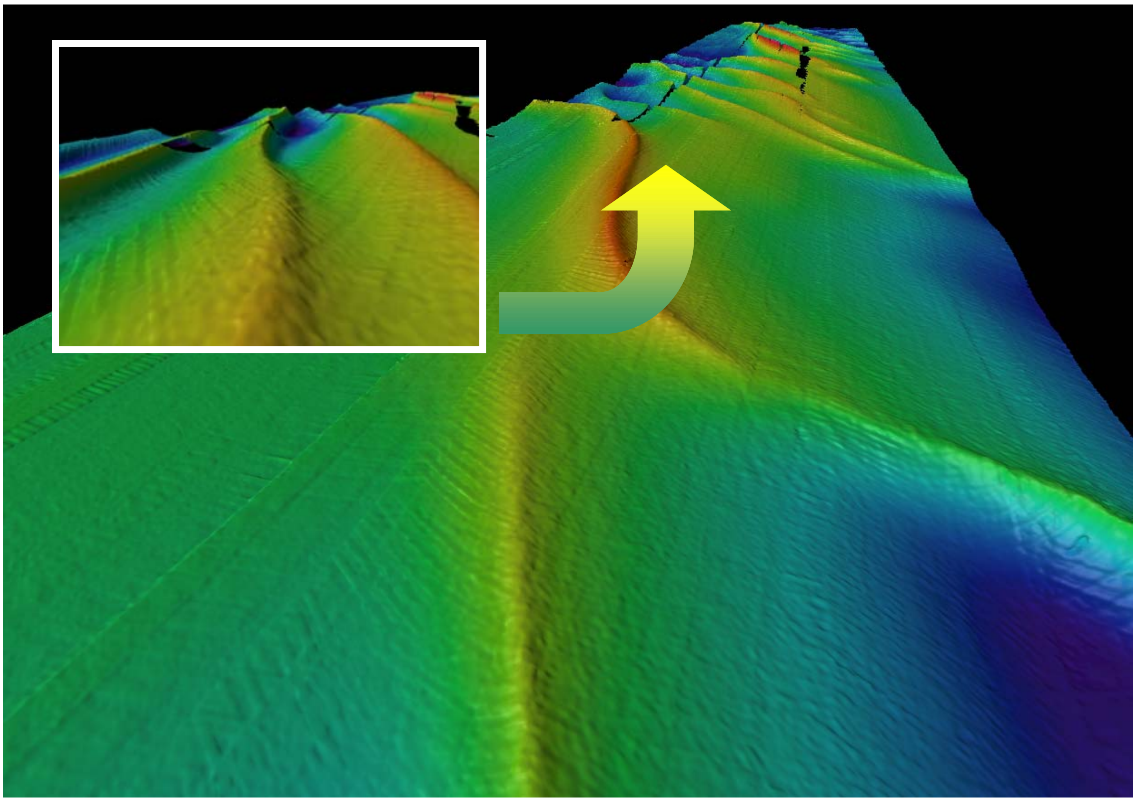
Title:	**Survey Data Analysis for Hemptons Turbot Bank**
Author(s):	Jonathan White (Marine Institute)
Document owner:	Jonathan White (Marine Institute)
Reviewed by:	
Workgroup:	
MESH action:	Action 3
Version:	3
Date published:	16/11/2006
File name:	Survey Data Analysis Investigation for Hemptons Turbot BankIII.doc
Language:	English
Number of pages:	24
Summary:	This document reviews the approach of analysing multibeam bathymetric and backscatter data for habitat classification using grab samples and video footage for groundtruthing over an area called Hamptons Turbot Banks, a series of sand waves off the north coast of Ireland.
Reference/citation:	
Keywords:	Multibeam; Bathymetry; Backscatter; Sand waves; Bathymetric Position Index; Habitat classification; Ground truthing; Grab samples; Underwater Video
Bookmarks:	
Related information:	

Change history		
Version:	**Date:**	**Change:**
3	16/11/2006	Version 3

Survey Data Analysis for Hemptons Turbot Bank

Jonathan White
Marine Institute, Ireland



Hemptons Turbot Bank bathymetric model viewed from looking east

An investigation into the categorisation of survey data sets for mapping a sand wave seafloor system

Undertaken as part of the INTERREG IIIB project Mapping European Seabed Habitats

Abstract

As part of the MESH North Western Shelf Consortium, Hemptons Turbot Bank was surveyed using single and multibeam echo sounders, side scan sonar, grab samples and video transects. Data were investigated to examine how information for meso-scale habitat mapping may be best extracted from each. Multibeam bathymetry used to calculate Bathymetric Position Index, classification of backscatter through grey scale, frequency distribution, standard deviation and iso-intensity classification and demarcation by eye produced clear differentiation of seafloor areas with different acoustic signatures. Single beam echo sounder data were processed with EchoPLUS and investigation of echos 1 and 2, though with less determinate results. Side scan sonar data collected did not prove useful in the classification of the Hemptons Turbot bank sand wave area, while classification of *in-situ* ground truthing grab sample PSA, with multivariate analysis produced clear groupings of sediments and video tows classified to EUNIS level 4 categorised habitats well over the areas they were made.

Introduction

As part of the INTERREG IIIB project "Development of a framework for Mapping European Seabed Habitats" (MESH) a series of collaborative surveys were conducted on sites off the north coast of Ireland and west coast of Scotland by the MESH North Western Shelf Consortium (comprising the British Geological Survey, the Department of Agriculture and Rural Development – Northern Ireland and the Marine Institute, Ireland).

A series of sites were identified and surveyed over 2004, 2005 and 2006, representing a range of physical environments. The work contributes to two areas of research undertaken by the MESH group. It investigates and develops Standards of survey activities and Protocols of data analysis (Action 2) and Testing of Survey Protocols (Action 3).

This report deals with the analysis of seafloor survey data collected from Hemptons Turbot Bank, chosen as a target survey site for its recognised importance as a fisheries spawning ground to the fishing industry, the different techniques and methods of mapping the seafloor are investigated to determine the most appropriate surveying techniques and data processing protocols for distinguishing seafloor habitats over sand wave features.

Hemptons Turbot Bank is an area of sand waves sitting off the north coast of Ireland, west of Malin Head (55˚28'00"N: 006˚52'00"W to 55˚24'00"N: 007˚4'00"W) (Figure 1), depths of sand waves range from peaks at 19m to troughs going down to 50m (Figure 2).

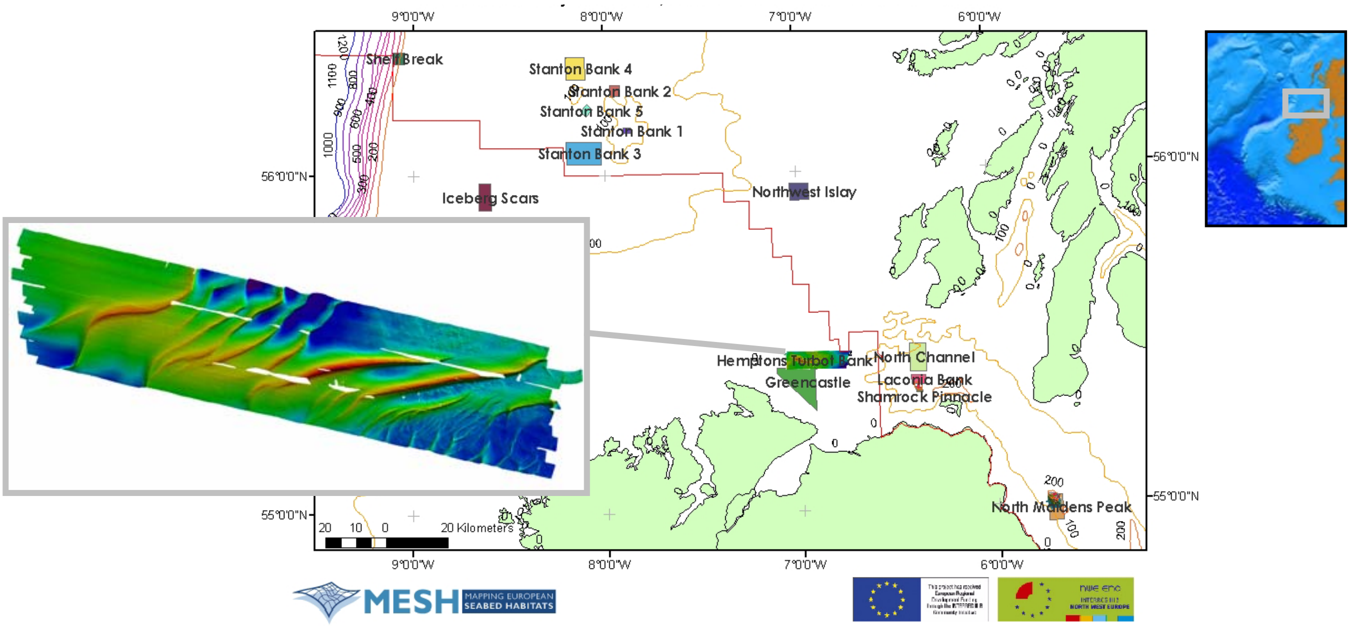


Figure 1. Hemptons Turbot Bank off the north coast of Ireland.

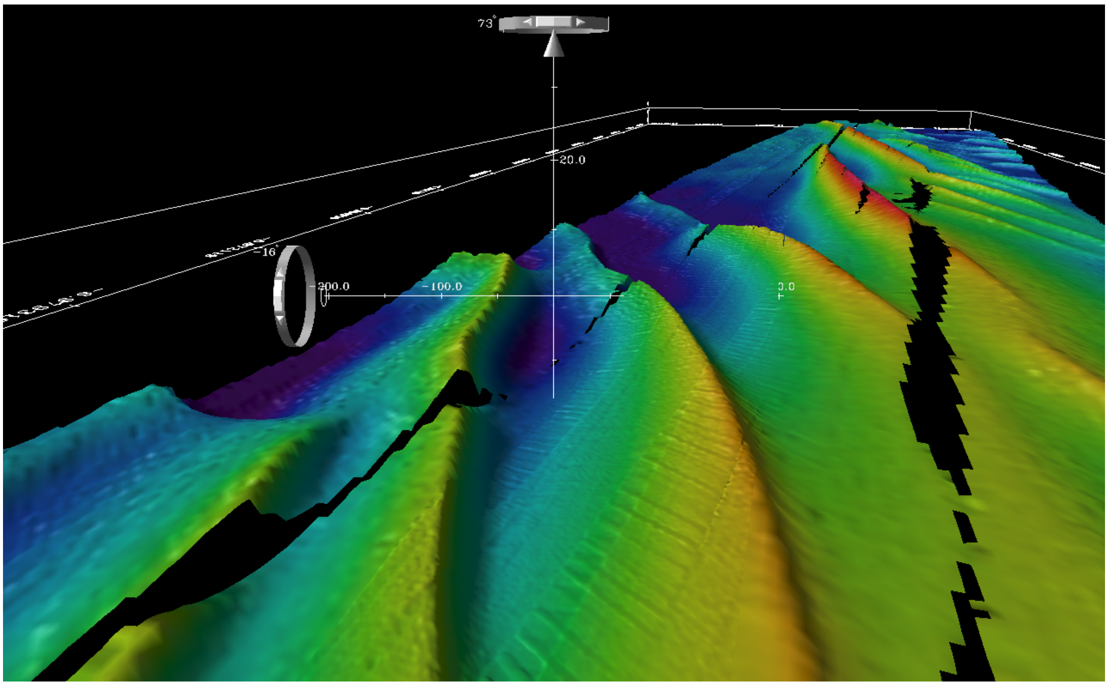


Figure 2. Sand waves of Hemptons Turbot Bank. Looking east northeast (73˚) from a perspective of 16˚. Vertical scale is exaggerated by a factor of 6. Scale is in metres.

Survey sites

A series of survey sites off the north coast of Ireland were identified for surveying to provide a range of substrate types, depths and geological diversity (listed in Table 1 and located in Figure 1). This report will deal primarily with survey data collected over Hemptons Turbot Bank.

Table 1. Survey areas and descriptions, locations are shown in Figure 1.

Survey area	Description
Hemptons Turbot Bank	**Sand waves and sand banks of importance for fisheries spawning grounds**
North Channel	Sand waves and sand banks
Northwest Islay	Sand waves and sand banks
Shelf Break	Edge of continental shelf – mud flats
Greencastle Codling Bank	Gently inclined sand to course sediment of importance for fisheries spawning grounds
Iceberg Scour marks	Flat soft sediments with apparent gouging caused by icebergs during glaciation.
Shamrock Pinnacle	Rock pinnacles
Laconia Bank	Rock platform
North Maidens	Rock platform
Stantons Bank 1	Rock pinnacles
Stantons Bank 2	Rock pinnacles
Stantons Bank 3	Rock pinnacles
Stantons Bank 4	Rock pinnacles
Stantons Bank 5	Rock pinnacles

Surveying was undertaken on two occasions over Hemptons Turbot Bank: as part of the Irish National Seabed Survey between June the 12th and 16th, 2004 (Figure 3) on the R.V. *Celtic Explorer* (survey CE04_02), and again between the 20th and 22nd of September, 2005 as part of a dedicated MESH survey from the R.V. *Celtic Voyager* (survey MESH_05_01).

During survey operations in 2004 two facets of the Multibeam Echo Sounder settings introduced factors to the acquired backscatter data set: a change in the absorption coefficient on June 16th introduced an data of different intensity range (bottom right in Figure 3) and during operations on June 14th the constant beam width "fixed distance" setting was chosen over "fixed beam angle", introducing to the data changes in gain as the multibeam re-adjusted beam angles to maintain beam width – apparent in the bottom left of Figure 3. Surveying techniques used included multi and single beam echo sounders, sub-bottom profiler and gravitometer. Multibeam data were collected to LINZ and IHO Order 2 standards.

The second survey over the Bank in September 2005 concentrated on the central sand waves (Figure 4) again with single and multibeam echo sounders, sub-bottom profiler and this time also with Sidescan Sonar. Multibeam coverage was just under 100% to maximise survey coverage and investigate coverage needs for habitat mapping. During the intervening period between the two surveys sand wave progression was evident with waves moving westward (Figure 5 and in detail Figure 6).

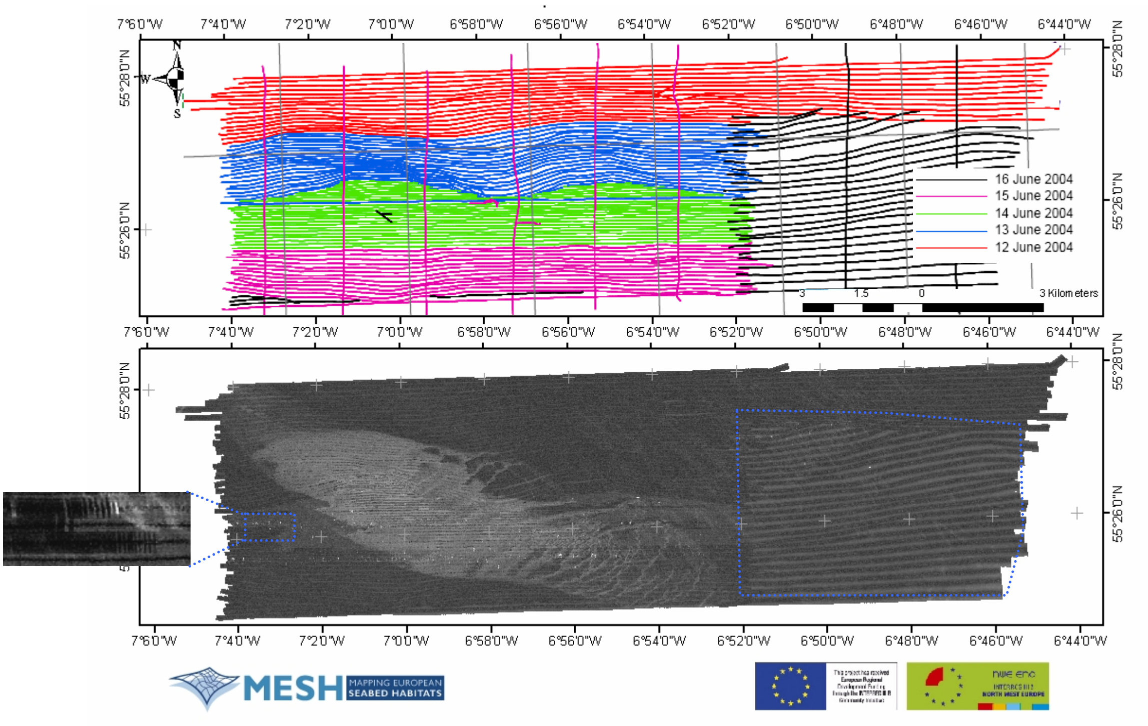


Figure 3. Survey lines, June 2004 and backscatter with survey setting facets in the data set indicated – bottom right owing to absorption coefficient settings and bottom left a result of setting beam angle control of the multibeam echo sounder to constant width.

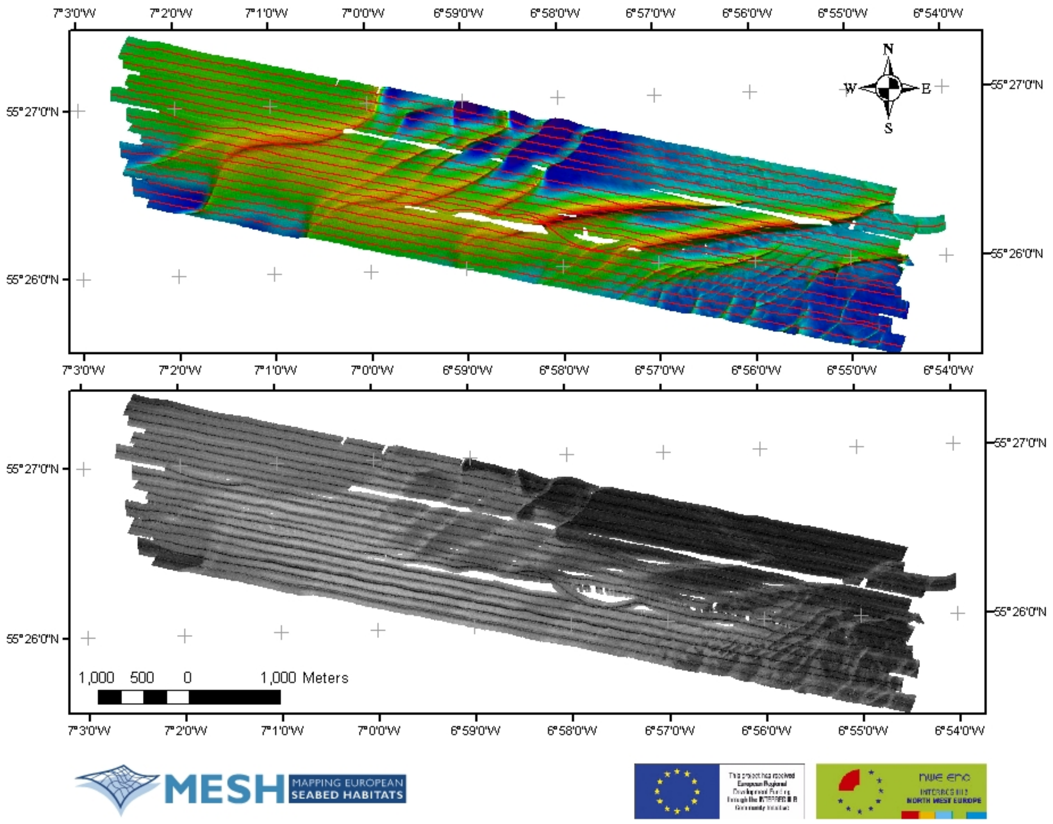


Figure 4. Shaded bathymetry with survey lines (top) and backscatter (bottom), September 2006.

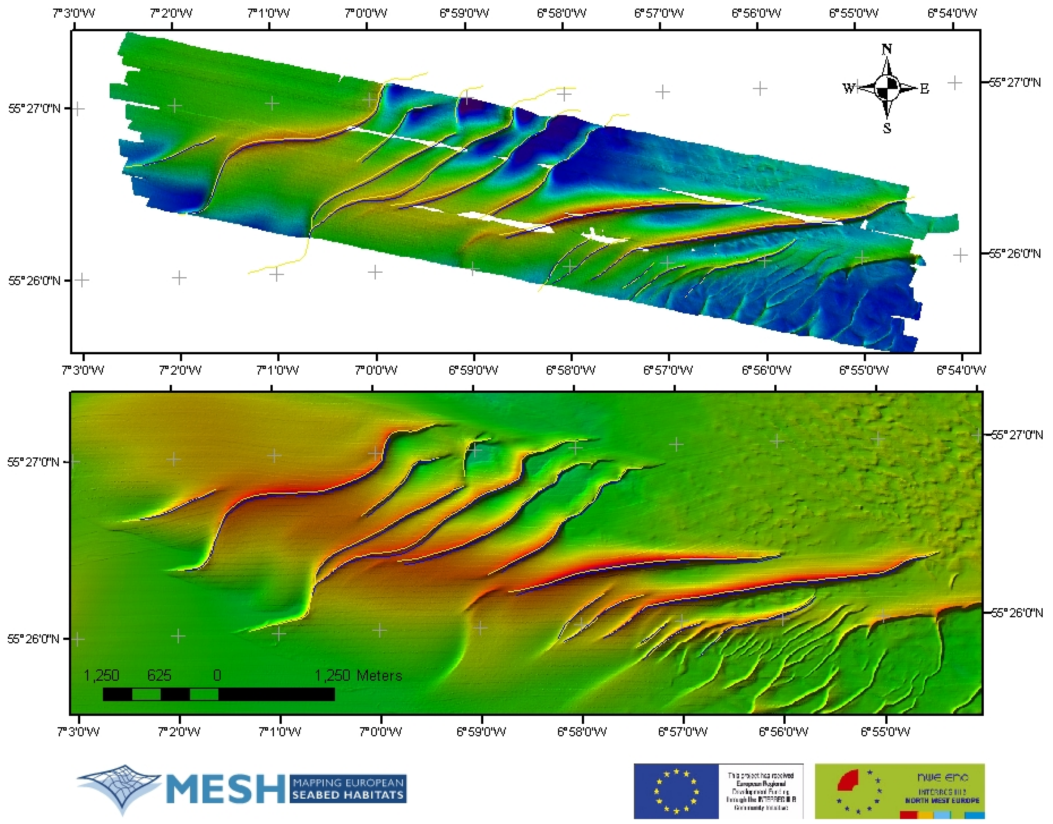


Figure 5. Progression of sand wave peaks from June 2004 (bottom; yellow line) to September 2006 (top; blue line).

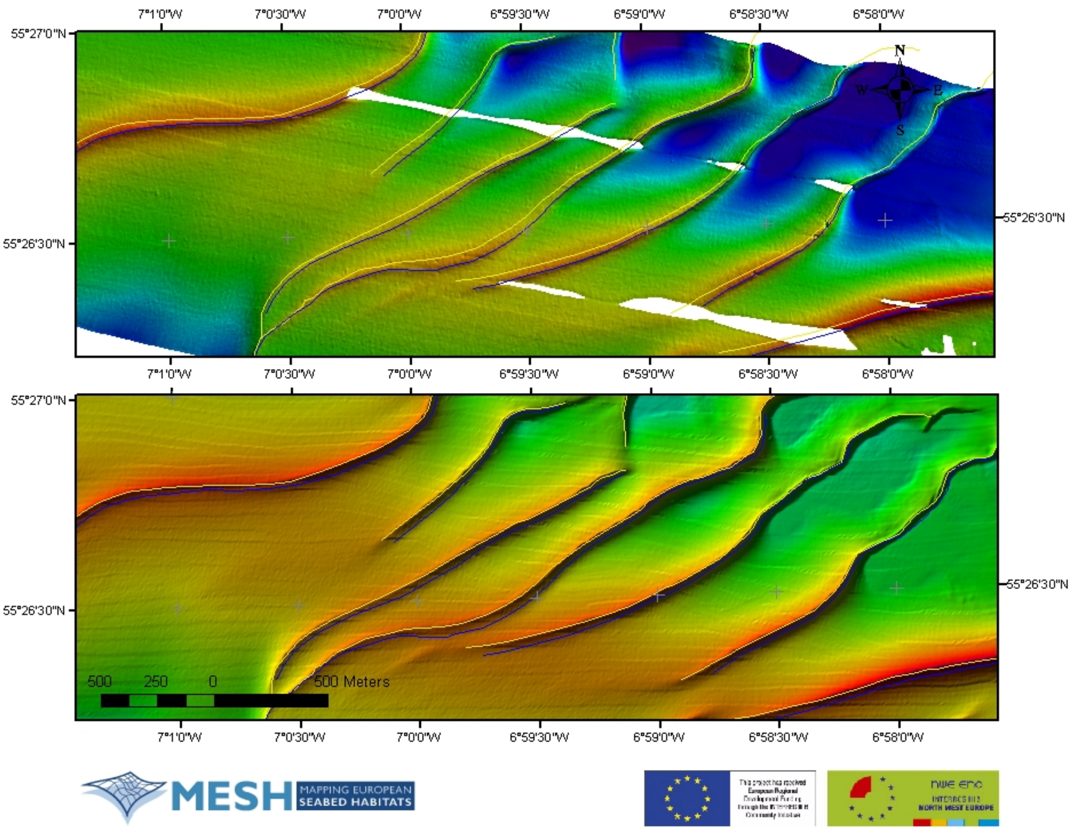


Figure 6. Detail of sand wave peak progression June 2004 (bottom; yellow line) to September 2006 (top; blue line).

Survey methods

Surveying techniques were used in accordance with operational procedures and are reported in the relative Irish National Seabed Survey survey leg reports: Survey Report: Leg CE 04_02 and Survey Report: Leg MESH 05_01 Zones 1 & 2). Instruments used on the two vessels are itemised in Table 2. Instruments highlighted in bold indicate the sources of data which were investigated for ability to different habitats through different analysis approaches.

Table 2. Surveying technologies used on the *Celtic Explorer* June 2004 (CE04_02) and *Celtic Voyager*, September 2005 (MESH05_01) over Hemptons Turbot Bank. (Systems in bold indicate data sets investigated in this report).

Technique	R.V. *Celtic Explorer* (CE04_02)	R.V. *Celtic Voyager* (MESH05_01).
Multibeam Echo Sounder (bathymetry & backscatter).	**Kongsberg Simrad EA 1002**	Kongsberg Simrad EA 1002S
Single Beam Echo Sounder	Kongsberg Simrad EA600	**Kongsberg Simrad EA 400**
Sidescan sonar	–	**GeoAcoustics towfish 159D**
Grab samples	**Shipeck grab for Particle Size Analysis**	Shipeck grabs for Benthic invertebrates
Video tows	–	**Sled mounted Simrad Camera**
Sub bottom profiler	Pinger	Pinger

Results

The following descriptions detail methods for assessing data sets acquired from seafloor mapping technologies for discriminating habitats. Acoustic echosounder techniques provide remote information of the seafloor, either as direct depth records which are corrected in detail for tidal changes and vessel motion or as intensity records, dependent upon the incident angle and texture of the seafloor (standardly recognised as roughness and hardness) and may be used to infer seafloor material. These data must however, be ground truthed with *in situ* sampling. Ground truthing tend to take two forms, either collection of physical seafloor material samples or imagery in the form of still photographs or video. Physical sampling are taken using grabs or cores and maybe for geological/ geophysical, chemical or biological infauna or epifauna examination. Biological epifaunal samples may also be collected using trawls.

The instruments and techniques employed in collecting the data analysed and described comprise a standard set of surveying protocols used by the Marine Institute's Seabed Survey/ Advanced Mapping Group, while the analysis of the resulting data are investigatory.

Multibeam echosounder – bathymetry

Multibeam bathymetric data are high density data which tend to be processed to create gridded seafloor models or digital elevation model (DEM). Produced by the Department of Geosciences, Oregon State University and the National Oceanic and Atmospheric Administration the Benthic Terrain Modeler is a GIS tool designed to calculate Bathymetric Position Index (BPI) for a seafloor DEM. A development of the Topographic Position Index used on landscapes to describe the elevation, slope and roughness of areas in relation to one another, the BPI enables each point of the seafloor to be classified based upon depth, slope and rugosity based upon that of surrounding cells (Figure 7).

The Benthic Terrain Modeller provides a step by step process in order to calculate BPI. Procedure of calculation (Figure 8) requires data to be in a projected raster format. User defined inner and outer radii need to be defined by the user for a "broad scale" BPI and a "fine scale" BPI (Figure 8), which are then processed in corroboration with slope and a user defined Dictionary of seafloor classes (LUNDBLAD *et al.,* 2006).

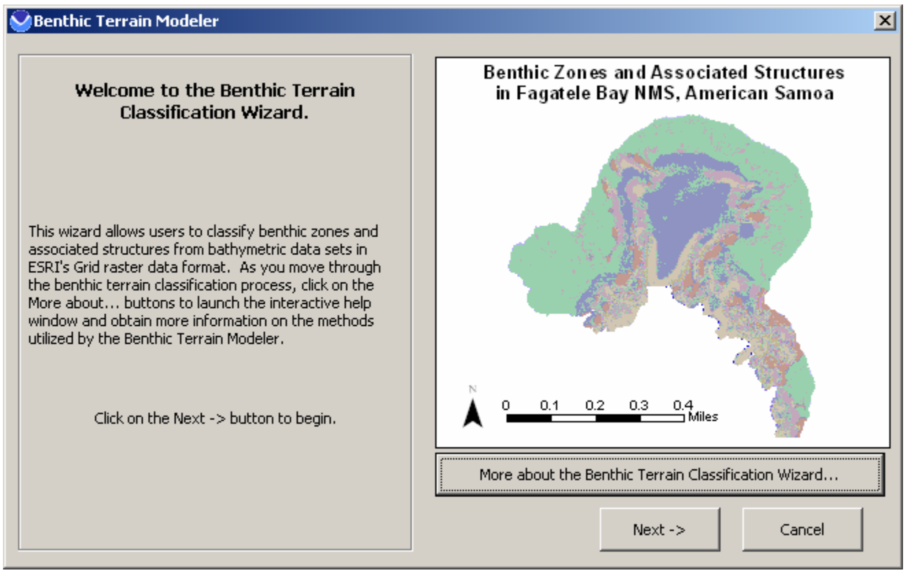


Figure 7. Opening page of the Benthic Terrain Modeler Bathymetric Position Index calculation wizard (NOAA, 2005).

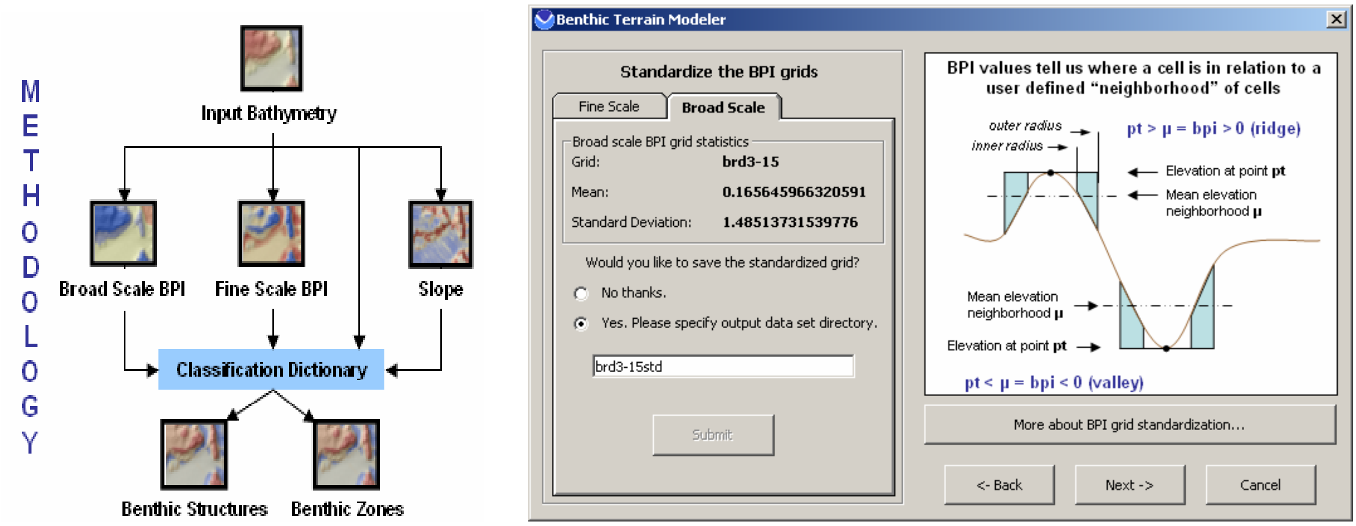


Figure 8. The flow methodology of BPI derivation and description of the inner and outer radii, which must be defined for calculation of broad and a fine scale BPIs (NOAA, 2005).

Bathymetric data from Hemptons Turbot Bank were processed through the BTM at a resolution of $2m^2$. Following an iterative process of trials, the inner & outer radii for calculation of broad scale BPI were defined as 3 & 15 units (*i.e.* 6m and 30m respectively) and fine scale radii were defined as 1 & 5 units (2m and 10m respectively).

Resulting board scale (Figure 9) and fine scale (Figure 10) BPIs shows clear demarcation of different areas of the sand waves. It is apparent from these analyses that the board scale BPI has fewer classes, covering a larger spatial extents and the fine scale BPI, with more classes, covering smaller spatial extents. Using the ZONE classification dictionary areas of the sand wave structures were clear derived though coarse in their definition as front of slopes, backs of slopes, flats and crests (Figure 11).

Development of user defined dictionaries did not yield detailed, reliable results. The dictionary requires definition of 8 fields (Table 3) with upper and lower BPI bounds being represented as standard deviation units; upper and lower bounds as the mapped units and; slope in degrees. Defining dictionary fields proved complex and time consuming with little useful derived information resulting while increasing the level of user subjectivity into the classifications. In consideration of this, the broad scale BPI proved a versatile, unbiased classification approach capable of deriving meaningful areas of the sand wave field. The classification in Figure 9 demonstrates the BTM classification with user defined class labels. This aggregation is independent of user subjectivity beyond the definition of inner and outer radii, which itself is an integral component of calculating Bathymetric Position Index.

Table 3. Dictionary fields in the Benthic Terrain Modeler.

Field	Description
Class	An integer number
Description	A text based description of the class (e.g. Reef Crest)
Fine Scale BPI Lower Bounds	Lower bounds of Fine Scale BPI data set
Fine Scale BPI Upper Bounds	Upper bounds of Fine Scale BPI data set
Broad Scale BPI Lower Bounds	Lower bounds of Broad Scale BPI data set
Broad Scale BPI Upper Bounds	Upper bounds of Broad Scale BPI data set
Slope Lower Bounds	Lower bounds of slope data
Slope Upper Bounds	Upper bounds of slope data
Depth Lower Bounds	Lower bounds of depth
Depth Upper Bounds	Upper bounds of depth

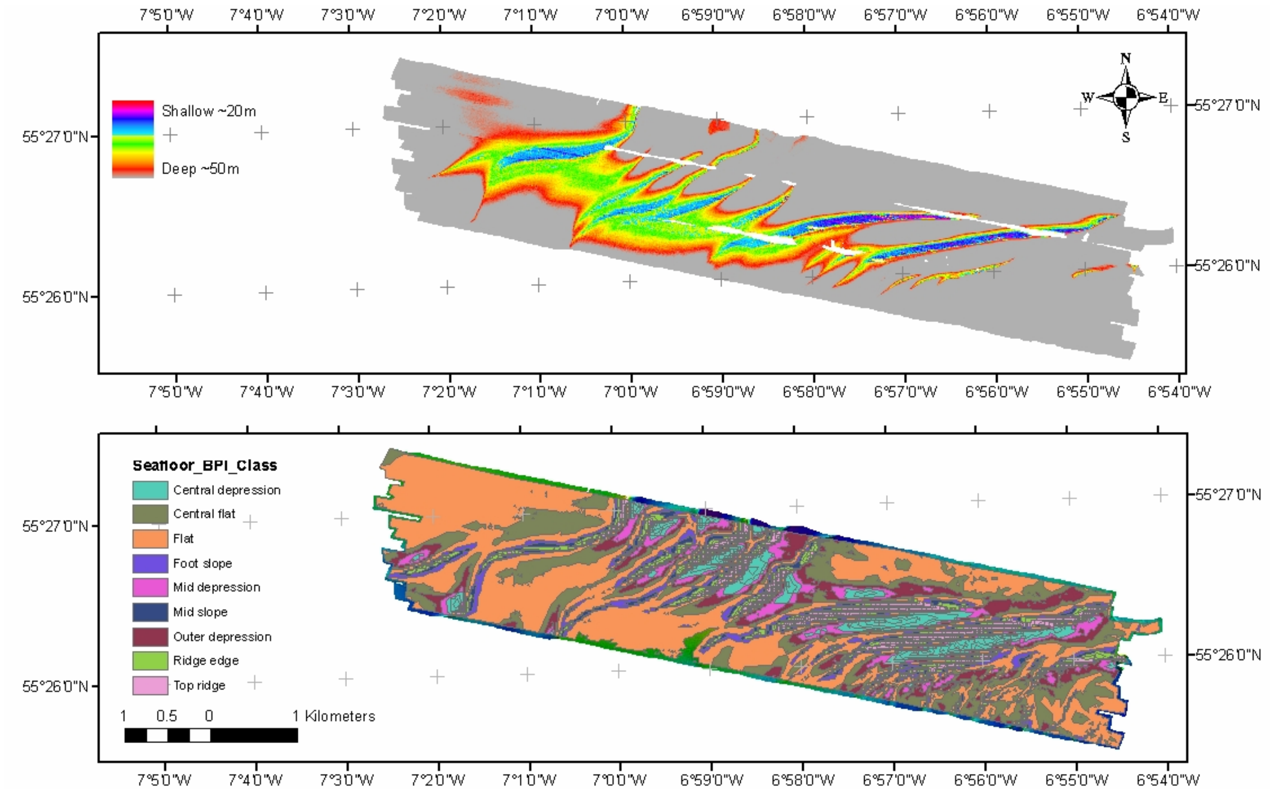


Figure 9. Broad scale BPI (bottom) and accompanying shaded relief (top).

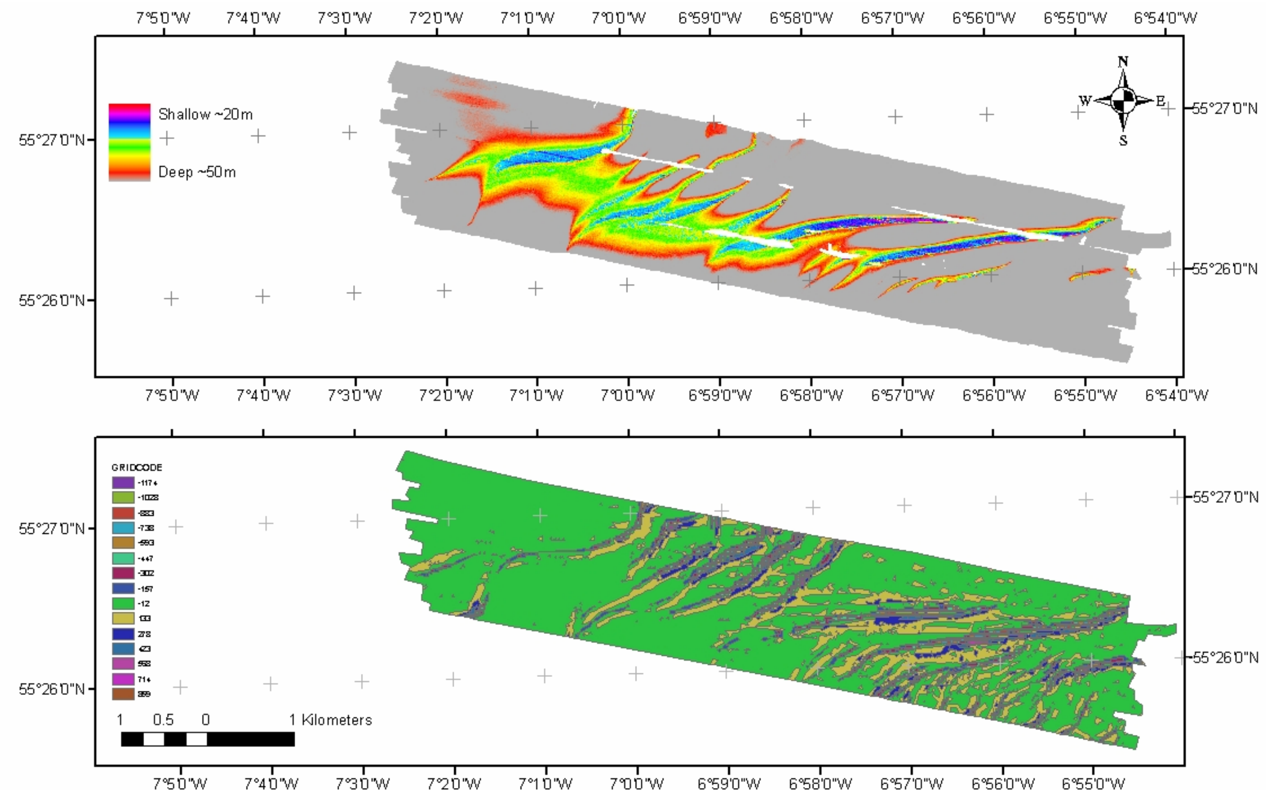


Figure 10. Fine scale BPI (bottom) and accompanying shaded relief (top).

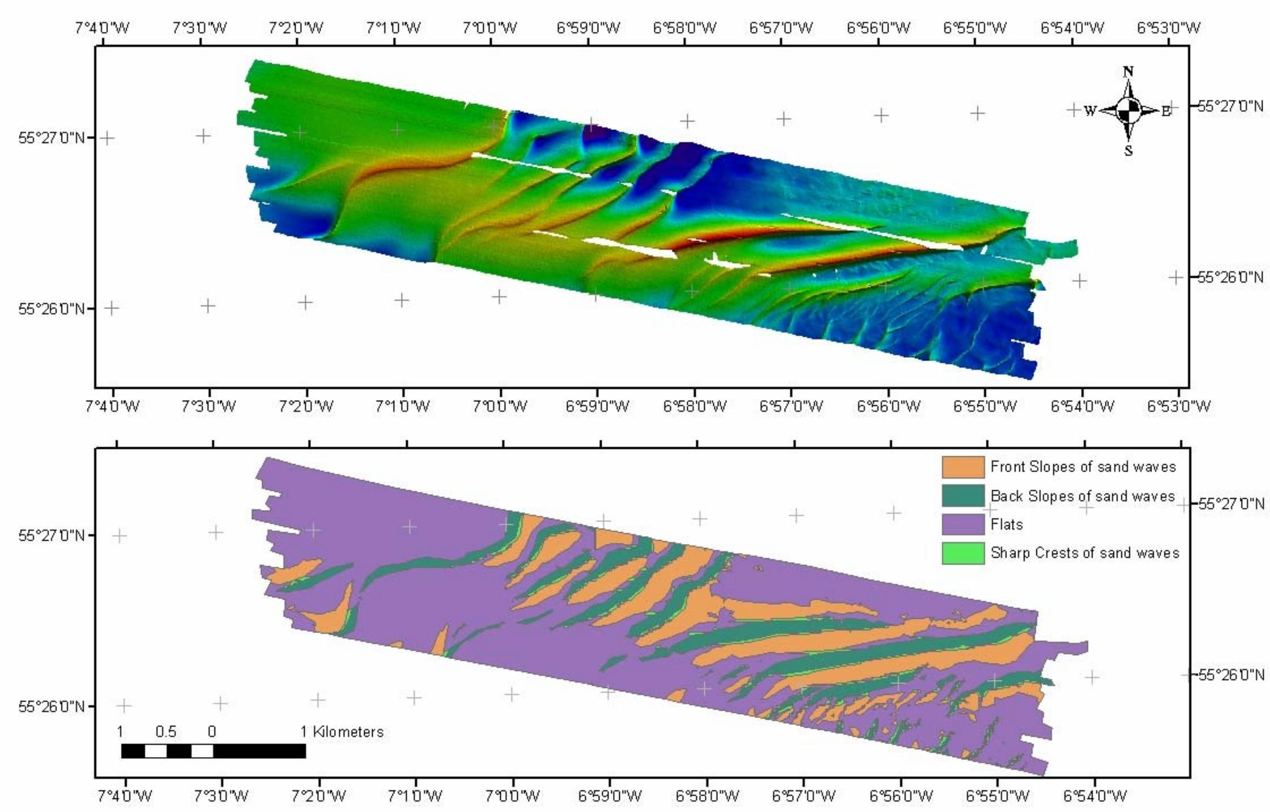


Figure 11. ZONE classification dictionary areas determined for Hemptons Turbot Bank (bottom) with shaded relief (top).

Multibeam echosounder – backscatter

Backscatter results from the intensity of the returning signal to the multibeam transducers from the seafloor and is affected by the incident angle (or grazing angle) of the beam on the seafloor, and the hardness and roughness of the seafloor (Figure 12) (for a more detailed description see the MESH report Review of Standards and Protocols for Seabed Habitat Mapping, www.searchmesh.net/).

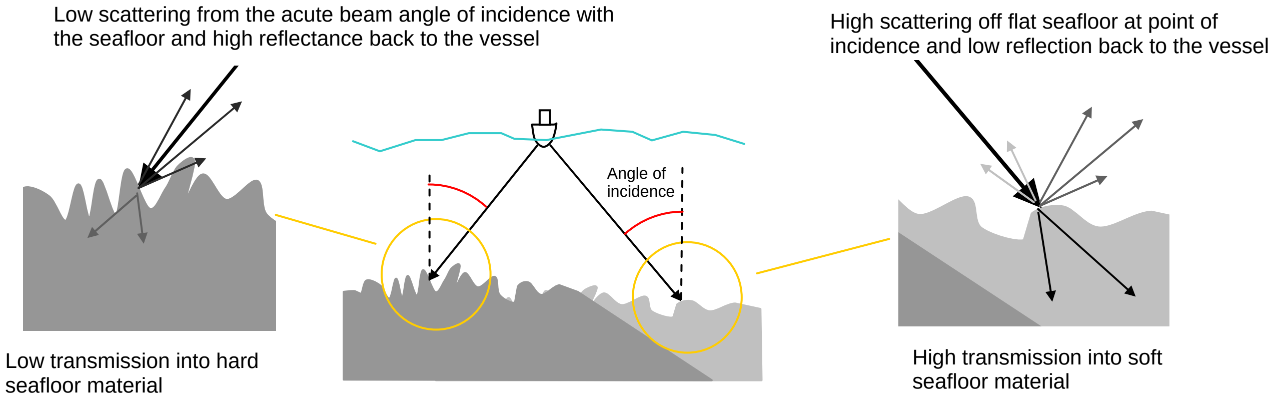


Figure 12. Diagrammatic representation of factors influencing the strength of returning multibeam backscatter signal owing to seafloor hardness and roughness. On the right, representing a softer seafloor material with a flatter angle of beam incidence with the seafloor, the strength of the signal reflected to the ships transducer will be low owing to high scattering (due to angle of beam incidence) and high energy loss through transmission to the sea floor, while on the left, representing a harder seafloor, signal strength loss through transmission into the seafloor will be less and the acute beam incident angle will give rise to greater strength of reflected beam to the ship.

Backscatter information returns an intensity signal, which may be geo-referenced, usually producing a grey-scale image of the seafloor (Figure 15). This is the customary way in which seafloor backscatter is mapped.

Classification of backscatter tends to be undertaken in take two distinct ways – manual and automated. Automated routines, their effectiveness and efficiency are described in proceedings from Colerain University/ MESH Backscatter Workshop (30th & 31st March, 2006). Manual classification may be untaken in several different ways, usually within a GIS environment, with a variety of visualisation approaches.

Demarcation of visible distinct areas of the grey scale backscatter map gave rise to 18 distinct areas (Figure 15). This process is straightforward and in the case of Hemptons Turbot Bank Sand waves has enabled the delineation of clear and distinctly different areas. The Grey scale displays pixel intensities on a black to white range of 0 to 255 respectively. The eye is able to distinguish in the region of 10 to 20 different shades of grey (Figure 13). Clearly, the classification of intensity values with a grey scale, or colour ramp will affect what the eye recognises as being a delineation or change. The gently, gradated change associated with a grey scale or comparable colour ramp may in instances give rise to uncertainty of where to define a delineating line.

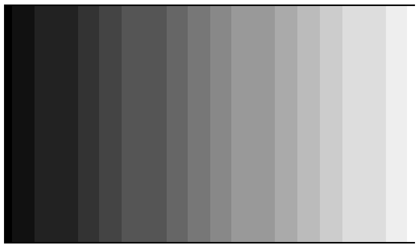


Figure 13. Example of grey scale ramp.

Note that the area bottom right of the following backscatter classifications has been demarked, however as previously indicated the distinguishing difference in backscatter of this area is an element of the survey settings and not the seafloor.

The choice of display: grey scale; colour ramp or colour classes, can change the visible differences of the backscatter image. By plotting the frequency range of the grey scale data (Figure 14) seven distinct classes were apparent, which when categorised produce a colour categorised map (Figure 16) from which 14 different areas can be outlined.

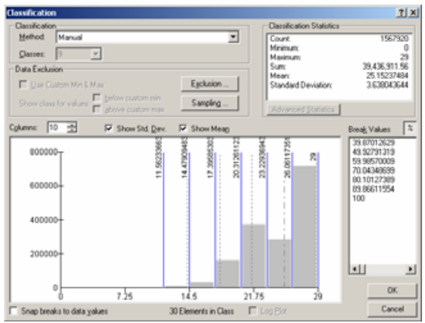


Figure 14. Manual classification of the frequency distribution of intensity values from the Hemptons Turbot Bank backscatter grey scale image. Data distributed into 10 columns to display the frequency gives 7 break values and 7 data classes (note, of the 10 columns only 6 are visible on the displayed *Y* axis).

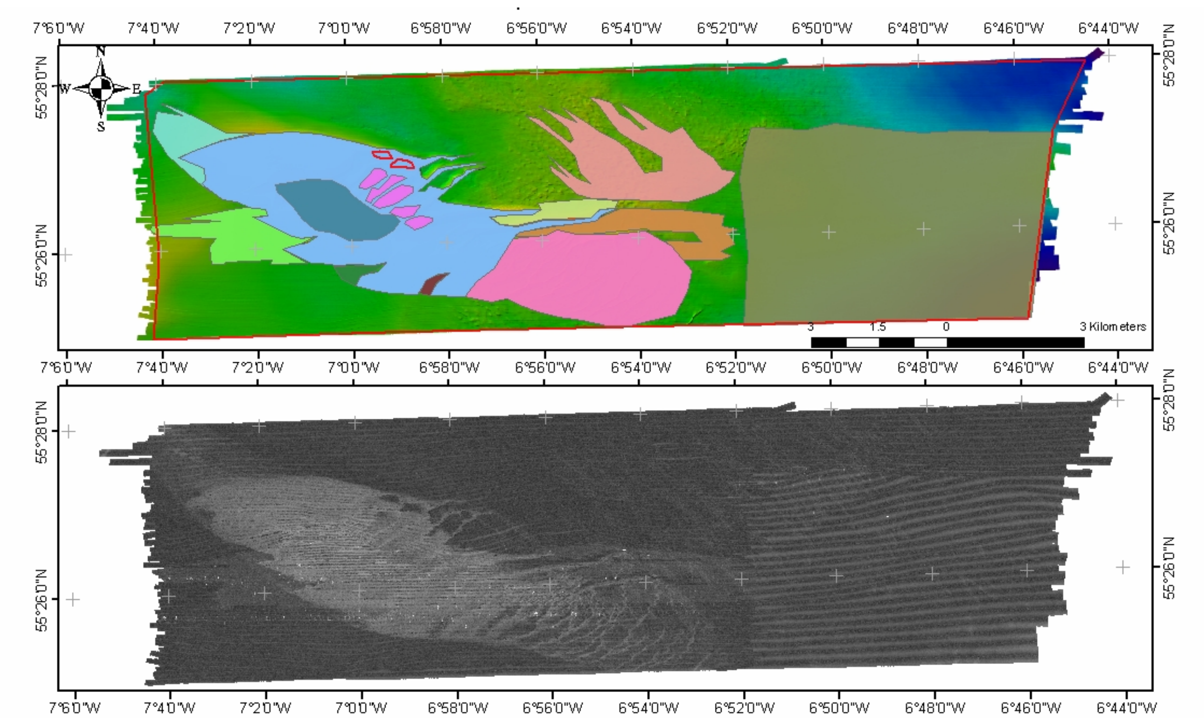


Figure 15. Multibeam backscatter image from Hemptons Turbot Bank (bottom) and evident areas of different intensities digitised by hand.

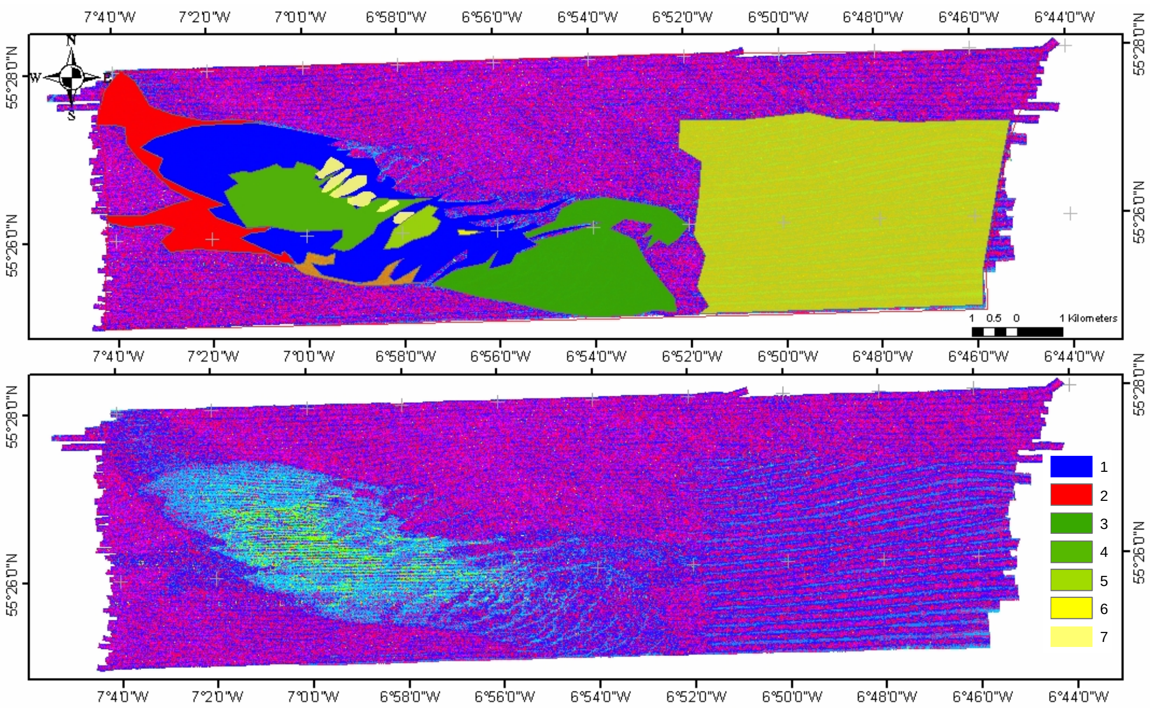


Figure 16. Colour classified backscatter into 7 intensity categories (Figure 14) from which the sea floor can be detailed into 14 areas.

The intensity frequency was classified around its distribution with breaks at standard deviation units (Figure 17). With 100 columns plotted two apparent distributions were visible in the frequency plot, with the maximum of the one skewed to the left (and peaking on the right) falling just inside the cut off of the 4th standard deviation unit. The cut offs give 5 classes of sea floor backscatter intensity (Figure 18) from which 14 classes of seafloor can be differentiated and demarked by eye.

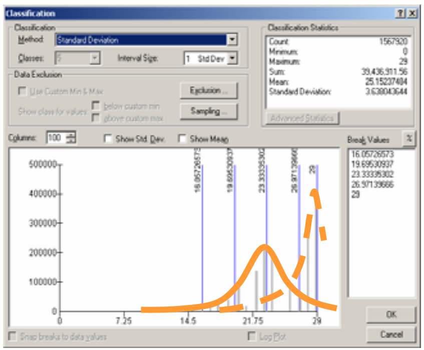


Figure 17. Classification of backscatter intensities according to frequency distribution by standard deviation units, with 2 apparent distributions indicated.

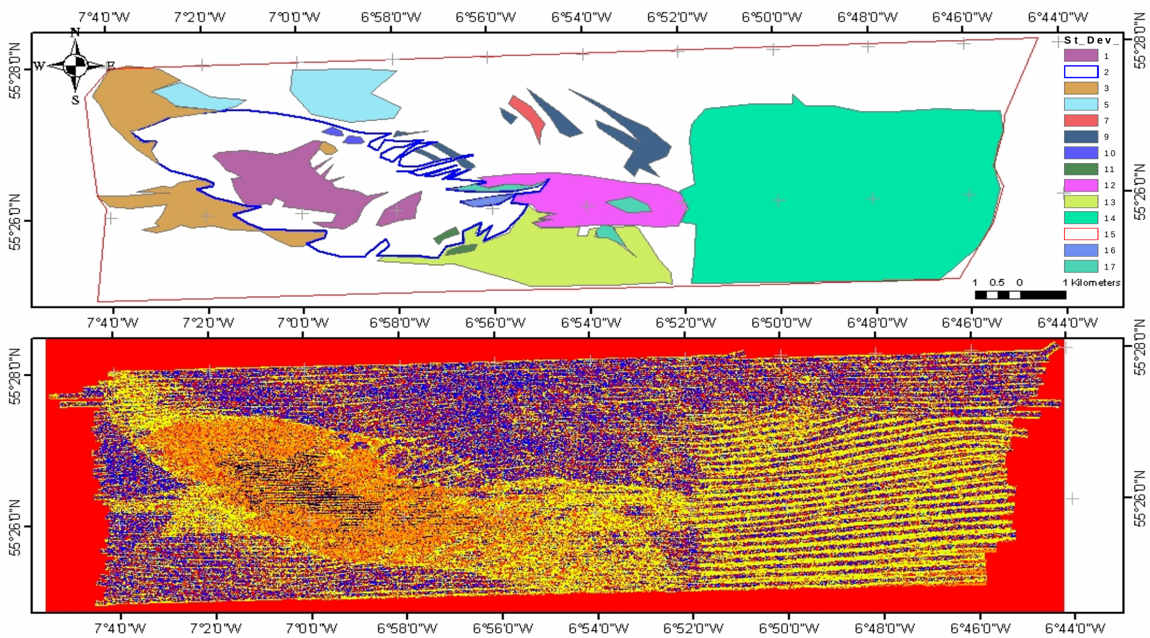


Figure 18. Colour classified backscatter into 5 intensity categories based upon standard deviation (Figure 17) from which the sea floor can be detailed into 14 areas.

It should be recognised that different choices of colour classes or colour ramps will influence the visible areas in the data. An example is given in Figure 19 where the derived standard deviation classification (Figure 18) is plotted with a change in the colour of one class (0.000 – 16.057). It is apparent from this simple example colour change that information may easily be lost if inappropriate plotting colour systems or scales were chosen.

Numerous techniques exist for grouping or averaging spatial values in GIS environments. Of these, Inverse Distance Weighting interpolation was investigated (Figure 20) using the neighbourhood method, including 15 values surrounding each point. The creation of this layer was computer processor intensive and it is evident that information in the data is diluted with no benefit to the seafloor classification. General exploration of other interpolation techniques came produced similar conclusions.

An alternative approach to connecting areas of similar intensity was investigated by drawing connections between points of like intensities thorough the GIS contouring tool, creating a set of 29 iso-intensity lines (Figure 21). Clear from this approach is the distinct derivation of areas defined through previous classification approaches (for example Figure 18), while removing any user subjectivity.

Figure 22 shows results from 2 automated, unsupervised backscatter classification techniques, one developed by a research team and the other commercially available. Comparison of these with the iso-intensity approach shows good agreement in the differentiation of areas of the seafloor. Note worthy is the differentiation of the middle area by both the research and iso-intensity approaches which was not delineated as distinctly different by QTC in this analyses.

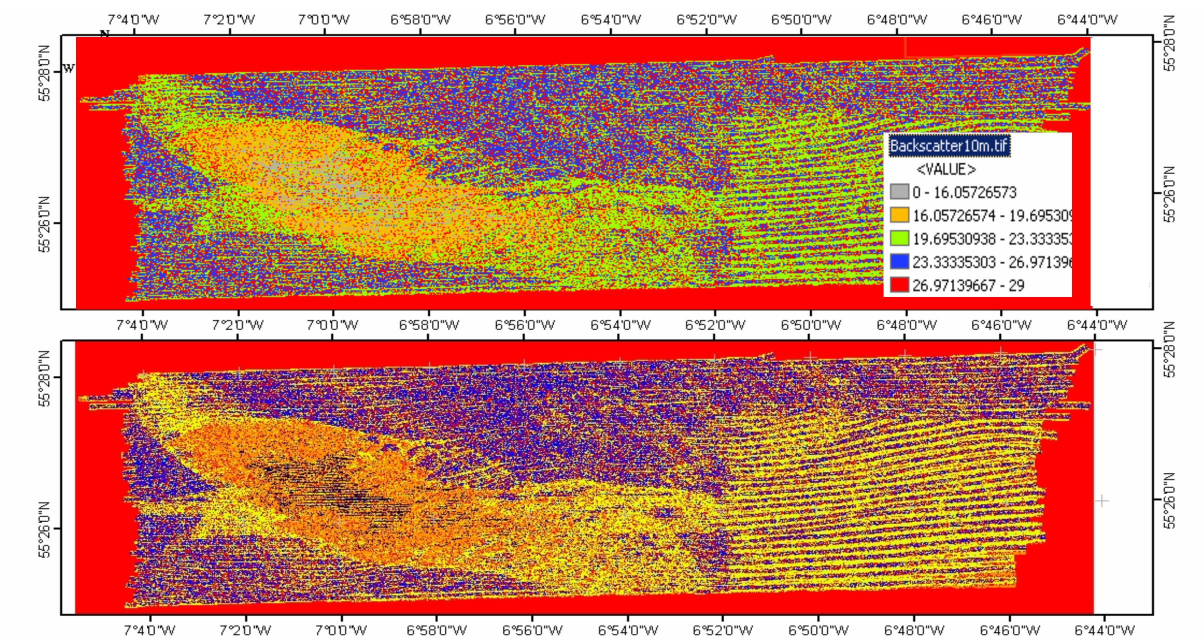


Figure 19. Influence of change of one colour class on the standard deviation categorisation given in Figure 18.

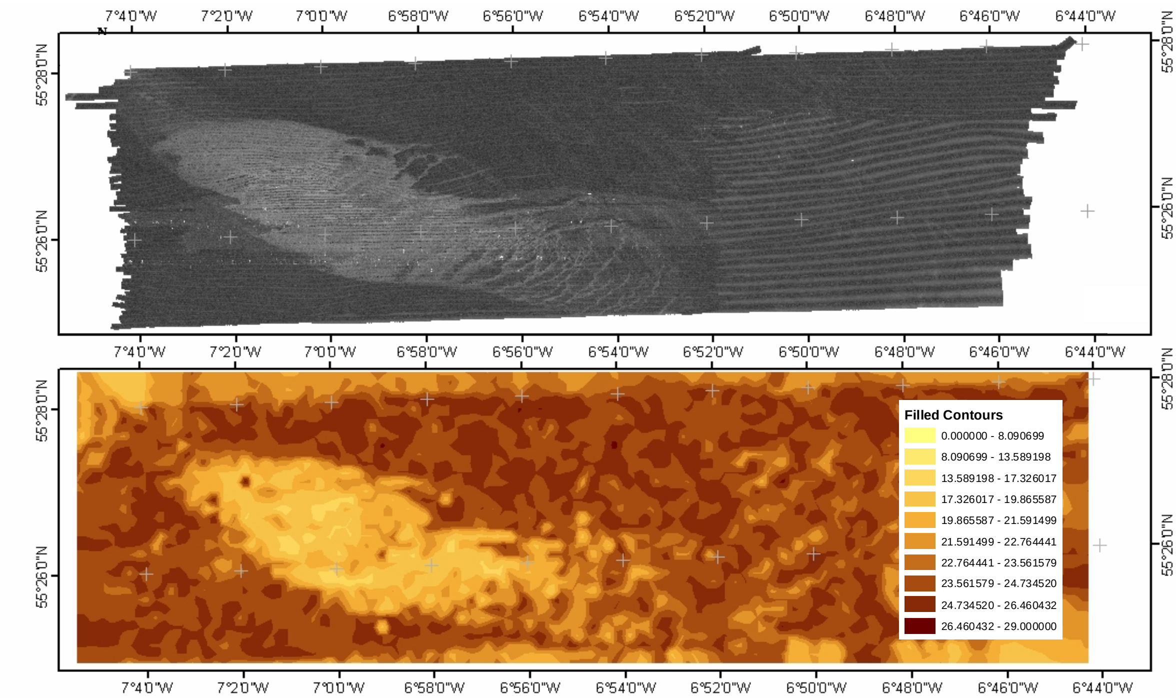


Figure 20. Inverse distance weighted interpolation of backscatter data (bottom) viewed with grey scale presented backscatter (above).

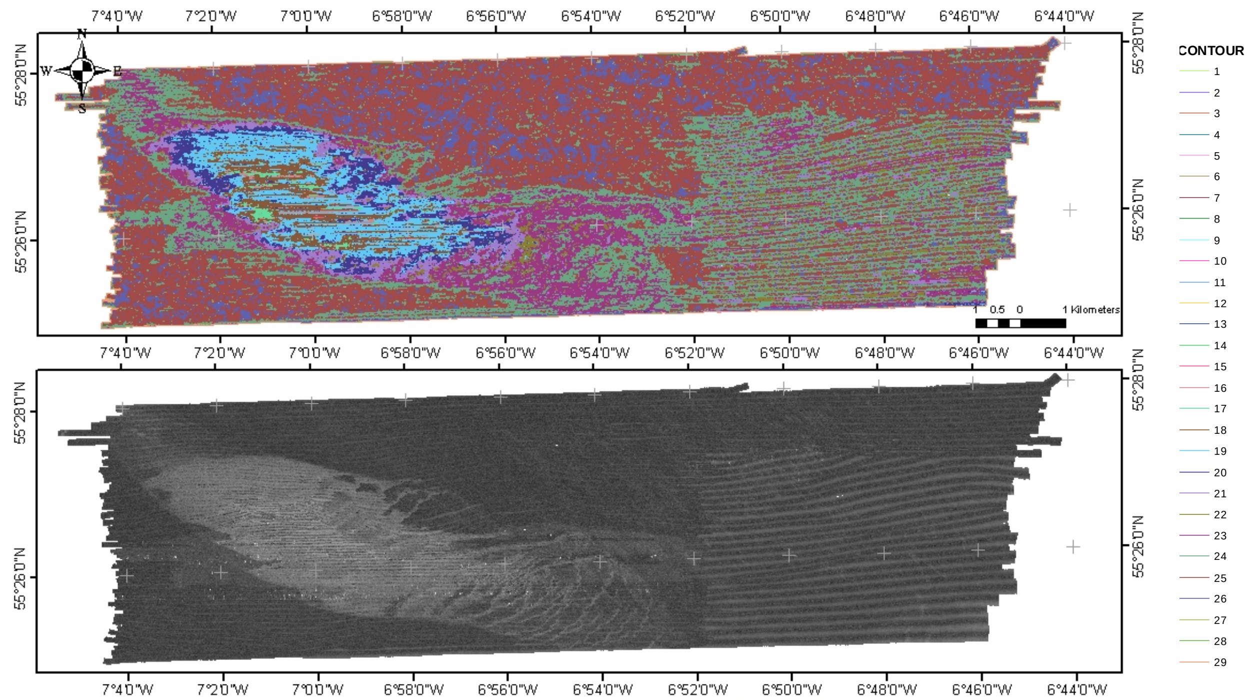


Figure 21. Contoured backscatter intensities (top) displayed with greyscale backscatter (bottom).

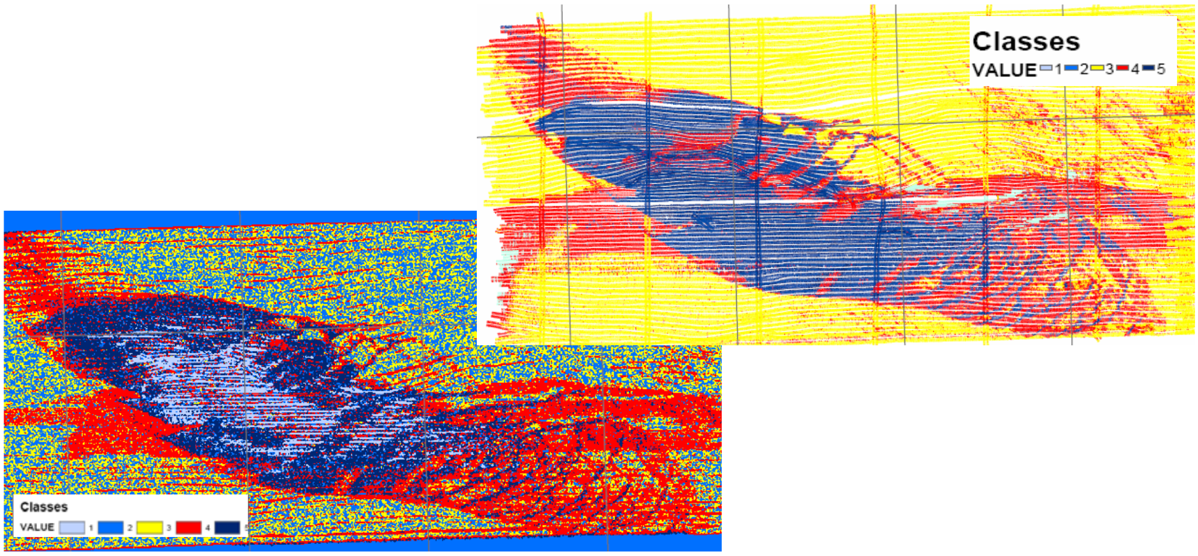


Figure 22. Automated classification of multibeam backscatter over Hemptons Turbot. Left made by research classification approach and right by QTC Multiview software (both care of I. Marsh, National University of Ireland – Galway).

Single Beam Echo Sounder EchoPLUS AGDS

Single beam echo sounder data comprise of an initial echo (E1) and a secondary echo (E2), which together can be processed with Automated Ground Discrimination Systems (AGDS) to estimate seafloor material. The AGDS system EchoPLUS was used to process data collected over the entire survey area, which included Hemptons Turbot Bank as a component, and box files for classifying areas of E1 and E2 defined over the full range of the survey. With 12 boxes defined and grouped into 7 categories for mapping the EchoPLUS did not differentiate areas over the Hemptons Turbot Bank. This is not overly surprising considering the predominantly sandy nature of the seafloor over the bank.

Comparison of initial echo (E1) and secondary echo (E2) (Figure 24), show however, that information is present in the data over the banks. This indicates that the set up of discriminate boxes in the EchoPLUS “box file” – the areas in an *X/Y* plot of E1 against E2, is critical in extracting the information. While boxes in a box file should be determined from datasets covering a large spectrum of sea floor types to ensure a range of responses types are present to be classified, more detailed discrete information is also contained. There is need for caution in this, as attempting to differentiate amongst extremely similar substrata types runs the risk of over exploit data and producing derived details which are not facets of the seafloor but articles of the survey or erroneous values. As analysis of box areas becomes more detailed, so outliers and erroneous values will begin to have a greater weighing in classifications.

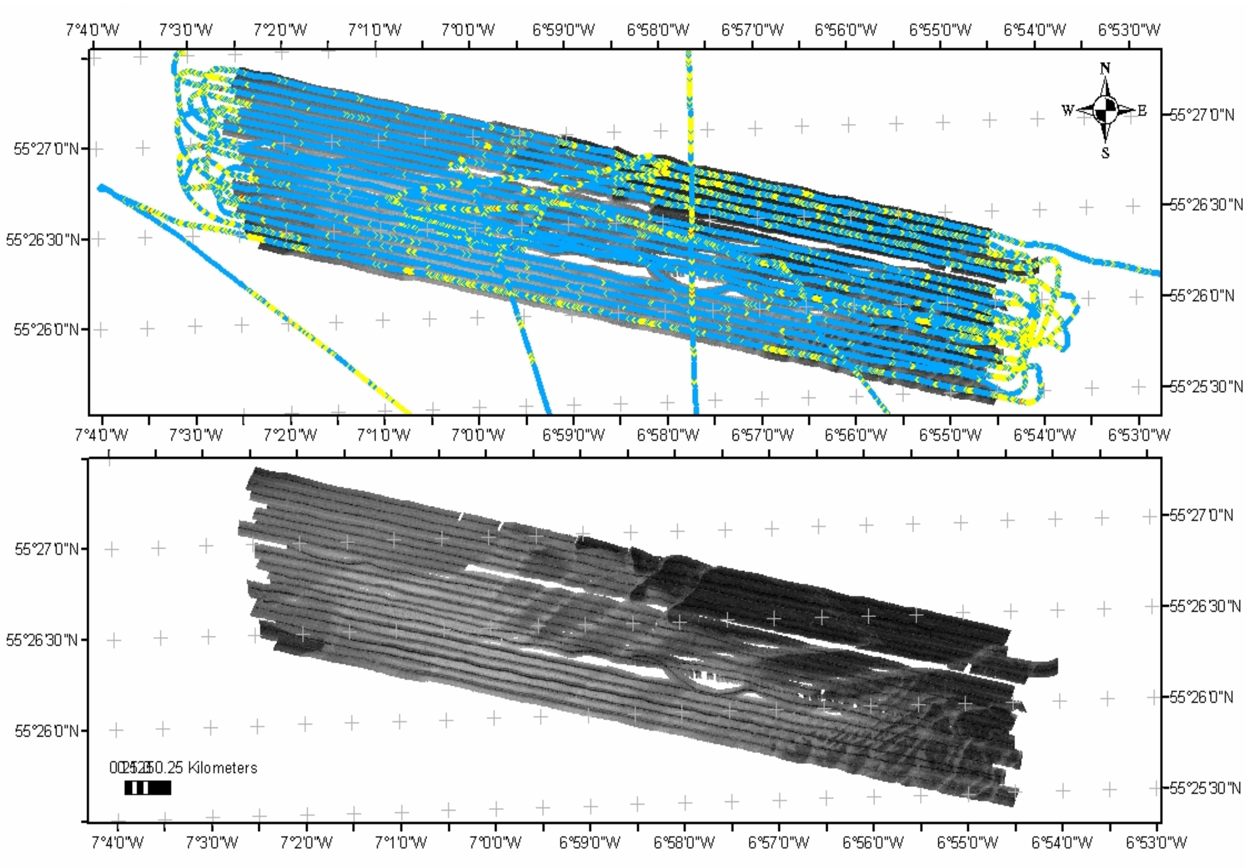


Figure 23. Single beam EchoPLUS AGDS results from Hemptons Turbot Bank (top) and multibeam backscatter (bottom).

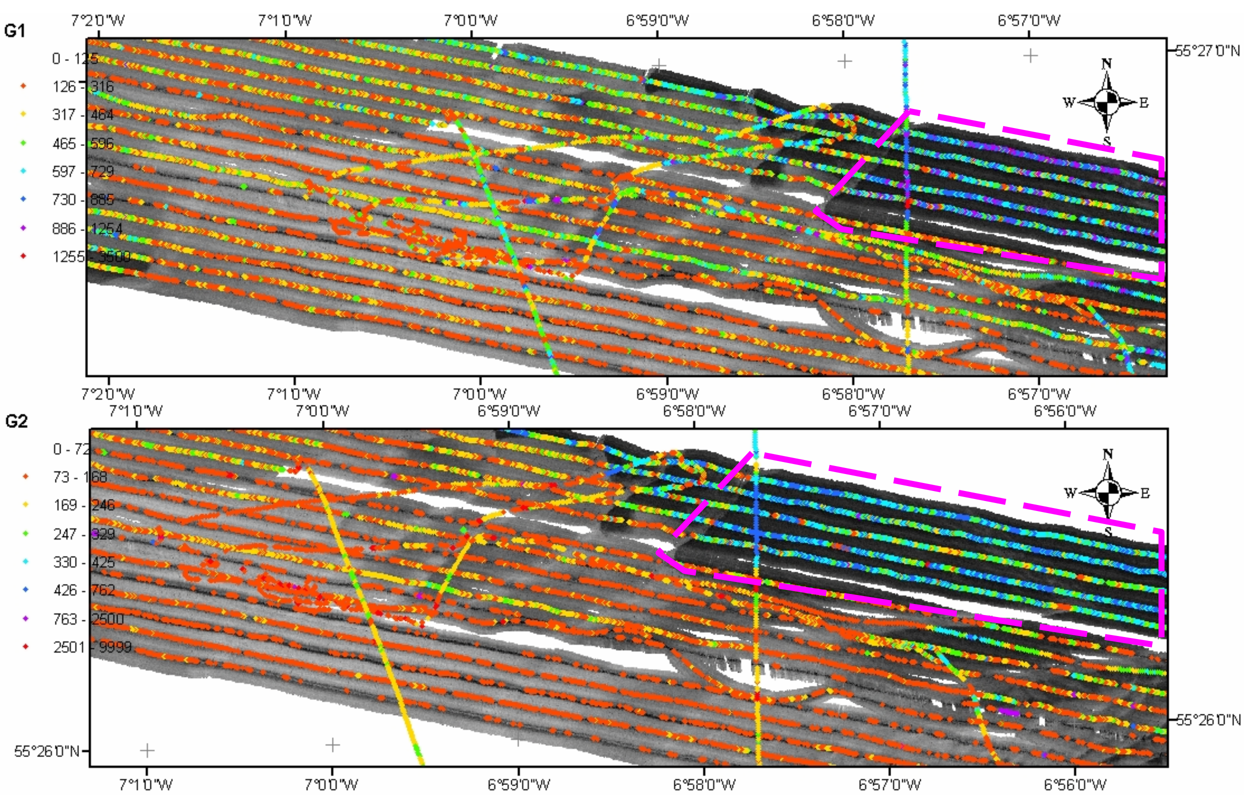


Figure 24. Singe beam echo sounder E1 data (top) and E2 data (bottom) plotted over multibeam backscatter. Area of different values indicated in the top right of each plot.

Sidescan sonar

Sidescan sonar imagery collected over the area (Figure 25) details some features of the sand wave filed, however, as is apparent this is no improvement on multibeam backscatter. Detail on sidescan sonar does tend to be of greater resolution than that demonstrated here and it is probably owing to survey speed being too high for satisfactory data acquisition. Additional comments of not are the direction of survey lines to sand waves. If survey lines were to have been run north to south as opposed east to west sand waves would have been more apparent in the resulting mosaic image. From the collected data delineation of seafloor areas is not appropriate.

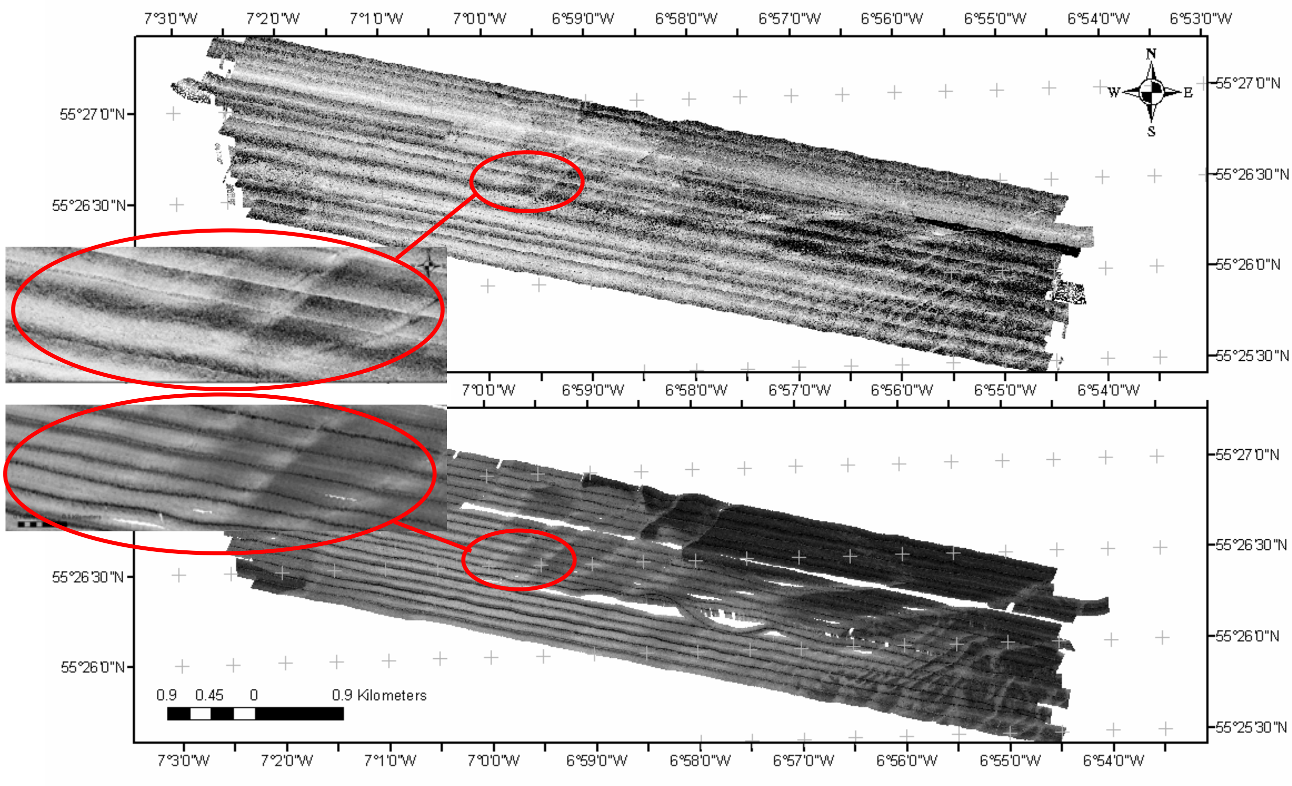


Figure 25. Sidescan Sonar image (top) shown with multibeam, backscatter grey scale (bottom) with highlighted areas showing detail.

Ground truthing:

Grab samples – PSA

Grab samples were processed for Particle Size Analysis (Figure 26) and data clustered using methods Cluster Analysis (Figure 27) and Detrended Correspondence Analysis (DECORANA) (Figure 28) multivariate analyses. From these, clearly distinctive groupings of the sediment samples are discernable which were corroborated through comparison with the proportional composition of the fractions (Figure 26).

Agreement between multivariate sediment classes and multibeam backscatter is evident for certain classes, for example samples 69, 79, 80 and 81; 75 and 76; 64 and 65, however, for each of these last two examples, a sample clustered with each according to its composition, is located in an area with different backscatter (samples 71 and 84 respectively) (coloured labels in Figure 26 represent multivariate sample groupings). This may be a consequence of sample processing, samples being boarder line cases in the multivariate analysis, the physical sample positional location of the grab differing to that recorded (as ship location) owing to the grab drifting below the vessel owing to currents or the sediment distribution being patchy in nature beyond the detection limits of acoustic instruments and returning a mosaiced signature class.

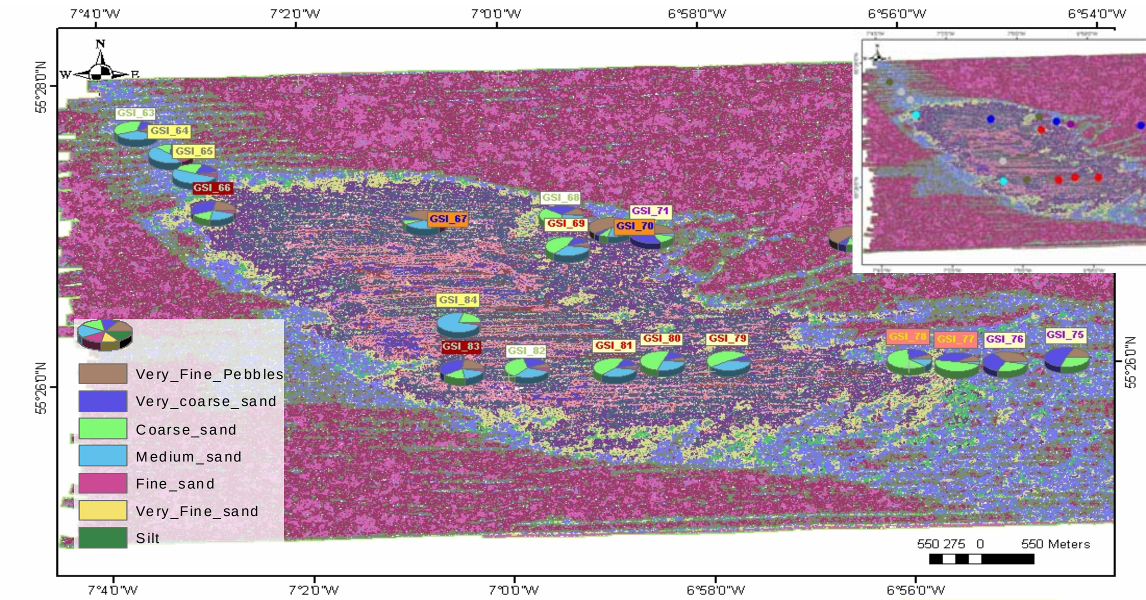


Figure 26. Particle Size analysis seafloor sample locations and compositions overlain on multibeam backscatter iso-intensity classification. (Labels on plots and simplified insert top right indicate multivariate groupings).

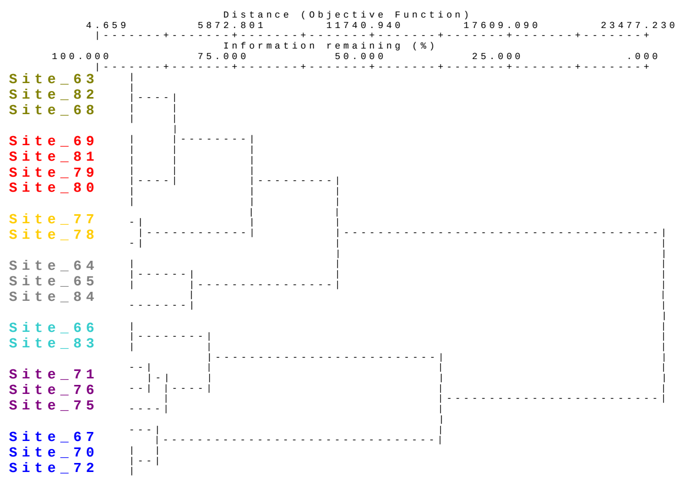


Figure 27. Cluster analysis of PSA samples.

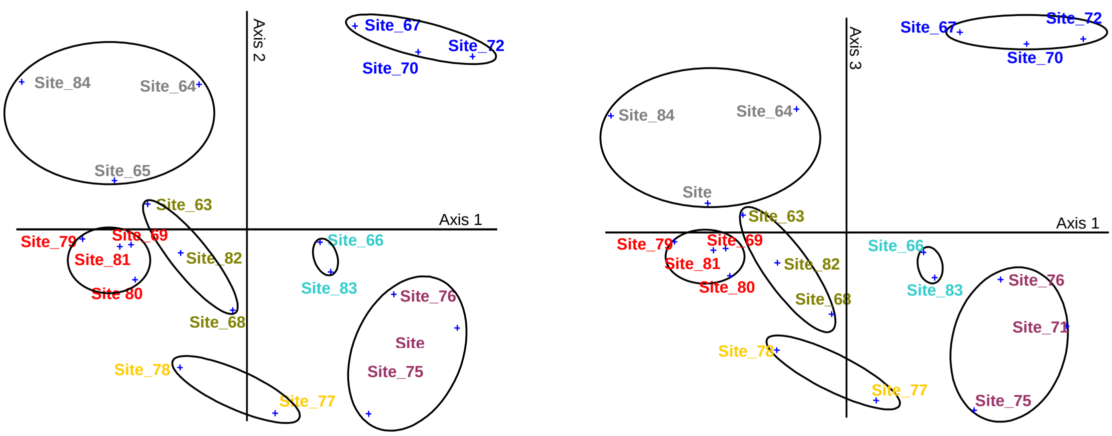


Figure 28. DECORANA analysis of PSA samples showing clusters derived from Cluster Analysis (Figure 27). (Axis 1 and 2 plotted on the left, 1 and 3 on the right).

Ground truthing:
Video tows (Simrad Camera)
Video tows across the seafloor can be used in many ways, as a survey tool for instance for shell fisheries data collection or as in this case, as a ground truthing tool for acoustic surveys. The use of the technique for ground truthing may also be employed in different ways. Tows lines may be targeted to run wholly within an acoustically homogeneous seafloor region to typify an area, to cut across a boundary between two regions to pinpoint the location of the change, or a combination, to locate the change and record why the difference arises. Footage may be assessed for it's biological composition, seafloor material or both. It may be subjectively analysed by watching the footage and assigning habitat names or labels, from a recognised classification system, by expert judgement/ empirical knowledge; semi-quantitatively assessed through enumeration of recognised life forms either for the entire transect or selected sub samples for known times or distances. Choice of sub sample sections for enumeration may be made in an organised, stratified manner (for instance 1 minute sections extracted every 5 minutes) or on a random bases for set times, for instance 10 randomly selected 1 minute sections). Choice of approach will depend upon the intended use of data and time availability for enumeration. For classification to the EUNIS system for instance, empirical knowledge is adequate to EUNIS level 4, while for hypothesis and multivariate statistical testing a more robust random sub-sampling and enumeration approach would be required.

The two video tows made across Hemptons Turbot Bank (Figure 30 and Figure 31) were each 30 minutes in length plus a few minutes each end of the official tow allowing for the sled to settle. Four still frames were extracted from the footage every 5 minutes and inspected for classification to the JNCC and EUNIS classification systems. Classification of the westerly video transect was categorised to the JNCC 04.05 code SS.SSa.Osa – Offshore circalittoral sand, and to EUNIS level 4 as Deep circalittoral sand (A5.27), described as: *Offshore (deep) circalittoral habitats with fine sands or non-cohesive muddy sands. Very little data is available on these habitats, however they are likely to be more stable than their shallower counterparts and characterised by a diverse range of polychaetes, amphipods, bivalves and echinoderms.* Examples of video stills are shown in Figure 30 with large & rotund sand ripples evident.

The easterly transect proved to consist of more coarse material (Figure 31) and was classified as to the JNCC 04.05 code SS.SCS.OCS – Offshore circalittoral coarse sediment, and to EUNIS level 4 as Deep circalittoral coarse sediment (A5.14), described as: *Offshore (deep) circalittoral habitats with coarse sands and gravel or shell. This habitat may cover large areas of the offshore continental shelf although there is relatively little quantitative data available. Such habitats are quite diverse compared to shallower versions of this habitat and generally characterised by robust infaunal polychaete and bivalve species. Animal communities in this habitat are closely related to offshore mixed sediments and in some areas settlement of [Modiolus modiolus] larvae may occur and consequently these habitats may occasionally have large numbers of juvenile [M. Modiolus]. In areas where the mussels reach maturity their byssus threads bind the sediment together, increasing stability and allowing an increased deposition of silt leading to the development of the biotope A5.622.*

Review of the footage clearly shows more information than is transferred into EUNIS classes. An examples of this is portrayed in the sequence of video stills over a sand wave (Figure 32). From these it is evident that the fine scale structures; ripples or barchans and barchanoid ridges on the longitudinal sand waves can be recorded with this technique. Nomenclature and classification of such bedforms is however, presently limited with no evident association in EUNIS beyond circalittoral sand or coarse sediment.

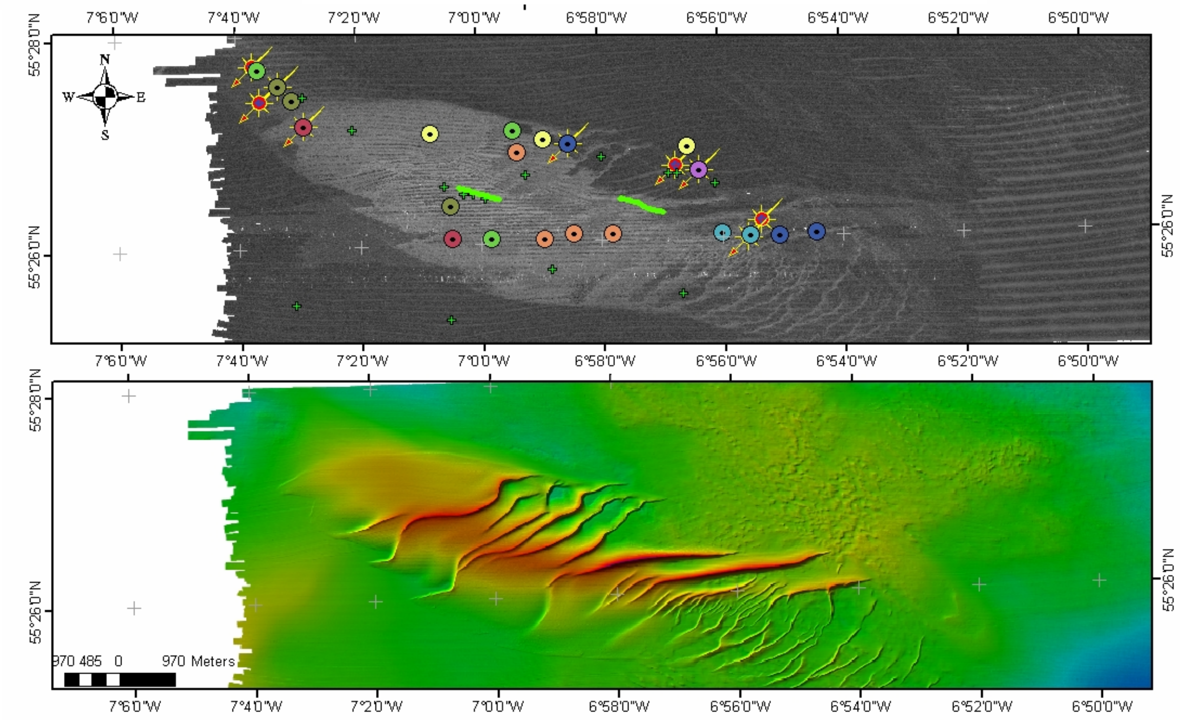


Figure 29. Locations of video tows made over Hemptons Turbot Bank (green lines top).

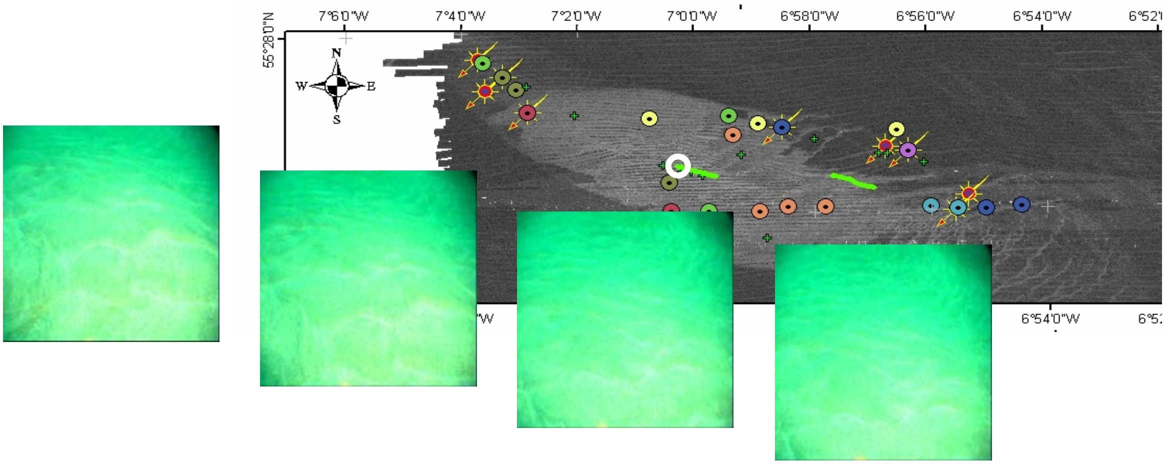


Figure 30. Examples of stills from the westerly video transect - white circle indicates location.

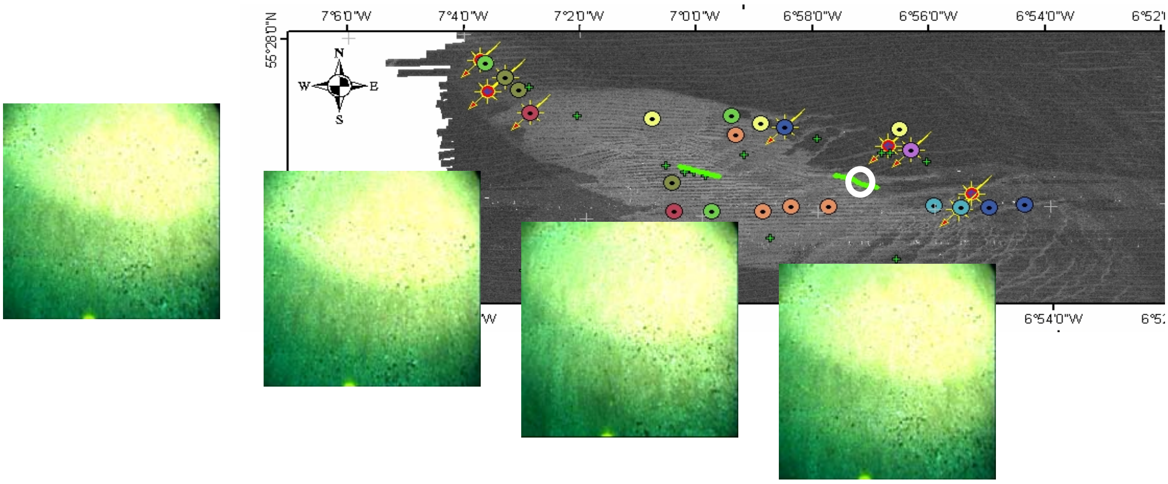


Figure 31. Examples of stills from the easterly video transect - white circle indicates location.

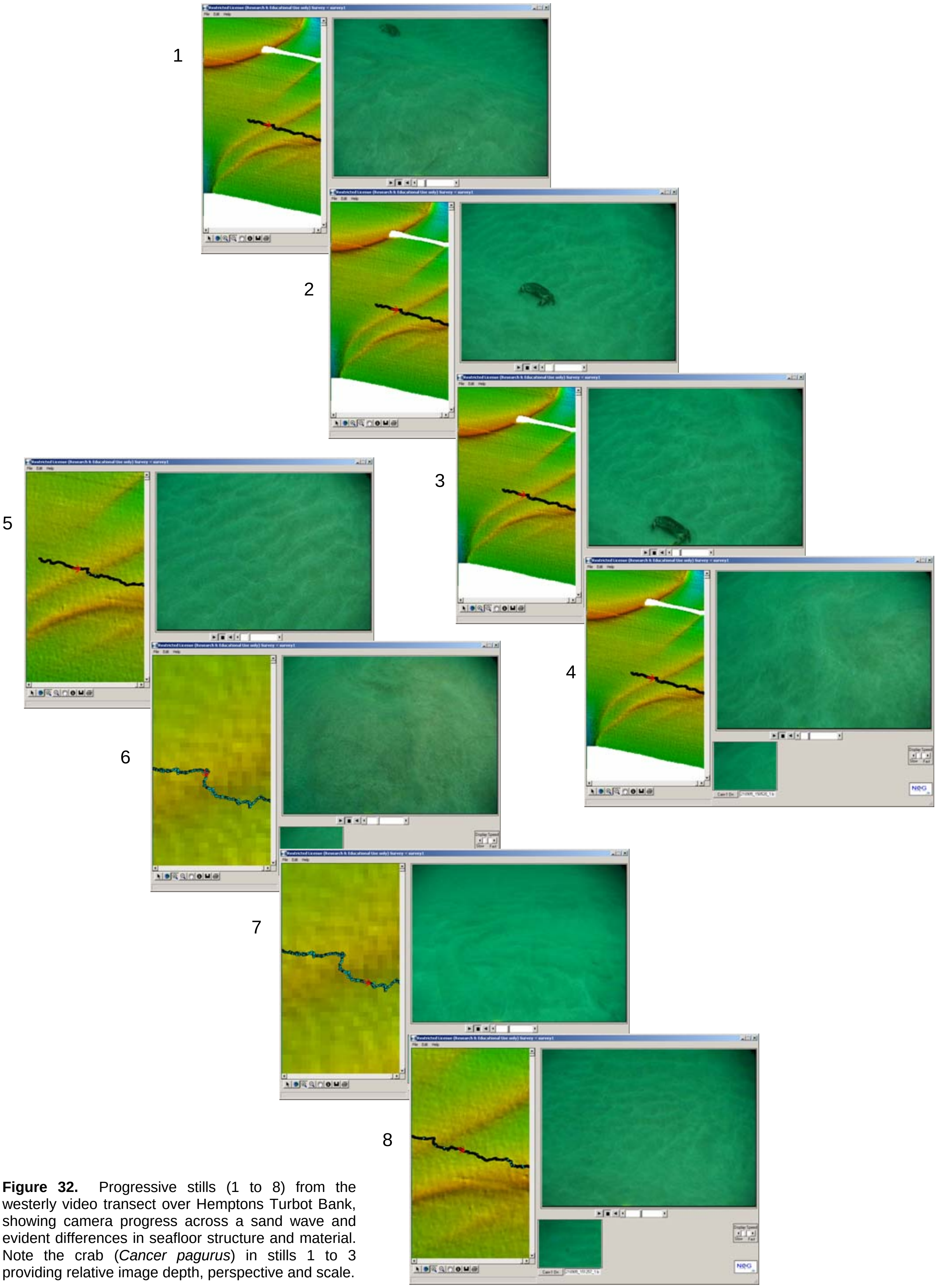


Figure 32. Progressive stills (1 to 8) from the westerly video transect over Hemptons Turbot Bank, showing camera progress across a sand wave and evident differences in seafloor structure and material. Note the crab (*Cancer pagurus*) in stills 1 to 3 providing relative image depth, perspective and scale.

Conclusions

The itemised surveying technologies and techniques are acknowledged in the field of marine biological and surficial resource surveying as the most pertinent for discriminating and mapping seafloor types at the meso-scale of 1's to 100's of metres. Data were collected under standard survey conditions, providing representative sets for investigation. The data interrogations were directed toward most amenable, accessible and information rich approaches. There will clearly be numerous other approaches for analysing such data, and depending upon PC processor and memory sizes available, analysis application choice and time available, each will have applicable advantages, disadvantages and levels of appropriateness. The described analyses were performed on a standard *circa.* 2002 desktop PC primarily using ArcGIS version 9. This processing set up was chosen to provide a realistically achievable critical investigation of the data without access to specialist tools or PC power. The exceptions to this are Multibeam backscatter and Sidescan sonar mosaics, which were produced by surveying software Caris and CODA respectively and would be available, post survey, in the formats which they were investigated.

The analyses clearly demonstrate strengths and deficits of the tools used over the sand wave system of Hemptons Turbot Bank. Benthic Position Index is clearly a strong tool in categorising areas of the seafloor in relation surrounding areas and bathymetry. Capable of being used in a subjective and more objective manner, this tool needs 'tuning' to each data set being processed with it and is at litany of the user, giving best results from a user with good understanding of the bathymetry being processed and requirements of the end classification. The obvious limitation of the technique is its sole reliance on bathymetry, which does not incorporate any seafloor material or biological information.

Classification of multibeam backscatter should be performed in an iterative manner. Different patterns in the data should be investigated using grey scale, colour ramps and colour classes categorising different fractions in the data spread and ensuring that each is brought out to eye of the user to enable a fully informed classification. Recognition of elements in the data that are facets of surveying and not of the seafloor is critical. Such survey elements in data tend to be apparent owing to their uniform alignment – along the survey lines.

Single beam echo sounder data processed thought EchoPLUS Automated Ground Discrimination System (AGDS) did not show any discernable patterns over Hemptons Turbot Bank, though investigation into the spread of echo 1 and Echo 2 showed that information is present in the data. This is probably a result of the defined boxes in the EchoPLUS box file. Care should be taken if trying to extract fine detailed information in such data as erroneous points will begin to exert a larger influence as finer differentiation is attempted from data with a low spread.

The third acoustic, remote sensing technique investigated, side scan sonar, in this instance over Hemptons Turbot Bank provided no useful information for discriminating areas of the seafloor with different characteristics. Detail was probably lost owing to the high survey speed. If survey lines had been run perpendicular to the sand waves more detail of their features would probably have been recognisable in the mosaic, which may be capable of imaging finer detail ripples on the sand waves.

The two ground truthing techniques used, PSA from grab samples and EUNIS classification from video transects provided reliable seafloor categorisation. The scale of these methods is obviously much finer and the coverage much lower than the acoustic, remote techniques. The data provided is therefore, accurate, however the spatial area covered is extremely small and not beneficial for meso scale mapping purposes alone. Issues of accurate positioning of sample and video data on to the seafloor present problems for tying together the sampled classifications with acoustically defined areas. This may be overcome by using USBL under water triangulation positioning with video and ROV surveys. Grab sampling presents a further problem owing to the lack of horizontal differentiation required for usbl positioning. Replicate sampling may to some extent overcome this, by providing an averaging of the components within the replicate samples.

The survey approaches and their analyses have been targeted to try and maximise the information return from survey over the Hemptons Turbot Bank which represents a characteristic sand wave system. While information from these techniques and its extraction will be different over differing seafloor types, the approach to there investigation will be similar and each should be investigated in as many ways as possible.

References

LUNDBLAD E.R., WRIGHT. D.J., MILLER, J., LARKIN, E.M., RINEHART, R., NAAR, D.F., DONAHUE, B.T., ANDERSON, S.W and BATTISTA, T. (Accepted for publication in, 2006)., A Benthic Terrain Classification Scheme for American Samoa. Marine Geodesy