ENGLISH
NATURE

Mapping the distribution of benthic biotopes at Flamborough Head

No. 121 - English Nature Research Reports

working today
for nature tomorrow

No. 121

Mapping the distribution of benthic biotopes at Flamborough Head

Jon Davies & Ian Sotheran

ISSN 0967-876X

Mapping the distribution of benthic biotopes around Flamborough Head

Jon Davies & Ian Sotheran

March 1995

BioMar is 50% funded by the Commission of European Communities under the Life programme

A collaborative study between English Nature and the BioMar programme

Contents

Figures

Mapping the distribution of benthic biotopes around Flamborough Head

Jon Davies & Ian Sotheran

Preface

The survey of the marine environment around Flamborough Head was undertaken as part of the BioMar Project which is funded by the European Community through the LIFE Programme. The BioMar 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 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.

Acknowledgements

The BioMar project wishes to acknowledge the financial support of English Nature (Nature Conservancy Council for England) to cover the costs of the field survey and reporting for the present project.

BioMar wish to acknowledge:

- Dave Screeton, the skipper of M.V. *Eva Ann* for all his help and experience during the field survey;
- Dr Paul Gilliland (English Nature) for providing background information and comments on an earlier draft;
- Paul Brazier (Joint Nature Conservation Committee) for supplying data from the Marine Nature Conservation Review.

Synopsis

Flamborough Head on the east coast of England is a prominent headland of Upper Cretaceous chalk which has considerable geological conservation value. Chalk is a relatively soft rock and readily bored by marine organisms which, when combined with the limited geographic distribution of chalk, form unusual and uncommon marine biotopes. Conflicting data were available to determine the offshore extent of these chalk reefs: estimates varied between 1 and 15 km offshore. To implement effective management of the marine benthic resource, English Nature required data on the geographic extent of the biotopes around Flamborough Head and requested the BioMar project at the University of Newcastle to conduct a biotope mapping survey.

At Newcastle University, the BioMar project 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, determined from direct observations or samples of the sea bed at pre-determined point locations. Biological data were collected using a towed video recorder and supplemented by grab sampling for sedimentary habitats. Data from previous investigations by the Marine Nature Conservation Review (MNCR) of the Joint Nature Conservation Committee were used for additional ground validation information.

Flamborough Head was surveyed by the BioMar team from August 8-12, 1994. The following data were obtained from this survey:

i The area surveyed extended from Bridlington to Bempton, to an approximate offshore limit of 5 km.

ii 49 video samples and two granulometric samples were collected.

iii Twelve generic biotopes were identified from the video and sediment samples

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

At Flamborough Head the offshore extent of the chalk reef was approximately 0.8 km from chart datum, although there were some rock outcrops in the areas of boulders and cobbles further offshore. To the south of the headland, there is a narrow, shallow sediment bank, Smithic Bank, which extends to the south west gradually broadening out into a sediment plain. No chalk was observed to the east of Smithic Bank and thus the results predict an offshore extent of approximately 1 km from chart datum to the south of Flamborough Head. The offshore extent of the chalk declines with increasing distance north: at the northern limit of the survey area the chalk extended 0.3 km offshore from chart datum.

A comparison was undertaken between the BioMar data and that collected by the MNCR. A close correlation was determined between these data and, by and large, the biotopes recorded at each MNCR site matched the predicted biotope from the BioMar survey. Miss matches between the data were probably due to the inherent errors in the position fixing systems.

Introduction

Management of the living resources and landscapes of the marine environment requires an inventory of these resources and their geographic location. Thus, mapping marine habitats (biotopes) forms a very useful basis for making decisions on the best approach for conserving the natural heritage of coastal waters.

Flamborough Head on the east coast of England is a prominent headland of Upper Cretaceous chalk which has considerable geological conservation value. The headland itself has steep cliffs 50m high with a broad wave-cut platform at their base which slopes seawards in a series of short vertical steps. With increasing distance north and south of the headland, the rock platforms become increasingly overlain with boulders and cobbles, finally becoming sandy shores north of Buckton Cliffs and south of Sewerby. Sublittoral topography is similar to the adjacent shores: off the headland the rock platforms extend into the sublittoral environment in a series of short steps which become overlain with stones and then sediment with increasing distance offshore.

Due to its prominence into the North Sea, very strong tidal currents sweep around Flamborough Head on both the flood and ebb tides. These strong tides continually re-suspend fine particulate matter, particularly material eroded from the soft limestone and chalk rocks and overlying boulder clay of the adjoining coastline, giving rise to highly turbid water around the headland. Habitats out of the main tidal flows are subject to considerable deposition of silt which can influence the structure and composition of the epibenthic assemblage. Distribution of biotopes will reflect patterns in tidal streams.

Chalk is a relatively soft rock and readily bored by marine organisms which, when combined with the limited geographic distribution of chalk, form unusual and uncommon marine biotopes. Conflicting data were available to determine the offshore extent of these chalk reefs: estimates varied between 1 and 15 km offshore. To implement effective management of the marine benthic resource, English Nature required data on the geographic extent of the biotopes around Flamborough Head and requested the BioMar project at the University of Newcastle to conduct a biotope mapping survey.

Objectives

A baseline resource survey of the Flamborough Head area had three main objectives:

i Undertake an acoustic survey to determine the main habitats and in particular, the offshore extent of the chalk reefs.

ii Validate the acoustic survey using a video system to match the biological features with the physical habitats.

iii Produce colour maps of the geographic distribution, and an inventory of the major biotopes within the survey area.

Methods

At Newcastle University, the BioMar project 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).

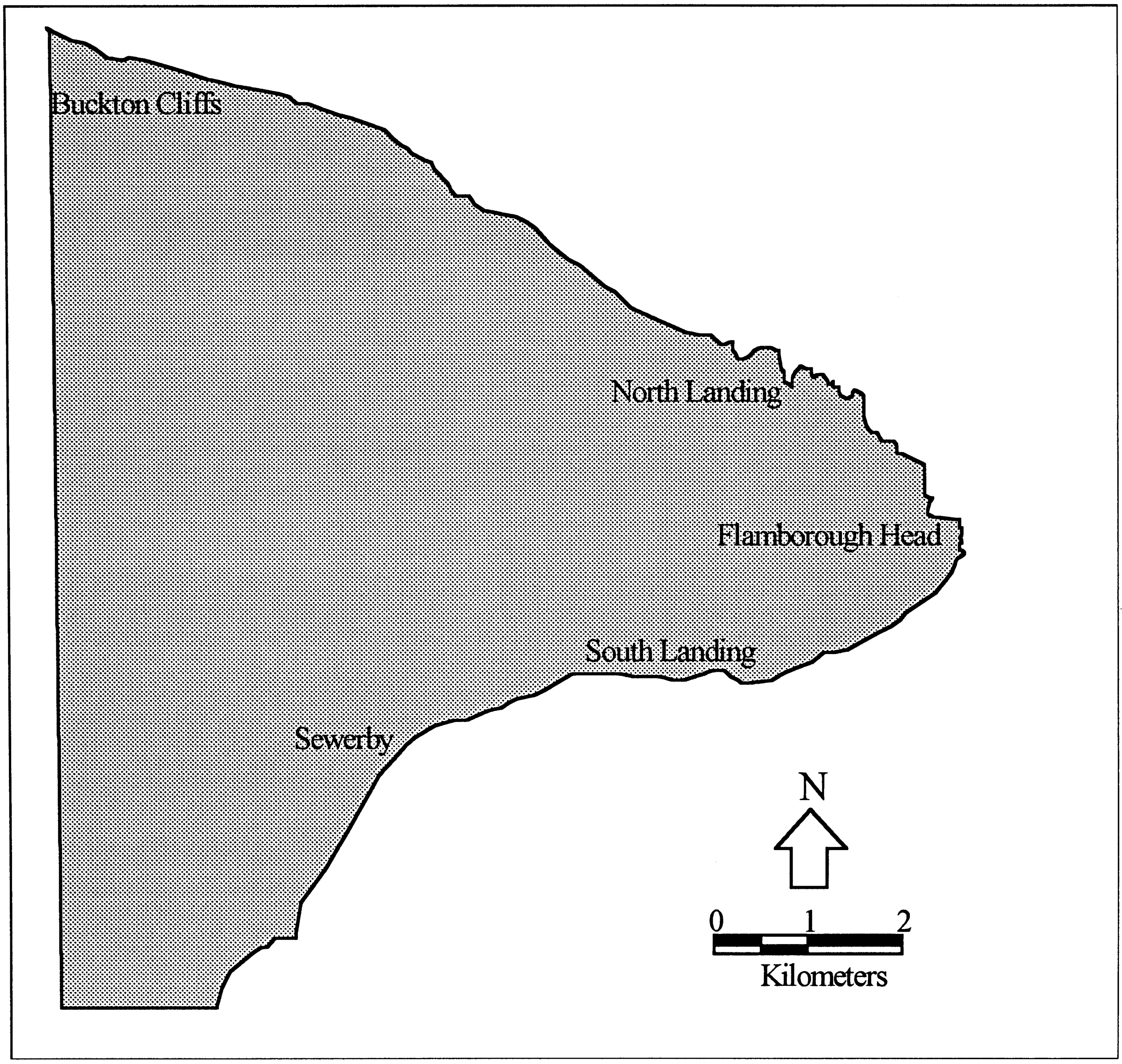

Figure 1 Location of survey area

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 bean 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 increasing with depth. Scanning sonar are considerably more expensive than vertical sonar and the results more difficult to interpret. A *RoxAnn* processor samples the return echo from a 200 kHz echo sounder which has a 17° beam width; Chivers *et al* (1990) provide a detailed description of this system. Position data were provided by a Global

Positioning System (GPS) using a differential receiver with an accuracy of ± 15 m (Trimble™ GPS with Scorpio Marine™ differential receiver). *RoxAnn* data were saved at 5 sec time intervals on a laptop computer; the computer also supplied time and date for each data point. Whilst the boat travels 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.

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 with 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 7 kn., a data point was saved every 20 m horizontal distance.

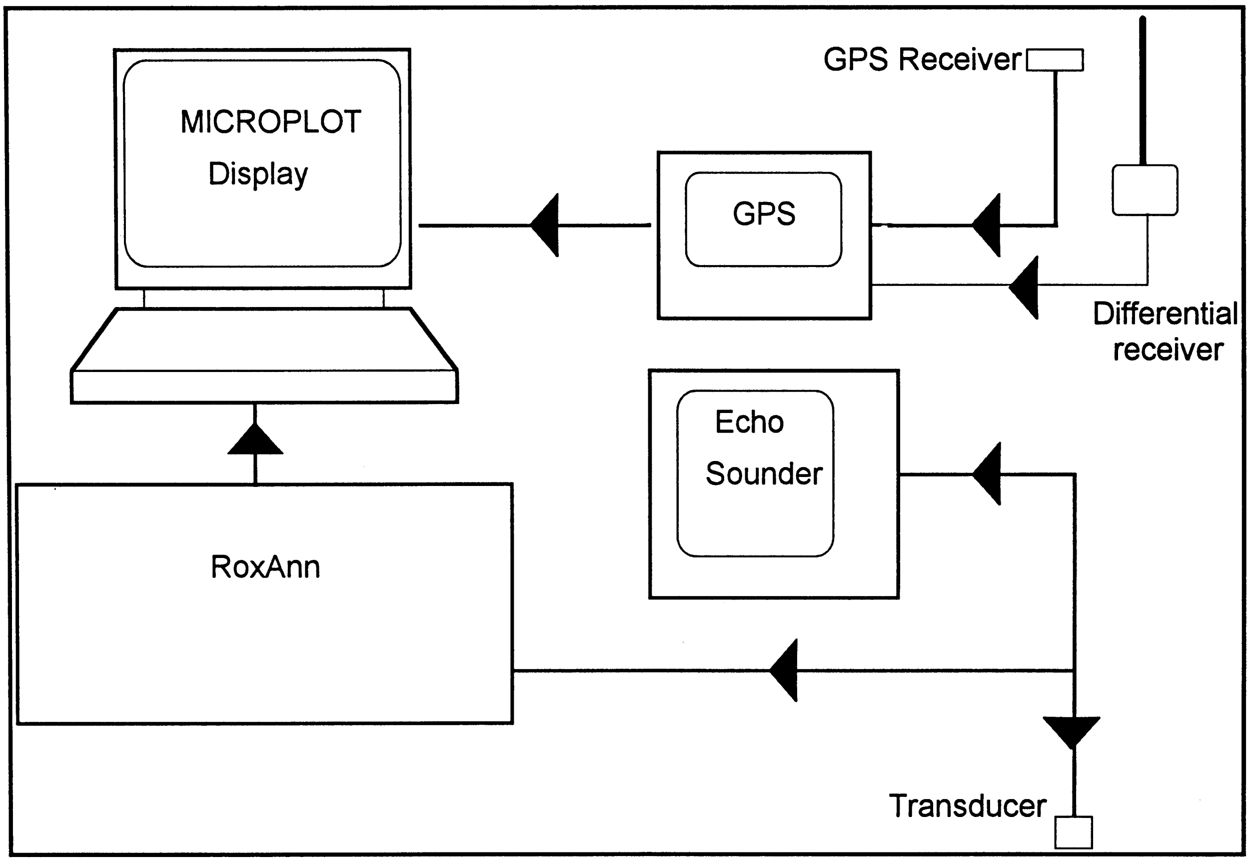

Figure 2 Schematic diagram of acoustic survey equipment

Acoustic tracking

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

Biological sampling

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 towed video recorder and supplemented by grab sampling for sedimentary habitats. The term biotope embodies both the physical habitat and the associated biological assemblage (Connor *et al.* In press). A small remote video system using a standard Hi8 camcorder in a waterproof housing mounted into a small sledge was the principle 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. Grab samples provided sediment for particle size analysis. Data from previous investigations by the Marine Nature Conservation Review of the Joint Nature Conservation Committee were used for additional ground validation information (Brazier *et al.* In prep).

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

Data analysis

All data analyses were undertaken using proprietary software on a desktop personal computer (PC): a central aim of the BioMar project is developing 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 within the *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

Biotopes descriptions were compiled from video recordings which were analysed for their physical and biological characteristics. The terminology used for describing physical characteristics followed the methods for the Marine Nature Conservation Review of the Joint Nature Conservation Committee (Hiscock, 1990). 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 (Brazier *et al.* 1995; Connor *et al,* In press). Whilst it was possible to distinguish some individual biotopes (and even to detect variations within a biotope type) using remote video, to achieve a consistent level of detail in the final biotope map it was necessary to group biotopes into generic categories or life form groupings; for instance one grouping could be 'circalittoral faunal turf' where it was difficult to distinguish between erect hydroids and erect bryozoans on a video recording.

Sediment samples were analysed for particle size distribution on the Wentworth scale following standard granulometric procedures (Buchanan 1984). It was not possible to analyse the sediment samples to determine their infaunal component and hence sedimentary areas were characterised and described by their particle size composition.

Matching acoustic data to biotopes

Matching biotopes to acoustic properties of the sea floor enables the distribution of biotope categories to be shown on a map. Initial matching was undertaken within *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) *ArcInfo* (Environmental Systems Research Institute Inc., 1992) and *MapInfo* (MapInfo Corporation). GIS provides the facility to accurately select track data adjacent to sample stations so acoustic limits can be determined for each biotope category. In addition, GIS has extensive cartographic facilities to produce the biotope 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 hourly by taking the hour from 30 minutes before to 29' 50" after the hour: *i.e.* the correction for 12:00 would be applied to data from 11:30:00 to 12:29:59. These data were transferred to the contouring program *Surfer for Windows* to produce bathymetric 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 *krigging* was most suited to random data points (Rossi *et al.* 1992). *Surfer for Windows* provides a krigging algorithm to reduce the track data to a rectangular grid of data points for the survey area; a grid size of 100 m by 100 m was selected for the present project.

Results

Flamborough Head was surveyed by the BioMar team from August 8-12, 1994. The following data were obtained from this survey:

i The area surveyed extended from Bridlington to Bempton, to an approximate offshore limit of 5 km. A *RoxAnn* track spacing of approximately 250 m was maintained throughout the survey area - see Figure 3

ii 49 video samples and two granulometric samples were collected (Appendix & Figure 5). Analyses of these samples were undertaken describe the major biotopes in the survey area.

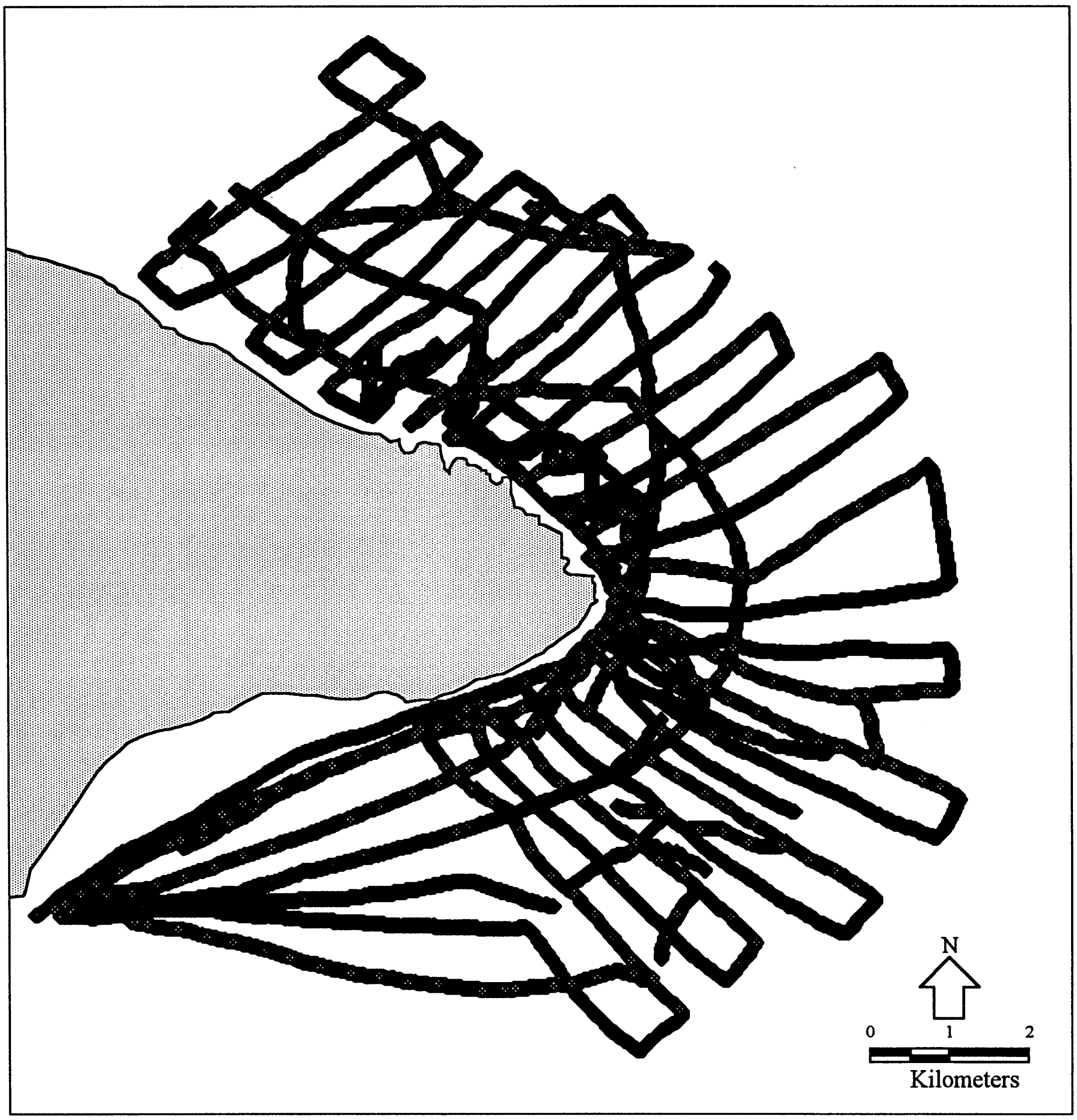

Figure 3 Location of the acoustic track around Flamborough Head

Bathymetry

A bathymetry map was compiled for the survey area (Figure 4).

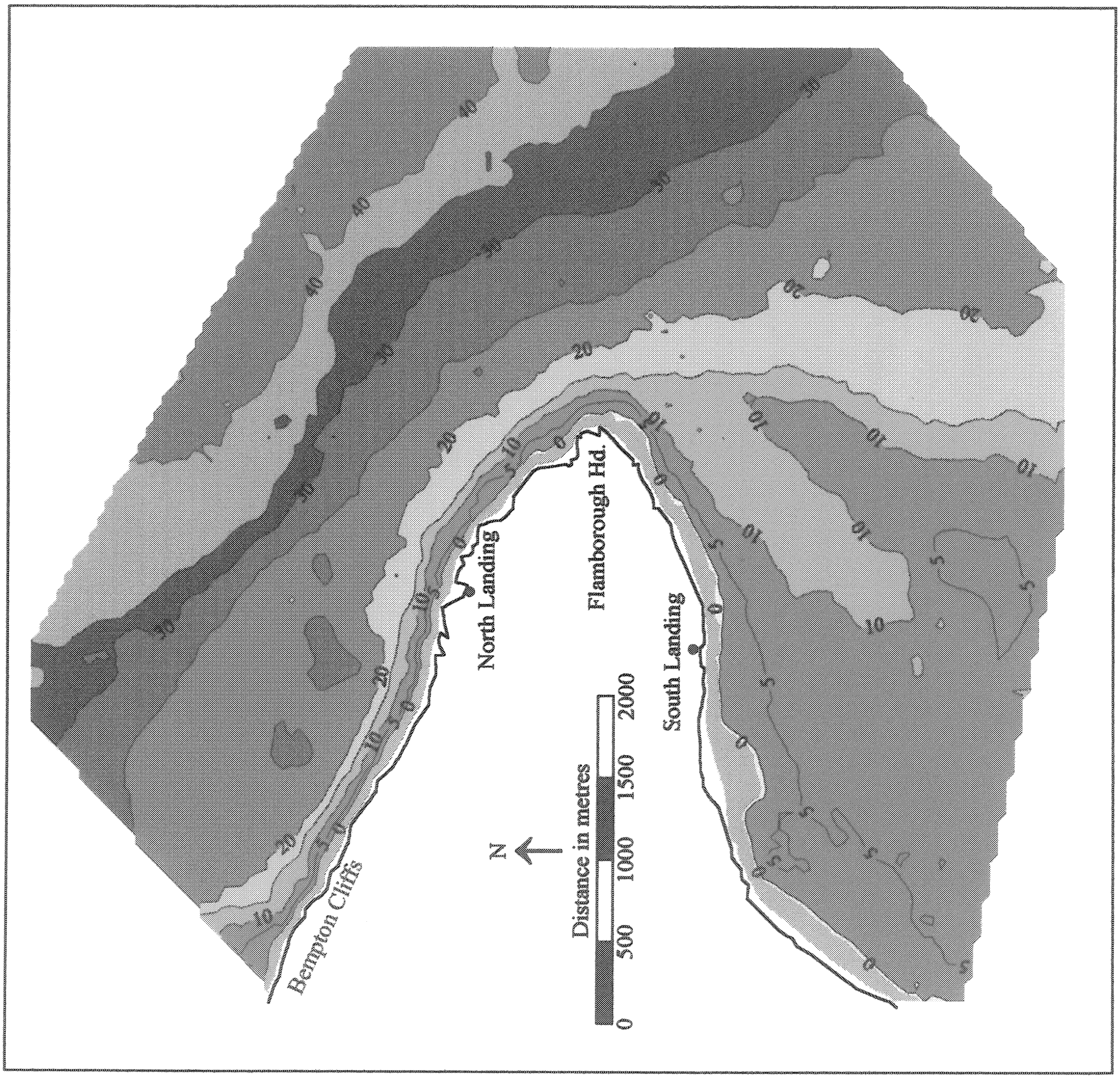

Figure 4 Bathymetry around Flamborough Head

Biotope descriptions

Twelve generic biotopes were identified from the video and sediment samples (Table 1). Figure 5 illustrates the biotopes present at each sample station.

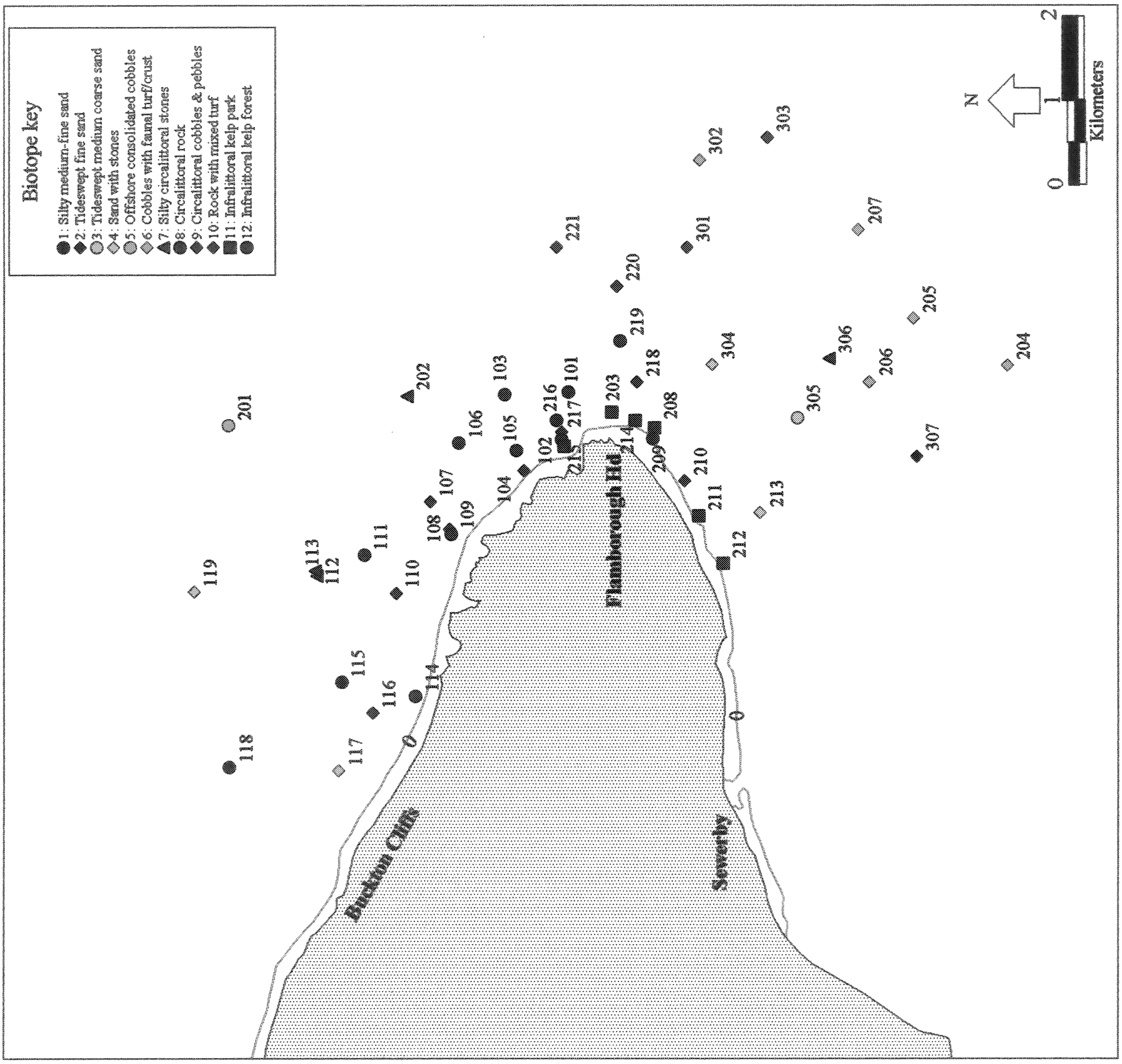

Figure 5 Location of video stations; Station number corresponds to video id in Appendix 1. Stations are coded by biotope as listed in Table 1

Table 1 Biotopes identified from ground validation stations. Sample code refers to the sample stations listed in Appendix 1.

Code	Biotope	Description	Sample code
1	Silty medium-fine sand with echinoderms	A level seabed of medium-fine sand with some broken shells on the surface (< 5%). Very sparse epibiota with starfish *Asterias rubens* and brittlestars *Ophiura ophiura* rare. Some burrows and mounds were observed although no infaunal samples were collected.	115; 118
2	Barren tideswept fine sand	Rippled fine sand (80%) subject to very strong tidal streams. Sediment appeared to be highly mobile and barren - no epibenthic or infaunal organisms were observed.	307
3	Barren tideswept medium-coarse sand	A plain of rippled medium (45%) and coarse sand (45%) with shell debris. Sediment highly mobile with some coal fragments on the surface. No epibenthic or infaunal organisms were observed.	305
4	Sand with stones with sparse faunal turf	Level seabed of sand overlying rock and stones (approximately 20-50%) - cobbles, pebbles and boulders - subject to strong tidal streams. Rock strongly scoured with a sparse epibiota of erect bryozoans (occasional) and starfish (rare) - *Asterias rubens.*	116; 117; 119; 211; 213; 304
5	Offshore consolidated cobbles	Plain of consolidated cobbles and pebbles with broken shells and sand/silt in the interstices; habitat was subject to strong tidal streams. Habitat was recorded in deep water (> 30m) offshore. Stones supported a sparse faunal turf of hydroids (rare), with starfish *Asterias rubens* (rare) and anemones *Urticina felina* (rare). A single holothurian was observed burrowing within the sediment between the stones. This biotope is an offshore variant of biotope 6.	201
6	Consolidated cobbles with faunal turf and faunal crust	Level plain of consolidated cobbles and pebbles with broken shells and sand/silt in the interstices; habitat was subject to moderate or strong tidal streams. Stones supported a sparse faunal turf comprising erect bryozoans (occasional to frequent) - *Flustra foliacea* (rare), and a faunal crust (occasional) - mainly keelworms *Pomatoceros* sp.. Largest stones supported the most diverse assemblages including rare erect sponges (*Haliclona* sp.) At site 205, the cobbles had distinct colonies of *Sabellaria spinulosa* (common) attached forming 'balls' on the surface of the sea bed.	204; 205; 206; 207; 302
7	Silty circalittoral stones with faunal turf	Habitat comprised very heavily silted mixed boulders cobbles, and pebbles with a sparse faunal turf subject to strong tidal streams. Epibiota were mostly erect bryozoans (occasional) - *Flustra foliacea*, with rare anemones *Urticina felina*, starfish *Asterias rubens* and *Crossaster papposus*, and the crab *Cancer pagurus*. Sediment overlying the rock appeared to be highly mobile which will result in high sand scour.	112; 113; 202; 213; 303; 306

8	Circalittoral rock and boulders with faunal turf	Rugged, heavily silted bedrock and large boulders in the lower circalittoral subject to strong tidal streams. Patches of coarse sand and cobbles were present on the rock and within gullies. Biota were characterised by a faunal turf (approximately 50-80% cover) comprising erect bryozoans (abundant), mainly *Flustra foliacea* (common to abundant) with *Alcyonidium diaphanum* (occasional), hydroids (common) - *Thuiaria thuja*, *Nemertesia antennina*, *Tubularia indivisa*, and *Sertularia argentea*, dead man's fingers *Alcyonium digitatum* (common), and erect sponges (occasional) - *Haliclona* sp.. Occasional faunal crusts were observed - keelworms *Pomatoceros* sp., sponges - including the boring sponge *Cliona celata,* and bryozoans, mostly on vertical surfaces. A dense population of the anemone *Urticina felina* was recorded in sediment between rock outcrops at site 111.	102; 103; 105; 106; 108; 109; 111; 114; 216; 217; 219
9	Circalittoral cobbles & pebbles with faunal turf	A mixture of heavily silted small boulders, cobbles and pebbles in the lower circalittoral subject to strong tidal streams. Biota were characterised by a faunal turf (approximately 50-80% cover) comprising erect bryozoans, mainly *Flustra foliacea* (common to abundant) with *Alcyonidium diaphanum* (occasional), hydroids (common) - *Thuiaria thuja*, *Nemertesia antennina*, *Tubularia indivisa*, and *Sertularia argentea*, and dead man's fingers *Alcyonium digitatum* (frequent). Occasional faunal crusts were observed - keelworms *Pomatoceros* sp., sponges and bryozoans. At site 218, the stones had a dense carpet of mussels *Mytilus edulis* (super abundant). At this site, edible crabs *Cancer pagurus* and plaice *Pleuronectes platessa* were occasional.	107; 108; 110; 116; 218; 220; 221; 301
10	Lower infralittoral and upper circalittoral rock with mixed turf	Lower infralittoral and upper circalittoral bedrock and boulders between 5-8 m characterised by a mixed turf of red algae (20-50% cover), hydroids (occasional) and erect bryozoans (occasional), and a mixed crust of coralline algae, sponges and colonial ascidians. Rock was rugged with many short (< 1m) vertical steps/gullies with a covering of fine sand and silt. Steep and vertical surfaces were dominated by epifauna, the algae dominating upward facing rock. Small patches of coarse sand and pebbles were present on the rock and within gullies. Biotope subject to strong tidal streams.	104; 203; 210; 210; 211; 217
11	Infralittoral rock with *Laminaria hyperborea* park	Rugged, silty bedrock and large boulders in the lower infralittoral (< 5 m) characterised by a kelp *Laminaria hyperborea* park. Kelp plants were occasional to frequent, with the rock covered with a dense turf of green, red and brown algae (approximately 80% cover). Vertical surfaces had a faunal turf characterised by colonial ascidians and sponges, with brittlestars (*Ophiopholis aculeata*) in crevices. There were small patches of sand, pebbles and small boulders within gullies.	208; 211; 212; 214; 215; 203
12	Infralittoral rock with *Laminaria hyperborea* forest	Rugged upper infralittoral bedrock characterised by a dense forest of the kelp *Laminaria hyperborea* with a lush turf of red and brown algae on the kelp stipes and the rock below the kelp canopy. A sparse epifauna, mostly encrusting sponges, were present on the kelp stipes and kelp holdfasts; the hydroid *Obelia geniculata* and the bryozoan *Membranipora membranipora* were present on the kelp fronds.	101; 209

Each generic biotope listed in Table 1 incorporates a number of Marine Nature Conservation Review biotopes (Brazier *et al.* 1995) (Table 2).

Table 2 A comparison between the biotopes identified by the BioMar and the MNCR surveys; *MNCR Code* refers to Brazier *et al.* (1995)).

BioMar Code	BioMar generic biotope	MNCR Biotope	MNCR Code
1	Silty medium-fine sand with echinoderms	Sublittoral muddy sand and gravel with echinoderm species	R5.65
2	Barren tideswept fine sand	Moderately exposed fine sand with polychaete and bivalve species	R5.43
3	Barren tideswept medium-coarse sand	*No corresponding biotope*	
4	Sand with stones with sparse faunal turf	Sand influenced, infralittoral bedrock, boulders and cobbles with *Laminaria* spp. park and *Halidrys siliquosa* Stable sublittoral mixed sediment with *Melinna cristata* ◆ Stable sublittoral mixed sediment with *Polydora* spp. and *Sabellaria spinulosa*	R5.52 R5.67 R5.68
5	Offshore consolidated cobbles	Stable sublittoral mixed sediment with *Melinna cristata* ◆	R5.67
6	Consolidated cobbles with faunal turf & faunal crust	Circalittoral boulder, cobble and pebble plains with hydroids, brittlestars and *Pomatoceros triqueter* Stable sublittoral mixed sediment with *Polydora* spp. and *Sabellaria spinulosa*	R5.60 R5.68
7	Silty circalittoral stones with faunal turf	Sediment influenced bedrock and boulders with *Sabellaria spinulosa*	R5.47
8	Circalittoral rock and boulders with faunal turf	Short vertical rock faces bored by *Hiatella arctica* Limestone and chalk with *Cliona celata*, *Polydora ciliata* and bryozoan turfs Upper circalittoral bedrock & boulders with coralline algae, *Asterias rubens* and *Pomatoceros triqueter* Lower circalittoral bedrock and boulder plains with erect hydroids, *Flustra foliacea*, *Securiflustra securifrons* and *Alcyonium digitatum* Tideswept circalittoral bedrock and boulder plain with dense *Alcyonium digitatum* **	R5.48 R5.58 R5.59 R5.61 R5.62 **
9	Circalittoral cobbles & pebbles with faunal turf	Circalittoral bedrock, boulders and cobbles with *Mytilus edulis* beds Tideswept lower circalittoral cobbles and pebbles with hydroid/bryozoan turfs **	R5.63 R5.64 **
10	Lower infralittoral and upper circalittoral rock with mixed turf	Sand influenced, infralittoral bedrock, boulders and cobbles with *Laminaria* spp. park and *Halidrys siliquosa* Lower infralittoral and upper circalittoral bedrock plains with red algae, hydroids and bryozoans **	R5.52 R5.53 **

11	Infralittoral rock with *Laminaria hyperborea* park	Lower infralittoral tideswept pebble plains with sparse *Laminaria saccharina*, *Laminaria hyperborea* and filamentous and foliose red algae ◆ Lower infralittoral rock with *Laminaria hyperborea* park	R5.49 ◆ R5.50
12	Infralittoral rock with *Laminaria hyperborea* forest	Upper infralittoral bedrock with dense *Laminaria hyperborea* forest Upper infralittoral bedrock with *Laminaria hyperborea* and *Laminaria saccharina*	R5.45 R5.46

** Biotope not recorded by the MNCR within the Flamborough Head area.
◆ Biotope not recorded by the BioMar team with the Flamborough Head area.

Distribution of biotopes

Spatial distributions of these biotopes within the survey area are shown in Figure 6. It must be emphasised that this map represents the **predicted biotope 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

For each biotope, a data range was determined for E1, E2 and depth based on the acoustic track adjacent (within 50 m) to a video station. These values were applied to the whole acoustic track to produce these biotope maps. This selection process generates 'hard' boundaries between biotopes 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 separate biotope is present.

Summary of biotope distribution

Inspection of Figure 6 indicates a number of broad trends in the distribution of biotopes around Flamborough Head. East of the headland, the sea bed is ‘hard ground’ with bedrock inshore and stones offshore. Either side of the headland, there are tongues of sediment extending towards the headland from the sedimentary areas farther north and south. Bathymetry and tidal streams have a significant influence on the distribution of biotopes. Specifically, high turbidity reduces light penetration which limits algal biotopes to shallow water. Throughout the survey area, inshore habitats at a depth < 5 m were rugged bedrock, often with large gullies and steps, or rock overlain with boulders which supported kelp biotopes. Due to the rugged nature of the sea bed, it was not safe to undertake the acoustic survey close inshore and thus insufficient data were available to accurately map the kelp forest and kelp park. Nevertheless, it was possible to collect some inshore video samples which indicated that the kelp forest extended to approximately 3 m, with the kelp park extending to approximately 5 m. These results were similar to Brazier *et al.* (In prep) who reported a lower limit of kelp at 2 m around the Flamborough Headland. Between 5-8 m, infralittoral rock supported a dense turf of filamentous and foliose algae with occasional kelp plants.

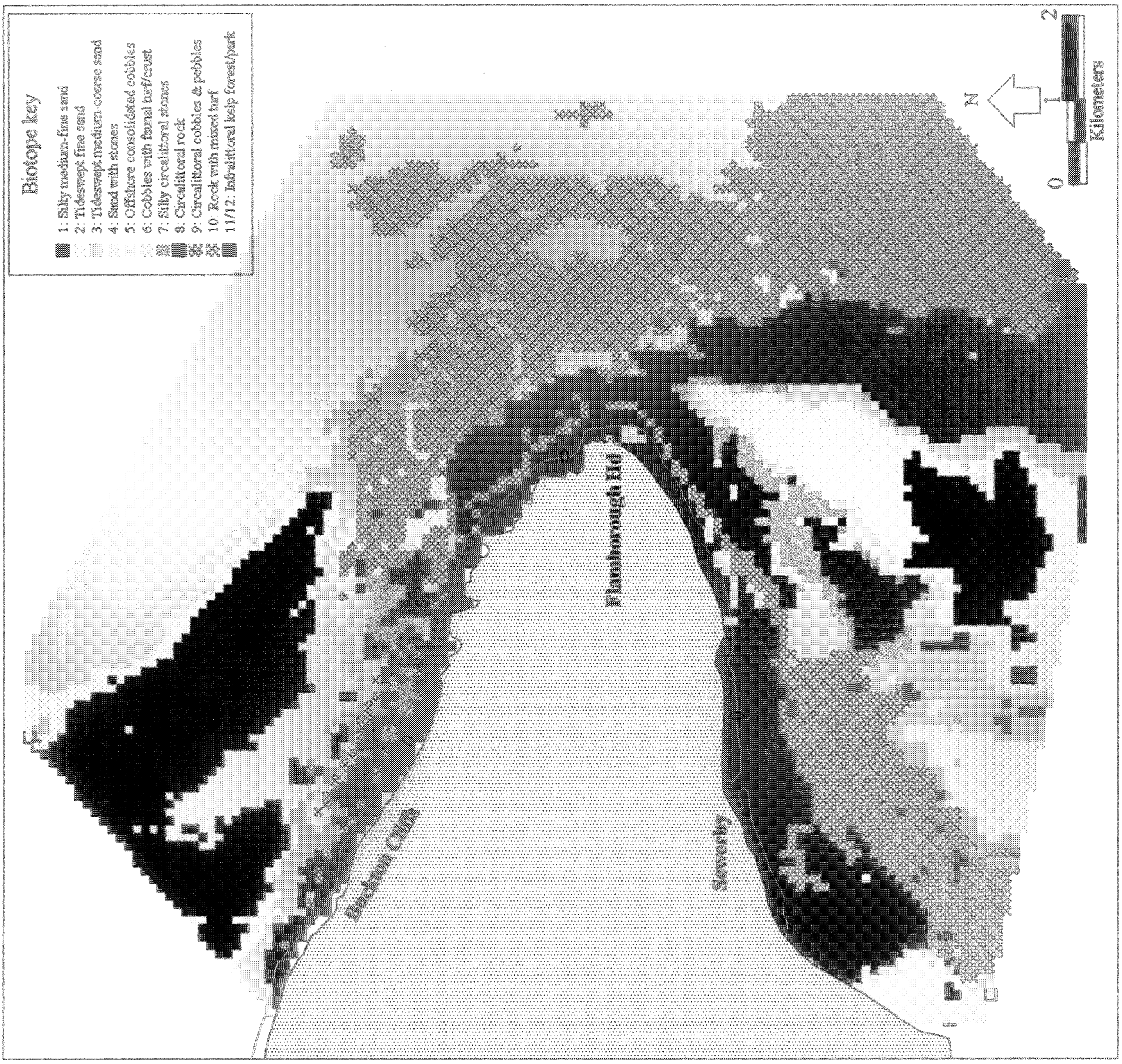

Figure 6 Predicted distribution of biotopes around Flamborough Head

Within these algal dominated habitats, vertical steps and the sides of large boulders supported animal dominated biotopes, the most notable being the assemblages of organisms boring into the soft rock. It is impossible to map biotopes on vertical surfaces other than to indicate their presence within the biotopes covering the horizontal surfaces.

East of the headland from 8-20 m, the sea bed was predominantly rugged bedrock terraces and large boulders, with patches of cobbles, pebbles and sediment overlying the rock. These circalittoral habitats supported a dense animal dominated turfs whose composition were linked to the rate of ambient tidal streams. Erect bryozoans, mainly *Flustra foliacea,* and hydroids were abundant where the tidal streams were fastest; colonies of dead man's fingers *Alcyonium digitatum* were present throughout but were most dense where the rate of tidal streams was reduced. Deeper than 20 m, the bedrock was overlain by stones and sediment although occasional outcrops were observed. Stability of the stones and the degree of siltation - which were linked to the rate of tidal streams - were the primary factors determining the biotope distribution. Stable habitats supported similar biotopes to the bedrock further inshore although the species richness was generally lower on the stones. Where the stability decreased or the degree of siltation increased, the species richness declined to the extent that the sea bed appeared barren in highly mobile areas. In general, between 20-30 m the stones were characterised by a bryozoan/hydroid turf (biotope 9) while >30 m the stones were consolidated into a pavement but subject to sand scour from overlying sediment. These offshore habitats supported a similar biotic assemblage to biotope 9 although species richness and abundance were much reduced. At station 218 located due east of Flamborough Head at a depth of 24 m, dense beds of the common mussel *Mytilus edulis* covered the cobbles where edible crabs *Cancer pagurus* and plaice *Pleuronectes platessa* were more common than any other station; this assemblage was also recorded by Brazier *et al.* (In prep). Returning to one of the stated aims of the present project, Figure 6 indicates that the offshore extent of the chalk reef was approximately 0.8 km from chart datum, although there were some rock outcrops in the areas of boulders and cobbles further offshore.

To the north west of Flamborough Head off Bempton Cliffs, the sea bed was predominantly sediment deeper than 20 m although small stones and broken shells were present in varying quantities. This 'tongue' of sediment was mainly fine sand with the underlying rock and stones appearing along the edge. Offshore habitats deeper than 30 m were mostly consolidated stones, or stones overlain with sediment, which supported a sparse turf of hydroids and bryozoans (biotopes 4-6). Figure 6 indicates that the offshore extent of the chalk declines with increasing distance north: at the northern limit of the survey area the chalk extended 0.3 km offshore from chart datum.

Similarly to the south of the headland, there is a narrow, shallow sediment bank, Smithic Bank, which extends to the south west gradually broadening out into a sediment plain. At its northern end, this bank is subject to fast tidal streams and the sediment is highly mobile and no epibenthic organisms were recorded. Sediment mobility results in a boundary zone either side of the bank where the underlying rock is periodically covered/uncovered and thus highly scoured. Few epibenthic organisms can survive in such a hostile environment and the rock surface appears devoid of life. Whilst Figure 6 indicates biotope 8 was present between 10-20 m, the species present will depend on the degree of scour. Further offshore beyond 20 m, the rock was overlain with cobbles and pebbles which supported a turf of hydroids and bryozoans (biotope 9). Figure 6 indicates the bedrock (chalk) extends south as a distinct band, approximately 1 km wide to the east of Smithic Bank to the southern limit of the survey area. In contrast, Figure 5 shows that the video samples within this area revealed the cobble sea bed supporting a faunal turf/crust (biotope 6). This is an example where the acoustic signature of the sea bed indicates the presence of a biotope although if additional physical environmental factors, such as sand scour, could be incorporated into the signature, a different biotope would be predicted. No chalk was observed to the east of Smithic Bank and thus the results predict an offshore extent of approximately 1 km from chart datum to the south of Flamborough Head.

Comparison with previous studies

Brazier *et al.* (1995) report the results of a series of marine biological surveys undertaken by the Marine Nature Conservation Review (MNCR) of the Joint Nature Conservation Committee which aimed to describe the biotopes present around Flamborough Head, and to provide data to assess the nature conservation importance of the area. Table 2 lists the biotopes defined by the MNCR (Brazier *et al.* 1995) and their relationship to the more generic biotopes defined from the BioMar video samples. These MNCR data were overlaid onto the predicted distribution of biotopes from the present survey (Figure 6) to explore the match between the two data sets. In general, there were no serious conflicts between the MNCR survey stations and the predicted biotope distribution. When considering mismatches, size of each pixel on Figure 6 (100 m x 100 m) and the accuracy of the position fixing systems should be taken into account: the BioMar survey used differential GPS (±15 m); the most recent MNCR survey used GPS (±100 m); GPS was not available to the older MNCR surveys and thus the accuracy of position will be much less (> ±250 m: Decca for example). In addition, the MNCR 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. These variations in position fixing will be most acute in shallow water where the transition from circalittoral to the infralittoral will occur over a horizontal distance within the accuracy of position fixing devices. Taking account of these factors, most conflicts between the MNCR and BioMar data sets proved lie within an envelope of acceptable error within the data.

When considering other mismatches it is important to take account of the pixel size of Figure 6 and the small scale variability which exists for most areas of sea bed. Patches of a different habitat 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 or SCUBA diver when the visibility may be 1-8 m (Brazier *et al.* 1995) may only record the patch rather than the more widely occurring habitat. Small scale variability must be considered when interpreting these biotope maps, particularly when exploring the correlation between data sets.

Opposite: This figure should be overlaid onto Figure 6 for comparison

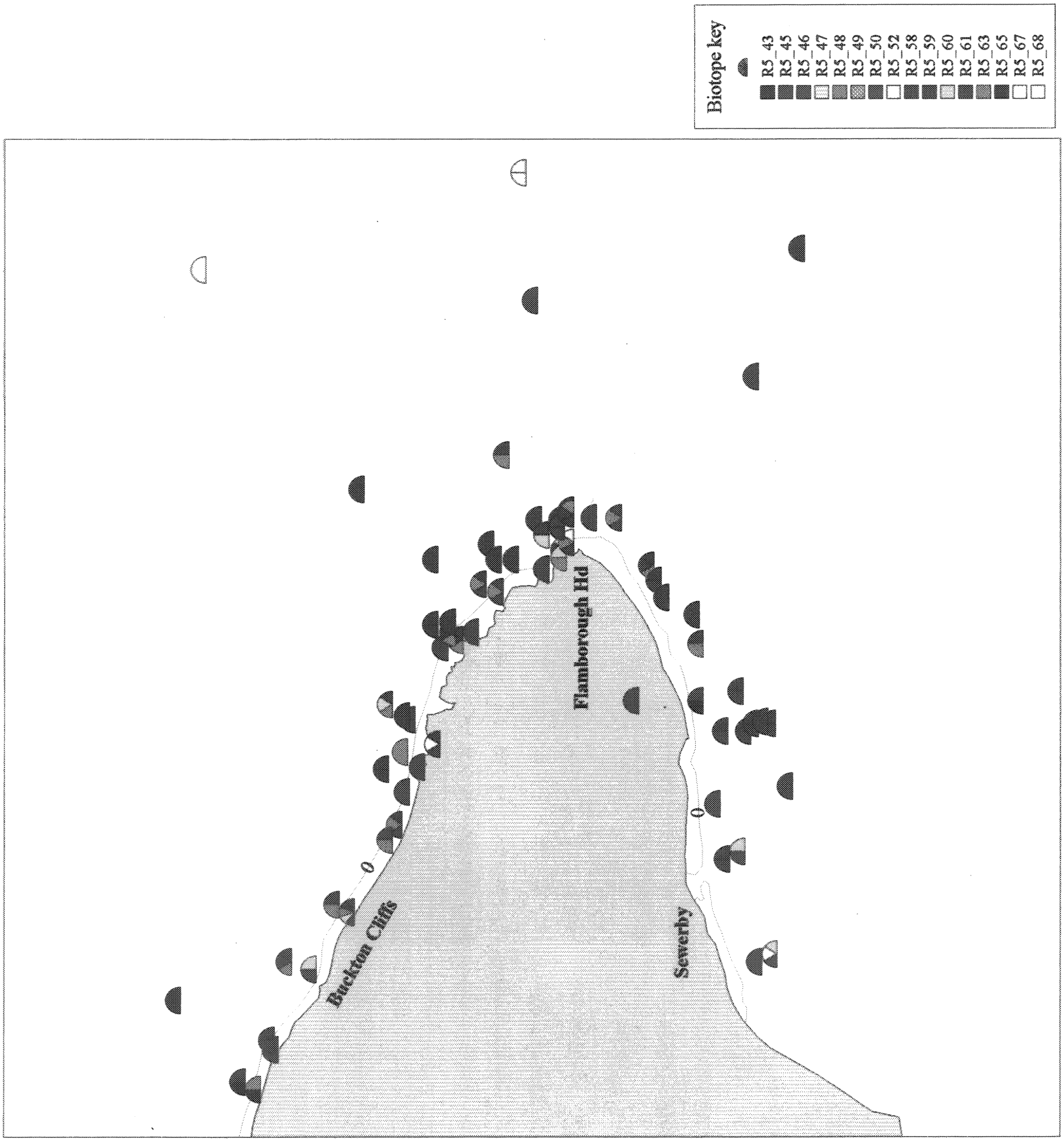

Figure 7 Biotopes recorded by the Marine Nature Conservation Review around Flamborough Head. Note: the symbols do not represent the proportion of each biotope at the station, merely their presence. Legend refers to the biotopes listed in Table 2.

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.

Brazier, D.P. 1995. The inshore marine biology of SE Scotland and NE England: biotope classification. Joint Nature Conservation Committee Report N°. 216, Marine Nature Conservation Review report: MNCR/OR/22.

Brazier, D.P. *In Prep.*. The inshore marine biology of SE Scotland and NE England: Area summaries. Joint Nature Conservation Committee

Buchanan, J.B. 1984. Sediment analysis. In: *Methods for the study of marine benthos*, second edition, edited by N.A. Holme & A.D. MacIntyre. Oxford, Blackwell Scientific Publications.

Chivers, R.C., *et al.* 1990. New acoustic processing for underway surveying. *The Hydrographic Journal, 56*, 9-17.

Connor, D.W. *et al*, In press. A classification system for benthic marine biotopes. Proceedings of 28th European Marine Biological Symposium, Crete, Sept. 1993.

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

Hiscock, K. 1990. Marine Nature Conservation Review: Methods. *Nature Conservancy Council, CSD Report*, No. 1072. Marine Nature Conservation Review Occasional Report MNCR/OR/05. Peterborough: Nature Conservancy Council.

Rossi, R.E. *et al.* 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.

Appendix: video samples and their associated biotopes

Video-id	Time	Date	Biotope
101	10:01:03	10/08/94	12
102	10:10:22	10/08/94	8
103	10:26:39	10/08/94	8
104	10:36:25	10/08/94	10
105	10:43:30	10/08/94	8
106	10:52:11	10/08/94	8
107	11:05:14	10/08/94	9
108	11:16:04	10/08/94	9.8
109	11:23:08	10/08/94	8
110	11:35:44	10/08/94	9
111	11:46:58	10/08/94	8
112	11:59:32	10/08/94	7
113	12:09:36	10/08/94	7
114	12:23:37	10/08/94	8
115	12:34:14	10/08/94	1
116	13:21:13	10/08/94	9,4
117	13:37:36	10/08/94	4
118	13:51:53	10/08/94	1
119	14:12:09	10/08/94	4
201	14:31:18	10/08/94	5
202	14:48:08	10/08/94	7
203	15:03:24	10/08/94	11,10
204	09:54:58	11/08/94	6
205	10:10:53	11/08/94	6
206	10:24:55	11/08/94	6
207	10:42:28	11/08/94	6
208	11:08:18	11/08/94	11
209	11:17:50	11/08/94	12
210	11:24:31	11/08/94	10
211	11:32:40	11/08/94	11,10,4
212	11:41:40	11/08/94	11
213	11:51:44	11/08/94	4
214	12:02:23	11/08/94	11
215	12:12:57	11/08/94	11
216	12:19:31	11/08/94	8
217	12:25:07	11/08/94	10,8
218	13:58:39	11/08/94	9
219	14:07:52	11/08/94	8
220	14:16:41	11/08/94	9
221	14:27:49	11/08/94	9
301	14:43:00	11/08/94	9
302	14:55:14	11/08/94	6
303	15:06:28	11/08/94	9
304	15:26:15	11/08/94	4
305	15:34:42	11/08/94	3
306	15:47:28	11/08/94	7
307	15:58:21	11/08/94	2