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Survey of the marine environment of north Northumberland: an assessment of the conservation interest of the marine biotopes

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SURVEY OF THE MARINE ENVIRONMENT OF NORTH NORTHUMBERLAND: AN ASSESSMENT OF THE CONSERVATION INTEREST OF THE MARINE BIOTOPES.

ROBERT FOSTER-SMITH & JON DAVIES

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SURVEY OF THE MARINE ENVIRONMENT OF NORTH NORTHUMBERLAND: AN ASSESSMENT OF THE CONSERVATION INTEREST OF THE MARINE BIOTOPES

PREFACE

The survey of the marine environment of the north Northumberland coast has been undertaken as part of the BIOMAR Project. BIOMAR is a project funded by the European Community through the LIFE Programme. The Project partners are Trinity College (Dublin), The Office of Public Works (Irish Republic), The Joint Nature Conservation Committee, AIDE Environment (The Netherlands) and Newcastle University.

One of the main aims of the BIOMAR Project is to devise a classification system for marine biotopes of the north-east Atlantic seaboard and to produce information on their range and distribution of in order to aid conservation assessment and the development of appropriate strategies for coastal zone management (CZM). The partners based at Newcastle University have the additional tasks of developing techniques for biotope mapping and applying them to specific management case studies in collaboration with other organisations.

The north Northumberland survey is one such project undertaken in collaboration with English Nature and the National Trust. The survey forms one half of a two-part project to assess the scope conservation management of the marine environment of north Northumberland. The other part of the project is a desk-top study of options for Coastal Zone Management (CZM) study, undertaken by the Marine Conservation Society. The whole Northumberland project has been part funded by English Nature as a trial study to promote the wise use of the shallow seas through voluntary guardianship and positive management.

1. INTRODUCTION

Both conservation importance and scenic value of the coast of north Northumberland are extremely high, as summarised in the companion report "An Assessment of the Scope for Conservation Management". However, the major recognised scientific interest of the coast is due to its geology and bird life, with some botanical interest in restricted areas. This interest has been established over a long period through systematic survey and continual monitoring by a variety of organisations and individuals (see Foster-Smith, 1988, for a review of the scientific and conservation interest of the Northumberland coast). This, in its turn, has lead to the need for various forms of conservation management, including the purchase or lease of land by organisations such as the National Trust to help secure sections of the coastal strip.

No such history of awareness of the richness of the marine fauna and flora exists and it is only recently that interest has been shown locally in the conservation interest of marine biotopes. The first study was carried out with the aid of volunteer divers in the 1970s and '80s (Edwards, 1983; Foster-Smith & Foster-Smith, 1987) and more recently by the Marine Nature Conservation Review (MNCR) (Connor, 1989; Holt, 1994). The latest phase of the MNCR in the region is nearing completion and will assess the conservation interest of the marine environment of the area in its local and national context (Holt, 1994).

Thus, most of the information on the distribution of marine biotopes has been collected by SCUBA techniques and related to geographical position. Although biotope distribution maps based on point locations have been produced for the area (Holt, 1994), these lack the interpretive power of maps showing continuous coverage. The latter are potentially of great use for conservation management for the following reasons:-

1. A comparison of areas occupied by different biotopes is valuable in its own right for assessing the conservation importance of each biotope type in terms of what is rare and what is typical.

2. Maps can place in context information from a variety of sources. Detailed information about specific biotopes at point locations (such as that gathered by SCUBA divers) can be given added significance if some idea of the likely extent of that biotope around the sampling point is known.

3. Maps can show patterns of occurrence of biotopes that can help interpret the marine ecosystem of an area. Such a general picture is extremely useful when assessing the significance of local variations.

4. The management implications of studies of single biotope types can be more clearly assessed if the distribution of that biotope is known.

5. The position of the constituent biotopes relative to patterns of ownership and usage will have implications for opportunities for management. In this context, maps are a suitable way of summarising the interaction between different types of information.

6. Boundaries can be set for areas of special conservation interest, such as Special Areas for Conservation (SACs), which can be justified in terms of biotope distribution.

Thus, the main purpose of the survey was to produce a map of biotopes (or categories of biotopes). Information from previous surveys has been incorporated into the mapping process where possible. A conservation assessment has been made of the marine biotopes within the survey area which, together with the maps, has been used to help formulate options for appropriate management techniques discussed in the accompanying Coastal Zone Management (CZM) study.

The report concludes with an evaluation of the usefulness of biotope mapping to the preparation of CZM plans.

2. INTRODUCTION TO THE SURVEY AREA

The area selected for mapping lies between the mouth of Budle Bay to the north and Craster to the south and extended 3.2km (2 miles) offshore (see Map 1). The justification for selecting this section of Northumberland is discussed fully in the CZM study. From a practical viewpoint, this size of area was considered to be suitable for a mapping exercise given the time available for survey and post-survey analysis.

The general features of the coastline, including the geology of the sea floor, bathymetry, hydrography, has been discussed in some detail by Foster-Smith (1988), Connor (1989) and Holt (1993). Only a brief introduction is given here.

The rocks are predominantly sedimentary consisting of shales, limestone, thin-bedded sandstone and massive sandstone from the Middle and Upper Limestone Group of the Carboniferous. An intrusion of quartz dolerite, the Whin Sill, was formed in the late Carboniferous and this partially metamorphosed the surrounding country rocks. The Farne Islands are the most easterly outcrop of Whin Sill. The rock strata have a general dip to the south east of about 10 degrees, although there are many local exceptions.

Faulting has brought the same sequence of rocks to the surface at different points along the coast. For instance, the Great Limestone and the underlying Whin Sill are exposed at Dunstanburgh Castle, Emblestone, Newton Point, Snook Point and Beadnell Point. Both these rocks are very hard and durable and form prominent reefs.

The rocks of the shore and shallow sea have been eroded to form a wave-cut platform. Sea levels associated with inter-glacial periods are thought to be very similar to those of today and the wave-cut platform is likely to have been formed over many interglacial periods and as a result it extends offshore to about 5-6km (beyond the offshore limit of this survey). The platform is strewn with boulders that have either resulted from erosion of the bedrock or are glacial erratics.

A thick layer of boulder clay covers much of the solid geology in the region and is a major source of silt in the inshore waters off the Northumberland coast. This silt settles in areas of lower current speed but is easily stirred up into suspension by wave action or strong tidal currents. Thus, the inshore waters carry a heavy silt burden which is particularly noticeable in areas of low current when wave action is high.

The coast is open and exposed to the dominant winds from the north and east. There is very little local shelter and as a result most beaches are considered to be either exposed or moderately exposed. Tidal currents offshore can reach 2-3 knots and there is a residual drift to the south. However, tidal currents are accelerated around the Farne Islands achieving speeds of up to 4 knots.

3. SURVEY METHODS

3.1. Introduction

The underlying basis of the BIOMAR marine biotope classification is the importance of the links between the biological community and physical characteristics, primarily substratum type and depth. These key physical factors can be relatively easily obtained remotely to give a much greater coverage than could be obtained by direct viewing of the biotopes. Thus, biotope mapping is, in principle, a process of matching restricted information on biological components to more general coverage of key physical characteristics of the sea floor.

The equipment and protocol used for mapping biotopes are the subject of a detailed review being undertaken by the BIOMAR partners at Newcastle University and only an outline of the current methodology is given here.

3.2. Equipment

Remote survey of the sea floor is done acoustically and the equipment routinely used in BIOMAR surveys employs a RoxAnn processor which samples the return echo from a 200kHz echo sounder. Apart from depth, RoxAnn produces two pieces of information derived from the first (E1) and second (E2) echoes that can be interpreted as a measure of roughness and hardness of the sea floor respectively (Chivers *et al* 1990). Information on position is provided by a GPS. These track data are collected and saved at set time intervals (5sec) on a laptop computer, which also supplies time and date for each data point, utilising MICROPLOT navigation software (Figure 1a). The apparatus is entirely self-contained and portable so that it can be set up on a wide variety of craft.

MICROPLOT displays track data as they are being collected and the data is also stored so that it can be re-run and edited at a later stage. MICROPLOT displays the track data on the computer screen superimposed, if required, on a map or chart of the coast. The track is coloured according to combinations of E1 and E2 or by depth. The combinations of E1 and E2 are displayed graphically on the screen and boxes can be drawn to encompass ranges of values as desired (see lower right of screen display, Figure 1b). Construction and labelling of these boxes to change the track display is the primary way of editing the track to form a satisfactory picture which can then be sent to a colour printer for the production of a hard copy (see Map 2 as an example).

Information is obtained from a limited area under the survey vessel as it proceeds and a map of the acoustic properties of the sea floor is built up from parallel tracks: the closer the tracks are to each other, the more complete is the coverage.

The primary equipment for ground-truthing is a towed video connected by an umbilical to a monitor at the surface and the tapes recorded by the camera are replayed for analysis. The video is mounted in a steel cage with runners so that the system can be dragged along the sea floor as the boat drifts. The records of the tapes form the basis for the descriptions of the biotopes but they have been supplemented by a visual inspection of sediment brought to the surface using grabs.

3.3. Protocol for Survey and Data Analysis

The protocol for BIOMAR remote surveys and data analysis is summarised in Figure 2. There are three main stages to the production of the biotope map:-

1. Acoustic survey and the preparation of maps of the acoustic characteristics of the sea floor: The survey area is tracked over with the acoustic survey equipment to indicate the distribution of different acoustic properties of the sea floor. The tracks are analysed to show small increments in the values of E1 (roughness), E2 (hardness) and depth. Maps for each of these factors are prepared by contouring equal-value points (isopleths). These maps are overlain to produce a composite map indicating areas with similar acoustic and depth characteristics. During the field survey the rough map so produced is used to select suitable sites for ground truthing.

FIGURE 1a. Schematic Diagram of the Acoustic Survey Equipment

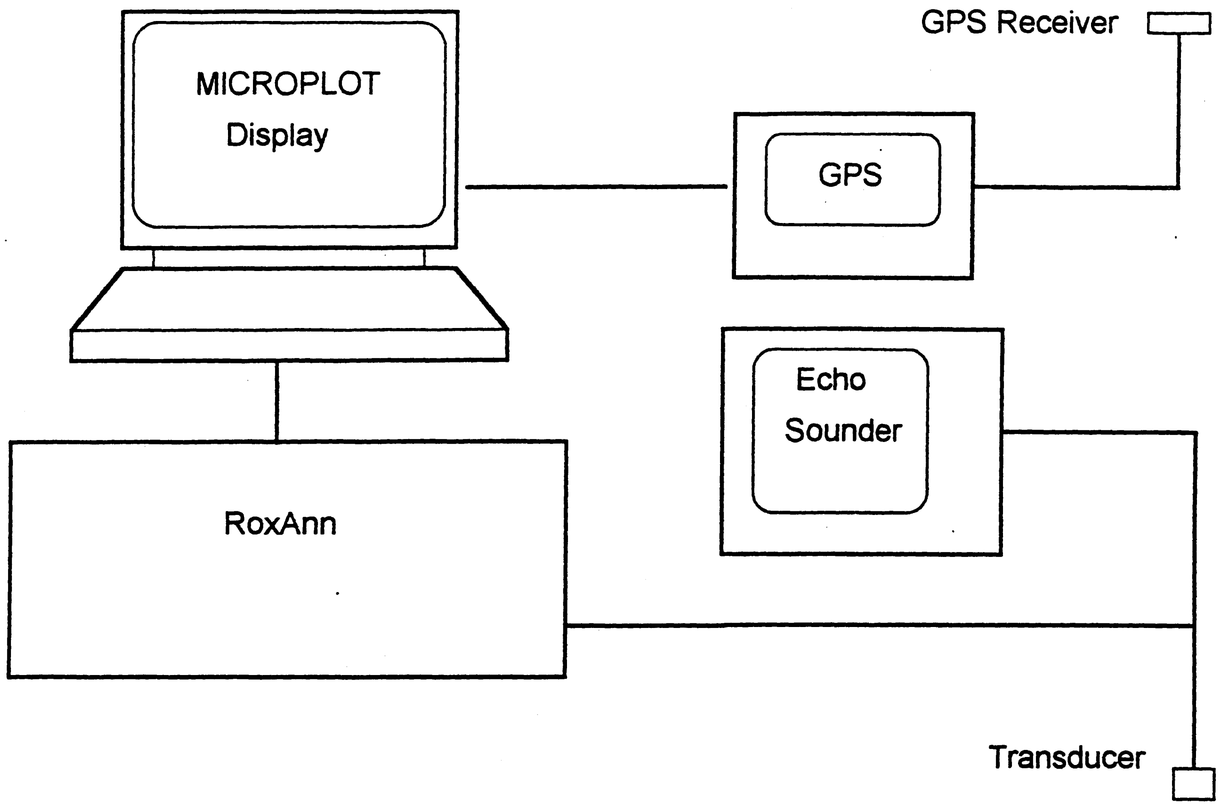
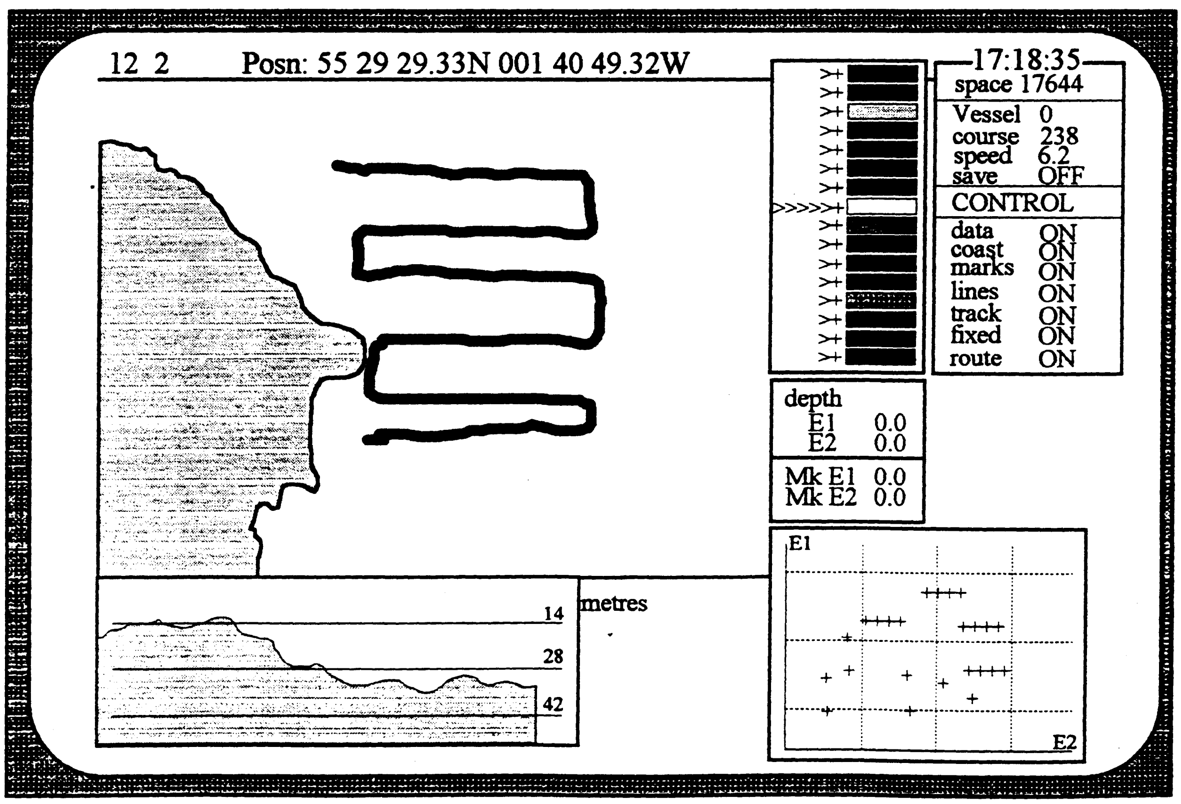


FIGURE 1b. Screen Display of Track Data in MICROPLOT



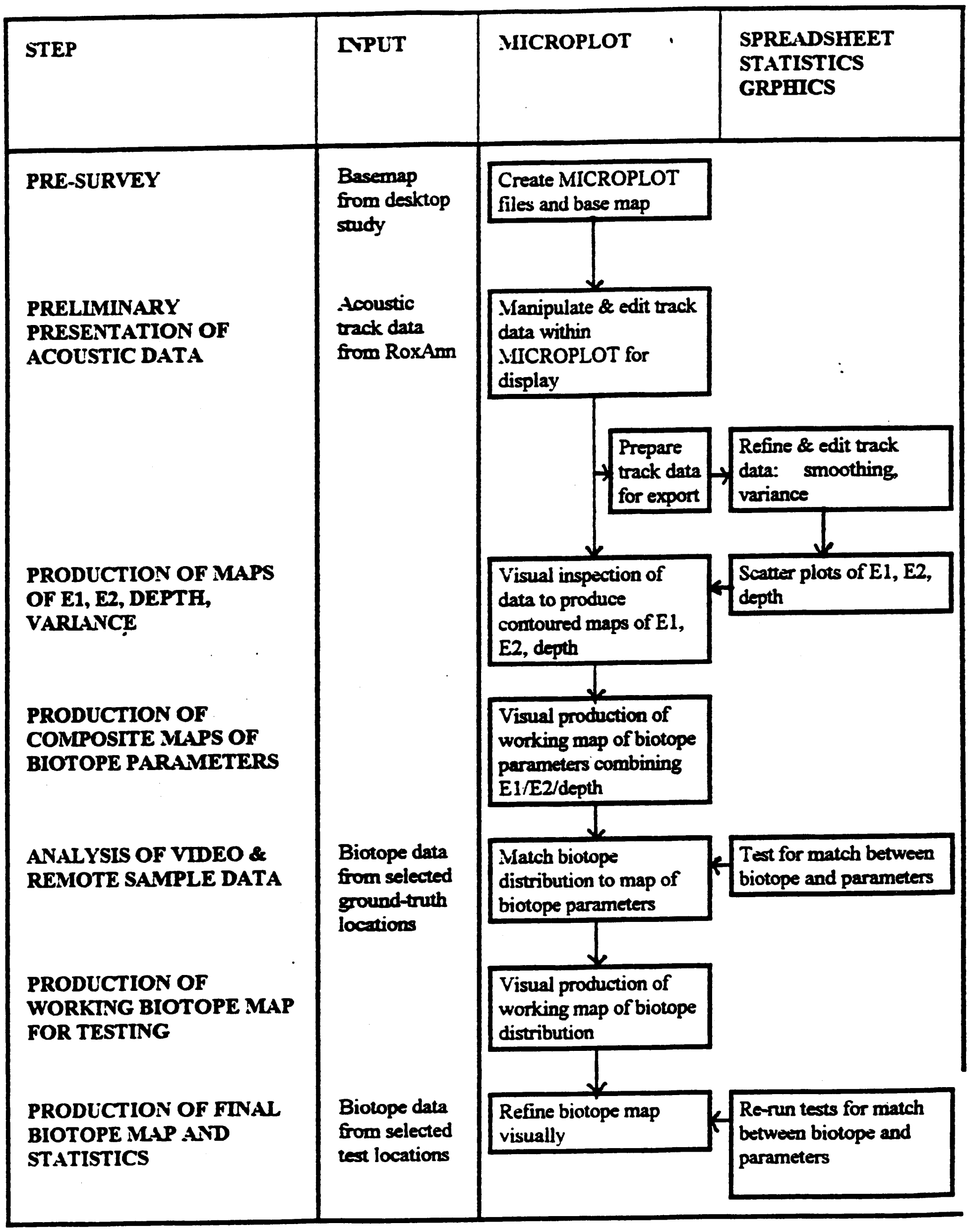


FIGURE 2. Outline of the process of data acquisition and analysis for the production of the biotope map

2. Ground-truthing acoustic data and matching biotopes to the map of acoustic characteristics: On the basis of the acoustic survey, types of ground are selected for ground-truthing using remote video supplemented by grab and dredge sampling. Video recordings are analysed by a number of physical and biological characteristics. The terminology used for describing physical characteristics is that used by the MNCR (Hiscock, 1990) whilst for biological description emphasis is placed on recognising various life forms. These have been developed from SEASEARCH methods (Foster-Smith. 1992) for the BIOMAR Project. The biotopes present are then categorised according to a standard national classification system which is flexible enough to allow for local variation (Connor *et al* 1993; Foster-Smith, 1994).

Decisions have to be made as to the level of discrimination possible between biotopes using acoustic survey and remote viewing to discriminate between biotopes. Whilst it is possible to distinguish some biotopes (and even to detect variations within a biotope type), it is likely that (for a number of reasons both theoretical and procedural) that groups of biotopes will need to be mapped together in biotope categories.

3. Deriving the biotope map: Matching biotopes to acoustic properties of the sea floor enables the distribution of biotope categories to be shown on a map. This can be done by adjusting the boundaries of the of map of acoustic/depth properties through editing the display of the acoustic data within MICROPLOT. Some analysis of the data can also be done outside of MICROPLOT (see Figure 2).

4. DISCUSSION OF SURVEY RESULTS AND PREPARATION OF THE BIOTOPE MAP

The survey took seven days boat time during August and September, 1993. Approximately 190 km of track data were collected, although a proportion was edited out as being unreliable. 60 drops were made with the video camera to ground-truth the acoustic data, giving over three hours of recordings of the sea floor. Analysis followed the procedure outlined above although the results from selected key stages only are presented here.

4.1. Biotopes: A summary comparison between biotopes derived for the present survey and for the MNCR

Detailed description of the biotopes recorded during the present survey is included in the Appendix. A summary of the biotopes is given here (Table 1) and related to the provisional list of biotopes for the infralittoral and circalittoral zones as derived by the MNCR for the survey area (Holt, 1994).

In general, the two biotope descriptions are roughly equivalent despite the emphasis on life form in the present study. The shallow (upper infralittoral) kelp biotopes are underrepresented in the BIOMAR survey due to the difficulty of viewing dense kelp by remote camera and using a boat in shallow water. Biotopes on vertical surfaces are also underrepresented because of the difficulty of positioning the remote camera.

The BIOMAR survey has split some of the MNCR biotopes. Thus, MNCR biotope R5.42 has been split into upper and lower circalittoral and the lower circalittoral further split into a loose boulder biotope (13) and an embedded boulder biotope (14). Again, the MNCR biotope R5.43 has been split according to the degree of silt influence (9, 11,12). It is felt that the creation of more biotopes in the lower infralittoral and circalittoral has allowed a more complete interpretation of these extensive zones (see below).

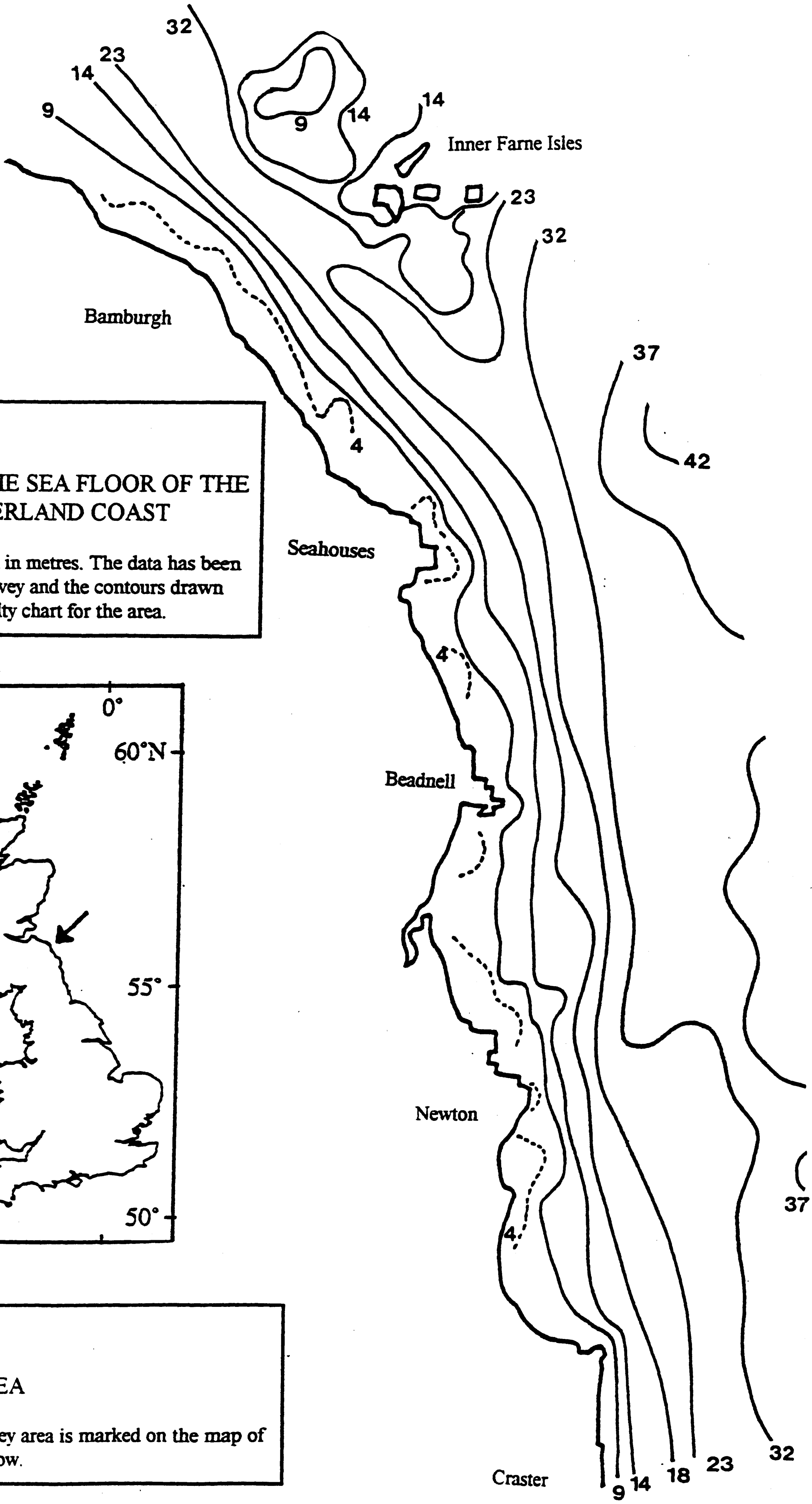
4.2. Depth characteristics of the area

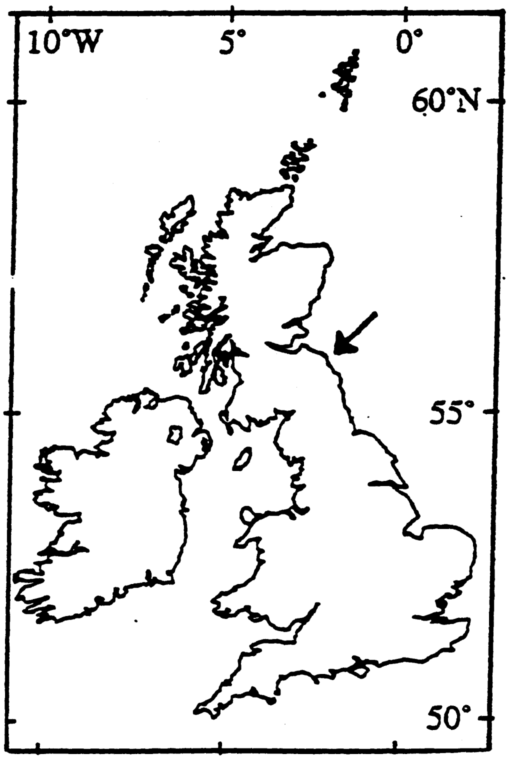
Bathymetry as determined from the track data is shown in Map 1. The depths were not corrected to chart datum and thus must be regarded as being, on average, the depth below mid tide. In general, depth decreased gradually away from the shore, as is typical for most of the coast in this region. Some features are worthy of note. Firstly, deeper water was found within the 2 mile offshore limit of the survey east of Seahouses and the 32m contour comes within 1 mile of Newton and, secondly, a large area between 32m and 37m lay to the north of Newton whilst there was a shallower patch of ground to the south.

MAP 1a.

BATHYMETRY OF THE SEA FLOOR OF THE NORTH NORTHUMBERLAND COAST

The depth contours are given in metres. The data has been derived from the acoustic survey and the contours drawn with reference to the Admiralty chart for the area.





MAP 1B.

THE SURVEY AREA

The location of the survey area is marked on the map of Great Britain by the arrow.

TABLE 1. A COMPARISON BETWEEN THE BIOTOPE CLASSIFICATION DERIVED FROM THE NORTH NORTHUMBERLAND SURVEY AND THE DRAFT MNCR BIOTOPE CLASSIFICATION.

	BIOMAR classification for North Northumberland		**MNCR classification for south-east Scotland, north-east England**
Biotope code	**Biotope title**	**Biotope code**	**Biotope title**
	Infralittoral rock with kelp forest		
1	Infralittoral bedrock or boulders with dense kelp forest	R5.28	Dense *Laminaria hyperborea* forest
2	Lower infralittoral bedrock or boulders with sparse kelp and dense algal turf	R5.34 (part)	*Laminaria hyperborea* park
3	Lower infralittoral bedrock or boulder with *Echinus* grazed algal film	R5.34 (part)	*Echinus* grazed rock with coraline algae
4	Lower infralittoral upper circalittoral boulders, cobble & sand with kelp park	R5.31	Tide swept pebble plains with sparse *Laminaria* spp. and red algae
	Upper circalittoral rock with algae		
5	Upper circalittoral bedrock with sand covering and sparse red algal turf	R5.36	Sand influenced *Laminaria hyperborea* park
6	Upper circalittoral rock with faunal turf and mixed algal/faunal crusts	R5.38	Bedrock terraces with *Alcyonium digitatum, Pomatoceros triqueter, Echinus esculentus* and brittlestars
7	Upper circalittoral boulders with mixed algal/ faunal crusts and faunal turf	R5.42 (part)	Boulder, cobble & pebble plains with hydroids, brittlestars and *P. triqueter*
8	Upper circalittoral tideswept cobble plains with algal crusts & faunal turf	R5.41	Tide swept cobbles & pebbles with a hydroid & bryozoan turf
	Lower circalittoral rock with faunal custs and turf		
9	Lower circalittoral bedrock with faunal turf, crusts & brittlestar beds	R5.43 (part)	Bedrock & boulder plain with hydroids, *Flustra foliacea, Securiflustra securifrons,* & *Alcyonium digitatum*
10	Lower circalittoral bedrock with dense *Alcyonium digitatum* with brittlestars	R5.44	Bedrock and boulder plains with dense *Alcyonium digitatum*

11	Circalittoral bedrock & boulder, sand influenced with faunal crusts & turf	R5.43 (part)	See above
12	Circalittoral bedrock, silt influenced with faunal turf	R5.43 (part)	See above
13	Lower circalittoral boulders with faunal crusts	R5.42 (part)	See above
14	Lower circalittoral tide swept boulder, cobble and sand with faunal crusts	R5.42 (part)	See above
	Gravel		
15	Circalittoral gravel	R5.48	Mobile sublittoral sand & gravel
	Sand		
16	Coarse silty sand ridges		to be completed
17	Coarse silty sand with rock		to be completed
18	Medium fine sand		to be completed

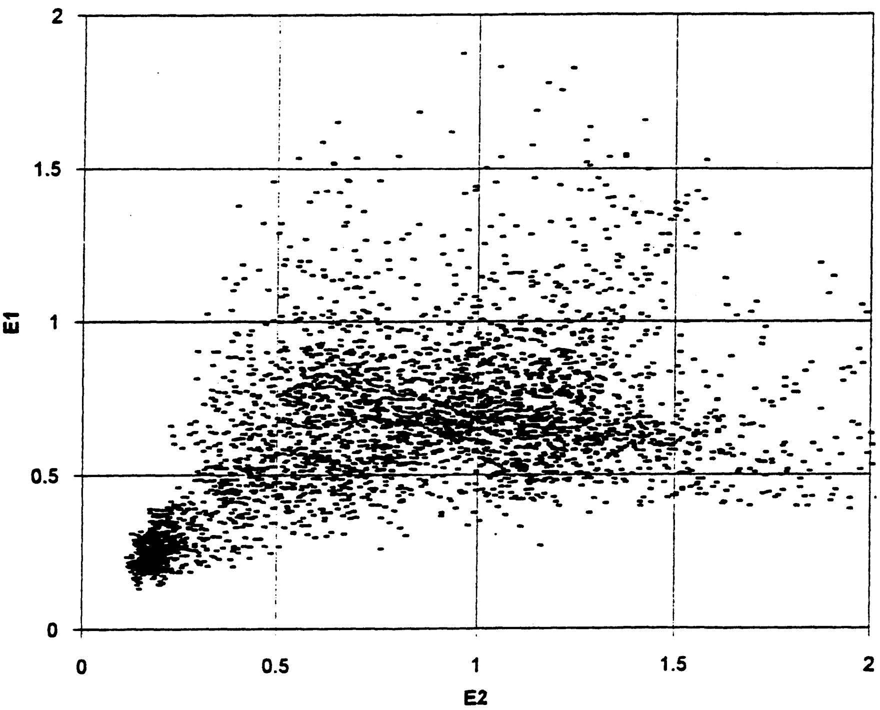
4.3. The relationship between acoustical properties and biotopes

The biotope map (Map 3) has been derived by combining information from RoxAnn that has been through a series of edits taking account of information on depth and the ground-truth data. Thus, the map is highly interpreted and its accuracy is limited by the discriminative powers of sounder and RoxAnn signal analyser, the coverage of the acoustical data and the number and distribution of ground-truth points. This section outlines the process of analysis of the data that underlies the biotope map.

Roughness (E1) and hardness (E2) properties and biotopes: Map 2 is a print-out of the track data that have been analysed according to an E1/E2 composite box configuration shown in the inset. The boxes were designed to give maximum discrimination between the biotopes as determined by remote viewing. An explanation of this box configuration and how it relates to values of E1 and E2 and biotope in the survey area is given below.

Figure 3 shows the spread of E1/E2 values for all track records. The data form a cloud of points indicating an approximate proportionality between E1 and E2. Indeed, much of the area can be interpreted in terms of E1 (roughness) alone. From the shore to a distance of about 1km smooth/soft areas (sand) alternated with extremely rough (kelp/rock) areas. Further offshore a moderately smooth zone (sandy bedrock) gave way to rougher, but not necessarily harder, ground (bedrock, boulders and patchy sand).

FIGURE 3. Spread of E1/E2 Values



The values for E1 and E2 are in arbitrary units that are derived from an integration, performed by RoxAnn, of the strength and duration of each signal.

Thus, the majority of the area covered by the track data has been coloured using boxes which show a closer relationship to E1 values than E2 . Indeed, E2 on its own showed that much of the sea floor beyond the sand/kelp zone was extremely patchy in terms of hardness and not easily interpretable. However, E2 added a useful dimension to the general picture presented above in three areas: First, coarse sand gave a distinctly higher E2 value than medium fine sand; second, a distinct area of silty bedrock could be traced extending northwards from the southern boundary of the survey area; third, a discrete area of sparse kelp on tideswept sand and boulders over bedrock was located in Farne Sound north west of Inner Farne.

Acoustic characteristics and boundaries between biotopes: RoxAnn is well suited for picking up boundaries between sizeable areas of different substratum, such as between rock reefs and sand plains. For example, one feature of note that was identified from the acoustic survey was the area of coarse sand south east of Inner Farne that bounded a tongue of deeper cobble ground that stretched north into the channel between Inner Farne and the mainland. One day's survey in this particular area took place on spring tides and it was very noticeable, from the drift of the boat, that the strong southerly current that ran down the channel gave way to a gentle northerly drift at about the 23m contour and was coincident with a change in substratum from cobble to coarse sand, indicating a strong eddy effect.

Track variability: The edited map of track data (Map 2) shows a degree of variability that makes a direct conversion of the acoustic data to a biotope map difficult without careful interpretation. A one-to-one conversion of the E1/E2 values to substratum type is unsatisfactory. Rather, consistency in the range of values for E1/E2 over short sections of track gave a better indication of the predominant substratum. However, it must be acknowledged that such patterns are detected by eye and that, as yet, no computer-aided techniques have been employed to enhance the acoustic picture.

Track variability arises because of (a) variability of the response of the acoustic system to the substrata and (b) heterogeneity of the biotopes themselves. It was not possible to map areas to a greater accuracy than 100m because of GPS variability and the inability to precisely pinpoint the position of the towed camera relative to the boat. In large areas of relatively uniform habitat (such as the cobble ground west of Inner Farne) this presents little problem. However, much of the survey area was highly variable over very small distances (as indicated by the number of biotopes recorded on the same camera tow) and even patchy over areas of less than 10m x 10m (as indicated by the number of biotopes which are of mixed substratum type).

Depth and biotope discrimination: MICROPLOT does not display depth combined with E1 or E2. However, depth is an important factor in determining biotope type and this is illustrated in the following example: The area immediately west of Inner Farne (Inner Sound) predominantly gave E1/E2 values that have been represented predominantly by the colour blue, with a substantial but lesser proportion of purple (Map 2) and ground-truthing indicated this to be an area of cobble. This is contrasted to large areas further offshore which are coloured predominantly purple with lesser amounts of blue on the map and were of mixed bedrock and boulder. These two types of ground cannot easily be distinguished acoustically by their E1/E2 values. However, the depth characteristics were quite different, with the former lying at moderate depth (between 18m and 32m) and the latter, offshore area found in deeper water (greater than 32m).

Further information can be extracted from an inspection of localised variations in depth. For example, the nearshore area dominated by E1/E2 values represented by the colour green were more topographically variable than the rocky areas further offshore. Also, reefs could be traced extending up to 1 km offshore from Seahouses and Newton. The rock strata within 1 km of the shore between Dunstanburgh Castle and Craster dip quite steeply to the east and the topography was observed to be a series of cliffs facing west with east-facing dip slopes.

4.4. The biotope map

It is necessary to treat the biotope map with caution, bearing in mind the above points. The following conventions have been used in preparing the map:-

1. The areas show, in most cases, groups of biotopes rather than single biotopes. Therefore, the headings given to the areas delineated in Map 3 embrace a number of biotopes that might be expected to be found within them. The areas are described either by the predominant biotope or by a mixed description of the major biotopes.
2. Code numbers referring to biotope types are included with the position of the ground truth stations on the map. It is to be expected that a proportion of biotopes will outside areas enclosing most other examples of that biotope. These miss-matches are labelled and their number and position give some indication as to the level of confidence that can be placed in the biotope map.

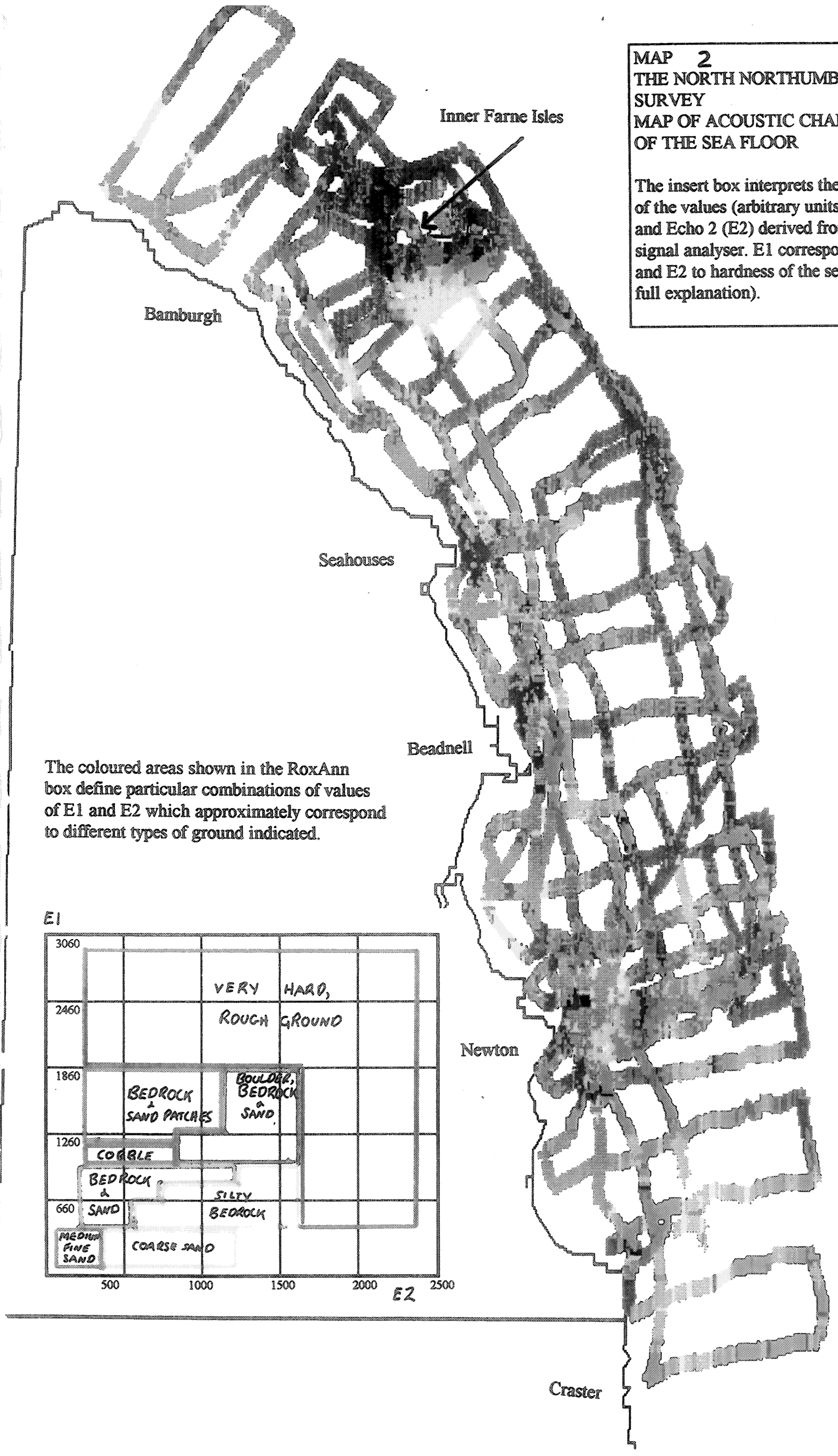
MAP 2

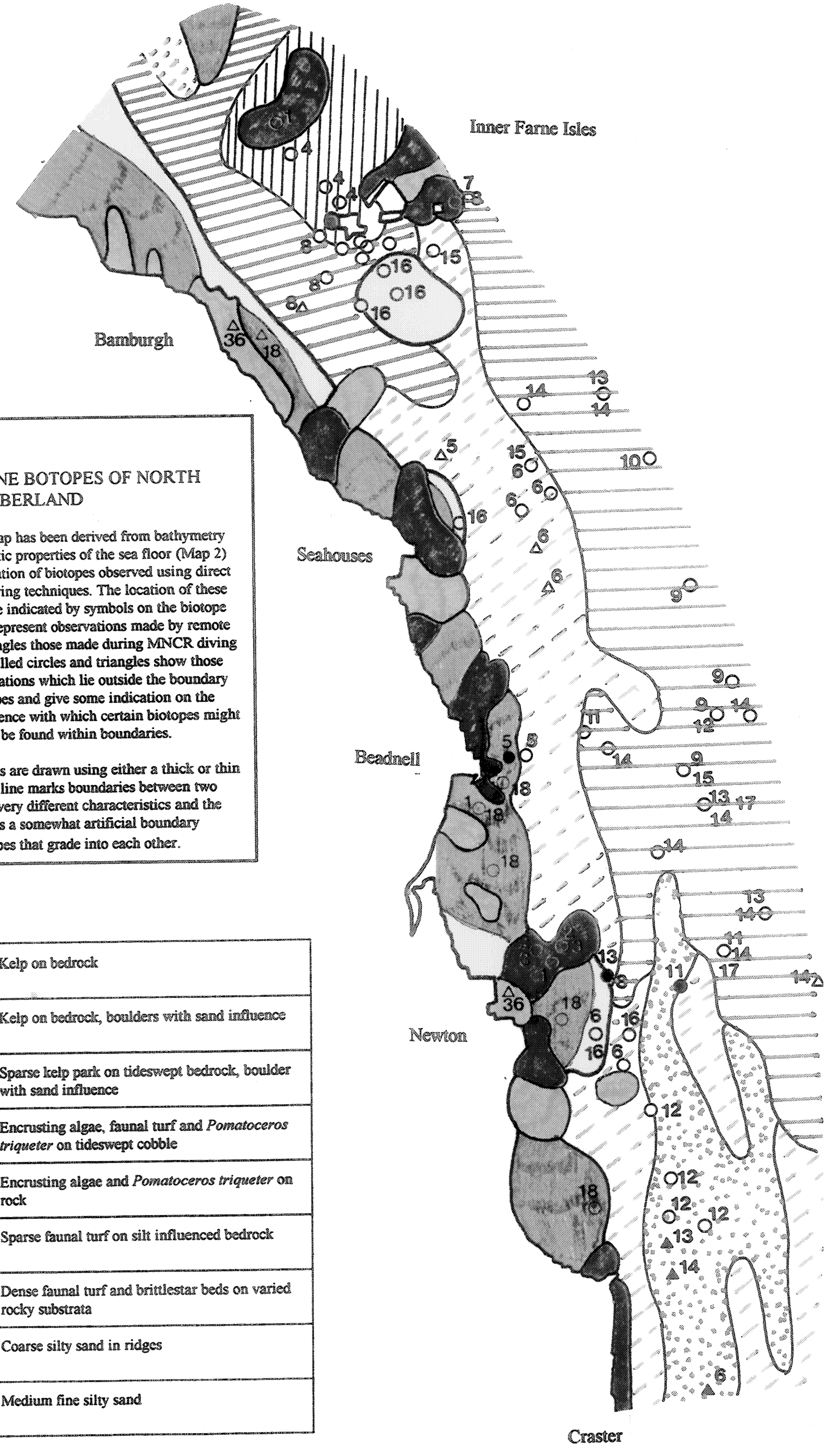
THE NORTH NORTHUMBERLAND MARINE SURVEY

MAP OF ACOUSTIC CHARACTERISTICS OF THE SEA FLOOR

The insert box interprets the colours in terms of the values (arbitrary units) of Echo 1 (E1) and Echo 2 (E2) derived from the RoxAnn signal analyser. E1 corresponds to roughness and E2 to hardness of the sea floor (see text full explanation).

The coloured areas shown in the RoxAnn box define particular combinations of values of E1 and E2 which approximately correspond to different types of ground indicated.





MAP 3

THE MARINE BOTOPES OF NORTH NORTHUMBERLAND

The biotope map has been derived from bathymetry (Map1), acoustic properties of the sea floor (Map 2) the the distribution of biotopes observed using direct or remote viewing techniques. The location of these observation are indicated by symbols on the biotope map. Circles represent observations made by remote video and triangles those made during MNCR diving surveys. The filled circles and triangles show those biotope observations which lie outside the boundary for such biotopes and give some indication on the level of confidence with which certain biotopes might be expected to be found within boundaries.

The boundaries are drawn using either a thick or thin line: the thick line marks boundaries between two biotopes with very different characteristics and the thin line marks a somewhat artificial boundary between biotopes that grade into each other.

- Kelp on bedrock
- Kelp on bedrock, boulders with sand influence
- Sparse kelp park on tideswept bedrock, boulder with sand influence
- Encrusting algae, faunal turf and *Pomatoceros triqueter* on tideswept cobble
- Encrusting algae and *Pomatoceros triqueter* on rock
- Sparse faunal turf on silt influenced bedrock
- Dense faunal turf and brittlestar beds on varied rocky substrata
- Coarse silty sand in ridges
- Medium fine silty sand

3. Whilst some boundaries can be drawn with confidence, others represent artificial divisions along a cline. Those which are firm boundaries are shown as thick lines; those which are less clearly defined are shown as thin lines.

Estimates of area have been made by copying the boundaries onto graph paper.

The following biotope categories are illustrated on Map 3. The numbers prefixed by R5 are those biotopes taken from the draft MNCR community classification for south-east Scotland and north-east England. (Brazier *et al*, 1994):-

A. Kelp on bedrock: A number of kelp biotopes were found on very hard bedrock or large boulders which gave very high values for E1 and often, but not always, for E2. Shallow (upper infralittoral) kelp was dense and overgrown with red algae (Biotope 1) and progressively less dense and overgrown with increasing depth (lower infralittoral Biotope 2) to grade into a sparse, urchin-grazed kelp park in the lower infralittoral/upper circalittoral (Biotope 3).

This group of biotopes was associated with rocky headlands on the mainland and the Farne Islands. These areas contain many vertical rock faces not easily observed by remote survey techniques but are known to be species-rich (Foster-Smith & Foster-Smith, 1987; Connor, 1989; Holt, 1994).

Area covered by category: 416 hectares (7.1% of total area covered by the survey)

B. Kelp on sand influenced bedrock or boulders: Many areas, often closely associated with headlands and sand, were characterised by extremely variable E1 values. Although not ground-truthed during this survey, these shallow grounds are known from previous surveys to be of sparse kelp (including both *Laminaria hyperborea* and *Laminaria saccharina*) on sandy bedrock or boulder with an understorey of sparse red algal turf on rock(Biotope R5.36).

Area covered by category: 217 hectares (3.7% of total area covered by the survey)

C. Sparse kelp park on tideswept bedrock, boulder and sand: A large area in Farne Sound consisted of one biotope (Biotope 4). However, the biotope was extremely mixed and patchy on a small scale and this was reflected in the wide range in E1 and E2 values. Much of the area gave characteristic, moderately high values for both E1 and E2, especially close to islands, and they have been represented as black on Map 3.

Area covered by category: 263 hectares (4.5% of total area covered by the survey)

D. Encrusting algae, faunal turf and *Pomatoceros triqueter* crusts on tideswept cobble: This also appeared to be a single biotope area (Biotope 8), although the proportions of the major species varied from one ground-truth point to another. This biotope is regarded by Connor (1989) and Holt (1994) as being species rich.

Area covered by category: 519 hectares (8.9% of total area covered by the survey)

E. Encrusting algae, faunal turf and *Pomatoceros triqueter* crusts on bedrock, often heavily sand influenced: A large area of ground at moderate depth (14m - 32m) was predominantly of one variable biotope (Biotope 6) of terraced bedrock often with a covering of sand. In shallower water (15m) there was a sparse algal turf (Biotope 5) whilst in other areas patches of coarse, ridged sand (Biotope 16) or gravel (Biotope 15) were found. The E1 and E2 values were variable, but usually moderately low. These would appear to be biotopes of low species diversity. Brittle-star beds were found at some locations in Biotope 6.

Area covered by category: 1460 hectares (25% of total area covered by the survey)

F. Sparse faunal turf on silt influenced bedrock: This is an important variant of 'E' above and is largely represented by Biotope 12. The faunal turf was quite well developed, but the rock surfaces were covered in a layer of silt and crusts of *Pomatoceros triqueter* were poorly represented. The areas covered by this group of biotopes would appear to be of low species diversity although the rare bryozoan *Smittina landsborovii* was frequently seen.

Area covered by category: 470 hectares (8% of total area covered by the survey)

G. Faunal turf, faunal crusts and brittle-star beds on varied rocky substrata mixed with patchy coarse sand: The 32m contour coincided with a change in E1 and E2 values and also the distribution of biotopes. Below 32m E1 values were high and E2 values moderately high. The biotopes appeared to be divided into those which were dominated by a dense faunal turf (Biotopes 9 & 10) and those which were largely of boulder, heavily sand influenced and dominated by the keel worm *Pomatoceros triqueter* (Biotopes 11, 13 and 14). Dense brittlestar beds were common at this depth.

Area covered by category: 1479 hectares (25.3% of total area covered by the survey)

H. Coarse silty sand in ridges: Without more detailed data this has been considered to consist of a single biotope type (Biotope 17). The razor shell *Ensis siliqua* was probably common and the sand eel *Ammodytes tobianus* appeared to be associated with this biotope.

Area covered by category: 338 hectares (5.8% of total area covered by the survey)

I. Medium fine silty sand: Without more detailed data this has been considered to consist of a single biotope (Biotope 18).

Area covered by category: 667 hectares (11.4% of total area covered by the survey)

5. DESCRIPTION OF THE SURVEY AREA

The distribution of substrata within the survey area follows the general pattern for the Northumberland coast: low rocky headlands and associated offshore reefs alternate with exposed bays of medium fine sand. Map 3 emphasises the isolated nature of the sandy bays and the small proportion of the area occupied by the species rich infralittoral rocky reefs (approximately 7.1%). Infralittoral rock also fringes many of the islands of the Farnes archipelago. The full extent of the very hard, rough substrata around the Farne Islands as a whole has not been determined, but they do not appear to be extensive around the Inner Farne. Again, the map shows the Farnes to be a relatively small area of offshore shallow bedrock when seen in relation to the rest of the coast.

A wave cut platform of terraced bedrock, boulder and patches of finer sediments forms a gradually deepening shelf that extends out beyond the 3.2 km (2 mile) survey limit. The shallower (upper circalittoral) part of the wave cut platform is generally sand influenced and somewhat uniform as compared to the deeper (lower circalittoral), more variable areas. However, the biological component of the biotopes would appear to be very similar throughout the platform consisting of a bryozoan/hydroid turf and ubiquitous crusts of *Pomatoceros triqueter*. It is difficult to select any biotopes that are of greater diversity or hold species of particular conservation interest. However, in terms of habitat complexity, the biotopes composed of stacked boulders with interstices (Biotope 14) and highly broken bedrock (Biotope 10) may provide a refuge for more species than the terraced bedrock biotopes.

Tidal currents are accelerated around the Farne Islands and the position of the current swept biotopes reflect this. Of particular note is the likely extent of the species rich cobble ground in the Inner Sound. Another feature of note is the area of shallow ground south east of Inner Farne (coarse sand) that bounded a tongue of deeper water that stretched north into the channel between Inner Farne and the mainland. Sand eels (*Ammodytes tobianus*) have been frequently observed on this coarse sand and are an importance as a source of food for sea birds.

Currents are weaker in the south of the survey area (Holt, 1994) and the biotopes in this section are more silty than in the north of the survey area. Despite the presence of silt covering much of the rock surface, the faunal turf appears equally as rich in this southerly section as in the north, and encrusting sponges and the bryozoan *Smittina landsborovii* make the area of no lesser scientific interest than the more silt-free areas to the north.

6. CONCLUSIONS

The following is a summary of the main points emerging from this BIOMAR mapping survey considered to be important for an assessment of the conservation interest of the area:

1. The mapping exercise indicated that by far the majority of the marine biotopes were of faunal turf (hydroids and bryozoans) and *Pomatoceros triqueter* associated with mixes of bedrock, and boulder with lesser amounts of cobble and sand (categories D, E, F and G above) which together accounted for 67.2% of the survey area. All the biotopes in this latter group appeared to be of similar species composition, although the proportions of constituent species varied. It is, therefore, difficult to discern any biotopes based on conspicuous life-forms that are of special interest from amongst them.

2. Most of the open coast biotopes recognised from south-east Scotland and north-east England can be found within the survey area (Holt, 1994). |However, the biotope map points up the transitional position the survey area occupies between the more silt-free biotopes to the north and the siltier biotopes to the south. Thus, whilst much of the area is occupied by biotopes typical of the region as a whole, the representation of the biotopes within the survey area might be considered when assessing its conservation interest.

3. Shallow (infralittoral) rock biotopes (categories A, B, C) accounted for about 16.3% of the total survey area and were restricted to rocky headlands and the Farne Islands. Of these category A (7.1% of total area) is known to contain a high diversity of species and habitats (Foster-Smith & Foster-Smith, 1987; Connor, 1989; Holt, 1994).

4. Large areas of sand accounted for only 16.5% of the total survey area and were restricted to bays between rocky headlands and to a sandbank south of Inner Farne. These sandy areas are likely to be of importance for diving and bottom-feeding sea birds (Foster-Smith. 1988) and their restricted distribution close to shore should be noted especially with reference to disturbance.

5. The tide swept cobble ground in the Inner Sound (8.9% of the total area) is thought to be of special interest on account of the species-rich faunal turf and fauna inhabiting the interstices between the cobbles (Connor, 1989; Holt, 1994).

There are two main conclusions from the BIOMAR mapping exercise. First, the survey area contains a full range of biotopes that are typical of the region of south-east Scotland and north-east England. Second, the biotopes of greatest species diversity or of conservation importance to sea birds are to be found close inshore (particularly around rocky headlands) and around Inner Farne.

7. EVALUATION OF THE MAPPING SURVEY AS AN AID FOR CONSERVATION ASSESSMENT

Mapping is NOT a replacement for more detailed survey: rather, the two should be regarded as complementary and forming part of a whole survey strategy. Species diversity is poorly ascertained as only a limited number of species can be recognised from remote survey. The techniques employed by BIOMAR to date are not well suited for the investigation of vertical surfaces, overhangs or interstices.

However, maps have been used to present a clear overview of the area. The additional knowledge gained of biotope boundaries and distributions through the mapping exercise has added to what is known from diving surveys. This overview has lead to the creation of biotopes (or biotope variants) over and above those recognised by the MNCR that are significant in terms of coverage and help to show broader patterns of ecological variables, such as silt influence.

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APPENDIX

Biotope Descriptions

The following biotope descriptions are based on video recordings made during the survey. The descriptions follow the format used by the MNCR with the major exception that life forms are recorded rather than particular species due to the difficulty of identifying species confidently from video. The percentage values given in the descriptions are estimate of cover of the particular life form or species and the abundances are given following the MNCR procedures where R = rare, O = occasional, F = frequent, C = common, A = abundant and S = superabundant.

The biotopes were drawn up on the basis of recognisable features consistently found in a number of records or outstandingly unique characteristics (if the biotope description was based on one or a very small number of records). Reference was made to the draft classification of biotopes for this region (Brazier *et al* 1994) in an attempt to use the same biotopes. However, in some instances amalgamation of the MNCR biotopes was necessary as discrimination could not be made at a sufficiently detailed level using the video. In other cases biotopes were split or new biotopes created when it was felt that the remote survey methods could discriminate between these divisions and that sufficiently large areas of the new biotopes could be mapped to justify their creation (see Table 1 for a comparison between the BIOMAR biotopes for the survey area and those of the MNCR)

Infralittoral rock with kelp forest

1. Infralittoral bedrock or boulders with dense kelp forest

A variable substratum of bedrock, boulders and often patches of cobble and sand found at depths from 3 - 8 m: The substratum type was often difficult to determine because of the density of the kelp forest. The kelp, *Laminaria hyperborea*, was tall and the stipes were thickly overgrown by red algae. In many instances the fronds were overgrown by the bryozoan *Membranipora membranacea* or the hydroid *Obelia geniculata*. Because of the lack of detail available from the video records, no breakdown of the biotope composition is given.

Equivalent MNCR coding: R5.28

Video records 2:15, 2:16, 3:2a, 3:18, 3:21.

2. Lower infralittoral bedrock or boulders with a sparse kelp forest and dense algal turf

Bedrock or large boulders at depths from 8 - 12 m: The kelp forest of *Laminaria hyperborea* exhibited a sharp boundary at these depths forming an open but continuous canopy above about 10 m whilst below this depth the kelp was extremely sparse. However, the algal understorey and encrusting layer remained characteristic throughout the biotope. The algal turf consisted of the brown weeds *Dictyota dichotoma* (C-S) and *Desmarestia aculeata* (C), and the red alga *Ceramium* sp. (0-C). The vertical rock surfaces were densely encrusted with *Pomatoceros triqueter*. *Echinus esculentus* was recorded as occasional or common. There are only two records for this biotope and therefore no breakdown is given below.

Equivalent MNCR coding: R5.34(part)

Video records: 1:11b, 1:13a.

3. Lower infralittoral bedrock or boulder with *Echinus* grazed algal film

Large whinstone boulders close to reef or cliff at depths from 8 - 12 m: Very sparse urchin grazed kelp park with boulders was covered by green/brown algal film (30-90%) and patches of encrusting coralline algae (nr-50%). *Pomatoceros triqueter* encrustations were restricted to lower sides of boulders.

Equivalent MNCR coding: R5.34 (part)

Video records 1:11, 1:13, 2:1, 2:2.

Composition of life forms

Form	Frequency of occurrence (total records 4)	Abundance/ cover (range)	Median
Kelp park	2	nr-10	
Algal crusts	4	30-100	75
Faunal crusts	2	nr-20	
Echinus esculentus	4	O-A	

4. Lower infralittoral/upper circalittoral boulders, cobble and sand with sparse kelp park

Extensive plane of cobble (20-50%) and coarse sand (20-80%) mixed with boulders at depths from 12 - 16 m: There was a very sparse kelp park of short *Laminaria hyperborea* and *Laminaria saccharina* with fronds densely overgrown with *Obelia geniculata* (A) and *Membranipora membranacea* (C), with a turf or red algae (mixture of *Ceramium* sp., *Ahnfeltia plicata* and *Plocamium cartilagineum*) and *Desmarestia aculeata* (nr-F). *Pomatoceros triqueter* and encrusting corallines algae formed a patchwork of crusts over the boulders and mixed encrustations on cobbles.

Equivalent MNCR coding: R5.31

Video records 2:12, 2:13, 2:14.

Composition of life forms

Form	Frequency of occurrence (total records 3)	Abundance/ cover (range)	Median
Kelp park	3	1-20	10
Algal turf	3	<5-20	10
Faunal crust (*P. triqueter*)	3	<1-10	7
Algal crust (corallines)	3	<1-15	10
Echinus esculentus	3	O-F	

<u>Lower infralittoral/upper circalittoral mixed rock and sediment with algal turf</u>

5. Lower infralittoral/upper circalittoral bedrock with sand covering and sparse algal turf

Bedrock terraces with a covering of medium-fine sand found at depths of from 10 - 15 m: the reef edges were either bare of sand or thinly covered and the sand layer became thicker further down the reef slope. Bare rock was encrusted with *Pomatoceros triqueter* and encrusting coralline algae and a sparse red algal turf growing through thin coverings of sand.

Equivalent MNCR coding: none

Video records 3:3, 3:4.

<u>Upper circalittoral rock with algal crusts and faunal turf and crusts</u>

6. Upper circalittoral sand influenced bedrock with faunal turf and algal/faunal crusts

Bedrock terraces (40-90%) with patches of coarse sand (10-60%) with occasional medium-sized boulder, often moderately silt influenced. Found at depths from 20 - 25 m. Faunal turf composed largely of *Flustra foliacea* or *Alcyonium digitatum*, with lower abundances of *Nemertesia antennina*, *Abietinaria abietina* and *Thuiaria thuja*. Silt formed cushions often bound with a low turf of bryozoans. *Pomatoceros triqueter* was common or abundant on bare rock surfaces, especially vertical surfaces.

Equivalent MNCR coding: R5.38

Video records: 1:2, 3:14a, 3:15, 3:16

Composition of life forms

Form	Frequency of occurrence (total records 4)	Abundance/ cover (range)	Median
Encrusting corallines	4	10-20	15
Faunal turf	4	10-75	40
Faunal crust (*P. triqueter*)	4	5-30	15
Faunal silt cushion	2	0-30	
Brittlestar bed	2	0-70	
Echinus esculentus	2	O	

7. Upper circalittoral boulders with mixed algal/faunal crusts and faunal turf

Boulders with a variable cobble/sand component found a depths from 15 - 20 m: *Pomatoceros triqueter* was generally abundant mixed with a smaller proportion of encrusting coralline algae.

Equivalent MNCR coding: R5.42(part)

Video records 2:17b, 3:5.

8. Upper circalittoral tideswept cobble planes with algal crusts and faunal turf.

Extensive tideswept cobble or small boulders (75-100%) plain with possible patches of coarse sand (nr-20%) at depths from 15 - 28m: Coralline crusts formed extensive patches on the cobbles and were recorded even at depths of 28m. The faunal turf was dominated either by *Abietinaria abietina* (F-S) or *Alcyonium digitatum* (F-A). *Opthiothrix fragilis* beds were recorded as being common at two locations.

Equivalent MNCR coding: R5.41

Video records 2:3, 2:4, 2:7, 2:10, 2:11, 2:17a, 3:5

Composition of life forms

Form	Frequency of occurrence (total records 7)	Abundance/ cover (range)	Median
Algal crust (corallines)	7	10-60	30
Faunal turf	6	nr-60	22
Faunal crust (*P. triqueter*)	5	nr-40	15
Echinus esculentus	7	O-F	C

<u>Lower circalittoral rock with faunal crusts and turf</u>

9. Lower circalittoral bedrock with faunal turf, faunal crusts and brittlestar beds

Horizontal bedrock or bedrock terraces with an occasional large or medium-sized boulder at depths from 30 - 35 m, sometimes silt influenced, and with patches of coarse sand. Faunal turf was mixed and composed of bryozoans/hydroids and *Alcyonium digitatum*. Conspicuous species were *Securiflustra securifrons* (O-F), *Abietinaria abietina* (F), and *Alcyonium digitatum* (F-C) with lower abundances of *Nemertesia antennina* (nr-F) and *Thuiaria thuja* (nr-O). The brittlestars were predominantly *Ophiocomina nigra* with a smaller proportion of *Ophiothrix fragilis*. In some recordings brittlestar arms were seen protruding out of crevices in vertical surfaces, possibly of *Amphipholis squamata* or *Ophiactis bali*. *Pomatoceros triqueter* encrusted vertical and other bare rock surfaces.

Equivalent MNCR coding: R5.43(part)

Video records 2:18b, 2:18c, 3:10, 3:11

Composition of life forms

Form	Frequency of occurrence (total records 5)	Abundance/ cover (range)	Median
Faunal turf	4	20-50	30
Faunal crust (*P. triqueter*)	4	<5-20	10
Brittlestar bed	4	10-80	50
Echinus esculentus	1	nr-O	

10. Lower circalittoral bedrock with dense Alcyonium digitatum and brittlestar beds

Rugged bedrock with numerous 1-2m deep, criss-crossing gullies recorded once from 37 m. The community was dominated by *Alcyonium digitatum* (80% cover) with lesser amounts of *Abietinaria abietina* (C), *Nemertesia antennina* (O) and *Thuiaria thuja* (O). *Pomatoceros triqueter* gave a cover of 20%, mostly on vertical surfaces, and brittlestars (mixed *Ophiothrix fragilis* and *Ophiocomina nigra*) 10% cover. There were numerous arms of brittlestars protruding from the highly fissured vertical rock surfaces.

Equivalent MNCR coding: R5.44

Video record: 3:12

11. Circalittoral bedrock and boulder heavily influenced by sand and silt with faunal crusts and faunal turf.

Terraced bedrock (50-80%) and boulders (20-50%) often mixed with smaller patches of sand and cobble with large areas of silt cushions on their horizontal surfaces found at depths from 20 - 33 m. *Pomatoceros triqueter* was the most abundant conspicuous species with *Flustra foliacea* (C) forming small patches of turf on prominent rocks. *Alcyonium digitatum* (R-F), *Abietinaria abietina* (nr-F) and *Thuiaria thuja* (nr-R) were also constituents of the faunal turf.

Equivalent MNCR coding: R5.43(part)

Video records 1:4b; 1:5a, 3:6.

Composition of life forms

Form	**Frequency of occurrence (total records 3)**	**Abundance/ cover (range)**	**Median**
Faunal crust (*P. triqueter*)	3	40-50	43
Faunal turf	3	5-25	16
Silt cushion	3	10-30	23
Echinus esculentus	3	O-C	O

12. Circalittoral bedrock heavily silt influenced with faunal turf

Terraced bedrock at depths from 18 - 25 m heavily sand influenced. Occasionally the vertical drops formed small cliffs of 2-5m (estimated). Short bryozoans to form patches of dense, silty turf. *Flustra foliacea* (O-C), *Securiflustra securifrons* (nr-F), *Alcyonium digitatum* (nr-O), *Nemertesia antennina* (nr-O) and *Tubularia indivisa* (nr-R) formed a minor constituent of the turf. Although *Pomatoceros triqueter* was the major component of the faunal crust, there were also sponges (unidentified) and a notable bryozoan *Smittina landsborovii*. In one instance (2:18b) there was a substantial brittlestar bed (60%) of *Ophiocomina nigra*.

Equivalent MNCR coding: R5.43(part)

Video records 2:18b, 5:1, 5:3, 5:4, 5:5.

Composition of life forms

Form	**Frequency of occurrence (total records 5)**	**Abundance/ cover (range)**	**Median**
Faunal turf	5	10-75	33
Faunal crust	5	<1-<5	
Echinus esculentus	4	O	

13. Lower circalittoral boulders with faunal crust

Large or medium sized boulders (75-100%) stacked on top of each creating interstices with occasional patches of silty coarse sand (nr-15%), found at depths from 23 - 40 m. Faunal crusts of *Pomatoceros triqueter* covered much of the rock surfaces whilst a sparse faunal turf was always present but whose composition varied consisting of *Alcyonium digitatum* (nr-A), *Flustra foliacea* (nr-A), *Abietinaria abietina* (nr-F) with occasional records of *Thuiaria thuja* (nr-R). The conspicuous bryozoan *Smittina landsborovii* was recorded once in this biotope (record 1:7b).

Equivalent MNCR coding: R5.42(part)

Video records 1:6b, 1:7b, 1:9b, 2:18a, 3:13b, 5:6

Composition of life forms

Form	Frequency of occurrence (total records 6)	Abundance/ cover (range)	Average
Faunal crust (*P. triqueter*)	6	10-80	60
Faunal turf	6	<5-20	10
Brittle star bed	4	nr-80	18
Echinus esculentus	3	nr-C	

14. Lower circalittoral tideswept boulder, cobble and sand mixture with faunal crust

A varied substratum of predominantly cobble (10-80%) and boulder (10-60%) embedded in coarse sand (10-50%) with some gravel present in most records (nr-20%), found at depths from 28 - 40 m. A faunal crust of *Pomatoceros triqueter* colonised most surfaces although silt and a short bryozoan/silt turf were found on horizontal surfaces in many instances. The composition of the faunal turf was variable, consisting of *Alcyonium digitatum* (nr-C), *Abietinaria abietina* (nr-C), *Flustra foliacea* (nr-A) with occasional examples of *Thuiaria thuja* and *Nemertesia antennina*. In two records the brittlestars *Ophiocomina nigra* and *Ophiothrix fragilis* formed dense beds.

Equivalent MNCR coding: R5.42(part)

Video records 1:4a 1:6a, 1:7a, 1:8, 3:7, 3:9, 3:13a

Composition of life forms

Form	Frequency of occurrence (total records 7)	Abundance/ cover (range)	Median
Faunal crust (*P. triqueter*)	7	5-75	32
Faunal turf	7	<5-30	15
Echinus esculentus	6	R-F	O
Brittle star beds	3	nr-90	

Gravel

15. Circalittoral gravel

Silty gravel (100%) area at 27 m: A single example of this biotope was recorded amongst biotope 6. The gravel was barren of infauna except for a few specimens of *Sabella pavonina*. *Asterias rubens* was frequent.

Equivalent MNCR coding: R5.48

Video record: 3:14b

Sand

16. Coarse silty sand ridges

Extensive planes of coarse silty sand in ridges from 20 - 30 cm high found at depths from 18 - 28 m: The siphons of the razor shell *Ensis siliqua* were observed at two locations and empty razor shells seen in all except two locations. Otherwise, the sediment appeared barren of infauna. *Asterias rubens* (nr-C) and *Carcinus maenas* were also recorded. Organic debris was observed in the troughs of the sand waves in many instances.

Video records: 1:2, 1:3, 2:5, 2:6, 2:9, 3:17.

17. Coarse silty sand with boulders and bedrock

Restricted areas of coarse silty sand with occasional boulders or close to outcrops of bedrock found at depths of from 20 - 27 m: Barren sand sometimes in ridges and in one instance overlying bedrock, which was exposed in the troughs of the ridges.

Video records: 1:5c, 1:7c, 2:17a

18. Medium fine sand

Plains of more restricted areas of medium fine sand showing ripples 5 - 10 cm high found at depths from 8 - 12 m: Apparently barren of infauna. In one instance the sand ripples sparsely covered horizontal bedrock (5:7).

Video records: 1:1, 1:9a, 3:1, 3:2b, 3:3a, 5:7, 5:8.