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Mapping the distribution of benthic biotopes in Falmouth Bay and the lower Fal Ruan Estuary

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BioMar

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January 1995

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A collaborative study between English Nature and the BioMar programme

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Preface

The survey of the marine environment of the Falmouth Bay and the lower Fal Ruan Estuary has been 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.

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- Sam Davies (Fal Bay Estuaries Initiative) for her assistance in planning the field survey.

Synopsis

In July 1994, the BioMar project completed a baseline survey of the lower Fal Ruan Estuary, Falmouth Bay and the east side of the Lizard peninsula to map the geographic distribution of the main biotopes. In particular, the survey aimed to map the distribution of living and dead maerl in the estuary and Falmouth Bay to provide data for English Nature. The survey of the Lizard peninsula provided data to assist the Marine Nature Conservation Review of the Joint Nature Conservation Committee select stations for a detailed resource survey.

These areas were surveyed using a RoxAnn acoustic system supported by direct observation of the sea bed using a drop-down video camera, and sediment samples collected by grab. Analysis of these data revealed 12 generic biotopes within these survey areas. Maps of bathymetry and the predicted distribution of biotopes were prepared using geographic information systems.

Living maerl was most abundant in the Fal Ruan Estuary with only small fragments recorded from the other areas. Falmouth Bay was predominantly sedimentary with the sediment mainly dead maerl or maerl derivatives. Inshore habitats along the east site of the Lizard peninsula were mostly rock supporting kelp biotopes in shallow water, and a rich faunal turf in deep water (approximately > 15 m below chart datum). Sea fans *Eunicella verrucosa* were abundant in these deep rock habitats, particularly in the vicinity of the Manacles.

Introduction

Management of living resources which are subject to exploitation requires data on their geographic extent. Maerl, a calcareous alga, forms large beds on the surface of sediment where the living maerl occurs in shallower water depths than the dead material. Living maerl beds are a fragile habitat and have a high conservation value. Dead maerl is extracted for use as a soil conditioner, an animal food additive and as a bio-filtration component. Extraction of the non-living component is a destructive process and potentially can damage the living beds. Mapping the distribution of living and dead maerl forms a very useful basis for making decisions on the best approach to managing the living resource. Therefore it was proposed that a baseline mapping survey be conducted of maerl beds at St Mawes Bank in the Fal Ruan Estuary, and in Falmouth Bay.

A baseline resource survey would have three objectives:

i Undertake a broad-scale acoustic survey to determine the geographic extent of the maerl beds and their associated major physical habitats.

ii Validate the acoustic survey by collecting benthic obervations to match the biological features with the physical habitats.

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

Maps indicating the broad distribution of biotopes are a valuable tool when planning more detailed surveys, for instance to assess the conservation value of an area. A knowledge of the biotope distribution ensures that survey stations are positioned to sample the complete range of biotopes within the survey area. In 1994, the Marine Nature Conservation Review (MNCR) of the Joint Nature Conservation Committee were planning a survey of the Lizard peninsula to determine to range of biotopes present and assess the conservation value of the area. Therefore besides Falmouth Bay and the Fal Ruan Estuary, the BioMar team surveyed the east side of the Lizard peninsula to assist the MNCR with their survey planning.

Survey area

Three areas were surveyed and are shown in Figure 1:

i Fal Ruan Estuary - only the lower estuary was surveyed from Mylor River south to the entrance, which included St Mawes Harbour but excluded Falmouth Harbour.

ii Falmouth Bay - the area surveyed extended from Porthmellin Head to the east, and Nare Point to the south west.

iii Lizard - the area surveyed extended south from Nare Point to Black Head.

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 in a geographic information system (GIS).

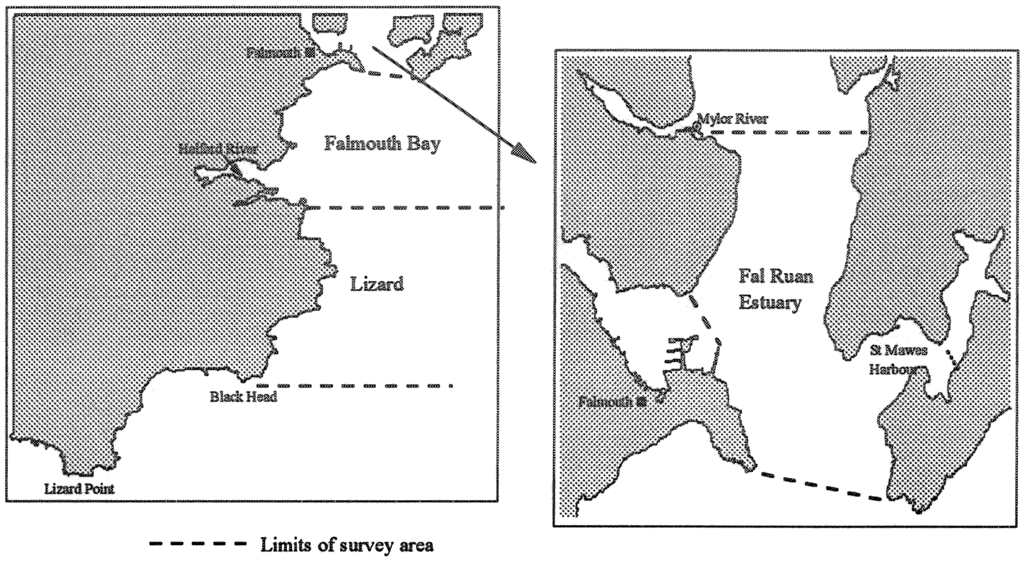

Figure 1 Location of survey areas

Acoustic surveying

Acoustic surveys of the sea bed were undertaken using a *RoxAnn* processor which samples the return echo from a 200 kHz echo sounder; Chivers *et al* (1990)) provide a detailed description of this system. In addition to depth, *RoxAnn* generated two measurements derived from the first (E1) and second (E2) echoes which were interpreted as measures of roughness and hardness of the sea bed respectively. Positional data were provided by a Global Positioning System (GPS) using a differential receiver with a published 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, 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 E1 and E2 or by depth, superimposed on a chart of the coast.

Acoustic tracking

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 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 which results in the contagious distribution of 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 (1 km) and then heterogeneous areas, or areas of specific interest, were tracked in more detail (0.25 and 0.125 km spacing) to determine the spatial organisation of sea bed characteristics.

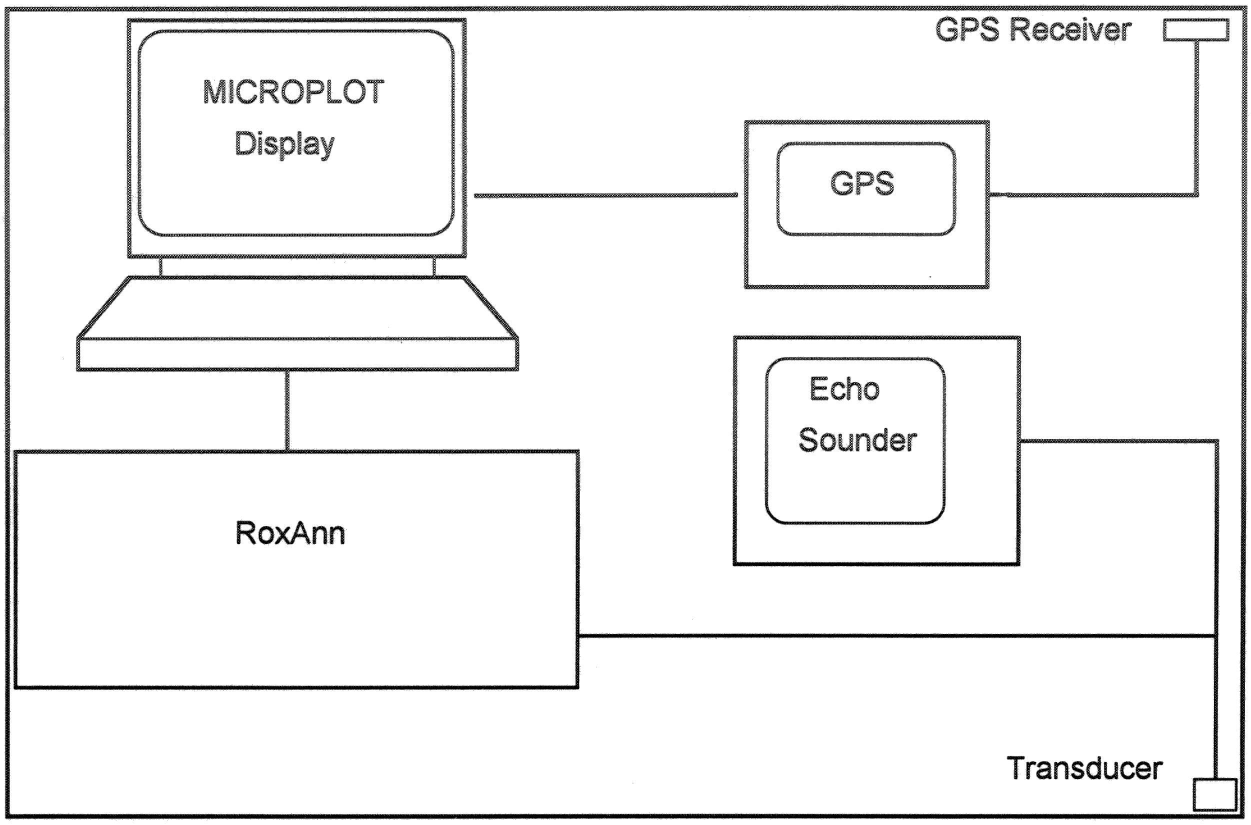

Figure 2 Schematic diagram of acoustic survey equipment

Sampling

Acoustic mapping using the *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 (biotopes), 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. 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. Where available, data from previous investigations were used for additional ground validation information.

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 (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 addtion, 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

The three areas were surveyed during the period 4-8 July, 1994 at varying levels of detail:

i Lower Fal/Ruan Estuary from Mylor Creek to the estuary mouth, including St Mawes Bank at a track spacing of approximately 250 m (Figure 3).

ii Falmouth Bay from Porthmellin Head to the entrance to Nare Point was surveyed with a track spacing of approximately 250 m (Figure 4).

iii East side of the Lizard peninsula south from Nare Point to a southern limit of Black Head was surveyed with a track spacing of approximately 1 km (Figure 5).

Within these areas, data were collected from 67 video stations and eight grab sample stations (see Figure 9 & Appendix 1).

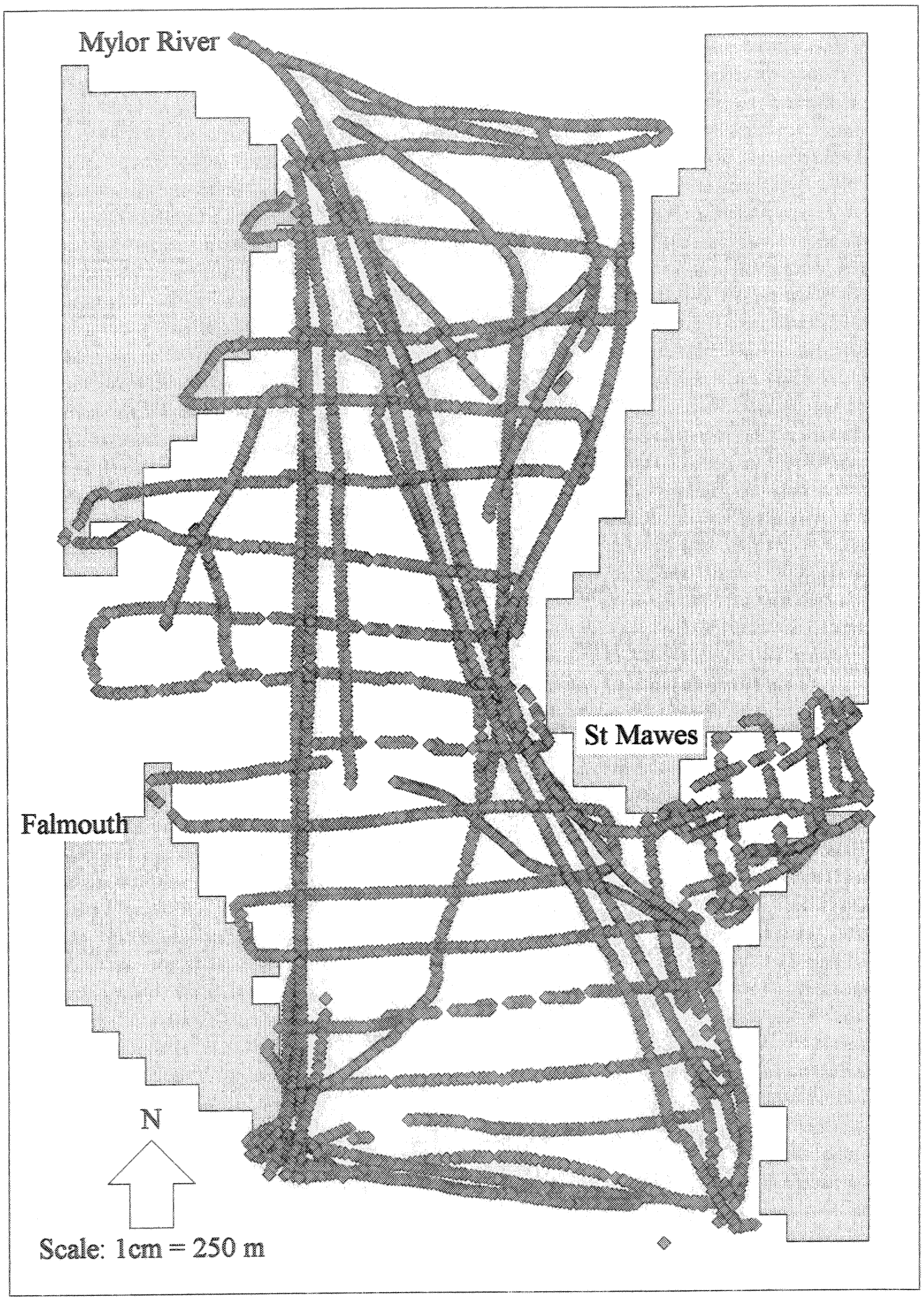

Figure 3 Location of the acoustic track in the lower Fal Ruan Estuary

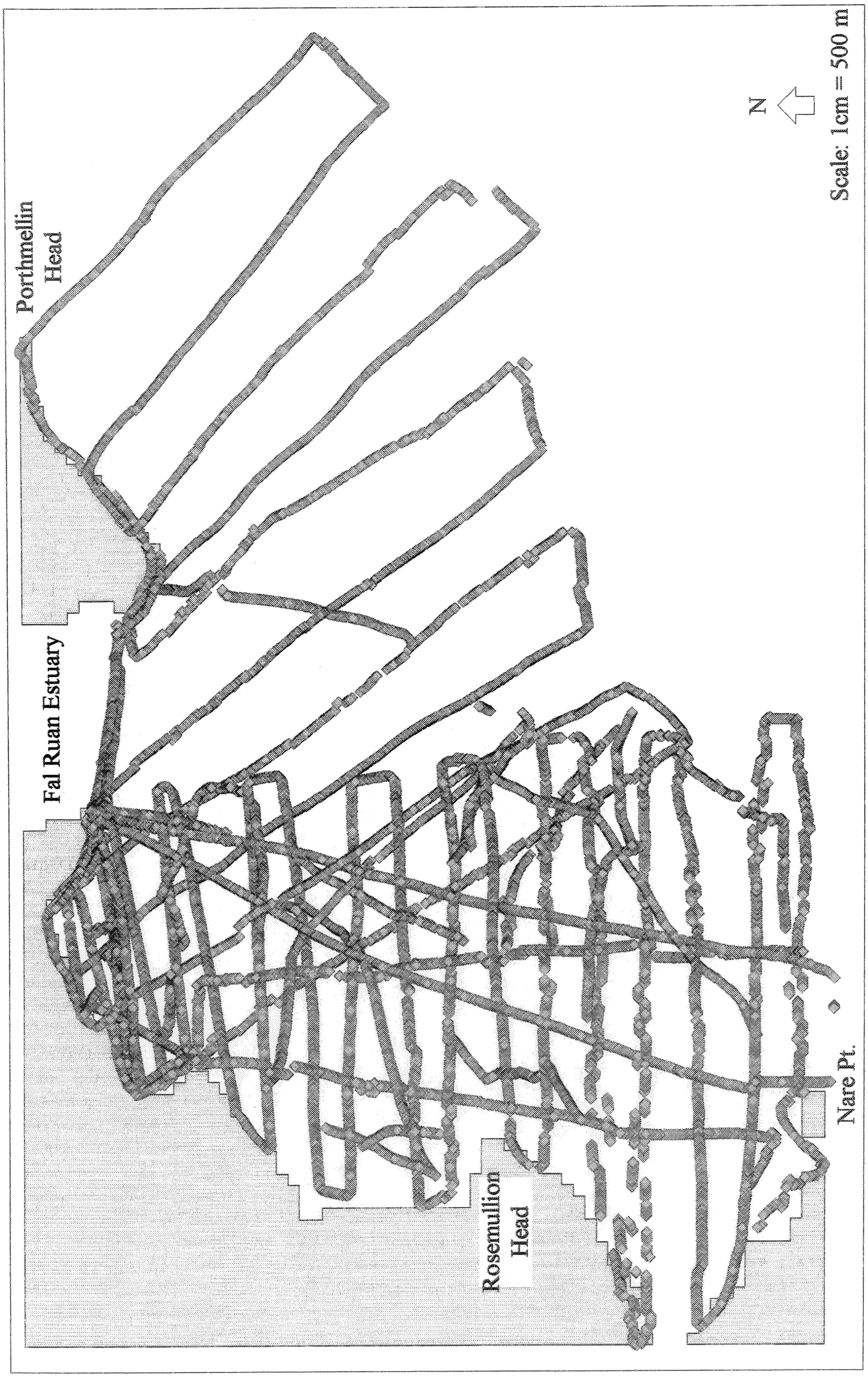

Figure 4 Location of the acoustic track in Falmouth Bay

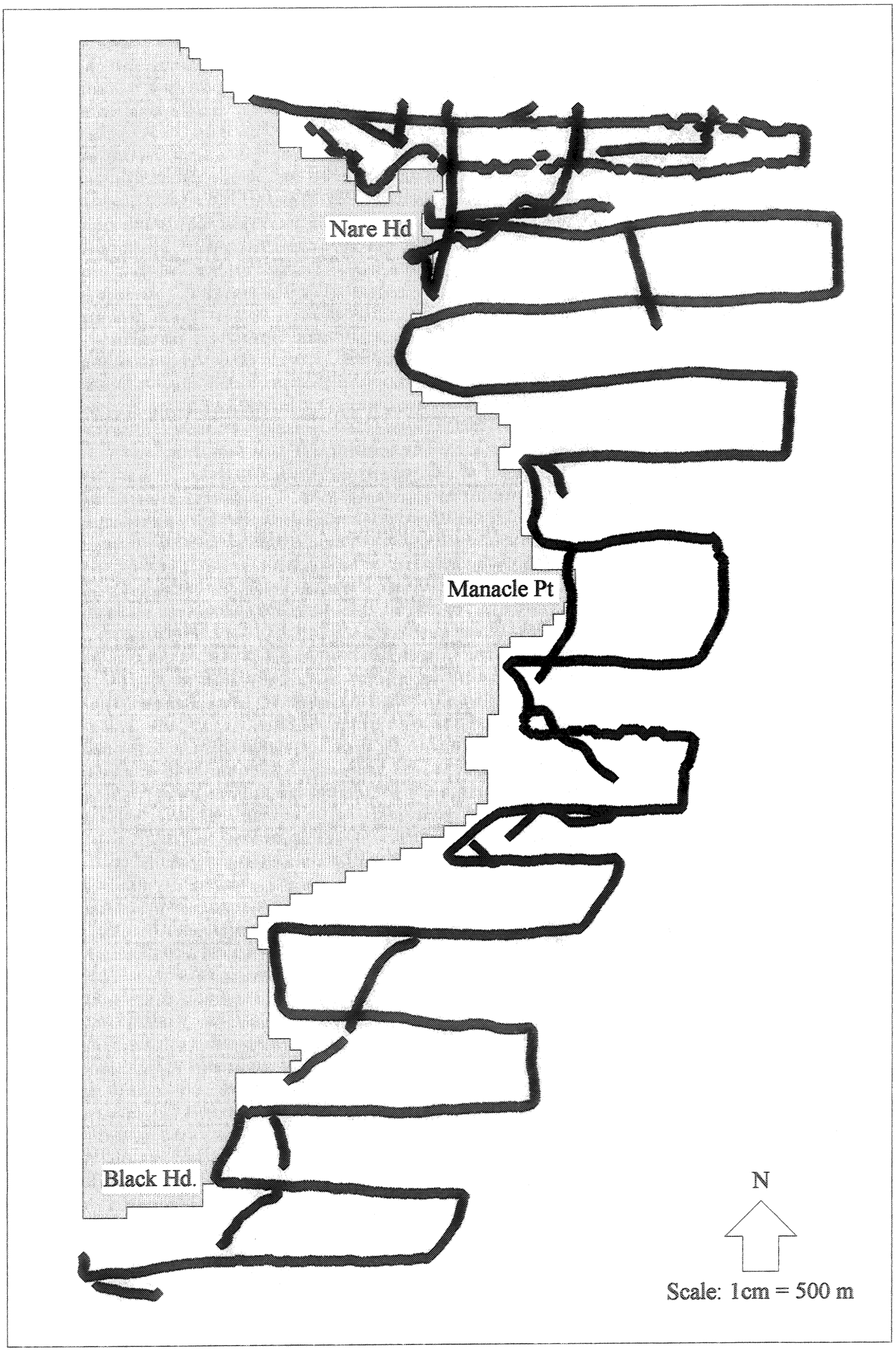

Figure 5 Location of the acoustic track off the Lizard

Bathymetry

A bathymetry map was compiled for each survey area (Figures 6-8).

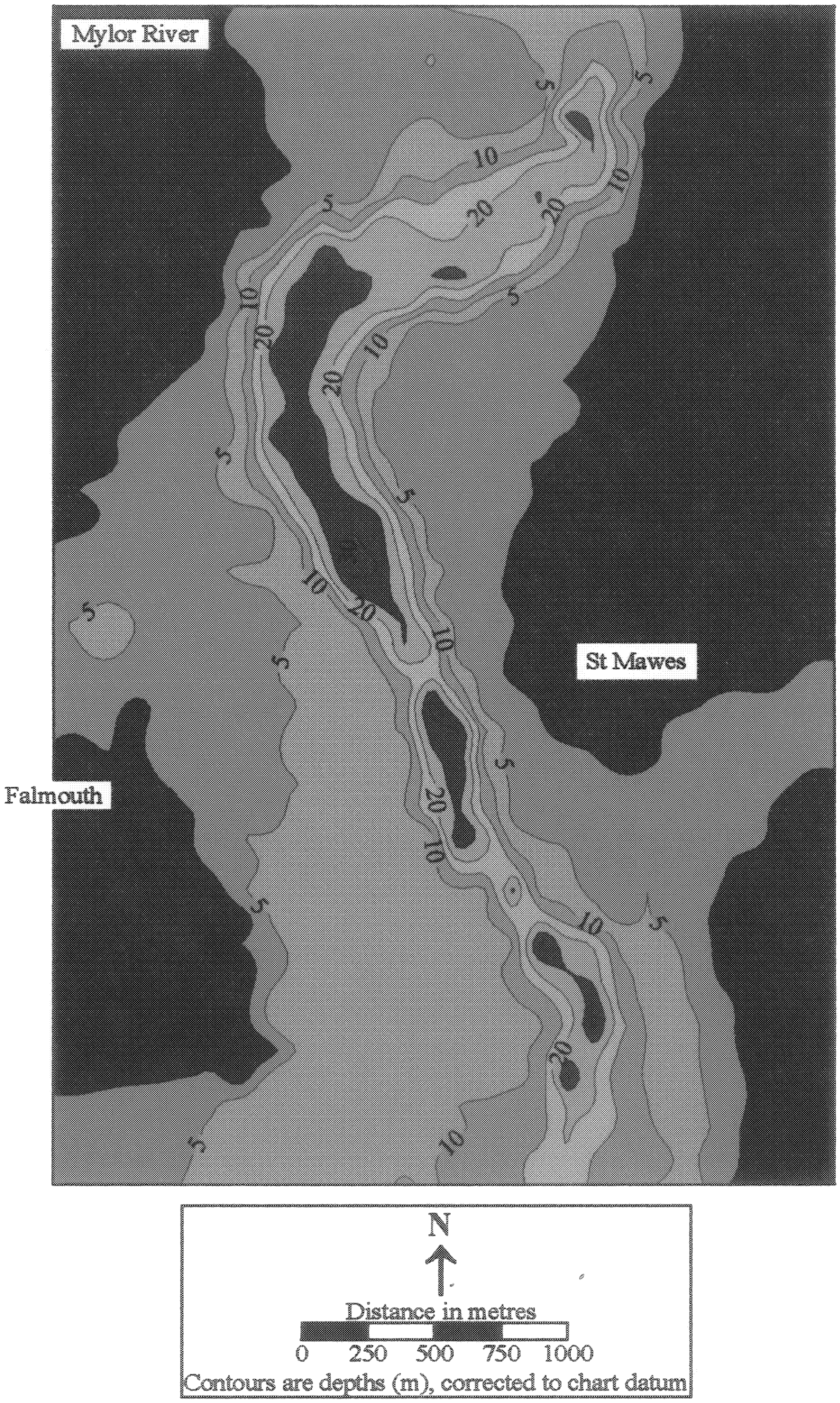

Figure 6 Bathymetry for the lower Fal Ruan Estuary

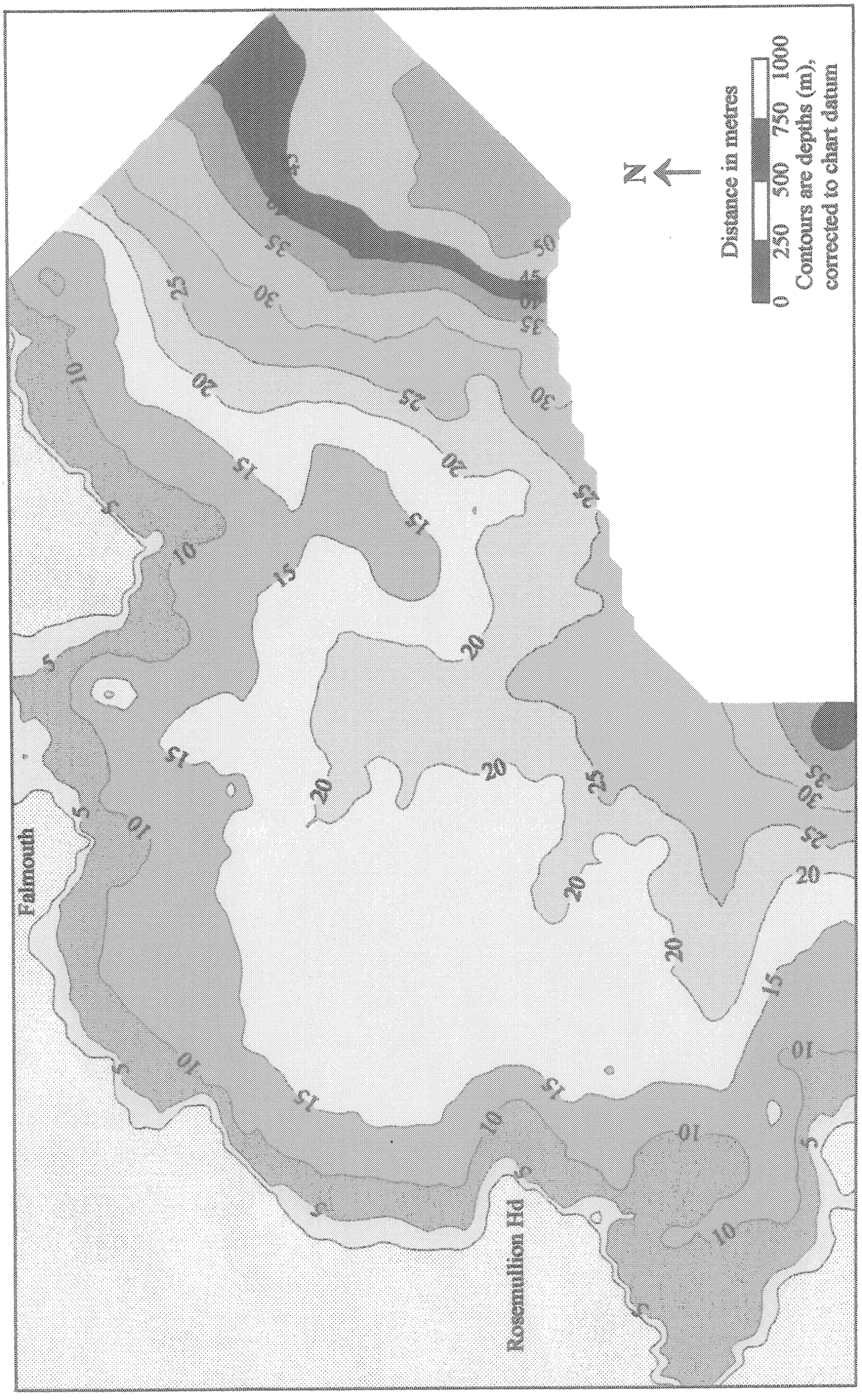

Figure 7 Bathymetry for Falmouth Bay

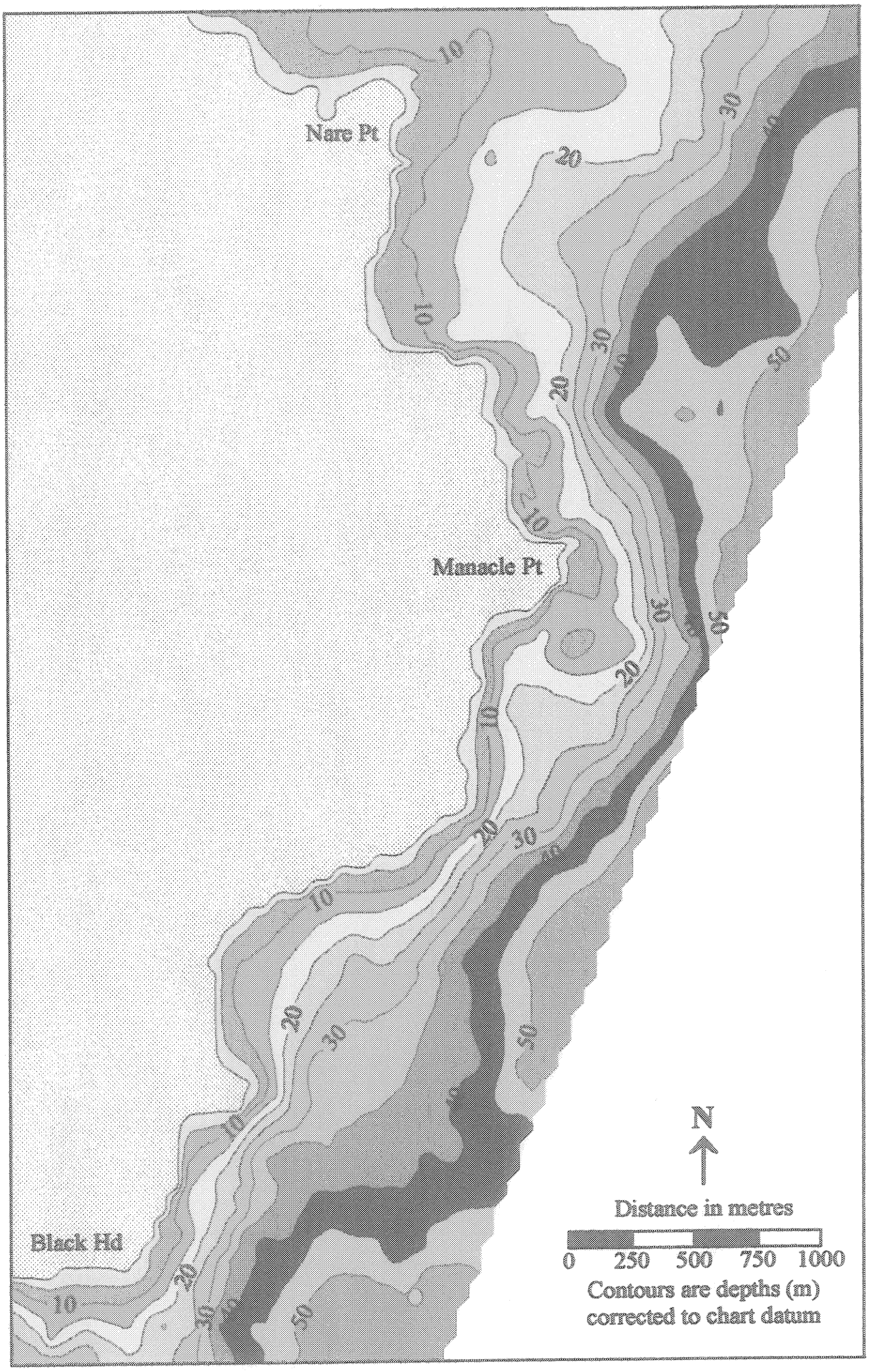

Figure 8 Bathymetry for the east side of the Lizard

Biotopes descriptions

Twelve generic biotopes were identified from the ground validation samples (Table 1). Each generic biotope listed in Table 1 will incorporate a number of Marine Natture Conservation Review biotopes (Connor *et al.* In press); the actual number will vary and has not been enumerated for the present report.

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	Fine sand	Sea bed comprised level fine sand with occasional shell and maerl fragments. Epifauna were sparse with occasional echinoderms - *Marthasterias glacialis, Ophiura ophiura.* No data on the infaunal assemblage although some burrows & mounds were observed; *Amphiura* sp. were observed at 223. In the Fal Ruan Estuary drift algae were observed on the seabed.	5; 223; 308; 415; 419
2	Coarse & medium sand	Coarse and medium sand were recorded in more exposed locations than biotope 1. Sediment was generally level although ripples and small waves were present. Coarse sand was derived from broken shells, maerl fragments and occasional gravel. In shallow water (< 15 m), filamentous red algae were attached to the larger fragments. Epibenthic organisms were very rare. No infaunal data were collected although burrows and mounds were observed.	8; 103; 201; 304; 314; 410; 416
3	Medium sand with *Laminaria saccharina* and *Chorda filum*	Biotope was recorded in St Mawes Harbour and comprised a plain of medium-fine sand with *Laminaria saccharina* and *Chorda filum* at an abundance of 'occasional' to 'frequent'.	408; 409
4	Intact dead maerl, swept into waves with sparse algal turf	A coarse sediment habitat where the sediment comprised intact dead maerl with distinct branches approximately 10 mm long, empty shells (5%) and small pebbles/gravel (5%). Sediment was swept into waves by water movement - maerl formed the waves with the empty shells and pebbles concentrated into the troughs. Occasional patches of sediment were visible within the maerl. At depths < 15 m, filamentous red algae were attached to the shells and small pebbles at approximately 1% cover; occasional kelp plants were recorded in shallow (< 10 m) water. Some fragments of living maerl were observed on the top of the waves. Few organisms were observed on the sea bed with occasional starfish - *Marthasterias glacialis* - and crabs - *Cancer pagurus.* The holothurian *Neopentadactyla mixta* were recorded as 'rare' within the maerl.	4; 105; 106; 206; 207; 209; 210; 212; 217; 219; 307; 405

5	Crushed maerl, coarse sand & shells with sparse algal turf	A coarse sediment habitat similar to biotope 4 except the maerl was crushed into smaller fragments and only small undulations (rather than large waves) were observed. Shells and stones comprised a higher proportion of the sediment - approximately 15-20 % in total. Filamentous algae were present in shallow water with the percentage cover reaching 20% at station 205. Epifauna were similar to biotope 4.	202; 205; 208; 216; 225
6	Coarse sediment with sparse fauna turf	A coarse sediment habitat which comprised a plain of coarse sand generally with a veneer of dead maerl lying on the surface; maerl was mostly small crushed fragments. Empty shells and stones were present but comprised < 5% of the sediment. In general, this biotope was recorded in deeper water than biotopes 4 & 5, with hydroids and erect bryozoans attached to stones and shells. Burrows and pits - probably made by crabs - were observed as sediment patches in the maerl . A dense brittle-star bed was recorded at station 403.	104; 219; 303; 309; 402; 403; 404
7	Dead maerl, fine sediment, shells & stones with sparse mixed turf	A very heterogeneous habitat which combined many of the features of biotopes 4-6 but included larger stones (10%) - mainly cobbles. It was mostly recorded within the Fal Ruan Estuary where occasional kelp plants (*Laminaria saccharina*) were attached to larger stones at depths < 10 m in very sheltered areas (station 411). Filamentous algae were attached to stones, often forming distinct patches (20% cover).	205; 224; 411; 412; 413; 414
8	Living maerl with an algal turf	Stations were located on St Mawes Bank where the living maerl formed distinct clumps lying on fine sand. Maerl had a dense epiflora of filamentous red algae. Density of maerl was variable with occasional patches (> 1 m^2) of bare sand.	107; 417; 418
9	Infralittoral stones with an algal turf	Habitat comprised mainly flat and angular stones - pebbles through to small boulders - with sediment in the interstices. Larger stones were covered with filamentous algal turf (up to 60% cover), with scattered kelp *Laminaria hyperborea* plants present on the most stable stones at depths < 15 m. Epifauna comprised a sparse turf of hydroids ('occasional') and dead man's fingers *Alcyonium digitatum* ('rare'); sea urchins *Echinus esculentus* were 'rare'. A higher density of epibiota were recorded on larger, less silted stones.	101; 211; 215; 220; 401; 406
10	Infralittoral rock with kelp forest	Dense forests of *Laminaria hyperborea* were recorded on stable boulders and bedrock at depths < 15 m. A turf of filamentous and foliose red and brown algae covered the kelp stipes and the rock below the canopy. Dense colonies of the hydroid *Obelia geniculata* were present on the kelp fronds. In gullies and on the large boulders, vertical surfaces were covered by a faunal crust of sponges, and a faunal turf of *A. digitatum* and hydroids.	203; 204; 306; 311; 316; 407

11	Circalittoral stones with faunal turf	Habitat comprised flat angular stones ranging in size from pebbles through to small boulders at depths > 15 m. Stones had a covering of fine sediment, with occasional large patches (> 2 m^2) of sediment. Stones were covered with a sparse faunal turf of hydroids - mainly *Nemertesia* spp. , and *A. digitatum*. Other species observed were sea-fans *Eunicella verrucosa,* Ross coral *Pentapora foliacea*, the holothurian *Holothuria forskali*, solitary ascidians and erect sponges. In general larger, more stable stones with less silt had a higher species richness.	102; 213; 214; 218; 221; 222; 224; 315
12	Circalittoral rock & boulders with faunal turf and mixed crust	Stable large boulders and bedrock reefs at depths > 15 m were covered with a faunal turf and crust (approximately 20%) and pink encrusting algae. The species recorded were similar to biotope 11 although their abundance was generally higher. Horn wrack *Flustra foliacea*, erect branching sponges, encrusting sponges including *Cliona celata* and *Polymastia* sp. were also observed; dense populations of the ascidian *Dendrodoa grossularia* were recorded on vertical surfaces. At stations 310 and 312, very dense forests of *E. verrucosa* were observed. Patches of sediment were present between stones and in the base of gullies.	301; 302; 305; 310; 312; 313

Distribution of biotopes

Spatial distributions of these biotopes within each survey area are shown in Figures 10-12. It must be emphasised that these maps represent 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, a different biotope is present.

Summary of biotope distribution

In general terms, the lower Fal Ruan Estuary has a deep (> 30 m), narrow channel flanked by shallow sediment banks. The western bank and base of the channel were a heterogeneous mixture of mud, stones and dead maerl. St Mawes bank to the east had a dense covering of living maerl lying on fine sand; the density of the maerl varied but declined rapidly with increasing depth along the edge of the channel. In St Mawes Harbour the sea bed was predominantly sedimentary. At the entrance to the estuary, the sea bed was mainly stones and dead maerl which was subject to strong tidal flows.

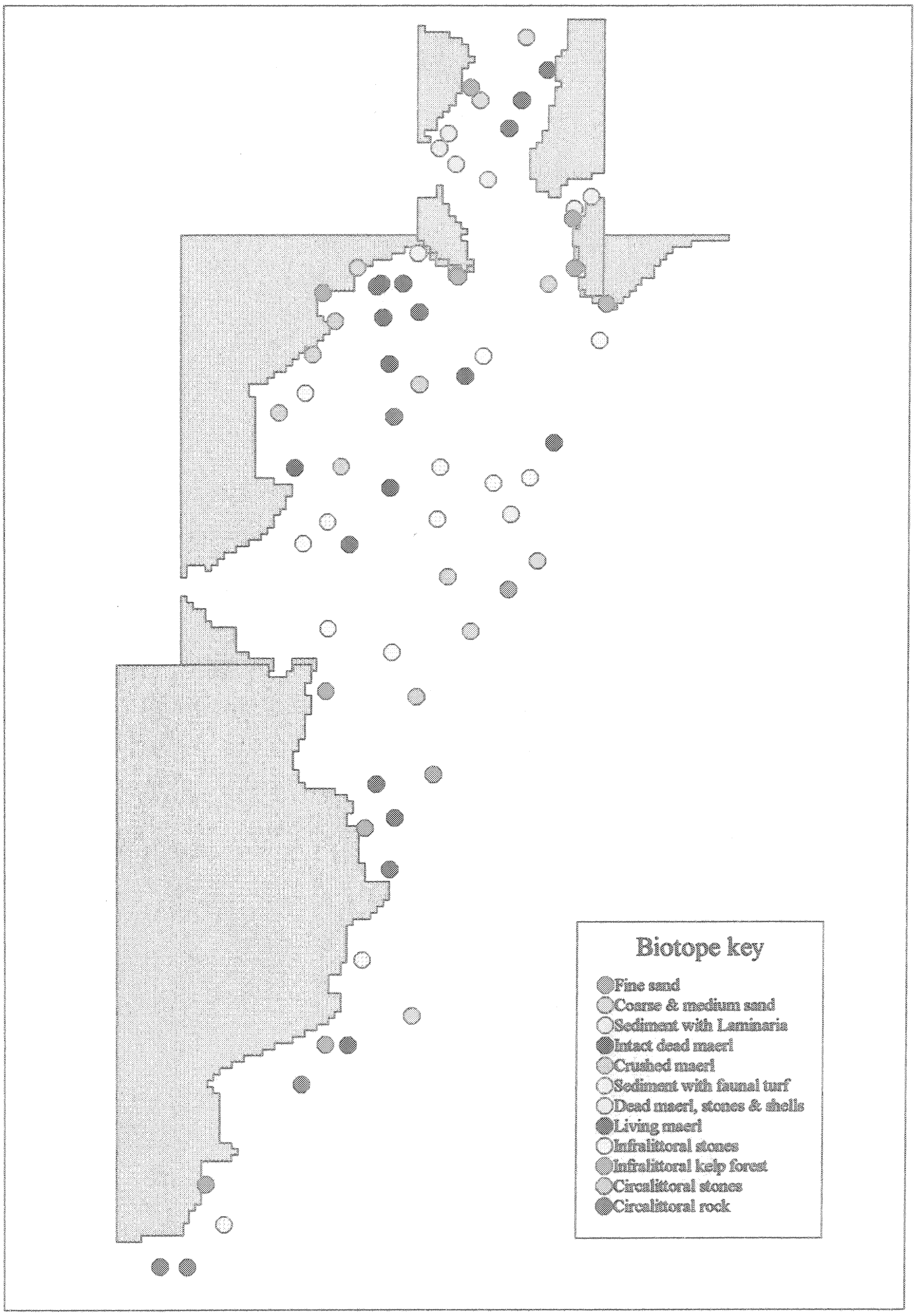

Figure 9 Location of video stations; stations are coded by biotope as listed in Table 1

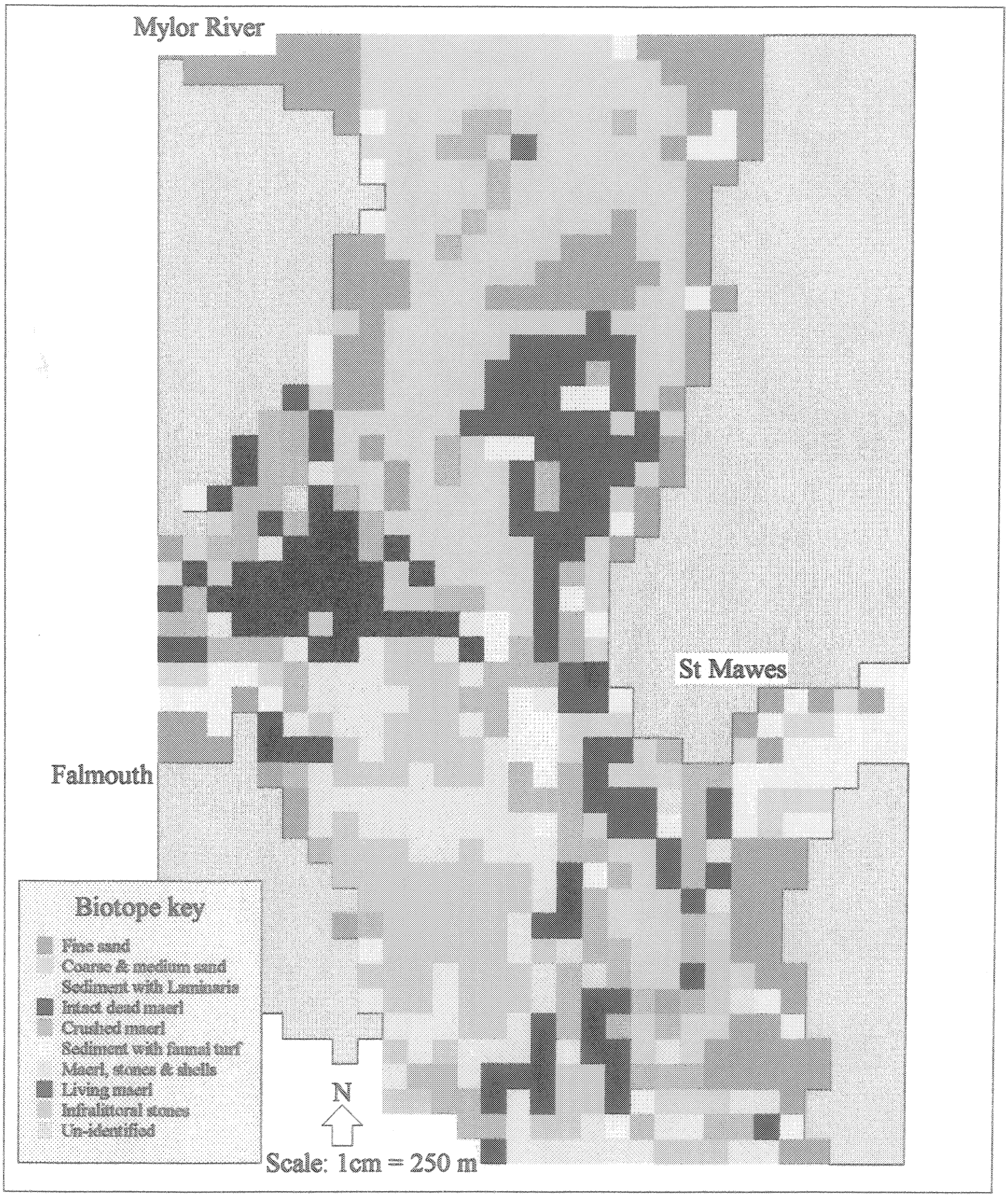

Figure 10 Predicted distribution of biotopes in the lower Fal Ruan Estuary

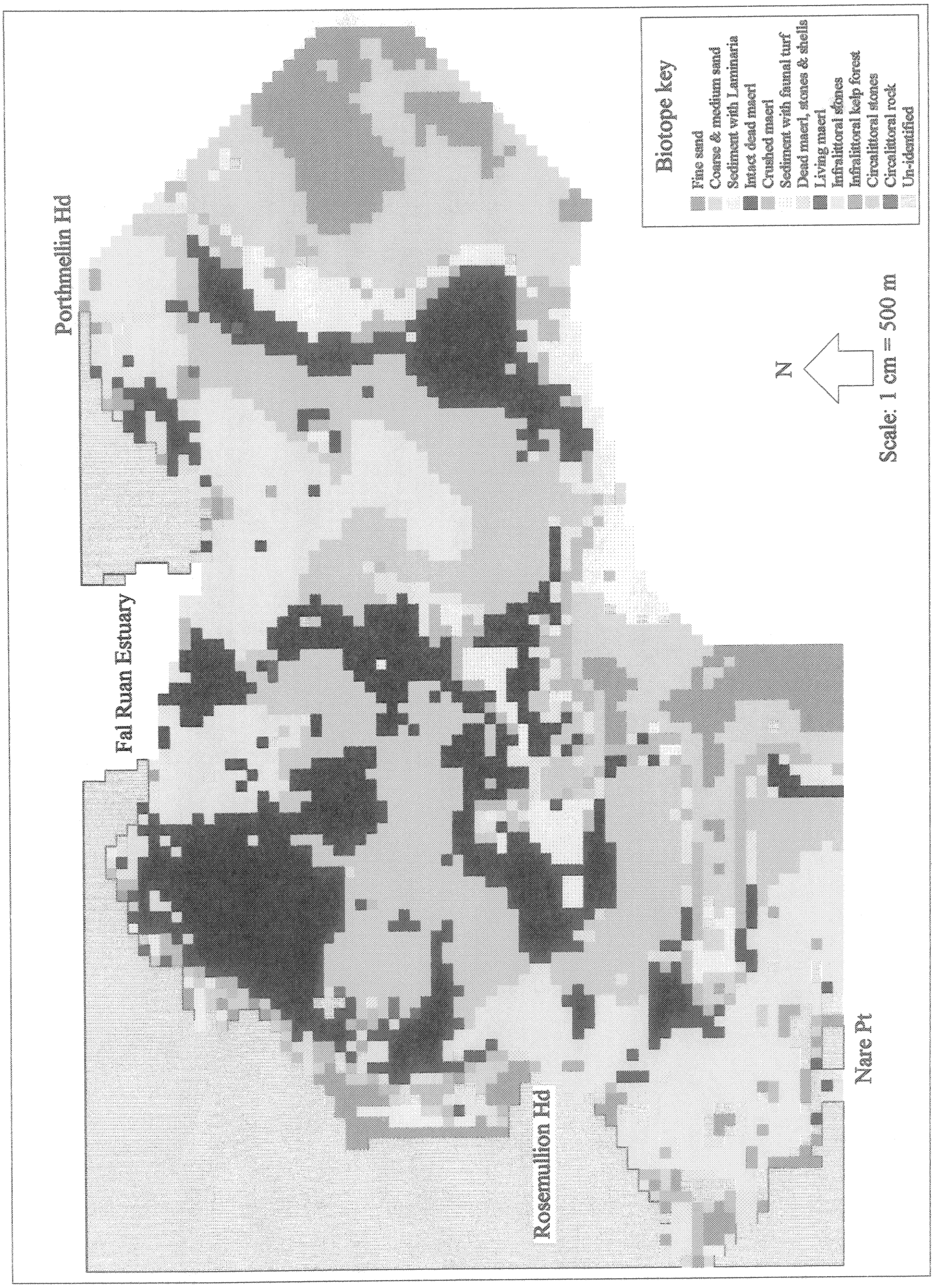

Figure 11 Predicted distribution of biotopes in Falmouth Bay

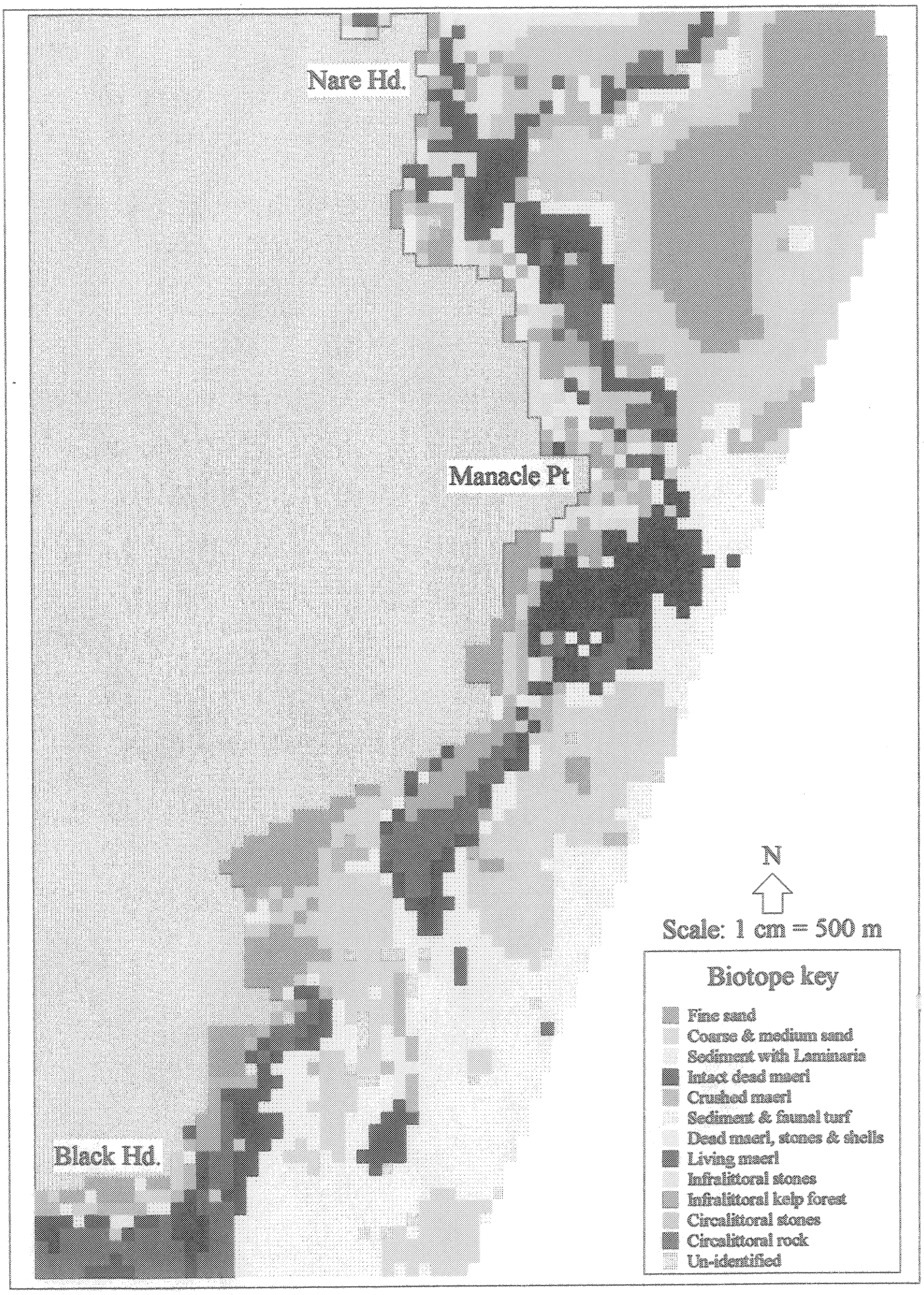

Figure 12 Predicted distribution of biotopes on the east side of the Lizard peninsula

Falmouth Bay was predominantly sedimentary, mainly dead maerl - intact pieces, crushed, or maerl derived sand, with empty shells and small stones. Whilst these maerl-based sediments have been described as four biotopes, there was considerable overlap and the boundaries were a gradual transition rather than an abrupt change. Rocky biotopes were present adjacent the coast in the south west and to the north east of the bay. From 15-20 m the sea bed was mainly stones with sedimentary habitats extending from 20 m offshore to the survey limits.

Rock biotopes characterised the inshore areas along the east coast of the Lizard peninsula particularly associated with the headlands, with sedimentary biotopes present in the small bays; offshore biotopes were predominantly sedimentary. Infralittoral rock habitats supported dense kelp forests whilst circalittoral rock was covered with a rich faunal turf. Sea-fans and erect sponges were common throughout but abundant in the vicinity of the Manacles. The sea bed sediments appeared to be highly mobile - large waves were present - with a low silt content and a sparse fauna.

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Appendix 1

Sample_id	Time	Date	Lattitude	Longitude	Sample number	Biotope
101	15:32:25	05/07/94	N 50 05 15.12	W 005 03 18.60	Take 1	9
102	15:45:33	05/07/94	N 50 05 27.42	W 005 02 16.20	Take 2	11
103	15:56:14	05/07/94	N 50 05 49.56	W 005 01 46.86	Take 3	1
104	16:19:09	05/07/94	N 50 06 25.08	W 005 02 45.90	Take 4	6
105	16:47:32	05/07/94	N 50 06 40.50	W 005 03 24.42	Take 5	4
106	17:06:59	05/07/94	N 50 07 39.54	W 005 02 27.30	Take 6	4
107	17:38:59	05/07/94	N 50 10 3.30	W 005 01 49.26	Take 7	8
201	09:18:28	06/07/94	N 50 08 36.90	W 005 01 2.52	Take 1 & Grab 1	1
202	09:28:48	06/07/94	N 50 08 28.37	W 005 01 22.86	Take 2 & Grab 2	5
203	09:43:01	06/07/94	N 50 08 31.63	W 005 02 36.66	Take 3	10
204	09:49:36	06/07/94	N 50 08 30.91	W 005 02 35.46	Take 4	10
205	09:56:54	06/07/94	N 50 08 42.48	W 005 03 8.22	Take 5 & Grab 3	7
206	10:08:38	06/07/94	N 50 08 26.65	W 005 03 19.20	Take 6	4
207	10:36:56	06/07/94	N 50 08 24.96	W 005 03 40.02	Take 7	4
4	10:41:28	06/07/94	N 50 08 26.40	W 005 03 36.72	Grab 4	4
5	10:49:07	06/07/94	N 50 08 34.20	W 005 03 56.10	Grab 5	2
208	10:59:02	06/07/94	N 50 08 6.18	W 005 04 13.14	Take 8	5
209	11:24:58	06/07/94	N 50 08 8.82	W 005 03 34.26	Take 9	4
210	11:37:17	06/07/94	N 50 08 12.06	W 005 03 5.46	Take 10	4
211	11:49:17	06/07/94	N 50 07 50.10	W 005 02 13.14	Take 11	9
212	12:04:44	06/07/94	N 50 07 44.82	W 005 03 27.72	Take 12	4
213	12:22:18	06/07/94	N 50 07 34.38	W 005 03 3.60	Take 13	11
214	12:29:34	06/07/94	N 50 07 17.34	W 005 03 23.04	Take 14	12
215	13:14:32	06/07/94	N 50 07 28.51	W 005 04 35.58	Take 15	9
216	13:29:21	06/07/94	N 50 07 17.94	W 005 04 56.70	Take 16 & Grab 6	5
217	13:44:14	06/07/94	N 50 06 49.44	W 005 04 42.54	Take 17	4
218	13:54:58	06/07/94	N 50 06 50.70	W 005 04 4.50	Take 18	11
219	14:10:26	06/07/94	N 50 06 21.96	W 005 04 14.40	Take 19	6

220	14:24:49	06/07/94	N 50 06 10.44	W 005 04 33.84	Take 20	9
221	14:39:04	06/07/94	N 50 06 10.44	W 005 03 55.92	Take 21	12
222	15:02:08	06/07/94	N 50 05 55.31	W 005 02 36.12	Take 22	11
223	15:18:25	06/07/94	N 50 06 4.75	W 005 01 24.66	Take 23	2
224	15:39:11	06/07/94	N 50 06 28.37	W 005 01 47.04	Take 24	7
225	16:10:56	06/07/94	N 50 07 48.54	W 005 04 30.72	Take 25 & Grab 7	5
8	16:25:13	06/07/94	N 50 08 20.41	W 005 04 24.00	Grab 8	1
301	13:15:35	07/07/94	N 49 59 53.64	W 005 06 13.62	Take 1	12
302	13:23:48	07/07/94	N 49 59 53.82	W 005 05 50.94	Take 2	12
303	13:33:50	07/07/94	N 50 00 16.32	W 005 05 22.26	Take 3	6
304	13:44:26	07/07/94	N 50 00 36.84	W 005 05 38.10	Take 4	1
305	14:05:13	07/07/94	N 50 01 29.88	W 005 04 22.38	Take 5	12
306	14:20:05	07/07/94	N 50 01 50.87	W 005 04 3.72	Take 6	10
307	14:29:01	07/07/94	N 50 01 50.95	W 005 03 44.88	Take 7	4
308	14:40:07	07/07/94	N 50 02 7.02	W 005 02 53.76	Take 8	2
309	14:53:54	07/07/94	N 50 02 35.33	W 005 03 35.58	Take 9	6
310	15:06:01	07/07/94	N 50 03 22.62	W 005 03 15.24	Take 10	12
311	15:32:26	07/07/94	N 50 03 43.74	W 005 03 36.24	Take 11	10
312	15:42:12	07/07/94	N 50 03 49.26	W 005 03 12.48	Take 12	12
313	15:56:01	07/07/94	N 50 04 6.59	W 005 03 28.26	Take 13	12
314	16:12:36	07/07/94	N 50 04 12.48	W 005 02 42.72	Take 14	1
315	16:33:20	07/07/94	N 50 04 52.44	W 005 02 58.32	Take 15	11
316	16:50:31	07/07/94	N 50 04 54.36	W 005 04 11.76	Take 16	10
401	10:33:32	08/07/94	N 50 05 26.76	W 005 04 11.34	Take 1	9
402	10:57:03	08/07/94	N 50 06 44.40	W 005 02 1.86	Take 2	6
403	11:09:53	08/07/94	N 50 06 52.02	W 005 02 44.94	Take 3	6
404	11:26:53	08/07/94	N 50 06 47.70	W 005 01 32.94	Take 4	6
405	11:48:56	08/07/94	N 50 07 6.12	W 005 01 14.10	Take 5	4
406	12:03:43	08/07/94	N 50 07 59.94	W 005 00 40.32	Take 6	9
407	12:16:59	08/07/94	N 50 08 19.15	W 005 00 35.58	Take 7	10
408	13:48:34	08/07/94	N 50 09 14.46	W 005 00 50.76	Take 8	3

409	13:55:44	08/07/94	N 50 09 7.87	W 005 01 3.96	Take 9	3
410	14:00:09	08/07/94	N 50 09 2.75	W 005 01 5.34	Take 10	1
411	14:15:12	08/07/94	N 50 09 21.90	W 005 02 14.34	Take 11	7
412	14:28:42	08/07/94	N 50 09 29.40	W 005 02 40.20	Take 12 & Grab 9	7
413	14:38:55	08/07/94	N 50 09 45.23	W 005 02 46.80	Take 13	7
414	14:54:16	08/07/94	N 50 09 37.44	W 005 02 53.76	Take 14	7
415	15:06:56	08/07/94	N 50 10 2.81	W 005 02 22.20	Take 14 & Grab 10	2
416	15:20:12	08/07/94	N 50 10 9.42	W 005 02 30.18	Take 16 & Grab 11	1
417	15:36:42	08/07/94	N 50 09 48.78	W 005 01 58.56	Take 17& Grab 12	8
418	15:53:47	08/07/94	N 50 10 19.50	W 005 01 29.64	Take 18	8
419	16:01:52	08/07/94	N 50 10 36.06	W 005 01 47.46	Take 19 & Grab 13	2

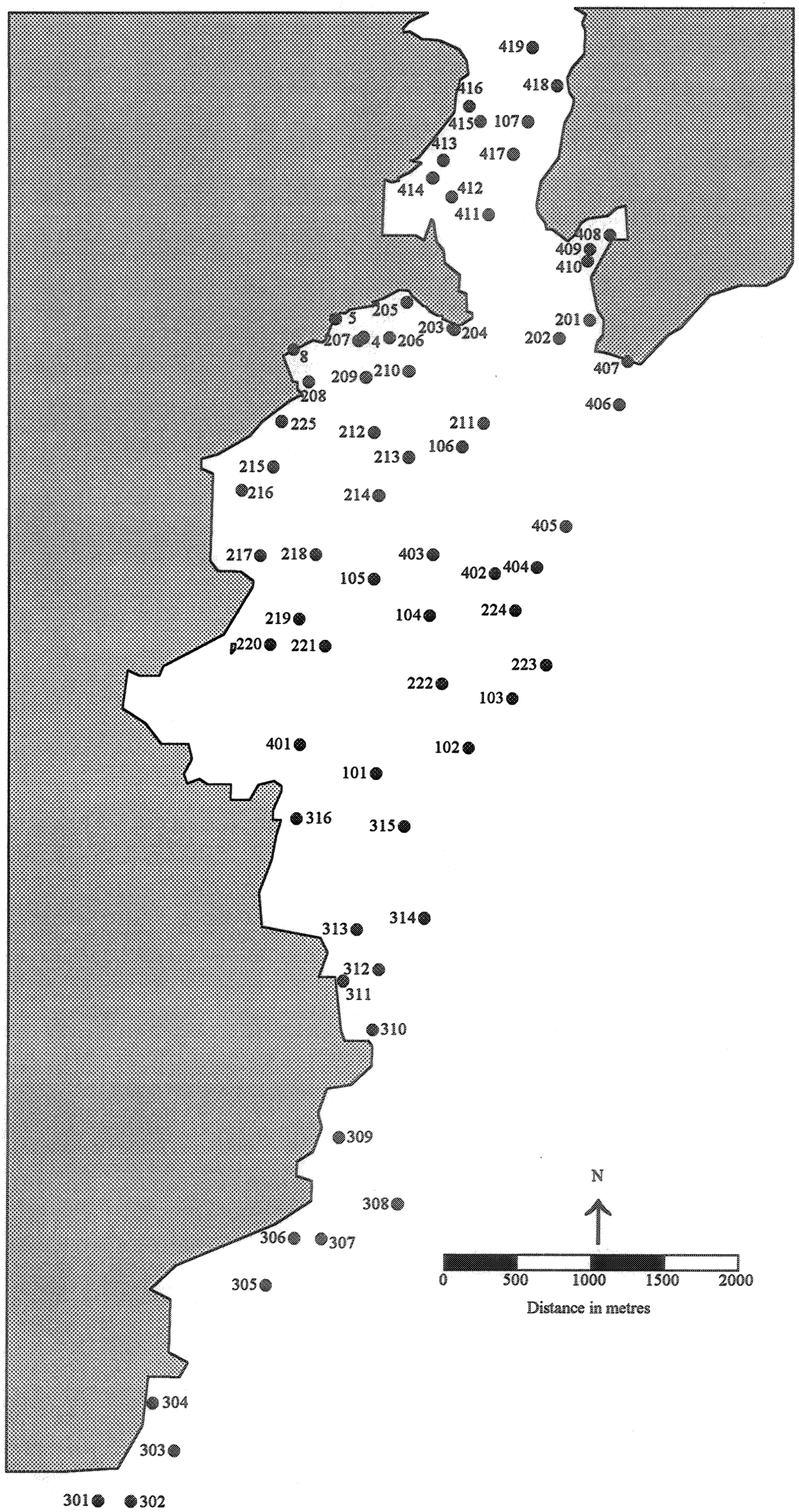

Figure 12 Location of video stations