ENGLISH NATURE

No. 231

Broad scale biological mapping of Lundy Marine Nature Reserve with particular reference to reefs

Maritime Team

Ian Sotheran
Rob Walton

English Nature Research Reports

Initial distribution list

Sotheran, I. & Walton, R. 1997. Broad scale biological mapping of Lundy Marine Nature Reserve with particular reference to reefs. *English Nature Research Report* No 231

English Nature	
Enquiry Service (for external library distribution)	x17
Main Library (for agency library distribution)	x8
Maritime Team	x2
Roger Covey, EN Truro	
Jo Crix, EN Okehampton	x2

JNCC
Keith Hiscock
MNCR

SNH
John Baxter

CCW
Mandy Richards
Blaise Bullimore

DoENI
Martin Bradley

Liza Cole, Lundy Warden
Neil Downes, Devon SFC
Robert Irving
Colin Munro
Sarah Fowler
John Schofield, LFS
BMAP, University of Newcastle

English Nature Research Report

No 231

Broad scale biological mapping of Lundy Marine Nature Reserve with particular reference to reefs

Ian Sotheran
&
Rob Walton

Nominated officer: Dr. P.M. Gilliland
Maritime Team, English Nature

A collaborative study between English Nature and the Benthic Mapping & Assessment Project, Newcastle University

ISSN 0967-876X

Contents

List of Figures

Preface

A survey of habitats, including particular reference to the reefs around Lundy Island, Bristol Channel was undertaken by the Benthic Mapping and Assessment Project (BMAP), at the University of Newcastle, under contract to English Nature. One of the main aims of the BMAP team at Newcastle University has been to develop techniques for biological mapping and applying them to specific management case studies in collaboration with other organisations.

Acknowledgements

The BMAP project wishes to acknowledge the financial support of English Nature for the present project.

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

- The skipper, Clive Pearson & crew, for their patience and interest, particularly for the phrase "Well it's been different!"
- Alistair Davidson & Frank Fortune, Scottish Natural Heritage, for their efforts in the ground validation campaign and their piloting skills of the ROV.
- Drs Dan Laffoley & Paul Gilliland for their assistance during the survey and providing background information for the project.

Synopsis

Lundy Island is situated in the Bristol Channel 18 km North of Hartland Point, North Devon. It is 4.9 km long from north to south and 1.3 km across at its widest point. Considering these dimensions, Lundy is host to an extensive variety of flora and fauna. The sublittoral and littoral environments have high species diversity. For this reason the waters around Lundy were designated as the U.K.'s first statutory Marine Nature Reserve in 1986. The area of the reserve encompasses the complete 15 km of coastline to the height of the highest astronomical tide, extending approximately 2.5 km offshore which covers approximately 13.9km^2 of seabed. Lundy has been forwarded as a candidate Special Area of Conservation (SAC) under the EU Habitats and Species Directive.

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 have no biological meaning unless they are related to biological assemblages, which are determined from direct observations or samples of the sea bed at pre-determined point locations. Biological data were collected using a ROV and a towed video recorder.

Lundy was surveyed between July 15th and July 19th inclusive. A total of 9 video samples and 16 ROV samples were collected.

A map of the **predicted lifeform distribution** based on the acoustic characteristics of the sea bed was prepared for the survey area. Any reference to this map must make clear that these distributions were a prediction, and any judgements based on this map must take account of the limitations of the mapping technique.

The reefs around Lundy were found to support a diverse range of communities, and were found in inshore areas around the whole of the island. Off the west coast large reefs extend offshore, and on the east coast steep reefs and pinnacles support rare species, namely *Eunicella verrucosa* and *Leptopsammia pruvoti*. The reefs on the east coast do not extend offshore to the same extent as those on the west coast, but the terrain is more dramatic with frequent vertical or sheer faces.

A comparison was undertaken between BMAP data and that collected by previous surveys. A close correlation was found between these data and, by and large, the lifeforms recorded at each site from previous surveys matched the predicted lifeform from the BMAP survey. Mis-matches between the data were probably due to inherent errors in the positioning system used by previous surveys.

Introduction

Background to biological resource mapping

Understanding the extent and distribution of marine habitats and biota is an essential element on the process of developing effective management of marine sites. Such spatial-based nature conservation information is necessary in order to match up conservation interests with uses and management regulations.

Resource mapping is a well established practise for terrestrial and coastal maritime management but maps showing a continuous coverage of subtidal marine biological resources are not readily available. Terrestrial mapping makes extensive use of remote sensing technology using images of electromagnetic reflectance recorded by sensors mounted on satellite or airborne platforms. Satellite remote sensing techniques have been extensively used in tropical coastal management (Green, *et al.*, 1996) but most temperate waters are too turbid to provide images of the seabed deeper than a few metres. Acoustic (sonar) technology replaces electromagnetic reflectance as the most efficient method of remote sensing turbid subtidal environments.

Sonar systems visualise the topography and physical nature of the seabed and have a wide application for mapping in the hydrographic and geological disciplines. Recent development of acoustic ground discrimination systems has improved our ability to map the physical nature of the seabed (Chivers et al., 1990; Collins *et al.*, 1996). Biological communities however often have catholic physical environmental requirements and therefore habitat maps will not directly relate to biological resource maps. In addition, bathymetry is a fundamental factor determining the distribution of biological communities and current ground discrimination systems do not incorporate bathymetry into thier map. This is a major limitation of these systems. Careful integration of acoustic data with biological data from ground validation samples can form the basis of biological resource maps.

Geographic Information Systems (GIS) are computer based systems for storing, analysing, querying and displaying geographically referenced information. Data are stored in layers which can be overlaid to build up a picture of an area. GIS have made a significant contribution to terrestrial environmental management because remote sensing and GIS provide the necessary tools to generate resource maps which can be queried at different scales to answer specific management questions. GIS have made a significant contribution to coastal management but most systems do not incorporate benthic data below low water (Furness, 1995). If acoustic survey techniques could utilise GIS technology, it would be possible to generate effective resource maps for the subtidal marine environment.

BMAP at the University of Newcastle-upon-Tyne, developed a strategy for mapping marine benthic communities using acoustic ground discrimination systems and GIS (Davies *et al.*, 1995). In particular, BMAP has concentrated on the intermediate scale developing methods to interpret acoustic data to produce biological resource maps.

Aim of the Lundy Survey

Lundy Island is situated in the Bristol Channel 18 km North of Hartland Point, North Devon. It is 4.9 km long from north to south and 1.3 km across at its widest point. Considering these dimensions, Lundy is host to an extensive variety of flora and fauna. The sublittoral and littoral environments have high species diversity. For this reason the waters around Lundy were designated as the U.K.'s first statutory Marine Nature Reserve in 1986. The area of the reserve encompasses the complete 15 km of coastline to the height of the highest astronomical tide, extending approximately 2.5 km offshore which covers approximately 13.9km^2 of seabed. Lundy has been forwarded as a candidate Special Area of Conservation (SAC) under the EU Habitats and Species Directive.

For the Lundy candidate SAC and statutory Marine Nature Reserve a considerable amount of information already exists with regards to the conservation of marine resources. This information has been collected in two ways: location-specific information which usually relates to quantitative information on the abundance of certain species present; and broad-brush data on the relative distribution of seascape and habitat features. There was however a need to accurately establish the location and extent of the reefs around Lundy and the communities they support, the feature for which the SAC has been identified together with associated habitats within the Marine Nature Reserve. The present study concentrates on the area of the Marine Nature Reserve and examined in detail an area to the east of Lundy which includes much of the known reef interest. (Figure 1)

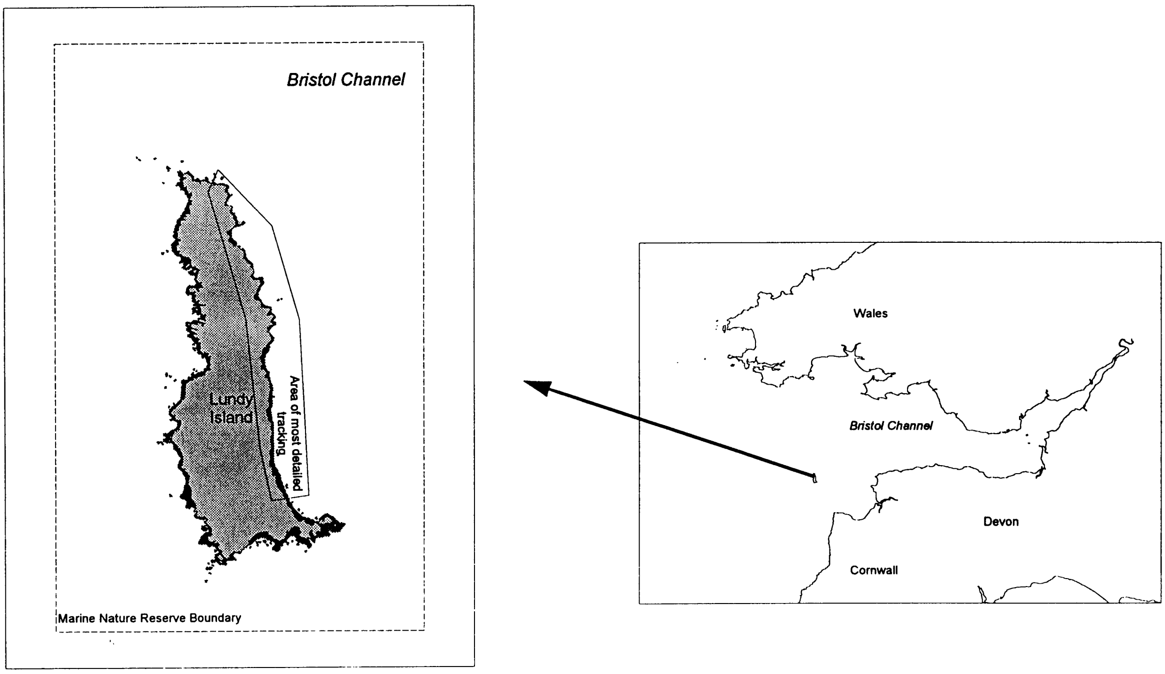


Figure 1 Location of survey area

Review of previous studies.

A large number of mainly descriptive surveys have been carried out around Lundy and it has been possible to provide a reasonably comprehensive review of the range of habitats and communities present (see references in English Nature 1994). Systematic surveys of algae and animals carried out as part of the listing of marine flora and fauna (various fauna lists in the Report of the Lundy Field

Society and Irvine *et al.* 1969 for flora) provide good check list of the species present around Lundy.

Table 1 lists some of the previous surveys carried out around Lundy for which information was reviewed; Figure 3 shows the location of each of the sites for each of these surveys.

Table 1 Previous surveys around Lundy

MNCR Survey Number	Survey Title
74	SWBSS field surveys of sublittoral habitats and species around Lundy, 1978-79
80	SWBSS field survey of sublittoral habitats around Lundy, 1977
181	Sublittoral monitoring at Lundy, 1984
182	Marine biological monitoring at Lundy, 27 July - 3 August 1985
183	Marine biological monitoring at Lundy, 26-29 March; 26 July - 2 Aug-86
192	Marine biological monitoring at Lundy, 18-25 July 1987
224	Lundy MNR: sublittoral monitoring and maintenance, 1988
357	Lundy Marine Nature Reserve. Report of the 1983 Lundy Working Party

Of these surveys, the data collected by the biological monitoring surveys, (numbers 182,183 and 192) gave details of specific sites around Lundy, but did not give a general broadscale 'picture' of the area. These sites which have been surveyed in detail could be used to provide information for specific management issues.

Methods

Acoustic surveying

There are a number of different types of sonar which vary in the area of sea bed sampled. Scanning type sonar such as side-scan sonar, transmit a wide beam of sound which samples a broad swathe of sea bed. In contrast, vertical sonar transmits a cone of sound which insonifies a small area of sea bed, the area of which increases with depth. Scanning sonar are considerably more expensive than vertical sonar and the results can be difficult to interpret. In contrast, AGDS which are based on vertical sonar, provide data on the sea bed structure in addition topography.

BMAP used a *RoxAnn* processor which samples the return echo from a 200 kHz echo sounder with a 17° beam width; Chivers *et al.* (1990) provide a detailed description of this system. Position data are 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 are saved at 5 sec time intervals on a laptop computer; the computer also supplies time and date for each datum. Whilst the boat travelled along a set path at a speed (over ground) of 4 kn., a continuous set of measurements (or track) of the physical nature of the sea bed were recorded and displayed on the computer using *Microplot* navigation software (Figure 2).

Microplot 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.

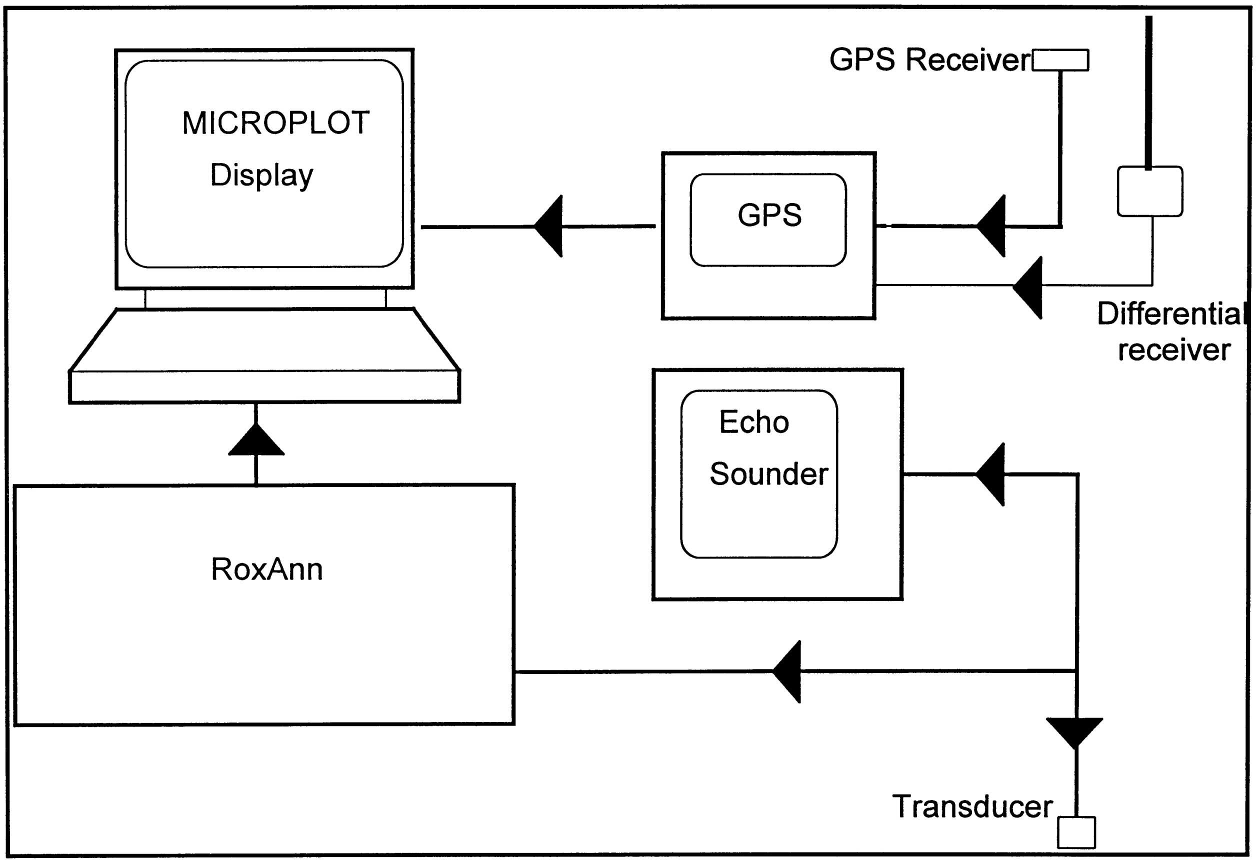


Figure 2 Schematic diagram of acoustic survey equipment

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 4 kn., a data point was saved approximately every 20m 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 geomorphological 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 apart) to determine the spatial organisation of sea bed characteristics.

Biological sampling

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 pre-determined 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 validate existing data which may be valuable in dynamic environments subject to rapid change.

Biotope data were collected using a Remote Operated Vehicle (ROV) and a separate drop down towed video camera. The term biotope embodies both the physical habitat and the associated biological assemblage (Connor *et al.* 1996). The ROV was operated by staff from SNH, the vessel was held stationary whilst the ROV was manoeuvred over the seafloor. An umbilical connected the subsurface unit to the surface unit, via which images could be viewed and recorded by the operators. A small remote video system using a standard Hi8 camcorder in a waterproof housing mounted into a small sledge was used as an additional ground validation device. This system was connected by an umbilical to a monitor at the surface and was towed along the sea bed as the boat drifted.

Selection of sampling stations was undertaken on the basis of preliminary analysis of acoustic data (see below). Ideally, 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.

Data analysis

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

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 using *Microplot* 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 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.

Analysis of ground-validation samples

Video recordings were analysed for physical and biological characteristics and used to compile lifeform descriptions. The terminology used for describing physical characteristics followed the methods for the Marine Nature Conservation Review (Hiscock, 1996). For biological description, emphasis was placed on recognising various life forms where the terms have been developed from *Seasearch* methods (Foster-Smith, 1992) for the *BioMar* Project All biotopes recorded were categorised according to a standard national classification system which is flexible enough to allow for local variation (Connor *et al.*, 1996).

The data from the video footage was analysed primarily to identify lifeform types as these could be used as a mapping unit. Biotopes were assigned to each lifeform type secondarily, the biotopes could not be identified primarily from the remote survey methods due to lack of detailed species lists. Therefore biotopes which have been assigned to lifeforms were identified from incomplete samples (Connor *et al.*, 1996) and need to be considered as such for any further interpretation.

It is imperative for mapping that ground validation samples have associated with them position in order to relate them to other information. Data from previous surveys had positions logged but the accuracy of them varied, some had been collected by GPS and others did not indicate how they were collected. Additionally map projections and geographic spheroids have an influence in locating sample sites. These data are rarely recorded and thus renders the positional information ambiguous when using it for mapping purposes.

The data collected during the South West Britain Sublittoral surveys (Hiscock 1981, 1984b, 1986a & 1986b & Nash & Hiscock ,1978) is a few years old and it was thought unwise to use such data for ground validation of acoustic tracks due to temporal changes which may have occurred and for the position fixing reasons mentioned above.

Matching acoustic data to lifeforms

Matching lifeforms to acoustic properties of the sea floor enables their distribution to be shown on a map. Initial matching was undertaken using *Microplot* by adjusting the boundaries of the map of acoustic/depth properties through editing the display of the acoustic data. These data were then exported from *Microplot* 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 accurately select track data adjacent to sample stations so acoustic signatures can be determined for each lifeform category. In addition, GIS has extensive cartographic facilities to produce the lifeform maps.

Bathymetry

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 30 minutes, taking the period from 15 minutes before to 14' 59" after: *i.e.* the correction for 12:00 would be applied to data from 11:45:00 to 12:15:59. These data were transferred to the contouring program *Surfer for Windows* to produce bathymetric maps for the survey areas. 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 25 m by 25 m was selected for the present project.

Results

BMAP undertook the fieldwork during the period July 15-19th, 1996 inclusive. All data collected during the survey were loaded into a GIS and then mapped. Video recordings were analysed for physical and biological characteristics and used to compile lifeform descriptions Video footage for each sample site was edited and archived.

Results from the individual stages were:

Acoustic survey

Figure 4 shows the location of the acoustic track around Lundy. The acoustic tracks encompassed and covered the whole of the sublittoral section of the MNR.

Bathymetry

From the acoustic data bathymetry maps were prepared for the whole survey area, Figure 5, and for a detailed area along the east coast of the island, Figure 6. Three dimensional models of the areas were also prepared and are shown in Figure 7.

Biological survey

Ground validation sampling

A total of 9 video samples and 16 ROV samples were collected (Figure 8 & Appendix 1). All samples listed in Appendix 1 are coded for their biotopes which are described below.

Biotopes identified

The biotopes described from all sample stations are listed in Appendix 1 along with the sample sites where they were recorded. The codings are taken from, and the descriptions are based on, those found Connor *et al.* (1996).

In many cases, it is not possible to compile a detailed species list and hence biotope descriptions from remote survey methods. Therefore it has been necessary to modify the biotope descriptions to reflect this change in detail. Table 2 presents these "biotope complexes", referred to as lifeforms. It lists those biotopes which are most likely to be found within the lifeform type and gives a general description of the lifeforms.

Table 2 Life-form categories based on information from ground validation data. Code refers to legends of figures 9 & 10.

Code	Lifeform	Biotope complex	Description
LF1	Dense kelp	MIR.Lhyp MIR.Lhyp.Pk	*Laminaria hyperborea* on exposed bedrock and boulders with rich understorey of hydroids, bryozoans and foliose algae.
LF2	Rippled medium sand with burrows	? IGS.Mob	Medium rippled sand with obvious burrows and mounds but no obvious epifauna
LF3	Rich mixed turf on bedrock	MIR.AlcByH MCR.ErS.Eun MIR.FoR	A rich faunal and algal turf of hydroids, bryozoans, foliose reds.
LF4	Rich faunal turf on bedrock	MCR.ErSPenPol MIR.Lhyp MCR.ErS.Eun ECR.AlcMas ECR.CorCri	A rich turf, with *Alcyonium digitatum*, hydroids, bryozoans. *Pentapora foliacea, Eunicella verrucosa* common. *Leptopsammia pruvoti* present within this lifeform
LF5	Short mixed turf on scoured rock with encrusting algae	MIR.Lhyp.Pk	Hydroids, bryozoans and ascidians on bedrock and boulders with crustose algae
LF6	Fine sand and mud	IGS.Mob(P)	Shallow fine sand and mud with no obvious burrows or epifauna often found to depth >20m
LF7	Faunal turf on coarse sand	?	Sand with patches of algal debris with *Anemonia viridis* frequent
LF8	Algal turf on coarse sand	?	*Chorda filum* and foliose algae on infralittoral coarse sand and gravel.

Distribution of biotopes

Linking acoustic data with lifeform data

Whilst it is possible to identify biotopes by video or direct observation, it is necessary to group biotopes into lifeform categories to prepare biological maps at a scale appropriate for environmental management (>1:10,000). Attempting to map each individual biotope at this scale would result in an overly complex and rather confusing map. It must be stressed that lifeform categories were defined from the biological component of the biotopes and therefore lifeform maps display the biology of the area. Whilst there is a strong correlation between the biological and physical component of a biotope, each biotope often represents a range of physical conditions - for instance kelp forest on bedrock, boulder and cobble. Thus habitat maps would not adequately represent the biological component of seabed biotopes. Nevertheless, as lifeforms comprise a number of biotopes, some interpretation will be required to determine which biotope will be present at any location on the map. It will be necessary to refer to the nearest sampling station to aid such interpretations. Some of the lifeform categories could not be matched to an appropriate biotope and these have been marked '**?**'. Hopefully future classification of biotopes will be able to deal with these lifeform types.

Acoustic signatures were determined for each of these life-forms which were applied to the track data. Maps of the acoustic characteristics of the seabed could then be interpreted as maps of the seabed biology (Figure 9). Given the preceding text, it must be emphasised that these maps represent the **predicted lifeform distribution** based on the acoustic characteristics of the sea bed. Any reference to these maps must make this point clear, and all judgements based on these maps must take account of the limitations of the mapping technique.*

Limitations of the mapping technique

Analysis of the acoustic data generates 'hard' boundaries between lifeforms and does not allow for any gradual transition from one type to another. Plainly for some biotopes particularly sedimentary biotopes, there will be a transition from one type to another and thus consideration of any boundaries on these maps must take account of likelihood of a transition. It is also possible (even probable) that for some areas, the physical characteristics of the sea bed will result in acoustic signature that matches one biotope, whereas in reality, direct observation would reveal a separate biotope.

* **Note from Nominated Project Officer.** The points raised in these sections, and the need to be aware of the limitations of the data collected, are illustrated by two examples relating to sediments discussed with Dr Keith Hiscock subsequent to the survey. The first is that there are likely to be a wider range of sediments than differentiated here, ie areas classified as "muddy sand" are likely to include, for example, course sand, eg of the south and north-west coasts, mud overlying gravel, eg of the south part of the east coast, and mud, eg in Gannets Bay. The second concerns the area mapped as "Bedrock with faunal turf" offshore of the east coast, some of which is more likely to be sedimentary habitat. Whilst these examples do not detract from the main results of the survey, which are focussed on the distribution of the reef habitats, they do highlight that further work would contribute to a more accurate interpretation of some of the predicted distribution map.

Table 3 Descriptions of biotopes identified within the lifeforms listed in Table 2

Biotope Code	Biotope title	Biotope description
ECR.AlcMaS	*Alcyonium digitatum*, large *Cliona celata* and *Pachymatisma johnstonia,* and *Nemertesia antennina* on moderately tide-swept exposed circalittoral rock.	Relatively dense *Alcyonium digitatum* and large growths of *Cliona celata* in moderately strong tides. It also has many hydroids and bryozoans, which form a turf.
ECR.CorCri	*Corynactis viridis* and a crisiid/*Bugula*/ *Cellaria* turf on steep or vertical exposed circalittoral rock	Wave exposed steep or vertical bedrock, often subject to moderate or strong tidal streams with dense populations of *Corynactis viridis* and a short bryozoan turf. Occasional *Cliona celata* and *Alcyonium digitatum* present. *Caryophyllia smithii* frequent. Anemones common.
IGS.Mob	Sparse epifauna on clean mobile infralittoral sand.	Coarse sandy sediment in shallow water on exposed coasts often contains very little infauna due to the mobility of substratum. Ubiquitous epifaunal species such as *Pagurus bernhardus*, *Carcinus maenas* and *Asterias rubens* are rarely encountered but are the most conspicuous organism present.
MCR.ErS.Eun	Erect sponges, *Eunicella verrucosa* and *Pentapora foliacea* on slightly tide-swept moderately exposed circalittoral rock	Moderately exposed rock in slight tidal currents and often relatively silty with a rich variety of species typically including branching and cup sponges, the sea fan *Eunicella verrucosa* and the Ross coral *Pentapora foliacea*. Typically a bryozoan turf is present amongst the larger species.
MCR.ErSPenPol	Erect sponges, *Pentapora foliacea, Polymastia* spp., and Nemertesia spp. on moderately exposed cobbles and boulders	Boulders, cobbles and outcrops of bedrock in moderately exposed situations, often with a light covering of silt. Patchy cover of a wide variety of sponges, hydroids and bryozoans with no one species obviously dominant. Tufts of *Nemertesia* spp. on tops of boulders and rocky ridges. *Pentapora foliacea* found frequently on the silty rock.
MIR.AlcByH	*Alcyonium digitatum* and a bryozoan, hydroid and ascidian turf on vertical moderately exposed infralittoral rock	Biotope found on vertical, shaded surface where algal growth is limited. This biotope has wide species composition.
MIR.FoR	Foliose red seaweeds on lower infralittoral rock	A biotope comprising of the red seaweeds from the kelp zone above with a faunal community from the circalittoral below. Some patches of brown algae.
MIR.Lhyp	*Laminaria hyperborea* and foliose red seaweeds on moderately exposed infralittoral rock	Moderately exposed infralittoral bedrock and boulders characterised by a canopy of *Laminaria hyperborea* beneath which is an understorey of foliose red algae.
MIR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	Moderately exposed, tide-swept, rock with dense *Laminaria hyperborea* forest is characterised by a rich understorey and stipe flora of foliose and crustose algae.

Discussion

Map production

The resulting lifeform distribution maps included do not conform to the standard colour coding scheme for biotope groupings (Connor *et al.*, 1996). Approximations will be necessary if the maps are to be interpreted using the standard colour codes. In addition, it was necessary to use patterns and shadings to represent lifeforms in order to avoid identical colours for different lifeforms.

Summary of biotope distribution

Examination of the lifeform maps (Figure 9 & 10) shows the Marine Nature Reserve around Lundy to have a varied distribution of lifeforms in inshore areas, with the seafloor becoming more homogenous further off-shore. The inshore lifeforms are infralittoral rock with rich *Laminaria hyperborea* forests, and the depth increases to between 10-15 m, a mixed turf is predominant with foliose red algae, hydroids and bryozoans common. At greater depths a faunal community predominates with *Alcyonium digitatum* and *Eunicella verrucosa* becoming more frequent. The seafloor levels off approximately 200 m from the shore and the dominant substrata is sedimentary.

The bathymetry around Lundy is complex (Figure 5). Around the island, the shores drop steeply into the circalittoral, To the east and west large shallow sediment banks, are present around 2 km from the shore. Near shore rocky areas supported rich infralittoral and circalittoral communities, whereas the sediment banks offshore have little evidence of epibenthic communities. Infaunal communities could be present although due to the limitations of the sampling techniques these could not be determined, other than the presence of burrows.

In the south-west an area of muddy sand occurs interspersed with patches of reef which run out from the shore. To the north-west the 'The Hens & Chickens', a complex reef area rises steeply from the seafloor, around which strong tidal streams flow, thus this area is predicted to support the communities associated with exposed hard substrata habitats.

The near shore east was surveyed in greater detail than the rest of the MNR, the detailed map (Figure 10) shows this area. Inspection of this map suggests that reefs* (interspersed with patches of sediment) are present along the full extent of the east coast. Some of this sediment appeared barren of epifauna but other areas were colonised by *Chorda filum* and occasional *Anemonia viridis*. The deeper reefs tend to be scoured by the actions of tide and the surrounding sediment although at shallower depths richer communities with the sea fan *Eunicella verrucosa* and Ross coral *Pentapora foliacea* were recorded. A ground validation site located around the area of the 'Knoll Pins' shows the reef habitat supported a very rich community including *Eunicella verrucosa, Pentapora foliacea* and the sunset coral *Leptopsammia pruvoti*.

The northern tip of Lundy extends sublittorally as exposed reef habitats and levels off to an area of hard ground supporting a rich faunal turf. To the north-west is a sand bank from which video samples revealed no obvious epifauna.

*The reefs referred to are areas of bedrock and/or boulders which are found in lifeforms, LF1, LF3, LF4 & LF5, with LF3 and LF4 being most conspicuous due to the rich communities found within them.

The southern end of Lundy is subjected to extreme tidal races and preliminary investigation proved it hazardous to manoeuvre the ROV. Slack water occurred at an inconvenient time and therefore this area was not ground validated in detail.

Comparison with previous studies

The results of the biological survey dives undertaken by Hiscock (1981, 1984b, 1986a & 1986b) and Nash & Hiscock (1978) were used to explore the match between the present study and this previous data. These previous data were overlain onto the lifeform maps from the present study. In general there were no serious conflicts between the biotopes attributed to a previous surveys station and the predicted lifeform distribution. When considering mismatches, size of pixel call (25 m x 25 m) and the accuracy of the position fixing systems should be taken in to account. The present study used differential GPS (±15 m) when available and GPS (±100 m) if not. Previous surveys used alternative methods, transits and/or DECCA (±250 m). In addition the previous studies often record a single position for a survey station which may, in the case of shallow inshore sites, represent a transect from 100-200m in length. Taking account of these factors, most conflicts between the previous survey data and the present studies data sets lie within an envelope of acceptable error.

When considering other mismatches it is important to take in to account the pixel size of Figure 9 and the small scale variability which exists for most of the seabed. Patches of different habitats can occur with a widely occurring habitat: for instance rock ridges can outcrop through overlying stones or sediment but may only extend for tens of metres in the horizontal direction. Direct observation by video camera or SCUBA diver may only record the patch rather than the more widely occurring habitat due to limited underwater visibility. Small scale variability must be considered when interpreting these lifeform maps, particularly when exploring the correlation between data sets.

Exploring the correlation of Figure 9 & Figure 10 from this study and maps from previous studies presented in Hiscock (1983), suffers similar problems to those mentioned above. Nevertheless if both maps are considered to have certain levels of error associated with them comparisons can be made. Figure 11 shows the predicted lifeform distribution map from the current study and is overlain with a transparency of the map taken from Hiscock (1983).

The patch of sand to the south of the 'Hen & Chickens' from Hiscock (1983), is mirrored by the present study. Similarly the area of 'mud overlying gravel' on the east coast described by Hiscock (1983) matches Figure 9, although the extent of this appears greater in the present study. Hiscock (1983) also suggests a tongue of small boulder and pebbles to the east of Lundy, which is also described by the present study although it is predicted to be slightly more to the east and to be a 'double tongue' of hard ground with faunal turf.

In conclusion the two maps do coincide although Figure 9 does extend to the limits of the MNR and has a slightly better resolution. The inshore area has more detail than Hiscock (1983).

References

Anon, 1991. *The Admiralty simplified harmonic method of tidal prediction*. Taunton, Hydrographer of the Navy.

Barrett, E.C. & Curtis, L.F. 1992. *Introduction to environmental remote sensing*. Third edition. London, Chapman & Hall.

Chivers, R.C., Emerson, N. & Burns, D.R. 1990. New acoustic processing for underway surveying. *The Hydrographic Journal*, 56: 9-17.

Collins, W., Gregory, R. & Anderson, J. 1996. A digital approach to seabed classification. *Sea Technology*: 37(8): 83-87.

Connor, D.W., Brazier, D.P., Hill, T.O., Holt, R.H.F., Northen, K.O., & Sanderson, W.G. 1996. *Marine Nature Conservation Review: marine biotopes. A working classification for the British Isles. Version 96.7.* Peterborough, Joint Nature Conservation Committee.

Davies, J., Foster-Smith, B., & Downie, A. 1995. A strategy for sub-tidal resource mapping and its usefulness in environmental decision making. In: *Directions in European Coastal Management* (ed. M.G. Healy, & J.P. Doody), Samara Publishing, Cardigan, pp. 223-234.

English Nature, 1994. Managing Lundy's Marine Wildlife: a management plan for the Marine Nature Reserve and Site of Special Scientific Interest, English Nature, Peterborough, pp. 82.

European Community, 1992. *EC Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora*. European Community, Brussels. pp. 43.

Foster-Smith, R.L. 1992. *SEASEARCH Starter Kit*. Ross-on-Wye, Marine Conservation Society.

Furness, R. 1995. *CoastGIS '95. Proceedings of the International Symposium on GIS and computer mapping for coastal zone management*. Sidney, Australia.

Green, E.P., Mumby, P.J., Edwards, A.J. & Clarke, C.D. 1996. A review of remote sensing for the assessment and management of tropical coastal resources. *Coastal Management*, 24: 1-40.

Hiscock, K. 1981. South-West Britain Sublittoral Survey. Field surveys of sublittoral habitats and species around Lundy. *Nature Conservancy Council, Field Studies Council, Oil Pollution Research Unit, Pembroke.* CSD Report, No. 354.

Hiscock, K. 1983. Lundy Marine Nature Reserve management plan. *Nature Conservancy Council, Huntingdon*. iv & 86pp. Unpublished

Hiscock, K. (*ed.*) 1984a. Lundy Marine Nature Reserve. *Report of the 1983 Lundy Working Party. Unpublished report to World Wildlife Fund / Lundy Field Society. Marine Conservation Society, Ross-on-Wye*

Hiscock, K. 1984b. Sublittoral monitoring at Lundy, July 28th to August 4th, 1984. *Nature Conservancy Council, Field Studies Council, Oil Pollution Research Unit, Pembroke*. CSD Report, No. 558.

Hiscock, K. 1986a. Marine biological monitoring at Lundy, July 27th to August 3rd 1985. *Nature Conservancy Council, Field Studies Council, Oil Pollution Research Unit, Pembroke.* CSD Report, No. 624.

Hiscock, K. 1986b. Marine biological monitoring at Lundy, March 26th to 29th, July 26th to August 2nd. *Nature Conservancy Council, Field Studies Council, Oil Pollution Research Unit, Pembroke.* CSD Report, No. 702.

Hiscock, K. *ed.* 1996. *Marine Nature Conservation Review: rationale and methods.* Peterborough, Joint Nature Conservation Committee. (Coasts and seas of the United Kingdom. MNCR series.)

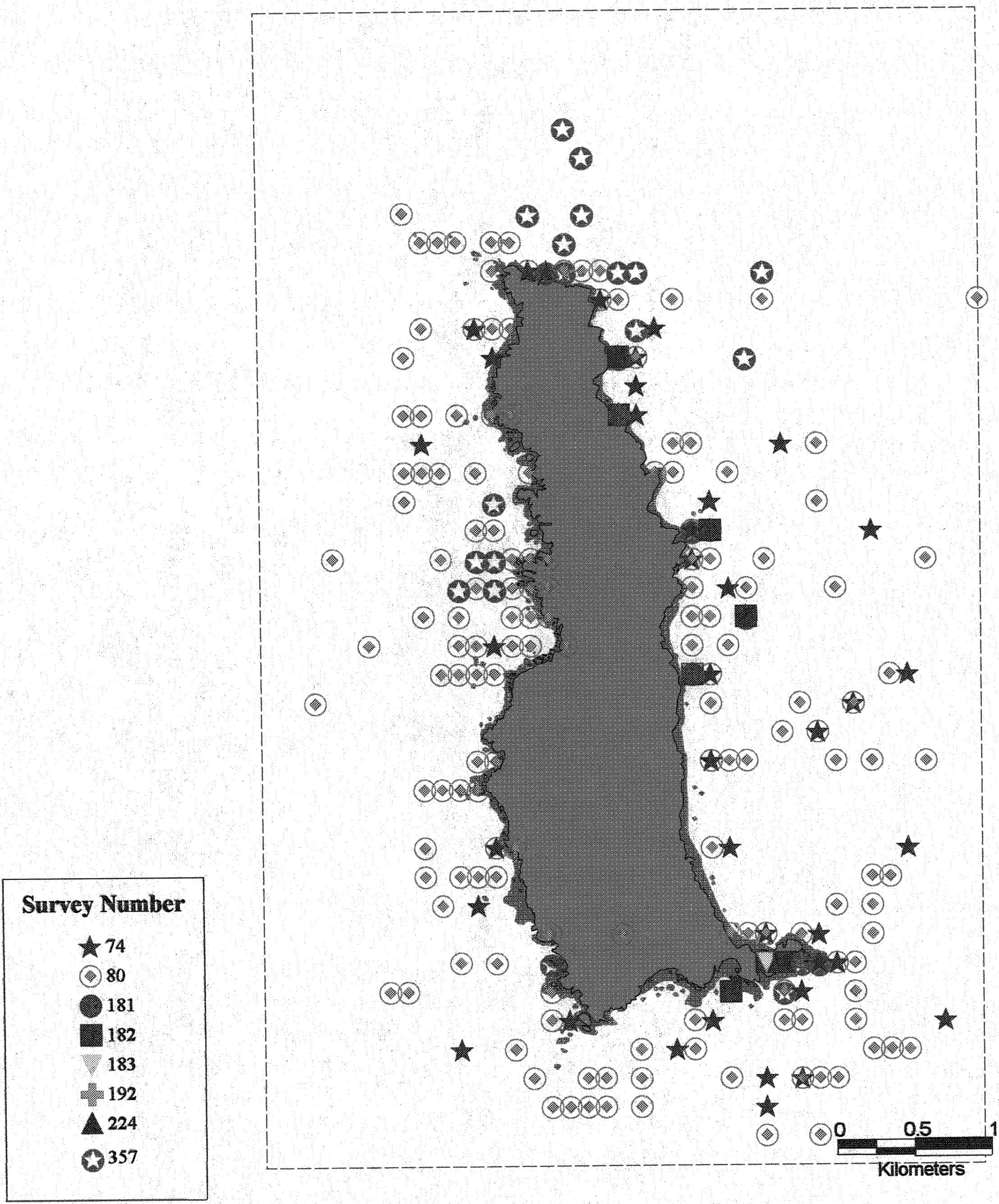
Nash, D.M., & Hiscock, K. 1978. South-West Britain sublittoral survey. Field survey of sublittoral habitats around Lundy. *Nature Conservancy Council, Oil Pollution Research Unit, Field Studies Council, Pembroke, Dyfed.* CSD Report, No.15

Rossi, R.E., Mulla, D.J., Journel, A.G. & Franz, E.H. 1992. Geostatistical tools for modelling and interpreting ecological spatial dependence. *Ecological monographs.* **62**: 277-314.

Simmonds *et al.* 1992. *Acoustic survey design and analysis procedures. A comprehensive review of current practice*. ICES Co-operative Research Report, N° 187. Denmark, ICES.

Figures

Figure 3 Location of previous survey sites around Lundy.



Survey_No	Survey_title
74	SWBSS field surveys of sublittoral habitats and species around
80	SWBSS field survey of sublittoral habitats around Lundy, 1977.
181	Sublittoral monitoring at Lundy, 1984.
182	Marine biological monitoring at Lundy 27 July - 3 August 1985
183	Marine biological monitoring at Lundy, 26-29 March; 26 July - 2
192	Marine biological monitoring at Lundy, 18-25 July 1987

Figure 4 Location of acoustic tracks around Lundy Island, Bristol Channel.

Figure 5 Bathymetry around Lundy.

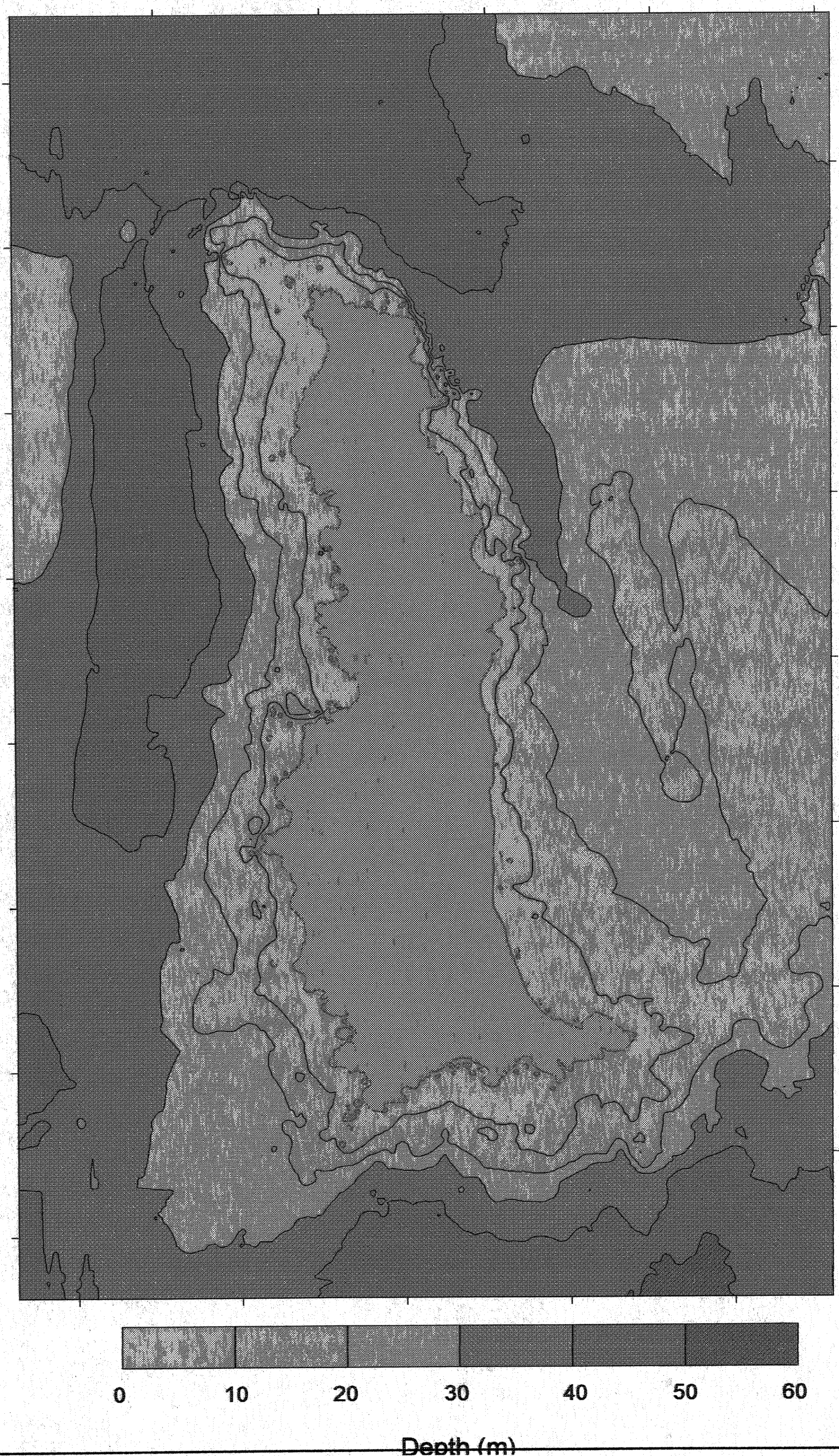


Figure 6 Detailed bathymetry of the NE coast of Lundy around Gannets Rock.

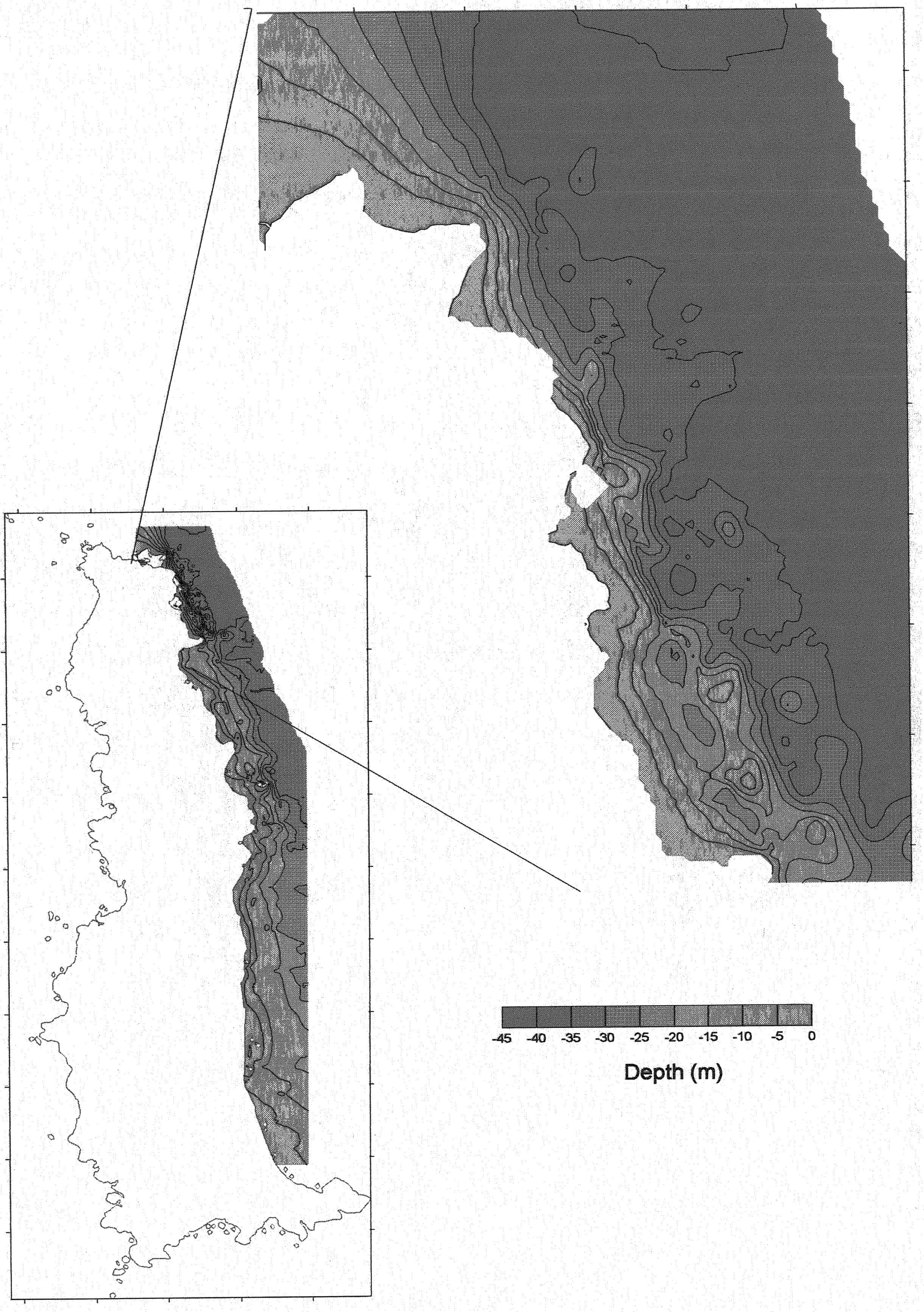


Figure 7 A three dimensional representation of the seafloor around Lundy. *N.B.* the vertical scale is exaggerated.

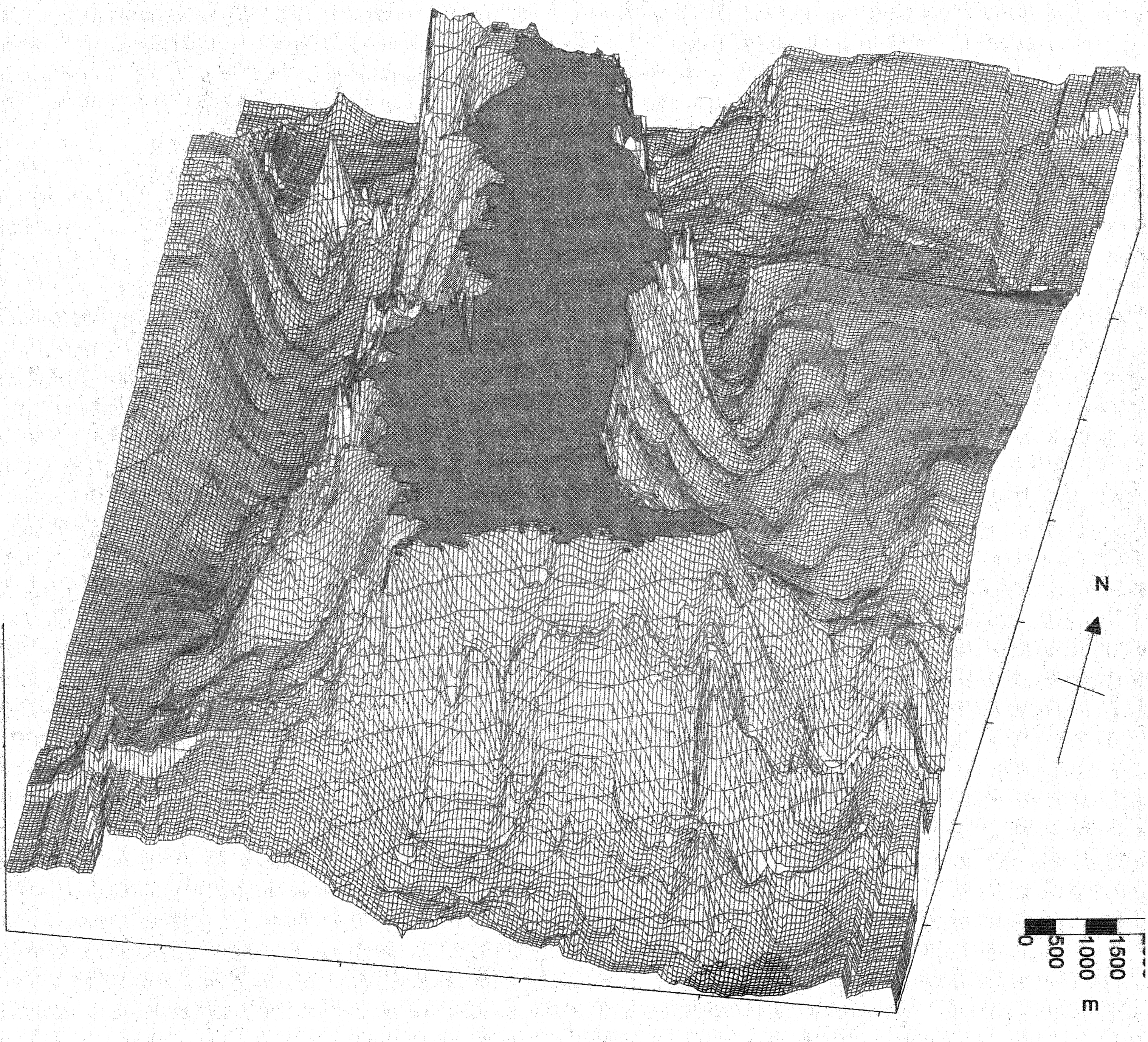


Figure 8 Location of ROV & drop down video sites around Lundy Island, coloured by lifeform type.

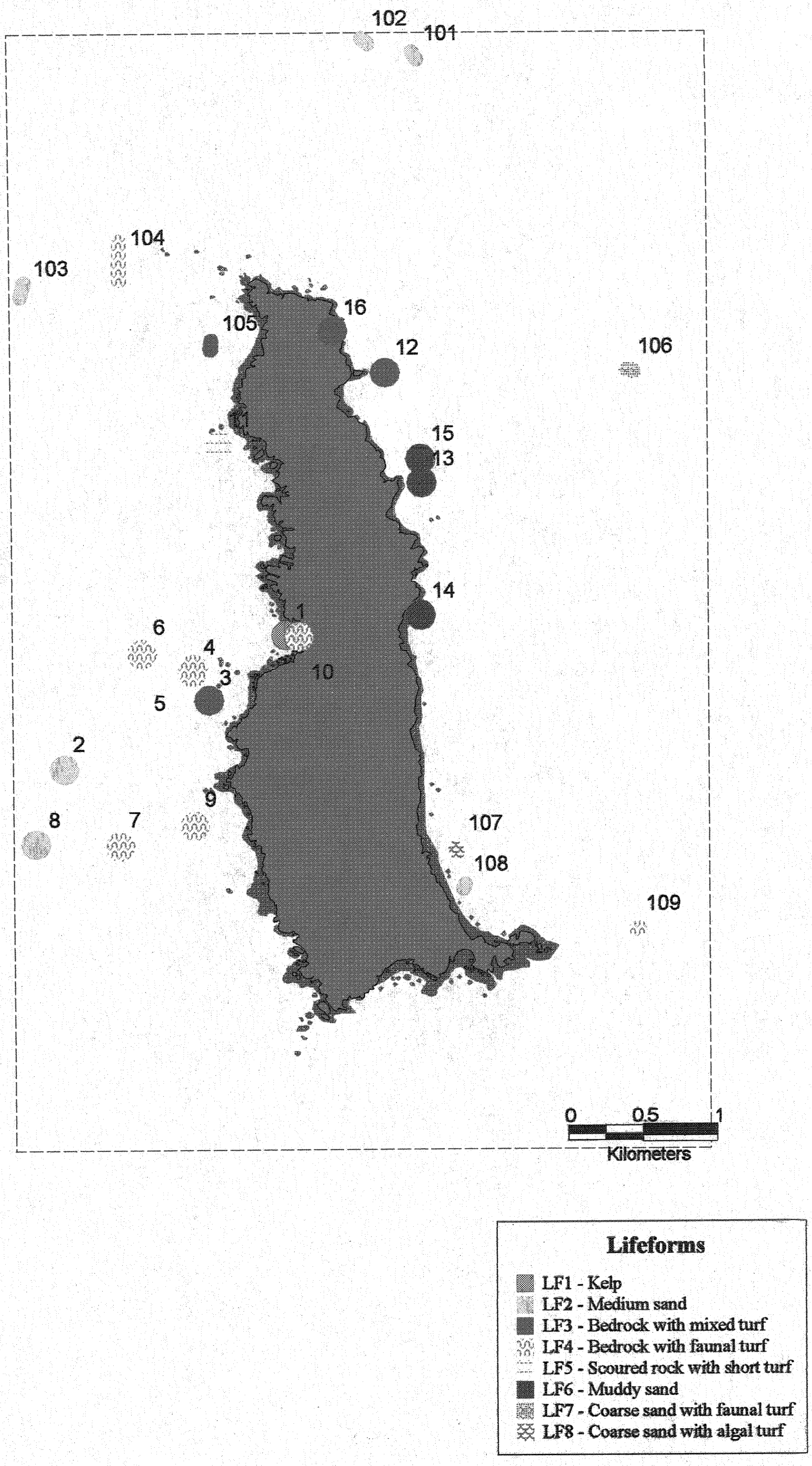


Figure 9 The predicted distribution of the lifeforms around Lundy Island, Bristol Channel.

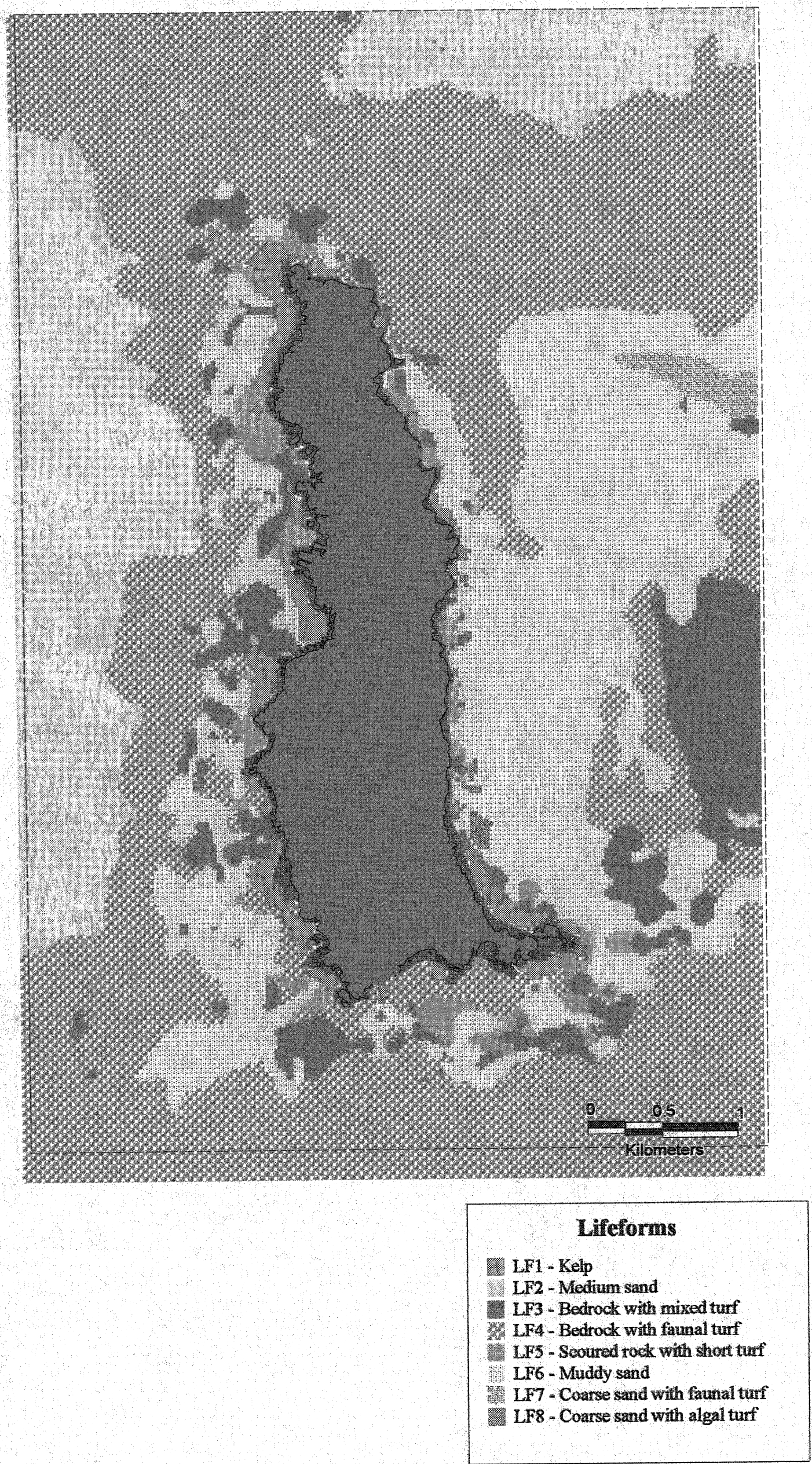
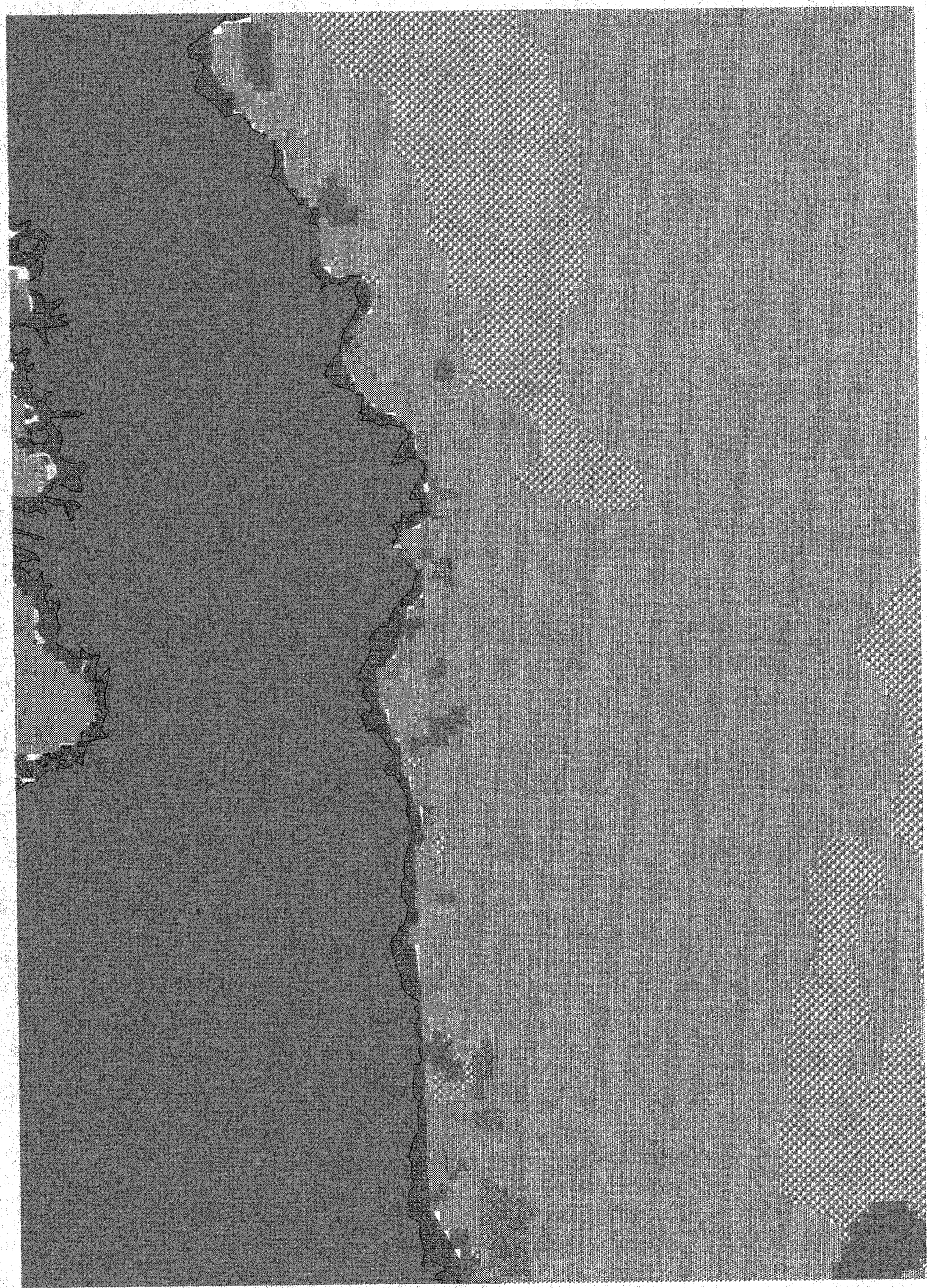


Figure 10 The predicted distribution of lifeforms around the east coast of Lundy.



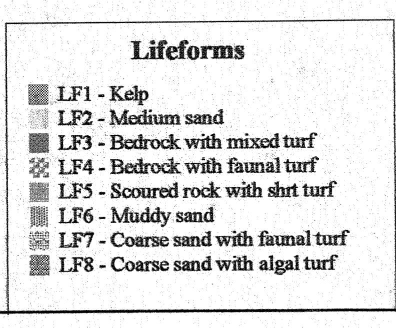
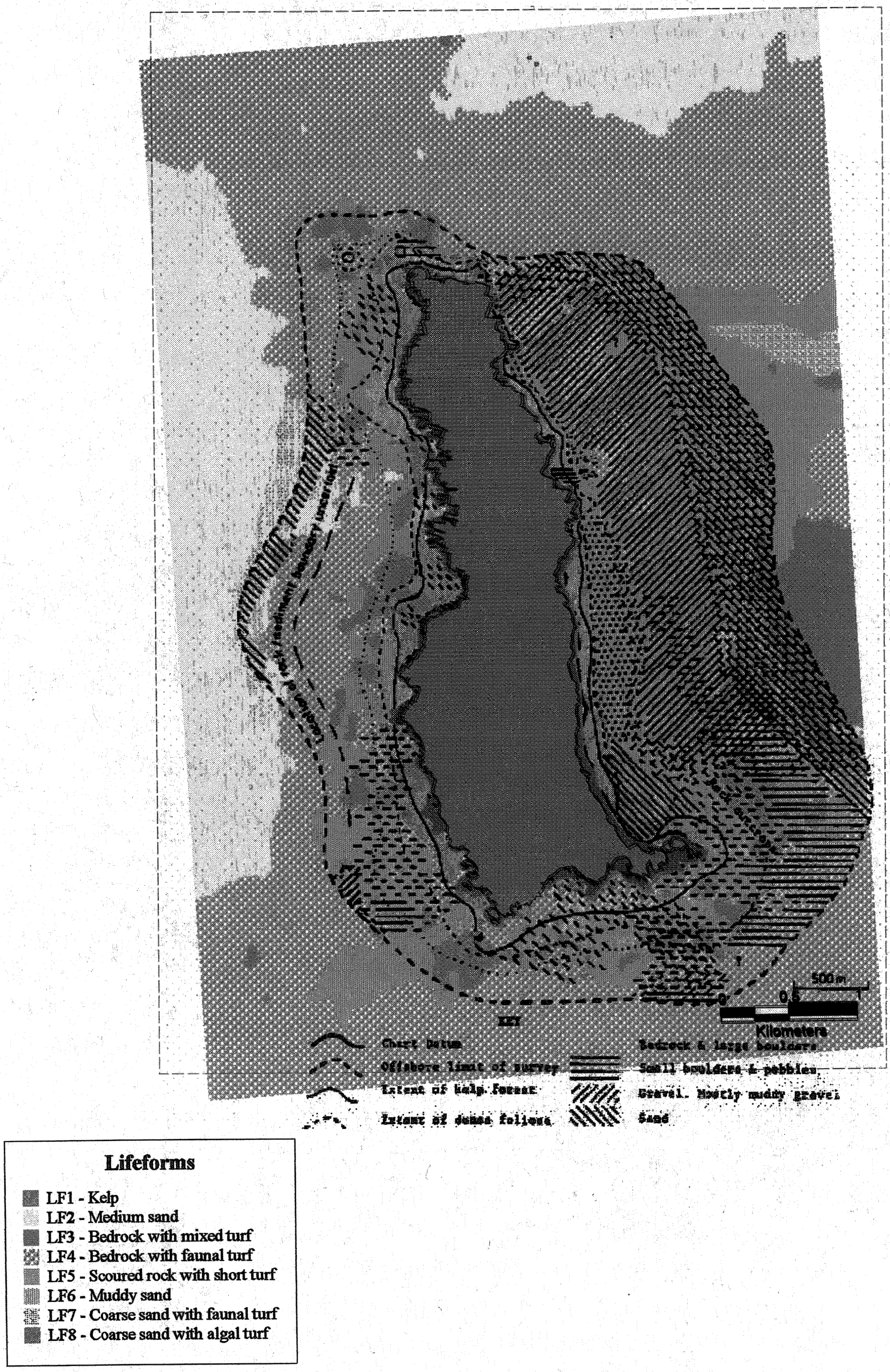


Figure 11 Distribution of sublittoral bottom types, taken from Hiscock, 1983, overlaying the map of predicted lifeform distribution



Appendix

Appendix 1 Video & ROV sample data

ID	Latitude	Longitude	Lifeform	Biotope 1	Biotope 2
ROV:					
12	51.1964	-4.66418	3	MCR.ErS.Eun	MIR.Lhyp
13	51.1898	-4.66073	6	MCR.ErS.Eun	MIR.FoR
15	51.1912	-4.66085	6	MCR.ErS.Eun	
16	51.1989	-4.66918	3	MIR.AlcByH	IGS.Mob
11	51.1921	-4.68019	5	MIR.Lhyp.Pk	
3	51.1768	-4.68121	3	?	
14	51.1819	-4.66085	6	MCR.ErS.Eun	
1	51.1807	-4.67379	1	MIR.Lhyp.Pk	
10	51.1806	-4.67259	4	MIR.Lhyp	
2	51.1727	-4.69517	2	?	
4	51.1785	-4.68282	4	MCR.ErSPenPol	
5	51.1787	-4.68274	4	MCR.ErSPenPol	
6	51.1796	-4.68769	4	MCR.ErSPenPol	
7	51.1681	-4.68985	4	ECR.AlcMaS	
8	51.1682	-4.69794	2	IGS.Mob	
9	51.1693	-4.68264	4	MCR.ErS.Eun	
Video:					
101	51.2154	-4.66131	2	IGS.Mob	
102	51.2162	-4.66603	2	IGS.Mob	
103	51.2014	-4.69897	2	IGS.Mob	
104	51.2031	-4.68968	4	ECR.CorCri	
105	51.1980	-4.68088	3	MIR.FoR	MCR.ErSPenPol
106	51.1965	-4.6406	7	?	
107	51.1678	-4.65749	8	?	
108	51.1657	-4.65675	2	IGS.Mob	
109	51.1631	-4.64004	4	MCR.ErSPenPol	