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AN ASSESSMENT OF TWO ACOUSTIC SURVEY TECHNIQUES AS A MEANS OF MAPPING SEABED ASSEMBLAGES IN THE EASTERN ENGLISH CHANNEL

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ABSTRACT

A survey was carried out in the Eastern English Channel to investigate the use of acoustic survey techniques, used in conjunction with traditional biological sampling methods, to map the variety and distribution of benthic habitats and their associated biological assemblages. Two acoustic techniques, digital sidescan sonar and an acoustic ground discrimination system, were used to classify and map the distribution of acoustically different substrata within the survey area. Benthic communities and sediment types within each of these regions were sampled using grab and underwater video/photographic techniques. Substrates within each acoustic region were generally homogeneous in distribution, and sediment types ranged across the survey area from cobbles and coarse gravel through to muddy sands. Analysis of the faunal data revealed the presence of statistically distinct biological assemblages within most of the acoustic regions, although species similarity between samples collected from within each acoustic area was often low. The application of acoustic techniques, used in conjunction with biological sampling techniques, to map the distribution of seabed habitats and associated benthic communities is discussed.

Keywords: mapping; sidescan sonar; biotope; habitat; benthic community

INTRODUCTION

Recent advances in acoustic technologies are offering new insights and opportunities to explore and map seabed habitats. Benthic studies have traditionally used grabs and/or dredges to describe the invertebrate fauna of the sea floor. Such techniques provide single, geographically separated points of data across the area of seabed under investigation. In order to produce biotope maps (physical habitats and their associated biological communities) from such sources of data it is necessary to interpolate between these data points. However, interpolation has the potential to overlook discrete seabed features and/or biological assemblages, which may lie between sample stations. For this reason the use of acoustic techniques to assist in mapping the geographical distribution of biotopes can be seen to have many potential advantages, including the prospect of 100% coverage of the seabed as resources allow or priorities dictate.

High-resolution biotope maps of the seabed may assist in future site-specific environmental assessments of potential aggregate dredging areas, and would be of value during any subsequent environmental monitoring activities. For this reason a programme of research funded by the Ministry of Agriculture, Fisheries and Food was initiated by CEFAS in April 1998 to investigate the utility of several acoustic remote sensing techniques, used in conjunction with biological sampling and underwater video surveys, for mapping biotopes on coarse substrates. This paper presents initial findings from this work.

MATERIALS AND METHODS

Acoustic Survey

Following preliminary underwater video surveys in May 1999, an area of seabed in the English Channel off Shoreham (12km x 28km) appeared to offer a suitable site for the study (Figure 1). An intensive survey of the area was conducted in July 1999 using a Datasonics digital chirps sidescan sonar with a Triton Isis logging system. Delphmap post-processing software was used to mosaic the imagery and classify texturally different regions. The system was operated on a 400m swathe range, and survey lines were spaced at 400m intervals in a north-south orientation in order to insonify 100% of the survey area. Vessel position was provided by the Veripos Differential Global Positioning system (DGPS) and towed sensor position calculated by vessel heading, towcable layback and towfish depth, all of which were logged in real time by the Isis system.

A QTC View system (Quester Tangent Corporation, Sidney, BC) was run concurrently with the sidescan sonar at a frequency of 200 kHz in conjunction with a Furuno single beam hull-mounted echo sounder. The QTC system records shape/phase characteristics of the first seabed echo, and using statistical analysis methods reduces these into three principal components known as Q-values (Q1, Q2, Q3). The Q-values are chosen automatically through principal components analysis by the QTC software from a total of 166 shape parameters. The survey was conducted in unsupervised mode, and seabed classification was achieved following reduction of the full data set using the QTC software package IMPACT. This software uses 3-dimensional cluster analysis to group similar acoustic returns as depicted by the three Q-values, into seabed classes. Each seabed (acoustic) class is allocated a percentage confidence estimate, which gives an indication of how well the associated points (acoustic returns) lie within each class. Subsequent ground-truthing should then enable each acoustic class to be associated with a seabed/sediment description. This approach only provides information concerning the substrate type as insonified immediately below the vessel's sounder.

A drop-camera frame fitted with an under-water video camera and light was deployed at a number of stations across the survey area in order to provide visual ground-truth data to aid interpretation of the side scan sonar and QTC data sets. Following the cruise the sidescan mosaic, along with reference to the video and QTC data, was used to divide the survey area into 8 acoustically distinct regions.

Benthic survey

The design of the macrobenthic grab survey was structured around the 8 acoustically distinct regions identified from the output of the acoustic survey. Sample stations were randomly positioned within each acoustic region, and the number of stations within each region was linked to the size of the area. The survey was conducted in August 1999. A total of 43 samples were collected from across the survey area using a $0.1m^2$ Hamon grab fitted with a sub-miniature video camera. The camera recorded an image of the seabed adjacent to the collection bucket of the grab, thus providing information about the undisturbed surface of the substrate at each sample station. Following estimation of the total sample volume, a 500ml sub-sample was removed for laboratory particle size analysis. The remaining sample was washed over 5 mm and 1 mm square mesh sieves to remove excess sediment. The retained macrofauna were fixed in 4-6% formaldehyde solution (diluted with seawater) for laboratory identification and enumeration.

In the laboratory samples were first washed with freshwater over a 1mm square mesh sieve in a fume cupboard to remove the excess formaldehyde solution. Samples were then sorted and the specimens placed in jars or petri-dishes containing a preservative mixture of 70% methanol, 10% glycerol and 20% tap-water. Specimens were identified to species level, as far as possible, using standard taxonomic keys. For each positive identification a representative specimen was retained in order to establish a reference collection. Particle size analysis is ongoing, and results are not available at this time.

Sample and species associations across the survey area were assessed by non-metric multi-dimensional scaling (MDS) ordination using the Bray-Curtis similarity measure on presence/absence data using the software package PRIMER (Clarke and Warwick 1994). Analysis of similarities (ANOSIM, Clarke, 1993) was performed to test the significance of differences in macrofauna assemblage composition between samples. The nature of the community groupings identified in the MDS ordinations was explored further by applying the similarity percentages program (SIMPER) to determine the contribution of individual species to the average dissimilarity between samples.

RESULTS

Acoustic data interpretation

Examination of the sidescan data revealed the presence of 8 acoustically distinct regions within the survey area (Figure 2). Underwater video footage established that differences between the acoustic regions were due to changes in substrate type, and that substrates were generally homogeneous in their distribution within each of the regions. An inshore-offshore sediment gradient was identified comprising: cobbles with attached algae in shallow inshore waters (depths around 10m) (region H and

H/F); areas of sand expressing a range of wave amplitudes (regions C and F); mixed coarse substrates (regions D and E); offshore gravel and sand in deeper waters (< 60m) (regions A and B). Difficulties in identifying boundaries between acoustic regions in the north of the survey area (regions H, H/F, and F) were encountered due to the reduced image quality caused by the shallow water depths. Examples from the sidescan record of the acoustically distinct regions, along with physical habitat descriptions derived from the underwater video footage, are illustrated in Figure 3.

Classification of the QTC data using the IMPACT post-processing software produced 8 statistically distinct acoustic classes. These are shown in Figure 4, and illustrate the inshore-offshore changes in sediment types identified from the sidescan record. In most cases each QTC acoustic class correlates with an acoustic region identified from the sidescan record, and each QTC class tends to be homogeneous in distribution within each region reflecting the homogeneous nature of the sediments. However, distinctions between sediment types from east to west (between regions D and F), and between regions from shallow water depths (regions H, H/F and F) are not obvious from the QTC data.

Biological data interpretation

A total of 233 taxa were identified from 43 hamon grab samples collected from across the survey area. Figure 5 shows the output from non-metric multi-dimensional scaling (MDS) ordination of this data following amalgamation of the two size fractions (1-5mm and >5mm) and inclusion of all colonial species (presence/absence transformation). Grouping of replicate samples from within each acoustic region is clearly visible which, following analysis of similarities (ANOSIM, Clark 1993), illustrates that in most cases there were significant differences in macrofaunal assemblage composition between groups of samples collected from each of the acoustically distinct regions (Table 1). However, the benthic communities between several pairs of adjacent regions (A and B; D and E; F and H/F; H and H/F) were not statistically distinct (Table 1).

Further exploration of the community groupings identified in the MDS, using the similarity percentages program SIMPER, reveal that the average similarity between replicate samples collected within an acoustic region is low (Table 2). This reflects the large number of low frequency species identified from the samples that contribute to the high dissimilarity between replicates from within an acoustic region. The output from SIMPER also indicates which taxa contribute the most towards the similarity between replicate samples from within each acoustic region (Table 2). Characterising species from each acoustic region are typical for the substrate types present within the region.

DISCUSSION

The methodology developed during this study, using a combination of acoustic, biological sampling and underwater video/photographic techniques, proved to be successful in mapping seabed assemblages within the survey area. Comparable approaches to the mapping of benthic communities include Magorrian *et al*. (1995), Greenstreet *et al*. (1997), Davies *et al*. (1997) using RoxAnn systems; Prager *et al*. (1995), Anderson *et al*. (1998) using QTC systems; and Wildish and Fader (1998), Phillips *et al*. (1990) using sidescan sonar. Although the outcomes are, in general, encouraging, the approaches have not yet reached the stage of uncritical, routine application. The current investigation usefully highlights the benefits and problems associated with this approach to habitat mapping.

The ability of sidescan sonar to insonify a swathe of seabed enabled a surface texture map, covering 100% of the survey area, to be produced. Division of the area into 8 acoustically distinct regions was made possible due to the presence of relatively strong physical gradients across most of the survey area, with regions displaying a high level of sediment homogeneity within discrete habitat boundaries. However, at certain locations within the survey area boundaries between acoustically distinct regions were less obvious, and this caused problems delineating the geographical extent of different habitats. This was particularly apparent from east to west across the three northern regions of the survey area (H, H/F and F), which were difficult to divide into regions due to the gradual change in substrate from cobbles in the west through to rippled sand in the east. The poor quality sidescan record caused by shallow water depths within this area also contributed to difficulties in defining habitat boundaries. This gradual east-west sediment transition was also reflected in the biological data; regions H and F were characterised by statistically different benthic communities, with region H/F comprising common species from both these regions, thus forming a non-statistically distinct transition region. Such transition regions between distinct habitats/assemblages have been referred to in the past (Dewarumez *et al*., 1992), and reflect the complex relationship between habitat type and community composition. The lack of clearly definable boundaries between adjacent habitats/assemblages can cause major problems when attempting to produce high-resolution seabed maps.

Small-scale sediment variability within a survey area may also cause problems when using the current approach to seabed mapping. The interpretative process used to divide the sidescan mosaic into acoustically distinct regions will be more difficult to conduct for areas where the seabed comprises complex, heterogeneous substrates, where boundaries between different habitats are indistinct. At what scale acoustically distinct regions are defined is an important issue, and has profound implications on the design and effort required for the biological survey. The presence of relatively strong physical gradients across the survey area in the current study, with regions displaying a high level of sediment homogeneity, undoubtedly facilitated the interpretation process, and allowed, in most cases, clear habitats and assemblages to be identified. The implications of small-scale variability of sediments for the mapping of seabed assemblages is currently under investigation and will be reported on at a later date.

Physical factors, especially sediment characteristics and hydrographic regime play a significant role in determining community composition (Holm, 1961; Sebens, 1991; Snellgrove and Butman, 1994; Paterson and Black, 1999; Seiderer and Newell, 1999; Rees *et al*., 1999). Detection of discrete biological assemblages across much of the survey area was probably assisted due to the clear differences in habitat characteristics between adjacent acoustic regions. This was particularly obvious between regions with gross habitat/sediment differences (e.g. regions H - cobbles and region C - mobile sand). However, acoustic regions displaying more subtle habitat differences (e.g. region A - sandy gravel and region B - sandy gravel with sand veneers) supported similar macrofaunal assemblages, making it difficult to divide the regions with respect to their biology. This observation emphasises the pragmatic need to make relatively general divisions of the area in terms of habitats, and avoid delineating areas with only subtle differences in physical habitat parameters if statistically discrete assemblages are to be identified.

As a mapping tool the use of sidescan sonar held a number of advantages over QTC-View. The swathe coverage of sidescan allowed a textural mosaic covering 100% of the survey area to be produced, which allowed relatively accurately detection of habitat boundaries. In contrast QTC could only discriminate sediment characteristics directly beneath the ship. Whilst this has the benefit of providing information on substrate characteristics, the technique proved less sensitive in detecting precise habitat boundaries. Problems were also encountered with the QTC system in shallow water depths (<15m), and even gross changes in sediment types (between regions H and F) were not confidently detected by the system. Further investigation of this data set is required before any firm conclusions on the suitability of the system as a stand-alone mapping technique can be made. However, QTC may provide valuable additional data concerning sediment properties when used alongside sidescan sonar. Interpolation would be necessary to produce a full-coverage habitat map based on the 8 acoustic classes distinguished through post-processing using the IMPACT software. Additional post-processing methodology applied to the QTC-View data is currently under investigation.

When classifying biotopes the main characterising species of an area are listed along side a description of the physical habitat (Connor *et al*., 1997; Davies and Moss, 1998). The combined use of sidescan sonar, QTC View and underwater video/photographic techniques proved to be an appropriate approach in order to provide information concerning the physical characteristics of an area of seabed. However, when characterising the seabed assemblages of an area the type of sampling gear used has a profound effect on how the community is described. In the current study a $0.1m^2$ Hamon grab was used to characterise the benthos within the acoustic regions. Whilst this approach provides quantitative data on infaunal species, and the smaller sedentary or sessile component of the epifauna, it is inappropriate as a tool for sampling the rarer megafauna component which may be a significant characterising feature on a larger scale. The later are best sampled using towed gear such as trawls or dredges. Therefore the type of sampling gear has a considerable bearing not only on the identification of characterising species, but also on the power to discriminate between habitat types on the basis of biological traits. The relevance of the characterising species for the management of activities within a mapped region is another important practical consideration which bears upon the biological sampling techniques employed. For this reason the deployment of a combination of sampling techniques would provide a more realistic means of describing the benthic ecosystem, accepting that the capacity to discriminate between habitat types on biological grounds may often be method dependant (Holm, 1961; Rees *et al*., 1999).

In summary, there were clear benefits in using a combination of acoustic techniques to assist in mapping the distribution of biological assemblages over the area of seabed under investigation. Results from the study suggested that sidescan sonar and, to a lesser degree, QTC, were suitable techniques for the production of a physical habitat map. This provided a useful basis for designing the biological survey, the outcome of which could then be overlain and statistically tested. Work is continuing on refinement of methodology for acoustic mapping of the seabed, on implications of small-scale patchiness and on appropriate biological sampling techniques.

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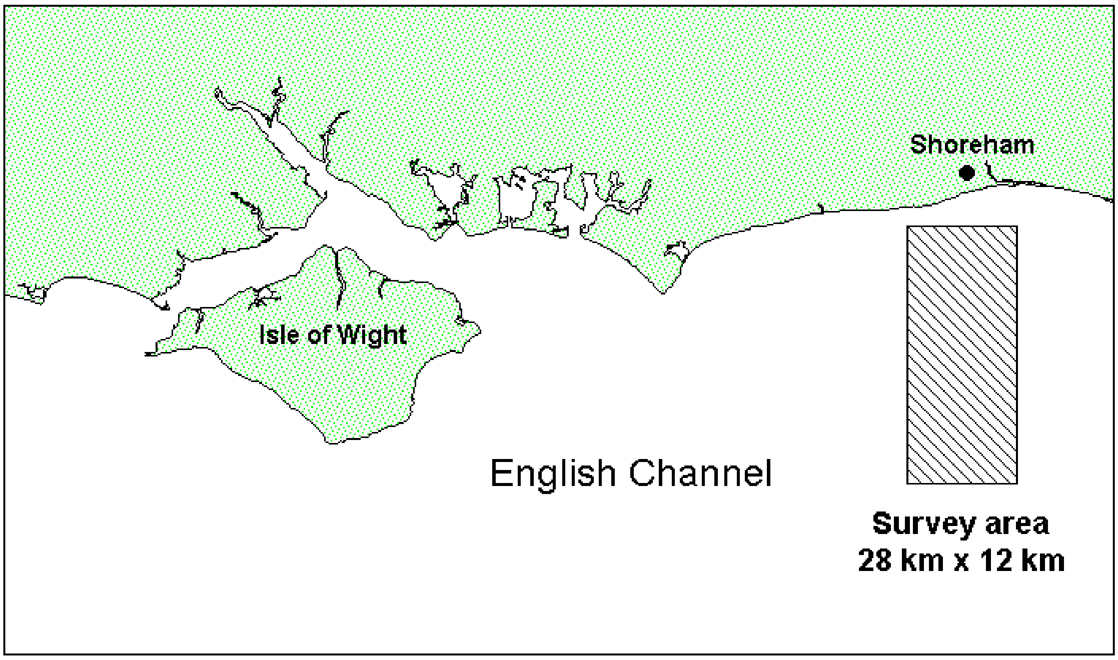

Figure 1. Location of the survey area, Eastern English Channel.

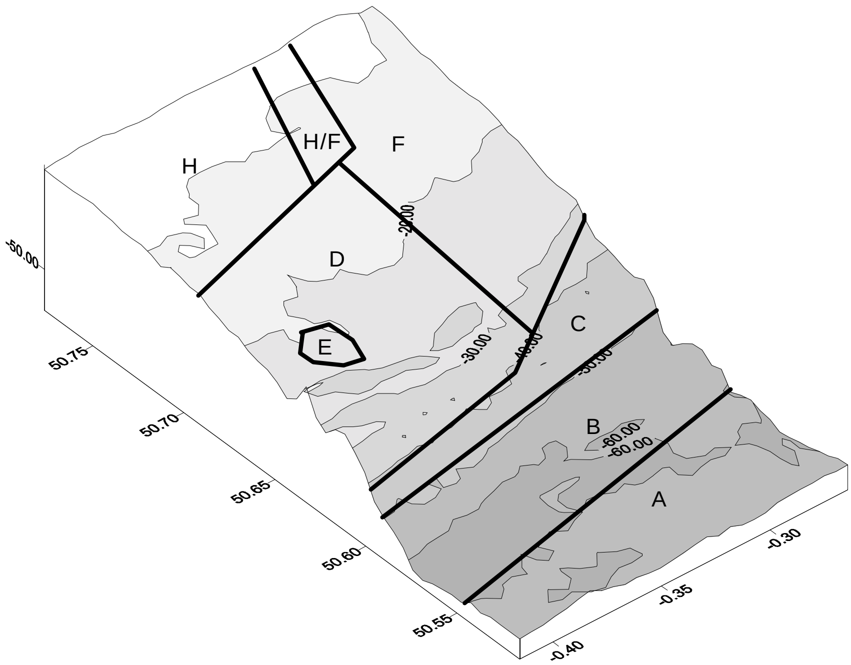

Figure 2. Bathymetric plot of the survey area, interpolated from the QTC data, showing the 8 acoustically distinct regions (A, B, C, D, E, F, H, H/F) determined from the sidescan data.

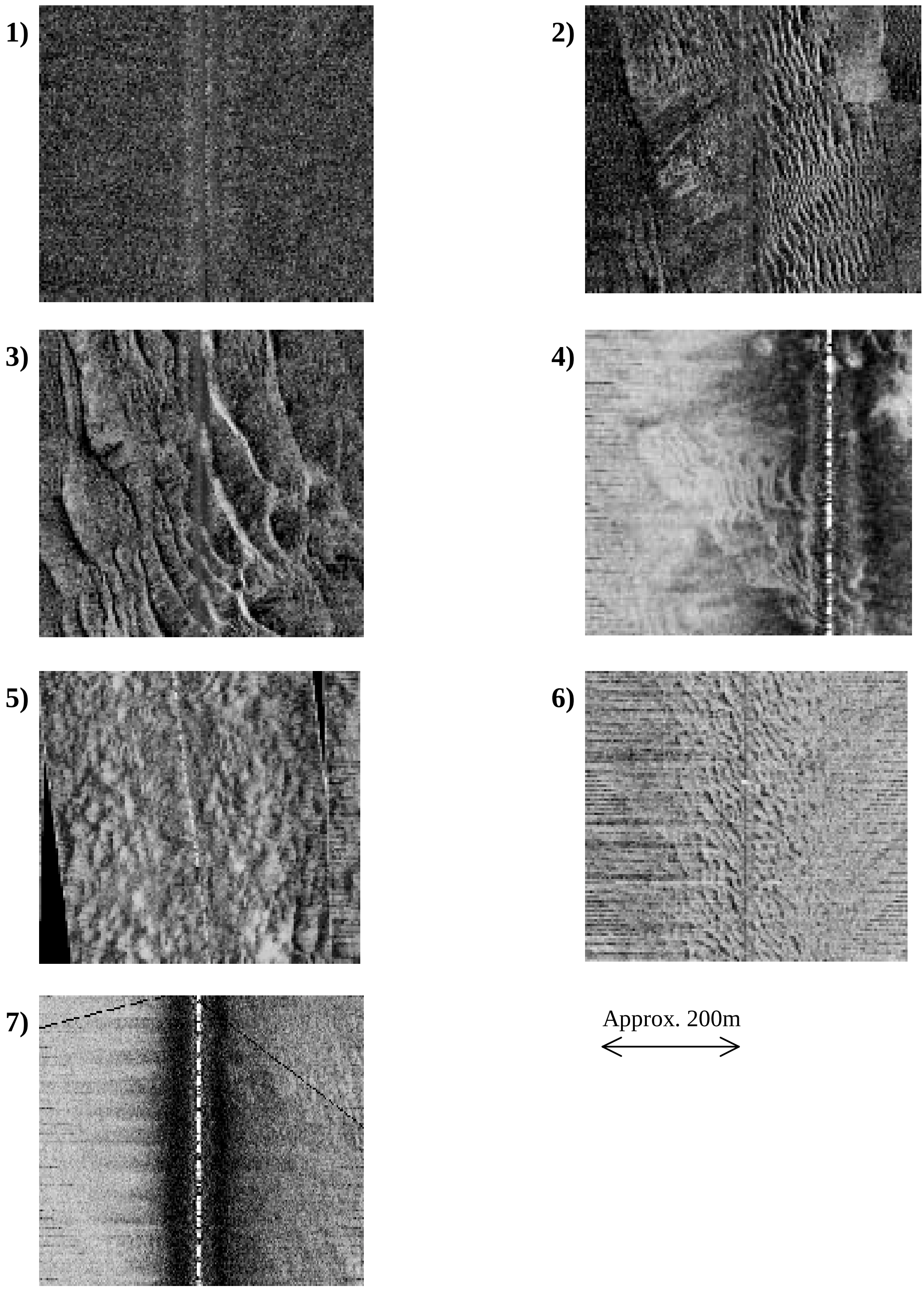

Figure 3. Examples of side scan sonar images from acoustically distinct regions. 1) Region A - Offshore sandy gravel; 2) Region B - Offshore sandy gravel with sand veneers; 3) Region C - Large sand waves; 4) Region D - Mixed heterogeneous sediment; 5) Region E - Uneven mixed heterogeneous substrates with boulders; 6) Region F - Inshore rippled sand; 7) Region H - Coarse gravel and cobbles with attached algae.

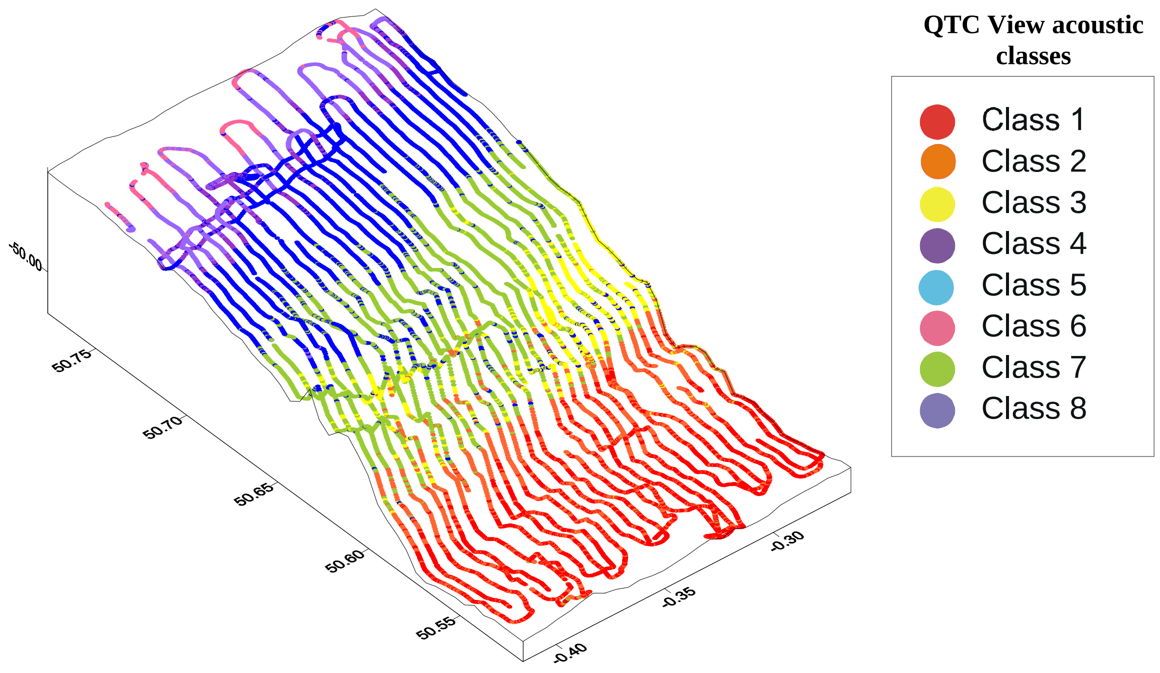

Figure 4. Plot of the QTC View data following post-processing using the Quester Tangent IMPACT software. 8 acoustically distinct classes are illustrated.

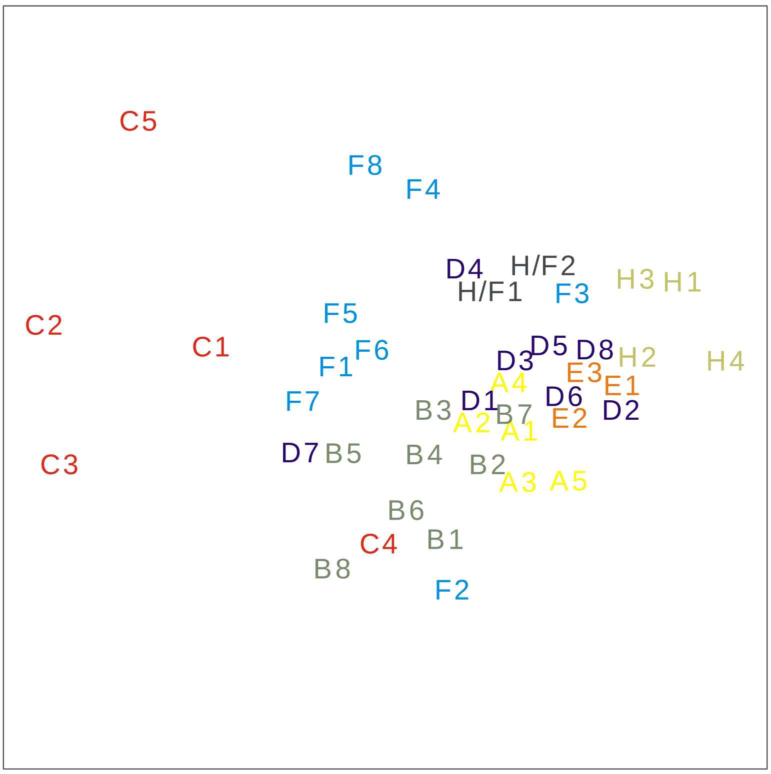

Figure 5. MDS plot for the macrofaunal samples from each acoustically distinct region. The letters refer to the acoustic region from which the sample was collected.

	H	F	H/F	C	B	A	D
F	93*						
H/F	89	87					
C	96*	89*	91				
B	92*	88 *	83*	91*			
A	85*	89*	80*	93*	75		
D	84*	86*	80	94*	83*	74*	
E	79*	91*	87	97*	89*	79*	79

Table 1. Dissimilarity between macrofauna assemblages from acoustically distinct regions based on untransformed species abundance data (* denotes significant difference at $p = 0.05$)

Region A	Av. Abundance	%	Cumulative %	
Echinocyamus pusillus	12.6	14.05	14.05	**Av. Similarity = 42.8%**
Ampelisca sp.	8.8	11.35	25.40	
Aonides paucibranchiata	6.6	10.42	35.82	

Region B	Av. Abundance	%	Cumulative %	
Echinocyamus pusillus	12.4	41.59	41.59	**Av. Similarity = 22.4%**
Spisula sp.	4.5	14.05	55.64	
Glycera sp.	1.5	7.08	62.72	

Region C	Av. Abundance	%	Cumulative %	
Abra prismatica	1.2	47.97	47.97	**Av. Similarity = 15.2%**
Glycera sp.	1.2	16.78	64.75	
Praunus sp.	0.6	10.96	75.71	

Region D	Av. Abundance	%	Cumulative %	
Maldanidae sp.	10.3	21.52	21.52	**Av. Similarity = 21.9%**
Lumbrineris latreilli	4.0	18.71	40.24	
Spisula sp.	4.1	8.24	48.48	

Region E	Av. Abundance	%	Cumulative %	
Heteromastus filiformis	17.0	15.07	15.07	**Av. Similarity = 18.7%**
Maldanidae sp.	4.7	12.39	27.45	
Ampelisca sp.	5.0	8.81	36.26	

Region F	Av. Abundance	%	Cumulative %	
Bathyporeia elegans	4.4	29.19	29.19	**Av. Similarity = 16.7%**
Ophelia limacina	1.5	21.83	51.02	
Spisula sp.	2.6	9.98	60.99	

Region H	Av. Abundance	%	Cumulative %	
Crepidula fornicata	43.7	34.34	34.34	**Av. Similarity = 28.9%**
Scalibregma inflatum	7.25	9.54	43.89	
Lumbrineris latreilli	4.25	6.51	50.39	

Table 2. Results from SIMPER analysis listing the 3 characterising species from each acoustically distinct region. Average abundance, similarity percentage, and cumulative similarity percentage for each species and the overall average similarity between replicate samples from within each region are listed.