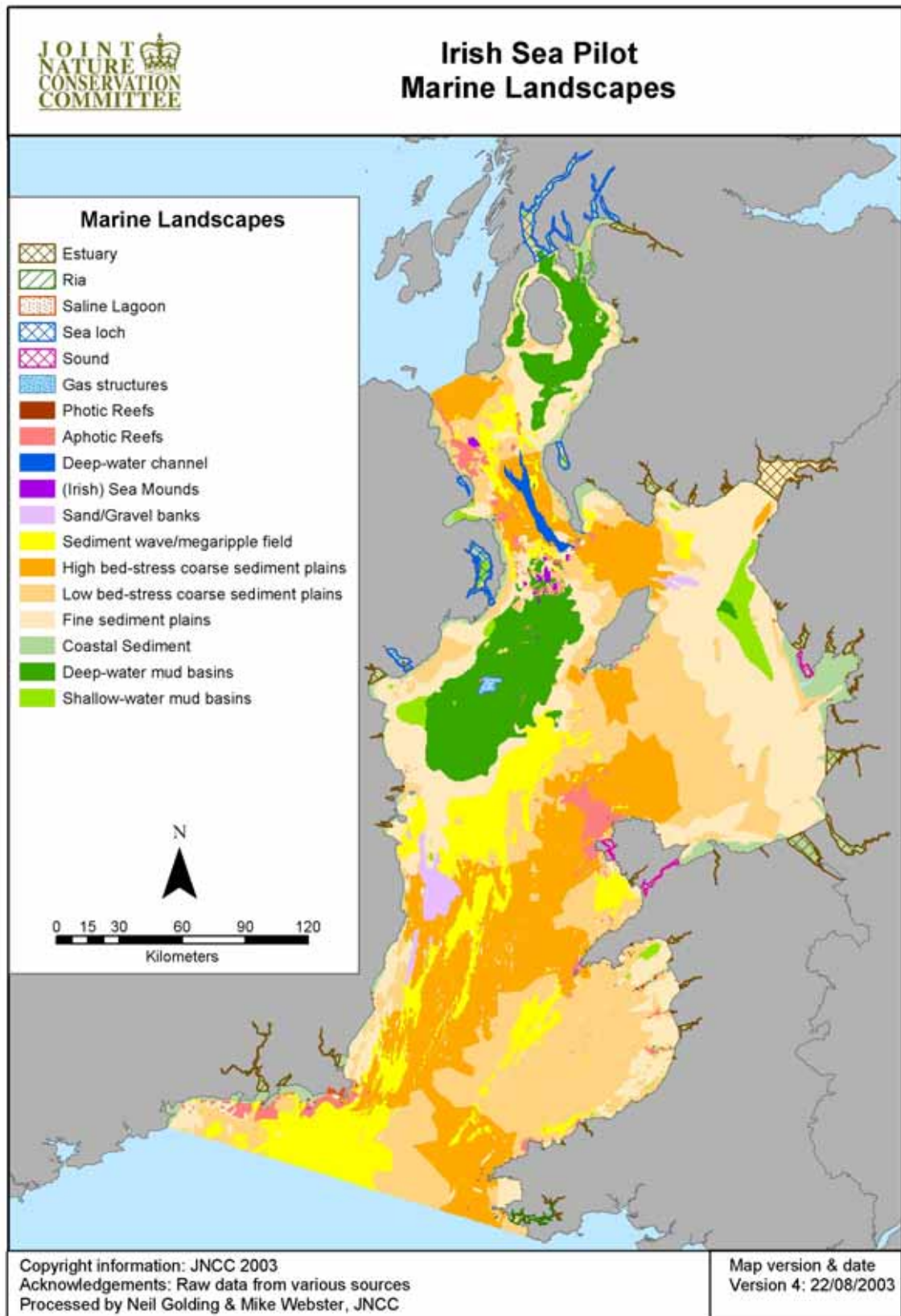


Figure 3.1: Coastal and seabed marine landscapes for the Irish Sea

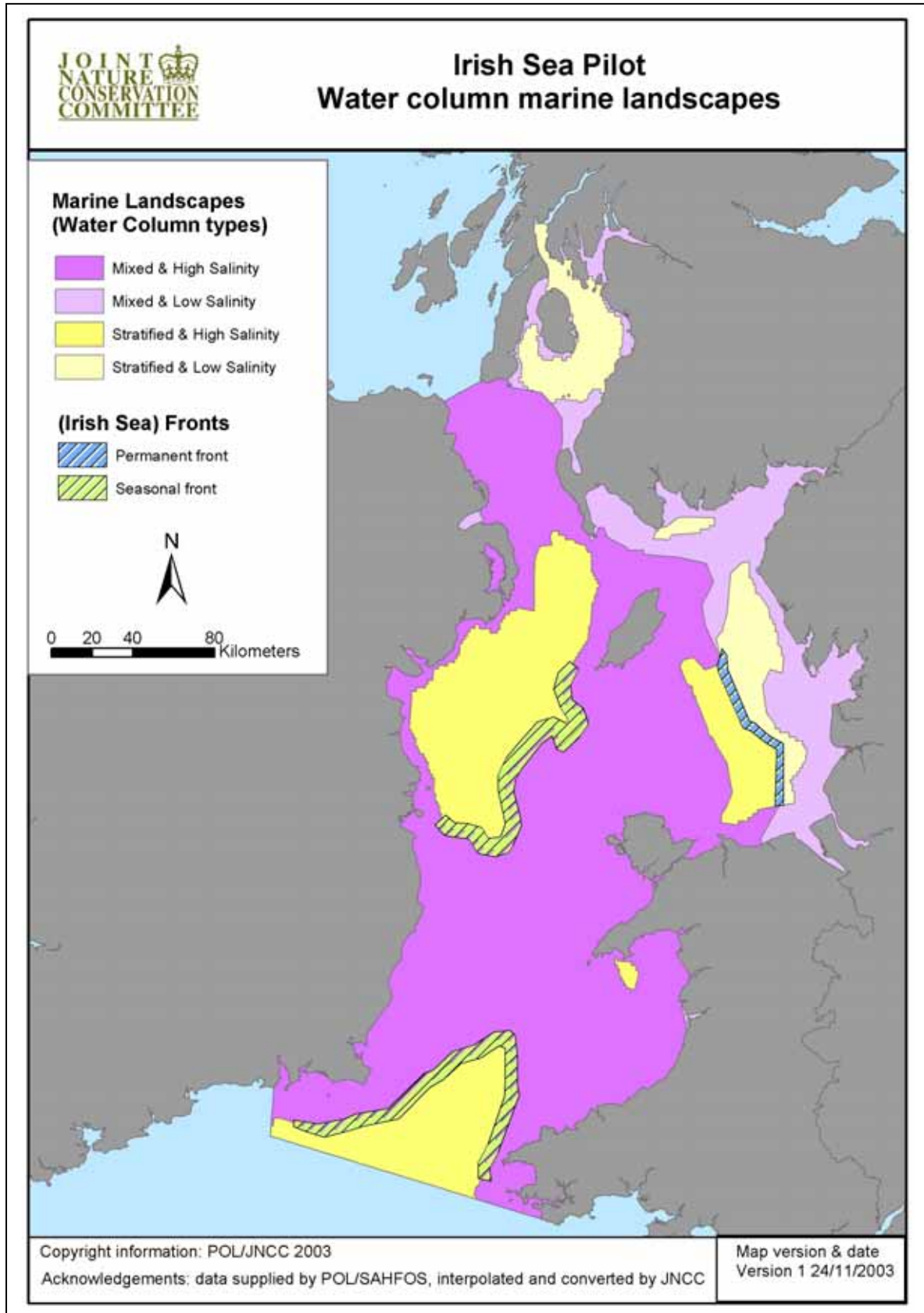


Figure 3.2: Water column marine landscapes for the Irish Sea

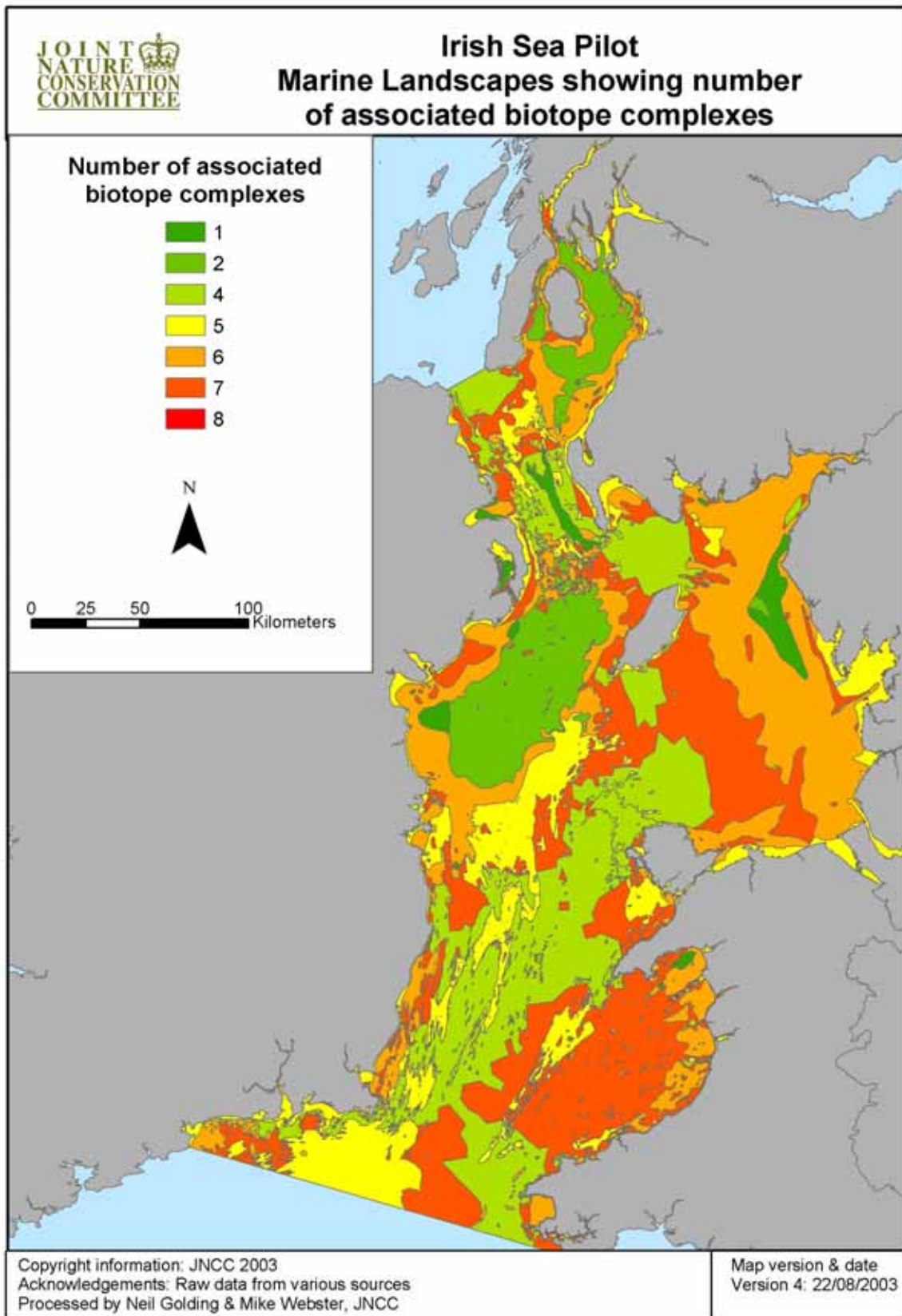


Figure 3.3: Marine landscapes showing number of associated biotope complexes.

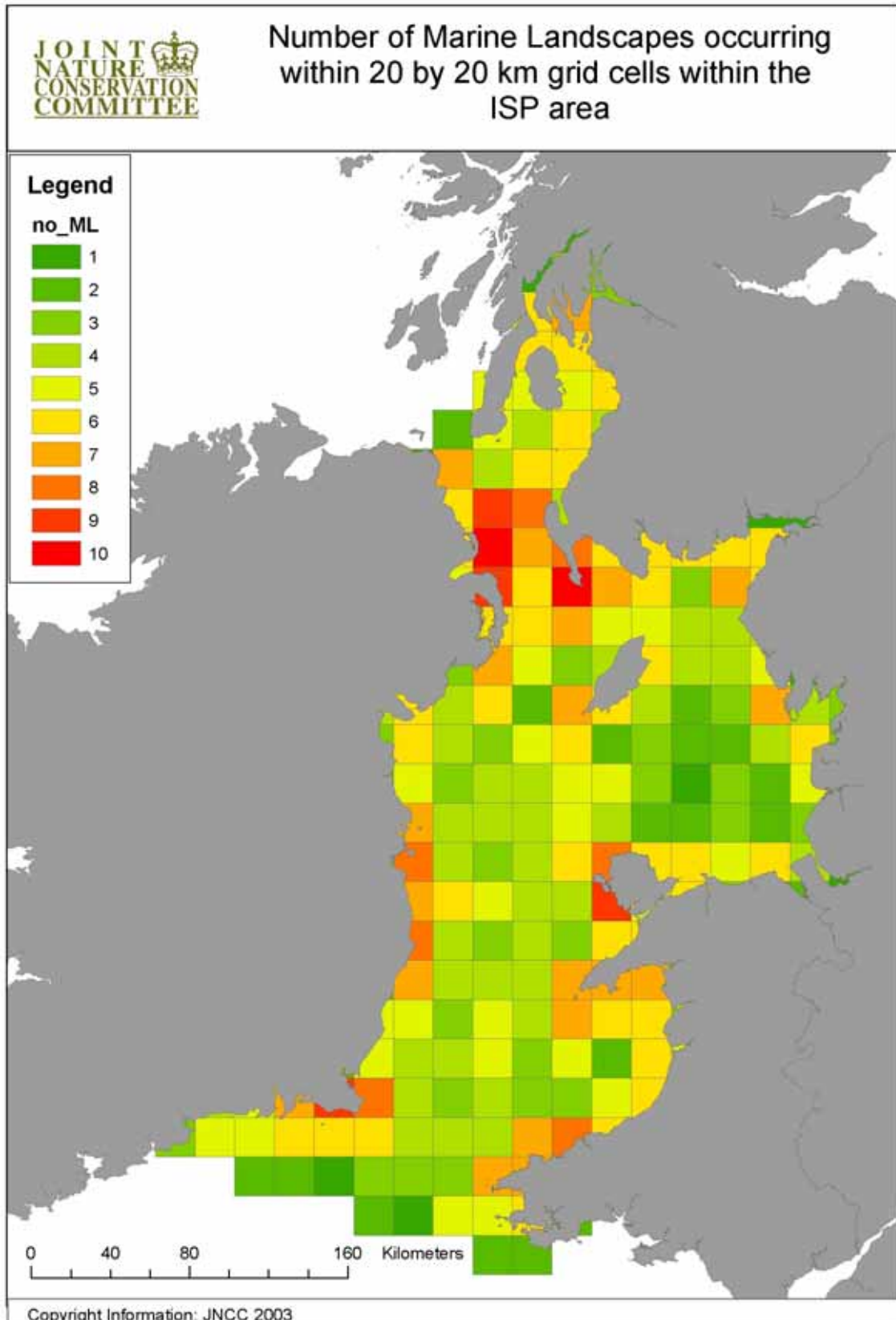


Figure 3.4 Map showing the number of inshore physiographic and seabed marine landscape types occurring in 20km by 20km grid cells.

4. Discussion and conclusions

The Pilot has demonstrated that the identification and mapping of a comprehensive series of marine landscape types using geophysical and hydrographical data is fully practicable at the Regional Sea scale. This study has shown that, from the results (table 3.1 & 3.2), it is possible to define and map a series of marine landscapes for the seabed from readily available geophysical data which are ecologically valid. The validation process has ascertained their biological character, and the types have been used in the development of a framework of conservation objectives (Lumb *et al.*, 2004a) and the assessment of measures necessary to achieve their sustainable use. This is in agreement with Roff & Taylor (2000) who demonstrated using recurring geophysical features as a surrogate for biological data.

In relation to the coastal and seabed marine landscapes, the results (table 3.5) show that just four of the 18 marine landscape types make up 77% of the area of the Irish Sea Pilot study area. In contrast, 12 of the marine landscape types make up less than 10% of the study area, and seven of these marine landscape types each cover less than 0.5% of the study area. Such scarce types could well merit special protection measures and warrant consideration in the current review of habitats listed on Annex I of the Habitats Directive (EC, 1992) (*Rias* and *Lagoons* already appear in Annex I).

There was, generally, a good correlation between the marine landscapes identified and the character of the seabed. However, partly because of the inherent simplification which took place in the generation of the marine landscapes, and partly because the available substrate data does not always reflect the actual condition of the seabed, there is greater variability of seabed characteristics than a straightforward interpretation of the marine landscape map would suggest. The same is true of the biological characterisation; in general the relation between marine landscapes and biological communities is very strong, but locally there can be considerable variation and complexity.

It is apparent from the map of coastal and seabed marine landscapes (figure 3.1) that areas of the Irish Sea differ in their variety of marine landscapes. Some areas are relatively uniform, with one or two marine landscapes, in others many more types of marine landscape are to be found. The grid cell system was used to compare the relative diversity of marine landscape areas, and the results are shown in (figure 3.4). Areas of high marine landscape diversity can be used to identify probable areas of high biodiversity where biological data are scarce, and this approach could be used to identify probable diversity hotspots in such areas. Figure 3.4 indicates areas of high marine landscape diversity off the coasts of Co Antrim and Co Down and eastwards to the Mull of Galloway, off Anglesey, off the coasts of Co Wexford, Co Waterford and Dyfed.

Marine landscapes can be used to predict the susceptibility of human impacts on their biological communities (Tyler-Walters *et al.*, 2003) (table 3.6), but there is a need to use some caution in this. Many of the biological communities which presently occur reflect some modification of the natural state as a result of human activity, and this could have implications for the conclusions reached. For example, areas of seabed subject to strong currents where sediments are mobile could be expected to support biological communities capable of accommodating a level of physical disturbance. If these communities were considered natural for such an area, human activity causing similar disturbance might, therefore, be assumed to be relatively harmless. However, species-rich biogenic reefs may

have developed in these areas but have been destroyed by dredging or trawling activity. Continuation of such activities would ensure that such reefs would not re-establish.

Marine landscapes have been used as a surrogate assessment unit during the identification of important marine areas, using the software tool Marxan (Ball and Possingham, 1999) (Lieberknecht *et al.*, 2004b). Note that this work links to the coastal and seabed marine landscapes of the Irish Sea provisional list.

Although the marine landscapes methodology is relatively straightforward, a number of issues have arisen, and these are discussed in further detail below. The marine landscape classification was heavily based on two readily available British Geological Survey (BGS) datasets at a scale of 1:250,000; DigBath250 and DigSBS250. BGS has a considerable amount of data on bedforms and sediments which is not compiled into digital format. These datasets could provide detail at scales of 1:100,000 or larger for important areas of the Irish Sea and other parts of UK waters, which could improve the 'confidence levels' of the resulting maps. However, compiling this data and making it available would require funding and investment.

Physiographic marine landscapes such as Estuaries and Sealochs were 'well-validated' by biological data. However, as these were defined in a different way to the seabed marine landscapes (EC, 1999), they may contain many different classes of seabed sediment, thus showing greater variation in their biological communities than the seabed marine landscapes.

The *Photic reef* marine landscape unit was defined using the presence of seaweed dominated communities (table 3.1). For future work, and in the absence of comprehensive biological data, this unit could be defined using remotely sensed/modelled 'photic zone' limits. This split using photic zone data could also be used to encompass a similar shallow/deep-water split for sediment plains.

There appears to be some merit in retaining the split between high and low bed-stress coarse sediment plains, as the biological communities found within these units reflect this distinction. For example, within high bed-stress coarse sediment plains, these areas were characterized by those biological communities 'preferring' coarser substrata whereas there is a broader swathe of finer sediment communities within low bed-stress sediment plains

One of the main areas which proved difficult initially was obtaining enough biological data, in the correct format to undertake the desired biological characterisation of individual marine landscapes. Many organisations were initially willing to contribute data, but then couldn't find the time or resources to supply it. The lack of data, particularly for offshore regions, has caused problems in other strands of Irish Sea Pilot work, e.g. Lieberknecht *et al.*, (2004b). Another problem arose when a single spatial position was tagged with up to five or six biological communities from survey data (i.e. one biological data 'dot' on the map representing five or six different biotope complexes ranging from sublittoral sediments to littoral rock). This resulted in a number of marine landscapes that were wrongly characterised with spurious data and this slowed the characterisation process down during the trial. This was especially prevalent in the coastal areas and is an issue of how data is collected in the field, to ensure maximum usability.

Scale of resolution of the maps is another challenge. This is particularly so when comparing data gathered at a relatively 'high resolution' spatially (e.g. nearshore and coastal data), and linking this to offshore data sets, which tend to be gathered at a lower spatial resolution. However, bearing in mind that the marine landscapes approach is essentially a mechanism aimed at offshore, widely distributed, more homogenous habitats – we should not expect it to work as well at a finer scale inshore (excluding distinct ecosystem units such as estuaries and sea lochs), and our experience partly reflected this.

The value of the marine landscapes approach is that it uses data which are currently available to enable management strategies for the marine environment to be developed and implemented. It is only to be expected, however, that mapped habitat information derived from future biological survey will be more accurate than marine landscape maps developed largely from geophysical and hydrographical data. As new information becomes available, this should be used to further refine the management strategies for the marine environment.

The Water Framework Directive requires the achievement of good ecological status in transitional and coastal waters. Good ecological status is defined as where the biological quality elements show only low levels of distortion resulting from human activity, deviating only slightly from those normally associated with the surface waterbody type under undisturbed conditions. Links could be made between the marine landscape types defined here and the habitat types defined for deriving reference conditions for water bodies for the Water Framework Directive (which are at a more detailed scale). The Water Framework Directive also requires water bodies to be risk assessed in terms of human pressures and sensitivities and the risk of failing to achieve good ecological status.

This study has shown that it is possible to produce maps at a regional sea scale and greater, which show the distribution and relative extents of seabed and water column marine landscape types, and their characteristic marine biodiversity, even where there is relatively little biological data. This is fundamental to improving our understanding of the marine ecosystem and underpinning its protection, recovery and sustainable use.

It is important for modelling and management to understand that there are links between the seabed and water column marine landscapes; where they are, and their implications. This is particularly important when looking at the conservation of more mobile species such as cetaceans and fish, as well as those organisms at the lower trophic levels; the phytoplankton and zooplankton.

There are numerous future uses for the marine landscape classification presented in this paper. As many human activities are closely associated with specific marine landscapes, e.g., fisheries over particular types of seabed or windfarms on particular types of coastal sediment, this makes it possible in principle to link the conservation interests and needs identified at the marine landscape scale through to the management of human activities taking place at that scale. Hence, marine landscapes provide one scale at which the vulnerability of the marine ecosystem to human activities can be assessed, particularly in offshore areas (Tyler-Walters *et al.*, 2003). They can also be used to identify areas where additional measures may be needed to protect or recover marine ecosystems, or the uses we make of them, including the identification of a network of nationally important marine areas (Lieberknecht *et al.*, 2004b).

The methodology and approach reported in this paper is a promising tool to implement improved spatial planning and management of the marine environment and its sustainable

use. It is recommended that this geophysical approach to marine landscape classification be extended to other UK regional seas. The series of 18 coastal and seabed, and four water column marine landscapes identified for the Irish Sea by the Pilot, will have to be extended to create a comprehensive list of marine landscapes for UK waters. More landscape types will be needed on the edge of the continental shelf and may include sea mounts and a range of glacial features such as iceberg plough marks. However, the likely costs of extending the marine landscapes work would be relatively small and would benefit a wide range of sectors, including nature conservation. In addition, this would enable further testing of the ecological characterisation in other marine areas, and work towards a consistent framework for management and nature conservation measures.

Recommendations⁴

The following recommendations are made with respect to Marine Landscapes

- R14** The marine landscape approach should be adopted as a key element for marine nature conservation and utilised in the spatial planning and the management of the marine environment. The approach should take account of broadscale marine habitat information, as this information becomes available over time. In coastal and estuarine waters the approach should seek to complement that taken under the Water Framework Directive (in relation to typology and reference conditions) at a more detailed level.
- R15** A list of internationally-agreed marine landscapes for the North-East Atlantic should be developed. It is suggested that the list identified for the Irish Sea be expanded to include landscapes not found in the Irish Sea and further refined as necessary. Work to complete the mapping of these marine landscapes in the North-East Atlantic should be undertaken in collaboration with other countries.
- R16** The methodology for sensitivity and vulnerability of marine landscapes should be further developed and refined, having due regard to relevant standards being developed in relation to the Water Framework Directive. It should be recognised that for purposes of local spatial planning, these assessments should be enhanced using the additional biological information which is available in inshore and coastal environments.

⁴ Recommendations as cited in Vincent *et al.*, (2004)

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