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Broad scale biological mapping of Morecambe Bay

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Benthic Mapping and Assessment Project
University of Newcastle

A collaborative project between University of Newcastle, English Nature and North Western and North Wales Sea Fisheries Committee

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Preface

The survey of Morecambe Bay was undertaken by the Benthic Mapping and Assessment Project (BMAP), at the University of Newcastle, under contract to English Nature (EN)and with the assistance of the North Western and North Wales Sea Fisheries Committee (SFC). One of the main aims of the BMAP team at Newcastle University has been to develop techniques for biotope mapping and applying them to specific management case studies in collaboration with other organisations. Morecambe Bay has been forwarded as a candidate Special Area of Conservation (cSAC). In support of future site management considerations there was a need to undertake habitat mapping to complement and build on existing data. The survey provided both training and mapping expertise which will support future management of the site.

Acknowledgements

The BMAP team at Newcastle University wishes to acknowledge the financial support of English Nature for the present project, and the assistance and contributions of the North Western and North Wales SFC.

Many people contributed to the success of the project. In particular, BMAP wish to acknowledge the following for their specific contribution:

- The Skipper & Crew of the *Aegis*. Thank you for the time and effort put into the survey, long hours of tedium and two difficult scientists can be hard to bear!
- Bill Cook for his assistance, support and enthusiasm before, during and after the survey.
- Dr Paul Gilliland for his support and in providing background information for the project.

Synopsis

Morecambe Bay, situated on the eastern coastline of the Irish Sea, contains an area of approximately 45,462 hectares. This consists primarily of extensive shallow coastal sediments along with subtidal river channels. It is an important site because of the wide range of communities present and there are conflicting pressures between industry, fishing and the conservation of biological resources in the area. English Nature identified a need for more information regarding the geographical distribution of broad biotope categories defined by lifeform within the embayment. It was also identified that a collaboration with the North Western and North Wales SFC for the duration of the survey would provide an ideal opportunity for dissemination of information regarding survey procedure.

At Newcastle University, BMAP has developed a survey protocol for mapping the seafloor using acoustic techniques validated by biological sampling, with the data stored and analysed using geographic information systems (GIS). A *RoxAnn* processor samples the return echo from an echo sounder. These acoustic data are related to biological assemblages, determined from direct observations or samples of the sea bed at point locations selected on the basis of the acoustic track data. Biological data were collected using a towed video recorder and by sediment grab sample analysis.

The survey was undertaken between the 12th and the 16th August inclusive, 1996. A total of 58 video samples were collected and 16 grab samples were taken during the survey. Nine generic lifeforms were identified from the video analysis, supported by sediment grab observations.

A map of the distribution of biotopes generalised to lifeforms was prepared for the survey area which was derived from the acoustic characteristics of the sea bed. Any reference to this map must make clear that these distributions are in the nature of predictions and all judgements based on this map must take account of the limitations of the mapping technique.

It was found that large areas of sparse faunal turf were a dominant feature, particularly on the western side of the Bay. This was interspersed with areas of rich faunal turf, particularly at the outlets of the Walney channel and the Wyre and Lune rivers. Large areas of rippled sand were found on the Eastern side of the Bay. Dominant lifeforms identified were *Sabella pavonina* and *Lanice conchilega*. Mussel beds were identified, with a live bed of *Mytilus edulis* found in the North Central part of the Bay.

Comparisons were made with previous MNCR work. Difficulties were found as survey sampling methods adopted were so different. Also the age of the MNCR data must be taken into consideration when working in such an area of constant mobility and flux.

1. Introduction

Effective marine environmental management requires base maps of the extent of the distribution of biological resources as well as an inventory. The production of marine biotope maps forms a very useful basis on which to make decisions on the best approach for conserving the natural heritage of coastal waters. Remote sensing techniques are the most cost effective method of resource mapping, and in turbid, temperate marine waters sonar is the optimal method of remote sensing the seabed. Acoustic ground discrimination systems are designed to map physical environmental variables: topography and seabed type. BMAP at Newcastle University has developed methods of analysing acoustic data in conjunction with biological information to produce biological resource maps using GIS.

1.1 Objectives

The purposes of the survey are two fold. Firstly, to produce maps at appropriate levels of detail to show the subtidal distribution of biological assemblages, particularly lifeforms. Secondly, to provide training and guidance to the North Western and North Wales SFC through joint participation in the process of data collection, analysis, interpretation and map production. To this end the SFC have acquired a *RoxAnn* processor to collect the acoustic data, in addition to a grab and underwater camera to obtain biological ground discrimination data. It is intended to enhance the SFC's ability to undertake future surveys, through training in the protocol employed.

1.2 Overview

The area of Morecambe Bay, was surveyed over the period 12 - 16 August, 1996. The survey area is shown in Figure 1 overleaf.

Morecambe Bay is the outlet for the Wyre, Lune, Keer, Kent and Leven rivers, whose estuaries merge to form an extensive area of shallow coastal sediments. The area is of international importance as the best example in the UK of west coast muddy sand flats, supporting a wide range of community types. These include large mussel beds and sponge communities. Sediments range from muddy fine sand in the inner reaches to more mobile, well-sorted sands towards the mouth. Two Sites of Special Scientific Interest (SSSI) already exist within Morecambe Bay and the Lune Estuary. It is for these reasons that Morecambe Bay has been forwarded as a pSAC.

Two principal surveys of the sublittoral zone in Morecambe Bay have been carried out under the auspices of the Marine Nature Conservation Review (MNCR). Emblow (1992) compiled a report on the hard substrata of the area, and a study of the sublittoral benthic sediment communities of Morecambe Bay (Rostron, 1992) was also undertaken.

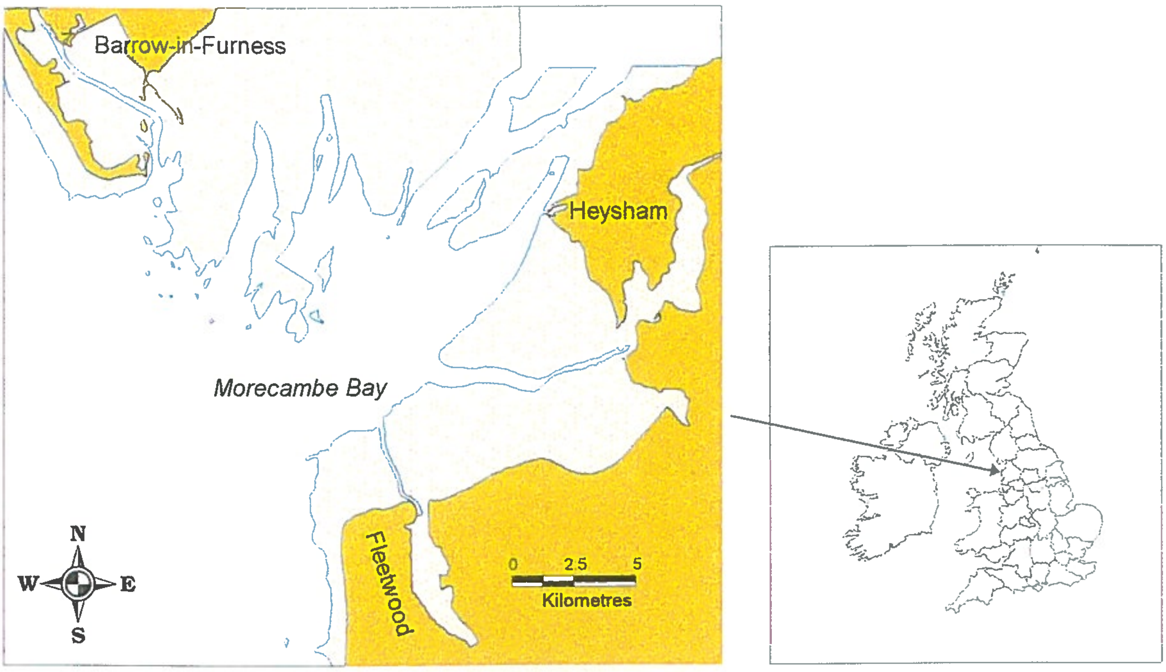

Figure 1 Location of survey area, Morecambe Bay

2. Methods

The methodology employed for acoustic survey work can be seen in figure 2. overleaf. The flow diagram shows a breakdown of the steps used from planning the survey to production of the biotope maps.

2.1. Acoustic surveying

A *RoxAnn* processor samples the return echo from a 200 kHz echo sounder which has a 17° beam width; Chivers *et al* (1990) provide a detailed description of this system. Position data were provided by a Global Positioning System (GPS) using a differential receiver with an accuracy of ± 15 m (Trimble™ GPS with Scorpio Marine™ differential receiver). *RoxAnn* data were saved at 5 sec time intervals on a laptop computer. The facility to save time was not available on the version of RoxMap in the SFC's possession. Whilst the boat travels along a set path at a speed (over ground) of 10 kn., a continuous set of measurements (or track) of the physical nature of the sea bed were recorded and displayed on the computer using *RoxpMap* navigation software (Figure 3.). *RoxMap* displayed the track data on the computer screen coloured according to combinations of roughness (E1) and hardness (E2) or by depth, superimposed on a chart of the coast.

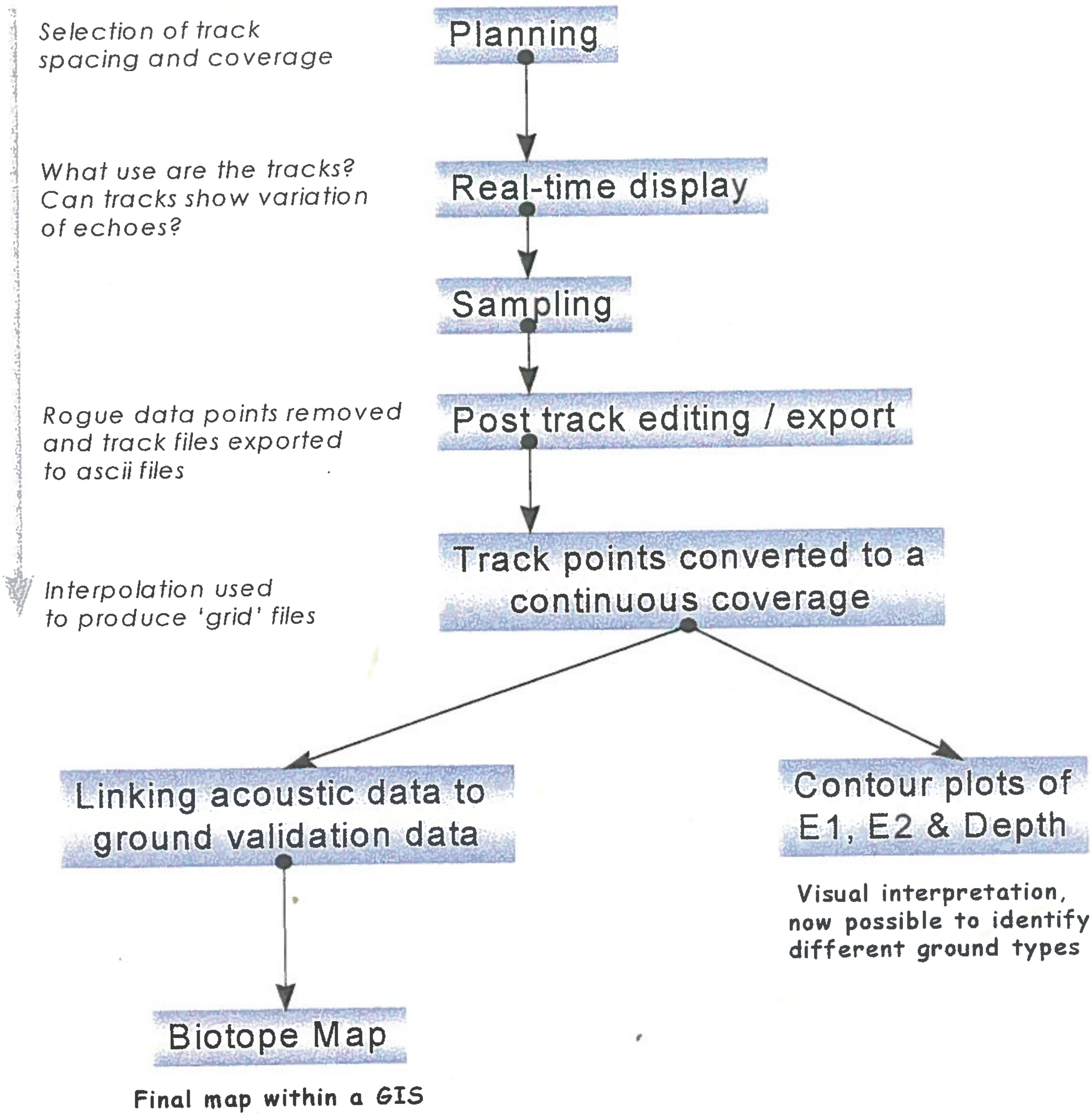

Figure 2. Methodology Employed for Acoustic Mapping

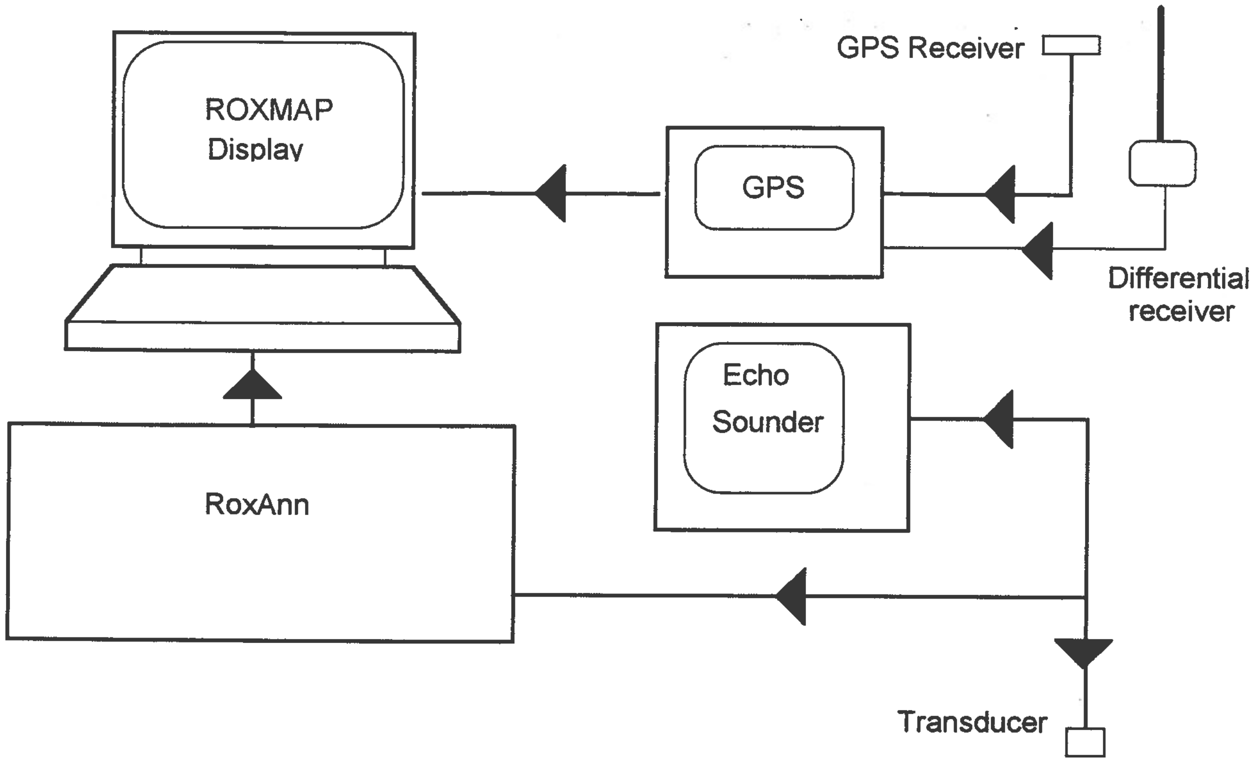

Figure 3. Schematic diagram of acoustic survey equipment

Using the hardware and software settings described above, it is possible to determine the area of sea bed sampled by the *RoxAnn* system:

- A beam width of 17° insonifies an area of approximately 7 m^2 at 10 m depth, increasing to approximately 170 m^2 at 50 m depth.
- At a save rate of 5 s and a boat speed of 10 kn., a data point was saved at approximately every 30 m horizontal distance.

Information is obtained from a limited area under the survey vessel and a map of the acoustic properties of the sea floor built up from a series of parallel tracks: the closer the track spacing, the more complete is the coverage. Nearshore coastal geology combined with coastal geomorphic processes generally produce a heterogeneous assemblage of physical habitats and their associated natural assemblages. Further offshore where the sea bed is predominantly sedimentary, there is generally less heterogeneity with large areas of similar sediment types. Consequently an adaptive survey strategy (Simmonds *et al*, 1992) was employed where the whole survey area was tracked at a broad level (0.25 km apart) and then heterogeneous areas, or areas of specific interest, were tracked in more detail (0.125 km spacing) to determine the spatial organisation of sea bed characteristics.

2.2. Biological sampling and Acoustic Ground Validation

Acoustic mapping using a *RoxAnn* system provides data on the physical nature of the sea bed - depth, smoothness/roughness and softness/hardness. These acoustic data have no biological meaning unless they are related to biological assemblages, determined from direct observations or samples of the sea bed at selected point locations. In remote sensing terminology, the acoustic data must be validated with *in situ* biological sampling and, if possible, with additional 'collateral data' such as sea bed geology and tidal streams (Barrett & Curtis, 1992). *In situ* validation data may be existing sample data from previous investigations, although it is preferable to collect new data so its location is accurately matched to the acoustic tracks. New data can also be compared to existing data which may be valuable in dynamic environments subject to rapid change.

All ground validation equipment was supplied by the North Western and North Wales SFC. Biotope data were collected using a small remote video system comprising of a standard SONY camcorder in a waterproof housing mounted into a small sled. The camera system was connected to the surface via a hauling line and an umbilical which was connected to a VHS video recorder and a monitor which allowed an operator to view and record the images of the seafloor. The camera sled was towed along the sea bed as the boat drifted. Although small and light, the camera system was effective. The presence of an electric winch for raising both the camera and grab allowed for more samples to be acquired than would normally be possible in the time allowed.

Grab sampling was also employed to verify the identification of ground types if underwater visibility was too poor for the video camera to provide reliable information of the seafloor. Samples were analysed on board to give an indication of obvious or abundant infauna present.

Selecting stations to sample was undertaken on the basis of preliminary analyses of acoustic data (see below). Given ideal circumstances, it is desirable to sample all possible combinations of acoustic characteristics present within the survey area. In practice the final number of samples collected will be a trade off between the quantity of data required, allowing for the availability and suitability of existing data, and the financial resources and the time available for sampling. In addition it is desirable to spread the sample stations throughout the survey area - to allow for spatial variations, and if possible to collect replicate samples for each ground type.

2.3. Data analysis

All data analyses were undertaken using proprietary software on a desktop personal computer (PC): a central aim of BMAP is to develop a cost effective PC based system which can be recommended to a wider audience as a tool for environmental management.

2.3.1. Preliminary analysis of acoustic data

Preliminary analyses were completed during the field survey both to select areas for more detailed tracking and to locate *in situ* samples. These analyses were completed within the *RoxMap* software. Initially tracks were analysed to show small increments in the values of E1 (roughness), E2 (hardness) and depth by assigning colours to narrow ranges of data. Basic contour maps were prepared, using *Surfer for Windows,* for each variable by contouring equal-value points (isopleths) and then overlaying these maps to produce a composite map which indicated areas with similar acoustic and bathymetric characteristics. During the field survey these maps were used to select sites for ground validation to represent the full range of E1, E2 and depth values within the survey areas.

2.3.2. Post-Processing: generating continuous coverages

Acoustic track data were corrected to chart datum using tidal corrections calculated from the tidal prediction program using the simplified harmonic method produced by the UK Hydrographic Office (Anon, 1991). Corrections were applied every 60 minutes, taking the period from 30 minutes before to 29' 59" after: *i.e.* the correction for 12:00 would be applied to data from 11:30:00 to 12:29:59. These data were transferred to the contouring program *Surfer for Windows* to produce bathymetric and continuous coverage E1 and E2 maps for the survey area. To convert the track data into a continuous coverage, it was necessary to interpolate adjacent track data to calculate values for intermediate areas. Standard geo-statistical procedures were employed for the interpolations; a review of geo-statistics suggested that the procedure *kriging* was most suited to random data points (Rossi *et al.* 1992). *Surfer for Windows* provides a kriging algorithm to reduce the track data to a rectangular grid of data points for the survey area; a grid size of 100 m by 100 m was selected for the present project.

2.3.3. Analysis of ground-validation samples

Video recordings were analysed to identify physical and biological characteristics to compile lifeform descriptions for the area of Morecambe Bay. The sediment grab sample data was characterised and conspicuous infauna identified at the time of collection during the survey.

2.3.4. Matching acoustic data to lifeforms

Matching lifeforms to acoustic properties of the sea floor enables the distribution of lifeform categories to be shown by interpreting the acoustic map in terms of the acoustic signatures of the various lifeforms. Initial matching was undertaken within *RoxMap* by adjusting the boundaries of the map of acoustic/depth properties through editing the display of the acoustic data. More comprehensive analysis was performed outside of *RoxMap*. The data were exported from *RoxMap* and post-processed using the spreadsheet *Excel* (Microsoft Ltd), the contouring program *Surfer for Windows* (Golden Software Ltd), and the geographic information systems (GIS) *Idrisi* (Clark University), and *MapInfo* (MapInfo Corporation). GIS provides the facility to select track data adjacent to sample stations (Buffering) so acoustic signatures can be determined for each lifeform category. In addition, GIS has extensive cartographic facilities.

To produce a final lifeform distribution map, image processing techniques were employed to analyse the continuous coverage maps with relation to the ground validation samples. Each ground validation sample was coded to a life form type and a process know as buffering was used to define an area surrounding each sample point. The areas for each lifeform were then used to select the underlying acoustic data from the continuous coverage maps. These data are then used to create an acoustic signature for each lifeform type, which could then be assigned to areas which have acoustic properties similar to the signatures for those lifeforms.

3. Results and Data Analysis

3.1. Acoustic survey

Figure 4. shows the location of the acoustic track in Morecambe Bay. A total of 22,916 track points were recorded. The map illustrates the variations in track spacing over the survey area. This is due in part to the concentration on areas of particular interest, for example, the Walney channel and Mort Bank. Also, the extensive intertidal area of Morecambe Bay poses considerable constraints on the time available in which the survey vessel can track certain areas of the Bay.

3.1.1. Track Data

The track data can be utilised for real-time investigation. Figure 4. shows the track data coloured by E1, which can be used for the investigation of ground types. This could be utilised as a decision making and planning tool during survey, for example when sampling. This is in fact one of the most useful applications for *RoxAnn* for the SFC. It is also useful to refer to the original track data so that areas with wide track spacing or where adjacent racks may show wide discrepancies can signal caution when viewing the continuous coverages.

3.1.2. Continuous Coverage

A bathymetry map was prepared for the survey area, and contour maps of E1 and E2 are shown in Figure 5. The values for E1 and E2 are arbitrary and should be taken as qualitative rather than quantitative data. It should be noted that when E1 and E2 are plotted against each other a close correlation exists. Thus, when E2 values are high, E1 values are usually high also, although the variation in strength of the first echo may indicate roughness. All depths were corrected to chart datum, the blue line shown in Figure 5 is the predicted 0m datum taken from the acoustic data collected.

3.2. Biological survey

A total of 58 video samples were collected (Figure 6. & Appendix 1). All samples listed in Appendix 1 are coded for their lifeforms which are described below. 16 grab samples were collected and analysed during the survey (Figure 6. & Appendix 2). Figure 6 shows the video samples coloured to indicate the particular lifeform found at each sample site.

3.2.1. Video Analysis

Problems were encountered with the camera and video system on three counts. Firstly, the general reproduction quality of the VHS recording produced is of a relatively low standard. Ideally the video footage would be recorded onto high quality media using a suitable recorder. Secondly, at depth and in poor visibility the light intensity produced by the camera system was insufficient to penetrate the suspended matter. Both of these problems acted to hinder interpretation of the video data collected and thus identification of lifeforms. Finally, one of the VHS tapes became corrupted, meaning some of the video footage could not be utilised. For the purposes of this report, classification was based on the initial description conducted while on survey for those video takes that have been lost.

3.2.2. Sediment Analysis

Sediment grab sampling was carried out as a secondary support to the video data. Analysis of the samples was carried out during the survey to a cursory level, and so does not allow for reliable classification. In view of the video footage lost and visibility problems faced, future surveys should place more reliance on the sediment sampling and subsequent analysis. The table of the grab sample analysis can be seen in Appendix 2, with the location of each drop in Figure 6. The samples collected provide support for accuracy of the biotope maps produced.

3.2.3 Lifeform descriptions

Table 1 includes descriptions of the lifeforms identified in Morecambe Bay along with the legend category used in Figures 7, 9 & 10.

Table 1 Descriptions of the Lifeforms identified from Morecambe Bay. *Sites recorded* refers to the sample stations listed in Appendix 1 and illustrated in Figures 7, 9 & 10.

Lifeform	Legend category	Description	Sites recorded
1	Mixed turf	Mixed turf, of various algal shrubs and a mixed faunal community on sand and cobbles	107;207;208;211; 221;222;225;234; 235;236;307
2	Faunal turf	Short faunal turf on large boulders with some sediment between.	231;301
3	Lanice	*Lanice conchilega* in medium sand. Present in dense beds and frequently in disturbed sediments where the animals had been evicted from the sediment.	210;212;215;217;224
4	Sabella	*Sabella pavonina* in medium sand. This lifeform was often found in dense beds on the substrata.	111;219
5	Mussel shell	Mussell shell on fine sand, some occasional live mussels (*Mytilus edulis*) were identified but were not present in great abundance.	109;302
6	Live mussel	Live mussels (*Mytilus edulis*) on sediment, either medium sand or sand interspersed with pebbles.	202;203;213;214
7	Rich faunal turf	Rich faunal turf of large sponges (*Cliona celata*) and *Sabella pavonina* on cobbles and boulders.	101;105;106;110;205;223; 227;228;229;230;232;310
8	Algal turf	Algal turf, consisting of small plants on cobbles and pebbles	209;216;218;220
9	Rippled sand	Mobile rippled fine sand with no obvious epifauna.	102;103;104;108;201;204; 206;226;233;237;304;305; 306;308;309

3.2.4. Previous work

The surveys carried out by the MNCR, review by Emblow, 1992, had only three sample sites which were within the area surveyed by the present study.

Rostron, 1992 carried out extensive grab and dredge sampling and used these to produce a community distribution map. The area of this map which lies within the cSAC has been reproduced in Figure 8.

Caution should be adopted when any reliance is placed on data that is not current, particularly with the Morecambe Bay area where sediment mobility is high. The Rostron data is difficult to incorporate into the BMAP analysis since they emphasise the infaunal component of biotopes whereas the present study lays stress on the epifaunal component.

3.3. Biotope Map Production

Two maps of predicted lifeform distribution have been produced, one coloured according to the scheme for habitat complexes based on physical variables such as habitat, depth and exposure (Connor et al., 1996), Figure 9, and the other coloured according to lifeforms (Bunker & Foster-Smith, 1996), Figure 10. Both allow an appreciation of where epifaunal communities are present, and what topographic features they are associated with. Accuracy of the maps is entirely dependent on spacing of track data and quantity of ground truthing. Smaller data sets will require increased extrapolation.

3.3.1. Lifeform Distribution

Nine lifeforms were identified for Morecambe Bay. These can be seen in table 1 overleaf. The distribution of these discrete groupings within the area were analysed. To aid the description, the area surveyed can be viewed from west to east (see Figures 9 & 10).

It can be seen that there are large areas of sparse faunal turf covering much of the western side of the Bay, interspersed with smaller areas of a rich faunal turf. The rich faunal turf appears to be concentrated in areas south and south east of the Walney Channel, where water movement and exposure of the sites is likely to be higher relative to adjacent areas. These areas of rich faunal turf appeared to be of significance in the area, as they were relatively rich in diversity when compared to surrounding lifeforms. Along Walney channel to its mouth and around Mort Bank the cobble, pebble and coarser sand substrata allows for communities of mixed faunal and algal turf, dominated by *Lanice conchilega* in some areas.

The central region of Morecambe Bay appears to be a mix of faunal turfs, *L. conchilega*, *Sabella pavonina* and *Mytilus edulis*. All form dense beds on the substrata. Often the *L. conchilega* tubes were scattered over the sea bottom. To the north of the central region a bed of live *M. edulis* was identified, and it was found to be in an intertidal area. This is of some interest as dredging licences have recently been granted to allow extraction of Mussel from this area. From the south central part of the bay fine rippled sand is the dominant feature, stretching north east.

In the eastern region of the bay, there are large areas of fine rippled sand which appeared to have no obvious epifauna and from brief examination of the sediment, infauna was either sparse or not present. A large area of rich faunal turf was identified north of the Wyre and west of the Lune, again suggesting the link with increased water movement and higher diversity. Some areas of Mussel have been predicted from the analyses although only two video samples in these areas showed mussels to be present. Towards Heysham there are small areas of Mussel with fringing areas of mussel shell.

4. Discussion and Recommendations

The aims of this survey were two-fold: to prepare a biotope map of the cSAC for English Nature, including a review of available data from previous surveys and to assist the SFC in the use of RoxAnn in remote survey for assessing and monitoring the status of particular shell fish stocks and habitats. It is hoped that EN and the SFC will work closely with monitoring the cSAC and that this project will facilitate the growth of this partnership.

The discussion will review the potential use of RoxAnn for English Nature and the SFC in the light of the experience of the present survey.

4.1. Acoustic remote sampling

There are two main stages in the collection and treatment of the acoustic data: real-time track display and the generation of continuous coverages through post-survey processing. Track display within *RoxMap* can be a powerful tool for real-time ground investigation through the construction of display boxes to colour track data, although the options for display are limited to combinations of E1 and E2 or depth. Real-time display of the track data is likely to be of primary use to the SFC and can show boundaries between different ground types and, therefore, could be used for detecting changes in the extent and boundaries of habitat types. However, caution must be used in applying this 'simple' approach to the use of RoxAnn to very localised habitats. If large areas are surveyed covering a wide range of habitats, then the scope for confusion between habitats based on the acoustic signature defined by *RoxMap* boxes increases.

RoxMap displays over large areas are also useful as general indicators of the geographic spread of very broad ground types, although interpolating between tracks 'by eye' and combining separate plots of E1, E2 and depth, or E1/E2 combined and depth can be confusing.

The *RoxMap* display serves a second purpose in pointing up areas where the continuous coverages generated must be viewed with caution because of wide track spacing and/or wide discrepancies between adjacent tracks.

Grids generated from the track data allow far greater scope for analysis than is possible within *RoxMap* with, potentially, the benefits of a less subjective approach to interpolation and the combination of data into a single map. However, processing the data can be intensive in terms of computation and the resulting images still require careful interpretation. It is likely that continued support to both English Nature and the SFC will be required for this, dependant upon the critical requirements of maps.

Future SFC survey might concentrate on the area of Mussel where licensing has been granted.This area could be monitored more closely and surveyed to a detailed level on a regular basis for effective assessment of the impact of dredging and the health of the Mussel population.

Other areas which may also be of interest for further study centres around the Walney Channel and to the north and west of the Wyre and Lune respectively. As mentioned above these areas appeared to be biologically rich when compared to the adjacent areas.

4.2. Sampling

Attempts to incorporate previous survey data into map generation points up the difficulties in deriving biotopes that can be used as a common denominator. There is uncertainty about the position of early records (pre- differential GPS) and discrepancies between early and recent data may also be due to real changes that have taken place over time.

More importantly, techniques that are designed to sample either the infauna or epifauna produce data that have very little proven relationship to each other and cannot easily be related to common biotopes. There is a need for surveys to combine both sampling strategies in order that a complete picture of biotopes can emerge.

4.3. Map design

Biotope maps must be judged against three standards: 1, are they clear and do they convey meaning; 2, are they sufficiently discriminating in the level of detail they show; 3, how much confidence can be put in the maps.

4.3.1. Map clarity.

Two versions of the biotope map have been produced; one using a proposed standardised colour scheme based on substratum, exposure (to wave energy) and depth whilst the second is based on life forms. It is considered that the latter gives more scope for colour to separate biotopes and give a general indication of the distribution of biological features.

4.3.2. Biotope detail.

The level of detail is quite broad, although provisional biotopes were created beyond those found in the MNCR classification system to cover the biological/physical features that could be mapped. It remains for English Nature and the Sea Fisheries Committee to judge if these are sufficiently detailed for their puroposes.

4.3.3. Confidence

Confidence can be variously assessed: However, very few mismatches occur in this survey between the sample data and the predicted life form based on acoustic signatures. This might be expected since all the sample data were used to generate the acoustic signatures and, ultimately, the map must be tested by its predictive capability in future survey work.

4.4. Summary of recommendations

1. The SFC should build up their experience of RoxAnn to discriminate between ground types on a localised basis within Roxpmap display.
2. The SFC may wish to liaise with Newcastle/English Nature to continue to build skills in post processing and biotope map production.
3. The present survey can be used to select sampling stations to monitor change in sublittoral sandbanks and other features of the cSAC.
4. The biotope map can form the base map with a GIS for the spatial display and analysis of other relevant data.
5. However, it is likely that this map will need modification and it is suggested that further sampling involving epifaunal and infaunal sampling methods is required to adequately describe the full range of biotopes present.
6. It is recommended that a standard approach can be agreed to biotope mapping involving remote acoustic sensing and appropriate ground sampling so that the cSAC can be comprehensively surveyed in a cost effective way at regular intervals to assess current status and change.

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Figure 4 Location of acoustic tracks in Morecambe Bay, coloured by E1.

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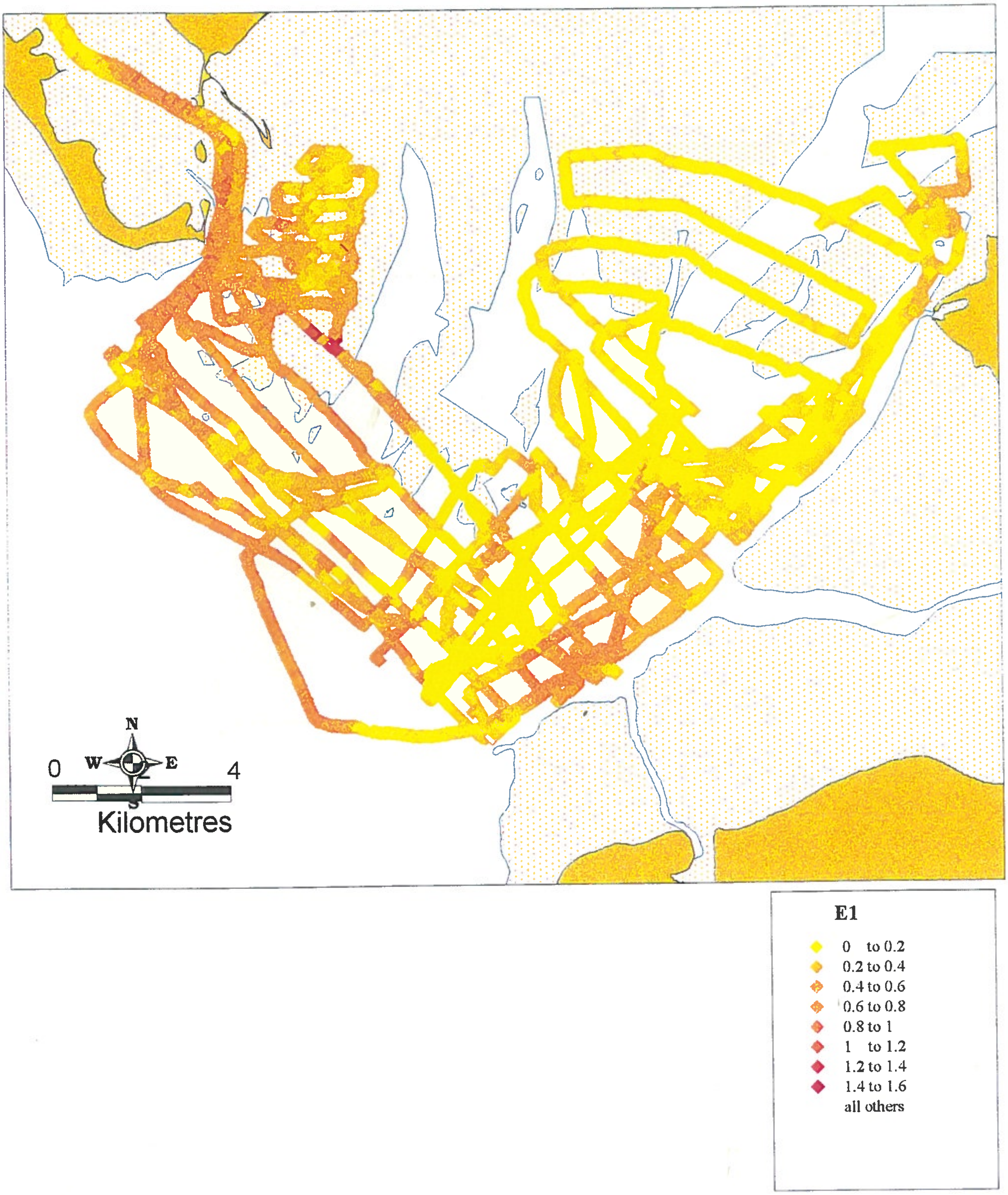
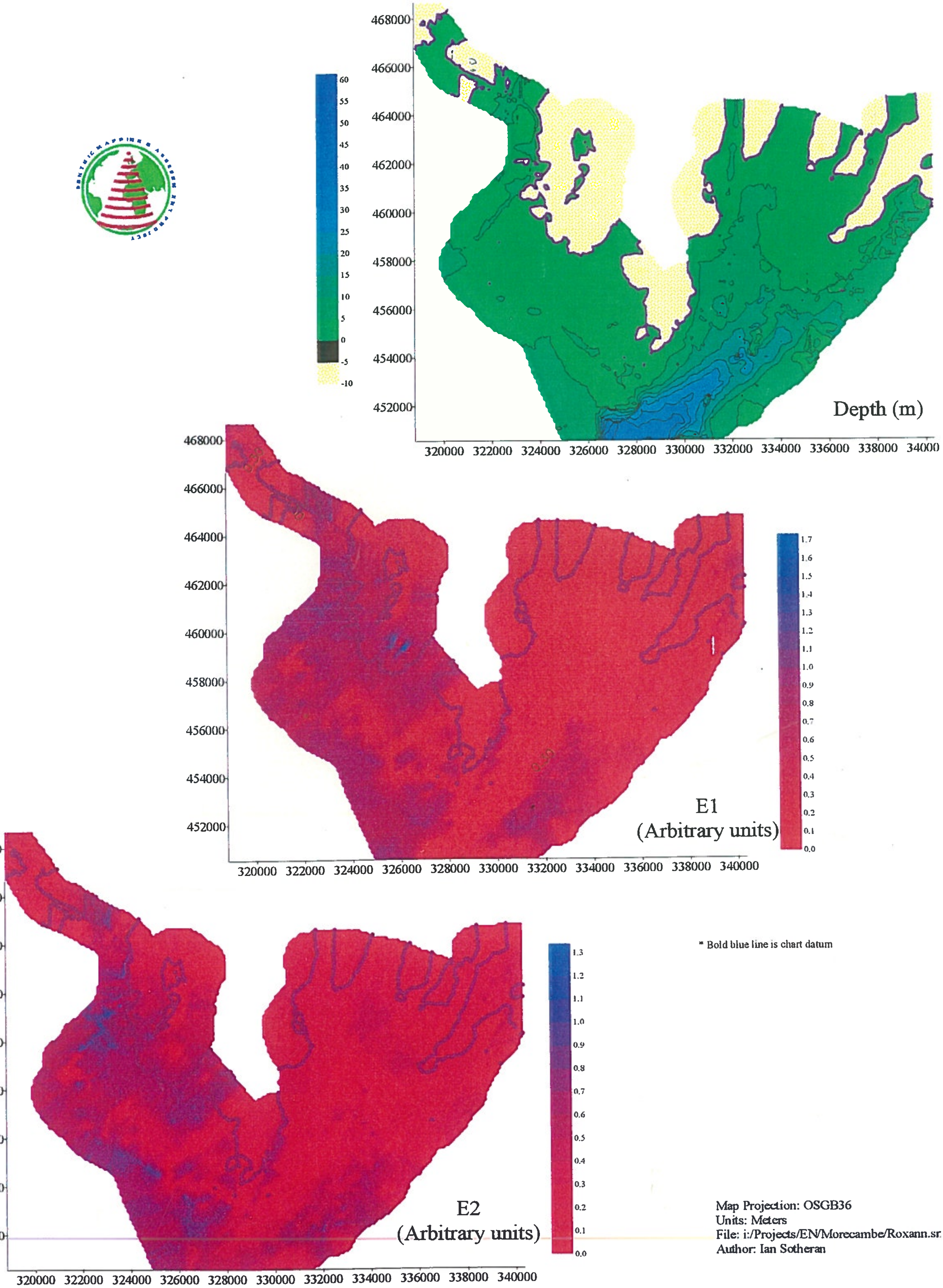


Figure 5 Bathymetry and countours of E1 & E2 for Morecambe Bay.



* Bold blue line is chart datum

Map Projection: OSGB36
Units: Meters
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Author: Ian Sotheran

Figure 6 Video takes and grab sample locations in Morecambe Bay

Author: ISS
Date: 14/1/97
File: i:/en/morecambe/mapinfo/dropsall.wor

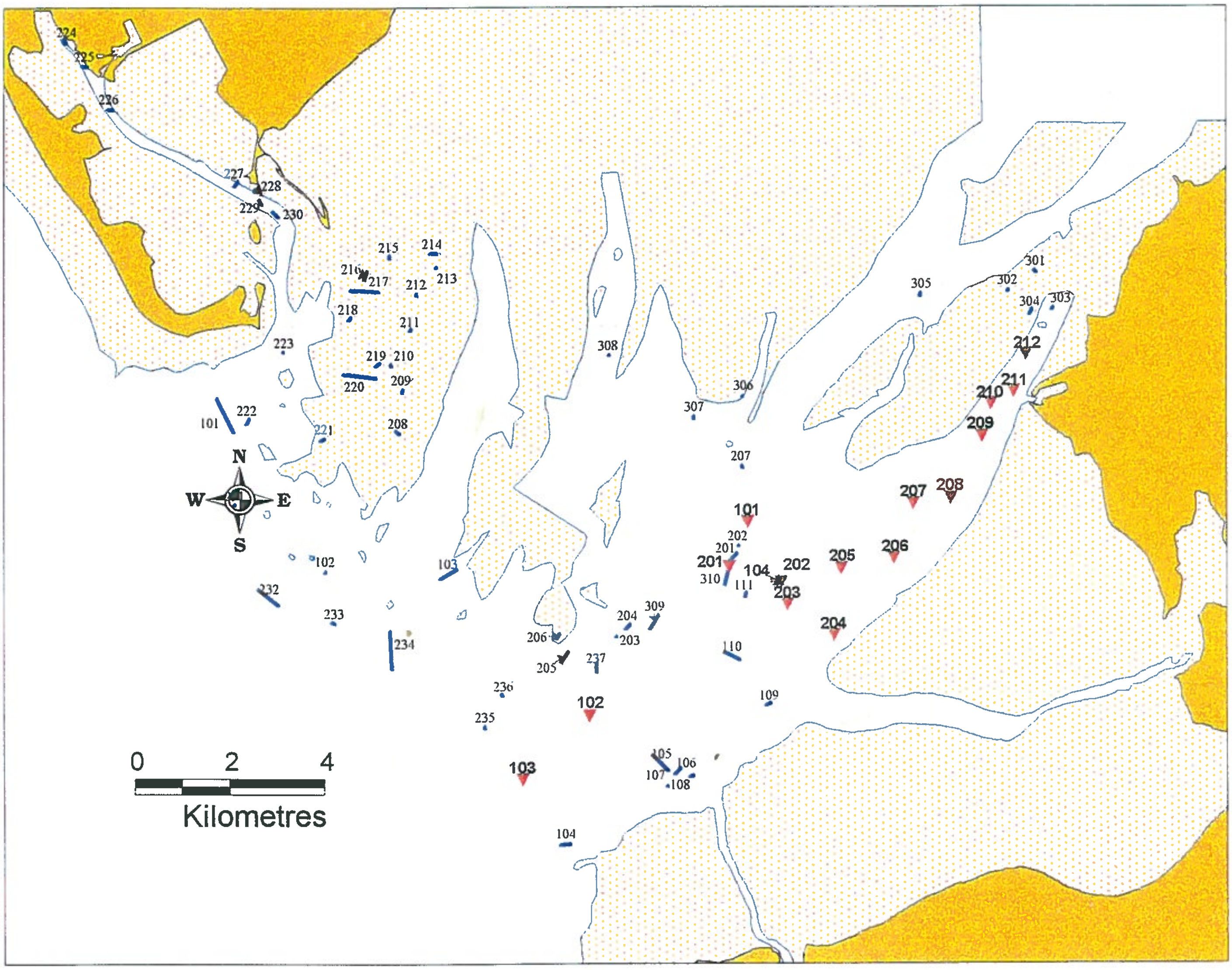
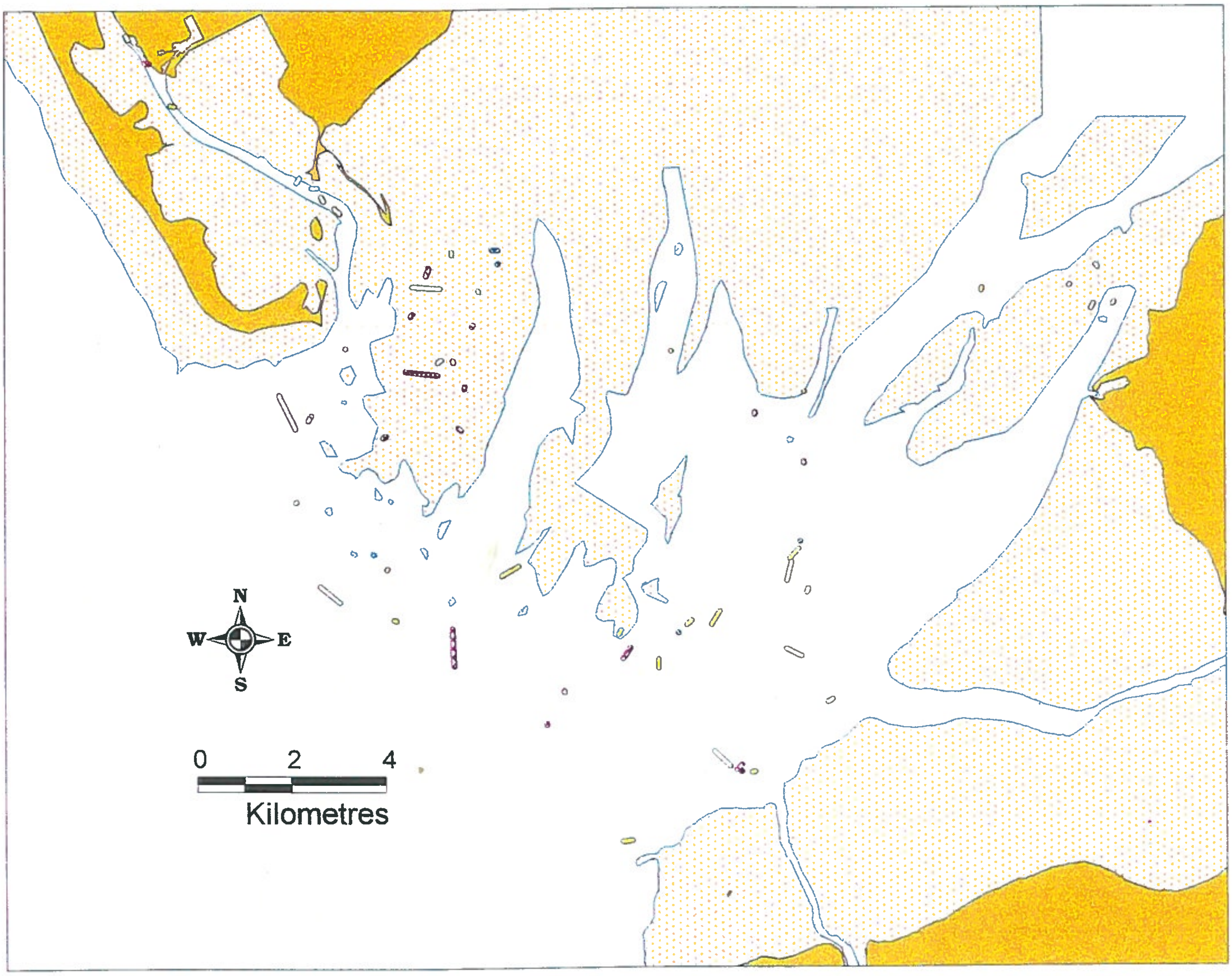


Figure 7 Video takes in Morecambe Bay coloured by lifeform type.

Author: ISS
Date: 14/1/97
File: i:/en/morecambe/mapinfo/drops2.wor



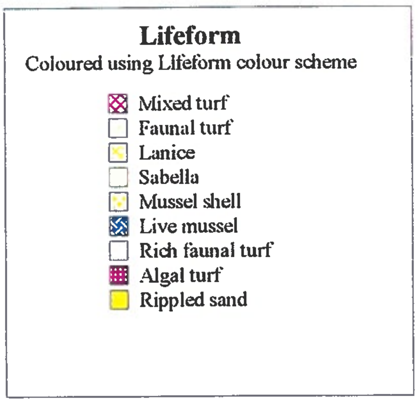
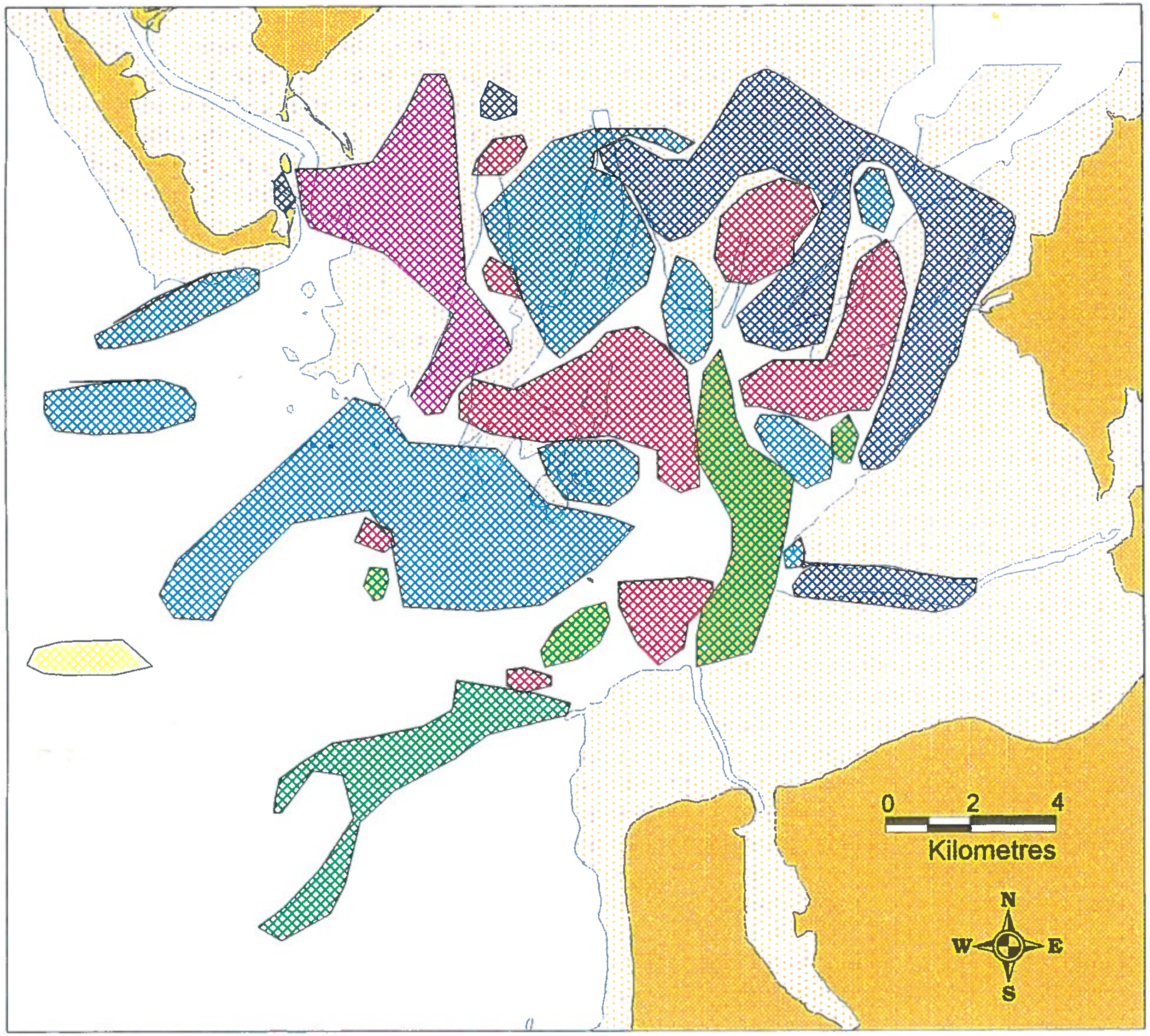


Figure 8 The distribution of the community types in Morecambe Bay, taken from Rostron, 1992.

Author: ISS
Date:14/1/97
File: i:/en/morecambe/mapinfo/rostron.wor



Community Types

Descriptions and codings taken from original report

MS 3 - Offshore transitional Mud/Sand Community

MS 7 - Pectinaria Mud Community

MS 11 - Magelona Sands

MS12 - Mixed Sands

MS 13 - Shallow Nephtys cirrosa Sands

MS 14 - Shallow Bathyporeia Sands

MS 15 - Miscellaneous Shallow Sand Community

MS 16 - Lanice / Mytilus Commmunity

Community types
Taken from Rostron, 1992

- MS 3
- MS 7
- MS 11
- MS 12
- MS 13
- MS 14
- MS 15
- MS 16

Figure 9 Predicted lifeform distribution for Morecambe Bay, coloured by biotope grouping colour scheme (after Connor, 1996).

Author: ISS
Date: 14/1/97
File: i:/en/morecambe/mapinfo/supera.wor

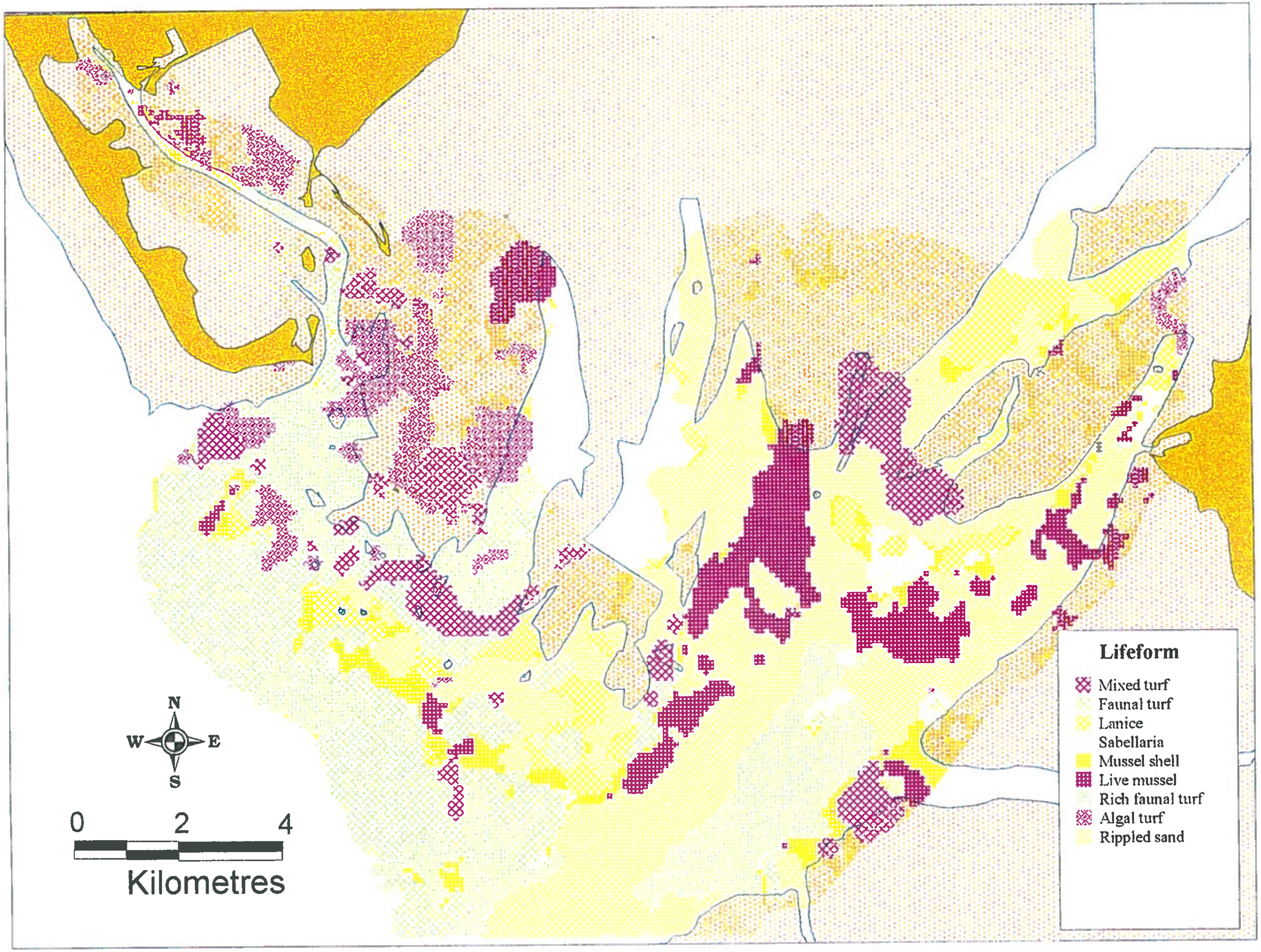
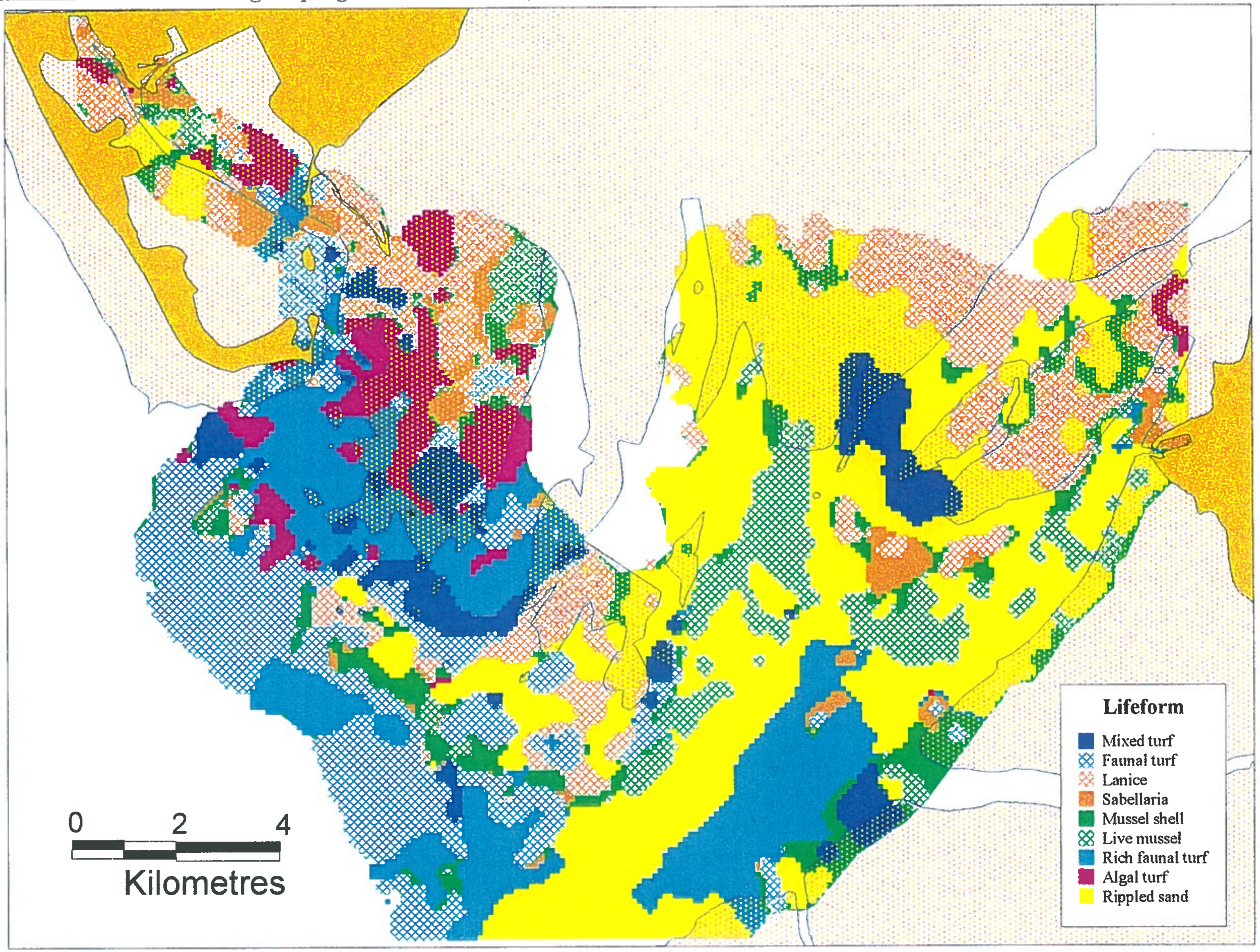


Figure10 Predicted lifeform distribution for Morecambe Bay coloured by lifeform grouping colour scheme (after Bunker and Foster-Smith, 1996)

Author: ISS
Date:14/1/97
File: i:/en/morecambe/mapinfo/super.wor



Appendix 1

	Start		End		
ID	Latitude	Longitude	Latitude	Longitude	Lifeform
101	54.0325	-3.18617	54.0262	-3.18098	7
102	53.9997	-3.15133	53.9995	-3.1515	9
103	54	-3.10917	53.9982	-3.1145	9
104	53.9477	-3.076	53.9478	-3.07283	9
105	53.9647	-3.04633	53.9618	-3.04133	7
106	53.9612	-3.03917	53.9622	-3.0375	7
107	53.9608	-3.03767	53.9608	-3.03767	1
108	53.9607	-3.03433	53.9608	-3.03333	9
109	53.9742	-3.00983	53.9747	-3.00833	5
110	53.9842	-3.02317	53.9828	-3.01833	7
111	53.9948	-3.0165	53.9955	-3.01617	4
201	54.0012	-3.022	54.003	-3.01917	9
202	54.0045	-3.0185	54.0045	-3.0185	6
203	53.9872	-3.05783	53.9872	-3.05783	6
204	53.9887	-3.055	53.9895	-3.0535	9
205	53.9823	-3.07567	53.9843	-3.07333	7
206	53.9868	-3.077	53.9877	-3.07617	9
207	54.0193	-3.01717	54.0197	-3.01733	1
208	54.0263	-3.1285	54.0258	-3.1275	1
209	54.0337	-3.1265	54.0342	-3.12633	8
210	54.0387	-3.13	54.039	-3.13017	3
211	54.0457	-3.12367	54.0453	-3.124	1
212	54.052	-3.12183	54.0522	-3.122	3
213	54.0572	-3.11567	54.0573	-3.1155	6
214	54.0598	-3.1155	54.0598	-3.1175	6
215	54.0595	-3.1305	54.059	-3.1305	3
216	54.0565	-3.13783	54.055	-3.13867	8
217	54.053	-3.143	54.0527	-3.13417	3
218	54.0478	-3.143	54.0473	-3.14367	8
219	54.0392	-3.13383	54.0387	-3.135	4
220	54.037	-3.14533	54.0363	-3.135	8
221	54.0248	-3.15167	54.0245	-3.15267	1
222	54.0287	-3.17583	54.0277	-3.17683	1
223	54.0413	-3.16483	54.0413	-3.16483	7
224	54.1005	-3.23567	54.0997	-3.235	3
225	54.0953	-3.22967	54.0952	-3.22833	1
226	54.0872	-3.22133	54.087	-3.22	9
227	54.0727	-3.1805	54.0735	-3.1795	7
228	54.0717	-3.17567	54.0717	-3.17383	7
229	54.07	-3.1725	54.0692	-3.17167	7
230	54.0678	-3.16817	54.0668	-3.1665	7
231	54.0123	-3.1805	54.0122	-3.18083	2
232	53.9963	-3.173	53.9933	-3.16667	7
233	53.99	-3.14933	53.9898	-3.1485	9
234	53.9812	-3.13	53.9883	-3.1305	1
235	53.9702	-3.10017	53.9698	-3.10017	1
236	53.9763	-3.09467	53.976	-3.0945	1
237	53.9822	-3.06417	53.9805	-3.06417	9
301	54.0565	-2.923	54.0562	-2.9225	2
302	54.0528	-2.93133	54.0527	-2.9315	5
303	54.0495	-2.91717	54.0492	-2.9175	7
304	54.0492	-2.92383	54.0483	-2.9245	9
305	54.0523	-2.9595	54.0518	-2.95967	9
306	54.0328	-3.01717	54.0328	-3.01717	9
307	54.029	-3.033	54.0285	-3.033	1
308	54.0405	-3.06	54.0405	-3.06	9
309	53.9912	-3.0445	53.9887	-3.04717	9
310	54.0005	-3.0215	53.997	-3.023	7

Appendix 2

Grab	Description	Species Identified
101	Fine sand/shell	*Pectinariidae* (empty)
102	Fine sand/shell	
103	Very fine sand	*Amphipoda, Nephtys*, Isopods
104	Very fine sand	*Amphipoda, Nephtys*, Lanice tubes
201	Very fine sand	Brittlestars
202	Mud/silt	*Nephtys, Pectinariidae*, bivalves
203	Coarse sand/shells	*Nephtys, Pectinariidae*, Ophiura
204	Coarse sand/shells	
205	Fine silty sand	*Nephtys, Pectinariidae*, Sabella tubes
206	Medium sand/some broken shells	*Nephtys*
207	Medium sand	*Nephtys*
208	Medium sand/some broken shells	
209	Medium sand, well sorted	
210	Fine sand, well sorted	
211	Clay	cockle (*Cerastoderma lamarcki*)
212	Coarse sand/shells	