THE IRISH SEA PILOT

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

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March 2004

JNCC Report No. 346

Golding, N, Vincent, M A, and Connor, D W 2004. *Irish Sea Pilot - Report on the development of a Marine Landscape classification for the Irish Sea.* JNCC. and online at www.jncc.gov.uk/irishseapilot.

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Acknowledgements

The authors wish to thank Steve Atkins, and Chris Lumb for their advice and comments, and Mike Webster for his GIS expertise.

Thanks are also due to the Master and crew of the *RV Prince Madog* and the *RV Lough Foyle*, Rohan Holt, Jon Davies, and Louise Lieberknecht for their assistance on the various research cruises.

We are grateful to those organisations that provided comments on the consultation draft, and also to Kate Northen, Martin Edwards, Jim Bennell, Jim Allen, Ivor Rees and Richard Shucksmith, Annika Mitchell, Matthew Service who did research under contract often at short notice and within tight deadlines.

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.

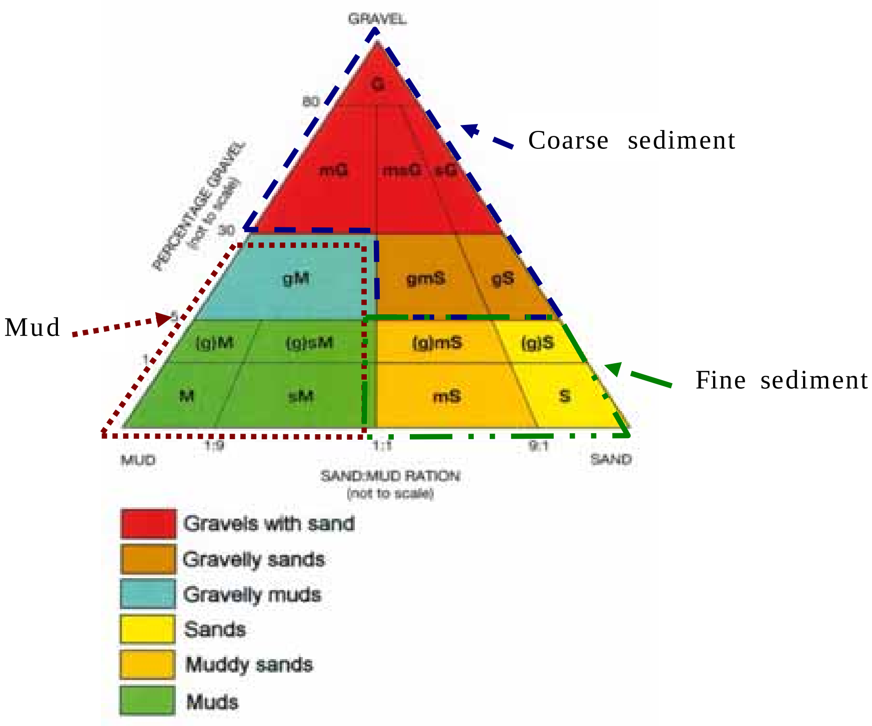

Figure 2.1: Modified version of the Folk classification for seabed sediments (James *et al*., 2002), showing the groupings of sediments within *Mud basin*, *Fine sediment plain* & *Coarse sediment plain* marine landscape types.

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 Mar*LIN* 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 $\geq$ 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 $3m^3$. 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 Coccolithaceae, 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
Estuary	0-30m	Mixed	Variable	Variable
Ria	Shallow: 0-20m	Typically rocky with sediment	Variable	A drowned river valley; often v-shaped in cross section
Saline Lagoon	V Shallow: 0-5m	Mixed	Weak currents	Parallel to coast, limited water exchange, large surface area: volume ratio
Sea loch	0-200m	Rocky with sediment basins	Variable	Includes fjords (have shallow sill & deep basins) & fjards (generally shallower)
Sound	0-30m	Gravels & sands	Strong currents	Narrow channel, open at both ends
Gas structures	Variable	Mixed	Very weak currents	Pockmarks/ depressions (hard structures)
Photic Reefs	Within photic zone (generally <10-20m in Irish Sea)	Bedrock, boulders & cobbles	Variable	Rough/uneven topography Contains Littoral Rock and Infralittoral Rock
Aphotic Reefs	Generally in aphotic zone (generally >10-20m in Irish Sea)	Rock/biogenic	Variable	Rough topography (not as pronounced as Sea Mounds)
(Irish) Sea Mounds	Rising >20m above surrounding seabed	Rock, often with sediment veneer	Variable	Sea Mound slope > 1-8%
Sand/ gravel banks	Variable	Sands & gravels	Strong currents	Bank slope >1-8%
Coastal sedimentDef	Intertidal -50m (& no BGS sediment data)	Muds, sands & gravels	Variable	Adjacent to coastline N.B. "Bucket" category, where no BGS data was available.
Shallow-water mud basin	0-50m	Muds	Very weak currents	Depression
Deep-water mud basin	Deeper than 50m	Muds	Very weak currents	Depression
Fine sediment plain	Variable	Sands & muddy sands	Weak currents	Negligible slope
Sediment wave/ megaripple field	Variable	Sands	Moderate/strong currents	Waves/ripples[1]
Low bed-stress coarse sediment plain	Variable	Cobbles, pebbles & muddy gravels	Low bed-stress	Negligible slope Evidence of fines in sediment
High bed-stress coarse sediment plain	Variable	Boulders, cobbles, pebbles & gravels	High bed-stress	Negligible slope No fines within sediment
Deep-water channel	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: Nymphe Bank

Table 3.2: Summary of biological characterisation for each Marine Landscape

Marine Landscape	Characteristic biology (bioptope complexes[2] 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 *et al*, 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 $3m^3$) 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
Dinophysis spp.	1.13	1.38	1.52	1.61
Decapod larvae	1.98	2.80	2.14	3.07
Total adult *Calanus*	1.91	1.44	2.32	1.45
Coscinodiscus wailesii	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**
Estuary	939	1.6
Ria	49	0.1
Saline lagoon	8	<0.1
Sea loch	600	1.0
Sound	69	0.1
Gas structures	58	0.1
Photic reef	278	0.5
Aphotic reef	1,237	2.0
(Irish) Sea Mounds	74	0.1
Sand/ gravel banks	540	0.9
Coastal sediment	3,606	6.0
Shallow-water mud basin	980	1.6
Deep-water mud basin	5,024	8.3
Fine sediment plain	13,218	21.9
Sediment wave/megaripple field	6,630	11.0
Low bed-stress coarse sediment plain	15,186	25.1
High bed-stress coarse sediment plain	11,760	19.4
Deep-water channel	234	0.4

Table 3.6: Assessment of relative vulnerability to different human activities at the marine landscape scale in the Irish Sea

Relative vulnerability of the marine landscape

- High vulnerability
- Low vulnerability
- Moderate vulnerability
- No detectable vulnerability
- Unlikely to be exposed to the activity

Relative sensitivity of the marine landscape

- ●●●● High sensitivity
- ●●● Moderate sensitivity
- ●● Low sensitivity
- ● No detectable sensitivity

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	●●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●●●
	Suction dredging for shellfish	●●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●	●●●
Smothering	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	●●●	●●●	●●●	●●●	●●	●●●	●●●	*	*
	Suction dredging for shellfish	●●●	●●●	●●●	●●●	●●	●●●	●●●	*	*
Smothering	Disposal of dredged spoil	●●	●●	●●	●●	●	●	●●●	*	*
Physical disturbance or abrasion	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

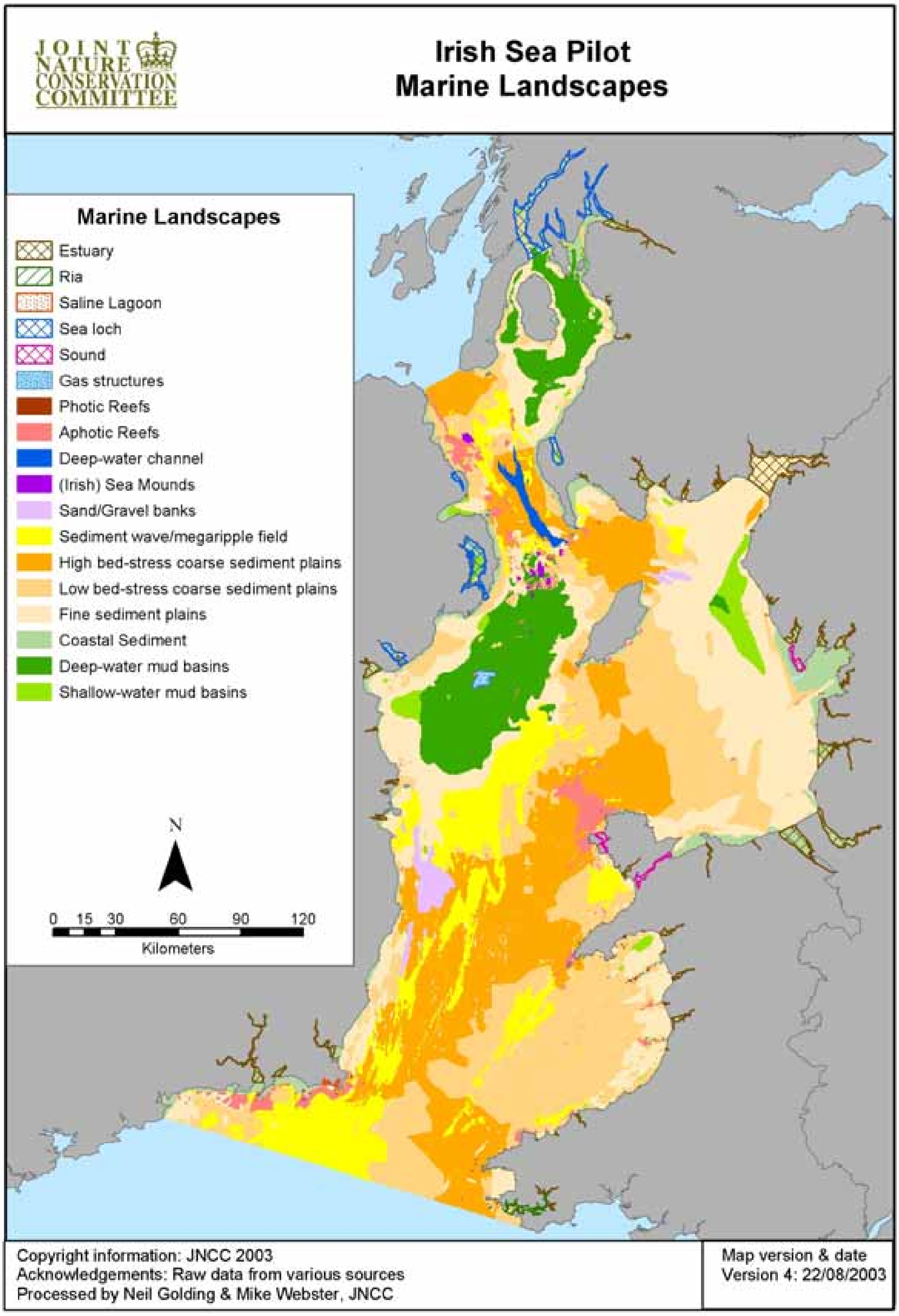

Figure 3.1: Coastal and seabed marine landscapes for the Irish Sea

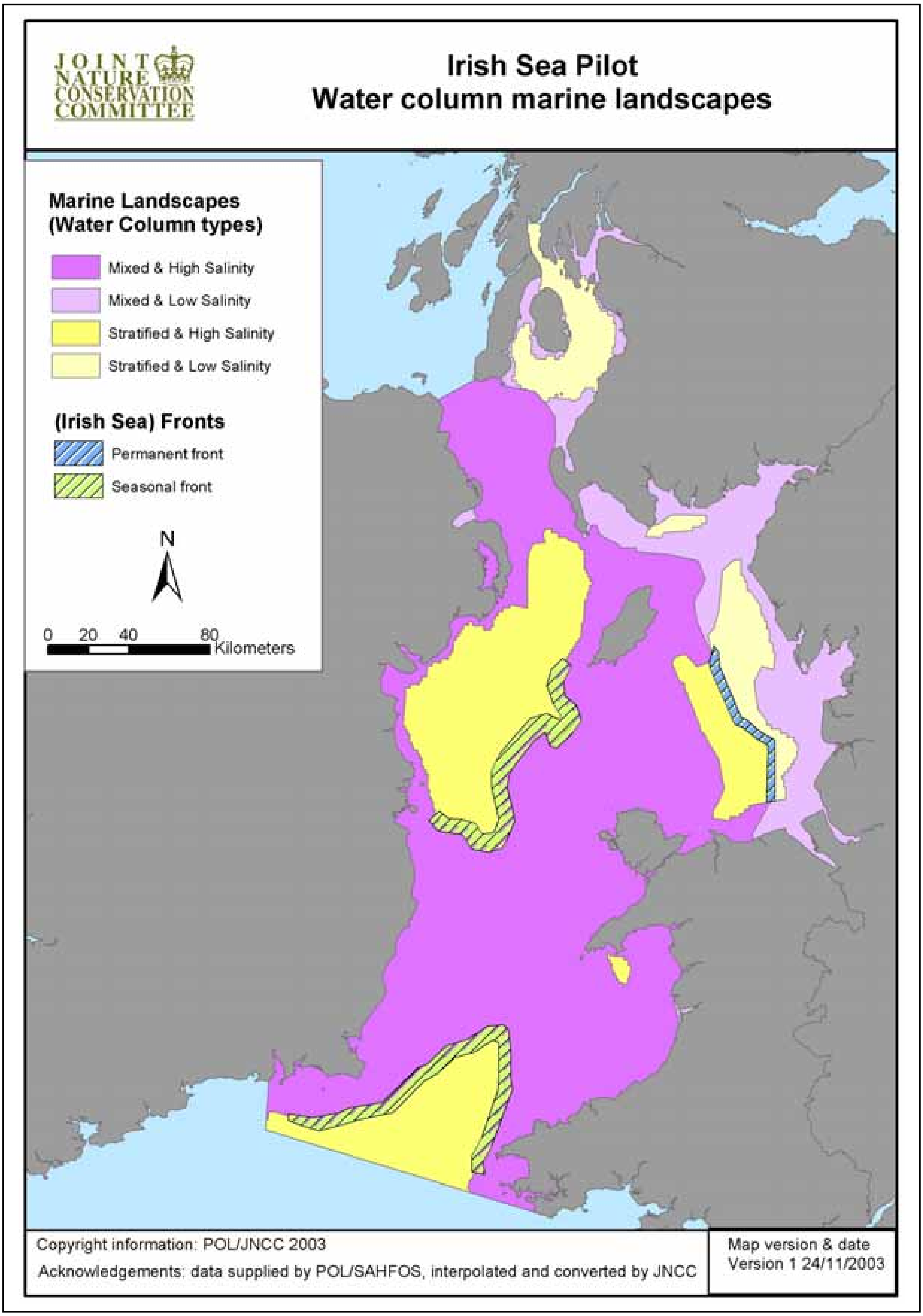

Figure 3.2: Water column marine landscapes for the Irish Sea

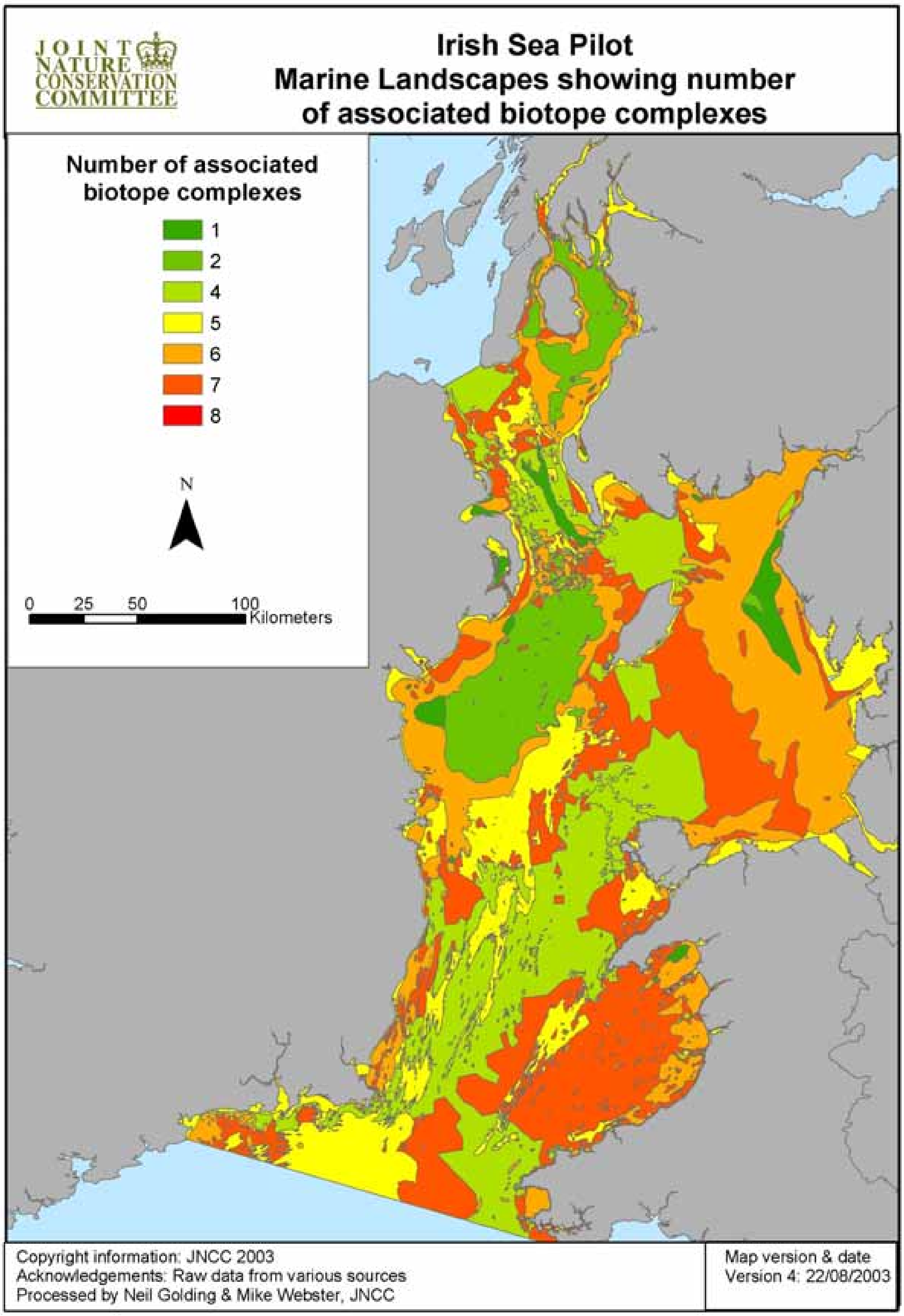

Figure 3.3: Marine landscapes showing number of associated biotope complexes.

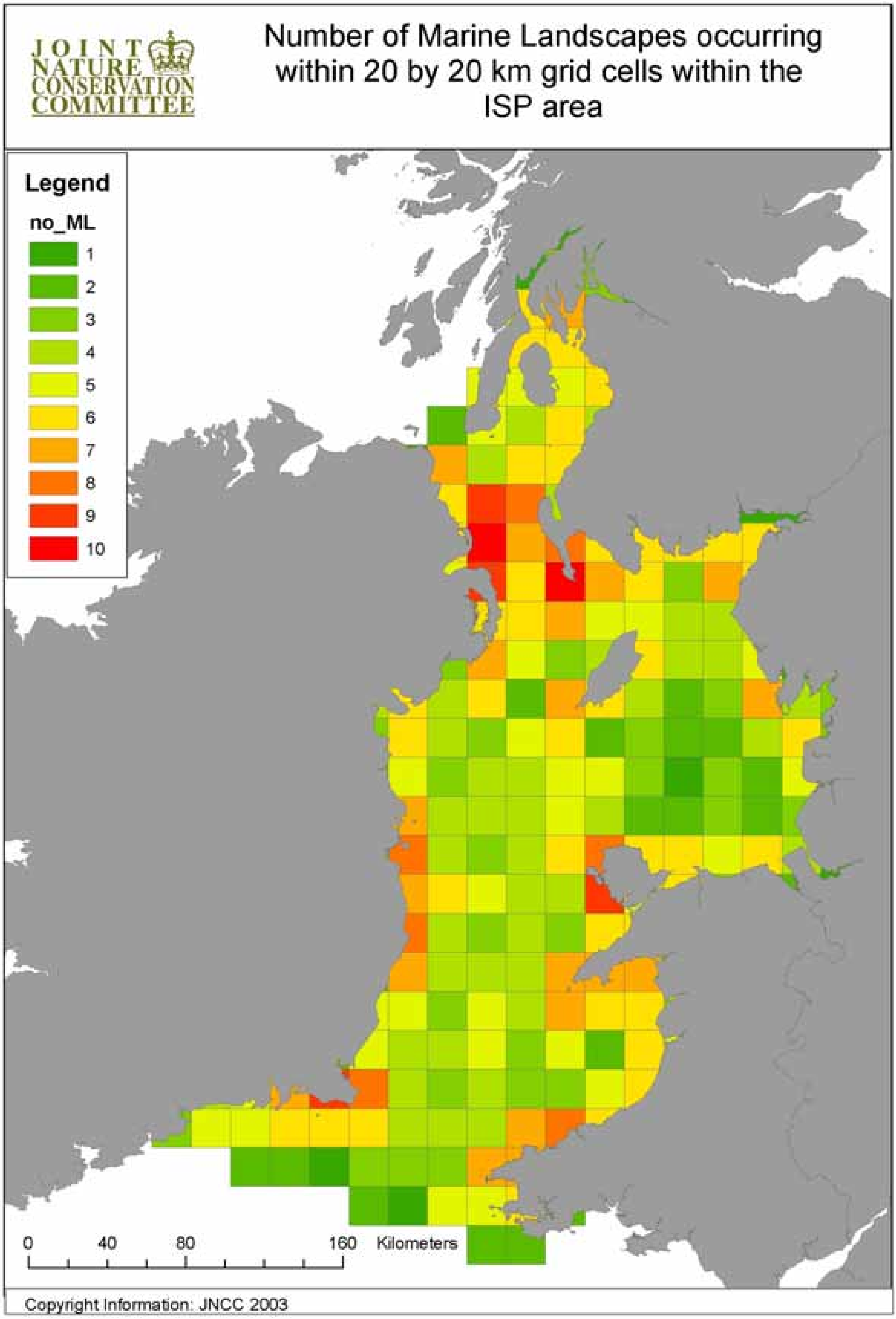

Figure 3.4 Map showing the number of inshore physiographic and seabed marine landscape types occurring in 20km by 20km grid cells.

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 biolological 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 biologica 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.

Recommendations[4]

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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6. Appendix I: RV Prince Madog Irish Sea pilot research cruise

6.1 Interpretation by video and photographs of some seabed habitats in the Irish Sea to the NW & W of Anglesey

Introduction

One of the strands of the JNCC Irish Sea Pilot Project in 2003 has been the development of a broadscale predictive seabed habitat map. This is based mainly on revised and simplified seabed sediment interpretations produced by the British Geological Survey. In essence, these broadscale divisions were mainly derived from the same geophysical and sediment grain-size data used to produce the BGS 1:250,000 Series of Seabed Sediment maps. The Anglesey Sheet (BGS, 1990), for which the interpretation was done by J.W.C. James and R.T.R. Wingfield, was based mainly on surveys done by BGS between 1967 and 1980. The geophysical surveys detected a large bedrock platform area extending well offshore to the northwest of Anglesey. This was found particularly off Carmel Head with bedrock exposures on the seabed and with wider areas of intermittent thin cover of lag or mobile sediment on the bedrock.

Many other parts of the Irish Sea with softer seabeds have had enough benthos sampling, including quantitative grab sampling, to use geological maps to make preliminary predictive assessments of the extent of biotope types. This was not the case northwest of Anglesey. Indeed the only substantial sampling here was from a series of naturalists dredge deployments by the present author in the mid 1960’s. Some of these dredges brought up clumps of Modiolus modiolus in sufficient amounts to imply that the horse mussel beds were in places of a scale to qualify as biogenic reefs under the Habitats Directive. See Moore (2002) for a map showing where Modiolus clumps were recorded as having been dredged in the 1960s. or found more recently. Whether biogenic of geologic origin, reefs are not as widespread as sediment or lag seabed habitats. Thus they merit extra consideration as possible locations for Special Areas of Conservation beyond the coastal zone. Some will also merit consideration if there is ecological zoning for fisheries management purposes.

This report covers a short series of camera tows which were made to examine the seabed habitats in the Irish Sea off the northwest of Anglesey. Sites targeted were locations near to boundaries on the BGS maps. Sites were also chosen where there were gaps in the ecological data that the Irish Sea Pilot project had managed to gather from desk studies. The camera tows were made in the period 2nd to 4th July 2003 from RV Prince Madog, on charter from VT Ocean Sciences and using School of Ocean Sciences, UW Bangor equipment. These camera tows were done specifically for the JNCC Irish Sea Pilot Project, thus supplementing photographic records brought together in the electronic Irish Sea Seabed Image Archive (Allen & Rees, 1999). Side-scan sonar lines and QTC acoustic seabed discrimination runs were made in the same locations on the cruise and are discussed later.

Methods

For the present work, video and still film cameras were mounted together on a sledge (Fig. 1) The still camera was a Photosea 1000 system. This comprises a 35mm camera with a Nikor water corrected lens mounted vertically on the forward part of the sledge frame. In this position the lens would have been 0.7m above the seabed when the skids of the sledge were flat on the bottom. The strobe was mounted behind and at an angle of 60o to the camera. It is rated at 150 watts. Photographs were taken at 42 second intervals using an electronic timer mounted in a separate housing. The film used was Fujichrome Sensia 200 daylight transparency film in 36 shot cassettes. Owing to the configuration by which the film runs though the special underwater camera, more frames get exposed on the leader than with conventional cameras. With automatic firing at 42 second intervals, 2 or 3 exposures would be in mid water during deployment. The number of interpretable seabed images from each successful deployment was usually about 25 to 28, varying slightly with the depth and the time taken to reach the bottom.

The video system uses a Rovtech colour camera mounted behind and below the Photosea strobe so as to look obliquely forward towards the same part of the seabed as the still camera. Lighting was by two 20 watt 12 volt lights mounted to either side of the forward part of the sledge. The video signal was recorded on the ship using a Sony digital recorder and digital 8 mini 60 minute tapes.

Towing was on a 12mm wire with a ball swivel between the sledge bridles and the wire. Tow lengths used were about twice the water depth. The 250 m umbilical cable was supported on a braided rope and handled separately from the towing wire. A tail rope with a surface buoy was streamed behind the sledge. The tail rope served the purpose of providing drag to pull the sledge clear of the ship in a stable manner and to provide a back-up means of recovery should the tow break.

The sledge was towed over the bottom with the ship heading into the tidal current at times near to slack water. The speeds over the ground usually aimed for were around 0.2 to 0.4 kts. Heading into the current helps to maintain steerage for the ship at such slow speeds and it helps ensure that any fine sediment cloud stirred up by the sledge is carried away from the field of view of the cameras. Tow durations aimed to get 20 minutes of seabed record so that in practice the gear was on the ground for 22 to 25 minutes. Typically the distance covered by the sledge in this time would have been about 160 - 220 metres.

Position fixing was by Differential GPS and was recorded on the ship to 3 decimal places of a Minute. When interpolating between positions recorded on the ship and actual positions of the sledge it must be remembered that the A frame gantry from which the gear is towed is about 14 metres behind the GPS aerial. Layback from the ship to the sledge would have been about 1.6 x the water depth, but less than this when first launched. The sledge descends steeply when deployed but more wire then has to be put out to limit lifting of the front of the sledge as it is towed forward.

Figure 6.1.1: Camera sledge with Photosea still camera system (black housings), and Rovtech video camera and lights (red plug retainers). The umbilical cable is coiled in the tub on the left and the tail rope buoy is to the right.

Results

Figure 6.1.2 shows where in the Irish Sea the camera deployments reported on were made. Numbering is as planned, not the sequence actually done. Four locations had been planned for and a fifth location was added during the cruise. Table 1 gives the deployment details, the numbers of minutes of video recorded and the numbers of still images obtained.

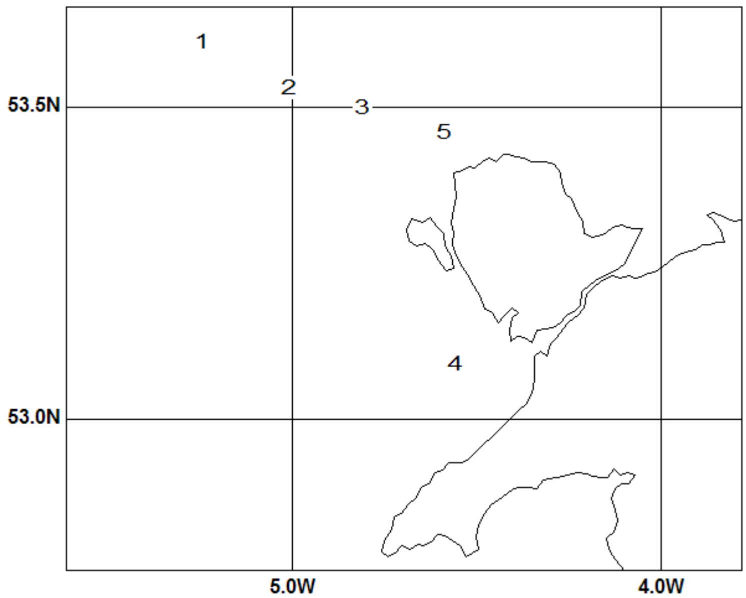

Figure 6.1.2: Station locations of five camera sledge tows for the Irish Sea Pilot Project July 2003.

Table 6.1.1: RV Prince Madog cruise Photosledge deployments

STATIONS	1	2	3	4	5
Date	03.07.03	03.07.03	02.07.03	03.07.03	04.07.03
Time Deployed	14 18	19 02	18 28	06 22	07 17
Latitude Deployed - North	53; 36.261	53; 31.812	53; 29.849	53;05.311	53; 27.588
Longitude Deployed - West	05; 15.039	05; 00.771	04; 49.027	04; 33.729	04; 35.647
Time on Bottom	14 21	19 05	18 33	06 24	07 20
On Bottom Latitude	53; 36.251	53; 31.834	53; 29.869	53; 05.314	53; 27.584
On Bottom Longitude	05; 15.022	05; 00.753	04; 48.992	04; 33.746	04; 35.626
Time Hauled	1450	19 28	18 55	06 51	07 42
Recovery Latitude	53; 36.363	53; 32.045	53; 29.937	53; 05.646	53; 27.565
Recovery Longitude	05; 15.212	05; 00.484	04; 48.827	04; 33.754	04; 35.313
Distance Covered Km.	0.27	0.47	0.19	0.61	0.32
Start depth m.	73.4	54.1	64.6	30.6	38.7
End depth m.	73.1	53.2	55.4	30.9	42.5
Wind	NW 3	NW 2	NW 2/3	NW 3	NW 3
Video record - Minutes	21	22	22	26	22
Number of still images	27	25	26	29	27

The following figures (6.1.3-6.1.18) are representative still camera images from a series of five camera sledge tows undertaken in the Irish Sea to the north-west and west of Anglesey 2nd to 4th July 2003. The images each show a small area of seabed equivalent to about 0.2m^2. The original images on 35mm slides have been digitally scanned for printing. Code numbers indicate first the number of the survey location and secondly the number of the seabed image in the sequence they were taken, starting at the first taken when the sledge landed on the bottom. Photographs were taken at 42 second intervals.

Figure 6.1.3:

Image Code ISP-Ang 1.03
Location Lat 53o 36.262' N; Long 05o 14.041' W
Depth 73.4 m
Orientation Top of image = SE
Date & Time Photographed 3rd July 2003 – 1422 BST

Habitat Interpretation: Rippled sand bed as a veneer overlying a shell hash layer. An ephemeral (slack/neap) cloaking of fine aggregated floc very thinly covers the sand. It was seen on video to be readily disturbed by wash from the sledge. The ripples were assymetrical. The mixing of the shell hash with the sand , including blackened queen scallops *Aequipecten opercularis* and other quite large old shells, suggests there has been bed disturbance to the bed, possibly by beam trawling.

Biotope Interpretation: Unstable sand veneer with a sparse benthos. Few identifiable macrofaunal organisms visible other than widely spaced *Ophiura (?albida)* and hermit crabs *Pagurus bernhardus* (on video). Infrequent "lebenspuren" trails only. Little obvious sign of burrowing or tube building fauna.

Figure 6.1.4:

Image Code ISP-Ang 1.12
Location Lat 53o 36.296 N; Long 05o 15.098 W
Depth 73.3 m
Orientation Top of image = SE
Date & Time Photographed 3rd July 2003 – 1430 BST

Habitat Interpretation: Rippled sand bed as a veneer overlying a shell hash layer. An ephemeral (slack/neap) cloaking of fine aggregated floc very thinly covers the sand. It was seen on video to be readily disturbed by wash from the sledge. The ripples were assymetrical. The mixing of the shell hash with the sand , including blackened queen scallops *Aequipecten opercularis* and other quite large old shells, suggests there has been bed disturbance to the bed, possibly by beam trawling.

Biotope Interpretation: Unstable sand veneer with a sparse benthos. Few identifiable macrofaunal organisms visible other than widely spaced *Ophiura (?albida)* and hermit crabs *Pagurus bernhardus* (on video). Infrequent "lebenspuren" trails only. Little obvious sign of burrowing or tube building fauna.

Figure 6.1.5

Image Code ISP-Ang 1.25
Location Lat 53o 36.344' N; Long 05o 15.180' W
Depth 73.1 m
Orientation Top of image = SE
Date & Time Photographed 3rd July 2003 – 1438 BST

Habitat Interpretation: Rippled sand bed as a veneer overlying a shell hash layer. An ephemeral (slack/neap) cloaking of fine aggregated floc very thinly covers the sand. It was seen on video to be readily disturbed by wash from the sledge. The ripples have a series of parallel grooves running obliquely across them with slightly more floc in them. These grooves do not look like natural features and may represent marks from the passage of an otter trawl footrope in the recent past. An otter trawler and a beam trawler were seen in the area while this station was being worked.

Biotope Interpretation: Unstable sand veneer with a sparse benthos. Few identifiable macrofaunal organisms visible other than widely spaced *Ophiura (?albida)* and hermit crabs *Pagurus bernhardus* (on video). Infrequent "lebenspuren" trails only. Little obvious sign of burrowing or tube building fauna.

Figure 6.1.6

Image Code ISP-Ang 2.01
Location Lat 53o 31.841' N; Long 05o 0.744' W
Depth 54.1 m
Orientation Top of image = SW
Date & Time Photographed 3rd July 2003 – 1905 BST

Habitat Interpretation: Embedded fine lag gravel bed surface. The level plain surface has indications of signs of sand scour.

Biotope Interpretation: Little sign of attached epifauna or of any obvious infauna.

Figure 6.1.7

Image Code ISP-Ang 2.15
Location Lat 53o 31.935' N; Long 53o 0.625' W
Depth 53.8 m
Orientation Top of image = SW
Date & Time Photographed 3rd July 2003 – 1915 BST
Habitat Interpretation: A large embedded boulder almost submerged in fine lag gravel or possibly bedrock scoured by glacial action and later sediments through which the rock just shows.

Biotope Interpretation: Some encrusting bryozoan sheets on the boulder / bedrock and a few small tufts of short hydroid / bryozoan turf which appear to have suffered scouring. There is little sign of attached epifauna or of any obvious infauna in the lag gravel.

Figure 6.1.8

Image Code ISP-Ang 2.16
Location Lat 53o 31.941' N; Long 05o 0.616' W
Depth 53.8 m
Orientation Top of image = SW
Date & Time Photographed 3rd July 2003 – 1916 BST
Habitat Interpretation: partially embedded lag boulders and cobbles surrounded by finer lag gravel. Larger stones appear sub-angular and scoured as would be expected of re-worked glacial till. .

Biotope Interpretation: Some encrusting bryozoan sheets on the boulders and a few small tufts of short hydroid / bryozoan turf which appear to have suffered scouring. There is little sign of attached epifauna or of any obvious infauna in the lag gravel. The sea urchin bottom right with spines of differing lengths in distinct rows is probably *Echinus elegans*.

Figure 6.1.9

Image Code ISP-Ang 3.05
Location Lat 53o 29.880' N; Long 04o 48.966' W
Depth 64.0 m
Orientation Top of image = SW
Date & Time Photographed 2nd July 2003 - 1836

Habitat Interpretation: Embedded lag cobbles surrounded by finer lag gravel with old *Modiolus modiolus* shells lying concave side down. Level surface appears scoured.

Biotope Interpretation: Small amount of encrusting bryozoan sheet on the bigger cobbles in spite of the scouring. A few, probably dead, barnacles can be seen. A single medium sized colony of *Alcyonium digitatum* is present. An *Urticina (felina?)* is partly within the image area bottom right.

Figure 6.1.10

Image Code ISP-Ang 3.08
Location Lat 53o 29.866' N; Long 04o 48.950' W
Depth 62.0 m
Orientation Top of image = SW
Date & Time Photographed 2nd July 2003 – 1838 BST

Habitat Interpretation: Embedded lag boulders and cobbles with finer lag gravel and a few old *Modiolus modiolus* shells lying Level surface appears scoured except for the slightly protruding boulder in the centre of the image .

Biotope Interpretation: Small amount of short hydroid / bryozoan turf on the protruding boulder, with several barnacles (largest probably *Balanus balanus*) and a small colony of *Alcyonium digitatum*. Lower level scoured gravel appears to lack obvious epifauna.

Figure 6.1.11

Image Code ISP-Ang 3.25
Location Lat 53o 29.923' N; Long 04o 48.861' W
Depth 57.0m
Orientation Top of image = SW
Date & Time Photographed 2nd July 2003 - 1851

Habitat Interpretation: Smoothed bedrock partially exposed with some coarse sand and broken shell fragments on the uneven surface of it. Greenish colour of the rock fits that of similar hard Precambrian schists found in NW Anglesey. A few old *Modiolus modiolus* shells are on the surface Rock surface appears scoured.

Biotope Interpretation: Small amount of short hydroid / bryozoan turf on the bedrock, with small amounts of encrusting epifauna indicative of rather scoured conditions.

Figure 6.1.12

Image Code ISP-Ang 4.01
Location Lat 53o 05.323' N; Long 04o 33.746' W
Depth 30.6 m
Orientation Top of image = S
Date & Time Photographed 3rd July 2003 – 0624 BST

Habitat Interpretation: Medium / Fine sand with some medium sized shell fragments mixed into the sand as well as being present in the ripple troughs, indicative of an underlying shell hash layer. The ripples are irregular and have a low rounded relief. Some aggregated fine floc is present on the sediment surface, together with partly cohesive eroding clastic material which may have been disturbed earlier. Visible shells look fragile and white as would be characteristic of *Abra alba* and *Fabulina fabula.* Mix of shell hash into the surface sand suggests some past disturbance to the bed probably by trawling.

Biotope Interpretation: There were several *Ophiura ophiura* in almost every image at this station. The larger one lower centre in this image has had several of it's arms damaged and is now regenerating them. This is a common feature of brittle stars in trawl disturbed areas. There are some small holes / burrows and the tops of small worm tubes.

Figure 6.1.13

Image Code ISP-Ang 4.05
Location Lat 53o 05.359'N; Long 04o 33.747'W
Depth 30.7 m
Orientation Top of image = S
Date & Time Photographed 3rd July 2003 – 0628 BST
Habitat Interpretation: Rippled medium / fine sand with small shell fragments mixed into the sand. The ripples are regular and with an asymetrical low relief. More shell fragments lie in the troughs.

Biotope Interpretation: In two parts of this camera tow there were unusual numbers of crabs *Inachus (dorsettensis?)*. These crabs appeared to have formed aggregations. There are 7 visible on this image most of which seem to be orientated in the same way, sideways to the ripples and hence probably to the tidal current.

Figure 6.1.14

Image Code ISP-Ang 4.23
Location Lat 53o 05.520' N; Long 04o 33.751' W
Depth 53.3 m
Orientation Top of image = S
Date & Time Photographed 3rd July 2003 – 0640 BST
Habitat Interpretation: Low rippling of Medium / Fine sand with small shell fragments mixed into the sand and a few intact fragile white shells lying on the surface. The ripples are semi-regular and with an asymetrical low relief. More shell fragments lie in the troughs.

Biotope Interpretation: The medium sized organism that has ploughed across the lower part of the image is probably the mollusc *Scaphander lignarius.* Moderate sized *Asterias rubens* were fairly frequent on this camera tow. This would be in keeping with the location carrying an infauna fairly rich in small bivalves which the starfish prey on.

Figure 6.1.15

Image Code ISP-Ang 5.02
Location Lat 53o 27.583' N; Long 04o 35.596'W
Depth 38.7 m
Orientation Top of image = W
Date & Time Photographed 4th July 2003 – 0720 BST

Habitat Interpretation: Sub-angular cobbles and boulders loosely embedded with coarse shelly sand between. The cobble surface, with no epifauna, ,appears to have been subject to intermittent burial in mobile sand with associated severe scour. A few shells of *Modiolus* and *Chlamys* sp. are visible.

Biotope Interpretation: Barren severely scoured bed surface. No sign of epifauna or infauna.

Figure 6.1.16

Image Code ISP-Ang 5.03
Location Lat 53o 27.582' N; Long 04o 35.596' W
Depth 38.7 m
Orientation Top of image = W
Date & Time Photographed 4th July 2003 – 0722 BST

Habitat Interpretation: Boulder lying on lag cobble / gravel surface around which the superficial loose medium sand has formed a scour pit. At this station the superficial sand was seen to be moving in the current or cascading down slopes with any slight disturbance.

Biotope Interpretation: Loose sand probably barren of macrofauna. Hydroid turf on top of the boulder including *Nemertesia antenina*.

Figure 6.1.17

Image Code ISP-Ang 5.12
Location Lat 53o 27.577' N; Long 04o 35.506' W
Depth 39.5 m
Orientation Top of image = W
Date & Time Photographed 4th July 2004 – 0728 BST
Habitat Interpretation: Boulders and possibly bedrock partly submerged by or overlain by loose medium sand.

Biotope Interpretation: Numerous *Urticina (? felina)* on partly sand covered rock. There is a sand encrustation of indeterminate origin on top of several boulders.

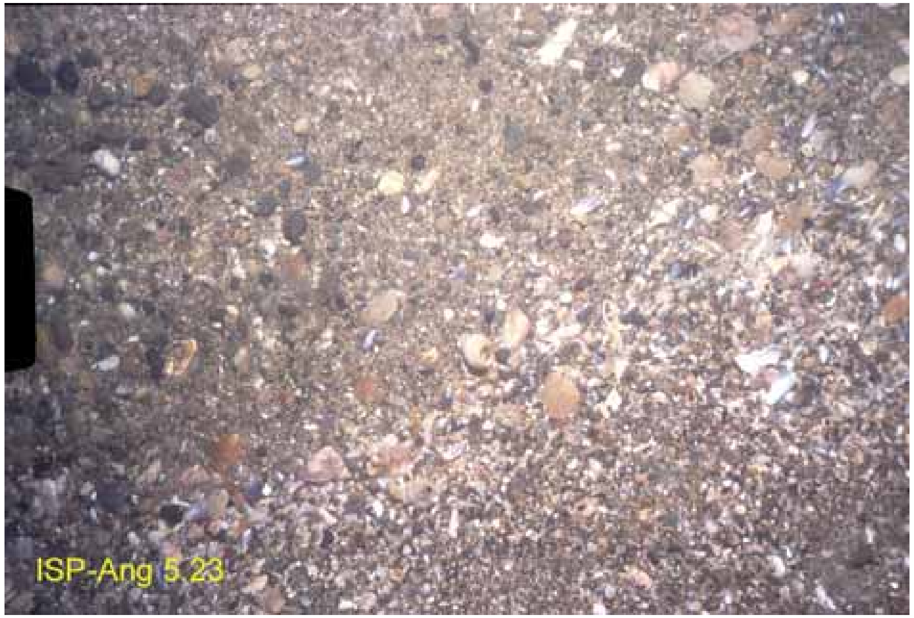

Figure 6.1.18

Image Code ISP-Ang 5.23
Location Lat 53o 27.570' N; Long 04o 35.397' W
Depth 42.5 m
Orientation Top of image = W
Date & Time Photographed 4th July 2003 – 0736 BST
Habitat Interpretation: Very loose coarse shelly sand in megaripples. On video the superficial sand was seen to be moving in the tidal current and was seen to avalanche on the steeper facees of the asymmetric megaripples without releasing any turbid cloud.

Biotope Interpretation: Apparently barren very loose sand.

Habitat and biotope interpretations

Interpretations are in these cases based more on the sediment or other seabed habitat features. This is because in a tide swept and sand scoured part of the Irish Sea the obvious fauna or identifiable bioturbation features are rather limited.

At the time of writing major revision of the sub-tidal sediment part of the JNCC Marine Habitat Classification was known to be in progress. The current revision was not complete while the earlier (1997.06) version (Connor et al, 1997) is acknowledged to be rather incomplete in respect of variations of Irish Sea lag dominated heterogeneous seabed types.

Station 1

The location of this camera sledge tow lies on or near an interpreted boundary on the BGS Bedforms and Seabed Character map (BGS, 1990) between areas shown as “Sand Carpet with Megaripples” and “Sandwaves”. For most of the tow the video and still images showed rippled sand only partly covering a hash of large shells such as Aequipecten opercularis, thus fitting the BGS “Sand Carpet” description.

In places it appeared as if some of the hash was partly embedded in cohesive grey clay. Some of the shells were blackened, indicating they had previously been buried in sediment for a considerable time. It should also be noted that during the SWISS project shells were identified that must have been archaic. Shells of Macoma calcarea were found in the superficial sediment. In modern times this is a cold water sub-arctic species, so it is assumed that these shells date back several thousand years to the immediate post-glacial marine transgression period.

There were signs that the bed had been disturbed by fishing gear with penetration below the superficial sand ripples. Recent net marks were noticed across one still image.

The fauna at the site appeared to be sparse with few hermit crabs or starfish visible. Under the Marine Habitat Classification the location and depth (60+m) would place the site as “Circalittoral”. The sediment type would place it in the excessively broad “Gravel and Sand” category. Seemingly being strongly rippled and unstable with a sparse fauna it would be classified as “Mobile”. However the 1997 classification lacked a “CGS Mob” category, only an “IGS Mob” one.

Using a draft 2003 version of the revised Sublittoral Sediment part of the Marine Habitat Classification supplied by J. Allen, Station 1 would not fit a point on the hierarchy lower than “Sublittoral Sand (SSa)” Habitat Complex level. At the next layer (Biotope Complex) there are seven sub-divisions of which three are “Circalittoral”. Two of these are muddy and the other is tagged as “Fine Sand”. However the sand of the ”Sand Carpet” was not fine and when grab sampled the amount of shell included would put it into a gravelly sand or slightly gravelly sand category.

Station 2

This location lies to the north west of one of the major troughs in the bed of this part of the Irish Sea that are presumed to represent peri-glacial drainage channels emanating from the eastern shallows of the Irish Sea before the marine transgression and cut into the till. On the BGS map the area was interpreted as having “sandy gravel” with some superficial sand ribbons shown on the bedform inset.

The seabed images showed surfaces mainly of well embedded lag gravel and cobbles with some larger boulders which were alao embedded. Thus the bed surface appeared to be rather level. Embedded lag of this type is a very widespread seabed type in the tide swept parts of the Irish Sea. This stable bedform surface would have been mainly determined by erosion of the glacial till in the surf zone during the post-glacial marine transgression. Scour by the small amounts of sand and shell that are present have packed the interstices and polished the exposed surfaces.

Attached epifauna was rather sparse low growing and impoverished, with most of the growth on any slightly larger boulders that happen to be stand a little proud of the rest of the scoured surface. Short hydroid tufts were visible on some boulders but did not cover the boulders. Previous sampling has shown that on this type of bottom , some of the cobbles may be cemented into place by *Sabellaria spinulosa* tubes. These occur around and between them without producing emergent colonies of mini-reefs. An infauna also occurs that is concealed in a cohesive deposit below and between the exposed surface lag.

On both the video and the still images, several sea urchins were seen. When those shown on the still photos were examined after digital scanning at high resolution and enlarging, they were seen to have spines in distinct rows with differing spine lengths. This is characteristic of *Echinus elegans* rather than the more familiar *E. esculentus*. *E. elegans* is regarded as a deeper water species occurring in 50 – 2000m. Some urchins appearing more like *E. esculentus* were also seen on the video record.

A few shells of the large heavy shelled bivalve *Glycimeris glycimeris* were seen but not in the quantities often seen on the lag gravel grounds in the middle of St George’s Channel slightly further south. *Glycimeris* dominated lag gravels form a visually distinctive type of habitat, though not covered in the 1997 Marine Habitat Classification. Neither were there significant numbers of *Aequipecten* visible at station 2.

Under the 2003 revised draft of the Marine Habitat Classification it is not clear whether the Irish Sea lag gravels with embedded cobbles should be put in the Habitat Complex for “Sub-littoral Coarse Sediment” or the Habitat Complex for “Sub-littoral Mixed Sediment”. Each of these has two “Circalittoral” Biotope Complex categories and none of the Biotopes really match.

Station 3

This study site was located within the area identified by BGS as having scattered outcropping bedrock with mobile sediment and lag cover. The video and photographic record confirmed this. The early parts of the tow had mainly embedded lag cobbles and gravel, but later the sledge ran over exposed bedrock. This appeared to be relatively planed down and smooth surfaced in keeping with a platform subject to glaciation. Where there was no epifauna present, the rock appeared green in colour, in keeping with the likelihood of a Pre-Cambrian schist outcropping here. Some of the exposed rock looked polished as if subject to sand scour inhibiting colonisation by epifauna.

As at the other sited, the epifauna crusts and short turf was mainly confined to places where boulders or bedrock stood slightly proud and would have been slightly less subject to scour by saltating sand grains and shell fragments.

No obvious superficial beds of *Modiolus modiolus* were seen. At least not of the form where faecal mud deposits accumulate. However a few small clumps were seen that might have represented horse mussels adhering to the cobbles and surrounding themselves with shell debris. It is also possible that some were living infaunaly and binding the coarse material together as has been reported from strong tidal current areas N of the Isle of Man and off Codling Bank.

As with the rather similar Station 2, none of the biotopes in the revised 2003 Marine Habitat Classification categories adequately match the situation seen at Station 3.

Station 4

In contrast to the other sites, this location was slightly out of the main tidal streams in Caernarfon Bay. The sediment was a rather uniform rippled sand throughout the tow, though with slight variations in the amounts of finely broken shell fragments visible. There was some deposition of fine floc on to the ripples and where it had been disturbed by the fauna the sediment appeared to be slightly cohesive. Disturbance by the sledge also brought up turbid clouds, suggesting that the sediment was a muddy sand or at least a slightly muddy sand under the immediate surface.

Most of the bivalve shell fragments appeared to be of relatively fragile white shelled species such as *Abra alba* or *Fabulina fibula*. Several paired valves of *Arctica islandica* were seen on the surface as well as *Acanthocardia* sp.

The images indicated quite a rich fauna with large numbers of *Ophiura ophiura* and hermit crabs. There appeared to be patches with worm tubes just protruding from the sediment. It could not be determined whether these were *Lanice conchillega* with only small fringes or the tips of large *Lagis koreni*. Holes in the sediment probably of bivalve siphons were also common. As befits a fairly rich area of sand seabed, there were numbers of *Asterias rubens*. The burrowing anemone *Cerianthus lloydi* was quite frequent. On one of the still images there is a trail leading to a partly sediment coated animal that has the characteristics of *Scaphander lignarius.*

A notable feature of the tow was the high numbers of spider crabs *Inachus (?dorsettensis)* seen as aggregations on two parts of the run. More than 6 sometimes occurred in one field of view. Also of note was their orientation relative to the sand ripples, suggesting that they were mostly lying sideways on to the bottom current.

The biotope present here would, in the strict sense, not really fit any of those listed in the 1997 version of the Marine Habitat Classification. In other respects it appears to lie between an *Abra* muddy sand community, in the senses broadly used by Petersen and Glemarec and a sand community of the shallow *Venus* type. It is perhaps best regarded as an *Abra* muddy sand biotope, but one which is less heavily enriched by excess organic fines. If this is confirmed then the BGS interpretation of a sand plain with some sand megaripples would not be a good predictor of it.

The 2003 revised draft of the Marine Habitat Classification offers no biotopes that closely match that seen at Station 4.

Station 5

This extra site was on the eastern flank of the area shown on the BGS maps as the tongue of bedrock with intermittent lag / sediment cover extending north-westwards from Anglesey. The tow also ran into a more complex area where the BGS interpretation was of gravelly sand in bedforms of “sand carpet” and sand waves.

The camera sledge tow ran from west to east. When it first landed the sledge was on highly scoured cobbles with coarse sand between. Indeed the spot looked as if it had only recently been uncovered by sand movements. As soon as the sledge moved it went into an area of rather angular boulders looking like an eroded moraine. There was clean and apparently loose well sorted sand lying between the protruding boulders. Mid way through the tow the sledge went over the edge of the probable moraine and out into deeper water. After more towing wire had been put out it landed on obviously very loose coarse shelly sand in megaripples. The sediment was so loose that as well as fragments being seen to move in the current, there were cascades of loose sediment down the steeper faces of the assymetrical megaripples. Between some of the ripples, a surface of small stones was just visible. Towards the end of the tow the sledge seemed to move on to an accumulation of medium sand. Much of the above sequence is in keeping with the earlier BGS interpretation from geophysical evidence.

Most obvious on the basal parts of boulders and protruding from the sand around the boulders were numerous *Urticina (?felina).* Indeed there were more than previously seen elsewhere on Irish Sea seabed photographs. Some of the boulders hand the hydroid *Nemertesia antennina* colonies growing on them. There were also sand covered colonies of unknown organisms on some boulders. The loose coarse sand encountered later in the tow appeared to be barren of macrobenthos.

This tow covered at least two separate biotope types, namely the tract of protruding boulders forming a complex mosaic with sand between the boulders, and the very loose sand just to the east and slightly deeper of the edge of the boulders. It was as if there had been an accumulation of boulders piled against the NE side of the bedrock platform.. The loose coarse sand was where turbulence would been expected down tide of the bedrock platform.

Tow 5 encountered several different habitats and biotopes which did not match those listed in either the 1997 Marine Habitat Classification or the revised sub-tidal sediment part.

Conclusions

Based on the video and photographic evidence, the geophysical based interpretations of the seabed habitats were often good predictors. This is especially so if those using the information take into account the processes that led to the generation of those sediment sand bedforms when trying to make ecological predictions.

One strength of the visual approach to seabed habitat interpretation is that it is often possible to detect the layered mosaics which occur. For example, deposits of fine floc settling onto and between sand ripples at slack water on neap tides can sometimes be seen. Such depositing organic matter may be important in the trophic pathways of the species that contribute to the biotopes. Where the sand is merely a veneer of ripples, the underlying lag or shell hash can be seen in the troughs.

It was apparent from this exercise and from previous experience that differences between muddy sands and other sands on the present sediment maps are not good predictors of the sequence of biotopes between highly mobile tide swept sands and the more enriched muddy sands holding *Abra* communities. The 1997 Marine Habitat Classification also failed to make adequate distinctions amongst the varieties of offshore sand / slightly muddy sand communities.

Looking at the video and still images from this exercise and previous deployments on Irish Sea lag gravels, it is clear that a critical factor is the extent to which any boulders stand proud. Most often the lag appears to lie as a firmly embedded nearly flat surface that is subject to intermittent sand scour. Epifauna is largely limited to those boulders that stand proud. In future studies it would therefore be ecologically relevant to distinguish between areas of embedded lag and tracts of boulders lying proud of the scoured surface.

Although good descriptions were obtained from the videos and still photographs, it was very difficult to match the situations seen with either the 1997 version of the Marine Habitat Classification or the current draft of a revision of the subtidal parts of it. Even when the results of grab sampling were also considered, it was difficult to find adequate matches between the situations at sea in this part of the Irish Sea and the classification.

Acknowledgements

Thanks are due to the Master and crew of RV Prince Madog for their skill in deploying the camera sledge and maintaining the requisite very slow speed over the ground. Thanks is also due to Richard Shucksmith for his help in setting up and operating the digital video gear. Neil Golding of JNCC commissioned the work, was responsible for choosing the sites and was SIC on the cruise. In addition, Jon Davies and Louise Lieberknecht,(JNCC), Rohan Holt (CCW), Jim Bennell (UW Bangor) participated in the cruise.

I am grateful to J. Allen of Hull University for allowing me to see drafts of parts of the revised MNCR Classification.

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6.2 Sidescan sonar survey of seabed marine landscapes in the Irish Sea to the NW & W of Anglesey

Introduction and methods

Side scan sonar surveys were undertaken at all the sites visited in order to supplement the data acquired using the QTC acoustic ground discrimination system (AGDS), the video tows and direct grab sampling. It was used to map the seabed texture out to 100m either side of the vessel.

At each of the 5 sites 3 parallel lines, 1.5 to 2km long, and nominally 200m apart were surveyed. The lines were surveyed in the direction of tidal flow so that the tow fish aligned itself directly behind the vessel. For at least one site all the lines were surveyed in the same direction (down-tide) in order keep the speed of the vessel through the water slow enough to enable the tow fish to get close to the seabed. (The tidal flow at this location close to the Skerries was very fast).

The sonar was a Cmax CM800 system utilizing a 300m fibre optic cable on a battery-powered winch. A sonar range of 100m and frequency of 325kHz (equivalent to the industry 500kHz standard) were selected in order to give the optimum resolution with the best lateral coverage. The digital data were recorded on optical magnetic discs and the analogue signal was printed out on a Dowty 3700 thermal printer. The digital data only has a dynamic range of 7.5 bits but this is optimised across the scan by automatic gain adjustment. Since the gain pattern is not recorded the absolute values of backscatter cannot be recovered. This means that this sonar is useful for mapping different sediment textures but it cannot be used for sediment classification using the amplitude of the backscattered signal.

The recorded sonar data was converted into Q'mips format, by replaying it on the sonar workstation. Once in this format it was read it into the Octopus 461 side scan sonar processing toolkit in order adjust and clean up the data prior to geo-referencing the sonar data using the process of mosaicing. The following processes were applied to the sonar data prior to mosaicing using the utilities package in the 461 toolkit:

- channel balancing and gain adjustment
- adjustment of bottom tracking for accurate Slant Range Correction (SRC).
- navigation extraction at regular time intervals (30 seconds)
- navigation editing to remove navigation spikes and turns
- layback adjustment to correctly position the towfish behind the vessel.

Each station was mosaiced using tile sizes of 400m x 400m with a resolution 2000x2000 pixels each using the Automosaic facility in the 461 toolkit. These tiles were saved as Geotiff files in which the associated georeferencing data are included. These can then be imported directly into GIS software (e.g. Mapinfo) where each tile can be assembled into a sonar mosaic which covers the whole of the site surveyed. (e.g. site 5 close to the Skerries consisted of 12 tiles which were assembled in a 4x3 mosaic).

Results

Each of the stations visited showed quite different textural characteristics. Figure 6.2.1 shows a side-scan mosaic from station 1. Figure 6.2.2 shows a more detailed section, demonstrating the sand waves observed at this station. The video/still track positions are marked on each figure. These correspond to figures in 6.1. Figure 6.2.3 shows a side-scan mosaic from station 2. . Figure 6.2.4 shows a more detailed section of side-scan, showing the gravelly substratum. Figure 6.2.5 shows a side-scan sonar mosaic from station 3. Figure 6.2.6 shows a more detailed section of side-scan, showing rocky/gravelly substratum. Figure 6.2.7 shows a side-scan sonar mosaic from station 4. Figure 6.2.8 shows a more detailed section of side-scan showing smooth sand. Figure 6.2.9 shows a side-scan mosaic from station 5. Figure 6.2.10 shows a more detailed section of side-scan showing a rough/rocky area north of the Skerries.

Discussion and conclusions

The sonar records were very useful for showing the variability of the texture of the seabed either side of the track of the vessel beyond the area covered by the QTC and video tow data. Some sites were relatively uniform in texture e.g. the Caernarfon Bay site. Others such as the site off the Skerries showed that the texture of the seabed features varied considerably. This could also be seen in the video tows and the QTC data. The sonar, however, should allow the features seen on the video to be correlated across the entire scan width covered by the side scan data.

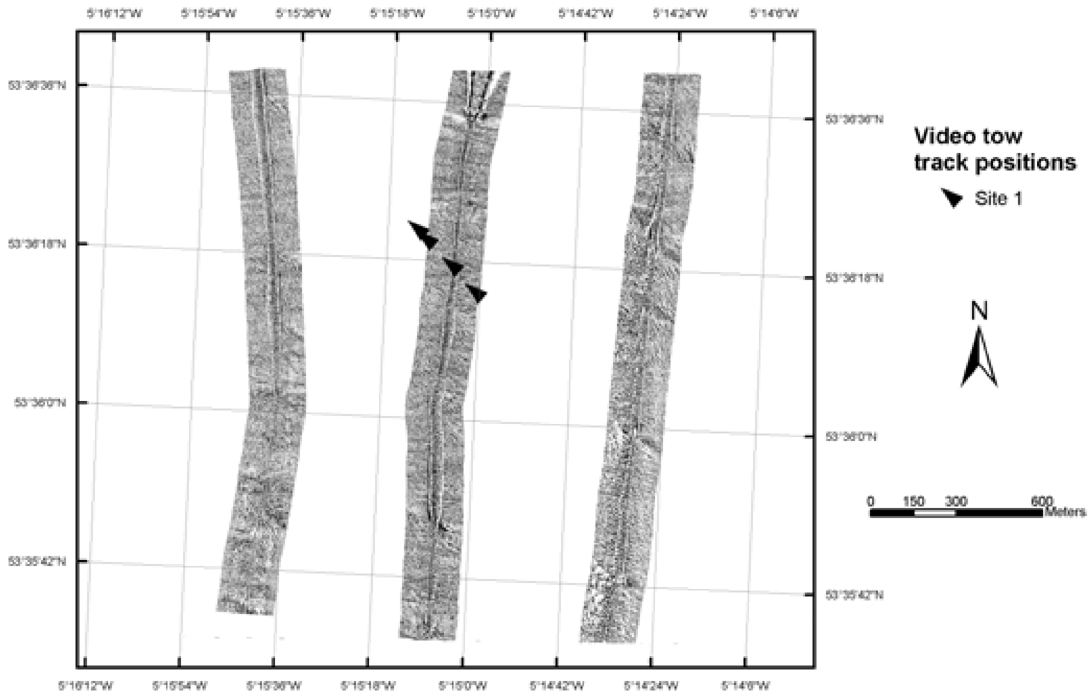

Figure 6.2.1: Side-scan mosaic from Station 1

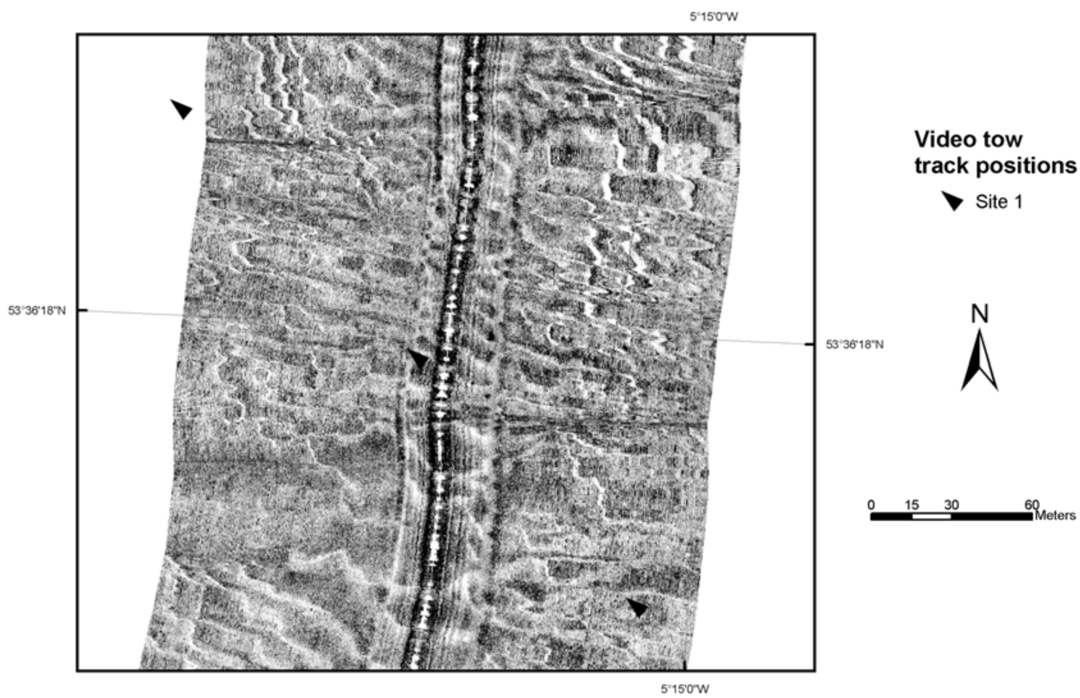

Figure 6.2.2: More detailed side-scan section from Station 1 showing sand wave detail

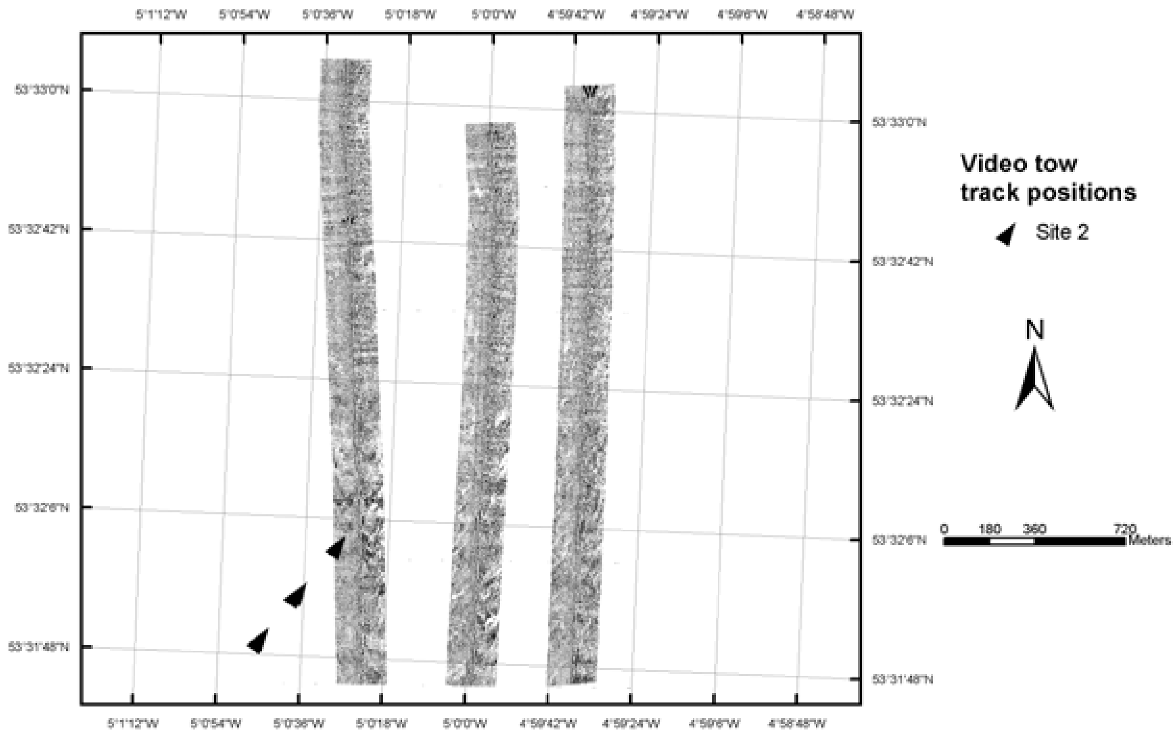

Figure 6.2.3: Side-scan mosaic from Station 2

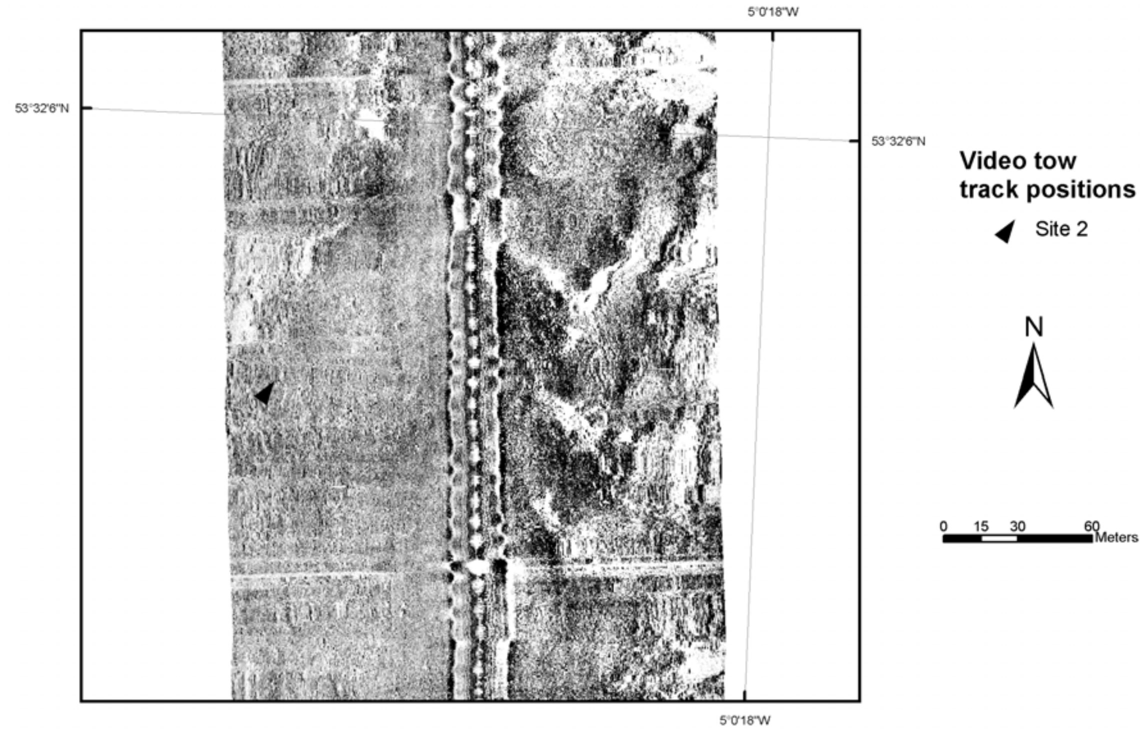

Figure 6.2.4: More detailed side-scan section from Station 2 showing gravel plains and waves.

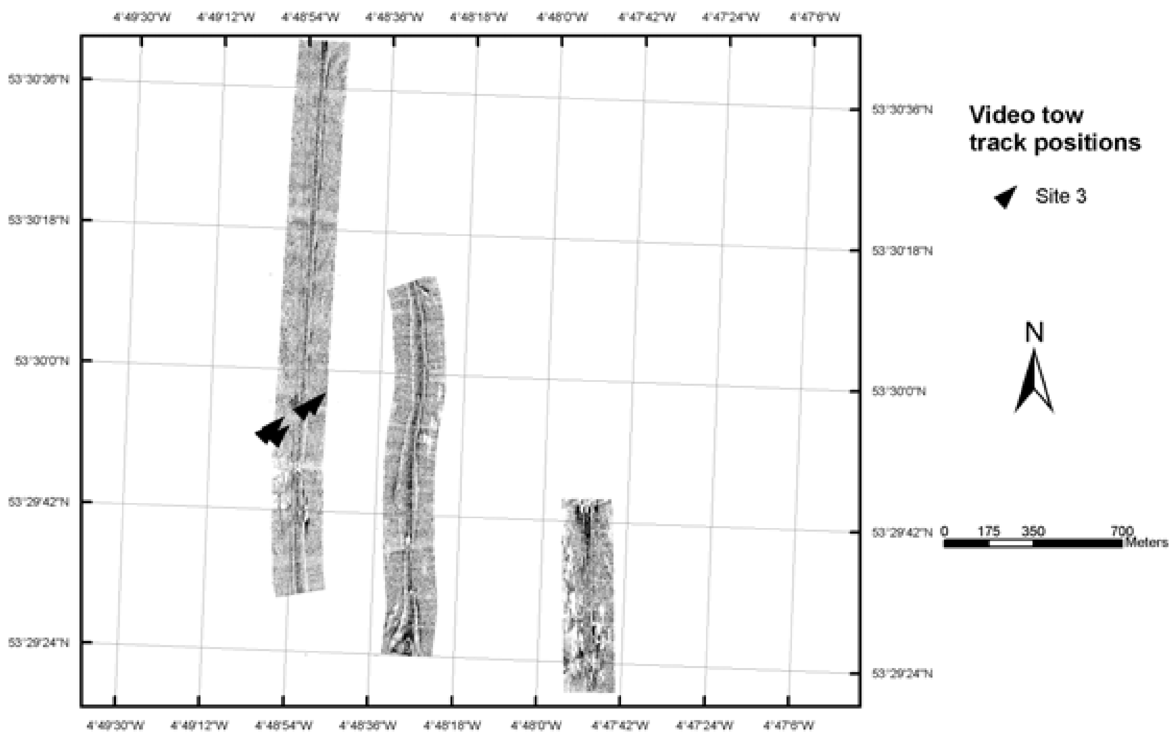

Figure 6.2.5: Side-scan mosaic from Station 3.

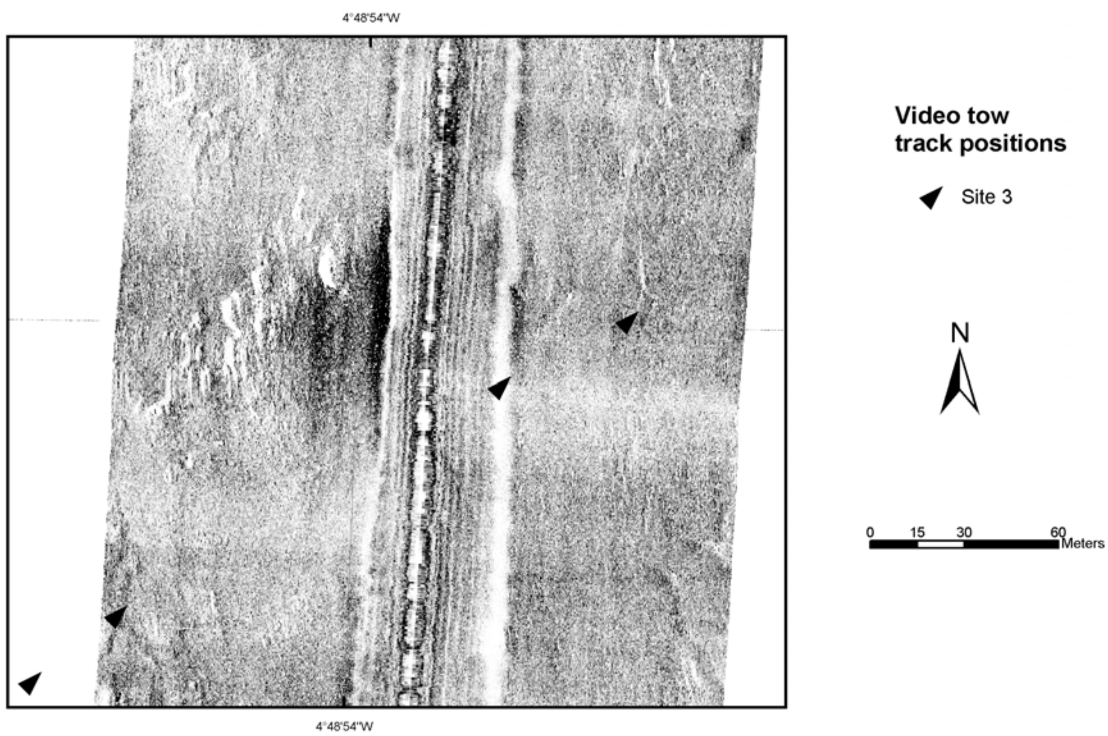

Figure 6.2.6: More detailed side-scan section from Station 3 showing rock/gravel detail

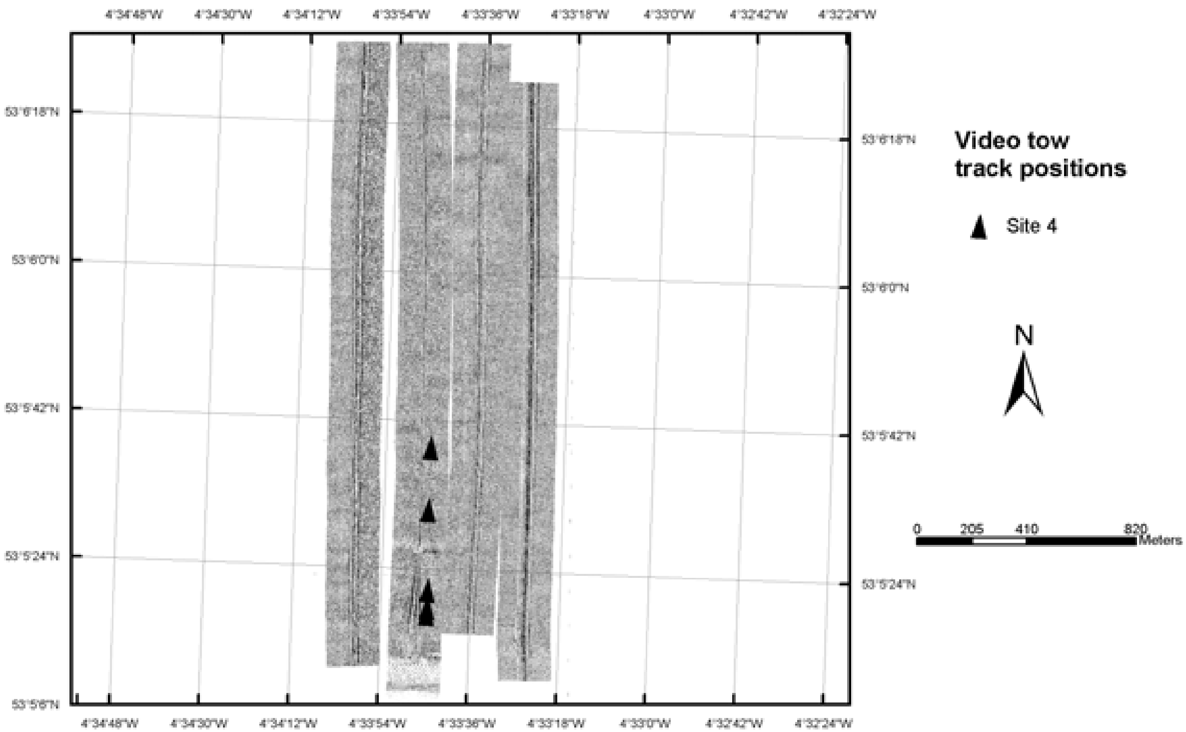

Figure 6.2.7: Side-scan mosaic from Station 4

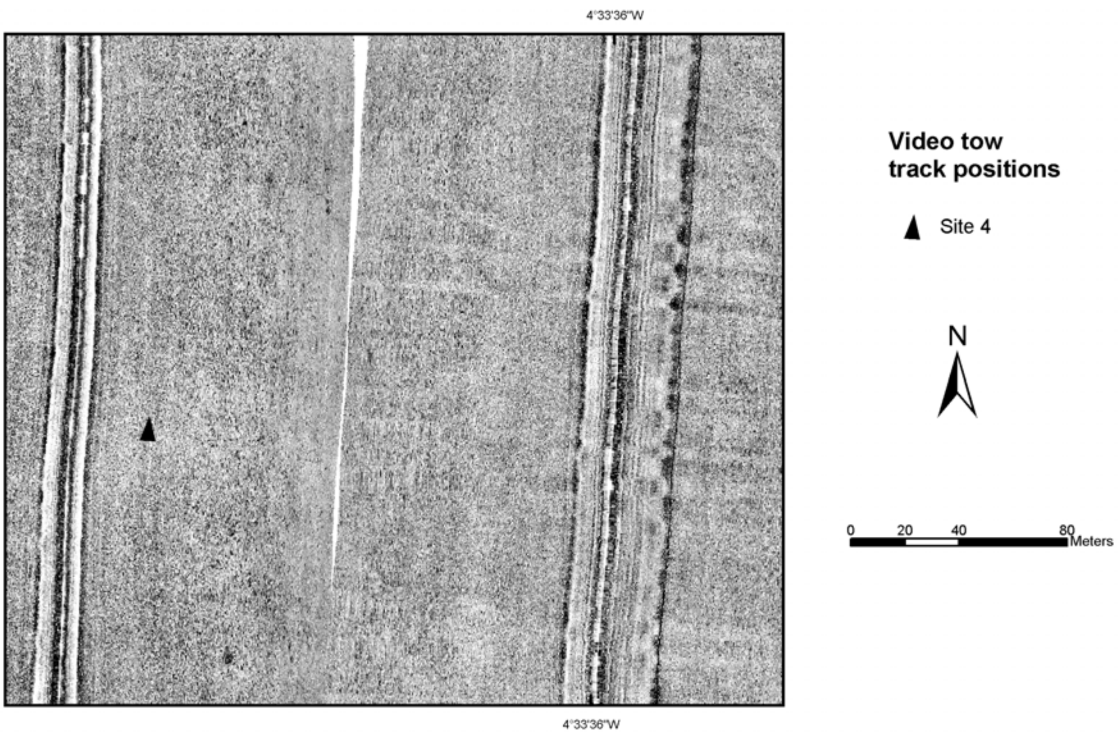

Figure 6.2.8: More detailed side-scan section from Station 4 showing smooth sand.

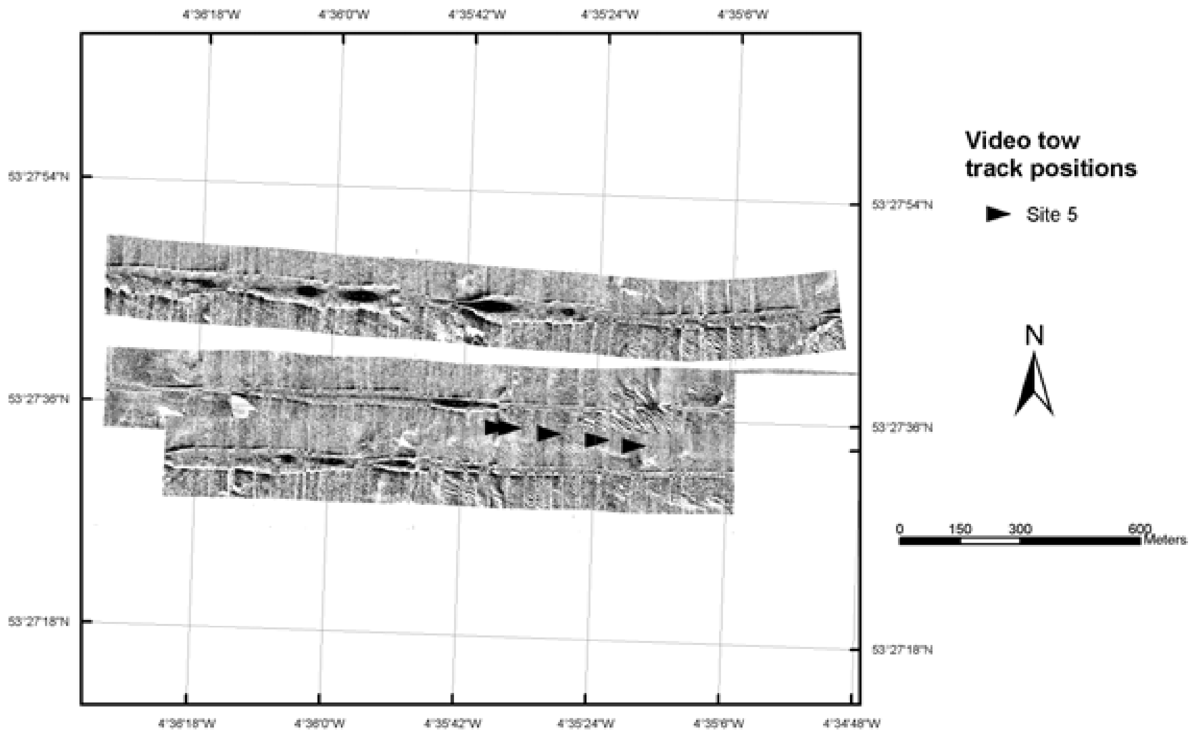

Figure 6.2.9: Side-scan mosaic from Station 5.

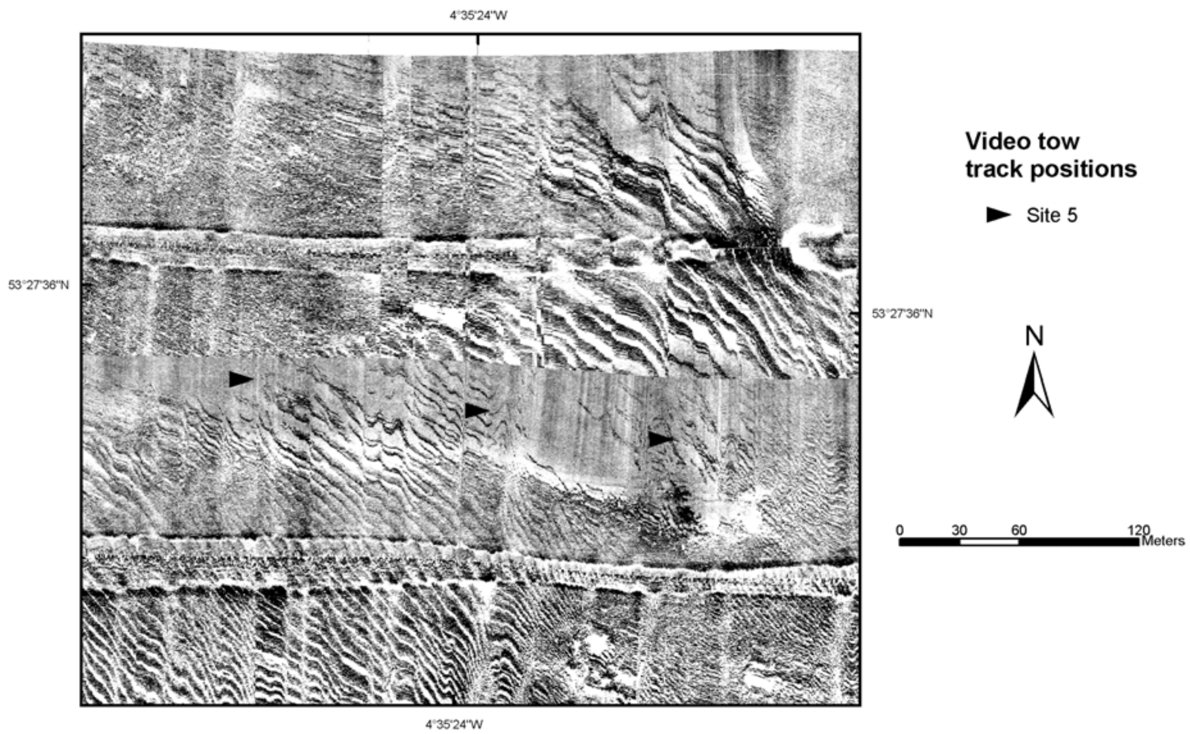

Figure 6.2.10: More detailed side-scan section from Station 5 showing a rough/rocky area

6.3 QTC View (Quester Tangent Corporation) AGDS (Acoustic Ground Discrimination Survey) of seabed marine landscapes in the Irish Sea to the NW & W of Anglesey

Survey summary

At each station, an acoustic survey was carried out by J. Bennell and R. Shucksmith from the School of Ocean Sciences, Bangor, using the Quester Tangent Corporation Acoustic Ground Discrimination Survey equipment installed on the RV Prince Madog. Although preliminary cluster analysis was carried out (an example output can be seen in figure 6.3.1), no further work was carried out, as it was deemed that data from towed video sledge, grab sampling and side-scan survey provided adequate ground truth data for testing the validity of the marine landscape classification.

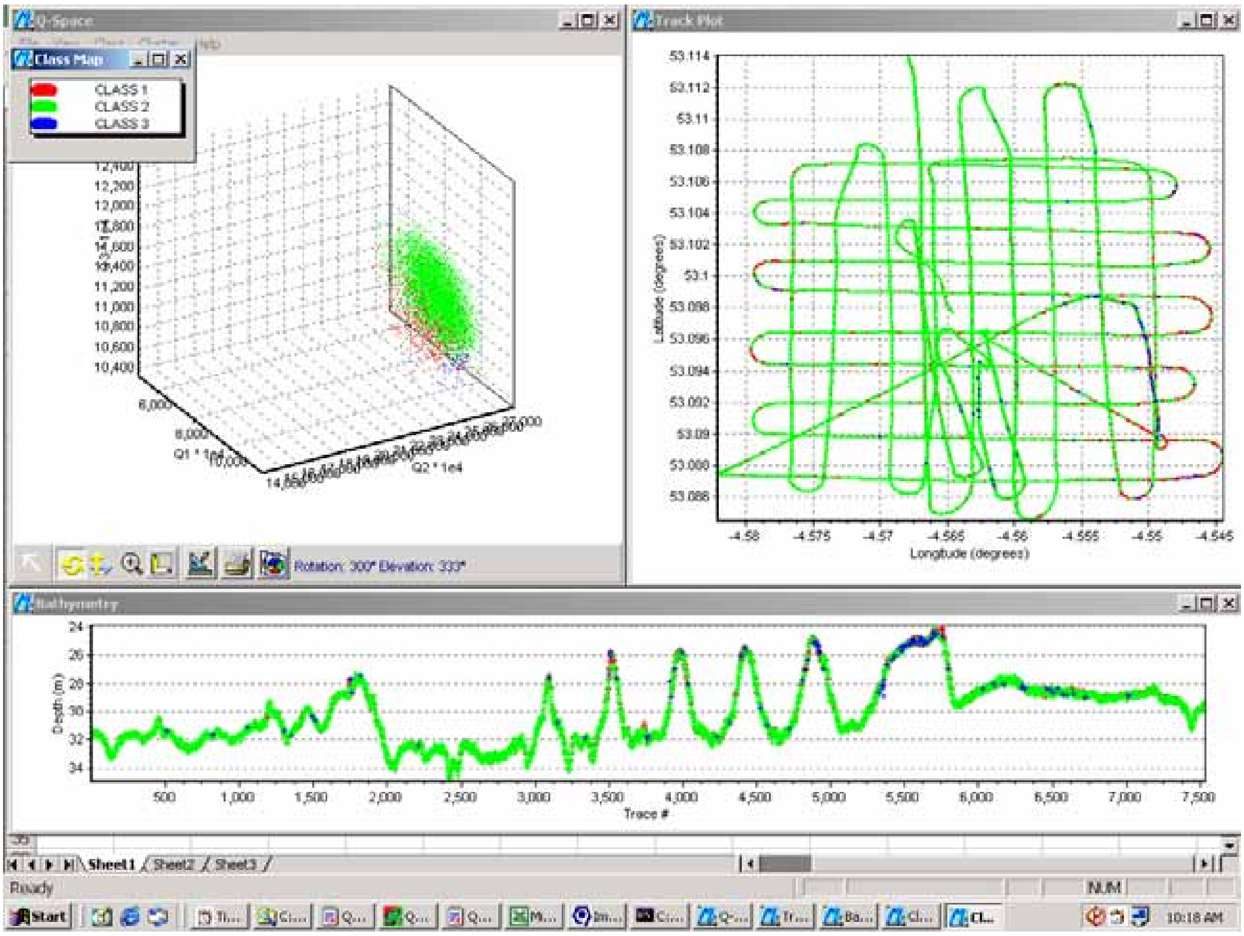

Figure 6.3.1: A screen grab from Quester Tangent Corporation View software showing preliminary clustering of different acoustic ground types.

6.4 Day grab sampling in the Irish Sea to the NW & W of Anglesey

Survey summary

Grab sampling using a 0.1m^2Day grab was carried out at five stations to the NW and W of Anglesey. Four replicate samples were taken at each station. The spatial locations of each sample are listed in table 6.4.1.

Grab samples were checked for adequacy and a photographic record was made of the whole sample for future reference (these have not been included in this report). Samples were sieved using a mesh size of 1mm^2, and then preserved using 40% w/v Formalin solution.

Biological samples were sorted and identified down to species level (or lowest determinable taxanomic level) by R. Shucksmith at the School of Ocean Sciences, Bangor. Colonial animals such as hydroids were identified as present/absent. The results can be seen in table 6.4.1.

Table 6.4.1: Taxanomic list and abundance data for five stations sampled in the Irish Sea to the NW and W of Anglesey.

	Station 1				Station 2				Station 3				Station 4				Station 5			
	Grab 1	Grab 2	Grab 3	Grab 4	Grab 1	Grab 2	Grab 3	Grab 4	Grab 1	Grab 2	Grab 3	Grab 4	Grab 1	Grab 2	Grab 3	Grab 4	Grab 1	Grab 2	Grab 3	Grab 4
Latitude	53° 36.172 N	53° 36.165 N	53° 36.007 N	53° 35.963 N	53° 32.464 N	53°32.423 N	53° 32.381 N	53° 32.325 N	53° 29.726 N	53° 29.876 N	53° 29.804 N	53° 29.908 N	53° 05.852 N	53° 05.830 N	53° 05.815 N	53° 05.792 N	53° 27.529 N	53° 27.534 N	53° 27.560 N	53° 27.584 N
Longitude	5° 15.208 W	5° 15.238 W	5° 15.280 W	5° 15.290 W	5° 00.181 W	5° 00.220 W	5° 00.254 W	5° 00.323 W	4° 48. 442 W	4° 48.743 W	4° 48.672 W	4° 48.641 W	4° 33.845 W	4° 33.760 W	4° 33.729 W	4° 33.698 W	4° 35.362 W	4° 35.436 W	4° 35.420 W	4° 35.473 W
Depth (m)	73.4	75.6	72.0	71.3	53.7	50.9	53.6	50.9	69.8	69.8	61.4	56.9	31.9	31.8	31.7	31.8	41.4	42.5	42.1	39.3
Tubularia sp.																x				
Tubularia indivisa										x										x
Coryne pusilla												x								
Bougainvillia ramosa										x										
Halecium hacinum						x	x			x		x								
Hydrallmania falcata					x	x	x	x	x	x		x								
Abietinaria abietina					x	x	x	x	x	x	x									
Abietinaria filicula																				x
Sertularia cupressina																				x
Obelia dichotoma							x	x				x								
Campanularia hincksii										x										
Urticina felina																	1			
Turbellaria sp.														1		1				
NEMATODA					5				1											
NEMERTEA	1				1		4	1	2	1			1	3	3	1				
Sipuncula sp.									3	6										
Golfingia sp.					1					2		1								

Phascolion strombi									1		4	4								
Harmothoe sp.					3	1	4	2	6	7	7				1					
Sthenelais limicola													4	4	5					
Pholoe inornata								1		1										
Pholoe synophthaemice		1							3		1					1				
Eteone flava				1																
Pseudomystides limbata					3	1			2	1	1									
Phyllodoce rosea													3	4		1				
Eumida sp.						1			5	2	4		1	2	1	2				
Typosyllis armilaris					1															
Typosyllis hyalina							1		2		1	1								
Typosyllis cornuta					6	3		1				1								
Exogone hebes	1																			
Exogone naidina											1			1						
Opisthodonta pterochaeta				1																
Sphaerosyllis sp.					2						4	2			1	1				
Pionosyllis propeweismanni					2				1		3									
Odontosyllis fulgerans								1												
Syllides articulocirrata										1										
Autolytinae					2		1		1	1										
Hesionidae sp.							1												1	
Nereis zonata					1	1				1										1
Nephtys cirrosa	3			4									1	1	4					
Nephtys kersivalensis									1											
Glycera lapidum	1	12		2	6	4	3	1	2	2	3	1								
Glycera alba													1		1					
Glycera tesselata														1						
Glycinde nordmanni				2	1	2														
Nothria conchylega		1																		
Lumbrineris gracilis	1	1			4		6		2	5			22	33	30	26				
Lumbrineris fragilis					1															

Nematonereis unicornis									1	3	1	1								
Protodorvillea kefersteini					2					2				1	1					
Notocirrus scoticus															1	1				
Scolopos armiger				1									1	3	3	5				
Pseudopolydora antennata						1				1										
Pseudopolydora pulchra													2	7	2	4				
Polydora caeca															1					
Spiophanes bombyx	10	11	3	10									20	40	45	38				
Spio filicornis	5	1	18	2	1			1		1										
Spio decorata													7	23	10	11				
Aonides paucibranchiata	3	2			27	9		2			2	1	1							
Prionospio fallax		1												1						
Laonice bahusiensis					8	2	8	1	4	12	7	3								
Scolelepis squamata				1																
Poecilochaetus serpens		1			2								1		3	6				
Pisione remota																			4	
Magelona filiformis															1					
Magelona mirabilis															1					
Cirratulidae sp.		1		1		1	1			2	2		1	1						
Scalibregmatidae																				
Scalibregma inflatum		2		16			1			1			4	5	19	17				
Ophelia limacina	4	4	1			1								1						
Ophelina acuminata				1					1											
Aricidea cerrutti		2																		
Aricidea catharinae													1	5	1	1				
Aricidea minuta																1				
Cirrophorus branchiata										2										
Paradoneis sp.					5				1	2										
Notomastus latericeus					1	1	2	1			1									
Mediomastus fragilis	1	1		2	16	3	1	2	1											
Nicomachinae sp.												1								

Lagis koreni				1										4						
Melinna elisabethae									48	13		1								
Ampharete lindstroemi					1	3	1				1		1	4	2	3				
Eclysippe vanelli							1													
Thelepus cincinnatus	1	7		2					1											
Polycirrus medusa	1				3	2	1		1	1	3			1						
Nicolea venustula									1											1
Lanice conchylega													6	6	19	9				
Terebellidae sp.							1													
Sabellaria spinulosa									4	2										
Euchone analis					9	1									1					
Jasmineira elegans		1							5			1								
Pomatoceros triqueter						1	5	1				1			3					
Pomatoceros lamarcki							5		1		4									
Balanus sp.									6											
Balanus balanus												41								
Balanus hameri										14										
Mysida spp.		1			1		1		3	4										1
Ampelisca spinipes					20	10		1			2		1	1		1				
Ampelisca brevicornis																1				
Argissa hamatipes													1		1	1				
Bathyporeia tenuipes													4	4	8	1				
Bathyporeia elegans	1	4	7	4																
Urothoe marina					1															
Harpinia antennaria														3		2				
Synchelidium maculatum	3	4	1	8																
Leucothoe incissa															1	1				
Hippomedon denticulatus			1	1																
Lembos longipes													2							
Gammaropsis palmata							1					1								
Gammaropsis maculata					2		6													

Photis longicaudata																1				
Melitidae					5	2		1												
Maera othonis							2		1	1	1									
Cheirocratus sundevalli												1								
Melita obtusata															2					
Atylus vedlomensis					1				2											
Atylus falcatus			1	1										2						
Atylus swammerdami															1					
Eysirus longipes										1										
Stenothoe marina							1	1												
Metopa alderi								1												
Metopa pusilla																				2
Unicola planipes	2	2		2																
Apherusa bispinosa					1															
Siphonoecetes kroyeranus															1					
Parapleustes bicuspis																				2
Dyopedos sp.								1												
Arcturidae																				
Astacilla longicornis								1												
Janira maculosa							3													
Sphaeromatidae sp.					1															
Eurydice pulchra					1															
Eurydice spinigera			1																	
Gnathiidae praniza																2				
Jaeropis brevicornis										2										
Aeginia longicornis						1														
Diastylis laevis													1			3				
Diastylis bradyi	2	6	3	1																
Nymphon brevirostre	1						2			1										2
Achelia echinata											1									
Crab zoea														1		1				

Pagurus bernhardus							1													
Galatheidae														1						
Galathea intermedia							3	3												
Pisidea longicornis									2											
Ebalia tuberosa						1														
Corystes cassivelaunus														1						
Liocarcinus holsatus					3	1														
Liocarcinus pusillus		1							2				1	1	1					
Monodaeus couchi									4	3										
Leptochiton asellus					7	3	18	8	4	15	2	5								
Emarginula fissura									1											
Puncturella noachina									1											
Trivia arctica							1	1												
Polinices polianus													1		1					
Nucula nitidosa						1									2					
Modiolus modiolus									1											
Nuculana minuta										1		3								
Glycimeris glycimeris					4	1														
Astarte sulcata									2		1									
Spisula elliptica	6		7	1		2									2					
Circomphalus casina					2															
Clausinella fasciata													1							
Timoclea ovata					8	2		1		3		1		2		2				
Dosinia exoleta													1	3	6	1				
Pectinidae							1													
Aequipecten opercularis										2										
Ensis arquatus														2						
Phaxas pellucidus				1									1	1	1	2				
Abra alba				1	3		2					1		6	4	4				
Abra nitida	12	11	7	29									1	2	2					
Gari fervensis													2		1					

Gari depressa				1																
Gari sp.					1															
Moerella donacina														1		2				
Thraciidae																				
Thracia phaseolina													3	8	5	3				
Crisiidae spp.											x									
Tubuliporidae spp.										x										
Alcyonidium diaphanum										x	x									
Flustra foliacea		x																		x
Ophiothrix fragilis									3	1										
Ophiura ophiura		1											2			1				
Ophiura albida																			1	
Ophiura spp.	1			1																
Amphipholis squamata							2		5	5	1									
Amphiura juvenille													1							
Echinocardium cordatum	3	7		7																
Psammechinus miliaris						1	1													
Polyclinidae spp.									x	x										
Molgulidae spp.									1											
Eurgyra arenosa																				2

8. Appendix III: SAHFOS/Irish Sea Pilot – Plankton Communities initial report.

M. Edwards and D. G. Johns, Sir Alister Hardy Foundation for Ocean Science (SAHFOS), Plymouth, UK.

Introduction and methods

Background

Modelled data from POL (stratified days and salinity), has been used to define four draft broad scale water column units for JNCC. In this preliminary report, data from the Continuous Plankton Recorder (CPR) survey has been used to further characterise these broad scale water column units in terms of their plankton/nekton communities.

SAHFOS have conducted a short preliminary report specifically examining the following areas requested by JNCC:

- examine the key species for the four broadscale water column units and characterise these areas by their species assemblages.

- Produce gridded maps for the Irish Sea to ascertain areas of high productivity/diversity.

- Identify key features of the plankton communities important for management e.g productive areas, potential harmful algal bloom areas, non-indigenous species.

Sampling by the Continuous Plankton Recorder

The Continuous Plankton Recorder (CPR) survey provides a unique long-term dataset of plankton abundance in the North Atlantic and North Sea. The survey has been running for almost 70 years, using 'ships of opportunity' to tow CPRs on regular, and incidental routes, sampling at a depth of 10 m. Each sample represents 18 km of tow and approximately 3 m3 of filtered seawater. Over 450 taxa of plankton are routinely identified by a team of taxonomists. CPRs have been towed for over 4 million nautical miles, accumulating almost 200,000 samples. The design of the CPR has remained virtually unchanged since sampling started, thus providing a consistency of sampling that provides good historical comparisons. By systematically monitoring the plankton over a period, changes in abundance and long term trends can be distinguished. From this baseline data, inferences can be made, particularly concerning climate change and potential anthropogenic impacts.

Definition of areas examined

Both draft water column units and CPR sampling coverage determined the four areas for this initial study. Area 1 encompasses a frontal boundary zone in Liverpool Bay, between stratified and low salinity and stratified and high salinity waters. Area 2 is centred in an area of stratified and high salinity waters. Area 3 is in the central Irish Sea, and is characterised by mixed and high salinity water. To facilitate the examination of oceanic influences another southern area has been further defined, area 4 is at the southern entrance to the Irish Sea, an area of stratified and high salinity (figure 8.1).

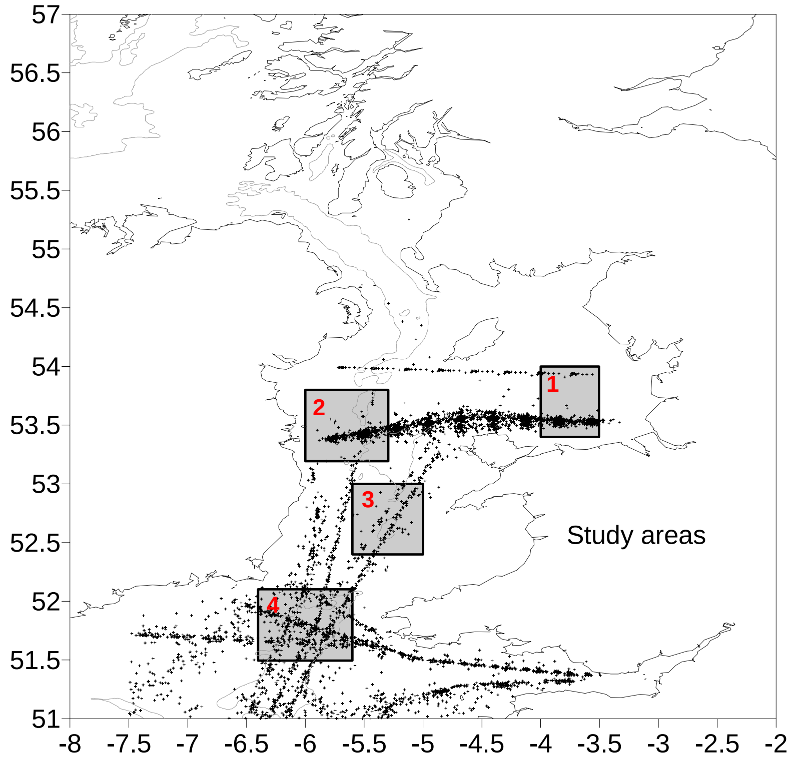

Figure 8.1: Map of the Irish Sea showing Continuous Plankton Recorder (CPR) samples and areas designated for the examination of plankton communities.

8.1. Results and discussion

Key species and diversity

To address the question of what plankton species characterise the original areas chosen by Proudman Oceanographic Laboratory, community data from the CPR survey were analysed. Both the phytoplankton and zooplankton assemblage was analysed. For all four areas species/taxa were extracted based on their relative frequency of sampling, all species/taxa that have occurred over a frequency of 1% on CPR samples have been listed in tables 8.1 to 8.4.

AREA 1

Dinoflagellates of the genus Ceratium are two of the most frequently sampled phytoplankters in area 1, with C. fusus (32.37%) being the most frequent, and C. furca (15.33%) the third most frequently recorded. The other three taxa in the top 5 most frequently recorded are all diatoms: Thalassiosira spp. (centric diatom, 15.67%), Rhizosolenia imbrica shrubsolei (pennate diatom, 12.95%) and Chaetoceros (Phaeoceros) (centric diatom, 12.78%). These are all ubiquitous phytoplankton taxa.

The phytoplankton community of area 1 has a number of taxa specific to it, that is they do not occur on over 1% of samples in the other 3 areas. These are all centric diatoms, Eucampia zodiacus (6.81%), Skeletonema costatum (3.07%), Coscinodiscus wailesii (2.73%), Fragillaria spp. (1.53%), Bacteriastrum spp. (1.19%), Navicula spp. (1.19%) and Rhizosolenia fragilissima (1.19%). This area also has the highest number of phytoplankton taxa occurring on >1% of samples.

In area 1, the most frequently recorded zooplankters are large (eyecount, greater than 6mm) chaetognaths (not speciated within the CPR survey), occurring on almost 50% of all samples. Three Calanoid copepods are in the top 5 most frequently sampled taxa, Para – pseudocalanus spp. (47.7%), Temora longicornis (32.88%) and Acartia spp. (32.71%). The last taxa to complete the top 5 are decapoda larvae (47.02%).

As with the phytoplankton community, the zooplankton community of area 1 has a number of area – specific taxa. These are Mysidacea (3.75%), Caprellidea (1.87%), Cumacea (1.02%) and Harpacticoida (1.02%), taxa that are associated with neritic waters and are mainly benthic in ecology.

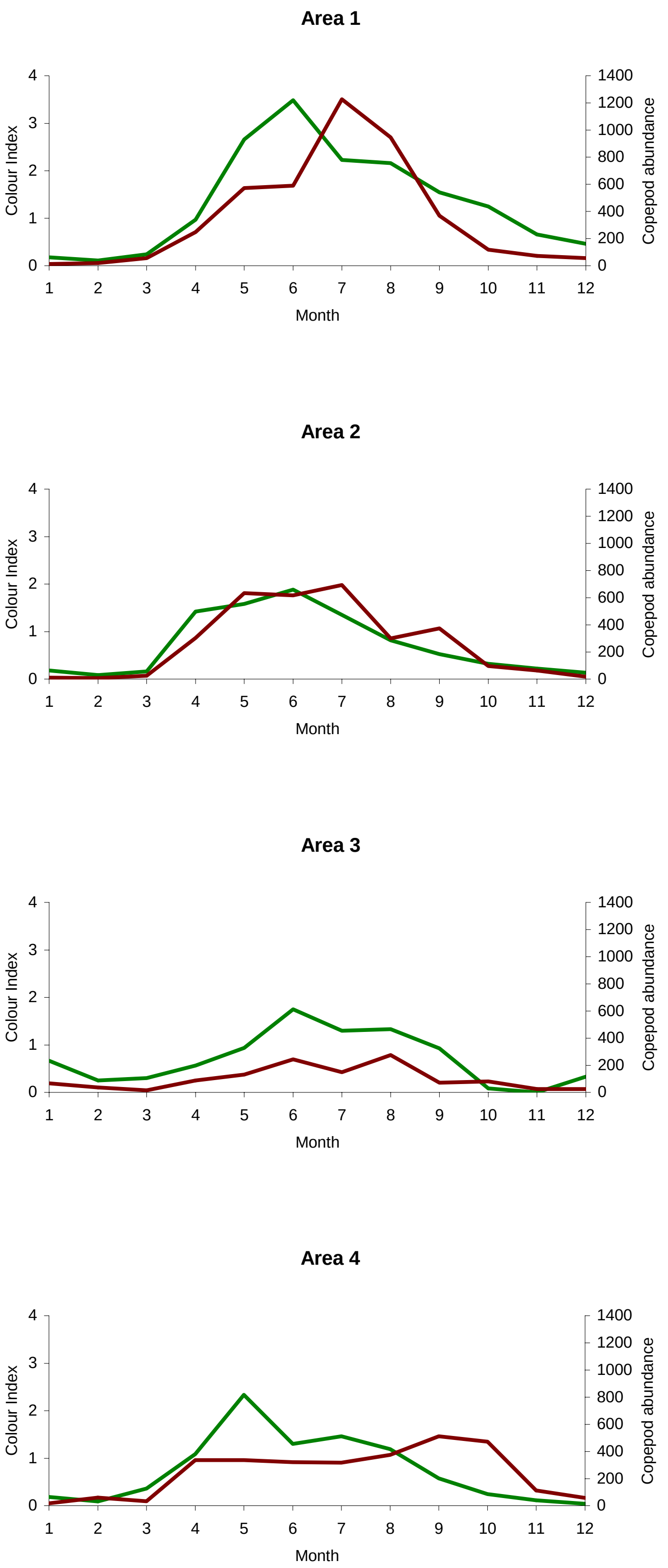

Figure 8.2: The seasonal cycles of phytoplankton colour (an assessment of phytoplankton biomass) (green) and total copepod abundance (brown) for all four areas.

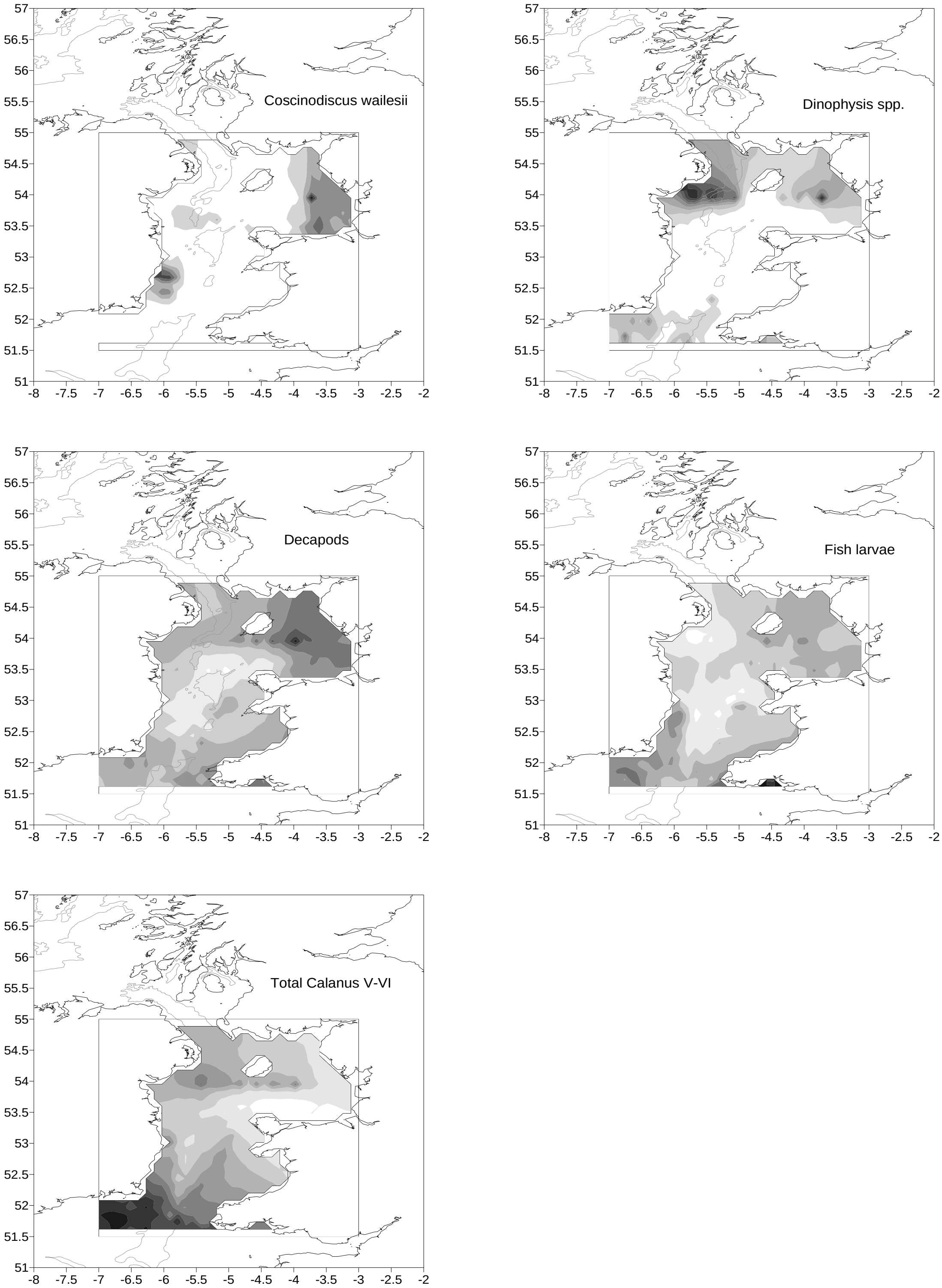

Figure 8.3: The spatial distribution and abundance of key ecological groups within the plankton in the Irish Sea: *Dinophysis* spp, *Coscinodiscus wailesii*, decapod larvae, fish larvae and Total *Calanus* spp.

AREA 2

This area has fewer taxa recorded on >1% of samples, and in fact has the same 5 most frequently recorded phytoplankters as area 1: Ceratium fusus (19.08%), Thalassiosira spp. (17.98%), Ceratium furca (15.79%), Chaetoceros (Hyalochaete) spp. (11.4%) and Rhizosolenia imbrica shrubsolei (8.77%). The area contains no taxa that are area – specific on >1% of samples.

As in area 1, the top 5 most frequently recorded zooplankton taxa includes the Calanoid copepods Para – pseudocalanus spp (35.75%) and Acartia spp. (32.02%), as well as Calanus V-VI Total (32.89%). Decapoda larvae (32.89%) and Chaetognatha (eyecount, 30.26%). There are no area – specific taxa.

AREA 3

This area has the fewest number of taxa recorded on >1% of samples. The 5 most frequently recorded phytoplankters are the diatoms Rhizosolenia hebetata semispina (pennate, 8.04%), Thalassiosira spp. (centric, 8.04%), Bacillaria paxillifer (centric, 6.25%) and Chaetoceros (Phaeoceros) (centric, 5.36%), and the dinoflagellate Ceratium fusus (7.14%). There are no area – specific taxa.

Area 3 has the Calanoid copepod groups Calanus V-VI Total (51.79%), Calanus helgolandicus (48.21%) and Para – pseudocalanus spp. (31.25%) as three of the most abundant taxa sampled. Decapoda larvae (44.64%) and Chaetognatha (eyecount, 28.57%) complete the top 5. Again, there are no area – specific taxa.

AREA 4

This area has 4 diatoms in the top 5 most sampled, Thalassiosira spp. (20.59%), Chaetoceros (Hyalochaete) spp. (11.76%), Rhizosolenia alata alata (10.68%), Rhizosolenia hebetata semispina (10.68%) and 1 dinoflagellate, Ceratium fusus (15.02%). There are two area – specific taxa, Coccolithaceae (1.7%) and Ceratium macroceros (1.08%), the former being indicative of oceanic inflow.

The top 5 zooplankton taxa are as follows: Calanus V-VI Total (74.15%), Calanus helgolandicus (72.29%), Para – pseudocalanus spp. (43.65%), Euphausiacea (43.5%) and Decapoda larvae (42.57%). The large number of Calanus are indicative of oceanic influences, as is also the presence of the area – specific presence of Radiolaria (1.08%). Also area – specific area Metridia (traverse, 3.25%) and Echinoderm post – larvae (3.1%).

Community summary

On examination of the 4 areas, it can be seen that diversity of the plankton community varies from area to area. Area 1 has the most diverse phytoplankton community, whereas area 4 has the most diverse zooplankton community, and both of these areas have considerably greater numbers of plankton taxa recorded on >1% of samples. It is apparent that a large number of planktonic organisms are endemic to more than one area. There are a number of area-specific organisms, both phytoplankton and zooplankton, found in the areas. Area 1 is highly indicative of neritic species with many area-specific diatom species and also the area has a high benthic component to the zooplankton assemblage (including such Crustacea as Mysidacea, Caprellidea and Cumacea). Areas 2 and 4 are indicative of higher salinity waters and have a numerous oceanic species within the plankton assemblage, Area 4 is particularly indicative of a more warmer and southerly assemblage.

Key features in terms of management

Using the figures 2 and 3, areas have been defined in terms of their productivity and other ecological aspects. Figure 2 shows the annual cycle of phytoplankton colour (an assessment of total phytoplankton biomass) and the abundance of total number of copepods (an assessment of secondary biomass) for all the areas examined. Figure 3 shows the spatial distribution of key ecological groups within the plankton: Dinophysis spp is a representative of a Harmful Algal Bloom; Coscinodiscus wailesii is a representative of a non-indigenous species; decapod larvae is representative of the benthic component of the plankton assemblage (meroplankton); fish larvae are representatives of a higher trophic component in the plankton and Total Calanus spp. are one of the most important components of the zooplankton community (a principle food-source for higher trophic levels).

The area of highest phytoplankton biomass and zooplankton abundance is Area 1. Area 1 has a distinct maximum in copepod abundance along the Liverpool Bay front and nearly twice as much phytoplankton biomass as any other region in the Irish Sea. No distinct maximum in copepod abundance is evident along the western Irish Sea front, although it appears to be an important area for larger copepods such as Calanus spp. Throughout the Irish Sea, the peak in phytoplankton biomass occurs in June with the exception of Area 4 which occurs one month earlier. Area 4 is the most important area for Calanus populations and it is thought that most individuals of Calanus are advected into the Irish Sea from a reservoir stock in the Celtic Sea. An important aspect of the zooplankton of Areas 1 and 4 is that they contain the eggs and larvae of many commercially exploited fish species, predominately whiting and dab. It is also the area with the highest abundance of decapod larvae some of which are commercially exploited.

Area 1 seems to be an important area in the formation of Harmful Algal Blooms, the Liverpool Bay area 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 produces ‘red tides’ and occurs in the inshore waters of south-east Liverpool Bay and the Solway Firth and the luminescent Noctiluca scintillans may also occasionally form blooms in this area. The red tides caused by Gyrodinium aureolum are of particular importance to the coastal manager because they have been associated with invertebrate mortalities. As well as these aforementioned species Dinophysis spp. is also common in both Areas 1 and 2. Dinophysis spp. are associated with Diarrhetic Shellfish Poisoning. Of other note was the occurrence of Cylindrotheca closterium recorded in bloom proportions in Area 4 in 2001. Area 3 and other mixed central waters in the Irish Sea do not have any problems associated with Harmful Algal Blooms. In Area 1 and the east coast of Ireland, the non-indigenous diatom Coscinodiscus wailesii is an important member of the phytoplankton assemblage. This species was first recorded in UK coastal waters in the English Channel in 1977 (originating from the Pacific) and has subsequently spread into the Irish Sea.

This study forms the basis of a preliminary study of plankton communities in the Irish Sea. A more comprehensive study with detailed interpretation is needed to designate marine areas in a manner of those proposed by JNCC.

Table 8.2: All species/taxa that have occurred over a frequency of 1% on CPR samples I Area 1.

Area 1			
Zooplankton	**%**	**Phytoplankton**	**%**
Chaetognatha Eyecount	49.23	Ceratium fusus	32.37
Para-pseudocalanus spp	47.70	Thalassiosira spp	15.67
Decapoda larvae	47.02	Ceratium furca	15.33
Temora longicornis	32.88	Rhizosolenia imbrica shrubsolei	12.95
Acartia spp	32.71	Chaetoceros(Phaeoceros) spp	12.78
Fish larvae	20.44	Odontella sinensis	12.78
Chaetognatha Traverse	20.27	Chaetoceros(Hyalochaete) spp	10.05
Calanus V-VI Total	19.59	Rhizosolenia hebetata semispina	8.52
Calanus helgolandicus	15.50	Paralia sulcata	7.16
Euphausiacea Total	14.99	Thalassionema nitzschioides	6.98
Centropages hamatus	14.65	Ceratium horridum	6.81
Echinoderm larvae	12.95	Eucampia zodiacus	6.81
Pseudocalanus elongatus Adult	12.78	Noctiluca scintillans	6.47
Larvacea	12.61	Protoperidinium spp	5.11
Copepod nauplii	9.03	Nitzschia seriata	4.94
Euphausiacea Adult	8.18	Rhizosolenia delicatula	4.43
Calanus Total Traverse	7.67	Rhizosolenia styliformis	4.43
Cirripede larvae	6.64	Ceratium lineatum	4.09
Oithona spp	6.47	Nitzschia delicatissima	3.41
Calanus I-IV	6.13	Asterionella glacialis	3.24
Evadne spp	5.79	Rhizosolenia stolterfothii	3.07
Fish eggs	5.79	Skeletonema costatum	3.07
Calanus fin finmarchicus	4.94	Bacillaria paxillifer	2.90
Copepod eggs	4.94	Coscinodiscus wailesii	2.73
Polychaeta larvae	4.43	Ditylum brightwellii	2.39
Centropages typicus	3.75	Silicoflagellatae	2.21
Mysidacea	3.75	Ceratium longipes	2.04
Lamellibranchia larvae	3.58	Ceratium tripos	2.04
Podon spp	3.24	Cylindrotheca closterium	2.04
Euphausiacea Juvenile	3.07	Unidentified Coscinodiscus spp	1.87
Limacina retroversa	2.73	Fragilaria spp	1.53
Gammaridea	2.56	Dinoflagellate cysts	1.36
Tomopteris spp	2.21	Dinophysis spp	1.36
Caprellidea	1.87	Prorocentrum spp	1.36
Cyphonautes larvae	1.19	Bacteriastrum spp	1.19
Tintinnidae	1.19	Navicula spp	1.19
Cumacea	1.02	Rhizosolenia alata alata	1.19
Harpacticoida Total	1.02	Rhizosolenia fragilissima	1.19
Hyperiidea	1.02	Rhizosolenia setigera	1.19
		Gonyaulax spp	1.02
		Odontella aurita	1.02

Table 8.3: All species/taxa that have occurred over a frequency of 1% on CPR samples in Area 2.

Area 2			
Zooplankton	**%**	**Phytoplankton**	**%**
Para-pseudocalanus spp	35.75	Ceratium fusus	19.08
Calanus V-VI Total	32.89	Thalassiosira spp	17.98
Decapoda larvae	32.89	Ceratium furca	15.79
Acartia spp	32.02	Chaetoceros(Hyalochaete) spp	11.40
Chaetognatha Eyecount	30.26	Rhizosolenia imbrica shrubsolei	8.77
Calanus helgolandicus	28.29	Thalassionema nitzschioides	7.46
Euphausiacea Total	24.34	Chaetoceros(Phaeoceros) spp	5.92
Euphausiacea Adult	19.74	Ceratium horridum	5.70
Temora longicornis	17.76	Odontella sinensis	5.26
Fish larvae	15.35	Nitzschia seriata	4.82
Calanus Total Traverse	13.16	Rhizosolenia hebetata semispina	4.61
Echinoderm larvae	12.28	Ceratium lineatum	4.39
Pseudocalanus elongatus Adult	12.06	Protoperidinium spp	4.39
Oithona spp	11.40	Ceratium tripos	3.95
Calanus I-IV	10.75	Ceratium longipes	3.07
Calanus fin finmarchicus	10.31	Ditylum brightwellii	2.85
Larvacea	9.65	Paralia sulcata	2.85
Tomopteris spp	8.55	Rhizosolenia styliformis	2.63
Copepod nauplii	7.68	Asterionella glacialis	2.41
Chaetognatha Traverse	7.24	Silicoflagellatae	2.41
Evadne spp	5.92	Bacillaria paxillifer	1.97
Centropages hamatus	5.48	Rhizosolenia alata alata	1.97
Euphausiacea Juvenile	5.04	Lauderia borealis	1.75
Metridia lucens	4.17	Prorocentrum spp	1.54
Podon spp	4.17	Scrippsiella spp	1.32
Copepod eggs	3.73	Unidentified Coscinodiscus spp	1.32
Cirripede larvae	3.29	Noctiluca scintillans	1.10
Fish eggs	3.07	Rhizosolenia setigera	1.10
Cyphonautes larvae	2.63		
Tintinnidae	1.97		
Centropages typicus	1.75		
Lamellibranchia larvae	1.75		
Limacina retroversa	1.75		
Foraminifera	1.10		
Polychaeta larvae	1.10		

Table 8.4: All species/taxa that have occurred over a frequency of 1% on CPR samples in Area 3.

Area 3			
Zooplankton	**%**	**Phytoplankton**	**%**
Calanus V-VI Total	51.79	Rhizosolenia hebetata semispina	8.04
Calanus helgolandicus	48.21	Thalassiosira spp	8.04
Decapoda larvae	44.64	Ceratium fusus	7.14
Para-pseudocalanus spp	31.25	Bacillaria paxillifer	6.25
Chaetognatha Eyecount	28.57	Chaetoceros(Phaeoceros) spp	5.36
Euphausiacea Total	27.68	Ceratium furca	4.46
Acartia spp	20.54	Ditylum brightwellii	4.46
Metridia lucens	18.75	Rhizosolenia alata alata	4.46
Calanus Total Traverse	11.61	Nitzschia delicatissima	3.57
Temora longicornis	11.61	Odontella sinensis	2.68
Fish larvae	10.71	Paralia sulcata	2.68
Calanus fin finmarchicus	9.82	Rhizosolenia imbrica shrubsolei	2.68
Pseudocalanus elongatus Adult	9.82	Thalassionema nitzschioides	2.68
Chaetognatha Traverse	8.04	Ceratium lineatum	1.79
Euphausiacea Adult	8.04	Protoperidinium spp	1.79
Larvacea	8.04	Rhizosolenia delicatula	1.79
Cirripede larvae	7.14	Rhizosolenia styliformis	1.79
Copepod nauplii	7.14		
Tomopteris spp	5.36		
Calanus I-IV	4.46		
Echinoderm larvae	4.46		
Euphausiacea Juvenile	4.46		
Limacina retroversa	4.46		
Centropages hamatus	3.57		
Centropages typicus	3.57		
Hyperiidea	3.57		
Oithona spp	3.57		
Candacia armata	2.68		
Copepod eggs	2.68		
Foraminifera	2.68		
Tintinnidae	2.68		
Evadne spp	1.79		

Table 8.5: All species/taxa that have occurred over a frequency of 1% on CPR samples in Area 4.

Area 4			
Zooplankton	**%**	**Phytoplankton**	**%**
Calanus V-VI Total	74.15	Thalassiosira spp	20.59
Calanus helgolandicus	72.29	Ceratium fusus	15.02
Para-pseudocalanus spp	43.65	Chaetoceros(Hyalochaete) spp	11.76
Euphausiacea Total	43.50	Rhizosolenia alata alata	10.68
Decapoda larvae	42.57	Rhizosolenia hebetata semispina	10.68
Calanus Total Traverse	37.77	Thalassionema nitzschioides	10.06
Acartia spp	34.52	Protoperidinium spp	7.28
Chaetognatha Eyecount	34.37	Chaetoceros(Phaeoceros) spp	6.97
Euphausiacea Adult	24.46	Ceratium lineatum	6.81
Metridia lucens	24.46	Ceratium tripos	6.50
Calanus I-IV	23.99	Nitzschia seriata	6.04
Fish larvae	18.73	Rhizosolenia imbrica shrubsolei	5.88
Echinoderm larvae	18.27	Nitzschia delicatissima	5.42
Euphausiacea Juvenile	17.80	Ceratium furca	5.26
Pseudocalanus elongatus Adult	14.24	Prorocentrum spp	4.64
Oithona spp	13.31	Asterionella glacialis	4.33
Centropages typicus	12.69	Ditylum brightwellii	3.87
Calanus fin finmarchicus	11.92	Rhizosolenia styliformis	3.72
Copepod nauplii	11.61	Dinophysis spp	2.79
Limacina retroversa	10.06	Odontella sinensis	2.79
Chaetognatha Traverse	9.29	Paralia sulcata	2.32
Temora longicornis	9.29	Ceratium horridum	2.17
Larvacea	8.67	Scrippsiella spp	2.17
Tomopteris spp	5.57	Dinoflagellate cysts	2.01
Evadne spp	4.64	Rhizosolenia stolterfothii	2.01
Candacia armata	4.49	Coccolithaceae	1.70
Cirripede larvae	3.72	Lauderia borealis	1.70
Fish eggs	3.41	Bacillaria paxillifer	1.55
Hyperiidea	3.41	Gonyaulax spp	1.55
Podon spp	3.41	Cylindrotheca closterium	1.39
Lamellibranchia larvae	3.25	Silicoflagellatae	1.39
Metridia Total Traverse	3.25	Ceratium macroceros	1.08
Echinoderm post-larvae	3.10		
Copepod eggs	2.94		
Tintinnidae	2.79		
Corycaeus spp	2.63		
Euphausiacea calyptopis	2.48		
Centropages hamatus	2.01		
Cyphonautes larvae	1.08		
Foraminifera	1.08		
Gammaridea	1.08		
Radiolaria	1.08		

7. Appendix II: *RV* Lough Foyle cruise *(Irish) Sea Mounds* (NW Irish Sea) Habitat Mapping

Introduction and methods

All surveys were undertaken aboard the RV Lough Foyle (DARD) during June 2003.

Acoustic surveys

A RoxAnn™ acoustic ground discrimination survey (AGDS) was undertaken of the main survey area between 1st and 3rd June 2003, by A. Mitchell. Two additional RoxAnn™ datasets were collected by M. Service on 23rd June 2003 during the multibeam sonar survey. All RoxAnn™ datasets were obtained using a hull-mounted 38kHz transducer, a GroundMaster RoxAnn™ signal processor combined with RoxMap software, saving at a rate of between 1 and 5s intervals. An Atlas differential Geographical Positioning Systems (dGPS), providing positional information, was integrated via the RoxMap laptop. Track spacing varied between 500m for the large area and 100m for the multibeam survey areas.

Multibeam sonar datasets were collected for two of the *(Irish) Sea Mounds* on 23rd June 2003, using an EM2000 Multibeam Echosounder (MBES, Kongsberg Simrad Ltd; operators: J. Hancock and C. Harper.). The sonar has a frequency of 200kHz and a ping rate of 10Hz. It operates with 111 roll-stabilised beams per ping with a 1.5 degree beam width along-track and 2.5 degree beam width across-track. The system has an angular coverage of 120 degrees. In addition to bathymetric coverage, the system has an integrated seabed imaging capability through a combination of phase and amplitude detection (referred to here as 'backscatter').

The EM2000 was deployed with the following ancillary parts:

- Seapath 200 – this provides real-time heading, attitude, position and velocity solutions with a 1pps timing clock for update of the sonar together with full differential corrections supplied by the IALA GPS network. The GPS derived heading is measured with a 2.5m beam, 0.075 degree RMS (root mean square).
- Motion Reference Unit - MRU5 - Roll and pitch accuracies of 0.03 degree RMS.
- Sound velocity meter - Applied Microsystems singaround velocimeter to measure sound velocity at the sonar head.

The data derived from the Seapath 200 and MRU5 were integrated within the Merlin acquisition software suit for full geo-reference solutions at each sounding (depth) location.

A number of software suites were used during the acquisition and subsequent data reduction. During the survey Merlin acquisition software was used on a Solaris UNIX workstation (Simrad Survey Systems) for acquisition and quality assurance/quality control. This recorded all the acquisition data and also applied sound velocity at the sonar head and through the water column. Roll, pitch, timing, and heading calibrations were undertaken with this software.

Tidal corrections were applied to the multibeam data from 10 minute tidal curves modelled using information from the Admiralty Tide Tables and the UK Hydrographic Office. The tidal models were entered directly into the navigation computer and to the multibeam acquisition software during acquisition so that real-time corrections could be made.

Post-processing of bathymetric data was carried by J. Hancock of Kongsberg Simrad. This involved using the software Neptune (Simrad Survey Systems) Version 4.11 for Windows to produce cleaned XYZ data (eastings, northings, depth). Subsequent to removing poor data points the bathymetric and amplitude (backscatter) data were processed using the Poseidon suite of programmes for production of the sonar mosaics. Further quality assurance/quality control was performed on the data using the software packages Cfloor (Roxar) and Fledermaus (IVS).

Ground-truthing surveys

Ground-truthing information was gathered on 4th June 2003 by M. Service and A. Mellor (QUB). 11 quantitative samples, over five locations were collected, using a ??? Day grab., with 11 Day grab samples completed over five locations, and four video tows were undertaken over four locations. Ground-truthing was limited by poor weather conditions and therefore the ground-truthing was restricted in its spatial coverage. The video tows were undertaken from a drop-frame that was deployed from the side of the ship such that layback was minimised. The video system comprised of a Kongsberg Simrad Osprey underwater video camera operated using a Simrad video control deck unit and recorded on VHS tapes via a Panasonic video recorder. Positional information was imprinted on the film using a dGPS linked to TrakView overlay system. Videotapes were later copied to DVD using a Phillips DVD Recorder. A stills camera system (Photosea 1000A 35mm camera and Photosea 1500S strobe) was also fitted to the drop-frame and operated through the Simrad video control unit. Slide film was used, with the resulting stills scanned onto computer using a Nikon CoolScan IV slide scanner. These images were enhanced using Adobe Photoshop, and catalogued with positional information, which was determined as far as possible using the associated video footage.

Due to very strong tidal currents in the survey area the video footage was of poor quality, as it proved problematic keeping the drop frame still or moving at a slow enough speed for the video camera to focus. In addition the water was of high turbidity which further degraded video images. Eight stills images were of adequate quality to enable further analysis, and these complemented the video footage.

RoxAnn™ data analysis

The datasets were exported from RoxMap and split into a number of spreadsheets due to the large size of the datasets so that they could be edited and examined within MS Excel, and by using non-earth plots in a GIS to examine erroneous depth values. The data was cleaned with respect to depth spikes and ‘sticking’ of E1, E2 (‘roughness’ and ‘hardness’) and depth values that occurred when the ship was turning. No positional jumps were present in the data. The data for the main survey area was then averaged for every 5 records so that the two spreadsheets containing the dataset could be amalgamated, and the relationships between E1 and E2 and these variables with depth could be examined graphically. There was no significant relationship between either variable and depth which deems the data acceptable for further analysis. The same checks were made on the multibeam area RoxAnn™ datasets and passed adequately.

For the main survey area, a variability index was calculated for raw E1 and E2 values, which shows how variable particular seabed areas are, was calculated by measuring the variability between sequential E1 and E2 data points. This was generated by square-rooting the absolute value of the next data point minus the current data point for each of E1 and E2, then adding these together. This provides a measure of along-track data variability for E1 and E2, which was used in later analysis. The entire dataset for the main survey area was amalgamated in Surfer. The two (Irish) Sea Mounds datasets collected during the multibeam survey were treated in a similar manner, although prior to calculation of variability indices E1 and E2 were standardised by dividing each value by the 95th percentile of the range, such that the two surveys could be compared if necessary in the future. Positions for all RoxAnn™ data were converted into Irish National Grid and to Universal Transverse Mercator projection (zone 30N) using Geocalc software.

Variograms were created in Surfer using E1 and E2 values. The variance within these variables appears to level off at a distance of 400-500m between points for the main survey area, which indicates the maximum interpolation distance possible if interpolation is to give more information than simply the local mean. The variables depth, E1, E2, and variability index were interpolated throughout the survey area using linear kriging interpolator within Surfer, with a search radius of 400m and pixel size of 30m2. For each of the multibeam datasets, the variograms levelled off at between 200 and 300m. Grids were interpolated in these areas using linear kriging, with a search radius of 200m and pixel size of 30m2. These interpolated grids were then imported into Idrisi where raster images of each grid were created, with values stretched between 0-255. Composite images of two combinations of the variables were then produced (A: E1, E2, depth; B: E1, E2, variability index). A collection of all four variables was created and this was used in the unsupervised classification of the data. The ISOCLUST routine in Idrisi was used to produce unsupervised cluster maps for the survey areas.

Unsupervised classification was used for the analysis of RoxAnn™ interpolated data due to the limited spatial coverage of the ground-truthing sites. The number of clusters created was determined using a histogram of the grid datasets in Idrisi, as an integral part of the ISOCLUST routine. For the main survey area some eight clusters were chosen, relating to eight different ground-types. For each of the multibeam survey areas, six clusters were created.

The resulting cluster maps were converted into vector files, and then exported from Idrisi as shapefiles. The shapefiles were imported into ArcMap, part of the ArcGIS 8.3 geographical information system (ESRI). The RoxAnn™ track data, video and grab sample positions were entered into MS Access, and loaded into the GIS such that they could overlay the cluster maps.

Multibeam data analysis

Multibeam data for two sites (Peak 1 and Peak 4) was provided as XYZ files and as backscatter mosaics (in .tif format). The XYZ files contained positions given in Universal Transverse Mercator (Zone 30N) projection, based on 5x5m grid spacing. The XYZ files were imported into MS Access, where the depth values were converted into negative numbers such that they were comparable with the RoxAnn™ data format and would enable production of elevation models. The data was loaded into ArcMap 8.3, and TIN (triangulated irregular networks) files created from the data using the 3D Analyst extension, which use depth as the elevation field. The TIN files were then converted into Raster grids. These elevation / bathymetric data layers were then presented in ArcScene 8.3, where they are viewed in 3D. The accompanying datasets (cluster maps, RoxAnn™ tracks, ground-truthing data) were overlaid on these bathymetric layers to improve habitat interpretation. The multibeam backscatter images were georeferenced in ArcMap and also added into ArcScene in 3D.

Ground-truthing data analysis

The video data was played back and where the footage was of adequate quality, notes were made of substrate type and characterising species. The positions of the video at such points were noted from the video overlay. The stills images showed considerably more detail than the video footage and added to the habitat descriptions by facilitating species identification. The positions of each clear area were entered in MS Access, with the associated species and substrate information. Once all footage had been examined, habitats were assigned to each area based upon the species and substrate descriptions. This data is provided in Annex I. The habitat categories identified from the video data are provided in Table 7.1 below.

For each of the grab samples, particle size analysis (PSA) data and species lists are provided. This data is summarised by the use of Shannon-Weiner diversity index and this, along with PSA data and species data, is provided in Annex II, along with a map showing the codes for each grab sample.

Results and Discussion

Main survey area

Figure 7.1 shows a bathymetric plot for the main survey area, and also shows the areas Peak 1 and Peak 4 that were surveyed using multibeam sonar. The bathymetry for the main survey area was produced from RoxAnn™ data. The region shows four distinctly raised areas, or peaks, with an additional peak/ridge towards the south of the region in the centre. The four peaks identified on figure 7.1 range between 3.5km and 1.5km in diameter, with the largest distinct peak being Peak 1 and smallest being Peak 3. The 'ridge' discussed above is approximately 10km in length with a maximum width of 3.5km. The features (peaks and troughs) appear to run generally in a NNW to SSE orientation, with the deeper areas towards the north of the region, shallowing to the south. The maximum depth is approximately 170m, with the shallowest depth found at 40m on Peak 1.

Figures 7.2 and 7.3 show the RoxAnn™ raw data for the region. As with the bathymetry, roughness and hardness data shows NNW-SSE running features. Each peak shows a notable increase in E1 and E2 (roughness and hardness), although in general Peak 1 and Peak 2 show the highest level of hardness (E2). This could in part be due to the shallower depth here, which may favour the second return echo. However no depth dependency was shown in any of the RoxAnn™ datasets and therefore it is possible that the substrate at these two peaks is harder or denser than that found in any other area of the survey region. It is also notable that the area known as Peak 4 shows a lower hardness range than any of the other peaks. The areas of lowest roughness and hardness occur in general from about 54°31' southwards, particularly dominating the west of the survey area. These areas interestingly do not only correspond to the deepest areas between the peaks, but also occur between Peak 2, Peak 3 and the peak/ridge towards the south in the centre of the survey area, as discussed above. The 'trough' in the centre of the survey area, measuring some 11km in length and 1.5km in width, and running NNW-SSE between 54°33' and 54°28', is characterised by very low roughness and hardness. The trough to the northwest edge of the survey area, of which only part of the feature was covered by the RoxAnn™ survey, shows generally higher roughness and hardness values than the more southerly trough, indicating that the substrate may be different. There are also a number of smaller raised areas east of the main trough that show moderate-high levels of roughness and moderate to low levels of hardness.

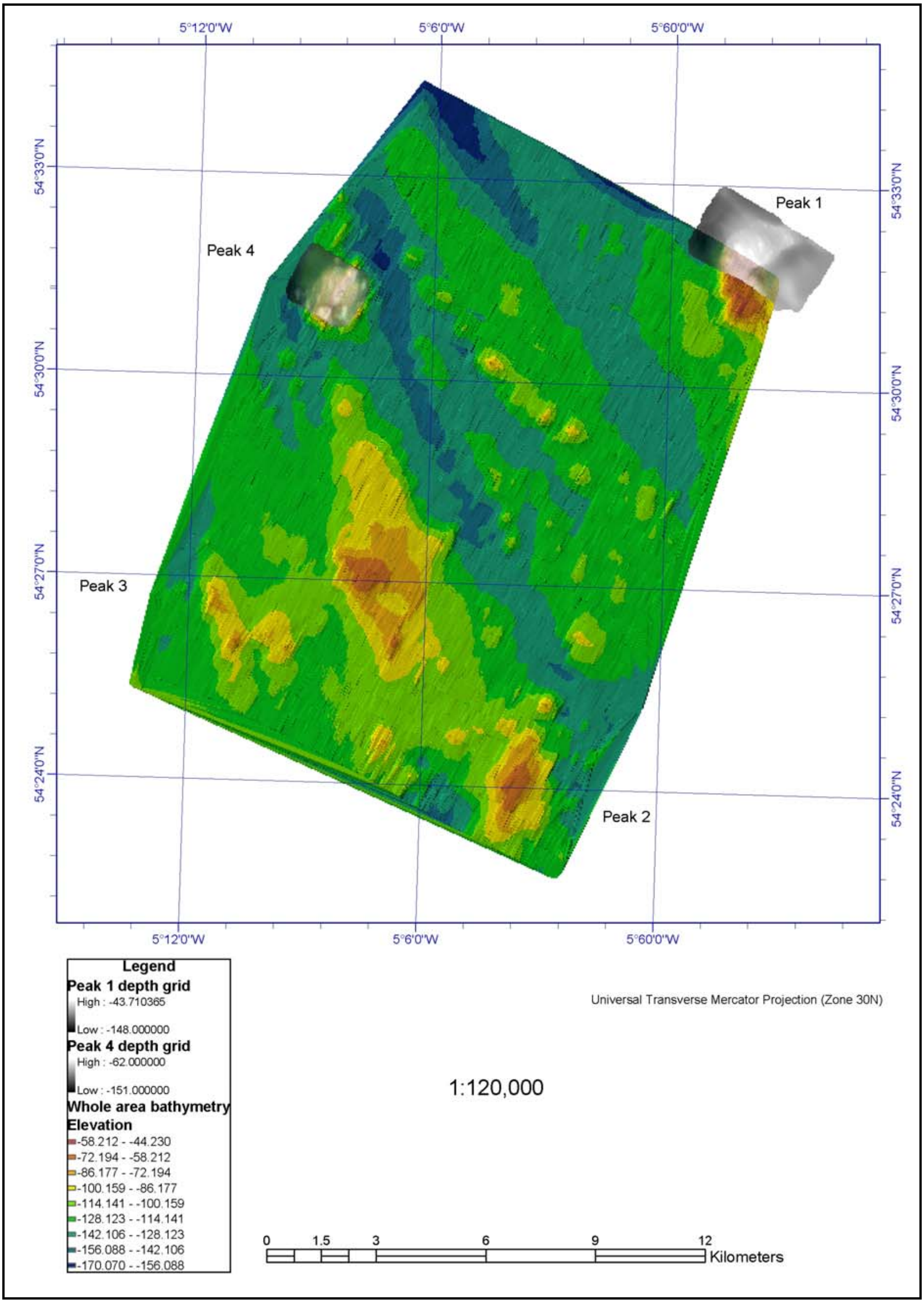

Figure 7.1: Bathymetry of North Channel Peaks region, created from RoxAnn™ data, with multibeam survey areas displayed (Peaks 1 and 4).

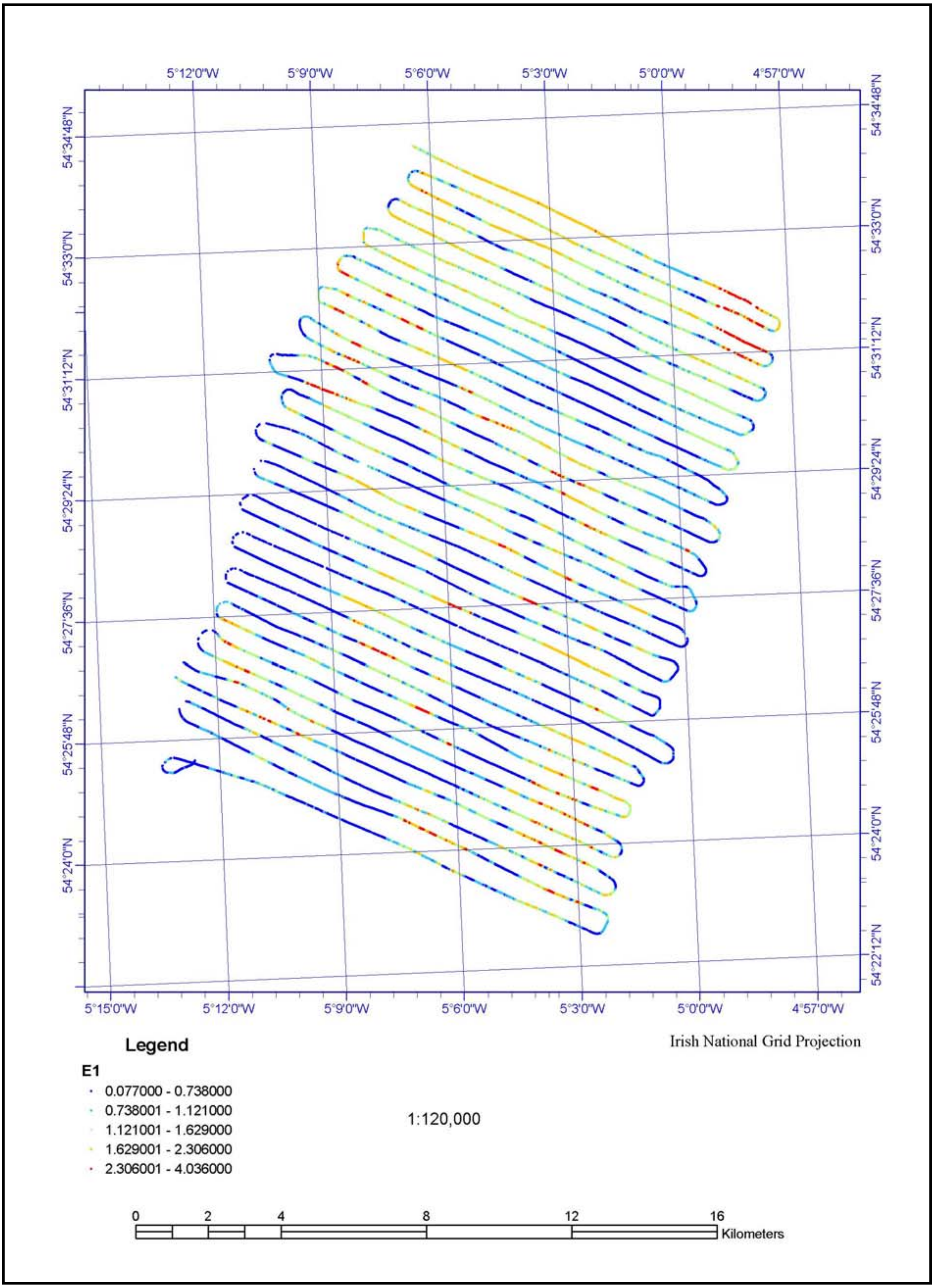

Figure 7.2: RoxAnn™ dataset for North Channel Peaks region, displayed according to E1 (roughness) values.

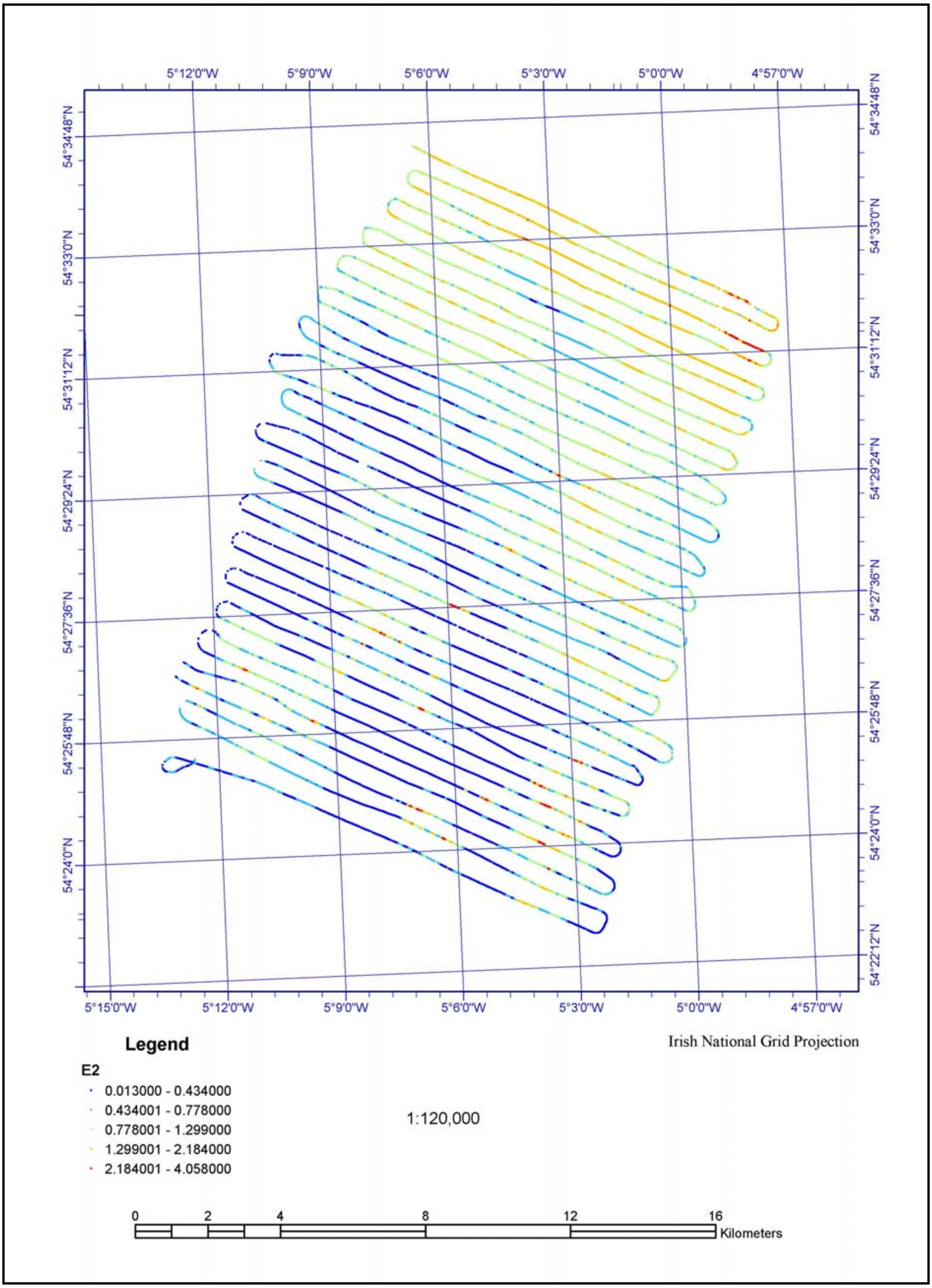

Figure 7.3: RoxAnn™ dataset for North Channel Peaks region, displayed according to E2 (hardness) values.

Figure 7.4 shows the unsupervised classification map of the RoxAnn™ dataset for the main survey area. Eight distinct groundtypes were identified, with clusters 8 and 2 exhibiting the highest values of roughness and hardness, and clusters 1, 6 and 3 the lowest values of roughness and hardness. Cluster 5 was characterised by moderate to high values of roughness but low hardness, while cluster 4 showed low levels of roughness but moderate levels of hardness. Cluster 7 showed moderate levels of both roughness and hardness. The peaks and ridges are characterised by cluster 8, and bordered by cluster 2. The main trough was dominated by cluster 1 and cluster 5, while clusters 3 and 6 dominate the extensive soft areas to the south of the survey area. As expected the clusters show a distribution following features running NNW to SSE.

The distribution of the ground-truthing surveys are also shown on Figure 7.4, and it can be seen that these fall on clusters 8 and 2. It is therefore not possible to ascertain what habitat each cluster relates to throughout the survey area due to the limited spatial coverage of the ground-truthing data. The habitats identified from the video footage and stills images show a degree of heterogeneity that is not reflected by the distribution of clusters, which is due to the scale of this heterogeneity being smaller than the spacing of the RoxAnn™ survey tracks. However, it is likely that both clusters 8 and 2 relate to bedrock outcrops (reef habitat), interspersed by crevices and areas filled with softer sediments (muddy sand) and loose boulders. Much of the bedrock is covered by a sediment veneer consisting of either muddy sand of shell gravel, which may explain the lower hardness values compared to the high roughness values given by RoxAnn™. The areas that correspond to troughs are most probably soft sediments such as bioturbated mud or muddy sand, bordered by sand and gravel areas (coarse sediments), possibly with a significant proportion of comminuted and whole dead shell. Additional spatially targeted survey effort is required to verify such ground-types, by means of grabs and towed underwater video.

On the basis of the identified distribution of peaks, a number of areas were chosen for the multibeam survey campaign to target reef habitat. Due to ship time constraints only two of these areas were completed by the multibeam survey: Peak 1 and Peak 4.

Full towed video and stills log sheets are presented in table 7.2 (Annex I). Figure 7.13 shows the location and codes of Day grab sampling stations. Full particle size analysis of each grab sample is shown in table 7.4 (Annex II). The results of the biological qunatittaive sampling are presented in table 7.5 (Annex II).

Table 7.1: Habitat Descriptions for the North Channel Peaks region.

Habitat code	Substrate description	Characterising fauna/flora	Energy environment	Comments
CR.HCR.FaT 	>70% bedrock outcrops and boulders.	Visually dominated by dense numbers of Alyconium digitatum or Metridium senile and Urticina eques. Turbularia spp. abundant (T. indivisa and T. larynx?). Some dense areas of Ophiothrix fragilis. Sagartia elegans and Balanus spp. common. Frequent occurrence of Echinus esculentus.	High energy/ very exposed to tidal currents	As per National Marine Habitat Classification version 03.02 (JNCC).
CR.HCR.ShM 	>70% bedrock or boulders with overlying shell and muddy gravel, which forms a veneer of varying thickness.	Some Alcyonium digitatum, Metridium senile, Ophiothrix fragilis, Ophiocomina nigra and occasional Balanus spp.	High energy/ very exposed to tidal currents	

Habitat code	Substrate description	Characterising fauna/flora	Energy environment	Comments
CR.HCR.MuS 	>70% bedrock or boulders with thin to thick muddy sand veneer on horizontal and gently sloping surfaces. Little or no shell.	Ophiothrix fragilis and Ophiocomina nigra abundant. Munida rugosa common. Patches of hydrozoan turf. On vertical bedrock slopes, dense patches of Alcyonium digitatum, Urticina eques and Metridium senile are common, and Echinus esculentus is frequent.	High energy/ very exposed to tidal currents	
CMS/HCR 	Small-medium boulders on muddy sand and gravel.	Thick hydrozoan turf on boulders. Munida rugosa and Sagartia elegans common. Tunicates frequent.	Moderate-high energy, with varying exposure to strong tidal currents	Occurs between bedrock outrcrops or in wide crevices
CMS.Sh (no still image available)	>70% muddy sand with a significant proportion of comminuted shell.	Tunicates frequent. Poor visibility restricted analysis of this habitat.	Moderate energy (often deeper and therefore less exposed to strong tidal currents).	

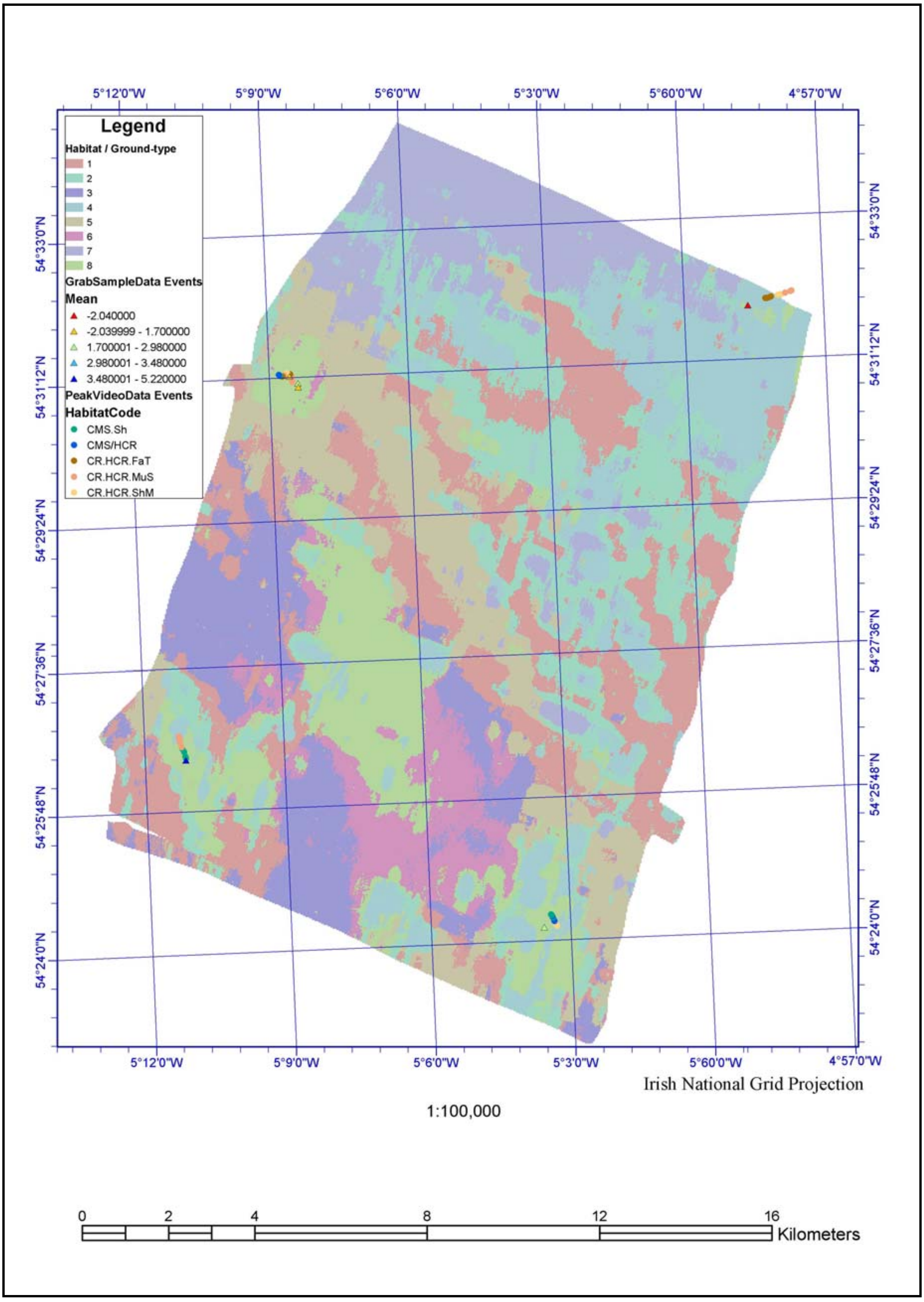

Figure 7.4: Unsupervised classification of RoxAnn™ data for the North Channel Peaks region, with video tow positions and grab sample positions displayed.

Peak 1 Survey Area

Figure 7.5 shows RoxAnn™ and multibeam survey tracks over Peak 1, along with the habitats identified by the video footage and the grab sample site. Underlying these data is an unsupervised cluster map based on the RoxAnn™ data for the area. It appears that the habitat CR.HCR.MuS occurs on cluster 2, while CR.HCR.ShM occurs on cluster 6 and CR.HCR.FaT occurs on cluster 4. All three clusters occur on very rough and hard ground, although cluster 6 also incorporates lower levels of roughness and hardness. From the available ground-truthing it would appear that clusters 2, 4 and 6 are representative of reef habitat, which in this survey area corresponds to a region of 3.75 km^2.

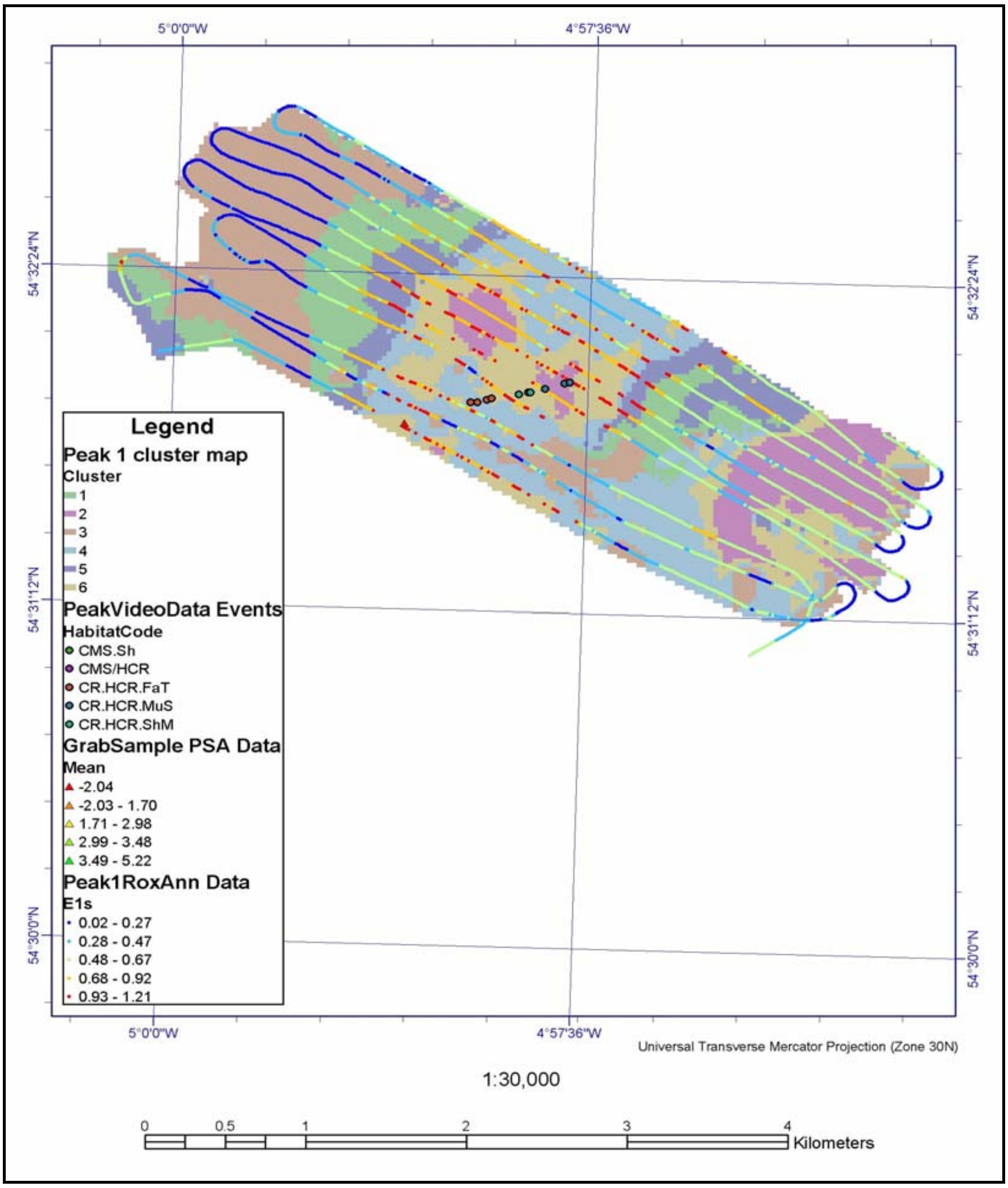

Figure 7.5: Unsupervised classification of RoxAnn™ data collected during multibeam survey of Peak 1, with RoxAnn™ tracks, video habitat category start positions and grab sample data displayed.

This also incorporates an area to the east (see Figure 7.5), which shows moderate levels of roughness and high levels of hardness and is classified as clusters 2 and 6. Cluster 6 may consist of rock with a dense faunal cover (including *Alcyonium digitatum*, *Metridium senile*, *Urticina eques* and *Tubularia* spp.) that could act to dissipate the acoustic energy from the transducer and therefore reduce the roughness and hardness values recorded by RoxAnn™.

Figure 7.6 below presents the multibeam bathymetric data for Peak 1. The distribution of reef outcrops is readily evident from this bathymetry, which, when overlaid by the cluster map (figure 7.7) indicates that clusters 2, 4 and 6 indeed correspond to such an area. The vertical/sloping areas bordering the peak, which should also be included as reef, consist predominantly of clusters 1 and 5. These regions correspond to an area of 2.204 km^2, giving a total of 5.96 km^2 reef habitat.

The multibeam backscatter data is overlaid upon the bathymetry in figure 7.8 below. Unfortunately there is little distinction between the different areas, although it can be seen that darker reflectance occurs on the raised areas (reef) and on an area to the east, which has also been identified as possible reef. Lower reflectance areas occur to the southeast and to the western border of the survey area, indicating possibly softer sediments. No obviously light areas are visible on the backscatter image, indicating that there are possibly no very soft or flat areas in this region, such as mud habitats.

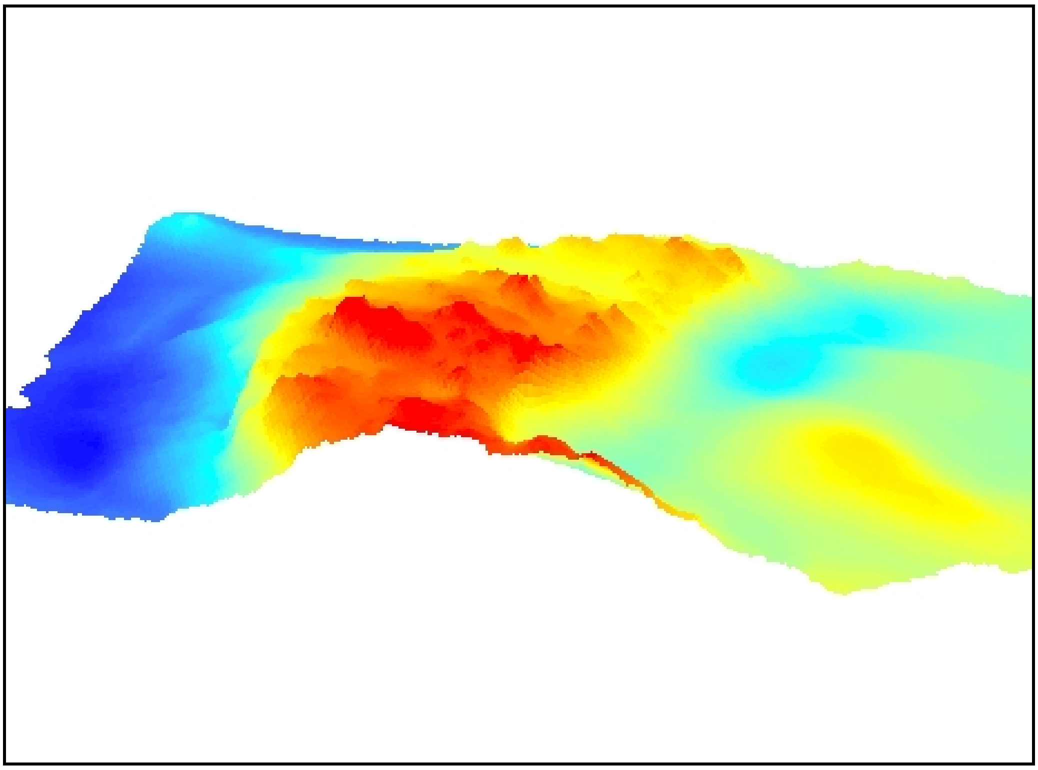

Figure 7.6: Multibeam bathymetry of Peak 1. Vertical exaggeration: x5.

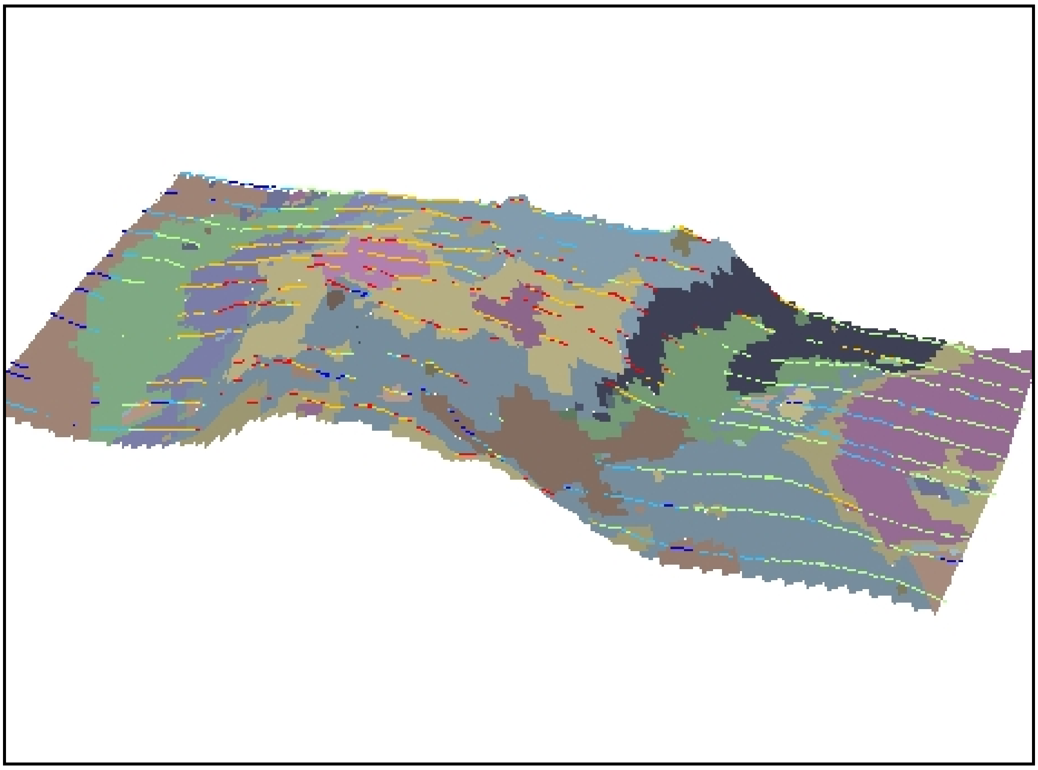

Figure 7.7: Cluster map overlaid upon multibeam bathymetry for Peak 1, with RoxAnn™ tracks displayed according to E1 (roughness). Vertical exaggeration: 5. Note dark blue area is in shade, and actually corresponds to purple area (see figure 7.5).

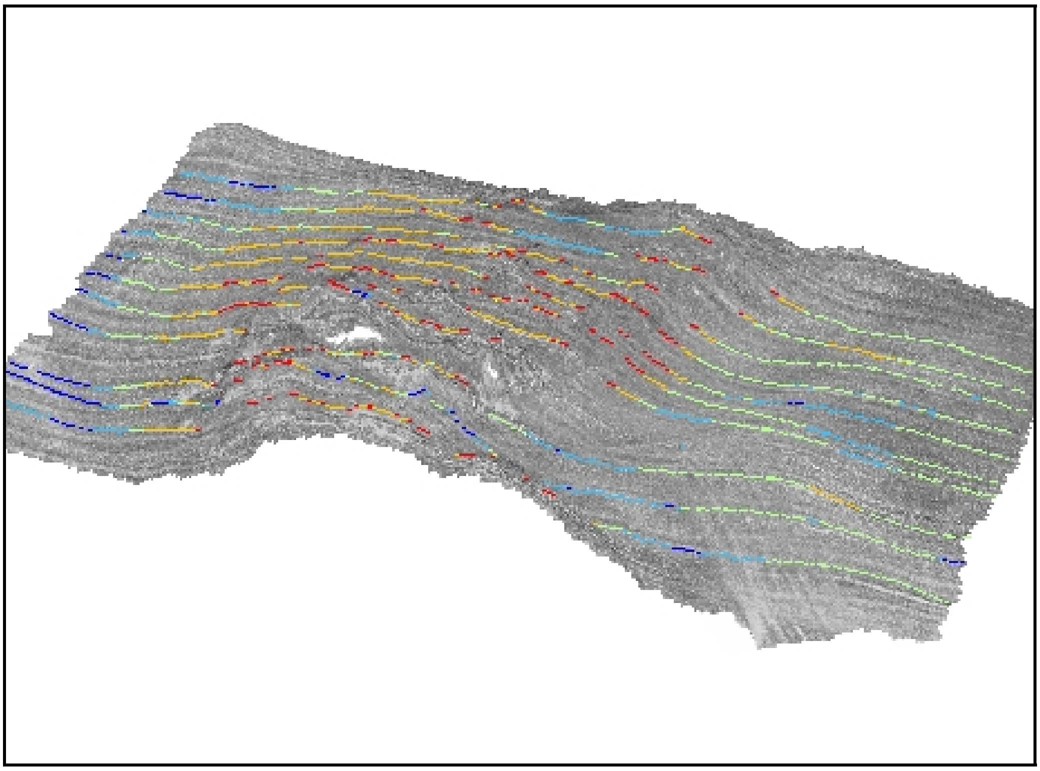

Figure 7.8: Multibeam backscatter data overlaid upon bathymetry for Peak 1, with RoxAnn™ tracks displayed according to E1 (roughness). Vertical exaggeration: 5.

Peak 4 Survey Area

Figure 7.9 shows RoxAnn™ and multibeam survey tracks over Peak 4, along with the habitats identified by the video footage and the grab sample site. Underlying these data is an unsupervised cluster map based on the RoxAnn™ data for the area. It appears that the habitats incorporating a significant proportion of muddy sand occur on cluster 3 (CR.HCR.MuS, CMS/HCR, CMS.Sh) while CR.HCR.FaT and CR.HCR.ShM occurs on cluster 6. The grab samples also tentatively support this, with a higher mean sediment phi occurring on cluster 6 and lower mean phi occurring on cluster 3. Cluster 6 generally shows higher values of roughness and hardness while cluster 3 shows a moderate range of roughness and hardness. The underwater video tow went over a peak and through crevices, which occur at a scale not comparable with the RoxAnn™ track data. It is notable, however, that the RoxAnn™ data shows a high degree of heterogeneity over the peak in the central region of the survey area, and therefore interpolated data is likely to be erroneous or can only be considered at a broad scale.

Using the multibeam data, it is more evident which areas correspond to reef habitat. Figure 7.10 presents the bathymetry for the Peak 2 area, with the RoxAnn™ cluster map overlain in Figure 3.3. Here, it is immediately apparent that the cluster map fails to detect the very heterogeneous ground in the area of the peak, and both clusters 3 and 6 fall on the sides and tops of each rocky outcrop, which would be expected to harbour a number of different habitats, as identified from the video footage. The tops of the outcrops are very current-swept and consist largely of dense faunal turf, with a dominance of *Urticina eques*, *Tubularia* spp. and *Metridium senile*. In the deeper waters, which are less subject to tidal flow, a sediment veneer frequently covers the rock with only vertical surfaces harbouring dense faunal turfs. Peak 4 is deeply fissured, as is evident in Figure 3.2, with such crevices filled with softer substrates and shell debris, with frequent occurrence of *Munida rugosa*, *Ophiothrix fragilis* and *Ophiocomina nigra*. Despite the shortcomings of the RoxAnn™-based cluster map in terms of representing the true seabed heterogeneity as evident from the multibeam bathymetry, both clusters 3 and 6 only occur on the bedrock outcrops and therefore an estimate of the area of reef habitat can be made from the cluster map. This gives a result of 2 km2. Clusters 1 and 4 occur in areas at the edge of the rock outcrops, and possibly consist of mixed habitats with coarse material (boulders and cobbles, with some gravel) mixed with muddy sands, while clusters 2 and 5 occur in deeper water with low roughness and hardness values, indicating soft substrates, possibly muddy sand. Again such habitat suggestions require verification by additional ground-truthing.

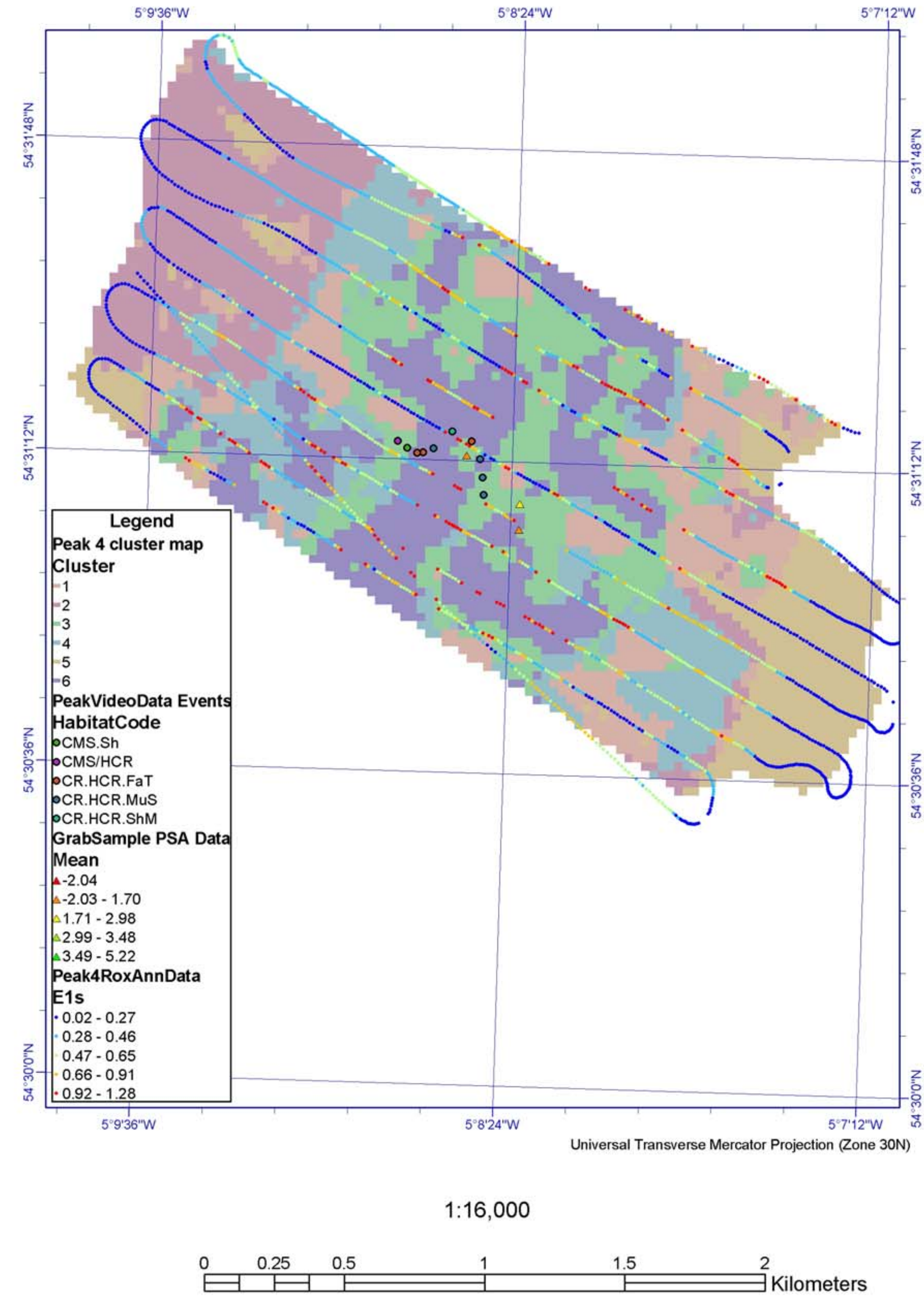

Figure 7.9: Unsupervised classification of RoxAnn™ data collected during multibeam survey of Peak 4, with RoxAnn™ tracks, video habitat category start positions and grab sample data displayed.

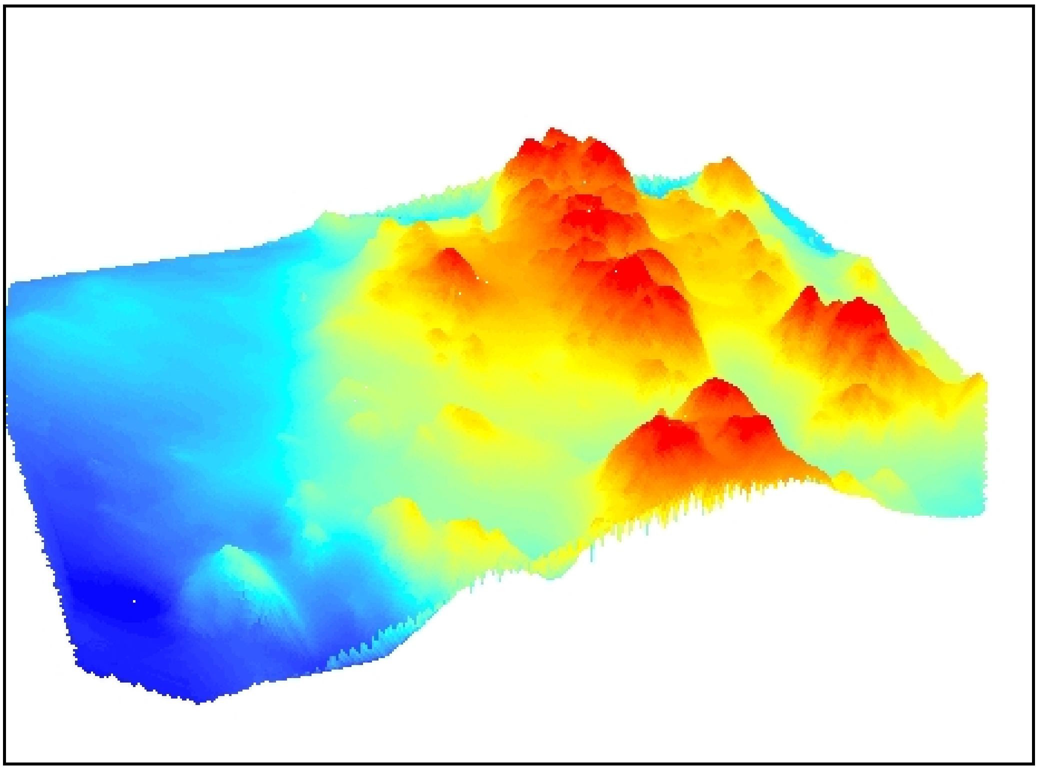

Figure 7.10: Multibeam bathymetry of Peak 4. Vertical exaggeration: x5.

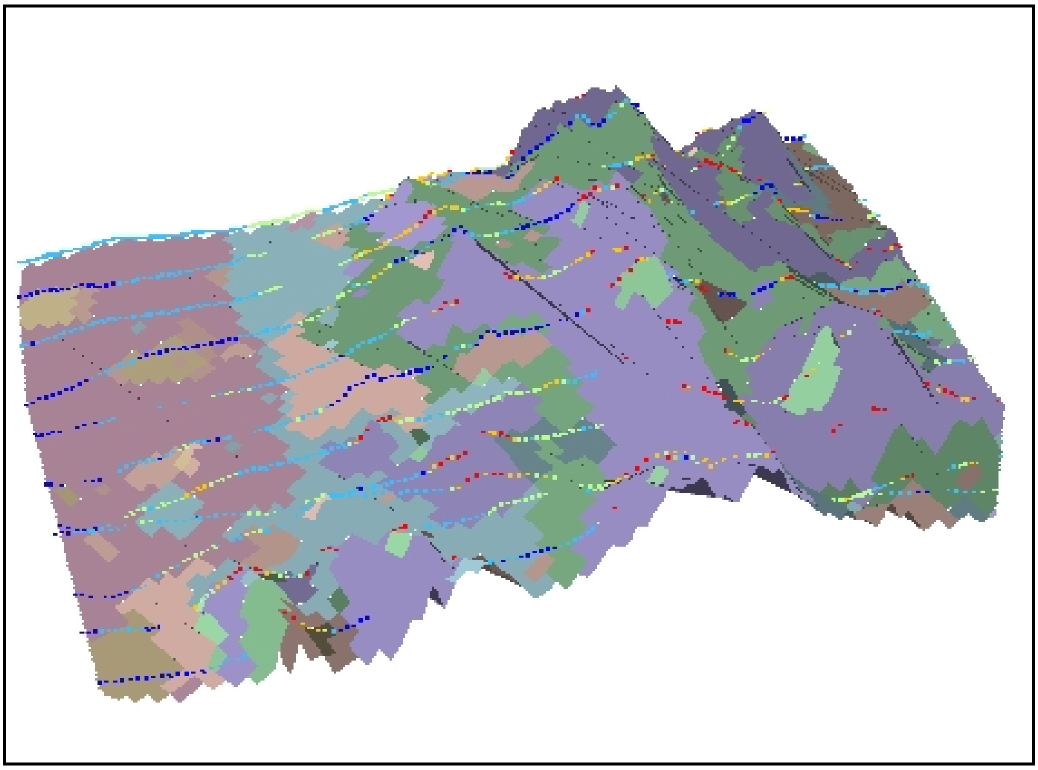

Figure 7.11: Cluster map overlaid upon multibeam bathymetry for Peak 4, with RoxAnn™ tracks displayed according to E1 (roughness). Vertical exaggeration: x5. Refer to figure 7.9 for cluster map legend.

The multibeam backscatter information is presented in 3D in figure 7.12. Dark reflecting areas indicating hard/rough substrates occur at the top of the outcrops as expected from the ground-truthing, and it would appear that many of the slopes of the outcrops show medium levels of backscatter, possibly coinciding with the video footage indicating thick sediment veneers over rock, which would be expected to reduce backscatter. This again agrees with the area classified as clusters 3 and 6 from the RoxAnn™ data. The lighter reflecting areas occur to the west of the survey region in the deeper water, in what was classified as cluster 2, where RoxAnn™ indicated low roughness and hardness. Such a region may consist of sand or muddy sands. A few small light reflecting areas occur immediately to the west of the outcrops, in what is an area classified as cluster 4, which may correspond to level, soft sediment areas. Ground-truthing would be necessary to confirm these suggestions.

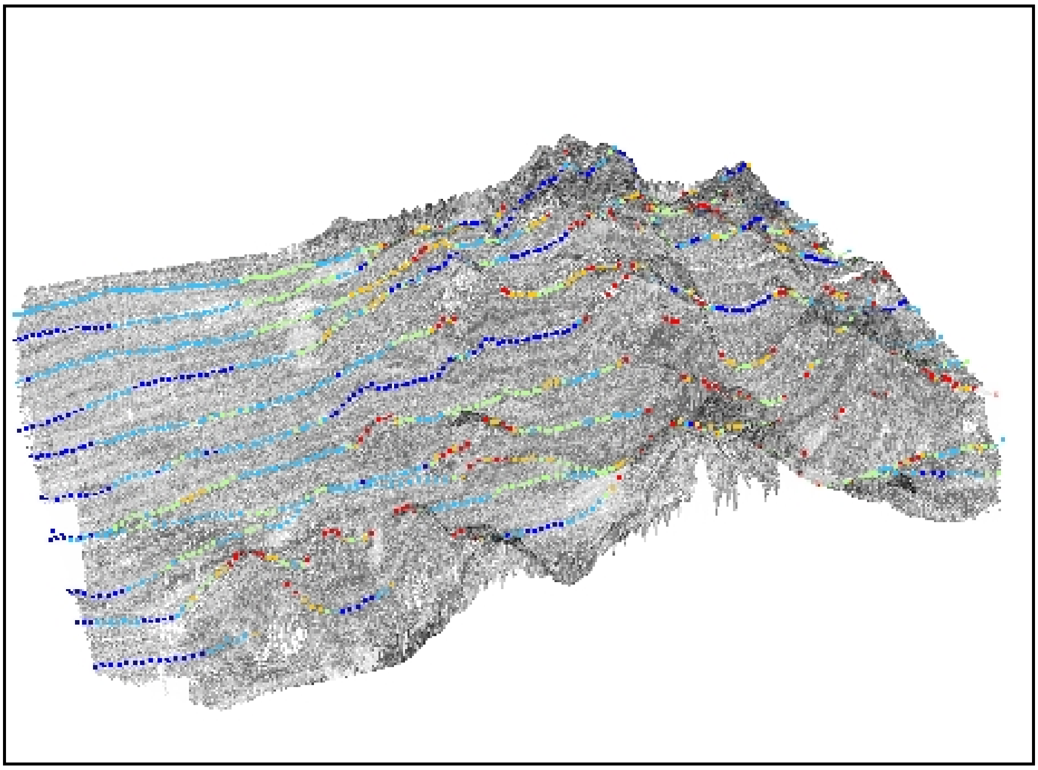

Figure 7.12: Multibeam backscatter data overlaid upon bathymetry for Peak 4, with RoxAnn™ tracks displayed according to E1 (roughness). Vertical exaggeration: x5.

In terms of biological diversity, Peak 4 showed the highest number of species determined from the grab samples (54 species in replicate NCP4A, taken at the edge of an outcrop), and showed a slightly higher Shannon-Weiner diversity index (average 3.16) than the other Peaks. Full results from the analysis of biological diversity can be found in Annex II; table 7.3.

Conclusions and Recommendations

The acoustic surveys, utilising both RoxAnn™ AGDS and multibeam sonar, identified a total of five significant areas of rocky outcrops within the survey area, corresponding to EC Habitats Directive Annex II Reef Habitat. Underwater video footage showed that such ‘peaks’ consisted of habitats typical of strongly current-swept areas, with dense faunal turfs characterised by thick carpets of anemones and soft corals. In deeper waters where some shelter is afforded from the tidal currents, a muddy sand or shell gravel veneer overlaid the bedrock, with its own characterising fauna. Peak 1 and Peak 4 of the reef areas were investigated in some detail, with bathymetric models built for these two regions based on multibeam data. The two areas, although predominantly sharing similar distributions of habitats, showed differing degrees of heterogeneity. Peak 1 showed a significant continuous area of high energy reef habitat ($3.75km^2$) and a smaller, deeper area of potential reef habitat to the east of the main peak ($2.21km^2$), while Peak 4 was revealed as a series of steep rocky outcrops and sediment-filled ‘crevices’, exhibiting a high level of heterogeneity over small distances. In this Peak 4 area the high energy reef habitat is believed to extend approximately 2 km^2.

It is recommended that further ground-truthing using towed sledge underwater video systems are used for investigation of the softer substrate areas as identified in paragraph 7.2.2.3, with associated grab sampling, and that further multibeam sonar and/or RoxAnn™ AGDS work be completed over the three remaining peak/ridge areas within the survey region, using tighter track spacing to facilitate recognition of the diversity and scale of habitats in such areas. In particular the ‘ridge’ running NNW-SSE warrants inspection, as it is the largest potentially continuous reef habitat within the survey region.

Annex I: Underwater video and stills log sheets

Table 7.2: Towed video and stills log sheets, showing habitat descriptions.

Peak ID	Video Section Start Latitude (dec)	Video Section Start Longitude (dec)	Latitude degree (N)	Latitude decimal minutes	Longitude degree (W)	Longitude decimal minutes	Still Image Code	Habitat Description	Habitat Code
1	54.53240	-4.97125	54	31.944	4	58.275	peak1a	Bedrock outcrops, dense *Alcyonium digitatum*, *Urticina eques* & *Metridium senile*, *Tubularia* spp. with *Echinus esculentus*	CR.HCR.FaT
1	54.53242	-4.97062	54	31.945	4	58.237		Bedrock outcrops, dense *A. digitatum*, *U. eques* & *M. senile*, *Tubularia* spp. with *E. esculentus*	CR.HCR.FaT
1	54.53257	-4.96970	54	31.954	4	58.182	peak1b22	Bedrock outcrops, dense *A. digitatum*, *U. eques* & *M.m senile*, *Tubularia* spp. with *E. esculentus*	CR.HCR.FaT
1	54.53267	-4.96925	54	31.96	4	58.155	peak1c23	Bedrock outcrops, dense *A. digitatum*, *U. eques* & *M. senile*, *Tubularia* spp. with *E. esculentus*	CR.HCR.FaT
1	54.53293	-4.96667	54	31.976	4	58		Shell and muddy gravel overlying bedrock. Some *A. digitatum* and *M. senile*, *Ophiothrix fragilis* and *Ophiocomina nigra*, *Balanus* spp.?	CR.HCR.ShM
1	54.53307	-4.96575	54	31.984	4	57.945	peak1d24	Shell and muddy gravel overlying bedrock. Some *A. digitatum* and *M. senile*, *Ophiothrix fragilis* and *Ophiocomina nigra*, *Balanus* spp.?	CR.HCR.ShM
1	54.53308	-4.96557	54	31.985	4	57.934		Shell and muddy gravel overlying bedrock. Some *A. digitatum* and *M. senile*, *Ophiothrix fragilis* and *Ophiocomina nigra*, *Balanus* spp.?	CR.HCR.ShM
1	54.53308	-4.96557	54	31.985	4	57.934		Shell and muddy gravel overlying bedrock. Some *A. digitatum*, *M. senile*, *O. fragilis*, *O. nigra*, & *Balanus* spp.?	CR.HCR.ShM
1	54.53332	-4.96413	54	31.999	4	57.848		*M. rugosa*, *O. nigra*, *O. fragilis* on rock with thin muddy sand veneer	CR.HCR.MuS
1	54.53365	-4.96228	54	32.019	4	57.737		*M. rugosa*, *O. nigra*, *O. fragilis* on rock with thin muddy sand veneer	CR.HCR.MuS

Peak ID	Video Section Start Latitude (dec)	Video Section Start Longitude (dec)	Latitude degree (N)	Latitude decimal minutes	Longitude degree (W)	Longitude decimal minutes	Still Image Code	Habitat Description	Habitat Code
1	54.53373	-4.96178	54	32.024	4	57.707		*Munida rugosa*, *Ophiocomina nigra*, *Ophiothrix fragilis* on rock with thin muddy sand veneer	CR.HCR.MuS
2	54.40338	-5.05508	54	24.203	5	3.305		Bedrock with muddy sand veneer and shell debris	CR.HCR.ShM
2	54.40367	-5.05543	54	24.22	5	3.326		Bedrock with muddy sand veneer and shell debris, crinoids?	CR.HCR.ShM
2	54.40435	-5.05593	54	24.261	5	3.356	peak2a25	Thick muddy sand in wide rock crevices, *Munida rugosa*, *Sagartia* spp.	CMS/HCR
2	54.40452	-5.05608	54	24.271	5	3.365		Some small boulders (loose) and pebbles on muddy sand. Tunicates.	CMS/HCR
2	54.40508	-5.05643	54	24.305	5	3.386		Muddy sand and comminuted shell	CMS.Sh
2	54.40535	-5.05663	54	24.321	5	3.398		Medium boulders and muddy sand	CMS/HCR
2	54.40563	-5.05688	54	24.338	5	3.413		Muddy sand and comminuted shell	CMS.Sh
2	54.40577	-5.05707	54	24.346	5	3.424		Muddy sand and comminuted shell	CMS.Sh
3	54.44140	-5.18493	54	26.484	5	11.096		Muddy sand and comminuted shell	CMS.Sh
3	54.44178	-5.18508	54	26.507	5	11.105		Muddy sand and comminuted shell	CMS.Sh
3	54.44278	-5.18553	54	26.567	5	11.132		Muddy sand and comminuted shell	CMS.Sh
3	54.44345	-5.18610	54	26.607	5	11.166		Muddy sand and comminuted shell, tunicates	CMS.Sh
3	54.44382	-5.18637	54	26.629	5	11.182		Muddy sand- thick veneer over rock? Some boulders and shell.	CR.HCR.MuS
3	54.44480	-5.18678	54	26.688	5	11.207		Muddy sand veneer on rock with patches of hydrozoan turf	CR.HCR.MuS
3	54.44553	-5.18693	54	26.732	5	11.216		Muddy sand veneer on rock with patches of hydrozoan turf	CR.HCR.MuS
3	54.44575	-5.18713	54	26.745	5	11.228		Muddy sand veneer on rock with patches of hydrozoan turf	CR.HCR.MuS
3	54.44602	-5.18725	54	26.761	5	11.235		Muddy sand veneer on rock with patches of hydrozoan turf	CR.HCR.MuS

Peak ID	Video Section Start Latitude (dec)	Video Section Start Longitude (dec)	Latitude degree (N)	Latitude decimal minutes	Longitude degree (W)	Longitude decimal minutes	Still Image Code	Habitat Description	Habitat Code
4	54.51892	-5.14150	54	31.135	5	8.49		Thick muddy sand overlying rock on horizontal surfaces; on rock slopes dense *Urticina eques* and *Metridium senile*	CR.HCR.MuS
4	54.51947	-5.14160	54	31.168	5	8.496		Thick muddy sand overlying rock on horizontal surfaces; on rock slopes dense *Urticina eques* and *Metridium senile*	CR.HCR.MuS
4	54.52005	-5.14177	54	31.203	5	8.506	peak4a26	Thick muddy sand veneer with hydroids (inc.*Tubularia* spp.) and anemones (*U. eques*, *Sagartia elegans*, *M. senile*) on rock	CR.HCR.MuS
4	54.52062	-5.14227	54	31.237	5	8.536	peak4a29	Rock with dense *U. eques*, *M. senile and some S.elegans*, *A. digitatum*, dense *Tubularia indivisa*, *Tubularia larynx* and nudibranch Dendronotus frondosus	CR.HCR.FaT
4	54.52092	-5.14333	54	31.255	5	8.6		Muddy gravel with shell (in between rock outcrops?), *Ophiocomina nigra*, *Ophiothrix fragilis* and *Echinus esculentus*	CR.HCR.ShM
4	54.52037	-5.14435	54	31.222	5	8.661	peak4d30	Sand veneer on bedrock with patches of *U. eques*, *A. digitatum* and *O. fragilis*	CR.HCR.MuS
4	54.52022	-5.14492	54	31.213	5	8.695		Dense *O. fragilis*, *M. senile*, *U. eques* and *Tubularia* spp. on bedrock	CR.HCR.FaT
4	54.52020	-5.14525	54	31.212	5	8.715		Dense *U. eques* and *Tubularia* spp. on bedrock	CR.HCR.FaT
4	54.52035	-5.14580	54	31.221	5	8.748		Muddy sand	CMS.Sh
4	54.52057	-5.14633	54	31.234	5	8.78		Muddy sand and gravel, with small boulders with hydrozoan turf	CMS/HCR

Annex II: PSA and biological diversity data from grab samples.

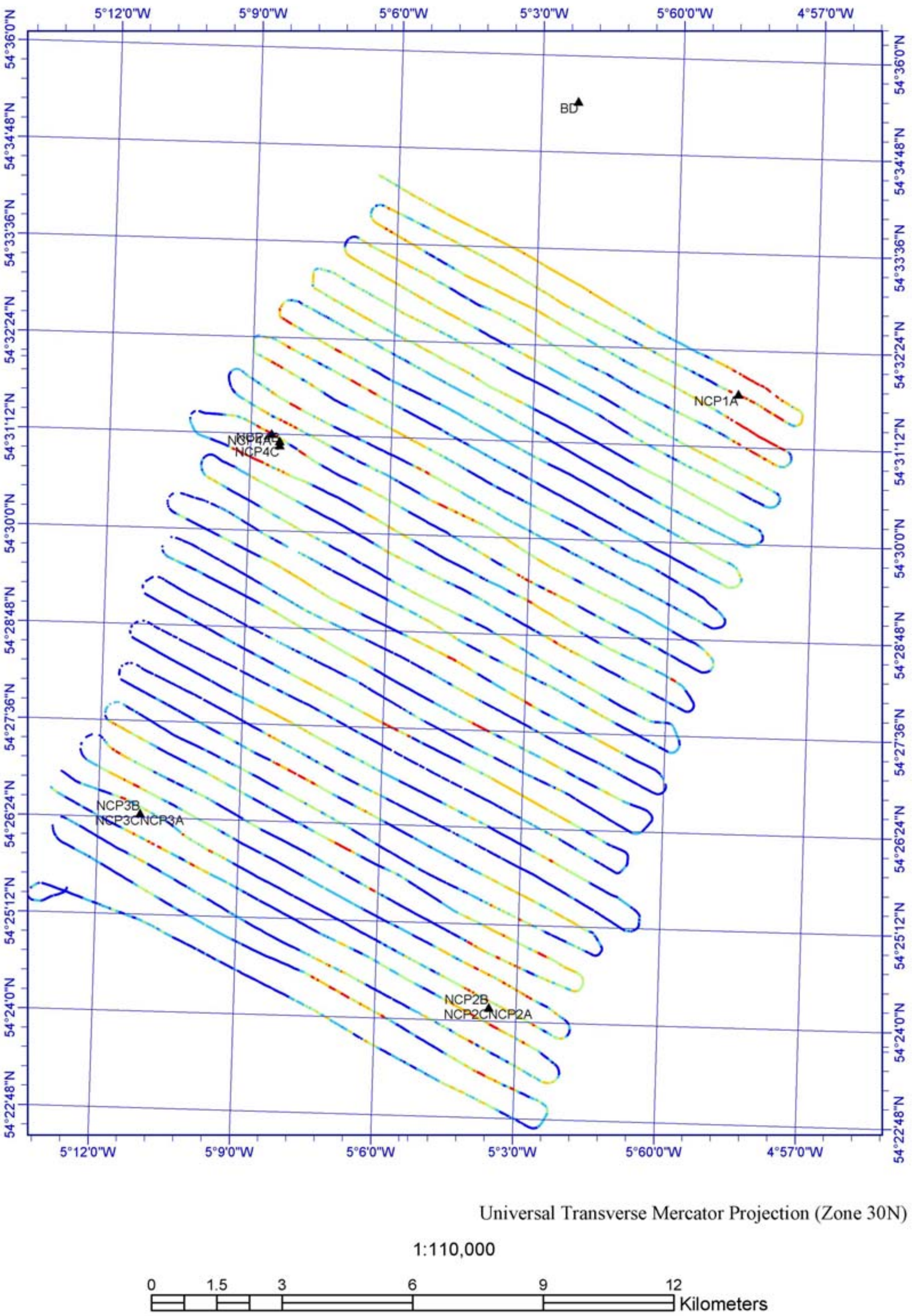

Figure 7.13: Map showing positions and ID codes of grab sampling stations.

Table 7.3: Shannon-Weiner diversity index from Day grab samples at each sample station.

GrabID	Latitude degrees (N)	Latitude decimal minutes	Longitude degrees (W)	Longitude decimal minutes	Latitude Decimal degrees	Longitude Decimal degrees	Shannon Weiner Diversity Index H	Variance H	Number of Species
BD	54	35.432	5	2.232	54.59053	-5.03720	2.6745	0.028253	25
NCP1A	54	31.864	4	58.654	54.53107	-4.97757	2.9718	0.012457	30
NCP2A	54	24.187	5	3.58	54.40312	-5.05967	2.9857	0.011424	28
NCP2B	54	24.187	5	3.58	54.40312	-5.05967	3.0137	0.010361	34
NCP2C	54	24.187	5	3.58	54.40312	-5.05967	n/a	n/a	4
NCP3A	54	26.46	5	11.094	54.44100	-5.18490	2.6096	0.009447	37
NCP3B	54	26.46	5	11.094	54.44100	-5.18490	2.5784	0.01663	41
NCP3C	54	26.46	5	11.094	54.44100	-5.18490	2.6265	0.009776	31
NCP4A	54	31.21	5	8.55	54.52017	-5.14250	3.5321	0.005426	54
NCP4B	54	31.12	5	8.37	54.51867	-5.13950	2.8026	0.008626	34
NCP4C	54	31.07	5	8.37	54.51783	-5.13950	3.1635	0.008349	48

Table 7.4: Particle Size Analysis from Day grab samples at each sample station

GrabID	Latitude degrees (N)	Latitude Dec minutes	Longitude degrees (W)	Longitude dec minutes	Lat Dec	Long Dec	Shell/Mineral	Mean	Sorting	Sort Class	Skewness	Skew Class	Kurtosis	Kurt Class
BD	54	35.432	5	2.232	54.59053	-5.0372	>2mm 40/60 SHELL/ MINERAL	1.7	4.71	Extremely poorly sorted	0.15	Positively skewed	0.97	Mesokurtic
NCP1A	54	31.864	4	58.654	54.53107	-4.97757	>2mm 50/50 SHELL/ MINERAL	-2.04	2.22	Very poorly sorted	0.22	Positively skewed	2.79	Very leptokurtic
NCP2A	54	24.187	5	3.58	54.40312	-5.05967	>2mm 70/30 SHELL/ MINERAL	2.98	3.7	Very poorly sorted	0.58	Very positively skewed	0.7	Platykurtic
NCP2B	54	24.187	5	3.58	54.40312	-5.05967	>2mm 60/40 SHELL/ MINERAL	2.6	4.09	Extremely poorly sorted	0.46	Very Positively skewed	0.75	Platykurtic
NCP2C	54	24.187	5	3.58	54.40312	-5.05967	>2mm 60/40 SHELL/ MINERAL	2.89	4.31	Extremely poorly sorted	0.3	Very positively skewed	0.72	Platykurtic
NCP3A	54	26.46	5	11.094	54.441	-5.1849	>2mm 80/20 SHELL/ MINERAL	3.48	3.67	Very poorly sorted	0.51	Very positively skewed	0.66	Very platykurtic
NCP3B	54	26.46	5	11.094	54.441	-5.1849	>2mm 80/20 SHELL/ MINERAL	5.12	3.77	Very poorly sorted	-0.32	Very negatively skewed	0.71	Platykurtic
NCP3C	54	26.46	5	11.094	54.441	-5.1849	>2mm 60/40 SHELL/ MINERAL	5.22	3.86	Very poorly sorted	-0.31	Very negatively skewed	0.78	Platykurtic
NCP4A	54	31.21	5	8.55	54.52017	-5.1425	>2mm 30/70 SHELL/ MINERAL	1.48	4.79	Extremely poorly sorted	0.33	Very positively skewed	0.69	Platykurtic
NCP4B	54	31.12	5	8.37	54.51867	-5.1395	>2mm 100/0 SHELL/ MINERAL	2.84	4.94	Extremely poorly sorted	-0.15	Negatively skewed	0.56	Very platykurtic
NCP4C	54	31.07	5	8.37	54.51783	-5.1395	>2mm 20/80 SHELL/MINERAL	1.06	4.46	Extremely poorly sorted	0.71	Very positively ske	0.66	Very platykurtic

Table 7.4: contd

GrabID	Latitude degrees (N)	Latitude decimal minutes	Longitude degrees (W)	Longitude decimal minutes	Latitude Decimal degrees	Longitude Decimal degrees	Gravel	Cobbles	Pebbles	Sand	Silt	Clay
BD	54	35.432	5	2.232	54.59053	-5.03720	36.97	0	36.97	43.06	13.75	6.21
NCP1A	54	31.864	4	58.654	54.53107	-4.97757	82.96	0	82.96	10.24	5	1.81
NCP2A	54	24.187	5	3.58	54.40312	-5.05967	9.19	0	9.19	54.78	27.93	8.1
NCP2B	54	24.187	5	3.58	54.40312	-5.05967	17.24	0	17.24	49.73	24.62	8.42
NCP2C	54	24.187	5	3.58	54.40312	-5.05967	18.06	0	18.06	34.3	38.17	9.48
NCP3A	54	26.46	5	11.094	54.44100	-5.18490	6.35	0	6.35	46.4	37.67	9.58
NCP3B	54	26.46	5	11.094	54.44100	-5.18490	7.62	0	7.62	28.13	51.42	12.83
NCP3C	54	26.46	5	11.094	54.44100	-5.18490	8.45	0	8.45	24.05	53.19	14.31
NCP4A	54	31.21	5	8.55	54.52017	-5.14250	37.77	0	37.77	31.84	23.06	7.33
NCP4B	54	31.12	5	8.37	54.51867	-5.13950	40.95	0	40.95	10.63	38.42	10.01
NCP4C	54	31.07	5	8.37	54.51783	-5.13950	55.05	0	55.05	16.31	22.01	6.63

Table 7.4: Contd

GrabID	Latitude degrees (N)	Latitude decimal minutes	Longitude degrees (W)	Longitude decimal minutes	Latitude Decimal degrees	Longitude Decimal degrees	No Modes	Largest Mode (um)	Mode (phi)	Median (um)	Median (phi)	Folk Clay Silt Ratio	Folk Sand Mud Ratio	Shepard 1954
BD	54	35.432	5	2.232	54.59053	-5.03720	4	304.48	1.72	390.36	1.36	Silty sand	Muddy sandy gravel	Clayey sand
NCP1A	54	31.864	4	58.654	54.53107	-4.97757	6	2401.84	-1.26	3693.12	-1.88	Sand	Gravel	Silty sand
NCP2A	54	24.187	5	3.58	54.40312	-5.05967	4	543.93	0.88	423.29	1.24	Silty sand	Gravelly muddy sand	Silty sand
NCP2B	54	24.187	5	3.58	54.40312	-5.05967	5	544.47	0.88	473.21	1.08	Silty sand	Gravelly muddy sand	Silty sand
NCP2C	54	24.187	5	3.58	54.40312	-5.05967	6	582.68	0.78	289.8	1.79	Silty sand	Gravelly mud	Sand silt clay
NCP3A	54	26.46	5	11.094	54.44100	-5.18490	6	546.55	0.87	270.65	1.89	Silty sand	Gravelly mud	Sand silt clay
NCP3B	54	26.46	5	11.094	54.44100	-5.18490	3	570.37	0.81	15.42	6.02	Sandy silt	Gravelly mud	Sand silt clay
NCP3C	54	26.46	5	11.094	54.44100	-5.18490	4	579.68	0.79	14.96	6.06	Sandy silt	Gravelly mud	Sand silt clay
NCP4A	54	31.21	5	8.55	54.52017	-5.14250	5	628.76	0.67	766.3	0.38	Silty sand	Muddy sandy gravel	Sand silt clay
NCP4B	54	31.12	5	8.37	54.51867	-5.13950	2	8.12	6.94	78.74	3.67	Silty sand	Muddy gravel	Clayey silt
NCP4C	54	31.07	5	8.37	54.51783	-5.13950	2	4951.66	-2.31	2634.72	-1.4	Silty sand	Muddy gravel	Sand silt clay

Table 7.5: Biological composition of Day grab samples at each sample station: No's per ??

	NCP1(A)	NCP2(A)	NCP2(B)	NCP2(C)	NCP3(A)	NCP3(B)	NCP3(C)	NCP4(A)	NCP4(B)	NCP4(C)	Beaufort Dyke
HYDROZOA sp.						1	6	2	5	8	1
ANTHOZOA sp.		4	2		1						
Alcyonium digitatum	2										
Edwardsia sp.	3		6		7						7
TURBELLARIA sp.	1					1			1		
ANOPLA sp.		3	3		5	1	2	7	2	3	1
Sipunculidae sp.				1		1	1				
Harmothoe sp.	5	4			1	1	2	1	2	1	2
Pholoe inornata	1						1	4			
Eulalia bilineata	1										
Glycera alba		3	3		4	1	2	1	1	2	1
Glycera lapidum	4										
Glycera rouxi			4		3	1	3	1	5	3	1
Glycinde nordmanni						1				2	
Goniada maculata		2	2		10	1				2	
Sphaerodorum gracilis									1		1
Hesionidae sp.			1								
Ophiodromus flexuosus	2									1	
Ehlersia cornuta	1		5	1	1	4	2			2	
Sphaerosyllis bulbosa	4										
Autolytus sp.							1	1	1	2	
Nephtys sp.						1	1				
Pareurythoe borealis	1										

Lumbrineriopsis paradoxa					2				2	1	1
Lumbrineris sp.		1									
Lumbrineris gracilis	1	2	4		16	3	20	11	23	8	1
Protodorvillea kefersteini									1		
Aricidea sp.										1	
Aricidea simonae		2	1								
Spionidae sp.			1								
Aonides oxycephala								1			
Aonides paucibranchiata	5										
Laonice sp.									2		
Laonice cirrata					7	3	9	7		2	
Minuspio cirrifera	5	1	3								
Spio filicornis			1			1				1	1
Spiophanes kroyeri								15	39	21	
Magelona sp.								1			
Cirratulidae sp.											2
Caulleriella zetlandica								1	3	3	1
Cirratulus filiformis	1		1			1					
Cirriformia tentaculata								1	2	1	
Diplocirrus glaucus		1						1	1	1	
Capitella sp.	2							1	1		
Capitomastus minimus								5	14	25	
Notomastus latericeus		1								4	
Maldanidae sp.(A)			1					1		1	
Maldanidae sp.(B)								2			
Euclymene sp.(b)							1				

Euclymene sp.			1		6	6	7	8	1	3	
Myriochele heeri		1	14		7	5	3	2		4	2
Owenia fusiformis			1					1		1	4
Sabellariidae sp.				1							
Sabellaria spinulosa								25	4		
Melinna cristata		13	15		97	73	61	4		1	
Ampharete grubei		1	3		3	3	2	5			
Amphicteis gunneri		4			7	7	3	1		3	
Terebellides stroemi					1	1		5	6	11	
Polycirrus sp.								5	9	9	
Parathelepus collaris	1				1					2	
Streblosoma bairdi					1						
Thelepus sp.								4			
Sabellidae sp.									1		
Chone duneri								2			
Euchone southerni			2				2	3		3	
Laonome sp.									1		
Serpula sp.								1			
PYCNOGONIDA sp.								1		1	
Eusirus longipes	2										
Monoculodes packardi	1										
Amphilochus spencebatei			1								
Metopa alderi								5			
Stenothoe sp.	1					1		1	3	4	
Stenothoe marina					4						
Harpinia antennaria					1		1			2	

Acidostoma sp.									2	1	1
Ampelisca sp.			1								
Ampelisca spinipes		2	6		6	2	3	1			
Ampelisca tenuicornis										1	
Haploops tubicola						3	8				
Ceradocus semiserratus	2										
Cheirocratus intermedius		1									
Maera othonis						1		5	1		1
Maerella tenuimana											1
Photis longicaudata		3	1		9	3	5				
Ericthonius punctatus								2			
Autonoe longipes		1	1		5	2		1	4		
Microdeutopus anomalus						2		2			
Dyopedos monacanthus							1				
Caprellidae sp.					3			3			
Astacilla longicornis		1									
Tanaidae sp.										1	
Hemilamprops rosea					1						
Diastylis lucifera						2					
Diastyloides biplicata		9	18		3		5	8	2		
DECAPODA juv	2		1		3	1	1	6		1	
BRACHYURA								1			
Hyas araneus						1					
CAUDOFOVEATA sp.		1	2			1		1	3		
Leptochiton asellus	1								3		3
Dendronotus frondosus					1		4				

Nucula nucleus									22	33	1
Jupiteria minuta					1						
Musculus discors										1	
Chlamys varia var. *nivea*						1					
Anomia ephippium	1				1			1			
Lucinoma borealis									2		
Mysella bidentata											1
Astarte sulcata		1			1	1		2		3	
Parvicardium sp.					2	14	13	1			
Abra alba										1	
Abra nitida		1	1					4			
Abra prismatica								1			
Venerupis senegalensis					1	1					
Timoclea ovata		5									
Corbula gibba		5	2	1		3				1	
OPHIUROIDEA juv					6	1	2	7			
Ophiothrix fragilis	3				1	2					
Amphiura sp.	5										
Amphiura chiajei		3	3							2	
Amphiura filiformis					16	8	9		2	1	
Ophiuridae sp.	18										
Ophiura robusta											16
ECHINOIDEA juv											1
Echinus esculentus	1										
Echinocyamus pusillus											1
Brissopsis sp.											1

Brissopsis lyrifera		1						1		1	
HOLOTHURIOIDEA juv			1								
Holothuriidae sp.	1										
Thyone sp.								5		2	1
Ascidiella sp.										1	
Nematoda	9		1			3	1	2			