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Mapping habitats and biotopes from acoustic datasets to strengthen the information base of Marine Protected Areas in Scottish waters

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Summary

The objective of this project was to generate seabed habitat maps for locations coinciding with Scottish MPA proposals with full coverage acoustic datasets to as detailed a hierarchical level as possible within the Marine Habitat Classification for Britain and Ireland (version 04.05), also known as MNCR classification, (Connor *et al* 2004). The acoustic data were at various stages of processing and interpretation, therefore the mapping of habitats and biotopes in some areas have required a greater amount of work to reach the same level compared to other areas.

The constituent polygons within the habitat/biotope maps are labelled to an appropriate level of the Habitat Classification and translated to the corresponding EUNIS code.

In order to generate seabed habitat maps for the areas the data associated with each area were required to undergo some preliminary preparation and processing in order to ensure suitability and compatibility with the mapping methodologies employed.

The data were then processed using several techniques: a top-down rule-based approach was adopted based on the methods developed by MESH, UKSeaMap and EUSeaMap, which utilised the updated seabed substrate information provided by BGS. In addition a bottom-up approach was taken to utilise the recently acquired point sample data and multi-beam bathymetry and backscatter data sets; this process took an object-based approach supplemented by supervised classification and categorisation.

Three maps for each location have been produced. The level of habitat detail which could be mapped was restricted to level 3 & 4 of the EUNIS classification with associated metadata and peripheral supplementary data to aid in future analysis and interpretation. A confidence assessment using the MESH confidence assessment method has been undertaken for each habitat map produced and certainty of classification maps accompany each habitat map also.

The assumptions and limitations of the data and the techniques and processes used to produce the maps are discussed to aid understanding and application of the maps.

These maps make an important contribution to the evidence base for the presence and extent of MPA search features underpinning the identification of MPA proposals in Scotland’s seas.

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1 Introduction

1.1 Background to Marine Protected Areas

Scottish Government is committed to a 'clean, healthy, safe, productive and biologically diverse marine and coastal environment that meets the long term needs of people and nature' (Marine Scotland, 2011a). The Marine (Scotland) Act 2010[1] and the UK Marine and Coastal Access Act 2009[2] contain provisions for Scottish Ministers to designate Marine Protected Areas (MPAs) in the seas around Scotland as part of a range of measures to manage and protect Scotland's seas for current and future generations (SNH & JNCC, 2012).

Work to identify MPAs is being delivered by the Scottish MPA Project, a joint project between Marine Scotland (Scottish Government), Scottish Natural Heritage (SNH), the Joint Nature Conservation Committee (JNCC), Historic Scotland and the Scottish Environment Protection Agency (SEPA) (SNH & JNCC, 2012).

Marine Scotland (MS) have responsibility for marine nature conservation through the powers in the Acts, however SNH and JNCC function within the project to provide guidance and scientific advice on the selection of Nature Conservation MPAs and the development of an ecologically coherent network. SNH lead on advice concerning Nature Conservation MPAs within Scottish territorial waters and JNCC lead on advice concerning Nature Conservation MPAs in offshore waters (beyond 12 nautical miles (nm) from the coast) adjacent to Scotland. The Nature Conservation MPAs will recognise features that are rare, threatened and/or representative and which contribute to a wider MPA network (SNH and JNCC, 2012: Marine Scotland, 2011b).

Nature Conservation MPA proposals have been proposed to Scottish Government based on the best available scientific evidence, incorporating stakeholder input which was sought at various stages and built into the project. The proposals are underpinned by the presence of Search Features; a range of important features for which MPAs are considered to be an appropriate measure. The sufficiency of data, quality or condition of the features and the suitability of the information source has driven the identification of areas. Search Features are a subset of Priority Marine Features (PMF) in Scotland's seas. A PMF is a habitat or species which has been identified as being of conservation importance in the seas around Scotland. More information on the identification of PMFs and search features can be found in the Site Selection Guidelines and the Advice to Scottish Government on selection of nature conservation MPAs (SNH and JNCC, 2012: Marine Scotland, 2011b).

1.2 Background to Special Areas of Conservation

The UK Government is currently taking steps to implement the Habitats Directive (EEC, 1992) in offshore waters (from 12nm to the limit of the UK Continental Shelf designated area). As part of this implementation JNCC have been asked by UK Government and the devolved administrations to provide advice necessary to identify areas that may qualify as possible offshore Special Areas for Conservation (SAC). SACs are to be selected for habitats listed on Annex I of the directive, of which 'reefs' are known to occur in Scottish offshore waters.

[1] http://www.scotland.gov.uk/Topics/marine/seamanagement/marineact

[2] http://www.legislation.gov.uk/ukpga/2009/23/contents

In the context of the Habitats Directive, Annex I reefs are described as being “hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone” (CEC, 2007, see Appendix 2).

The term, “arise from the seafloor” indicates that the reef must be topographically distinct from the surrounding seafloor. “Hard compact substrata” can include rocks (soft and hard), boulders, and cobbles, which are defined as being generally greater than 64mm clast size. Hard substrata may be covered by a thin and mobile veneer of sediment, but in order to fall within the definition of reef, the associated biota must be dependent on the hard substratum rather than the overlying sediment (CEC, 2007). Three types of reef are recognised in UK waters: bedrock reef, stony reef (including cobble and boulder reef), and biogenic reef made by cold-water corals, Ross worms (*Sabellaria spinulosa*) or horse mussels (*Modiolus modiolus*). Whilst the definition of bedrock reef is relatively straightforward, the definition of stony reefs can be more problematic, and so further guidance has been developed by JNCC following a workshop attended by the Statutory Nature Conservation Bodies (SNCBs) (Irving, 2009).

2 General objective

The objective of this project is to generate seabed habitat maps for locations coinciding with Scottish MPA proposals with full coverage acoustic datasets to as detailed a hierarchical level as possible within the Marine Habitat Classification for Britain and Ireland (version 04.05)[3], also known as MNCR classification (Connor *et al* 2004). The acoustic data were at various stages of processing and interpretation, therefore the mapping of habitats and biotopes in some areas have required a greater amount of work to reach the same level compared to other areas.

The constituent polygons within the habitat/biotope maps were to be labelled to an appropriate level of the Habitat Classification and translated to the corresponding EUNIS[4] code. Where possible, mapping should be to the biotope and biotope complex level (e.g. EUNIS level 4 & 5), although it is appreciated that sample data or the resolution of acoustic data may be insufficient to determine this level of detail. Where a biotope or biotope complex code could not be identified for a given area due to lack of information, then the appropriate habitat complex code was chosen. The attribute tables of GIS deliverables have been attributed accordingly (see results section).

2.1 Areas to be mapped

Four areas were selected (Figure 1), for which multibeam bathymetry and backscatter datasets were available along with associated point sample data from photographic imagery and sediment grab sampling. Multibeam bathymetry and backscatter datasets, originating from the Civil Hydrography Programme (CHP) of the Maritime and Coastguard Agency, have been processed by remote sensing specialists at the National Oceanography Centre (NOC) and subsequently interpreted by experts at the British Geological Survey (BGS) to produce seabed substrate maps for those areas. These datasets were generated through a Memorandum of Agreement between MS, JNCC, SNH, NOC, BGS and Marine Scotland

[3] http://jncc.defra.gov.uk/page-1584

[4] http://eunis.eea.europa.eu/

Science (MSS) (Marine Scotland *et al* 2011). The remaining area, West Shetland Shelf, was surveyed in 2011 through a partnering of MSS and JNCC.

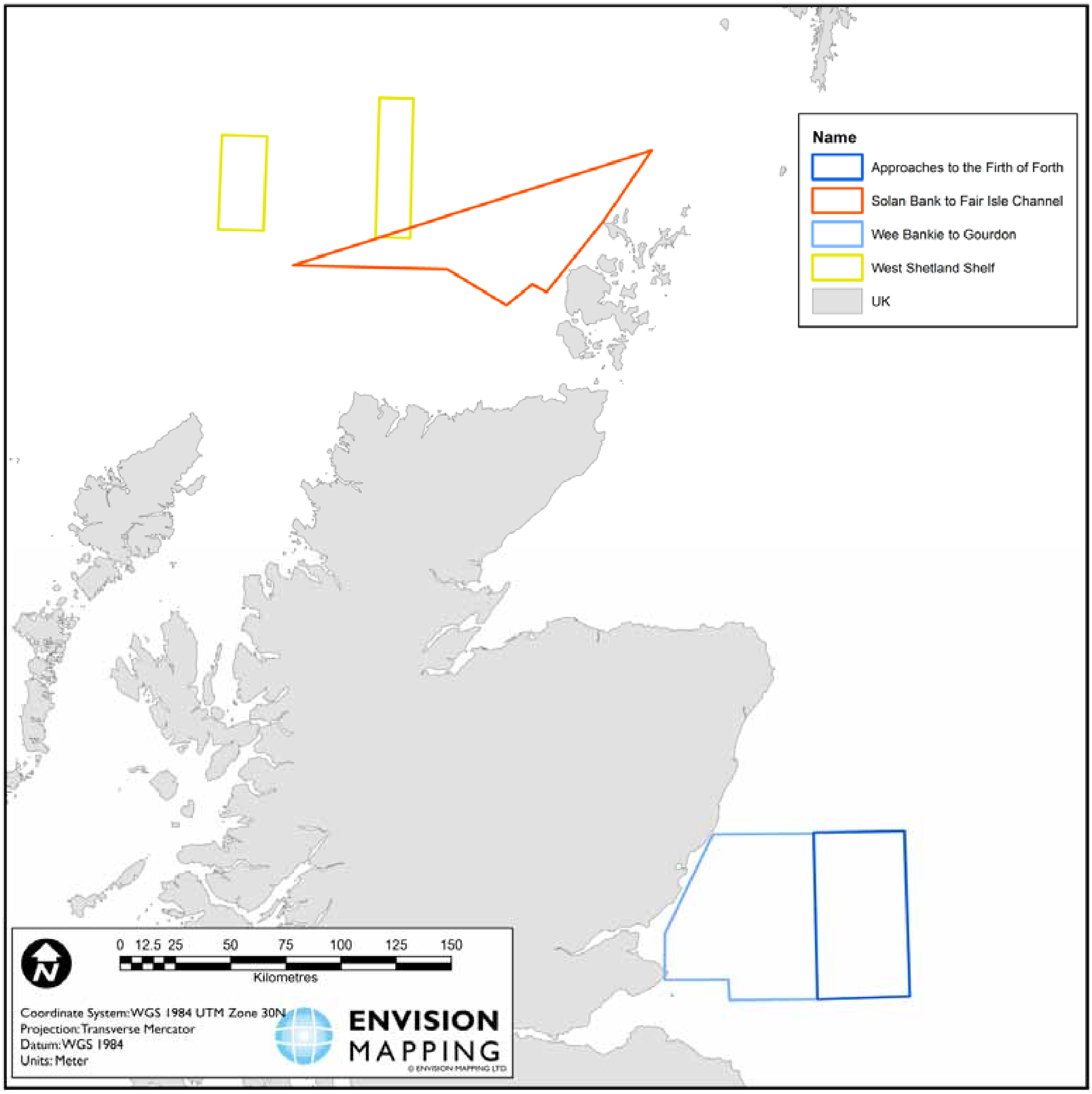

Figure 1. Outlines of project areas around Scotland.

No additional ground-truthing was carried out as part of this project; rather existing physical and biological sample data were found and used. Point sample data were available from the benthic sample database Marine Recorder[5] and recently completed survey data which had been allocated biotopes according to the Marine Habitat Classification for Britain and Ireland (v04.05) or EUNIS. An existing BGS Particle Size Analysis dataset was also available to help inform the distribution of sediments.

Full coverage UK-wide models of physical variables were also used in the form of wave and current disturbance used to determine energy thresholds and using light attenuation levels

[5] Freely available from http://jncc.defra.gov.uk/marinerecorder

the biological zones can be determined for each area. These datasets are freely available from the EUSeaMap website[6].

Table 1. A summary of data available for each area.

Area	Acoustic Data	Sample Point Data	UK wide data
Approaches to the Firth of Forth and Wee Bankie to Gourdon	Full coverage bathymetry and backscatter (MCA CHP)	963 Biotope point records (Marine Recorder & recent survey data) 390 PSA point records (BGS)	Biological zone Seabed energy levels Light attenuation (EUSeaMap)
Solan Bank to Fair Isle Channel	Full coverage bathymetry and backscatter (MCA CHP)	80 Biotope point records (Marine Recorder & recent survey data) 157 PSA point records (BGS)	Biological zone Seabed energy levels Light attenuation (EUSeaMap)
West Shetland Shelf	Partial coverage bathymetry and backscatter (MSS/JNCC survey)	1680 Biotope point records (Marine Recorder & recent survey data) 47 PSA point records (BGS)	Biological zone Seabed energy levels Light attenuation (EUSeaMap)

The approaches to the Firth of Forth and the Wee Bankie to Gourdon areas are adjoining each other and contained similar datasets, for this reason the areas were combined and mapped as a single area.

[6] http://jncc.defra.gov.uk/euseamap

3 Methods

In order to generate seabed habitat maps the data associated with each area were required to undergo some preliminary preparation and processing in order to ensure suitability and compatibility with the mapping methodologies employed.

The data were then processed using several techniques: a top-down approach was adopted based on the methods developed by MESH[7] (Coltman *et al* 2008), UKSeaMap[8] (McBreen *et al* 2011) and EUSeaMap (Cameron and Askew, 2011 and EUSeaMap, 2012a), which utilised the updated seabed substrate information provided by BGS, supplied through the MoA between MS, SNH, JNCC, MSS, BGS & NOC (Marine Scotland *et al* 2011). In addition, a bottom-up approach was taken to utilise the recently acquired point sample data and bathymetry and backscatter data sets, this process took an object-based approach supplemented by supervised classification and categorisation.

3.1 Data preparation

Datasets were available as GIS files with point and line features for seabed sample data (grab samples, photos and videos), polygon features were available for BGS seabed substrate maps and also for EUSeaMap biological zones and energy layers. The acoustic datasets used were geotiffs for backscatter data or gridded rasters for bathymetry data.

The ground-truthing data included both line and point data for each sample site, with some sites having associated grab sample point data also. These data were reviewed to produce a list of biotopes/habitats which occurred within the areas to be mapped. These data were then reviewed and summarised to produce a list of 'mapping units' for each area to be mapped. These mapping units represented the groups of biotopes or biotope complexes which it was possible to map. This list was reviewed throughout the mapping processes and refined to enable a meaningful map to be produced. A factor to consider during this process was the fact that a substantial amount of survey samples analysed did not fit the characteristics of existing biotopes within the current MNCR classification scheme. Analysts of the ground-truth data have made a number of biotope proposals which may be considered in the development of the offshore section of the MNCR classification scheme. A description of the mapping units and the biotopes these represent are provided for each area in the sections 3.5 to 3.7.

The seabed substrate dataset created by BGS was derived through expert interpretation. The methodology applied involves a manual review of available data by a geological expert. Key data sources include multibeam bathymetry and backscatter and derived outputs such as slope, aspect and rugosity. These remotely collected data are ground-truthed using particle size analysis results from grab samples, video tows and camera stills imagery. Archive seismic data can also used where appropriate to provide further information on the influence of sub-surface structures on sedimentary patterns. Review of these data in a GIS environment allowed digitisation of areas of different sediment type. Whilst these boundaries were drawn as distinct lines, it should be noted that they will be gradational in nature. The manual aspect of this methodology allows the expert to incorporate background knowledge relating to the area in question. This may include aspects such as the sedimentary regime, glacial history and localised hydrodynamic conditions, which may all impact on the

[7] MESH modelling: http://www.searchmesh.net/Default.aspx?page=1951[7]

[8] UKSeaMap 2010: http://jncc.defra.gov.uk/ukseamap

sediments present and add further understanding to that gleaned from the data sources discussed above. In this way, novel features can be captured and mapped, and artefacts (particularly in acoustic data) recognised and discounted. This methodology also involved review by a second expert in order to provide a level of QA/QC and repeatability.

The resolution of the bathymetry dataset was 7m and the backscatter 2.5m for the Firth of Forth, Wee Bankie to Gourdon and Solan to Fair Isle Areas, whereas the resolution of the West Shetland Shelf datasets were both 5m. The backscatter data for all areas contained processing or acquisition artefacts (Figure 4) and were noisy. In order to reduce the anomalous data a smoothing filter was applied to the backscatter data to remove small variations/speckling and also the resolution of both the bathymetry and backscatter data were simplified to 50m. This magnitude of resolution (10s of metres) was deemed appropriate as the analysis scale (the size of the units into which measurements are aggregated for data analysis and mapping), given the size at which features exist (phenomenon scale) and the level of the habitat classification at which those features fall (thematic scale). Note that these types of scale differ from cartographic scale which is the depicted size of a feature on a map relative to its actual size in the world. For example, in Figure 28, the cartographic scale is 1:350,000. Figures for each area showing the original data and the data used for processing are provided in sections 3.5 to 3.7.

For EUSeaMap data, existing biological zones and energy layers were available but the availability of higher resolution bathymetry and light level data which had been reviewed and updated (EUSeaMap, 2012b) meant that these layers could be updated to provide higher resolution inputs or data which was deemed more suitable and current. The biological zones layer and seabed energy layers were therefore updated and recreated for each of the areas.

3.2 Data processing

Data were processed using the same methodologies for all areas of analysis. The biological samples for the sites were summarised and tagged with a mapping unit code, and all original data for each sample was retained so any inconsistencies could be reviewed and accounted for. A single point sample layer was produced for each area.

The acoustic data sets were imported into image processing software, IDRISI, with which the smoothing filters were applied, and a consistent spatial resolution (50m) for comparable datasets was implemented. It is critical to the processing of the dataset that all imagery data are spatially coincident and of identical spatial resolution.

3.3 Habitat mapping methods

Existing habitat maps for the areas have been produced by EUSeaMap, UKSeaMap 2010 and MESH – the most recent being EUSeaMap: these mapping methodologies used a rule-based / top-down process in which coarse-resolution models of physical parameters are intersected with seabed substrata data to produce a categorised map of physical habitats at EUNIS level 3/4. The less detailed (lower) level of the hierarchy was used when a more detailed level (higher) could not be allocated. As a result of the multibeam surveys in the study areas, since EUSeaMap, more detailed seabed substrates maps have been produced by BGS using the backscatter and bathymetry datasets with associated PSA sample data (Marine Scotland *et al* 2011). The multibeam bathymetry data have also been used to improve the EUSeaMap energy and light layers.

To incorporate these new and updated datasets the rule-based – top-down approach was employed for each area and is detailed in section 3.3.1.

In addition to the rule-based / top-down methodology, a statistical/probabilistic approach was taken for each area. This methodology used the sample point data to interpret the physical parameters, giving a bottom-up data driven approach. This process can also incorporate an object-based analysis process which identifies areas of seabed which possess similar physical characteristics. These areas can be used as 'training' sites to interpret the whole area and they can be categorised to show the predominant habitat which is predicted in each of the areas.

The outputs from the bottom-up mapping approach required further contextual editing to remove data artefacts and to incorporate any additional background information which was known for each area.

3.3.1 Top-down – Rule-based mapping

Rule-based mapping used a series of input datasets which are reclassified using a system of rules or defined parameters to identify areas which have specific physical parameters associated with habitat classes. The key stages are illustrated in Figure 2.

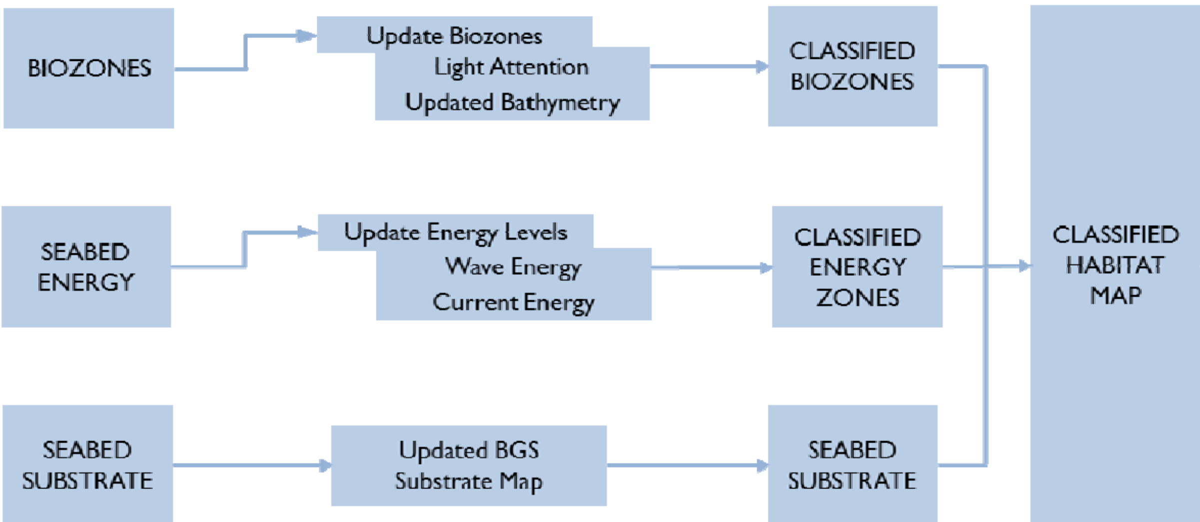

Figure 2. The key stages for a top-down mapping methodology.

A series of input datasets are required to produce the habitat map:

- biological zones, which reflect the changes in biological communities due to corresponding changes in light, energy and depth;
- seabed substrate, which reflect changes in substrate type associated with changes in biological communities; and
- energy conditions at the seabed, which incorporates information on both wave and tidal current energy;

The input dataset corresponding to the seabed substrate was provided by a recently produced seabed sediments and rock layer which was generated by BGS from the backscatter and bathymetric datasets collected as part of the MCA Civil Hydrography Program (MCHP). The data consisted of a GIS polygon file with associated attributes for seabed substrate classified according to Folk sediment classes (Folk, 1954) plus rock. JNCC subsequently grouped these into a smaller number of simplified substrate classes which relate to the MNCR and EUNIS habitat classifications (Long, 2006):

- Rock;
- Mud and sandy mud;
- Sand and muddy sand;
- Coarse sediment; and
- Mixed sediment

Some polygons were attributed as the Folk class ‘muddy sand’. In the absence of percentage mud content of samples underpinning the polygon attribution it was not possible to confidently assign these polygons to the ‘Sand and muddy sand’ class, since the threshold between this and the ‘Mud and sandy mud’ class lies part way through the muddy sand Folk class (see Long, 2006). As such the decision was made that those polygons should be labelled as “~sand and muddy sand” (which indicates a more muddy sand habitat) and pooled with the sand and muddy sand category to give a single category representing both. This simplified seabed substrate polygon layer was then converted to a raster dataset with a 50m resolution (to match the bathymetry and backscatter data resolution) with each pixel given a value to represent the classes above.

The energy layer was produced as a raster dataset from using a wave energy and current energy layer from the EUSeaMap project. These layers were categorised as LOW, MEDIUM or HIGH using the same classes as EUSeaMap and summarised as:

Table 2. Seabed energy classes and the kinetic energy associated with wave and current energies.

Wave energy	Kinetic energy (kNm^{-2})
High	> 1.2
Moderate	0.21 - 1.2
Low	< 0.21

Current Energy category	Kinetic Energy (kNm^{-2})
HIGH	>1.16
MEDIUM	0.13 – 1.16
LOW	< 0.13

Wave and current energy classes were combined using a rule-based approach. The highest category for each grid cell was selected, e.g. a cell with high wave energy and moderate current energy was assigned to a high energy category; a cell with low wave energy and moderate current energy was assigned to a moderate energy category. The resultant energy layer was produced using a resolution of 250m, which was the analysis scale used in the EUSeaMap project and suitable to be artificially increased to 50m to match the other dataset thus enabling data processing to occur. This does not alter the effective resolution of the data but simply enables the same data to be represented at a similar resolution to other data for mathematical operations.

A biological zones layer was supplied as an output from EUSeaMap, and from this the delineation between circalittoral and deep circalittoral was used for all areas. Areas deeper than 200m were assigned to the next deepest zone, ‘Upper slope’. The main EUSeaMap report refers to a boundary between the infralittoral zone and the circalittoral where 1% light reached the seabed, however this was revised during the last update of EUSeaMap when a 4.5% level was considered more appropriate for the light penetration data used (EUSeaMap, 2012a and EUSeaMap, 2012b). Light penetration data were obtained from EUSeaMap and where the 4.5% limit intersected with the new bathymetric data available from the MCHP, this was used as updated delineation between infralittoral and circalittoral at a higher resolution than previously available. The resulting layer was a raster image with the same resolution (50m) as the seabed substrate and seabed energy layers – although this is artificially high as the light attenuation data was only available at a resolution of 250m.

Table 3. Data definitions for biological zones used within the mapping methodology.

Biological zone	Data definition
Infralittoral	> 4.5% light penetration
Circalittoral	< 4.5% light penetration to wave base
Deep Circalittoral	Wave base to 200m
Upper Slope	> 200m

The three input layers were then combined using a rule-based model which overlays the datasets to produce zones which result in areas that relate to EUNIS Level 4 for sediment and 3 for rock (hard substrata). Table 4 shows the combination of energy, biological zones and seabed substrate that occurred within the area to be mapped, other combinations would be possible but were not found to occur.

Table 4. EUNIS and MNCR Codes and physical parameters associated with each.

EUNIS Code	EUNIS Name	MNCR Code	MNCR Name	Substrate	Biological zone	Energy
A3.2	Atlantic and Mediterranean moderate energy infralittoral rock	IR.MIR	Moderate energy infralittoral rock	Rock	Infralittoral	Moderate
A3.3	Atlantic and Mediterranean low energy infralittoral rock	IR.LIR	Low energy infralittoral rock	Rock	Infralittoral	Low
A4.2	Atlantic and Mediterranean moderate energy circalittoral rock	CR.MCR	Moderate energy circalittoral rock	Rock	Circalittoral	Moderate
A4.27	Faunal communities on deep moderate energy circalittoral rock	NULL	Not in classification	Rock	Deep circalittoral	Moderate
A4.3	Atlantic and Mediterranean low energy circalittoral rock	CR.LCR	Low energy circalittoral rock	Rock	Circalittoral	Low
A4.33	Faunal communities on deep low energy circalittoral rock	NULL	Not in classification	Rock	Deep circalittoral	Low
A5.13	Infralittoral coarse sediment	SS.SCS.ICS	Infralittoral coarse sediment	Coarse Sediment	Infralittoral	Any
A5.14	Circalittoral coarse sediment	SS.SCS.CCS	Circalittoral coarse sediment	Coarse Sediment	Circalittoral	Any
A5.15	Deep circalittoral coarse sediment	SS.SCS.OCS	Offshore circalittoral coarse sediment	Coarse Sediment	Deep circalittoral	Any
A5.26	Circalittoral muddy sand	SS.SSa.CMuSa	Circalittoral muddy sand	Sand and muddy sand	Circalittoral	Any
A5.27	Deep circalittoral sand	SS.SSa.OSa	Offshore circalittoral sand	Sand and muddy sand	Deep circalittoral	Any
A5.35	Circalittoral sandy mud	SS.SMu.CSaMu	Circalittoral sandy mud	Mud and sandy mud	Circalittoral	Any
A5.37	Deep circalittoral mud	SS.SMu.OMu	Offshore circalittoral mud	Mud and sandy mud	Deep circalittoral	Any
A5.43	Infralittoral mixed sediments	SS.SMx.IMx	Infralittoral mixed sediments	Mixed sediment	Infralittoral	Any
A5.44	Circalittoral mixed sediments	SS.SMx.CMx	Circalittoral mixed sediments	Mixed sediment	Circalittoral	Any
A5.45	Deep circalittoral mixed sediments	SS.SMx.OMx	Offshore circalittoral mixed sediment	Mixed sediment	Deep circalittoral	Any
A6.1	Deep-sea rock and artificial hard substrata	NULL	Not in classification	Rock	Upper slope	Any
A6.2	Deep-sea mixed substrata	NULL	Not in classification	Mixed sediment	Upper slope	Any
A6.3	Deep-sea sand	NULL	Not in classification	Sand and muddy sand	Upper slope	Any

3.3.2 Bottom-up – Probability-based mapping with Object-Based Image Analysis (OBIA)

Object-oriented (or based) image analysis (OBIA) is an approach that classifies remotely-sensed images and ancillary data based on objects rather than individual pixels. Once identified, objects can be used as input to the powerful set of existing classification routines. In this case, a supervised classification (Maximum Likelihood) was used to produce the resulting habitat maps. Figure 3 shows the stages in the processing.

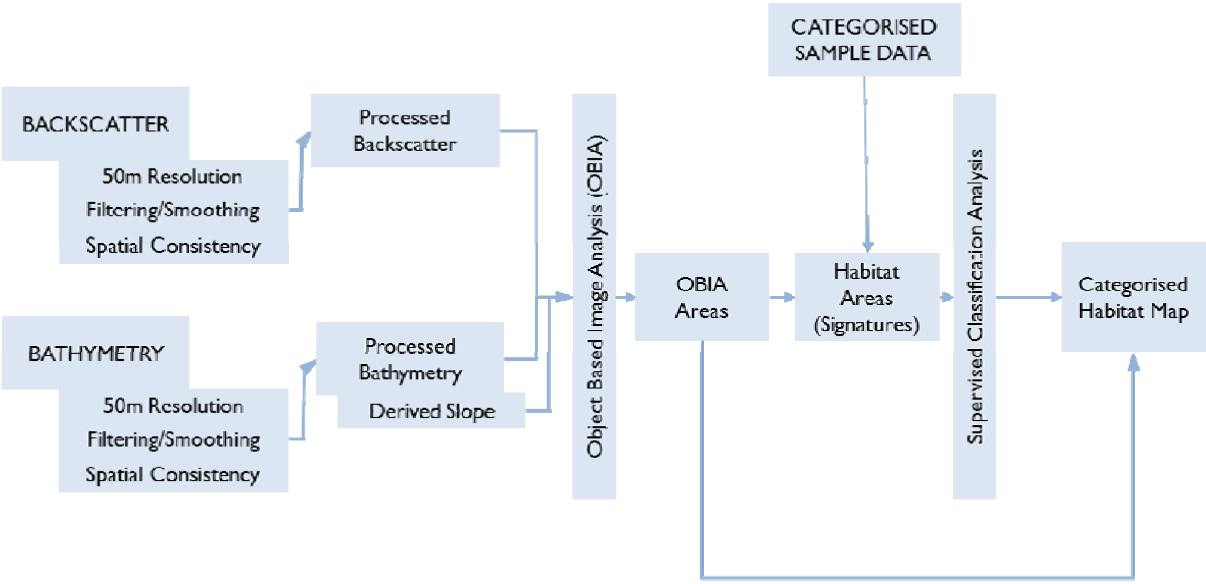

Figure 3. The key stages used with a bottom-up or probabilistic mapping method.

This method used the geophysical datasets of bathymetry and backscatter and also the derived dataset of slope, which enables areas which are raised or sunken relative to the surrounding seabed to be identified. The input datasets were reduced in resolution to 50m for ease of processing and also to represent the data at an appropriate scale to the features to be mapped (refer to section 3.1).

The bathymetry and backscatter images were then processed to identify features within the data which shared a similar physical nature in terms of their shape and variability. This process uses thresholds of size and similarity to assist in detecting areas. The search size is determined by the number of pixels to search using a moving window filter. In this case a 3x3 matrix was used equating to a 150m search which is the highest resolution which can be used. The image is searched and homogenous areas are identified, in that these will have low variability, with edges detected as areas which have higher values of variability.

A similarity tolerance is used to determine when adjacent areas should be joined to form a single area; in this case a value of 50 was used. Investigations into the effect of altering this value were examined and lower values decreased the size of the features detected and produced a very fragmented output with small areas which did not appear to relate to recognisable features. Increasing the value reduces the number of areas detected and a threshold of 90 produced quite large areas. A threshold value of 50 was chosen as a suitable value as this produced areas which seem to relate to recognisable features and patterns which are visually recognisable from the backscatter and bathymetry, in that the boundary lines coincided with distinct changes in backscatter and also related to corresponding changes in the bathymetry and related to the sample site distribution also. Object delineation at similarity tolerance lower than 50 could be due to variation in the backscatter and bathymetric data but these could not be related to the patterns or the distribution of the habitats identified from the sample sites which also applied to similarities greater than 50. Thus 50 was chosen as an appropriate level to use.

Once the polygons (objects) have been created using the OBIA, it was then possible to overlay sample data onto the polygons that intersected the sample positions. As each sample point had been assigned a biotope code to MNCR Level 3 or 4 where possible (See Section 2.1.4) each of the intersecting polygons were then attributed with this code. These polygons were then used as training sites within a supervised classification process.

Supervised classification is a data-driven modelling tool in that the process derives statistical relationships between the input variables and the ground-truth habitats. The training site is like a ‘cookie-cutter’ in that it cuts through all the image layers (bathymetry, backscatter and slope) and extracts the values for each dataset. These values are then used to create the habitat signature. The ‘signature’ is in the form of a statistical probability distribution in as many dimensions as there are input images. The probability distribution is calculated using the maximum likelihood estimator. Each habitat will have its own signature and together they form a signature catalogue.

These signatures are then applied for all the full coverage datasets (bathymetry, backscatter and slope) per area. The spectral values for each pixel (one value per dataset) are matched to the signature catalogue and each pixel is given a probability value of belonging to each habitat category depending upon where it lies in the probability distribution. The corresponding pixel of the habitat image is then assigned to the habitat that has the highest probability.

In addition to the supervised classification process, a further procedure can be used to categorise each of the areas identified by OBIA to one of the mapping categories. The majority category of the most likely habitat is assigned to each of the OBIA polygons to produce a re-categorised map using the OBIA polygon boundaries. This method simplifies the output and removes small features which have not been identified using OBIA but does enable all the identified object features to be mapped.

3.3.3 Supporting data layers

The supervised classification process produces a ‘hard’ classified map which shows the distribution of the most likely habitats as an output layer, and using the signatures it is possible to extract the probability of each habitat as a separate layer. This can aid in the understanding of the map and where confusion between habitats can occur and also a level of certainty of classification can be provided as an output. This indicates where the process has assigned an area to a habitat class, and will assign a high certainty value if there was a high likelihood of this habitat occurring and a very low likelihood of another habitat class occurring. If an area is assigned to a habitat class and there is a low probability of this occurring, or where there are multiple habitat classes with slightly lower probabilities then the certainty score will be lower.

3.3.4 Contextual editing

Each of the maps was reviewed and where there were obvious artefacts, either data gaps or backscatter lines with distinct changes in greyscale to adjacent lines, these were re-categorised to match mapping categories or features of neighbouring objects (Figure 4). This process is subjective and based upon the reviewer’s knowledge and for this reason all re-categorised area were marked as such and the original mapping unit retained to enable any editing to be traced and amended if required.

The classification process can also produce predicted habitats in locations where the occurrence of these would be impossible or improbable. These habitats are mostly determined by depth or biological zone and to rectify this, the biological zones layers from the rule-based approach was used to correct occurrences of incorrectly allocated habitat type. In all cases the original analysis mapping unit was retained for reference but a new mapping unit was used for mapping purposes.

Figure 4. Classified map boundaries show backscatter artefacts (No Data) and areas which have been edited.

3.4 Assumptions

Certain assumptions have been made during the mapping process, which relate to the input data quality, the relationships between the physical and biological environments and the statistical techniques applied when producing the maps.

It is assumed that the biotopes identified from the sample data represent the complete range of biotopes which could be expected to be found within each area and therefore the bottom-up based maps produced using these data represent the expected range of biotopes. If new or modified biotopes are subsequently found to occur within each of the areas the maps may require modification.

When using the sample point data within the bottom-up approach it has been assumed that the biotopes which have been allocated to each sample are correctly assigned. It is understood that allocation of biotopes to sample point data, especially video footage, can be difficult and small changes in sediment composition can significantly alter the biotope assigned. Also it is noted for some areas, the differentiation between offshore sediments and circalittoral sediments is not determined by physical factors such as depth and there can be spatial overlap in that samples identified as offshore and circalittoral can be almost coincident, which can influence the predicted distribution of these sediments within an area as the sample data would suggest the two different habitats can occur together. In order to compensate for this contextual editing has been employed to introduce a level of consistency to the maps produced.

The spatial accuracy of all data is assumed to be correct for all map products. The spatial resolution of the mapping is effectively 50m which should be within tolerances and accuracy of most modern position fixing equipment but it may be that positional offsets or rounding of figures may affect the recorded position and also some data is relatively old and therefore of lower spatial accuracy.

Using acoustic data to predict biological habitats assumes that the physical attributes of the seabed detected by the acoustic equipment represent the environmental parameters and habitat which determine the ecological conditions suitable for each biotope mapped. The acoustic equipment have been designed to detect the physical environment but not the ecological component of this, and therefore discrepancy between the predicted ecology and the actual ecology found should be expected and should be considered when referring to or utilising the spatial distribution of habitats. This is primarily relevant to the bottom-up approach which uses these data to derive the resulting maps but also the rule-based maps use a seabed substrate layer which similarly derived from the acoustic data using similar assumptions.

Within the rule-based mapping, using physical parameters to determine the distribution of biological zones and energy regimes matched with seabed substrate assumes these parameters are accurately determined and can predict the biological habitat/biotope which occurs within the range of parameters mapped.

This range of assumptions do lead to a level of uncertainly within all the predictive maps produced and users of the predictive maps should be aware of the maps limitations in terms of spatial accuracy and predictive accuracy. Confidence levels are produced for each map which can assist when using the maps but understanding the assumptions made during the mapping process can also aid in the understanding of the habitat maps.

3.5 Approaches to the Firth of Forth and Wee Bankie to Gourdon

3.5.1 Acoustic data

The acoustic dataset for the Approaches to the Firth of Forth and the Wee Bankie to Gourdon areas were initially separate and also contained variations between survey and processing or acquisition artefacts. These data were prepared and processed together to reduce these anomalies and also to provide a consistent image for the two areas using identical resolutions and spatial parameters. Figure 5 shows the bathymetric dataset post-processing and Figure 6 shows the backscatter data post-processing.

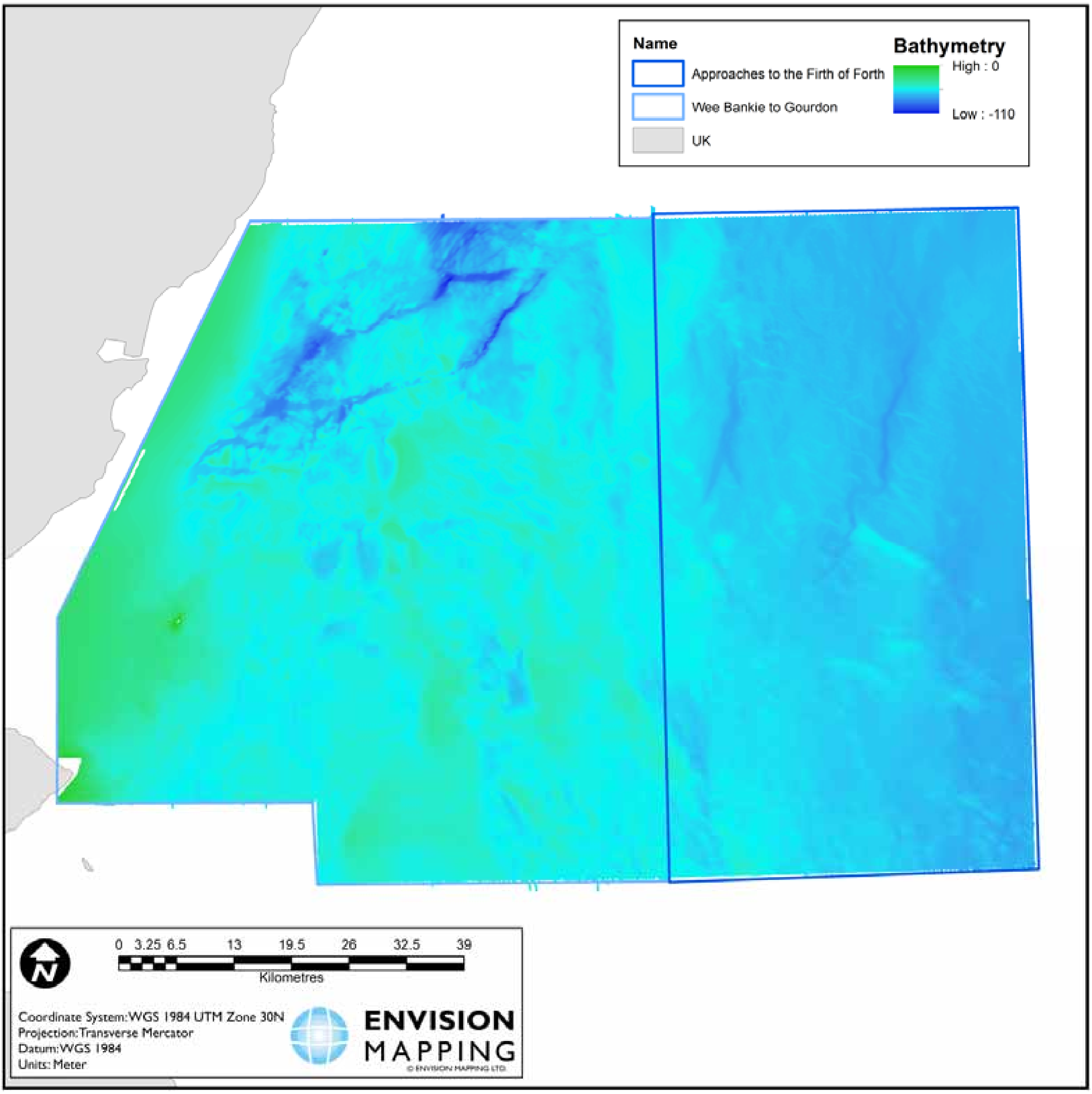

Figure 5. Processed bathymetry data for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas.

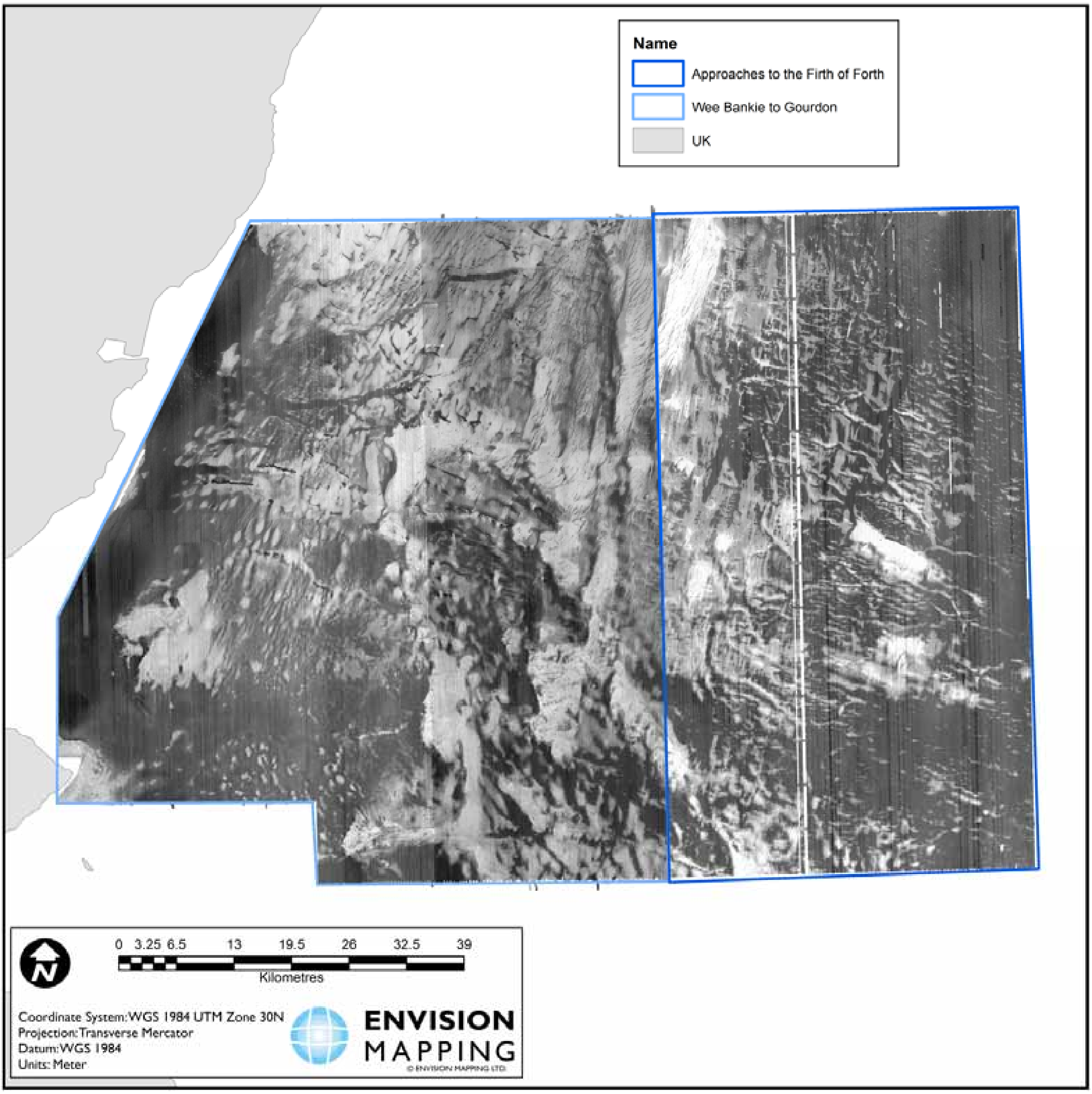

Figure 6. Processed backscatter data for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas.

The preparation and processing of the acoustic data reduces the original resolution of the data but does allow for consistency throughout the data set and seamless processing. Some artefacts still exist within the backscatter data and any influence these have upon maps produced from these data have been edited using contextual editing and review.

3.5.2 Physical parameters

The definition for the infralittoral category of the EUSeaMap biological zones layer has been refined since the production of the original EUSeaMap layer (Cameron and Askew, 2011), with a new light penetration limit of 4.5% defining the boundary between infralittoral and circalittoral (EUSeaMap, 2012b). The generation of a new biological zones layer (Figure 7) was required to take account of this change and shows the EUSeaMap original biological zones layer for the areas and the new updated biological zones. The infralittoral zone is considerably reduced within the areas and is restricted to very shallow inshore areas and an area around a rocky out crop (Bell Rock).

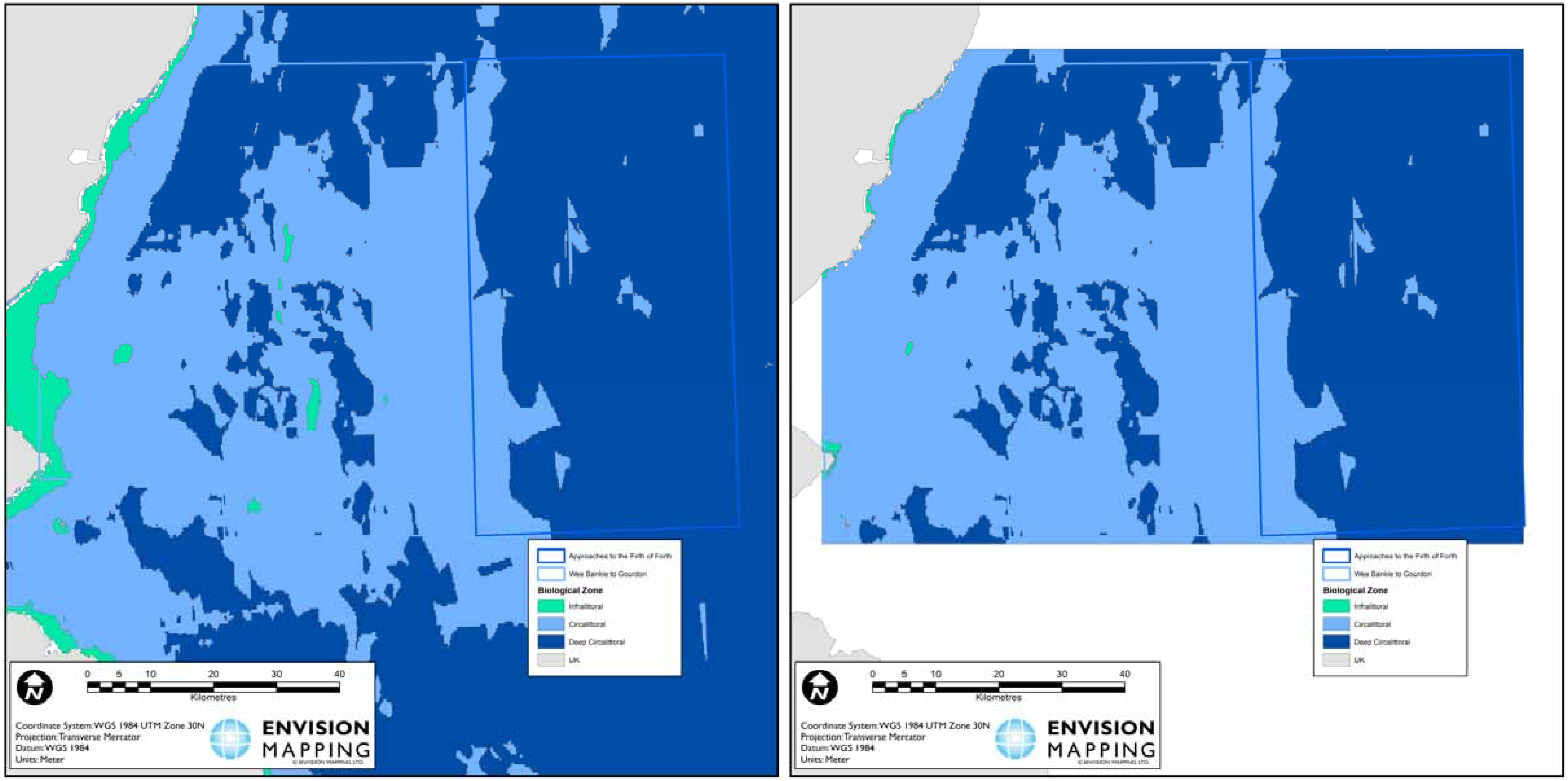

Figure 7. EUSeaMap biological zones data (left) and reclassified data (right) for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas.

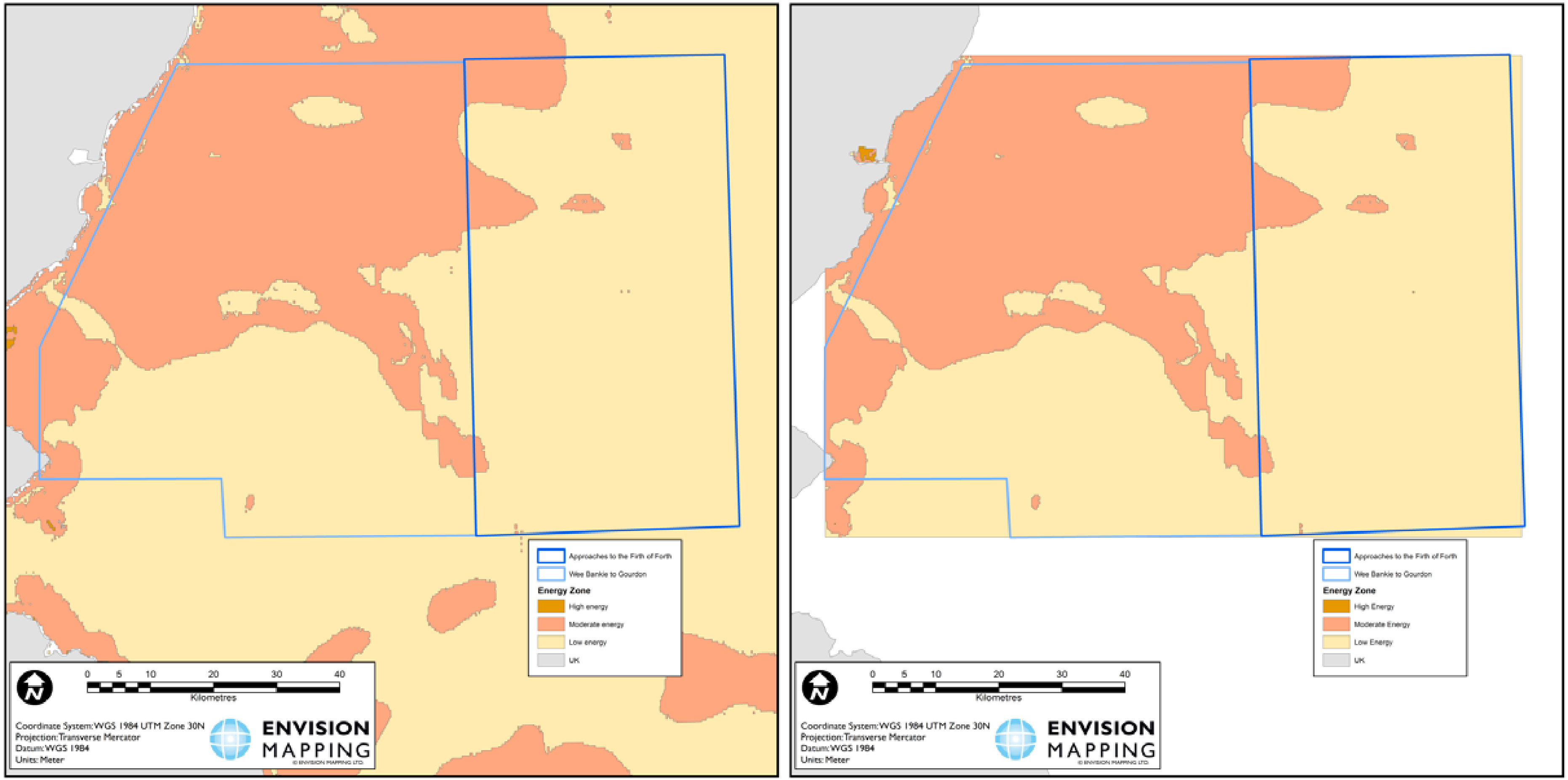

Figure 8. EUSeaMap seabed energy data (left) and reclassified data (right) for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas.

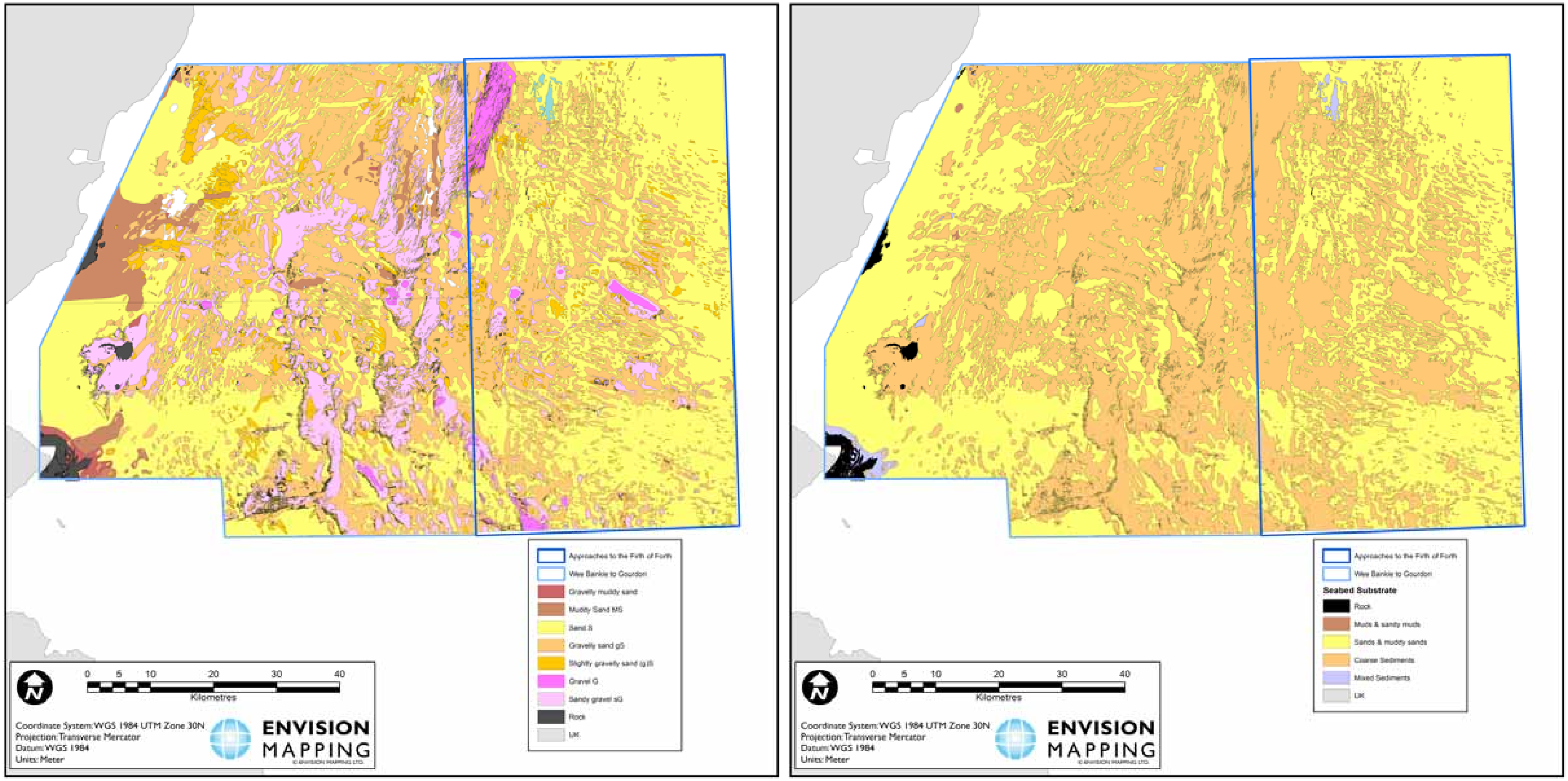

Figure 9. Seabed Substrates according to Folk classes (left) and reclassified data (right) for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas.

An updated seabed energy layer was also generated at a resolution matching the processed acoustic data and the newly generated biological zones layer. Figure 8 shows the original and newly produced energy layers in comparison. Only very small changes are obvious and slight changes in boundaries have occurred due to the change in resolution.

The top-down approach uses seabed substrate classes based upon a simplified Folk classification and the supplied BGS seabed substrate map was used with the substrates grouped using this scheme. Figure 9 shows the seabed substrates according to the Folk classification in comparison with the simplified seabed substrates. This reclassification amalgamates the sandy gravels into the coarse sediment categories and also the muddy sands into the sands category and this should be considered when reviewing the top-down based map.

Using these three input layers of seabed substrate, seabed energy and biological zones, the matrix shown in Table 4 was used to place all areas into the appropriate habitat category according to the rule-based top down methodology.

3.5.3 Samples & Mapping Units – for bottom-up approach

963 samples were available for use within the area to be mapped and these samples contained 32 classifications (some of which were proposed and therefore not official) (MNCR 04.05) (Figure 10) which were reviewed and refined to produce 12 mapping categories (Axelsson *et al* 2012; Pearce *et al* 2012).

The EUNIS habitats used as mapping units used for the bottom-up mapping for the Firth of Forth and Wee Bankie to Gourdon area are listed in Table 5, alongside the 'higher' level biotopes which fall within these mapping categories. The majority of mapping units and biotopes associated with these are physically similar habitats with a variation in infaunal communities or small variations in epifaunal elements.

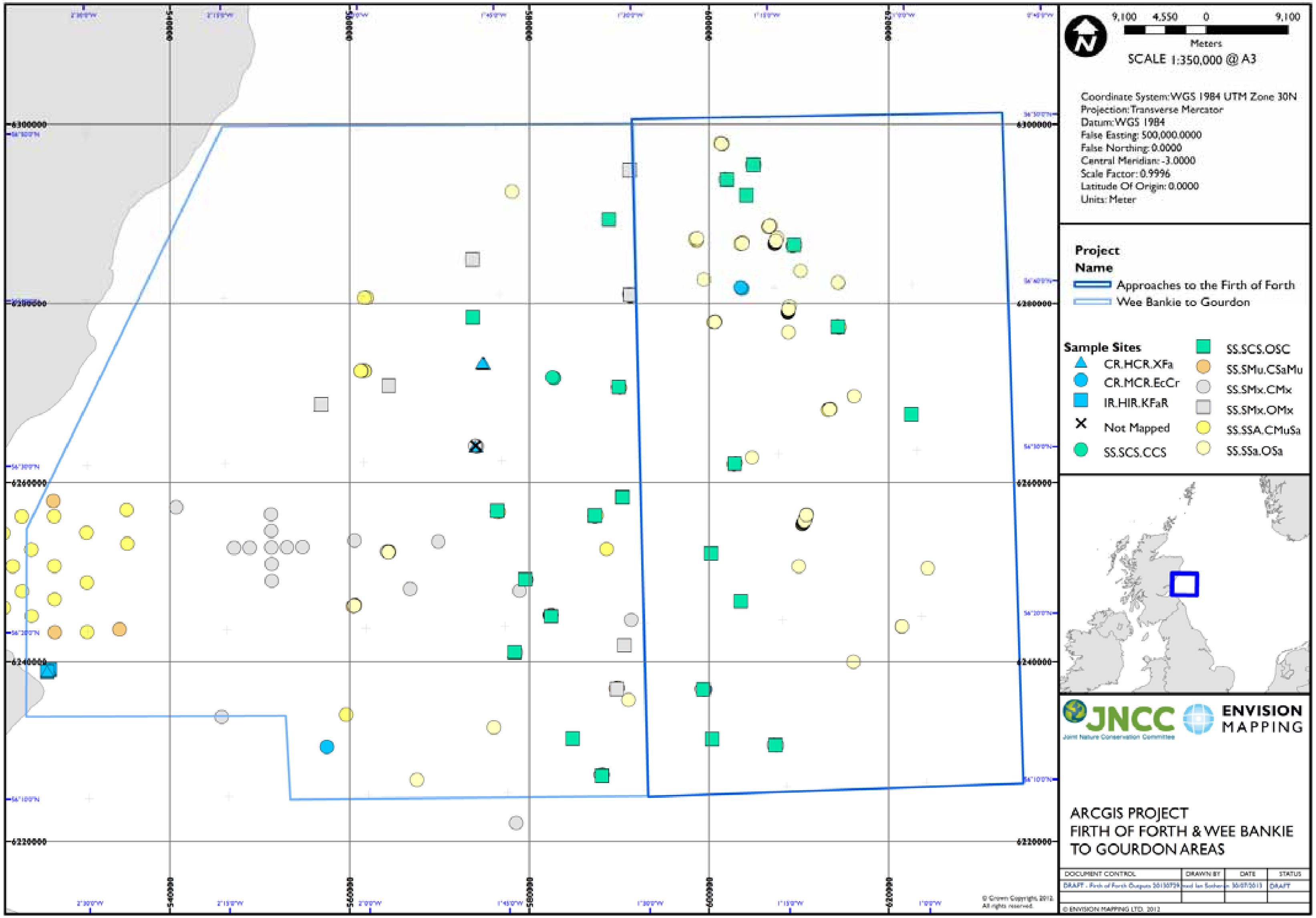

Figure 10. Sample points used for bottom up mapping for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas.

Table 5. The EUNIS Habitats used for mapping the Firth of Forth and Wee Bankie to Gourdon areas and the MNCR Biotopes associated with each.

EUNIS Code	Mapping unit name	MNCR Habitats identified from samples[9]
A3.11	Kelp with cushion fauna and/or foliose red seaweeds	IR.HIR.KFaR.FoR.Dic; IR.HIR.KFaR.LhypRVt
A4.13	Mixed faunal turf communities on circalittoral rock	CR.HCR.XFa.FluCoAs.X CR.HCR.XFa.(FluCoAs.X) CR.HCR.XFa.FluCoAs.SmAs CR.HCR.XFa.FluCoAs
A4.27	Faunal communities on deep moderate energy circalittoral rock	As A4.13 but determined by biological zone and energy levels
A4.33	Faunal communities on deep low energy circalittoral rock	As A4.13 but determined by biological zone and energy levels
A5.14	Circalittoral coarse sediment	SS.SCS.CCS SS.SCS.CCS.PomB
A5.15	Deep circalittoral coarse sediment	SS.SCS.OCS; SS.SCS.OCS.[PoGintBy]; SS.SCS.OCS.[Sbom]
A5.26	Circalittoral muddy sand	SS.SSA.CMuSa SS.SSa.CMuSa.AalbNuc
A5.27	Deep circalittoral sand	SS.SSa.OSa SS.SSa.OSa.[Sbom]
A5.35	Circalittoral sandy mud	SS.SMu.CSaMu SS.SMu.CSaMu.ThyNten SS.SMu
A5.37	Deep circalittoral mud	As A5.35 but determined by deep circalittoral biological zone
A5.44	Circalittoral mixed sediments	SS.SMx.CMx.OphMx SS.SMx.CMx.(OphMx) SS.SMx.CMx SS.SMx.CMx.(FluHyd) SS.SMx.CMx.MysThyMx SS.SMx SS.SBR.PoR.SspiMx (note 1)
A5.45	Deep circalittoral mixed sediments	SS.SMx.OMx.[PoGintBy]
	Not Mapped (note 2)	SS.SBR.SMus.ModMx

[9] MNCR Habitats identified from samples which include parentheses are ones which have been proposed by those who have analysed the survey sample data

EUNIS Code	Mapping unit name	MNCR Habitats identified from samples[9]
	Not Mapped (note 3)	CR.MCR.EcCr.FaAlCr.Adig CR.MCR.EcCr.FaAlCr.Flu CR.MCR
	Not Mapped (note 4)	SS.SMu.CFiMu.SpnMeg

Three mapping units or groups of biotopes were not mapped. In some cases this was due to the fact that the sample points representing these were singletons which could not be mapped in a representative way and point sample data is probably the most effective manner of representing these habitats within a map. Two samples were categorised as SS.SMu and when factored into the processing gave what was considered to be an overestimation of this habitat. When adjacent samples were examined a sandier habitat was suggested and for this reason the SS.SMu habitat was amalgamated into the A5.35 Circalittoral sandy mud category.

Notes:

1. SS.SBR.PoR.SspiMx – This *Sabellaria* biotope was not mapped as it occurred in three grab samples for which coincident video samples showed a mixed substrate and no distinct area could be identified to generate a signature and surrounding samples showed the site to be dominated by mixed sediments. The locations of this habitat are best represented as point samples overlain on the habitat distribution maps.
2. SS.SBR.SMus.ModMx was not mapped as this biotope occurred only at a single sample site and no distinct area could be identified to generate a signature and surrounding samples showed the site to be dominated by mixed sediments. The location of this habitat is best represented as a point sample overlain on the habitat distribution maps
3. CR.MCR.EcCr.FaAlCr.Adig; CR.MCR.EcCr.FaAlCr.Flu were discrete sample stations which appeared to be situated in a surrounding sediment habitat of sand and mixed sediments and these samples may be small exposed rocks rather than extensive areas of rock features.
4. SS.SMu.CFiMu.SpnMeg was recorded in one video and an associated photo sample at one site which was dominated by SS.SMu.CSaMu. The location of this habitat is best represented as a point sample overlain on the habitat distribution maps.

3.6 Solan Bank to Fair Isle Channel

3.6.1 Acoustic Data

The bathymetric and backscatter datasets were processed to produce consistent datasets for the whole area. Figure 11 shows the processed bathymetry datasets which show very little alteration in the data. The processed backscatter data (Figure 12) shows a contrast change in the data producing more distinct boundaries between features.

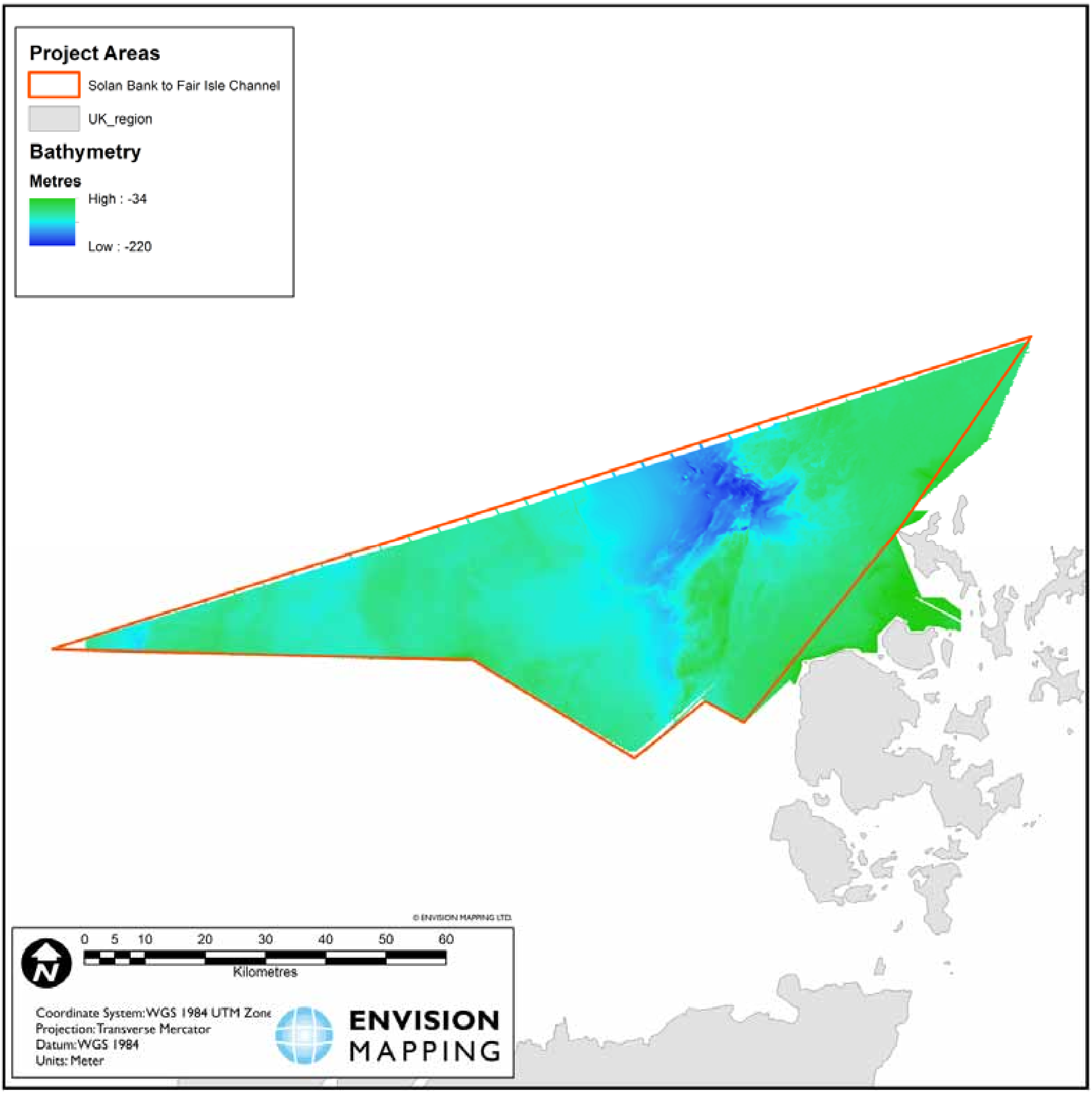

Figure 11. Processed bathymetry data for the Solan Bank to Fair Isle Channel area.

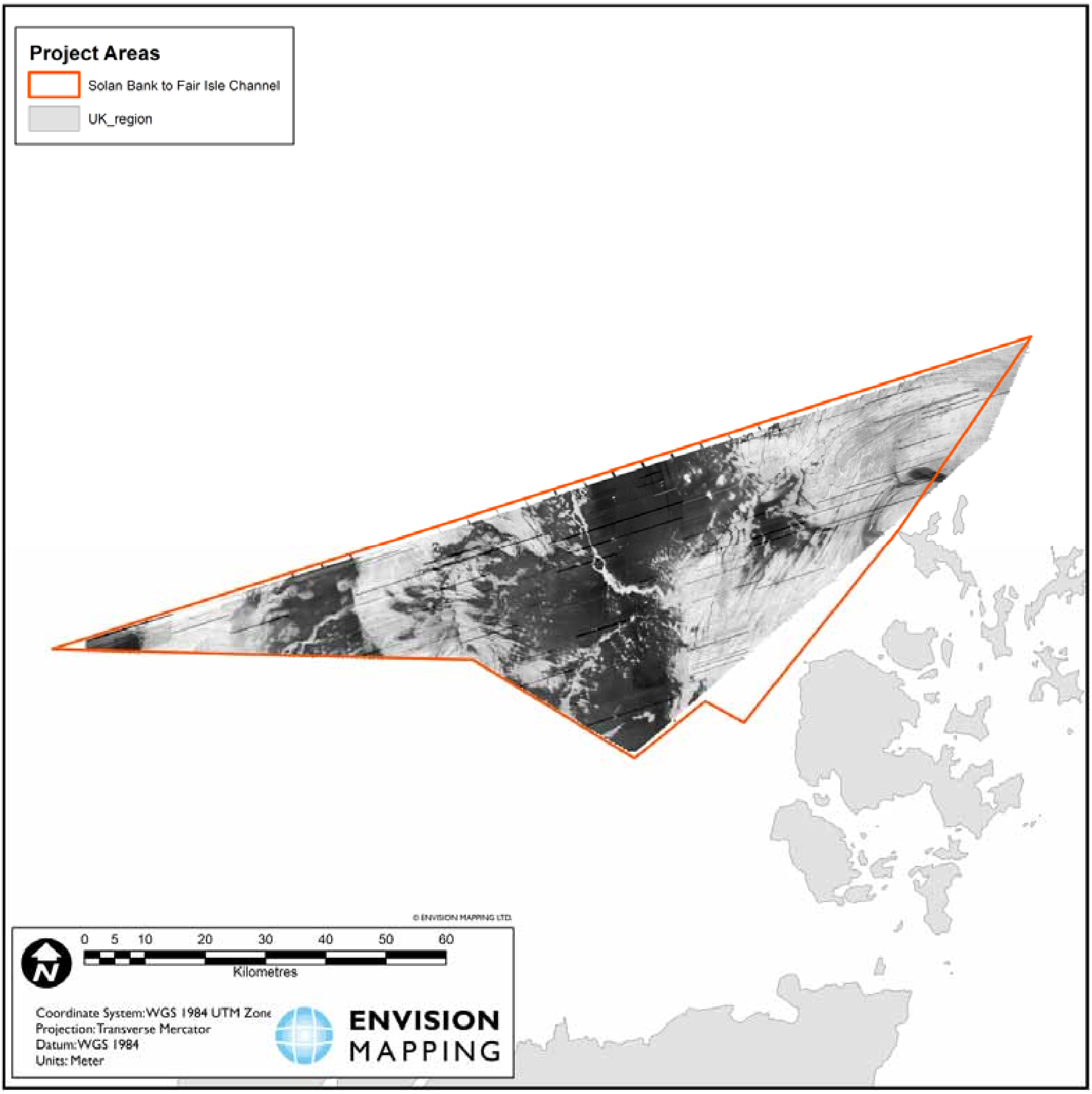

Figure 12. Processed backscatter data for the Solan Bank to Fair Isle Channel area.

The backscatter data does contain a relatively large amount of acquisition artefacts with changes in gain or power settings resulting in some survey lines that contain distinctly different values to those of adjacent survey lines and these can be seen more clearly in Figure 13.

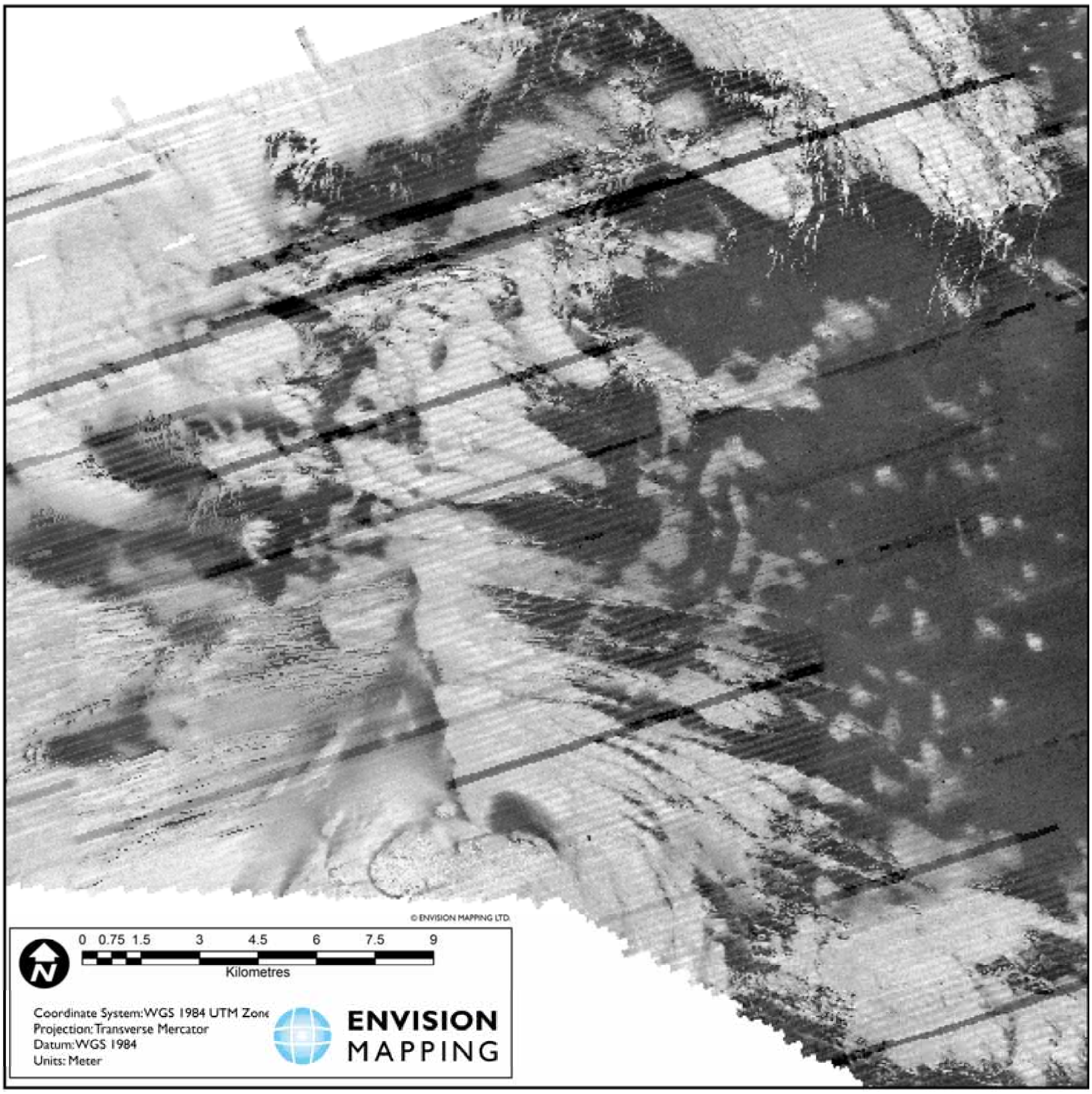

Figure 13. Solan Bank to Fair Isle Chanel backscatter data showing acquisition artefacts (darker and lighter lines).

3.6.2 Physical Parameters

The definition for the infralittoral category of the EUSeaMap biological zones layer has been refined since the production of the existing EUSeaMap layer with a new light penetration limit of 4.5% defining the boundary between infralittoral and circalittoral (EUSeaMap, 2012b). The generation of a new biological zones layer was required to take account of this change and Figure 14 shows the EUSeaMap original biological zones layer for the area and the new updated biological zones.

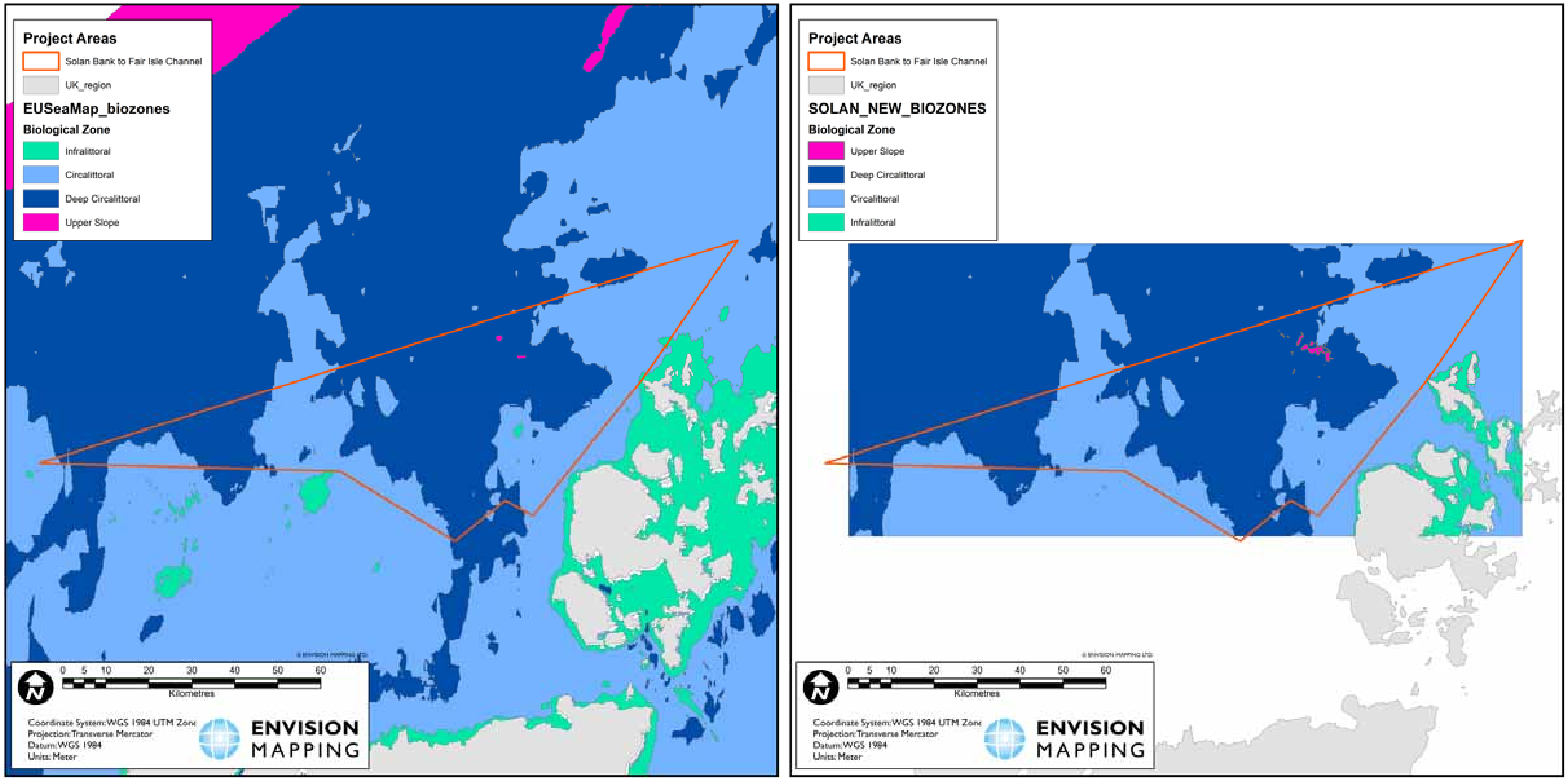

Figure 14. EUSeaMap biological zones data (left) and reclassified data (right) for the Solan Bank to Fair Isle Channel area.

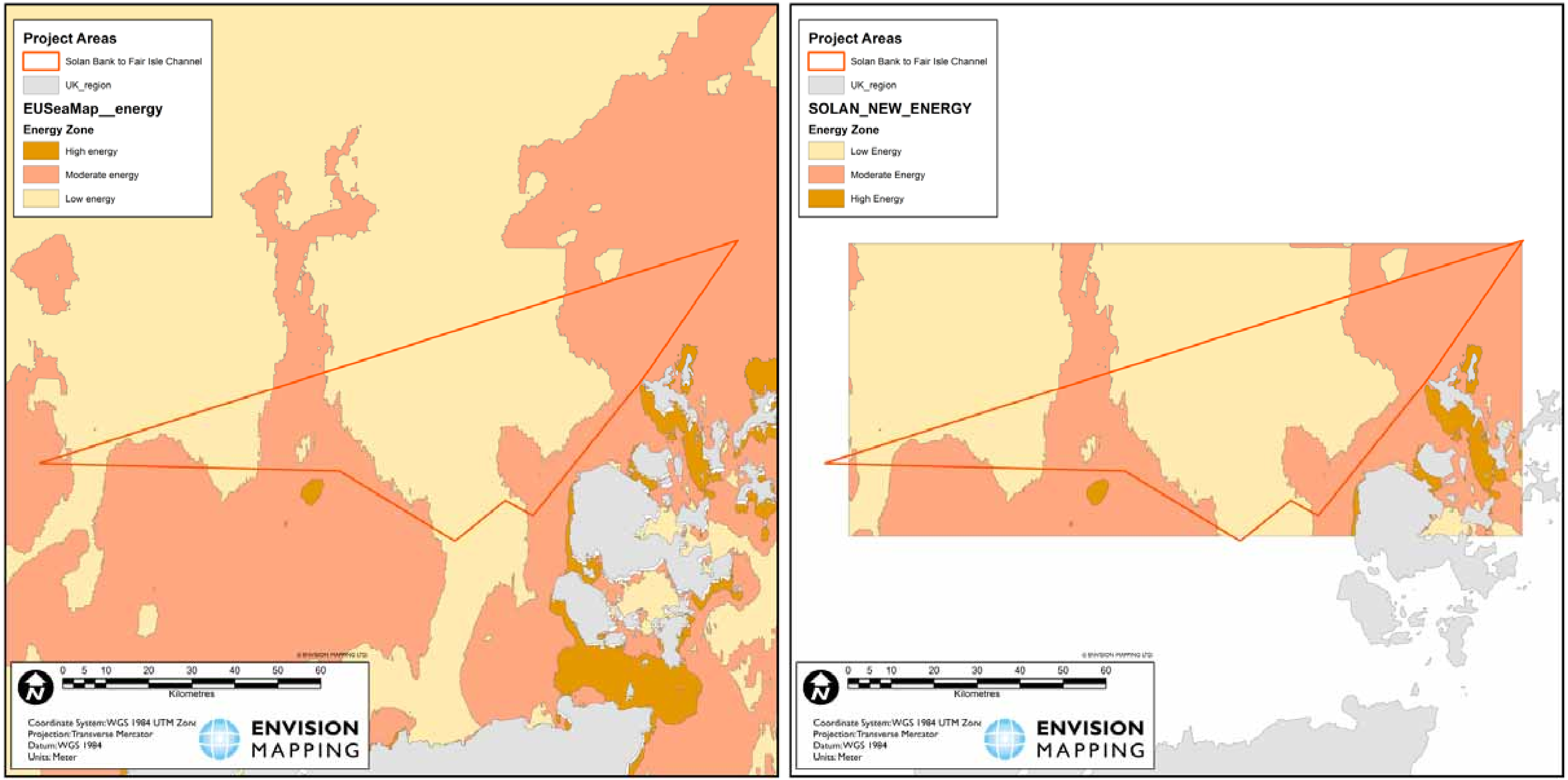

Figure 15. EUSeaMap seabed energy data (left) and reclassified data (right) for the Solan Bank to Fair Isle Channel area.

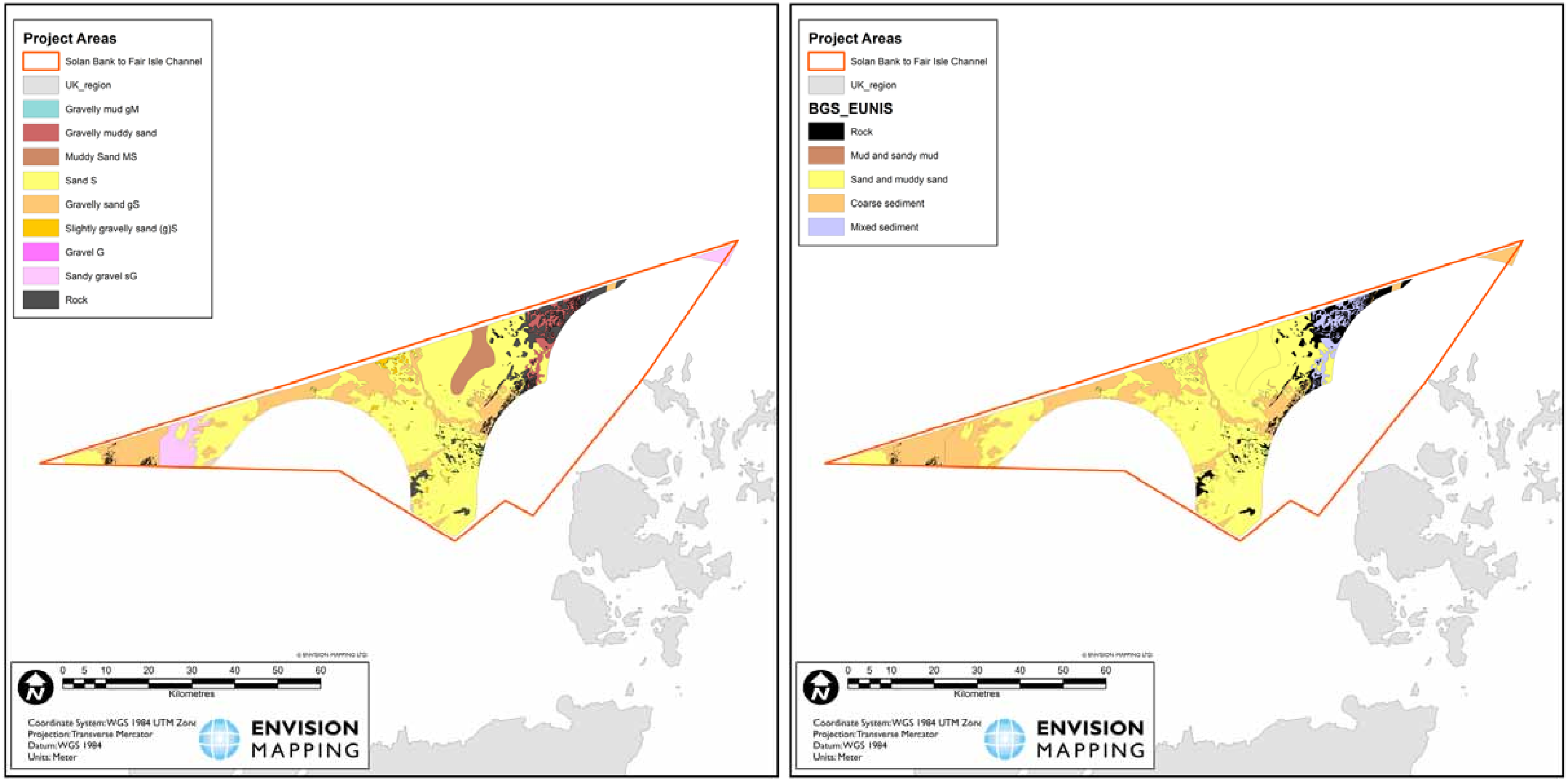

Figure 16. BGS Seabed Substrates (left) and reclassified data (right) for the Solan Bank to Fair Isle Channel area.

The updated biological zones result in the area no longer contain any infralittoral regions, and the upper slope regions have been refined using the updated 200m contour from the recent bathymetry data.

An update of the seabed energy levels within the area has been generated but this update has had very little impact on the distribution of the zones, but did provide updated boundaries at an appropriate resolution.

The BGS seabed substrates have only been provided from the area outside the 12 nautical mile boundary due to initial project drivers (i.e. mapping the offshore sands and gravel MPA search feature) and these data have been used within the top-down mapping methodology using the simplified substrate classification. Figure 16 illustrates the original BGS substrates categories with the simplified classes on the right. The muddy sediments in the central region have become incorporated into the sands and muddy sand category and the gravel area in the west of the area are mapped as coarse sediments.

The biological zones, seabed energy and seabed substrate layers were used within the top-down mapping methodology to produce a rule-based map of the expected habitats.

3.6.3 Samples & mapping units – for bottom-up approach

80 samples were available for use within the area to be mapped and these samples contained 5 biotopes (MNCR 4.05) (Figure 17), 62 of these samples were comprised of video/still samples collected at two stations surveyed opportunistically during the downtime of a trawl survey. Due to the restricted distribution of these samples, other habitat data were incorporated by using the BGS sample points which were categorised to the simplified classes (i.e. EUNIS Level 3) and used to increase the range and distribution of sample points.

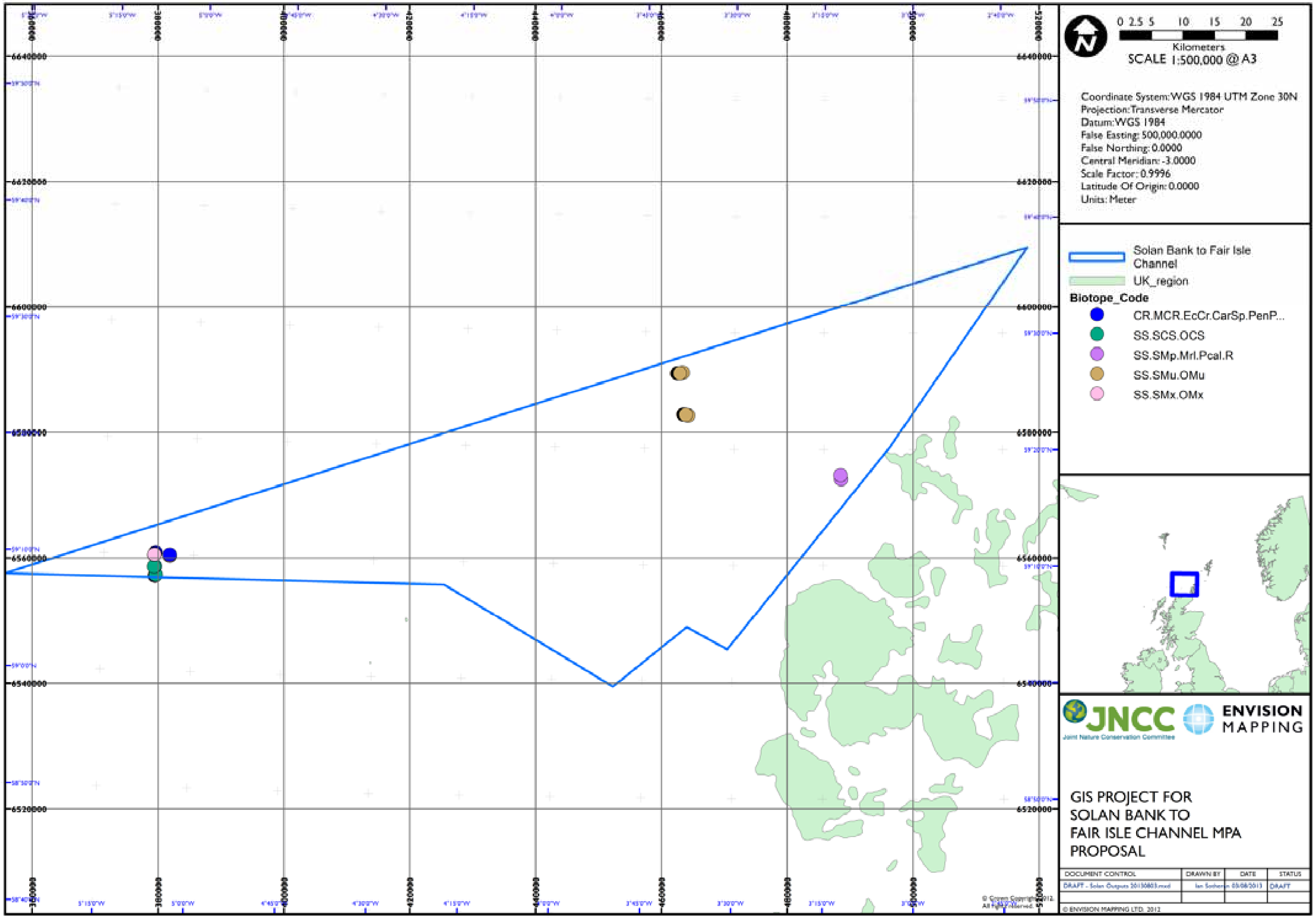

Figure 17. Biological sample points for the Approaches to the Solan Bank to Fair Isle Channel area.

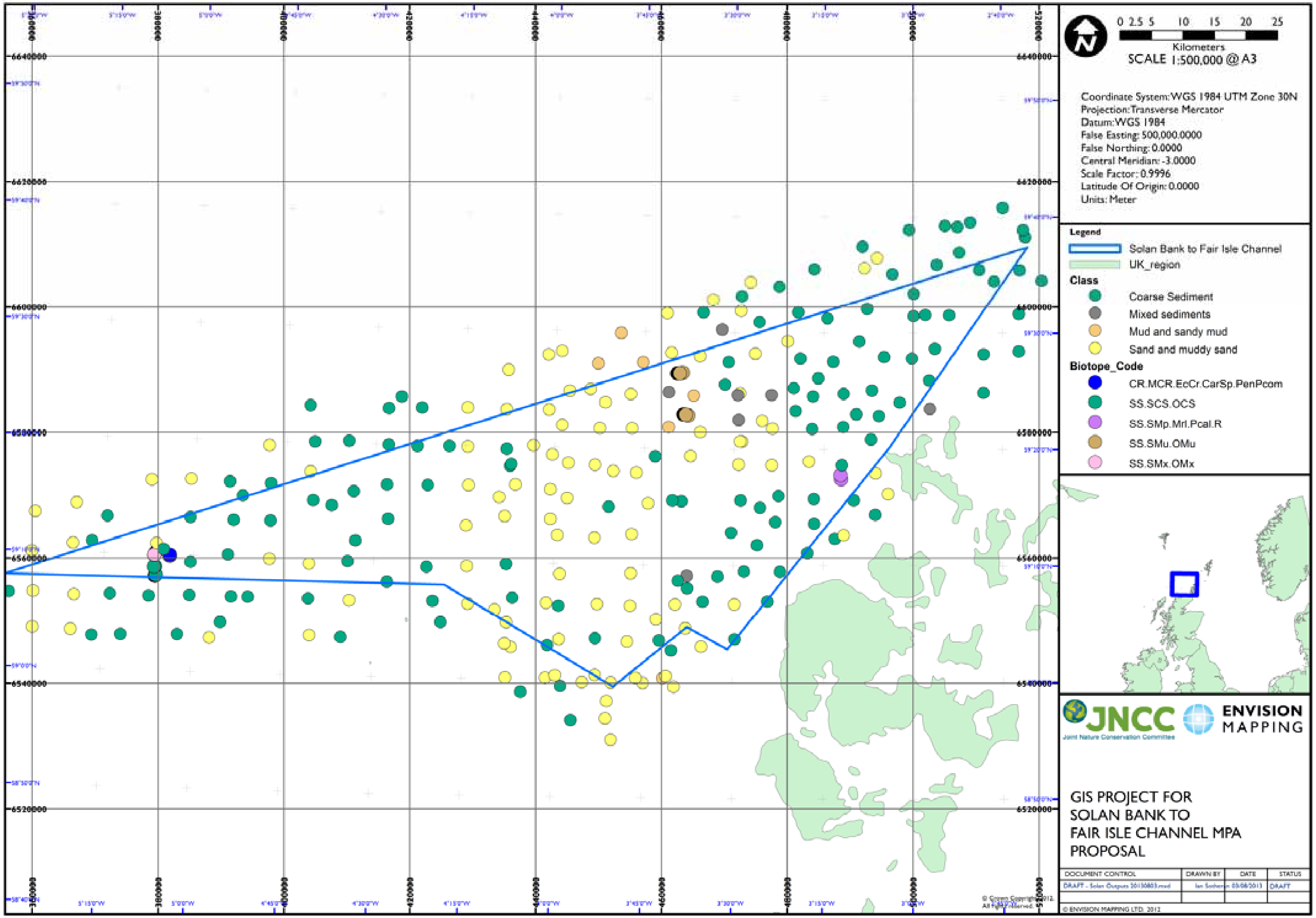

Figure 18. Sample points used for bottom up mapping for the Approaches to the Solan Bank to Fair Isle Channel area.

Using the BGS sample point data along with areas which had been identified as rock through the substrate mapping enabled the sands and muds and rock habitats to be incorporated into the mapping process which would have otherwise been omitted or severely underrepresented.

The range of samples were reviewed and refined to produce the 12 EUNIS habitats used as mapping units (Table 6).

Table 6. The EUNIS Habitats used for mapping the Solan Bank to Fair Isle area and the MNCR Biotopes associated with each.

EUNIS Code	Mapping unit name	MNCR Habitats identified from samples & BGS data
A4.3	Atlantic and Mediterranean low energy circalittoral rock	BGS Substrate: Rock but determined by circalittoral biological zone and low energy levels
A4.33	Faunal communities on deep low energy circalittoral rock	BGS Substrate: Rock but determined by deep circalittoral biological zone and low energy levels
A5.13	Infralittoral coarse sediment	As A5.15 but determined by infralittoral biological zone
A5.14	Circalittoral coarse sediment	As A5.15 but determined by circalittoral biological zone
A5.15	Deep circalittoral coarse sediment	SS.SCS.OSC; SS.SMx.OMx (note 1)
A5.26	Circalittoral muddy sand	As A5.27 but determined by circalittoral biological zone
A5.27	Deep circalittoral sand	BGS Substrate: Sand and muddy sands
A5.35	Circalittoral sandy mud	As A5.37 but determined by circalittoral biological zone
A5.37	Deep circalittoral mud	SS.SMu.OMu
A6.1	Deep-sea rock and artificial hard substrata	BGS Rock and determined by upper slope biological zone
A6.2	Deep-sea mixed substrata	As A5.15 but determined by upper slope biological zone
A6.3	Deep-sea mud	As A5.37 but determined by upper slope biological zone
	Not mapped (note 2)	SS.SMp.Mrl.Pcal.R
	Not mapped (note 3)	CR.MCR.EcCr.CarSp.PenPcom

Notes:

1. SS.SMx.OMx – This habitat was mapped within the coarse sediment classes as it occurred in samples for which MNCR and BGS samples showed a coarse substrate. No distinct area could be identified to generate a signature and surrounding samples showed the site to be dominated by mixed sediments.
2. SS.SMp.Mrl.Pcal.R ModMx was not mapped as this biotope occurred only at two sample sites at the periphery of the acoustic data and no distinct area could be identified to generate a signature to differentiate the areas from the surrounding substrate. The locations of this habitat are best represented as point samples overlain on the habitat distribution maps.
3. CR.MCR.EcCr.CarSp.PenPcom were at discrete sample stations which appeared to be situated in a surrounding sediment habitat of coarse sediments and these

samples may be small exposed rocks rather than extensive areas of rock features. The locations of this habitat are best represented as point samples overlain on the habitat distribution maps.

3.7 West Shetland Shelf (Windsock)

3.7.1 Acoustic Data

The bathymetric and backscatter datasets were processed to produce consistent data sets for the whole area. Figure 19 and Figure 20 show the processed bathymetry datasets for the western and eastern sections. The processed bathymetric data has very few differences to the original.

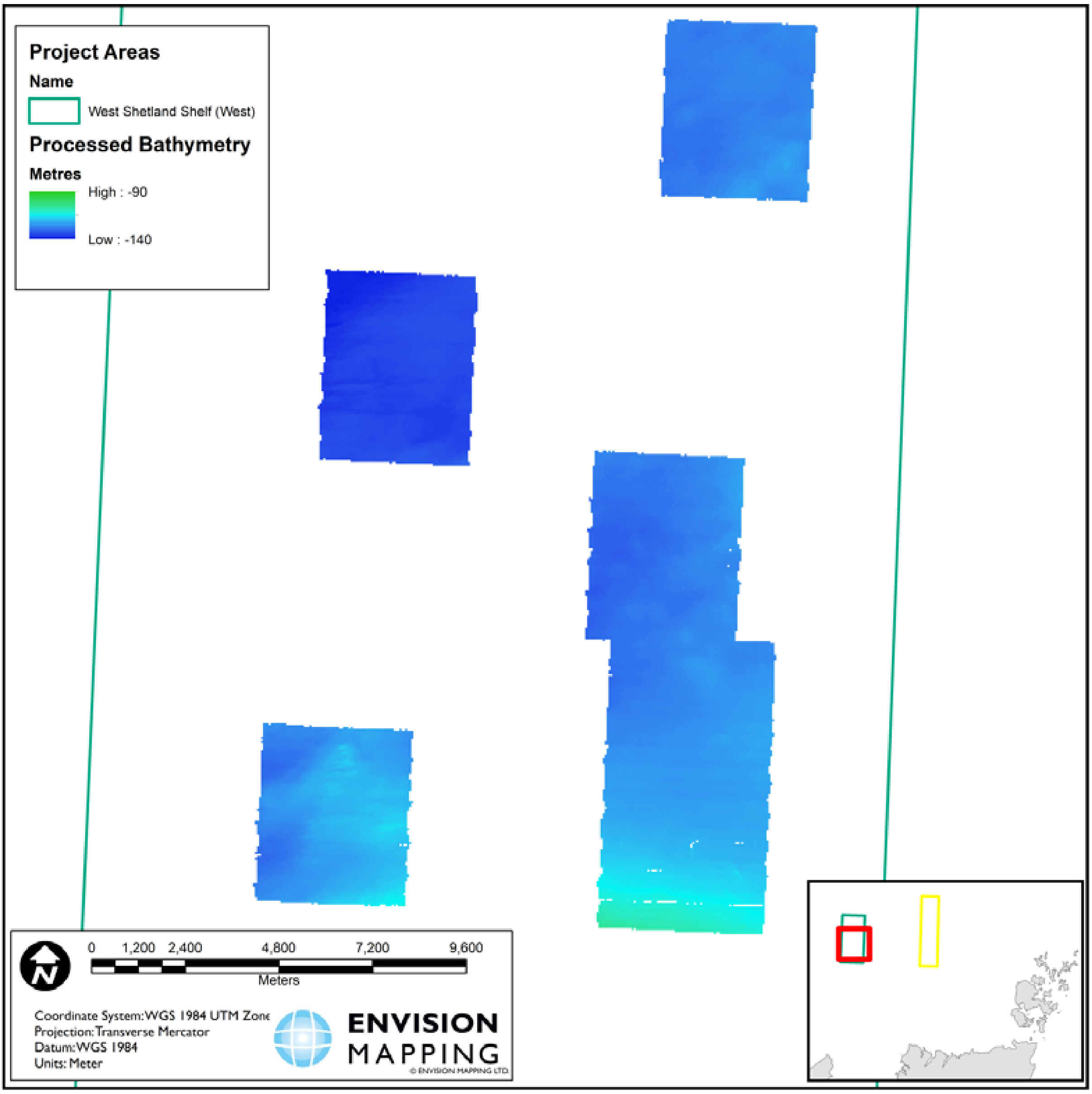

Figure 19. West Shetland Shelf Western Area: orginal bathymetry data (left) and processed data (right).

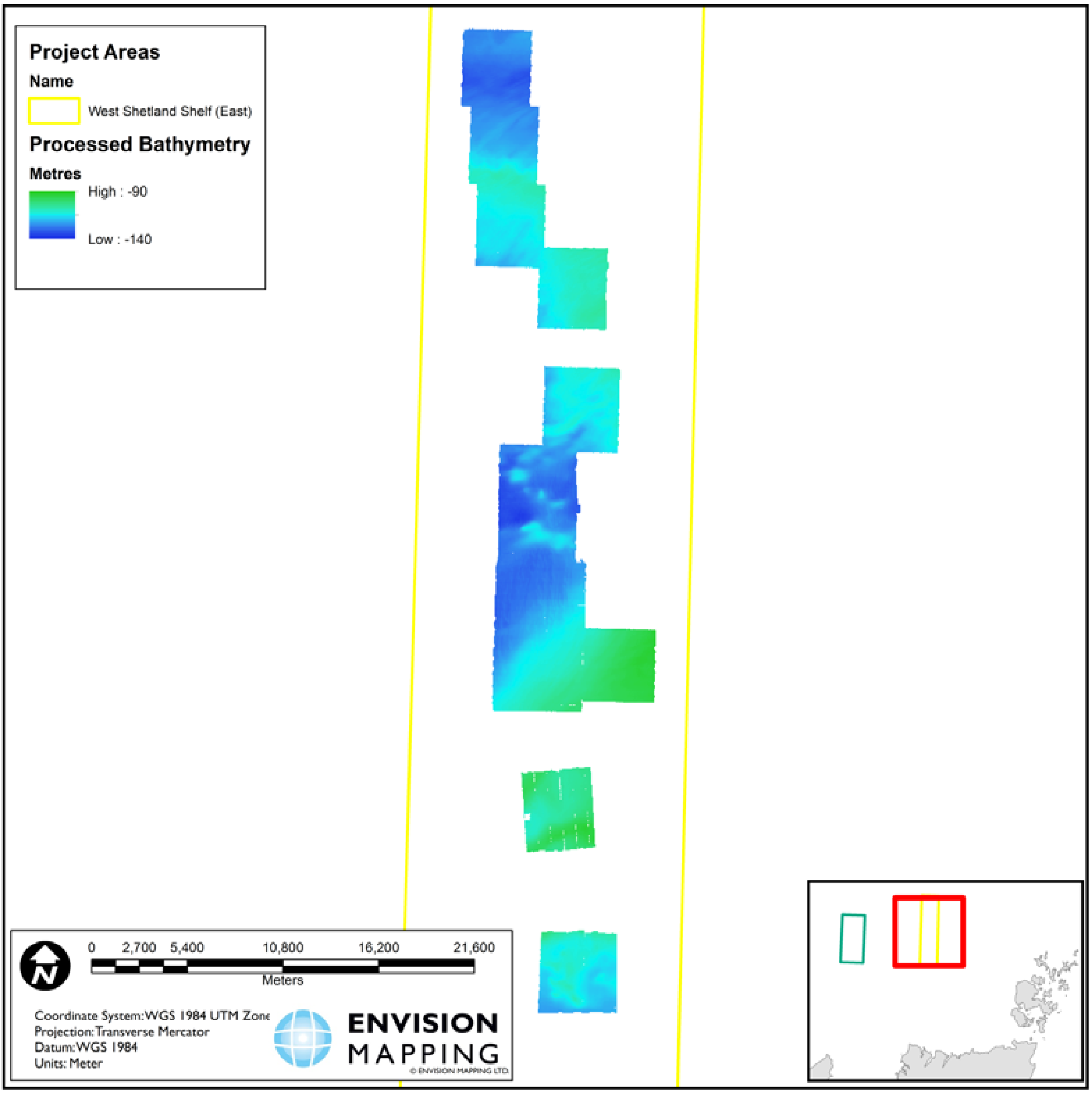

Figure 20. West Shetland Shelf Eastern Area: orginal bathymetry data (left) and processed data (right).

The backscatter data for the West Shetland Shelf area required a considerable amount of processing which involved the reduction of the resolution of the data and some heavy smoothing to remove acquisition artefacts and noise within the data.

The original and processed backscatter data (Figure 21 and Figure 22) shows the contrast change in the data producing more distinct boundaries between features although some of the finer details within the data are lost. Only the broader features with coarse outlines are retained due to the noise and erroneous data which has been collected along the centreline of the backscatter swath (Figure 23).

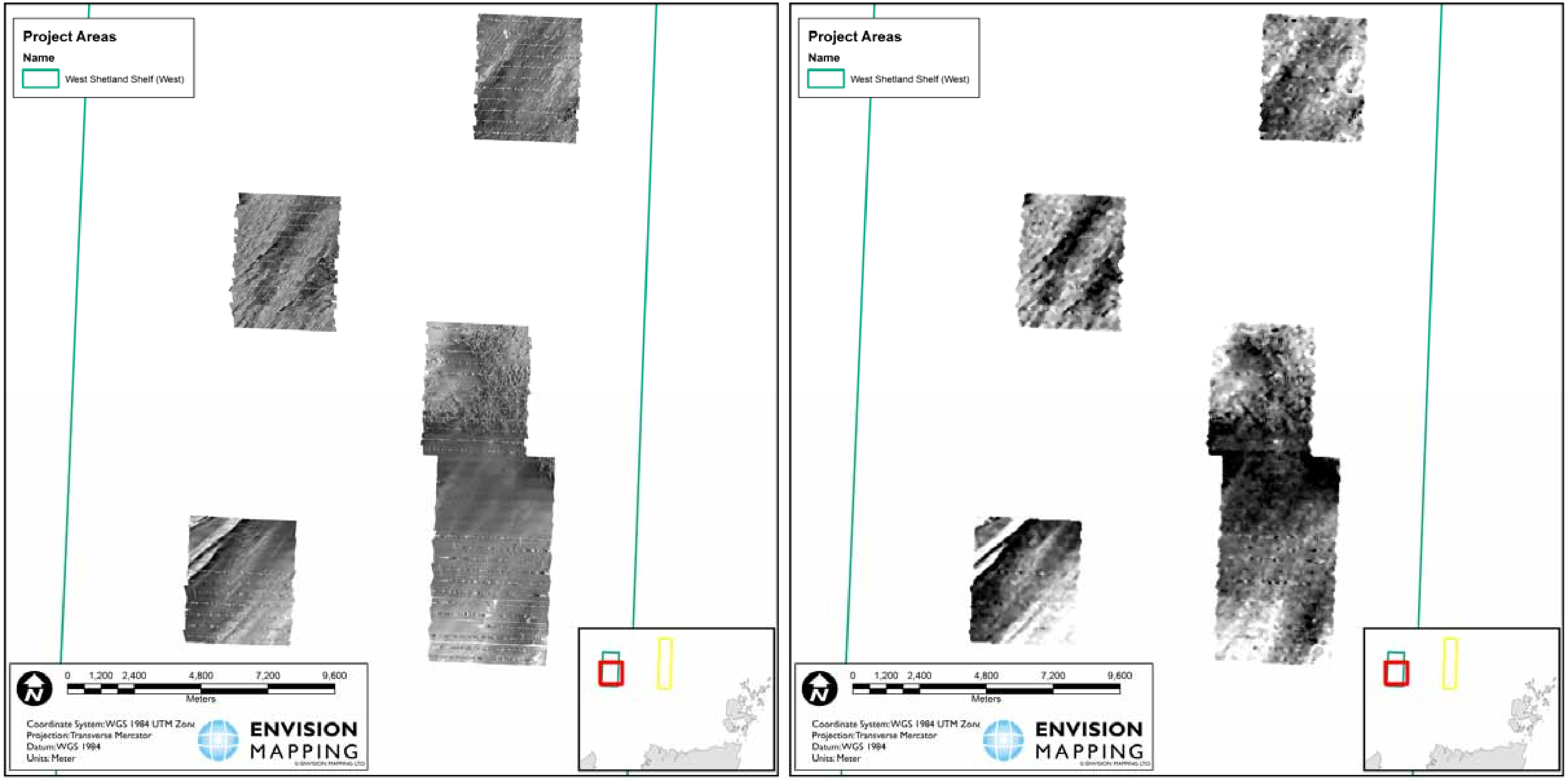

Figure 21. West Shetland Shelf Western Area: orginal backscatter data (left) and processed data (right).

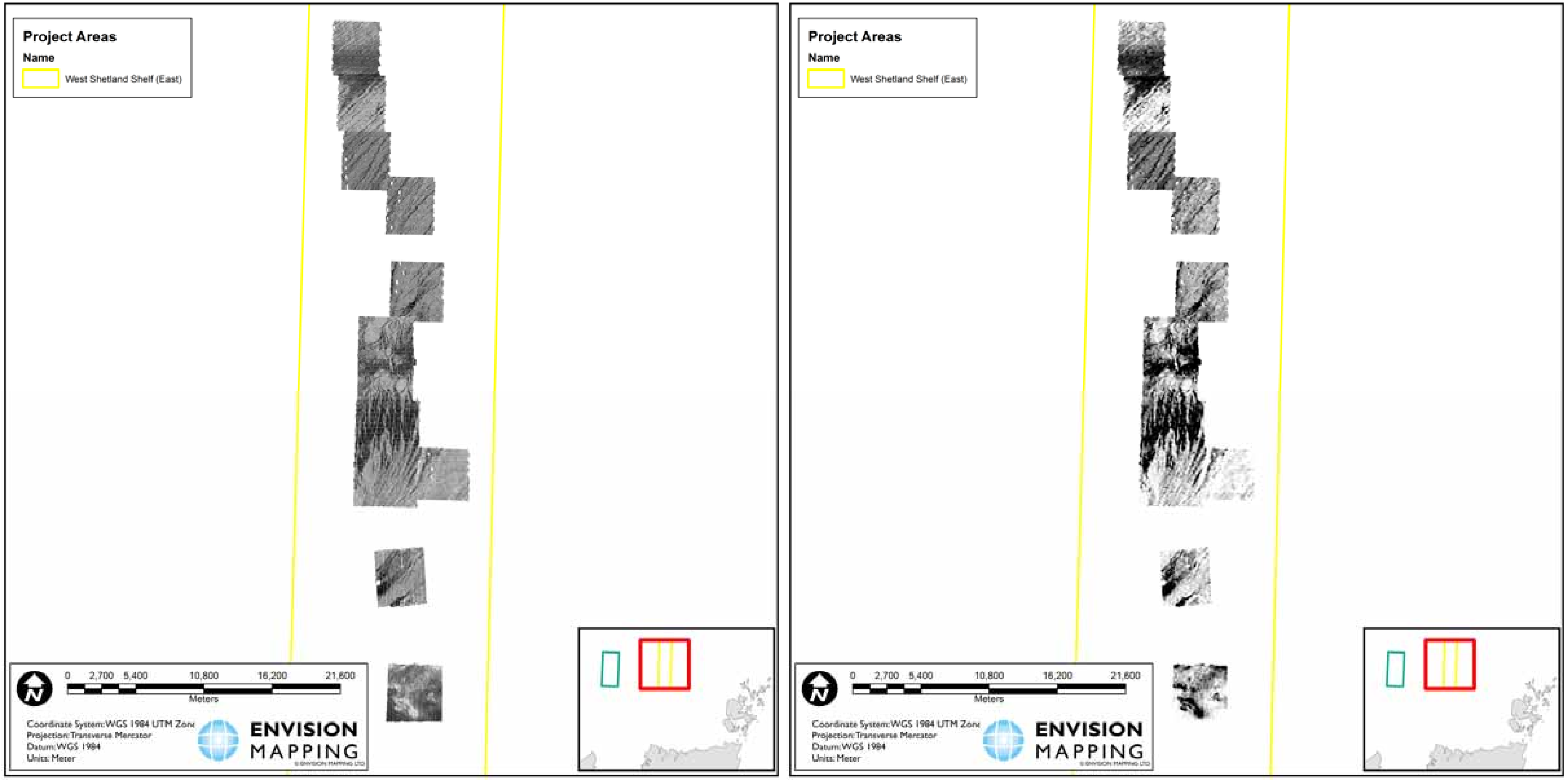

Figure 22. West Shetland Shelf Eastern Area: orginal backscatter data (left) and processed data (right).

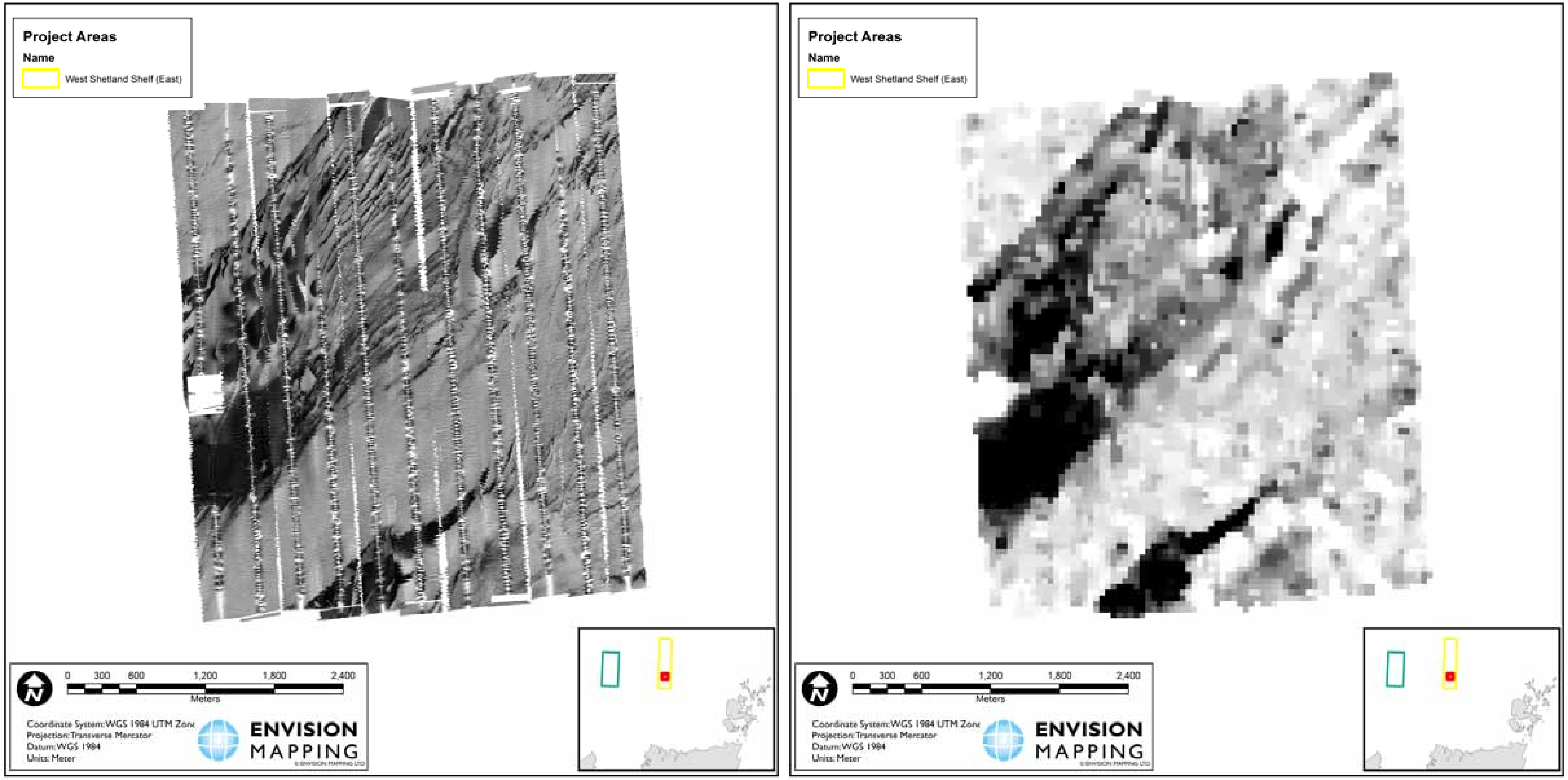

Figure 23. Detailed section of backscatter data showing the orginal data(left) and the heavlily smoothed and processed data (right).

3.7.2 Physical Parameters

The EUSeaMap biological zones layer contains no infralittoral or upper slope zones in this area and therefore did not require updating to incorporate the new bathymetry data. All the area with acoustic data fell within the deep circalittoral zone except for a small area at the eastern edge (Figure 24) which is within the circalittoral zone.

All the areas to be mapped were within the low energy zone of the EUSeaMap energy layer so no update to the supplied data was required to incorporate this data into the rule-based mapping methodology.

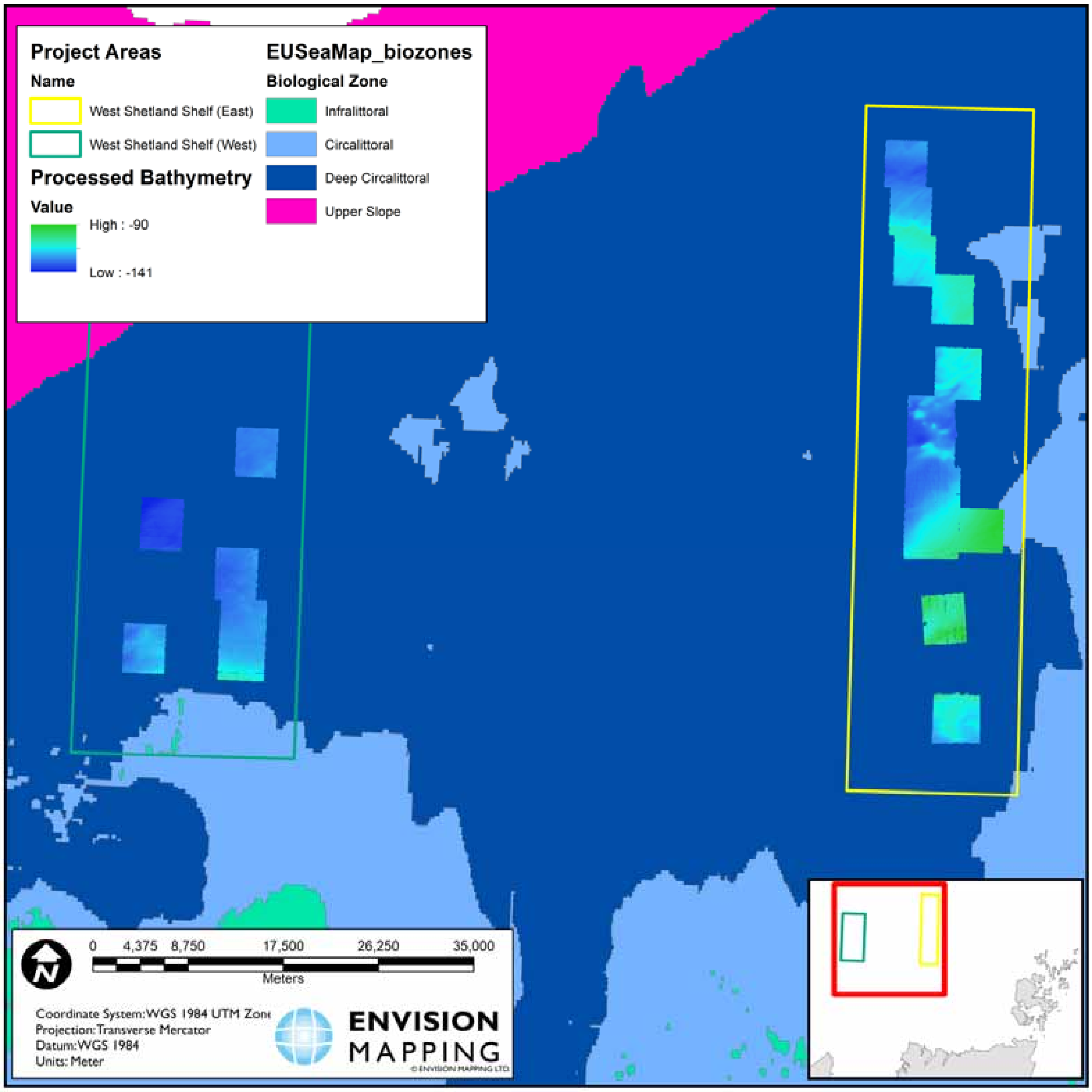

Figure 24. EUSeaMap biological zones for the West Shetland Shelf area.

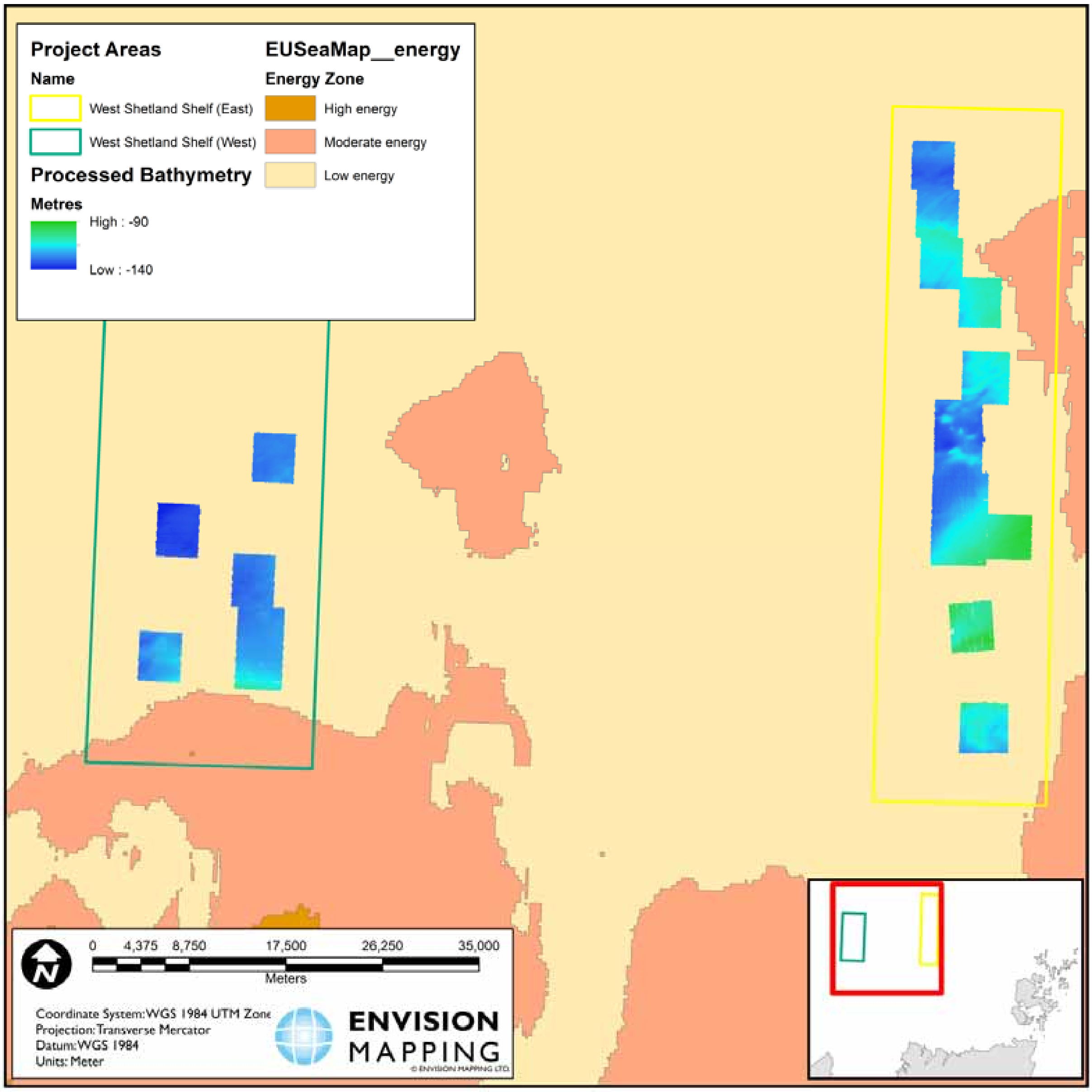

Figure 25. EUSeaMap seabed energy levels for the West Shetland Shelf area.

No BGS interpretation of seabed sediments/substrates has been undertaken for this area which is a required input layer for the top-down mapping methodology, therefore a seabed sediments layer was generated using a predictive mapping methodology using BGS sample point data and data from recent surveys (Goudge & Morris, 2012; Pearce *et al* 2012) as ground truth points. These sample data were categorised according to the five simplified substrate categories and used as training sites within a supervised classification process. The resulting classification of seabed substrates (Figure 26) shows the area to be dominated by coarse and mixed substrates with patches of sand and areas of rock interspersed, especially to the south east of the area.

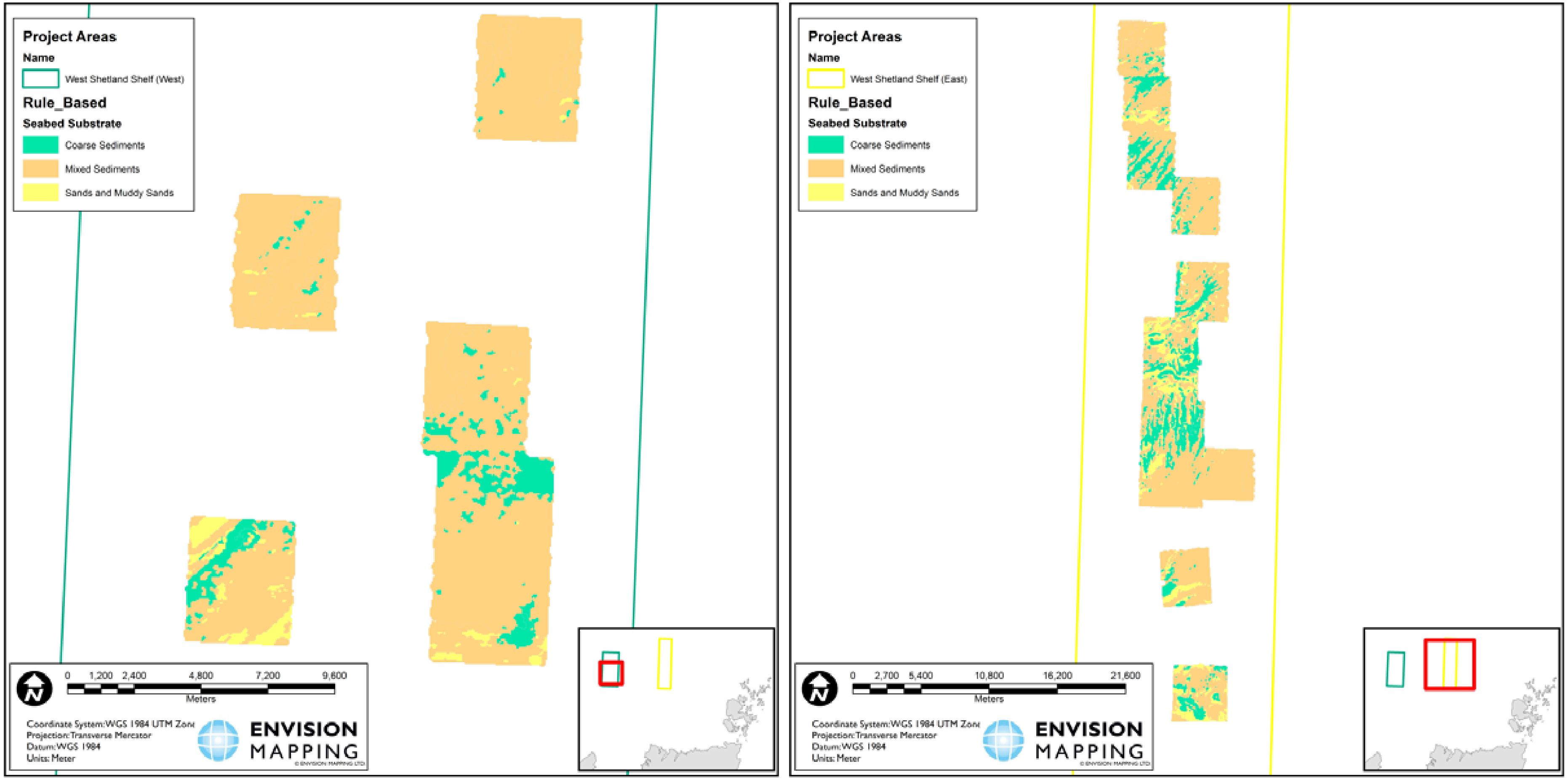

Figure 26. Seabed Substrates for the West Shetland Shelf area, western section (left) eastern section (right).

The existing EUSeaMap biological zones and seabed energy layers were used along with the produced seabed sediments distribution within the top-down mapping methodology to produce a rule-based biotope distribution map.

3.7.3 Samples & Mapping Units – for bottom-up approach

1680 samples were available for use within the area to be mapped and these samples contained 41 classifications (some of which were proposed and therefore not official) (MNCR 04.05) (Figure 27) which were reviewed and refined to produce seven mapping categories (Table 7).

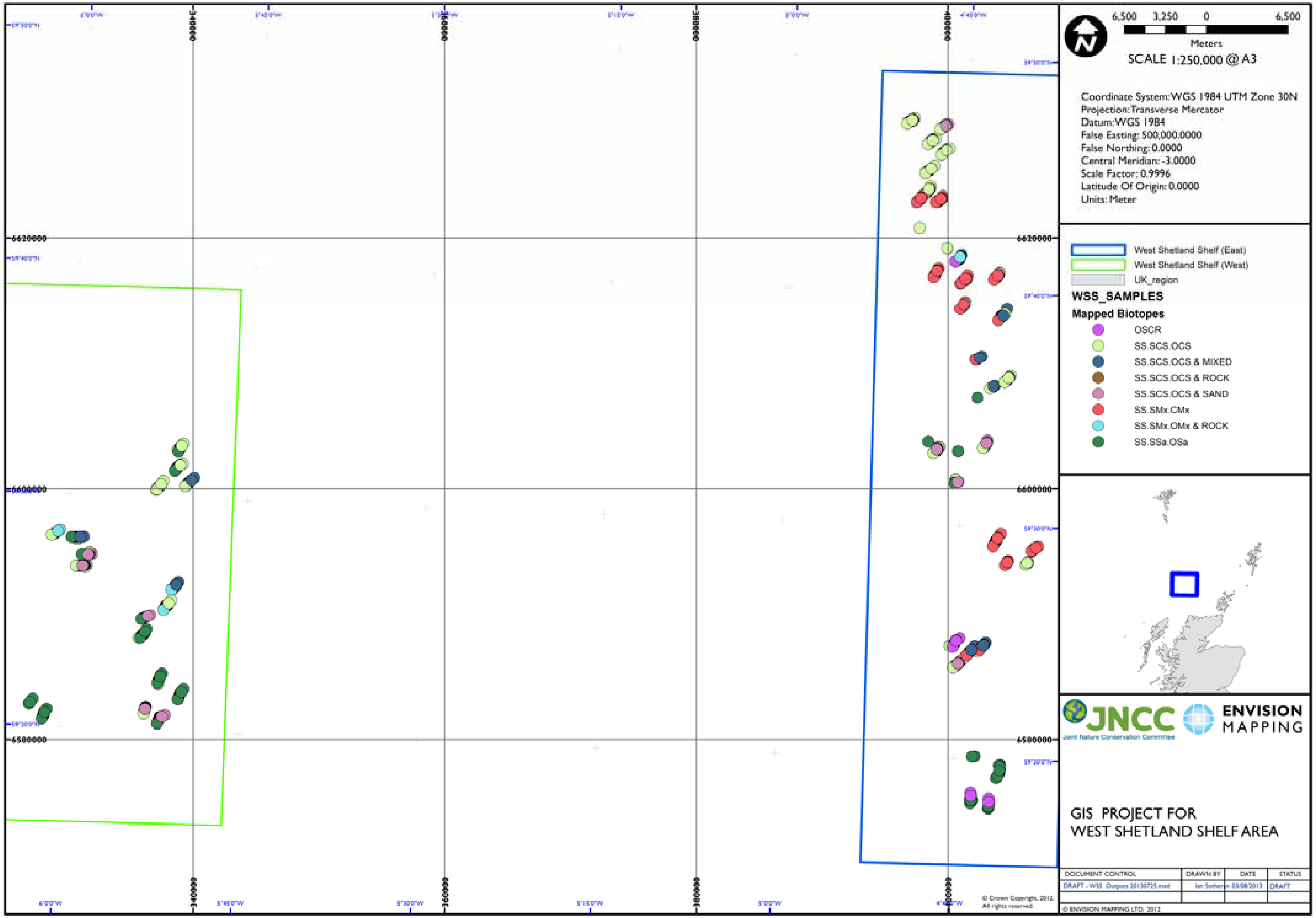

Figure 27. Sample points used for bottom up mapping for the West Shetland Shelf area.

Table 7. The EUNIS Habitats used for mapping the West Shetland Shelf area and the MNCR Biotopes associated with each.

EUNIS Code	Mapping unit name	MNCR Habitats identified from samples[10]
A5.14/ A4.33	A5.14 : Circalittoral coarse sediment/A4.33 : Faunal communities on deep low energy circalittoral rock	Mosaic of SS.SCS.OCS & CR.HCR.XFa Mosaic of SS.SCS.OCS & CR.MCR(spirorbids & bryozoan crust) Mosaic of SS.SCS.OCS & CR.MCR(spirorbids, spiky bryozoan & bryozoan crust) CR.HCR CR.MCR
A5.14/ A5.27	A5.14 : Circalittoral coarse sediment/A5.27 : Deep circalittoral sand	Mosaic of SS.SCS.OCS & SS.SSa.OSa Mosaic of SS.SSa.OSa & SS.SCS.OCS SS.SCS.OCS SS.SCS.OCS.[AbilEpusFaCrPo] SS.SCS.OCS.[PtriGintFaCr]
A5.14/ A5.45	A5.14 : Circalittoral coarse sediment/A5.45 : Deep circalittoral mixed sediments	Mosaic of SS.SCS.OCS & SS.SMx.OMx Mosaic of SS.SCS.OCS & SS.SMx.OMx(lacks muddy element) Mosaic of SS.SCS.OCS, SS.SMx.CMx.FluHyd, CR.HCR.DpSp.PhaAxi(sparse) & SS.SSa.OSa Mosaic of SS.SCS.OCS, SS.SMx.OMx & CR.HCR.DpSp.PhaAxi(sparse) Mosaic of SS.SCS.OCS, SS.SMx.OMx & SS.SMx.CMx.FluHyd(sparse) Mosaic of SS.SCS.OCS, SS.SMx.OMx(lacks muddy element) & CR.MCR(spirorbids, spiky bryozoan & bryozoan crust)
A5.27	A5.27 : Deep circalittoral sand	Mosaic of SS.SSa.OSa & SS.SMx.OMx(lacks muddy element) Mosaic of SS.SSa.OSa, SS.SMx.OMx & CR.HCR.DpSp.PhaAxi(sparse) Mosaic of SS.SSa.OSa, SS.SMx.OMx(lacks muddy element) & CR.MCR(spirorbids, spiky bryozoan & bryozoan crust) Mosaic of SS.SSa.OSa & SS.SMx.OMx(lacks muddy element) Mosaic of SS.SSa.OSa, SS.SMx.OMx & CR.HCR.DpSp.PhaAxi(sparse) Mosaic of SS.SSa.OSa, SS.SMx.OMx(lacks muddy element) & CR.MCR(spirorbids, spiky bryozoan & bryozoan crust)

[10] MNCR Habitats identified from samples which include parentheses are ones which have been proposed by those who have analysed the survey sample data

EUNIS Code	Mapping unit name	MNCR Habitats identified from samples[10]
A5.44	A5.44 : Circalittoral mixed sediments	SS.SMx.OMx SS.SMx.OMx & SS.SMx.CMx.FluHyd(sparse) SS.SMx.OMx(lacks muddy element) SS.SMx.OMx. SS.SMx.CMx.FluHyd SS.SMx.CMx.FluHyd(sparse) and determined by circalittoral biological zone
A5.45	A5.45 : Deep circalittoral mixed sediments	As 5.44 : Rock but determined by deep circalittoral biological zone
A5.45/ A4.33	A5.45 : Deep circalittoral mixed sediments/A4.33 : Faunal communities on deep low energy circalittoral rock	Mosaic of SS.SMx.OMx & CR.HCR.DpSp.PhaAxi(sparse) Mosaic of SS.SMx.OMx & CR.MCR(spirorbids, spiky bryozoan & bryozoan crust) Mosaic of SS.SMx.OMx(lacks muddy element) & CR.HCR.DpSp.PhaAxi(sparse) Mosaic of SS.SMx.OMx(lacks muddy element) & CR.HCR.XFa Mosaic of SS.SMx.OMx(lacks muddy element) & CR.HCR.XFa(sparse) Mosaic of SS.SMx.OMx(lacks muddy element) & CR.MCR(spirorbids & bryozoan crust) Mosaic of SS.SMx.OMx(lacks muddy element) & CR.MCR(spirorbids, spiky bryozoan & bryozoan crust) Mosaic of SS.SMx.OMx(lacks muddy element) & SS.SMx.CMx.FluHyd(sparse & lacks Flustra/Securiflustra) Mosaic of SS.SMx.OMx(lacks muddy element) & SS.SMx.CMX.FluHyd(sparse) Mosaic of SS.SMx.OMx(lacks muddy element), CR.MCR(spirorbids, spiky bryozoan & bryozoan crust) & SS.SSa.OSa

It should be noted that the five mapping categories are mixes or mosaics of biotope complexes, and this was originally thought to be a feature of video tows which would likely encounter a variety/range of substrates over the distance towed. However, upon examination, mosaics of different substrate and habitats were also found to occur within single still image sample points. For this reason the mosaics of different substrates were mapped and during this process the biotope complexes which represented the background substrate (i.e. SS.SCS.OCS) were subsumed into the mosaics and mapped as these amalgamated classes. This effect was examined spatially and where samples recorded SS.SCS.OCS as a distinct habitat it was often adjacent to a sample which indicated a mosaic habitat and often with no distinct change in acoustic data.

4 Results

4.1 Approaches to the Firth of Forth and Wee Bankie to Gourdon

4.1.1 Top-down – Rule-based

The resulting map produced using the top-down/rule-based mapping methodology shows the predominant seabed habitats to be sands with mixed and coarse sediments within the circalittoral and deep circalittoral biological zone regions. There are some harder rock areas identified closer inshore around Fife Ness, north of Arbroath and in the vicinity of Bell Rock. The Approaches to the Firth of Forth area has seabed habitats comprising of offshore deep circalittoral sands (SS.SSa.OSa / A5.27) with areas of raised bathymetry and banks of offshore deep circalittoral coarse sands and gravels. As the bathymetry shallows toward the Wee Bankie to Gourdon area, the raised banks remain of a coarse sands and gravels nature but change in their biological zone to become circalittoral. This remains the case over the raised areas of this region, with the deeper channels/troughs holding circalittoral muddy sands (SS.SSa.CMuSa / A5.26) and deep circalittoral sands (SS.SSa.OSa / A5.27).

4.1.2 Bottom up – Predictive modelling with Object Based Image Analysis

A supervised classification with OBIA produced an alternate map product (Figure 29) which shows the Approaches to the Firth of Forth area to be dominated by offshore sands with the raised banks comprising of coarse offshore sands and gravels. Moving towards the Wee Bankie and Gourdon area, the seabed begins to shallow and circalittoral coarse and mixed sediments are introduced along with hard substrate habitats which are classified as faunal communities on rock (A4.27 & A4.33). These are based on samples which are classified as these ‘faunal communities on rock’ habitats, but are described as faunal communities on a mixed sediments with cobbles and so should be treated as a mixed substrate environment of possible large pieces of hard substrate which may overlie a sediment base, with the harder stable material colonised by faunal communities.

Similar to the rule-based habitat map the solid rock habitats with a littoral biological zone likely to support kelp and red algae are found around Fife Ness and Bell rock with the adjacent deeper areas of rock supporting a mixed faunal community.

There are some deeper channels/troughs towards the northern section of the Wee Bankie to Gourdon area and these areas are composed of deep circalittoral sands with coarser habitats on the slightly shallower areas, but still within the deep circalittoral biological zone.

The third habitat map produced (Figure 30) was an OBIA which identified areas of similar seabed types which were then categorised to the most common underlying habitat type from the supervised classification. This categorisation process produced a less complex distribution of habitats than the supervised classification. A similar pattern is shown with the Approaches to the Firth of Forth area being dominated by offshore sands with coarse material making up the banks and shallowing to circalittoral mixed and coarse material within the Wee Bankie to Gourdon area, interspersed with harder stable substrates which support faunal communities.

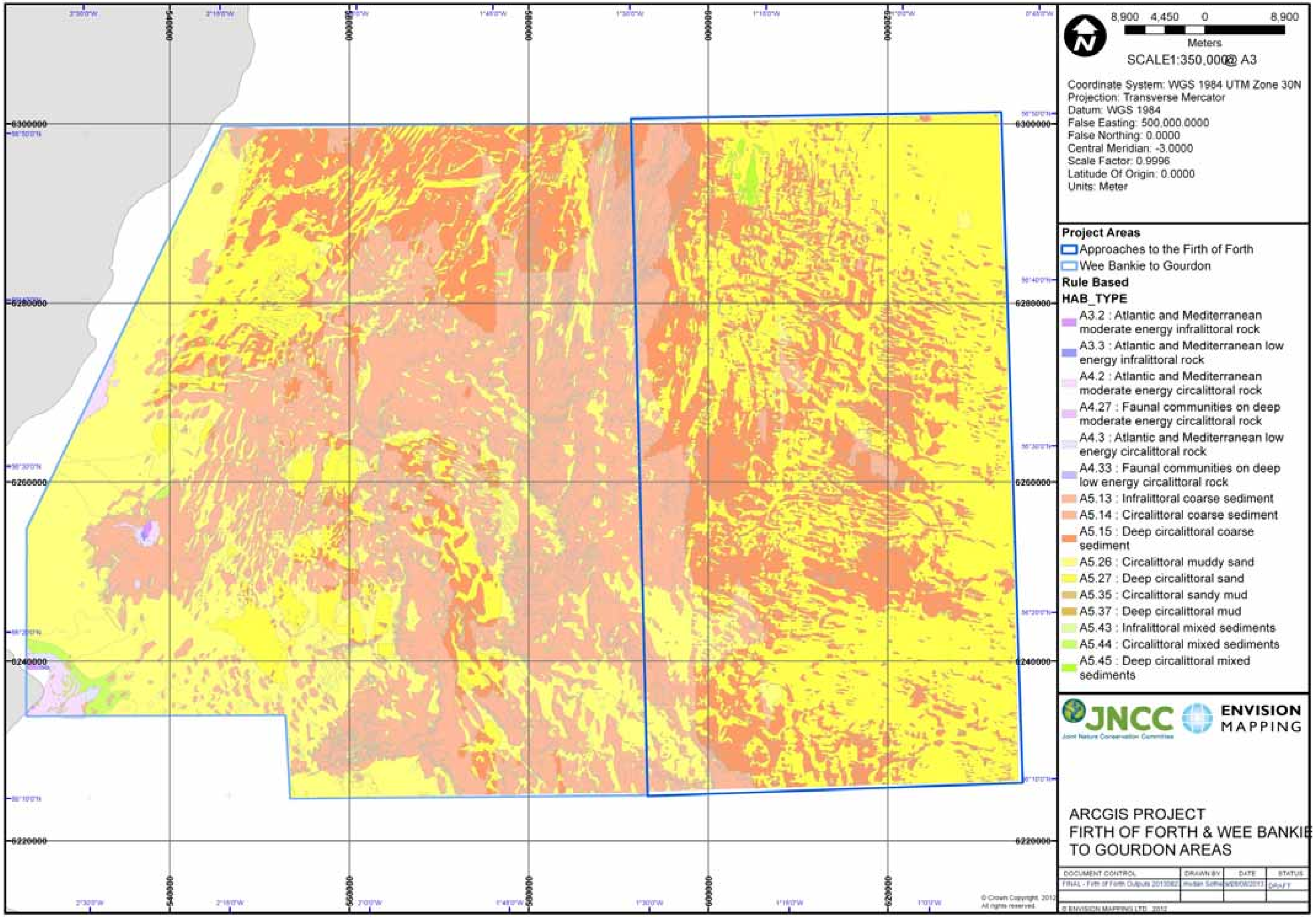

Figure 28. Top-down / Rule-based mapping habitat map for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas.

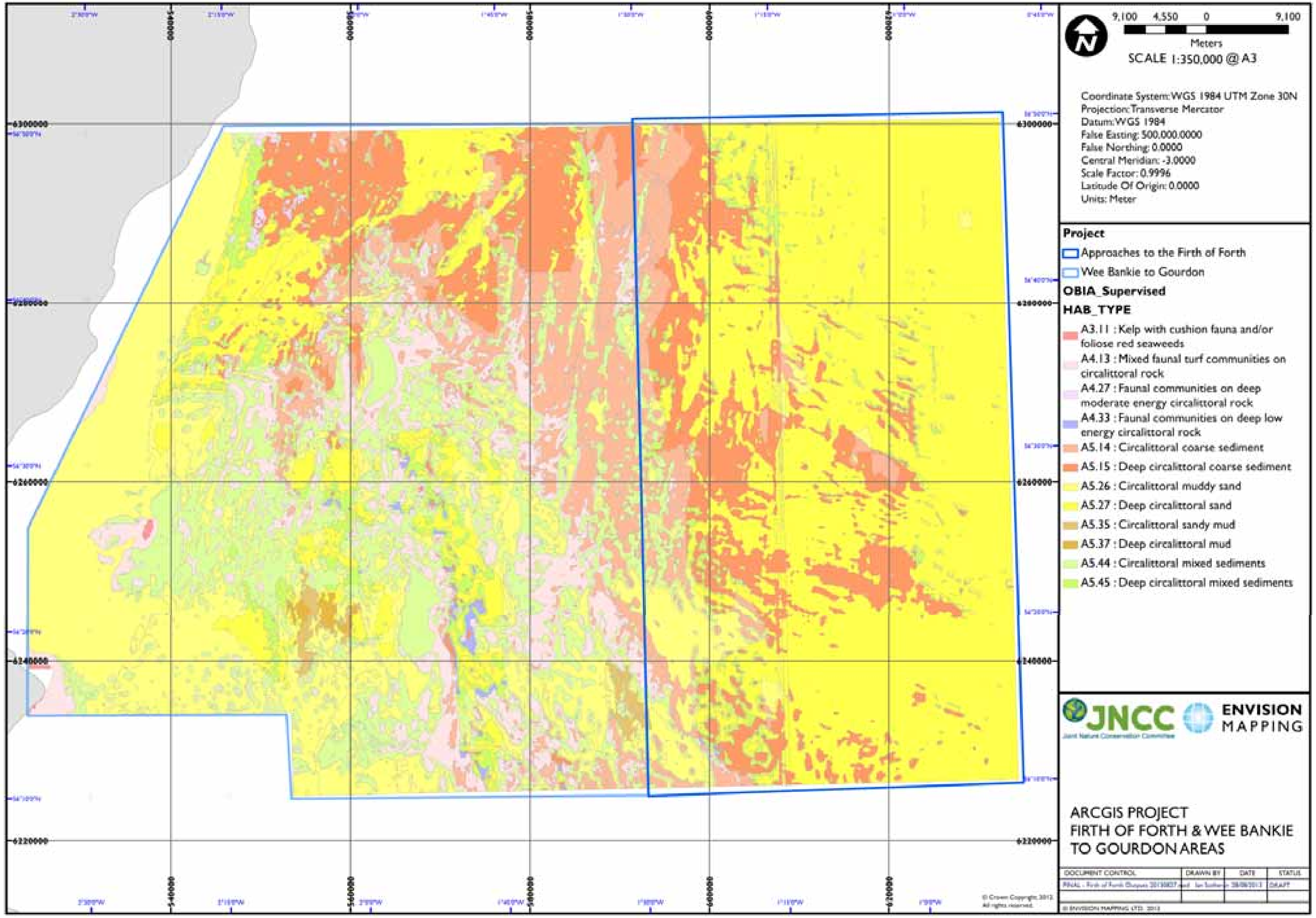

Figure 29. Bottom-up approach, object based supervised habitat map for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas.

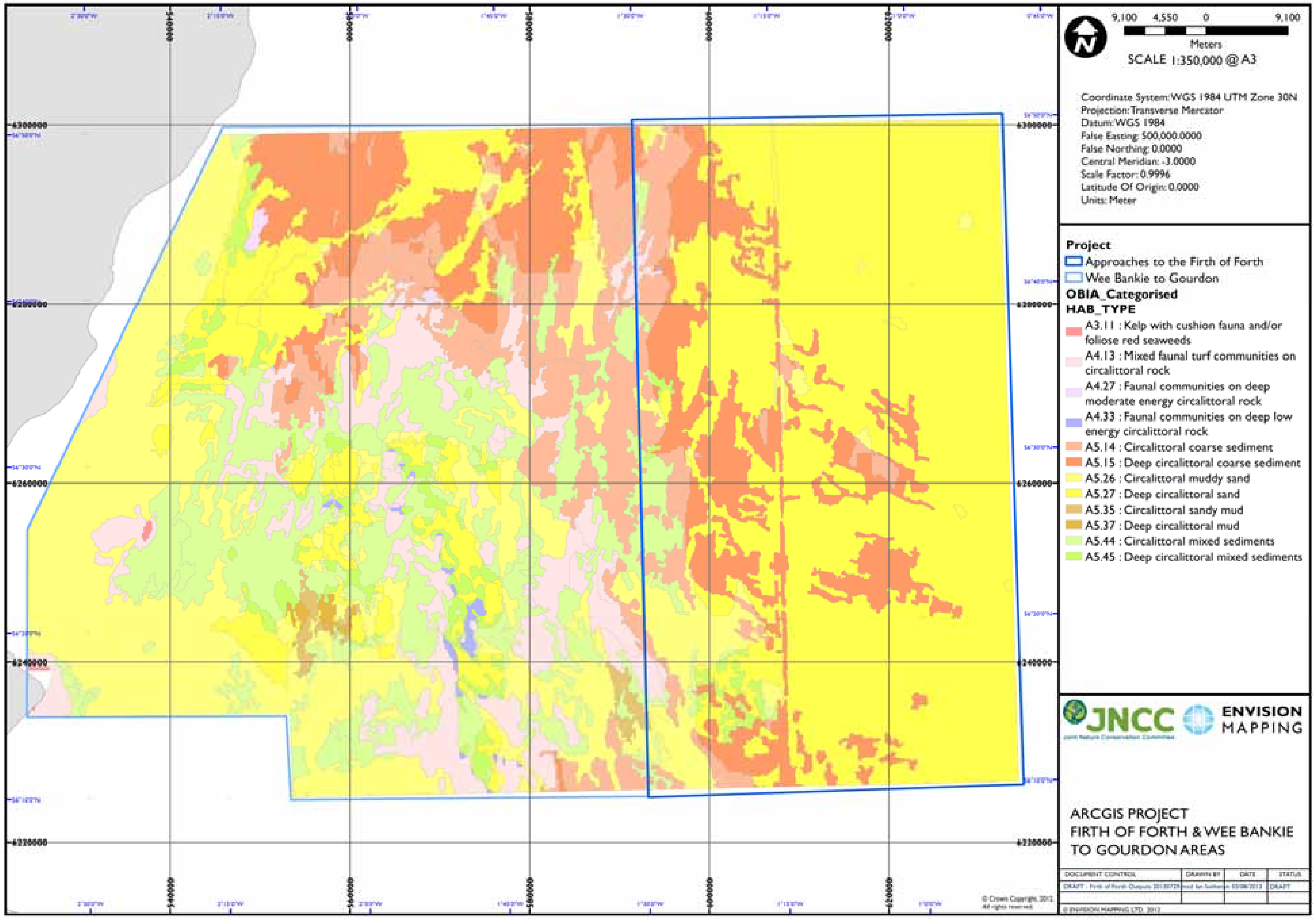

Figure 30. Categorised habitat map based upon a supervised classification for the Approaches to the Firth of Forth and Wee Bankie to Gourdon area.

4.2 Solan Bank to Fair Isle Channel

4.2.1 Top-down – Rule-based

A top-down rule-based method to determine seabed habitats based upon the sediment type, seabed energy and associated biological zone produced the map shown in Figure 31. The area of rule-based mapping is regulated by the seabed substrate map which excludes the area inside the 12 nautical mile boundary. Apart from the eastern tip of the area which is classified as coarse circalittoral seabed, the central eastern section of the mapped area shows mixed substrate habitats (A 5.44 & A5.45) interspersed with deep circalittoral (A4.33) and circalittoral rock habitats (A4.3).

The central region seems to be comprised of a sandy environment (A5.26, A5.27) with coarse habitats (A5.14, A5.15) forming well defined features with occasional patches of harder rock material to the south. Moving westwards the seabed environs appear to alternate between areas of deep circalittoral sand and shallower circalittoral coarse habitats with some relatively small patches of harder material forming rock based habitats (A4.2).

With the Solan Bank to Fair Isle area there are small areas which are deeper than 200m and are therefore classified as upper slope habitats and these occur to the west of the central area (mixed substrate and rock habitats mentioned above.

4.2.2 Bottom-up – Predictive modelling with Object Based Analysis

Sample driven supervised classification enabled the whole of the area which was encompassed by the backscatter and bathymetry data to be mapped and the resulting map (Figure 32) extends to within the 12 nautical mile boundary to cover a greater proportion of the Solan Bank to Fair Isle area.

The distribution of habitats appears to be very similar to that produced by the rule-based mapping process, with the additional areas covered showing expansions of the habitats likely to be found with the rule-based mapping. This is to be expected as the sample data used to generate the map was largely supplemented by the sediment sample data that was also used to produce the underlying seabed substrate map underpinning the rule-based habitat map.

The eastern section of the mapped area suggests a circalittoral coarse habitat (A5.14) with a very distinct sand bank forming a crescent shape at the south eastern edge of the area.

The central eastern section is shown to consist of habitats A4.33, faunal communities of deep low energy circalittoral rock, with the slightly shallower A4.3 variation present. There appears to be a larger area of this rock habitat than shown in the rule-based mapping but there is also a lot of a mixed substrate habitat which could suggest the mixed and the rock substrates are confused by the mapping methodologies or the underpinning data used to generate the maps.

A noticeable difference is the predicted distribution of the mud based habitat (A5.37 & A6.5) which does not feature in the rule-based map, yet the biological sample data collected with the central area does suggest a muddy habitat.

Again moving westwards the environment consists of alternating areas of sand based habitats (A5.27, A5.26) and coarse substrate habitats (A5.14, A5.15) with the additional area (within the 12nm boundary) encompassed by this supervised mapping approach giving similar boundaries and extensions of these habitat features.

Using the OBIA features and assigning the majority habitat category contained with each feature produced a map (Figure 33) which shows the same general distribution of seabed habitats in the Solan Bank to Fair Isle area and with similar boundaries. The distinct crescent shape sand bank is present, as is the area of muddy habitat in the central section. The boundaries of the habitats have been summarised which has reduced the detail shown and additionally some smaller features have been lost.

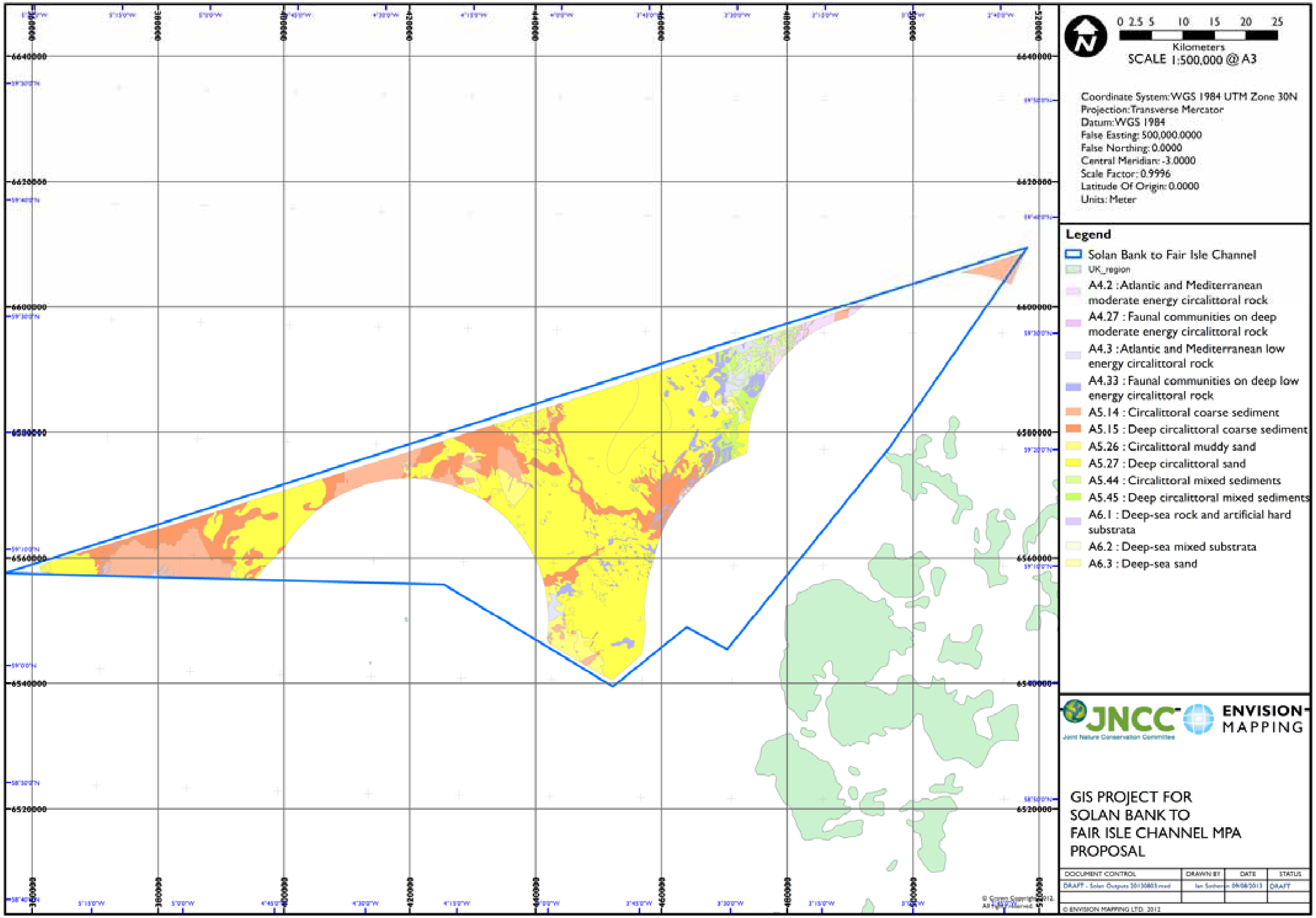

Figure 31. Top-down / Rule-based mapping habitat map for the Solan Bank to Fair Isle Channel area.

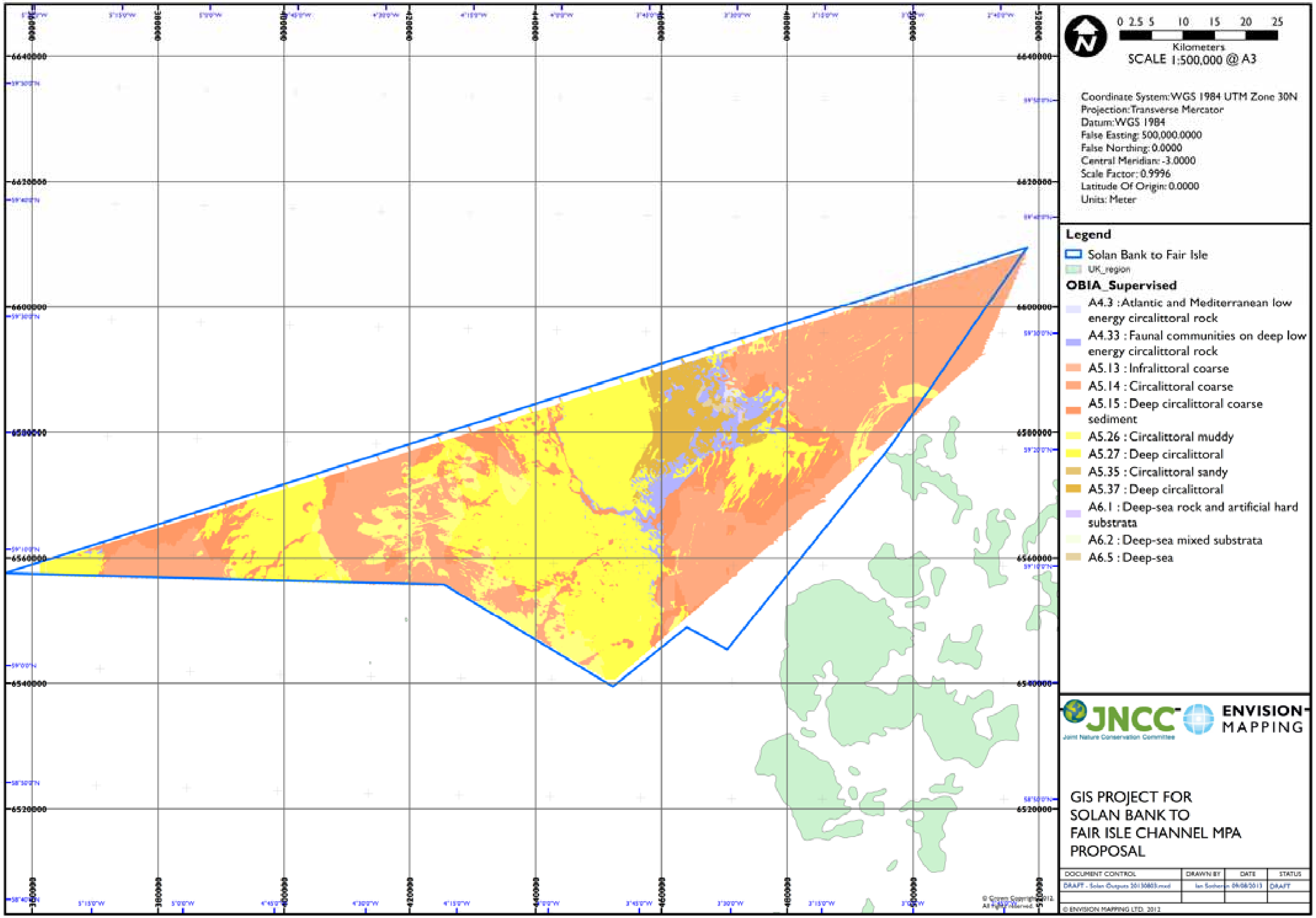

Figure 32. Bottom-up approach, object based supervised habitat map for the Solan Bank to Fair Isle Channel area.

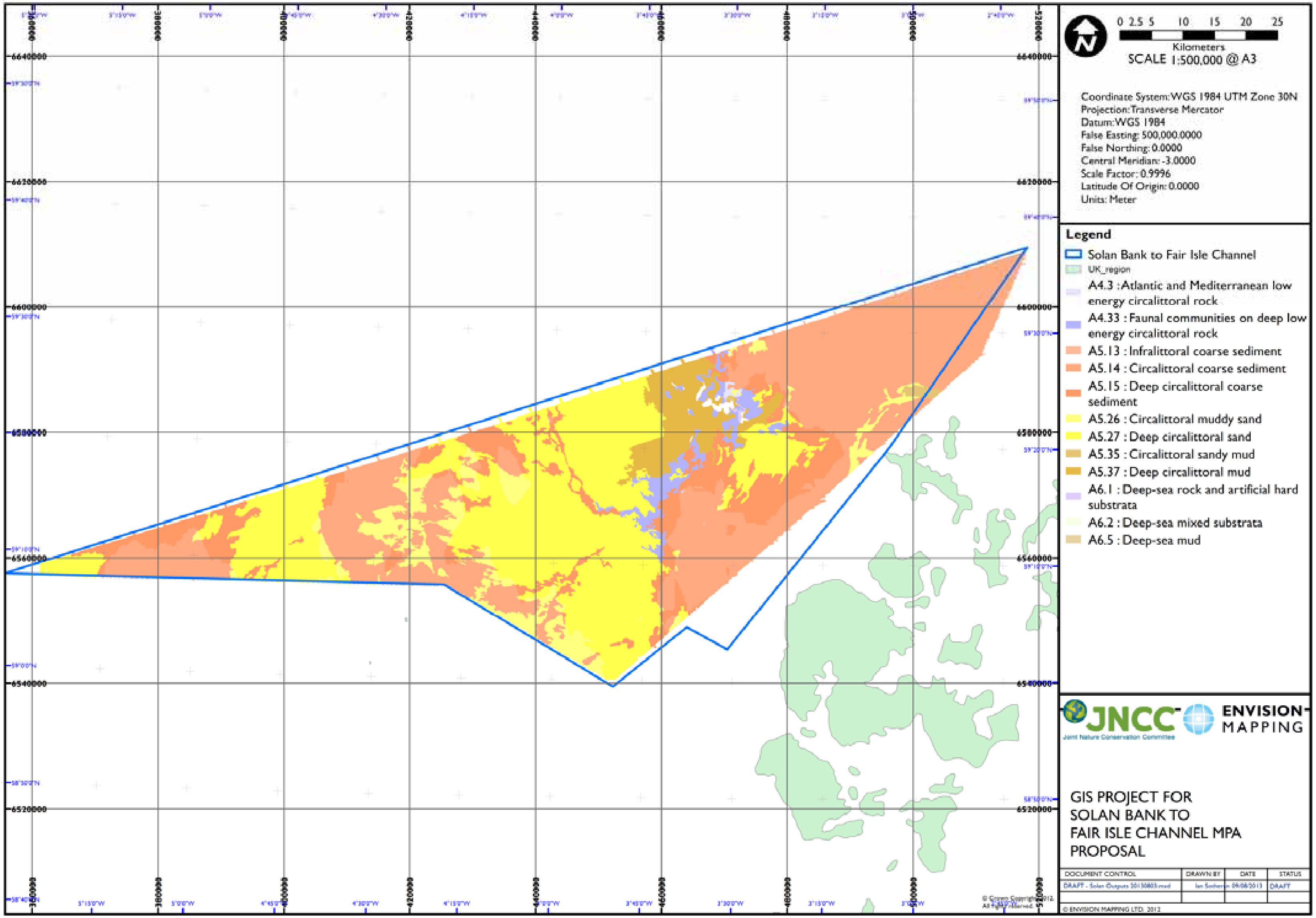

Figure 33. Categorised habitat map based upon a supervised classificaiton for the Solan Bank to Fair Isle Channel area.

4.3 West Shetland Shelf (Windsock)

4.3.1 Top-down – Rule-based

For a top-down / rule-based mapping methodology to be applied to the West Shetland Shelf area it was necessary to generate a seabed substrate map for the area as a BGS interpreted map of the area was unavailable (Section 3.7.2). The whole of the area covered by the acoustic data fell within the low energy levels for the rule-based mapping. Only a small section, the eastern most area of the data, fell within the circalittoral zone, and the remaining areas fell within the deep circalittoral. Therefore with the exception of the small circalittoral area the whole of the mapped area for the West Shetland Shelf area is classified as low energy deep circalittoral meaning the seabed substrate is the variable which defines the EUNIS habitats within the area.

Three seabed substrates were mapped for the area (Figure 26), which were then allocated the corresponding EUNIS habitat class, taking account of the biological zone and energy.

Table 8. Seabed substrate and corresponding EUNIS Habitat classes for West Shetland Shelf area.

Seabed Substrate	EUNIS class
Coarse Sediments	A5.15 : Deep circalittoral coarse sediment
Sands and Muddy Sands	A5.27 : Deep circalittoral sand A5.26 : Circalittoral muddy sand
Mixed Sediments	A5.45 : Deep circalittoral mixed sediments

The rule-based map shows the western section of the area is predominantly a mixed sediment substrate (A5.45) with patches of coarse material (A5.15) throughout and occasional areas of deep circalittoral sand (A5.27).

The eastern section has relatively large areas of mixed sediment substrate (A5.45) and a small section of circalittoral mixed sediments (A5.44) due to the change in biological zones which occurs in to the east. The raised banks throughout the area appear to be of a coarse substrate (A5.14) with the deeper areas and troughs occupied by mixed sediments which from ground truthing information does appear to contain larger stable rocks and an epifaunal community, and the slopes of some raised features are comprised of deep circalittoral sand habitats (A5.27). The coarser sediments are found to form linear raised features (Figure 35) and it can also be seen that some of the finer scale detail has been lost due to the backscatter processing but the main broad features and the extents are retained.

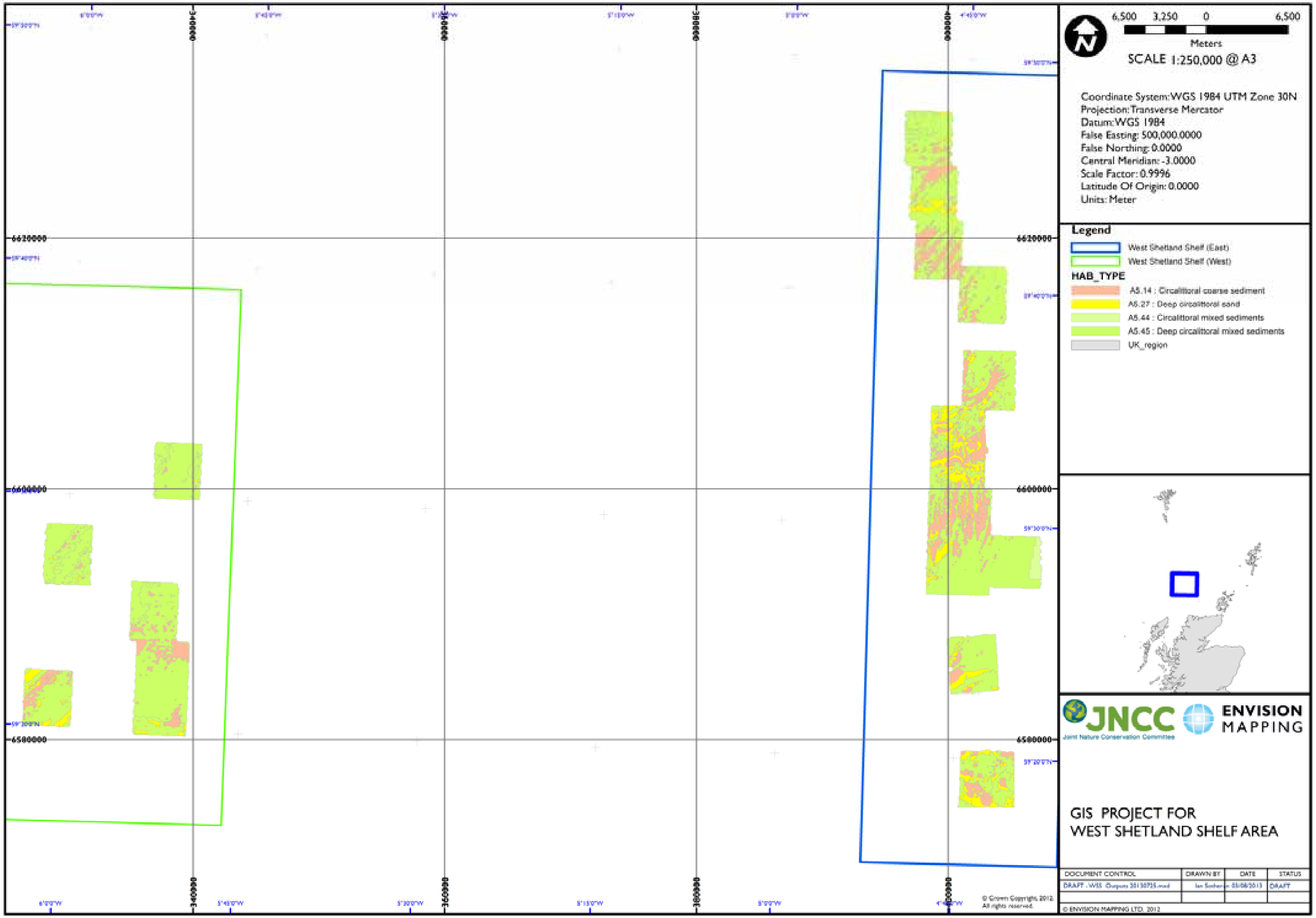

Figure 34. West Shetland Shelf area top-down / rule-based habiat map.

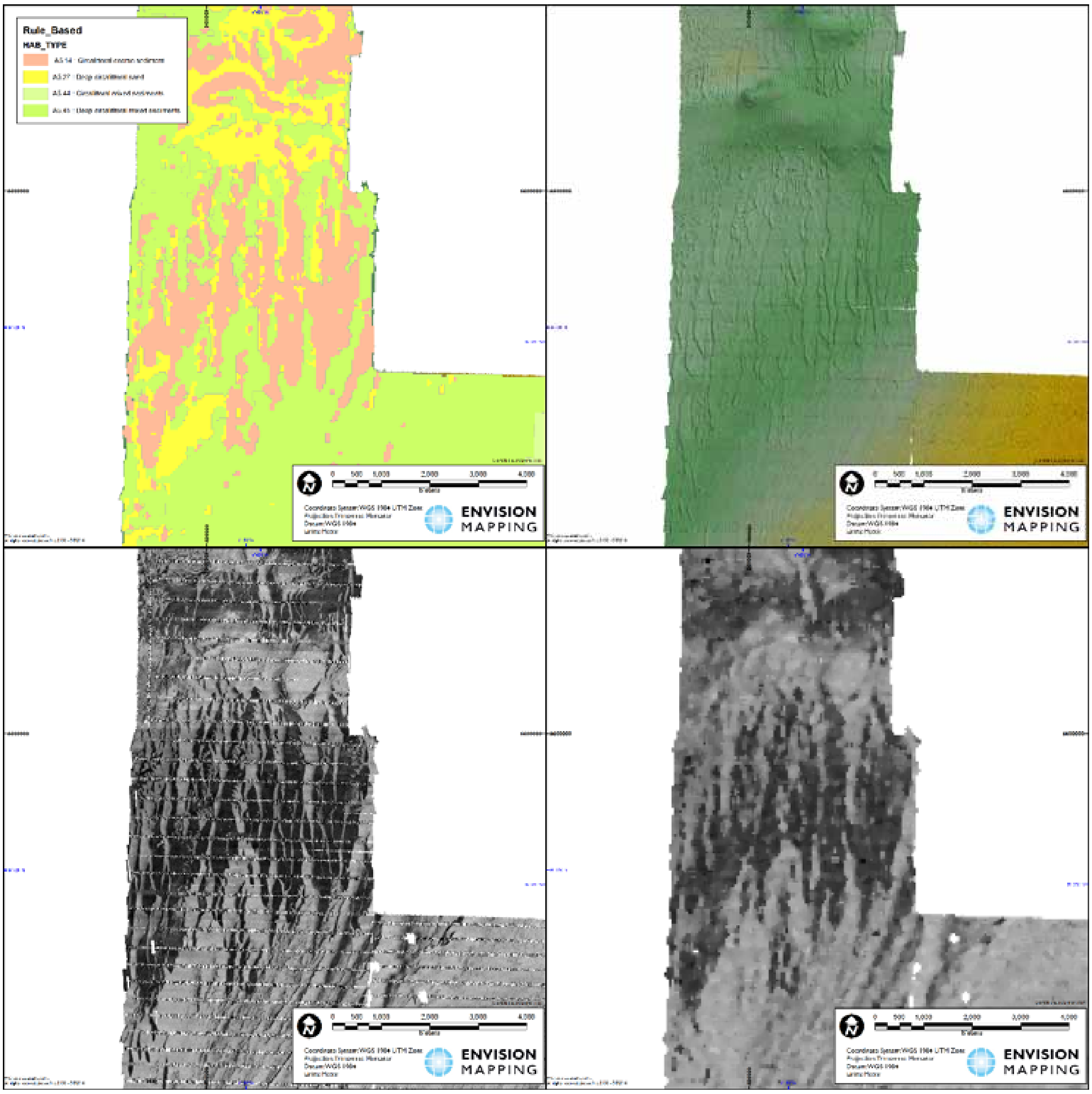

Figure 35. Linear coarse sediment (A5.15) features (top left) with shaded bathymetry (top right) and pre-processed backscatter (bottom left) and processed backscatter (bottom right) for the same area.

4.3.2 Bottom-up – Predictive modelling with Object Based Analysis

The resulting maps produced by the bottom-up mapping approach (Figure 36) are very similar to those produced by the rule-based method; this to be expected as the rule-based map uses seabed substrates derived using the bottom-up mapping approach with reclassified mapping units. This bottom-up approach used the seabed sample data (Section 3.7.3) which contains a relatively large amount of habitat mosaics and mixtures which could not be separately identified within the acoustic data and have therefore been mapped as mixtures or mosaics.

The western part of the area has a mixture of circalittoral coarse sediments (A5.14) and deep circalittoral mixed sediments (A5.45) over the majority of the seabed with areas of deep circalittoral mixed sediments with stable and hard substrates and rocks supporting an epifaunal community.

Figure 36. West Shetland Shelf area object based supervised habitat map.

The eastern section of the mapped area (as with the rule-based output) has a predominantly deep circalittoral habitat with raised features of coarse and sandy habitats (A5.14 & A5.27) with the slopes of some of the raised features comprised of deep circalittoral sands (A5.14). Moving northwards, linear features running in a northeast / southwest direction made of mixed sediments with faunal communities on rock or hard substrates form a major component. These features can be seen on the backscatter signal as stronger returns than the surrounding mixed sediment habitats (Figure 37).

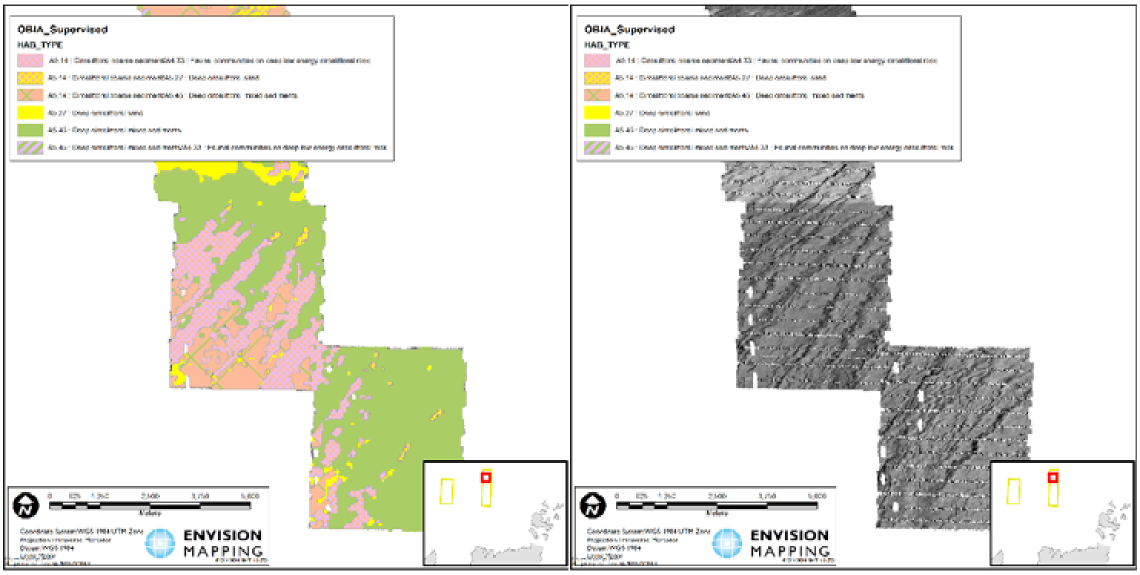

Figure 37. Deep circalittoral mixed sediments (A5.45) and faunal communities on deep low energy circalittoral rock (A4.33) [left] mapped over the liner northeast / southwest backscatter features [right].

The bottom-up mapping approach outputs reassigned and grouped using the object based analysis features and majority habitat category contained within each feature (Figure 38) produced a map with simplified boundaries of the large features with some detail lost during the allocation of this majority habitat. The linear features noted above have been amalgamated in to a single large feature which provide a general overview of the likely habitats which occur in the area but the smaller and more detailed habitat features are lost.

Figure 38. West Shetland Shelf area categorised habitat map based upon a supervised classificaiton.

5 Supplemental Information

5.1 Confidence Assessment

In order to assess the suitability of each map to its intended purpose, a confidence assessment using the MESH Confidence Assessment method (MESH, 2008) has been undertaken. This approach assesses the quality and suitability of the acoustic data, the point sample data, and the interpretative techniques using a scoring system (Table 10).

The maps for the Approaches to the Firth of Forth and Wee Bankie to Gourdon all score 64 with Solan Bank to Fair Isle maps scoring slightly lower at 59 and West Shetland Shelf a slightly higher 66. These scores all fall into the lower end of the ‘high’ confidence category.

The variation between the areas stems from the different forms and quality of the ground truth datasets, as scores for the acoustic data and the interpretation are identical for all maps, and the same standards and data processing have been undertaken with all areas. It is suggested the acoustic data for the West Shetland Shelf area be treated with caution as data standards have been applied but the overall quality of the data is poor in comparison to the other areas and it maybe that the score for this area is reduced.

The Solan Bank to Fair Isle area suffered from a lack of ground truth data. Supplemental data from BGS samples was required which reduced the confidence associated with the resulting maps, not due to the quality of the BGS sample data, but to the appropriateness of using these data for mapping EUNIS Habitat categories.

The Approaches to the Firth of Forth and Wee Bankie to Gourdon maps score 64 which is reduced slightly by the vintage of the ground truth data which ranges over a large time period and incorporates historical data and more recent data.

Table 9 provides list maps with their associated Globally Unique ID *(*GUI) and figure reference, the GUI code is used as the identifier for each map in the MESH confidence assessment results (Table 10).

Table 9. Map titles with associated GUIs and figure references.

Map Title	**MAP GUI**	**Figure**
Approaches to the Firth of Forth, Wee Bankie to Gourdon area Rule-based Map	GB001242	Figure 28
Approaches to the Firth of Forth, Wee Bankie to Gourdon area OBIA Supervised Map	GB001243	Figure 29
Approaches to the Firth of Forth, Wee Bankie to Gourdon area OBIA Categorised Map	GB001244	Figure 30
Solan Bank to Fair Isle area OBIA Supervised Map	GB001245	Figure 31
Solan Bank to Fair Isle area OBIA Supervised Map	GB001246	Figure 32
Solan Bank to Fair Isle area OBIA Categorised Map	GB001247	Figure 33
West Shetland Shelf area Rule-based Map	GB001248	Figure 34
West Shetland Shelf area OBIA Supervised Map	GB001249	Figure 36
West Shetland Shelf area OBIA Categorised Map	GB001250	Figure 38

Table 10. MESH confidence assessment output for each map produced.

MAP GUI	Remote Technique	Remote Coverage	Remote Positioning	RemoteStdsApplied	Remote Vintage	BGTTechnique	PGTTechnique	GTPositioning	GTDensity	GTStdsApplied	GTVintage	GTInterpretation	Remote Interpretation	Detail Level	Map Accuracy	Remote score	GT score	Interpretation score	**Overall score**
GB001242	1	2	1	2	3	2	2	2	2	2	2	2	3	1	2	60.0	66.67	66.67	**64**
GB001243	1	2	1	2	3	2	2	2	2	2	2	2	3	1	2	60.0	66.67	66.67	**64**
GB001244	1	2	1	2	3	2	2	2	2	2	2	2	3	1	2	60.0	66.67	66.67	**64**
GB001245	1	2	1	2	3	1	2	2	1	2	2	2	3	1	2	60.0	51.67	66.67	**59**
GB001246	1	2	1	2	3	1	2	2	1	2	2	2	3	1	2	60.0	51.67	66.67	**59**
GB001247	1	2	1	2	3	1	2	2	1	2	2	2	3	1	2	60.0	51.67	66.67	**59**
GB001248	1	2	1	2	3	2	2	2	2	2	3	2	3	1	2	60.0	71.67	66.67	**66**
GB001249	1	2	1	2	3	2	2	2	2	2	3	2	3	1	2	60.0	71.67	66.67	**66**
GB001250	1	2	1	2	3	2	2	2	2	2	3	2	3	1	2	60.0	71.67	66.67	**66**

5.2 Classification Certainty

In addition to the score produced for each map using the MESH confidence assessment method the process of supervised classification enables a map of how certain the process of classification has been. The process uses a maximum likelihood classifier which calculates the probability of each habitat occurring at every pixel and then uses the most probable habitat as the mapped habitat class. Investigating the different probabilities for each habitat at each location produces a classification certainty/uncertainty map. Certainty is highest whenever there is one habitat class that clearly stands out above the others in the assessment of class membership for an area, however, if there are equally probable habitats whose probabilities are very similar then the certainly of classification is low.

The certainty associated with the habitat mapping for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas show the homogenous sediment habitat of the offshore sand area to the east of the Approaches to the Firth of Forth area to be consistently high with increased uncertainly for the mixed and coarse substrate habitats. This increased uncertainty is likely to be due to the presence of multiple habitats being present within the ground truth data which occupy similar acoustic parameters and therefore the classification process produces a moderate probability for each habitat type with the most likely being mapped. There are a few discrete patches of low certainty which are not associated with any specific habitat and are areas in which the classification process has not identified a habitat with significantly higher probability than any other.

Classification certainty for Solan Bank to Fair Isle area again shows a high to moderate level of certainly of classification over homogenous sediment area with increases in uncertainty at boundaries and in heterogonous areas which can be expected as the probability of specific habitats is likely to be lower where the physical nature of the seabed changes. The artefacts associated with the backscatter data are showing as an area of increased uncertainty and these have been corrected with contextual editing.

The certainty of classification for the West Shetland Shelf area show some relatively high levels of uncertainty throughout the area which are likely to be associated with the varied quality of the acoustic data and also the mosaics of habitats present in the area. These mosaics of habitats expressed in the ground truth sample data mean that a distinct signature for each habitat is difficult to obtain as there will be considerable overlap in the acoustic values associated with each habitat type.

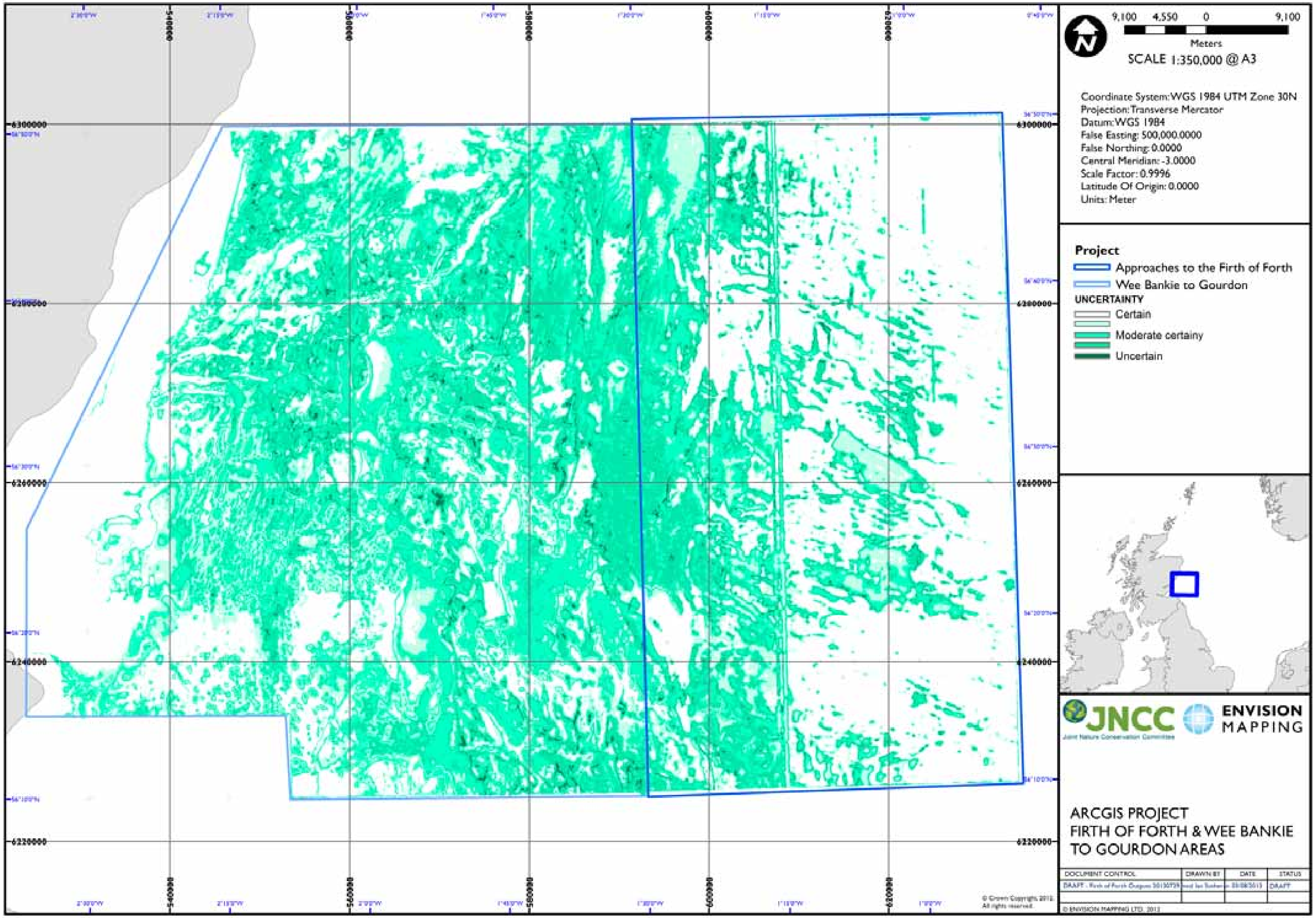

Figure 39. The certainty of classificaiton for the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas.

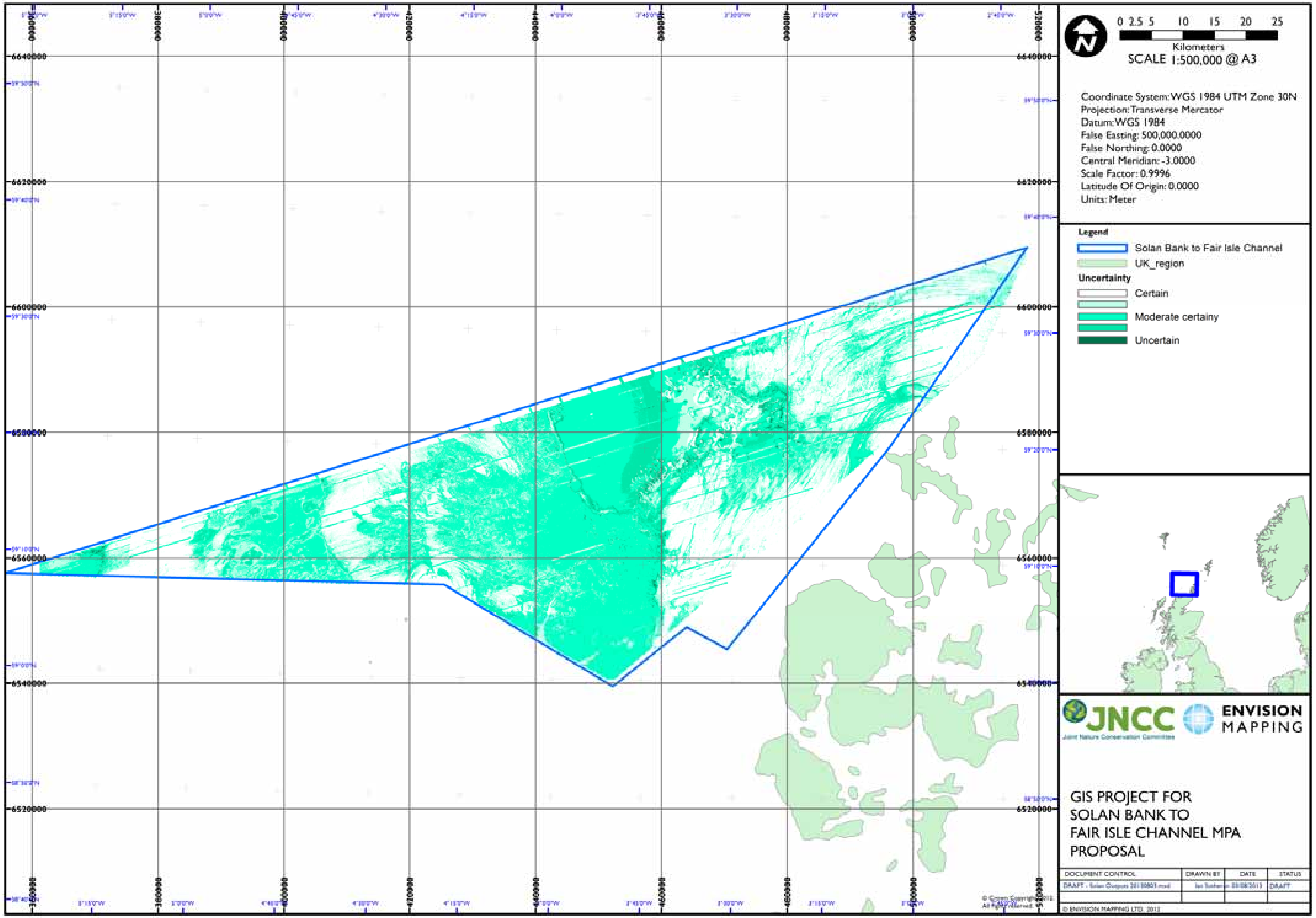

Figure 40. The certainty of classificaiton for the Solan Bank to Fair Isle Channel area.

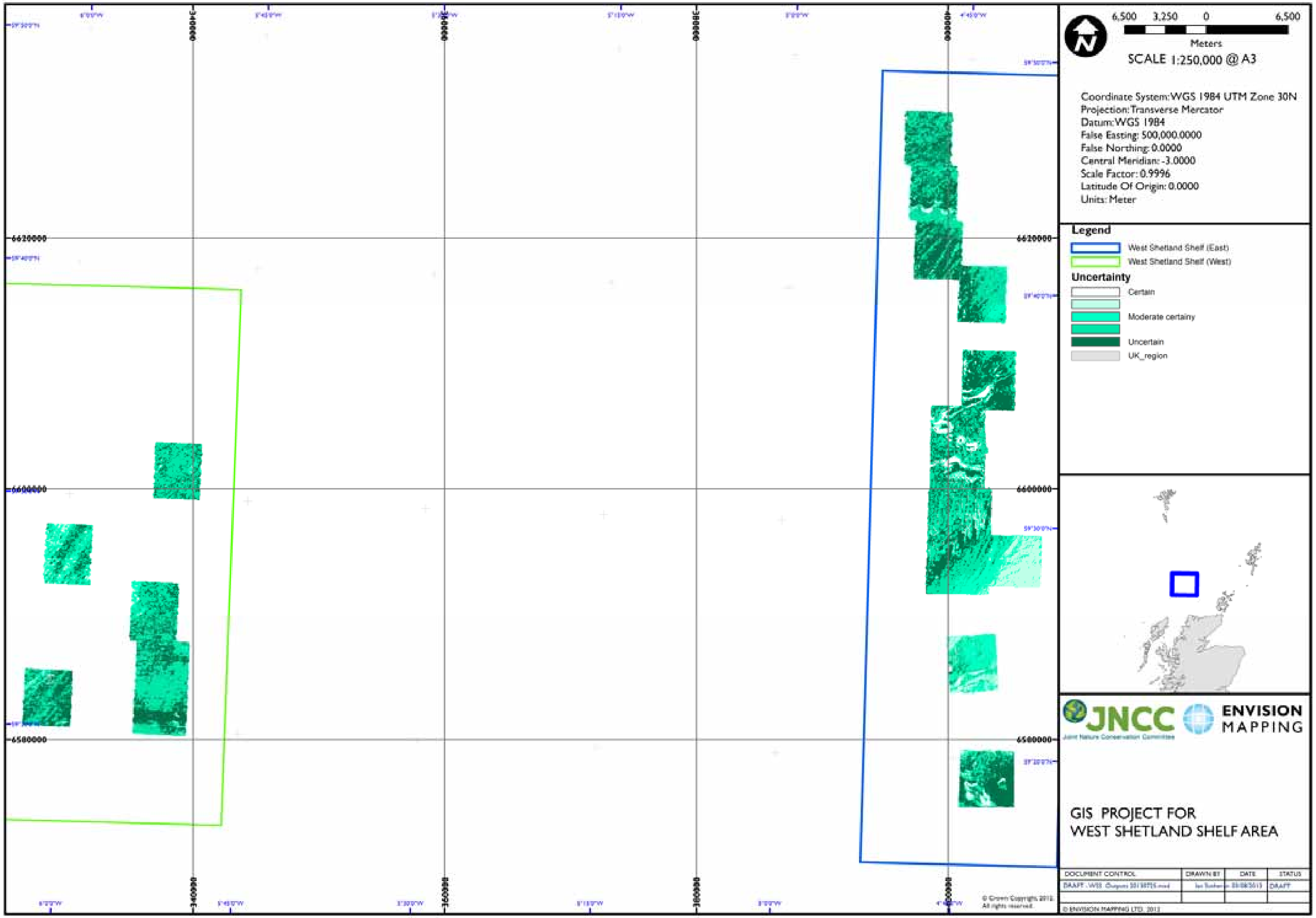

Figure 41. The certainty of classificaiton for the West Shetland Shelf area.

5.3 Cross tabulation

In order to assess and relate the predictive habitat maps to the seabed substrate maps produced by BGS a cross-tabulation has been carried out to produce a matrix which enables better comprehension of the relationships and variations between the two mapping classifications.

Table 11. Cross tabulation matrix for the BGS mapped substrates and the mapped habitat classes for the Firth of Forth and Wee Bankie to Gourdon areas.

		Rock & Folk Sediment Classes (BGS)										
MNCR & EUNIS Classes		(g)mS	(g)S	G	gM	gmS	gS	mS	S	sG	sG	Rock
IR.HIR.KFaR	A3.11	0%	0%	0%	0%	0%	0%	0%	**0.1%**	**0.2%**	0%	**0.5%**
CR.HCR.XFa	A4.13	0%	0%	**0.2%**	0%	0%	**2.9%**	0%	**0.1%**	**4.0%**	0%	0%
SS.SCS.CCS	A5.14	0%	0%	**0.4%**	0%	0%	**0.5%**	0%	0%	**2.6%**	0%	0%
SS.SCS.OCS	A5.15	**0.1%**	**0.6%**	**0.8%**	0%	0%	**12.4%**	0%	**1.4%**	**2.9%**	0%	0%
SS.SSa.CMuSa	A5.26	0%	**0.7%**	0%	0%	**0.2%**	**3.1%**	**2.2%**	**14.2%**	**0.1%**	0%	**0.1%**
SS.SSa.Osa	A5.27	**0.3%**	**1.2%**	0%	0%	0%	**5.3%**	**0.5%**	**25.5%**	0%	0%	0%
SS.SMu.CSaMu	A5.35	0%	0%	0%	0%	0%	0%	0%	**0.6%**	0%	0%	0%
SS.SMx.CMx	A5.44	**0.1%**	**0.8%**	0%	0%	0%	**8.8%**	**0.1%**	**2.6%**	**0.5%**	0%	0%
SS.SMx.OMx	A5.45	0%	**0.1%**	0%	0%	0%	1.0%	0%	**0.1%**	**1.5%**	0%	**0.1%**

Table 11 shows that for the Firth of Forth and Wee Bankie to Gourdon areas the seabed substrates mapped by BGS and the mapped habitat do seem to correlate well with the sand based habitat being associated with deep circalittoral and circalittoral sands. Gravels, gravelly sands and sandy gravels occur mostly within the circalittoral and deep circalittoral coarse habitats. The infralittoral rock (A3.11) habitats match with the rock substrate identified by BGS, yet the circalittoral rock habitats (A4.13) correspond to the sandy gravel and gravely sand seabed substrate which could be attributed to the variation in sampling techniques and classification systems.

Table 12. Cross tabulation matrix for the BGS mapped substrates and the mapped substrate classes for Solan Bank to Fair Isle area.

	Rock & Folk Sediment Classes (BGS)						
Simplified Folk/MNCR classes	gmS	gS	mS	S	sG	(g)S	Rock
Rock	1.2%	2.3%	0.0%	1.1%	0.0%	0.0%	1.5%
Coarse Sediment	**1.7%**	**14.2%**	0.0%	0.3%	**5.3%**	0.3%	**4.1%**
Sand & Muddy Sand	0.7%	3.8%	**3.0%**	**49.2%**	0.5%	**0.6%**	0.7%
Mud & Sandy Mud	0.1%	0.0%	1.2%	8.0%	0.0%	0.0%	0.1%

Table 12 shows that for the Solan Bank to Fair Isle area there is good concordance between the sand sediment class mapped by BGS and the “Sand and Muddy Sand” habitats which have been mapped. The coarse sediment habitats correspond with the gravelly sands (gS) and sandy gravels (sG). The mud habitats identified by the habitat mapping appear to correlate most strongly to the sand (S) sediment class from the BGS sediment distributions. Rock habitats are confused with a range of sediment classes from the BGS sediments and the areas mapped as rock in the BGS seabed substrate correspond with the coarse sediment habitats.

Table 13. Cross tabulation matrix for the BGS mapped substrates and the mapped habitat classes for West Shetland Shelf area.

		Rock & simplified sediment classes			
MNCR & EUNIS Classes		**Rock**	**Coarse Sediment**	**Mixed Substrate**	**Sand & Muddy Sands**
SS.SCS.OCS	A5.14	0.1%	0.0%	0.0%	0.0%
SS.SCS.OCS & CR.LCR[Deep]	A5.14/A4.33	0.0%	7.1%	0.0%	0.0%
SS.SCS.OCS & SS.SMx.OMx	A5.14/A5.45	0.0%	0.0%	35.3%	0.0%
SS.SCS.OCS & SS.SSa.OSa	A5.14/A5.27	0.0%	9.8%	0.0%	0.0%
SS.SMx.OMx	A5.45	0.0%	0.0%	29.6%	0.0%
SS.SMx.OMx & CR.LCR[Deep]	A5.45/A4.33	0.0%	0.0%	8.4%	0.0%
SS.SSa.OSa	A5.27	0.0%	0.0%	0.0%	9.7%

Table 13 shows that for the West Shetland Shelf area there is good concordance across the classes and that the coarse seabed substrate class corresponds to the mosaic habitat of deep circalittoral coarse sediment and deep circalittoral rock. The rock substrate, of which there is very little, is mapped under deep circalittoral coarse sediment habitat class. The deep circalittoral sand habitat is mapped consistently as “sand and muddy sand” in the seabed substrate map. The good concordances shown in this matrix are to be expected as the seabed substrate map was derived using the same bottom-up methodology with the same ground truthing sites.

6 Issues

A general issue that occurred in all the mapping areas was matching the deeper habitats to the MNCR habitat classification. The EUNIS habitat classification includes categories for the deep circalittoral rock habitats and for habitats which are deeper than 200m, and it was for this reason the EUNIS habitat classification was chosen as the mapping categories to show, as these deep habitats were assigned to a ‘Null’ value in the MNCR due to no corresponding category. An alternative would be to use categories of a lower level of the hierarchy (i.e. move from level 3 to level 2) but this would lose some of the information contained within the maps.

6.1 Approaches to the Firth of Forth and Wee Bankie to Gourdon

The resulting rule-based habitat map for the Firth of Forth and Wee Bankie to Gourdon areas predominantly shows coarse sediment biotopes occupying the central regions with banks and trough systems. The bottom-up approach shows these areas to contain ‘rock’ habitats which are stable hard substrates with an epifaunal community present. This confusion may be due to the sampling methods used to derive each map: the BGS seabed substrate map used within the rule-based mapping is based on PSA sample data which may not sample the harder material and the bottom-up approach has both sediment sample data and video and stills footage which may focus on epifaunal communities and can sample the harder material.

Within the bottom-up approach, the map has offshore biotope complexes (SS.SS.OMx/SS.SCS.OCS) and circalittoral biotope complexes (SS.SS.CMx/SS.SCS.CCS) distributed throughout the areas with no distinct ‘cut-off’ or delineation between the two different habitat types. This confusion is likely to have come about due to the allocation of biotope codes to the samples which have been used to produce the map. These samples also appear to be distributed throughout the region and often occur in adjacent samples (i.e. changes observed in the relatively short distance of a tow) without any physical cut-off applied or introduced and this will therefore influence the likely habitat distribution.

Using contextual editing removes some of the ambiguity in habitat distribution from the maps but it should be noted the biological zones information used to delineate the habitat types is based upon modelled and predictive data and should therefore be treated with due caution.

6.2 Solan Bank to Fair Isle Channel

The major issue with this area was the lack of sample points which could be used within the bottom-up mapping methodology. Using the BGS sample points to supplement the number of samples does help alleviate the issue, but in effect the resulting maps are a reiteration of the top-down approach as the seabed sediments mapped are correlated to the seabed substrate map produced by the BGS. Whilst this may not be a considerable issue, it should be borne in mind if the maps are to be used for decision making.

The backscatter data for the area had a considerable number of acquisition artefacts within the data which does introduce anomalies into the resulting maps and whilst attempts were made to remove these during contextual editing, some artefacts may remain.

6.3 West Shetland Shelf (Windsock)

An interpreted BGS seabed substrate map did not exist for this area (the acoustic data were not part of the original MoA) and one was required to be produced as part of the mapping exercise. As this map was not produced using the same sample methods as the other seabed substrate maps used for other areas there may be some differences in how seabed substrates may have been mapped and the interpretation of these.

Rock biotopes – samples allocated to "CR.HCR.DpSp.PhaAxi(sparse) with the description of mixed sediment with cobbles & pebbles" may be an over-estimation of the 'rock' habitat where it should be a mixed or coarse habitat.

Using contextual editing removes some of the ambiguity in habitat distribution from the maps but it should be noted the biological zones information used to delineate the habitat types is based upon modelled and predictive data and should therefore be treated with due caution.

The acoustic data available for the area was restricted to a series of blocks of data and maps have been produced for the areas covered by these data sets. These areas could be considered representative for the local region but without verification, any extrapolation or extension of the results outside of the current map areas should be treated with appropriate caution and caveated.

7 Limitations

Effective and appropriate application of the maps produced as part of this project is dependent on an understanding and appreciation of the limitations associated with the maps and the processing which has been applied in their production.

The spatial resolution of the data used to produce the maps presented here can vary considerably not only with the spatial accuracy of data acquisition but also the spatial resolution at which habitats are detected by each form of data. Point sample data on their own are, spatially, low resolution in terms of the coverage they provide, grab samples sample around 0.1 m^2, still images between 1-10m^2 and video samples between 10-100m^2. The acoustic data has been processed to provide an initial resolution of 7m but this has been reduced to 50m during processing. Using these various resolutions of datasets requires the point sample data to be summarised as there can often be multiple samples and habitats within a single pixel or spatial unit of the acoustic data.

Density, location and vintage of ground truthing sites can influence the maps generated using these data. The Approaches to the Firth of Forth Wee Bankie to Gourdon areas contain a relatively well dispersed and numerous ground truth dataset but these data have a variety of vintages of >10 years to <1 year and this can affect the biotope allocation associated with the samples, the positional accuracy of the data and the various sampling techniques can affect the habitat associated with each sample point. It was noted in the Firth of Forth dataset that adjacent samples which had been collected over various timescales and surveys and allocated habitat classes by different means did have a diverse range of habitats. This is to be expected with the range of sampling equipment used, video tows sampling relatively large areas, still images smaller areas and focused on epifaunal communities and the difficulty of identifying sediment types accurately from still or video images. Grab sampling also focuses on the infaunal communities present and do provide accurate particle size data, but the type of sampling equipment may influence the substrate detected with more focus on infaunal sediment rather than the epifaunal community.

The EUNIS Classification and the MNCR habitat classification have been employed as mapping units for the maps produced as these are the most appropriate units for management purposes, but the habitat classifications are in constant development and as an increase in knowledge of the marine habitats is gathered the definitions of habitat classes can alter or be refined and it should be understood that the cut-offs and delimitations used may not be accurate, but the best understanding at the current time.

Using a predictive bottom-up mapping approach does make a range of assumptions of both the acoustic data sets and the ground truthing data. It is assumed that the acoustic datasets are capable of detecting the habitats identified from the ground truthing and also that the habitats which have been identified from the samples fully represent the range and diversity of the habitats which occur in the area to be mapped, and that each habitat has an equal probability of occurring (this can be altered but equal probabilities have been assumed in this case). The resulting maps also show the most likely habitat at each location, this could be a habitat of low probability but one with a slightly greater probability than the next most likely, this can produce maps which represent low probability habitats, for this reason certainty/uncertainly maps have been included to enable the user to assess the appropriateness of the map for a required task.

A rule-based top-down approach does have a range of assumptions associated with the processing methodology and with the datasets used. The processing operates by using a series of ‘cut-offs’ or exact delineations within data sets (i.e. a 200m depth limit for deep circalittoral or a 1.16 Nm^{-2} limit for moderate current energy) and it is assumed these accurately or best represent the environmental conditions associated with each habitat class. The data employed with the process is also assumed to accurately represent the conditions which occur at each location mapped, whether this be the seabed substrate or the energy levels which occur. Each of these data are derived from either modelled data which has its own assumptions associated with it or by expert interpretation. The seabed substrate maps produced by BGS use sediment sample data to ground truth the multibeam and backscatter data, this sampling technique focuses on collecting a sediment sample which can be biased against sampling a surficial or hard substrate which may support an epifaunal habitat which is different to that found infaunally.

A top down approach also uses the physical seabed substrate to determine the distribution of biological communities and this can cause certain habitats to be confused or underrepresented. This is especially relevant in the Approaches to the Firth of Forth and Wee Bankie to Gourdon areas in that the ground truth information suggests an epifaunal community is present which occurs on a hard seabed substrate which is classified as circalittoral rock at the lower levels which is an underrepresented habitat in the seabed substrate map and is more likely to be mapped as a coarse or mixed substrate and therefore not matched to this habitat type.

Using the object based analysis features and assigning the majority habitat category contained with each feature produces outputs which have simplified boundaries and reduced detail in the spatial heterogeneity of the habitats present. Whilst this can be useful in presenting a summary and major trends in the distribution of habitats any application of these data should be aware of the limitation in these maps.

All the backscatter datasets for the four areas of analysis had some issues in terms of artefacts associated with data acquisition or processing (Figure 4) and the resulting maps were required to be edited to remove some of the effects of these artefacts. Additionally the backscatter data for the West Shetland Shelf area was very noisy (Figure 23) and required considerable smoothing to produce data which could be used within the mapping process and this smoothing removed some detail and reduced the resolution of the data available.

Interpretation of backscatter is also a difficult process which relies on the backscatter values and patterns within the data to consistently represent specific seabed substrates which can be problematic as seabed types can share similar backscatter values and ranges. Substrates that have a strong acoustic reflectance such as rock and mixed substrate may be confused without additional acoustic information being available, likewise low reflectance surface may also be confused especially at the resolutions available for use within this mapping process.

8 Conclusion

The objective of this project was to generate seabed habitat maps for locations coinciding with nature conservation MPA proposals in Scottish waters with full coverage acoustic datasets to as detailed a hierarchical level as possible within the MNCR and EUNIS classification schemes. This objective has been met through the delivery of a wealth of spatial information. The maps will make an important contribution to the evidence base for the relevant Scottish MPA proposals through best estimation of extent of search features generated by the processing of full coverage acoustic datasets in conjunction with survey sample data.

It is critical that such maps are used with clear understanding of how they were generated and the reasons for the differences between the outputs. The understanding can be supported through the use of the layers of certainty of classification and probability of each habitat's occurrence.

Each technique paints a slightly different picture in terms of feature presence and extent within the areas. The different approaches have their merits in utilising all available data and presenting the user with different interpretations of information with which to better understand the likely feature composition in the area. The next step is to examine the implications of this project on practical considerations of how and when the different mapping outputs might be best utilised by the JNCC in the development of marine nature conservation advice.

9 Acknowledgements

The acoustic and seabed substrate datasets from the Firth of Forth Banks area and the Solan Bank to Fair Isle area used in this project originated from the Agreement for Project Partners concerning the partnership for the processing and interpretation of multibeam backscatter data for Scotland's seas and other parts of marine waters off the United Kingdom. The multibeam bathymetry and backscatter data were supplied by the Maritime and Coastguard Agency, the backscatter data were processed by the National Oceanography Centre (NOC) and the British Geological Survey (BGS) interpreted these into seabed substrate maps.

The energy, light and wave base data layers used in the top-down rule-based mapping were produced and made freely available by the EUSeaMap project.

We would also like to thank JNCC colleagues, particularly from the Marine Ecosystem Team, for their input and advice on the practical application and considerations to be taken account of during the mapping project as well as ensuring it had use and benefits for multiple marine projects and programmes.

10 References

AXELSSON, M., DEWEY, S. & ALLEN, C. 2012. Analysis of seabed imagery from the 2011 survey of the Firth of Forth Banks Complex, the 2011 IBTS Q4 survey and additional deep-water sites from Marine Scotland Science surveys. *A report by Seastar Survey Ltd.* for the Joint Nature Conservation Committee, JNCC Report in prep

CAMERON, A. & ASKEW, N. (eds.). 2011. EUSeaMap - Preparatory Action for development and assessment of a European broad-scale seabed habitat map final report. Available at http://jncc.defra.gov.uk/euseamap

COLTMAN, N., GOLDING, N. & VERLING, E. 2008. *Developing a broad-scale predictive EUNIS habitat map for the MESH study area.* In: MESH Guide to Marine Habitat Mapping, www.searchMESH.net/mappingguide

COMMISSION OF THE EUROPEAN COMMUNITY. 2007. The Interpretation Manual of European Union Habitats - EUR27 [online]. Brussels: European Commission DG Environment. Available from: http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

CONNOR, D.W., ALLEN, J.H., GOLDING, N., HOWELL, K.L., LIEBERKNECHT, L.M., NORTHEN, K.O. & REKER, J.B. 2004. The Marine Habitat Classification for Britain and Ireland Version 04.05 JNCC, Peterborough ISBN 1 861 07561 8. Available from: www.jncc.defra.gov.uk/MarineHabitatClassification

EEC (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. *Official Journal of the European Communities* **L 206**.

EUSEAMAP. 2012a. EUSeaMap - Preparatory Action for development and assessment of a European broad-scale seabed habitat map. Maintenance report. October 2012. Available from https://webgate.ec.europa.eu/maritimeforum/system/files/20121010_MaintenanceReport_EUSeaMap_v1.0.pdf

EUSeaMap. 2012b. EUSeaMap Technical Appendix No. 1 Light data and thresholds. October 2012. Available from https://webgate.ec.europa.eu/maritimeforum/system/files/TechnicalAppendix_Light_EUSeaMap_20121010_FINAL.pdf

FOLK, R.L. 1954. The distinction between grain size and mineral composition in sedimentary nomenclature. *Journal of Geology*, **62**, 344-359

GOUDGE, H. & MORRIS, L. 2012. Seabed imagery analysis from three Scottish offshore towed video surveys: 2011 MSS BTSQ3 survey, 2011 1111s FRV Scotia Rona-Windsock survey & 2011 MSS Rockall survey. A report for the Joint Nature Conservation Committee, JNCC Report in prep

IRVING, R. 2009. The identification of the main characteristics of stony reef habitats under the Habitats Directive. Summary report of an inter-agency workshop 26-27 March 2008. *JNCC Report* No. 432. Available from: http://jncc.defra.gov.uk/default.aspx?page=5023

LONG, D. 2006. BGS detailed explanation of seabed sediment modified Folk classification. Available from http://www.searchmesh.net/PDF/BGS%20detailed%20explanation%20of%20seabed%20sediment%20modified%20folk%20classification.pdf

MARINE MANAGEMENT ORGANISATION. 2012. Recommendations on the use of habitats maps in the planning process and requirements for future planning areas. A report produced for the Marine Management Organisation, p41. MMO Project No: 1014. ISBN: 978-1-909452-03-9.

MARINE SCOTLAND. 2011a. A strategy for marine nature conservation in Scotland's seas. Available from: www.scotland.gov.uk/Resource/Doc/295194/0115590.pdf

MARINE SCOTLAND. 2011b. Marine Protected Areas in Scotland's Seas. Guidelines on the selection of MPA's and development of the MPA network. Available from http://www.scotland.gov.uk/Resource/Doc/295194/0114024.pdf

MARINE SCOTLAND, SCOTTISH NATURAL HERITAGE, JOINT NATURE CONSERVATION COMMITTEE, MARINE SCOTLAND SCIENCE, BRITISH GEOLOGICAL SURVEY & NATIONAL OCEANOGRAPHY CENTRE. 2011. Memorandum of Agreement - Agreement for Partners concerning the partnership for the implementation of Processing and interpretation of multibeam backscatter data for Scotland's seas and other parts of marine waters off the United Kingdom.

MCBREEN, F., ASKEW, N., CAMERON, A., CONNOR, D., ELLWOOD, H. & CARTER, A. 2011. UKSeaMap 2010: Predictive mapping of seabed habitats in UK waters. *JNCC Report*, No. 446. Available from http://jncc.defra.gov.uk/ukseamap

MESH. 2008. MESH Confidence Assessment. Available from http://www.searchmesh.net/Default.aspx?page=1635

PEARCE, B., GRUBB, L., EARNSHAW, S., PITTS, J. & GOODCHILD, R. 2012. Biotope Assignment of Grab Samples from Four Surveys Undertaken in 2011 Across Scotland's Seas. A report by Gardline Caledonia Ltd. for the Joint Nature Conservation Committee, JNCC Report in prep

SCOTTISH NATURAL HERITAGE AND JOINT NATURE CONSERVATION COMMITTEE. 2012. Advice to the Scottish Government o the selection of Nature Conservation Marine Protected Areas (MPAs) for the development of the Scottish MPA network . Scottish Natural Heritage Commissioned Report No. 457.

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Appendix 1: Workshop 1

A Mini workshop was held at JNCC Aberdeen Offices, 25 March 2013 with the agenda below:

09:30	Welcome; Introduction & Background to contract	Oliver Crawford-Avis
	Introduction to Tasks, Areas and Data	Ian Sotheran
10:45	BREAK	
11:00	Mapping Options & Considerations: Utilising data of varying resolutions Sample site distribution Assumptions Made Scale of Mapping Units Scale of Maps Confidence	Ian Sotheran
12:00	LUNCH	
13:00	Example maps from the Firth of Forth Banks area showing various mapping methods, [segmentation rule-based mapping, probability based mapping (supervised), object based image analysis] with advantages and disadvantages of each Methods & Possibilities for other areas	Ian Sotheran
14:30	BREAK	
14:45	Group Session for discussion: How would you use these maps? What are you requirements for mapping?	All
1600:	Summary of workshop and outputs	Oliver Crawford-Avis Ian Sotheran
16:30	Close	

A summary of the discussions and agreements from the workshop were:

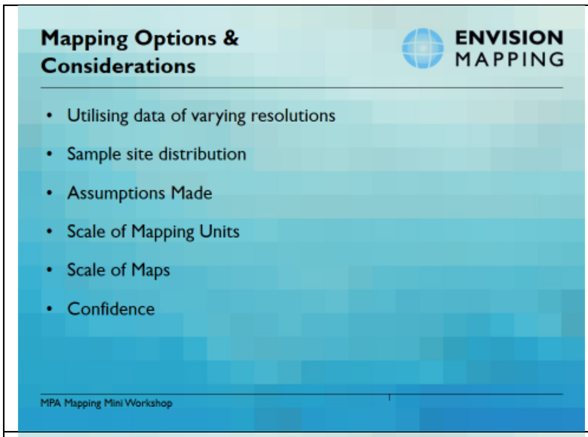
- Regarding issues with the current version of the habitat classification scheme
    - Rock and other hard substrata as a classification scheme category is very hard to map given the breadth of the definition (bedrock, cobbles, pebbles, etc). What is observed in survey imagery (ground type and biology) may be part of a mosaic of mixed substrata. Analysts can process to a very detailed level (of the hierarchy) which can be difficult to map. Depth ranges defined for biotopes may well be broader than stated. These are indicative based on best available evidence at the time of creating the scheme version. Makes the job of mapping extents more difficult
    - One option is to map the extent of areas which contain suites of biotopes.
    - There is a parallel workstream on the refinement of the offshore sediments section of the classification scheme
- Regarding the considerations of rule-based top down approaches versus bottom up approaches were discussed
    - Continuing the discussion on mapping the extent of suites of biotopes, it was suggested that the latest EUSeaMap biological zone predictions be used to inform the distribution of where biotopes (of biotope complexes) may be located
    - It was suggested mapping biotope extent was not appropriate given the data coverage and unlikelihood of having captured the full range in such large areas of acoustic data

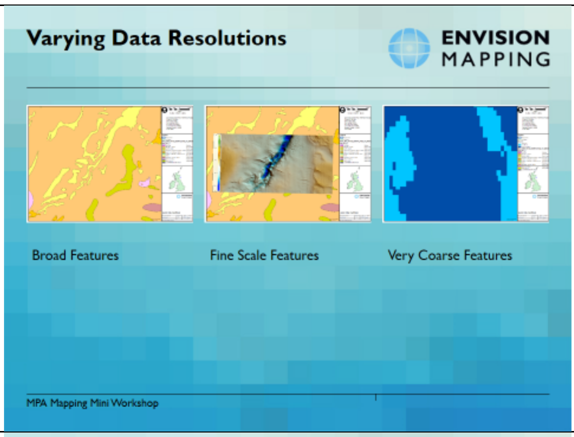
- Mapping at biotope complex level (eg EUNIS level 4 for sediments) was more appropriate. Whilst this is just physical habitat mapping, in terms of the scheme it is the parent level to the biotopes.

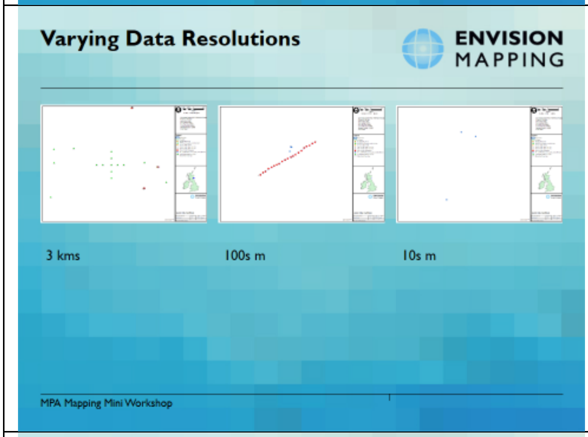
- Data availability and preparation
  - Whilst substrate layers were available from BGS based on the interpretation of the acoustic data, which can be transformed into the BGS modified Folk classes and transferable to EUNIS level 3 habitats, there is a mismatch between the EUNIS level 4 classes and those of Folk (e.g. fine sands & fine muds) thus a compromise would be needed it mapping EUINS level 4 biotope complexes)
- Scale and resolution of the analysis, need to ensure these are appropriate to the ground-truthing which is the principal limiting factor.
- Particular points on OBIA segmentation and classification, were that the quality of the map is highly influenced by the scale parameter and the quality of the training samples. Sampling may need to be iterative till conflict of signals is reduced to the lowest levels.
- Implications of data coverage on habitat mapping, and what is optimal for survey planning. Confidence in maps is dependent on the ground-truthing therefore when having to compromise data acquisition, emphasis should be put on ground-truthing
- Smallest manageable unit should dictate the smallest mappable unit. However units vary by project (management, monitoring, and mapping). The more detailed the mapping the more likely it will be subject to change with time in such dynamic environments.
- May employ a combination of techniques between the areas.
- Outputs required
  - suitable GIS products for presentation as well as internal working (given the current development of the habitat classification scheme)
  - Suite of data to enable the production of public facing maps (i.e. to a level of the scheme that is accepted and not due for review)
  - Data which can inform the variation, distribution and patchiness of the habitats/biotope complexes
  - Rule-based products can remain at the higher resolution enabling end-users to reduce according to the use of the information as needed

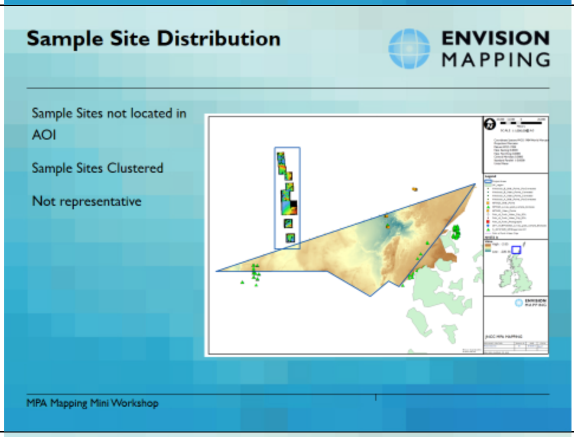
Table 14 provides the basic outline for a presentation used to highlight the mapping options and considerations which required discussion in order to progress and better understand the mapping process to be employed for the areas of analysis.

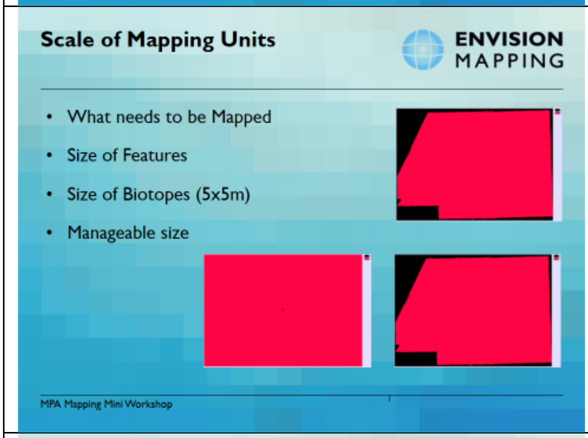
Table 14. Slides used in workshop 1 to illustrate and highlight some of the issues which required consideration during the mapping process.

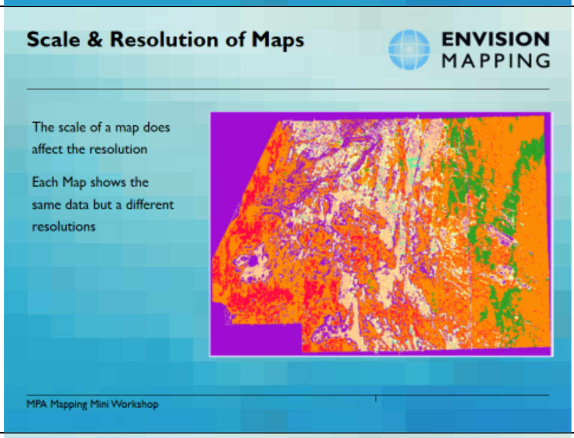


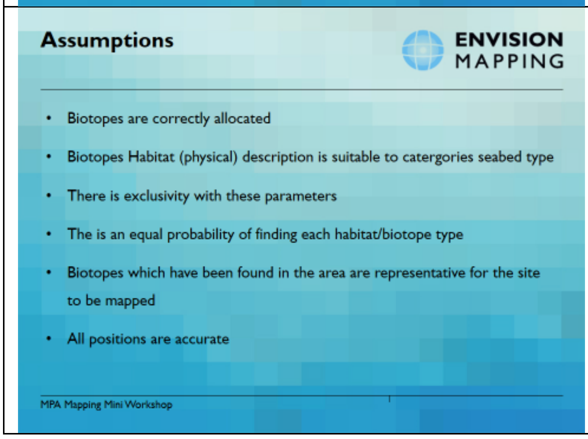


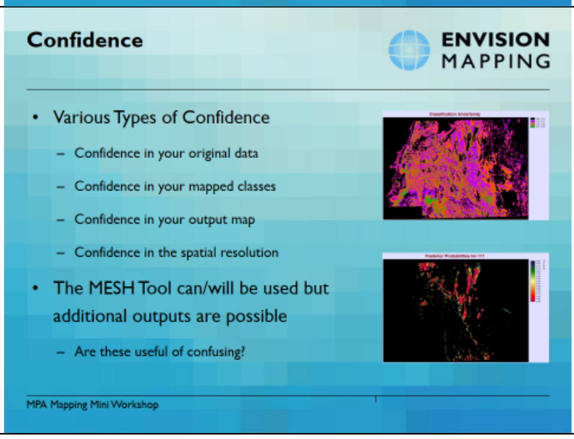












Appendix 2: Workshop 2

Following workshop 1 and incorporation of the conclusions further progress was made with the mapping of the areas and a second workshop was held at JNCC Peterborough offices to discuss final methods outputs and deliverables for the project.

11:00	Welcome; Introduction & re-cap of project	Oliver Crawford-Avis
11:15	Explanation of methodology applied	Ian Sotheran
12:15	LUNCH	
13:15	Results so far – description & explanation	Ian Sotheran
14:15	Explanation of further analysis undertaken on mapping distribution of biotope complexes/biotopes	Ian Sotheran
15:15	BREAK	
15:30	Explanation of supporting data layers (eg confidence & uncertainty)	Ian Sotheran
16:00	Session for discussion of products and further questions	All
16:30	Summary of workshop and outputs	Oliver Crawford-Avis Ian Sotheran
16:45	Close	

A summary of the conclusion and agreements from the workshop were:

- Produce output maps at EUNIS Level 3/4 (and MNCR Level 2/3) along with existing maps
- Produce Bayesian & Belief outputs to 3rd most likely
- Updated Light levels at 4.5% for threshold for infralittoral, with JNCC to provide documentation
- For rule-based maps an additional field for inclusion of Folk classifications from BGS is a possibility but due to licencing restrictions this has not been possible
- For sands habitats use either EUNIS A5.25 or A5.26. A5.26 has been used in the maps and this does include the muddy element of the sediments which was found in the sample data
- Acoustic artefacts are to be manually edited and accounted for
- A supervised categorised output was noted as a possibility to be investigated and provide as an output if possible (this has been provided as the supervised categorised maps)
- Supporting data outputs: The following supporting information will be investigated and supplied if possible
    - Classification Certainty/Uncertainty
    - Probabilities for mapped class
    - Layer for 1-3 likely biotopes (Belief model) with score by object (same shape)
- Cross tabulate BGS SBS map with the predictive maps table in report mismatch match concordance table (rather than points to remove sampling error)
- GIS outputs to include an analysis code and a mapped code, the analysis code to be the initial output but also information on biological zones, sediments and energy classes and any contextual editing notes

- West Shetland Shelf habitats to be reviewed and agreed prior to production of final maps
- Investigate SMu code in Wee Bankie area - is derived from very few samples and maybe amalgamate with Sandy Muds, BGS suggesting muddy sand, samples will be reviewed

Appendix 3: Processing Parameters & Technical Notes

Object Based Image Analysis Parameters:

This processing required all input data to possess equivalent spatial parameter and resolutions. These are presented for each area below and should be used if any subsequent processing is required. Any amendments to these parameters should be documented.

Approaches to the Firth of Forth and Wee Bankie to Gourdon

columns	2224
rows	1571
ref. system	WGS84 UTM30N
ref. units	m
unit dist.	1.0000000
min. X	523591.625
max. X	634791.625
min. Y	6223628.5
max. Y	6302178.5
resolution	50

Solan Bank to Fair Isle Channel

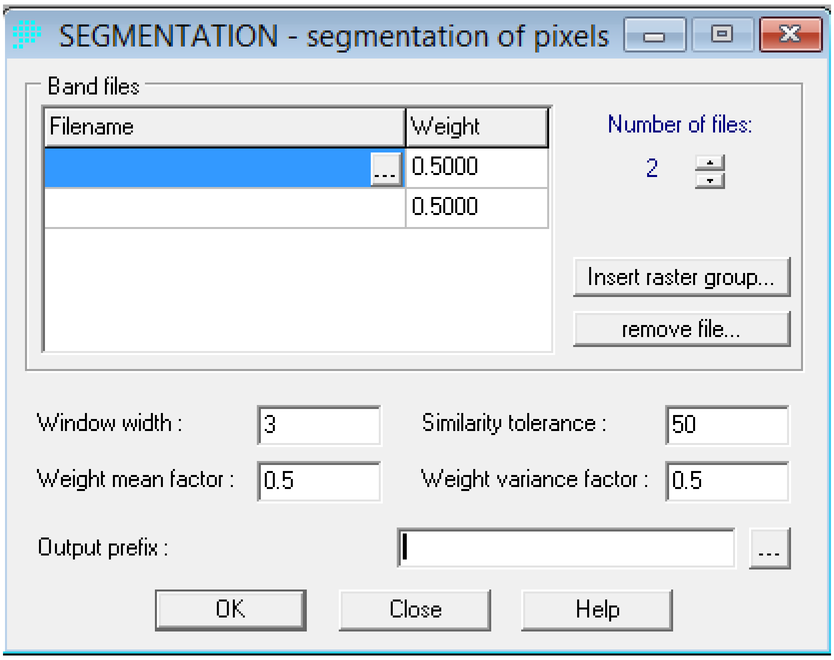
columns	3134
rows	1364
ref. system	WGS84 UTM30N
ref. units	m
unit dist.	1.0000000
min. X	361200
max. X	517890
min. Y	6540605
max. Y	6608795
resolution	50

West Shetland Shelf (Windsock)

columns	1621
rows	1111
ref. system	WGS84 UTM30N
ref. units	m
unit dist.	1.0000000
min. X	326400
max. X	407450
min. Y	6574600
max. Y	6630150
resolution	50

Object Based Image Analysis/Processing

The software used to undertake this task, IDRISI Selva Edition, used a module entitled ‘Segmentation’ to identify features within the images and classify them. The following parameters were used within the module:



SEGMENTATION Operation

BANDFILES:- Specify the number of files and enter their names into the grid. The bands will be given equal weights by default. This can be altered if desired but equal weightings were used.

WINDOW WIDTH: Specify the width and height of the moving window from which a variance image of each layer will be derived, such as a 3 x 3 window. A width of 3, equivalent to 150m was used.

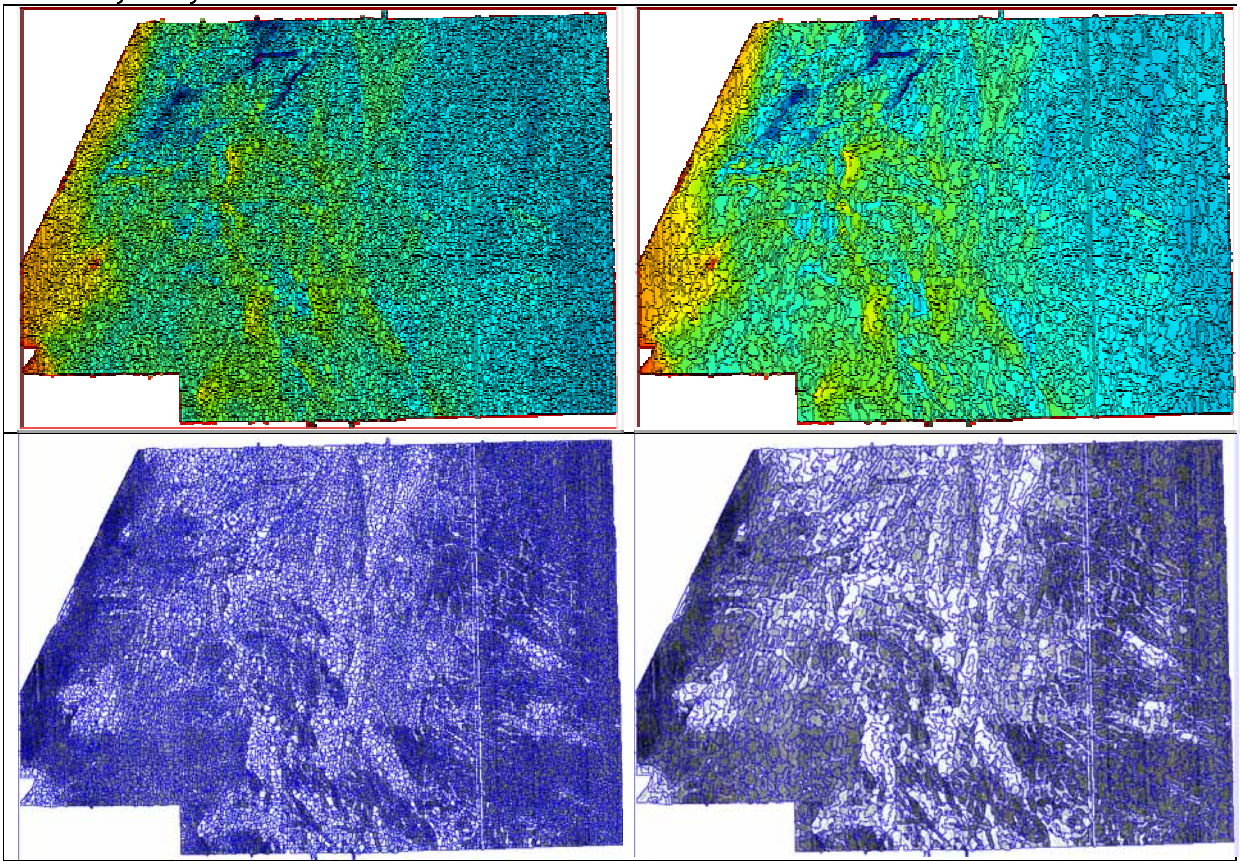
WEIGHTS FOR MEAN AND VARIANCE: These values alter the similarity threshold between neighbouring segments, leave at default of 0.5

SIMILARITY TOLERANCE: This value is to be used to control the generalization level and a corresponding segmentation is generated as an output image, the larger the tolerance value, the fewer the image segments in the output. (see note below)

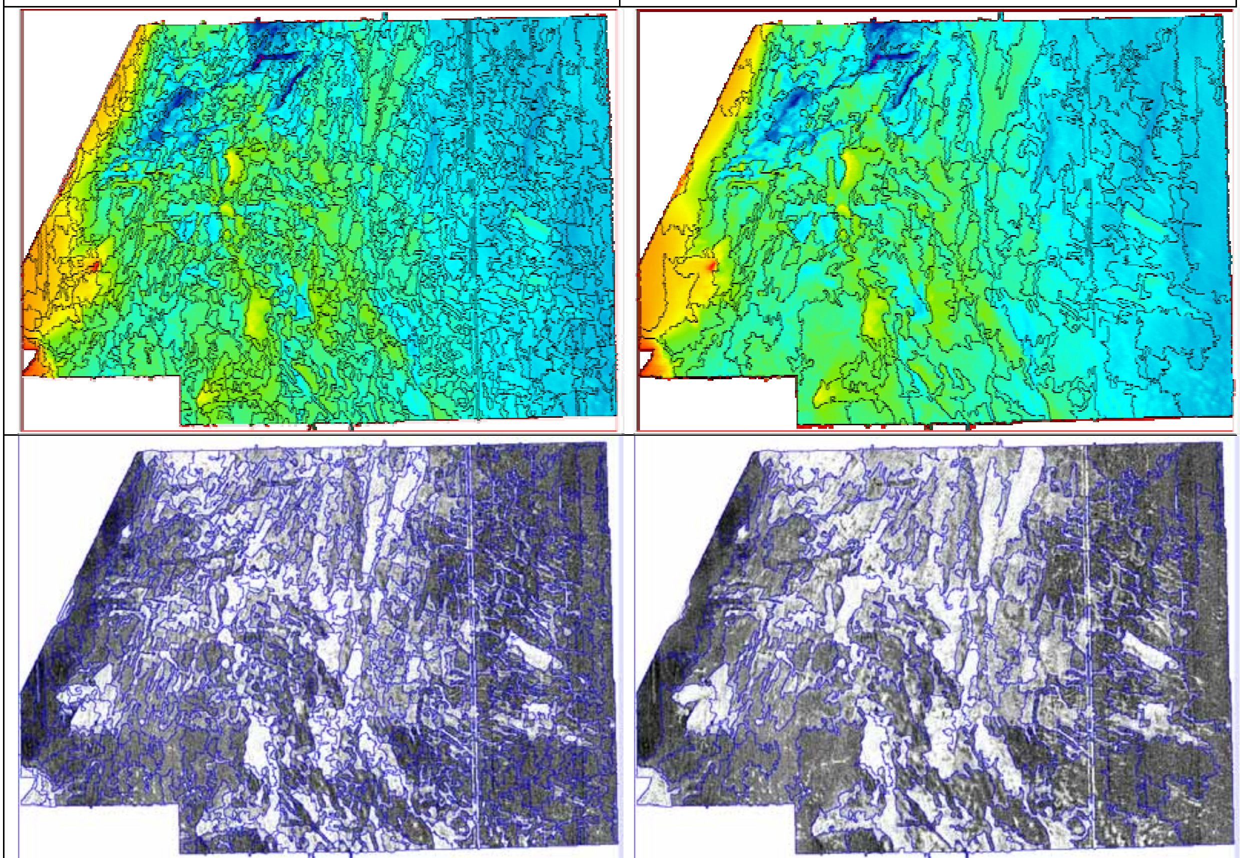
OUTPUT PREFIX: The output filename includes the prefix followed by an underscore

NOTE: Investigation into the effect of altering this value were examined and lower values decreased the size of the features detected and produced a very fragmented output with small areas which did not appear to relate to recognisable features, increasing the value reduces the number of areas detected and a threshold of 90 produced quite large areas. A threshold value of 50 was chosen as a suitable value as this produced areas which seem to relate to recognisable features and patterns which are visually recognisable from the backscatter and bathymetry and related to the sample site distribution.

Figure below shows the output from the process using difference threshold values overlain on bathymetry and backscatter datasets.



Threshold Value 10 | Threshold Value 30



Threshold Value 50 | Threshold Value 90

Supervised Classification - Maximum Likelihood

The Maximum Likelihood classification is based on the probability density function associated with a particular training site signature. Pixels are assigned to the most likely class based on a comparison of the posterior probability that it belongs to each of the signatures being considered.

MAXLIKE is also known as a Bayesian classifier since it has the ability to incorporate prior knowledge using Bayes' Theorem. Prior knowledge is expressed as a prior probability that each class exists. It can be specified as a single value applicable to all pixels, or as an image expressing different prior probabilities for each pixel.

All signatures used with the Maximum Likelihood module were given equal probabilities and no prior probabilities were incorporated

Classification of OBIA - SEGCLASS

The SEGCLASS module is a majority rule classifier based on the majority class within a segment. Typically, the classified image is derived using the Maximum Likelihood classifier with the segment-based training and signature files. The segmentation image is derived from the segmentation module. SEGCLASS is used improve the accuracy of the pixel-based classification and produce a smoother map-like classification result while preserving the boundaries between segments. During the module operation each of the segments identified during the OBIA routine is classified to the majority class in the underlying supervised image.

Appendix 4: MPA Search Features

Seabed habitats and their components only – full list includes low or limited mobility species, mobile species and large-scale features (Marine Scotland, 2011b)

MPA search feature	Component habitats / species	Scottish marine area
Blue mussel beds	*Mytilus edulis* beds on littoral sediments	Territorial waters
	Mytilus edulis and *Fabricia sabella* in littoral mixed sediment	Territorial waters
	Mytilus edulis beds on sublittoral sediment	Territorial waters
	Mytilus edulis beds on reduced salinity infralittoral rock	Territorial waters
Burrowed mud	Seapens and burrowing megafauna in circalittoral fine mud	Both
	Burrowing megafauna and *Maxmuelleria lankesteri* in circalittoral mud	Both
	Tall seapen *Funiculina quadrangularis*	Both
	Fireworks anemone *Pachycerianthus multiplicatus*	Both
	Mud burrowing amphipod *Maera loveni*	Offshore waters
Carbonate mound communities	Carbonate mound communities	Offshore waters
Coral gardens	Coral gardens	Offshore waters
Deep sea sponge aggregations	Deep sea sponge aggregations	Offshore waters
Flame shell beds	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment	Territorial waters
Horse mussel beds	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata	Territorial waters
	Modiolus modiolus beds on open coast circalittoral mixed sediment	Territorial waters
	Modiolus modiolus beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata	Territorial waters
	Modiolus modiolus beds with *Chlamys varia,* sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata	Territorial waters
Inshore deep mud with burrowing heart urchins	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud	Territorial waters
Kelp and seaweed communities on sublittoral sediment	Kelp and seaweed communities on sublittoral sediment	Territorial waters
Low or variable salinity habitats	Faunal communities on variable or reduced salinity infralittoral rock	Territorial waters
	Kelp in variable or reduced salinity	Territorial waters

MPA search feature	Component habitats / species	Scottish marine area
Maerl beds	Maerl beds	Territorial waters
Maerl or coarse shell gravel with burrowing sea cucumbers	*Neopentadactyla mixta* in circalittoral shell gravel or coarse sand	Territorial waters
Native oysters	*Ostrea edulis* beds on shallow sublittoral muddy mixed sediment	Territorial waters
	Native oyster *Ostrea edulis*	Territorial waters
Northern sea fan and sponge communities	*Caryophyllia smithii* and *Swiftia pallida* on circalittoral rock	Territorial waters
	Mixed turf of hydroids and large ascidians with *Swiftia pallida* and *Caryophyllia smithii* on weakly tide-swept circalittoral rock	Territorial waters
	Deep sponge communities (circalittoral)	Both
	Northern sea fan *Swiftia pallida*	Both
Offshore deep sea muds	*Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy sediment near margins of deep stratified seas	Offshore waters
	Foraminiferans and *Thyasira* sp. in deep circalittoral fine mud	Offshore waters
	Levinsenia gracilis and *Heteromastus filifirmis* in offshore circalittoral mud and sandy mud	Offshore waters
	Paramphinome jeffreysii, *Thyasira* spp. and *Amphiura filiformis* in offshore circalittoral sandy mud	Offshore waters
	Myrtea spinifera and polychaetes in offshore circalittoral sandy mud	Offshore waters
Offshore subtidal sands and gravels	*Glycera lapidum*, *Thyasira* spp. and *Amythasides macroglossus* in offshore gravelly sand	Offshore waters
	Hesionura elongata and *Protodorvillea kefersteini* in offshore coarse sand	Offshore waters
	Echinocyamus pusillus, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand	Offshore waters
	Abra prismatica, *Bathyporeia elegans* and polychaetes in circalittoral fine sand	Offshore waters
	Maldanid polychaetes and *Eudorellopsis deformis* in offshore circalittoral sand or muddy sand	Offshore waters
	Owenia fusiformis and *Amphiura filiformis* in offshore circalittoral sand or muddy sand	Offshore waters

MPA search feature	Component habitats / species	Scottish marine area
Seagrass beds	*Zostera noltii* beds in littoral muddy sand	Territorial waters
	Zostera marina/angustifolia beds on lower shore or infralittoral clean or muddy sand	Territorial waters
	Ruppia maritima in reduced salinity infralittoral muddy sand	Territorial waters
Sea loch egg wrack beds	*Ascophyllum nodosum* ecad *mackaii* beds on extremely sheltered mid eulittoral mixed substrata	Territorial waters
Seamount communities	Seamount communities	Offshore waters
Shallow tide-swept coarse sands with burrowing bivalves	*Moerella* spp. with venerid bivalves in infralittoral gravelly sand	Territorial waters
Tide-swept algal communities	Fucoids in tide-swept conditions	Territorial waters
	Halidrys siliquosa and mixed kelps on tide-swept infralittoral rock with coarse sediment	Territorial waters
	Kelp and seaweed communities in tide-swept sheltered conditions	Territorial waters
	Laminaria hyperborea on tide-swept infralittoral mixed substrata	Territorial waters