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Broadscale mapping of habitats and biota of the sublittoral seabed of The Wash

Broadscale Mapping of Habitats and Biota of the Sublittoral Seabed of the Wash.

Final report of the 1996 Broadscale Mapping Project (BMP) Survey.

R.L. Foster-Smith, I. Sotheran and R. Walton

February, 1997

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Summary

The aims of the BMP survey of the Wash were to map the sublittoral communities and biota and to provide support and training for the Eastern Joint Sea Fisheries Committee (EJSFC) in the use of the *RoxAnn* ground discrimination system. A separate report entitled "Guide to Ground Discrimination Surveys" (Foster-Smith *et al.* 1997) has been produced for the EJSFC.

Although two weeks were spent on field work, the amount of data collected was limited due to the failure or the two EJSFC *RoxAnn* systems. Nevertheless, the BMP portable system enabled much of the Wash to be surveyed with quite intensive tracking of some sites. The towed video produced acceptable recordings only in the outer parts of the Wash due to poor visibility, and ground truthing relied on grab and trawl samples. Data from previous surveys were also incorporated into the interpretation of the acoustic images.

The survey indicated that many of the important conspicuous species, particularly *Sabellaria spinulosa* and *Ophiura albida*, were found over a broad range of habitat types throughout much of the Wash. This has meant that biotope mapping, which requires the biota and habitat characteristics of biotopes to be fairly distinctive, is probably of limited value for management of the Wash in a local context. It is suggested that species distribution and the distribution of community indices, such as diversity, in relation to habitat types may be of greater value at this stage. Maps showing this type of information are presented and recommendations for further work are made. A summary of these recommendations is as follows:-

It is recommended that a broadscale comprehensive stratified sampling programme involving epifaunal and infaunal sampling be undertaken based on acoustic ground types. It is recommended that a measure of species diversity and richness for the whole of the Wash is one of the objectives of the survey and that an assessment is made of the association of *Sabellaria spinulosa* with diversity and richness.

It is suggested that the Eastern Joint Sea Fisheries Committee is best placed to perform broadscale, regular survey which would provide a sound context for the interpretation of all other studies on productivity and populations in the Wash.

The EJSFC should build up their experience of *RoxAnn* to discriminate between ground types on a localised basis within *Microplot*. The EJSFC may wish to liaise with Newcastle University and English Nature to continue to build skills in post processing and biotope map production.

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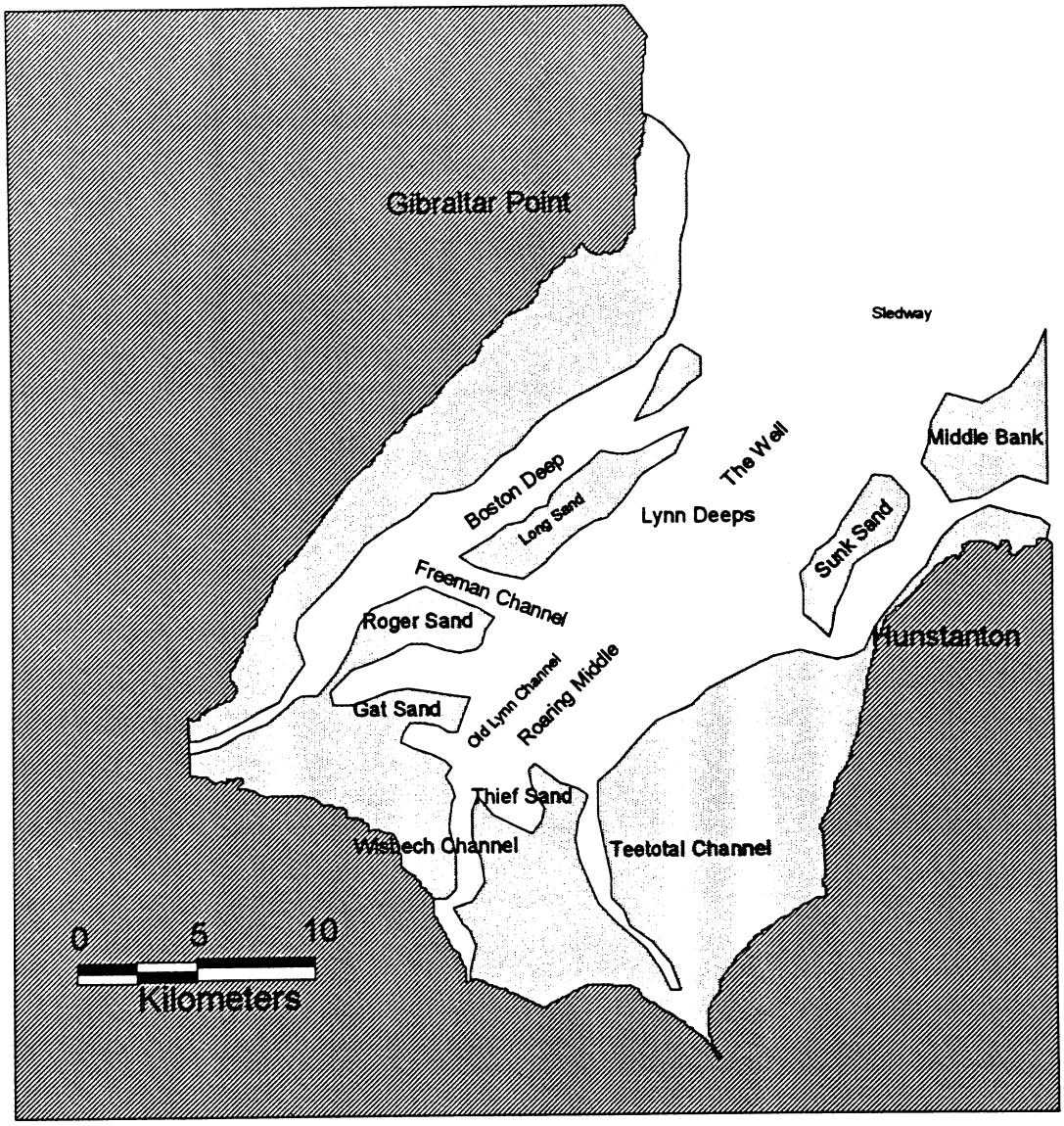


Figure 1. Map showing the locations of features and places in the Wash.

1. Introduction

The Wash and North Sea adjoining the south Lincolnshire and north Norfolk coasts has been selected as one of the trial areas for testing broadscale habitat and biota mapping techniques as part of the 3 year Broadscale Mapping Project (BMP). This sea area contains sites of conservation importance, illustrates many issues associated with mixed fisheries and contains areas of aggregate extraction and, on the coast, sand replenishment schemes.

The Wash forms part of the Wash and north Norfolk coast candidate Special Area for Conservation (cSAC) and has been recommended because the Wash is the largest embayment in Britain with extensive intertidal mudflats and sandflats and subtidal sandflats. The Wash also supports one of the largest populations of the common seal *Phoca vitulina*. Of the marine invertebrates the polychaete *Sabellaria spinulosa* is specifically mentioned since there is a suggestion that this species enhances species diversity and richness through its reef-building activities. There is anecdotal evidence to suggest a decline in the abundance and distribution of this species in the area.

The 1996 survey is expected to contribute to the knowledge base of this conservation area. In addition, the survey is being used to train staff of the Eastern Joint Sea Fisheries Committee in the use of ground discrimination techniques and it is hoped that such links formed between the ESFC and the Newcastle University team will continue and develop to their mutual benefit.

In summary, the purposes of the survey were:-

1, to remotely survey the Wash using acoustic ground discrimination techniques;
2, to sample selected locations using video, grab and trawls;
3, to augment these samples with data from two previous faunal surveys: (a) the CSD report of diving and dredging surveys carried out in 1985 and 1986 (Dipper *et al.*, 1989), and (b) a grab sample survey for 1991 (NRA, 1994).
4, to produce maps of the area indicating the distribution and extent of biological communities and associated habitats (biotopes);
5, to collaborate with the Eastern Joint Sea Fisheries Committee in carrying out the survey and assisting them in the use of their acoustic ground discrimination systems on their research and patrol boats.

The survey area, showing the main features referred to in the report, is shown in Figure 1.

2. Methods

2.1. General guide to the use of ground discrimination systems for mapping biotopes

The collection of field data (both acoustic ground discrimination and direct sampling) and the principles involved with using this data for the construction of biotope maps has been summarised in a Guide given to the Eastern Joint Sea Fisheries Committee entitled "Guide to Ground Discrimination Surveys" (Foster-Smith *et al.* 1997) and it is proposed that this document forms the basis of a manual which will be developed for training of non-specialists in planning acoustic surveys, the use of ground discrimination acoustic equipment and the preparation of biotope maps.

2.2. Field methods adopted for the Wash survey

The survey was carried out during two weeks in August, 1996. It was intended that the survey would utilise the *RoxAnn* ground discrimination systems on board the Eastern Joint Sea Fisheries Committee vessels: *Protector 3* and *Surveyor*. However, it was apparent that neither of their fixed systems were producing reliable records and, therefore, the portable system belonging to the Newcastle University team was used for both weeks. This system, described briefly below, was fitted to *Surveyor*. Although this system produced reliable track records, far less data was collected than had been anticipated. Nevertheless, most of the area to be surveyed was covered and some selected locations were surveyed in detail (see tracks in Map 1).

2.2.1. Acoustic ground discrimination system

The equipment routinely used by the Newcastle University team for acoustic survey is based on a *RoxAnn* signal processor which samples the return echo from a 200kHz echo sounder (Figure 2a). 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 was provided by a GPS. These track data are collected and saved at set time intervals (5 sec) on a laptop computer, which also supplies time and date for each data point, utilising *Microplot* navigation software (Figure 2b). 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 (superimposed, if required, on a map or chart of the coast) as they are being collected. The data are logged and can be re-run and edited at a later stage. 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 are drawn to encompass ranges of values as desired (see lower right of screen display, Figure 2b). Construction and labelling of these boxes to change the track display provides an initial way of editing the track to form a satisfactory picture.

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 and the nature of the ground between tracks is interpolated during subsequent data processing.

The real-time display of track data within *Microplot* is extremely valuable in giving an initial impression of the distribution of different ground types and can be used to select sample sites.

Figure 2a. Schematic Diagram of the Acoustic Survey Equipment

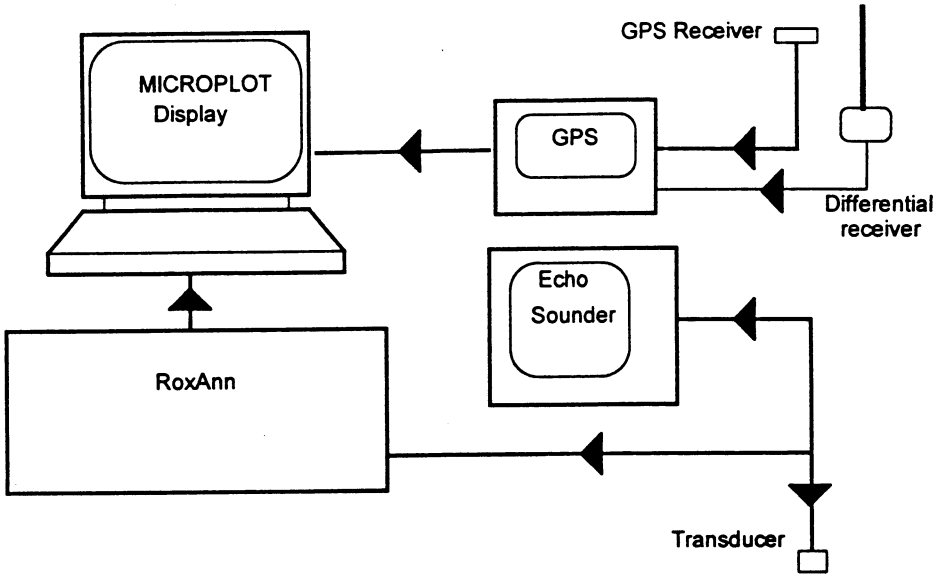
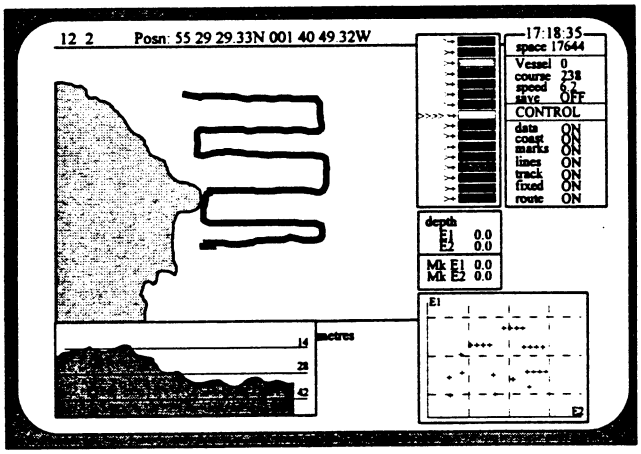


Figure 2b Screen Display of Track Data in MICROPLOT



2.2.2. Sidescan sonar

Sidescan sonar was deployed at a limited number number of locations within the Wash and, although not extensively analysed, the information on sediment features and texture was used to supplement descriptions of biotopes.

2.3. Sampling methods employed

The primary technique used for ground-truthing was a Day grab. A towed video sledge and trawl were also used although the poor visibility rendered the underwater camera of limited use in the Wash. A sediment sample was taken from the Day grab and dry sieved in the laboratory. The rest of the sample was passed over a 1mm sieve on board and the conspicuous infauna noted. Lists of the conspicuous species and sediment characteristics were made for each of the sample sites.

Trawls were also used to obtain larger samples of the epifauna and mobile fauna.

Sample sites were selected from distinctive areas as indicated by the pattern of acoustic characteristics displayed in *Microplot*. Ideally, the sites should have been selected following a more in-depth analysis of the acoustic data, but this was not possible due to time and equipment constraints and the distances involved with covering the survey area. It was hoped that a representative selection of sample sites were chosen.

2.4. Map production and analysis of survey data

The standard steps in the production of biotope maps routinely used by the BMP project are as follows:-

The survey area is tracked over with the acoustic survey equipment to indicate the distribution of different acoustic properties of the sea floor. The track data are processed to show, separately, small increments in the values of E1 (roughness), E2 (hardness) and depth. Maps for each of these factors are prepared using computer-aided techniques to interpolate between track data and contour equal-value points. *Surfer*^{tm} and *Vertical Mapper*^{tm} contouring software are routinely used for this stage in the analysis. These maps are overlain within a GIS environment, *MapInfo*^{tm} , to produce a composite map indicating areas with similar acoustic and depth characteristics. During the field survey the rough maps so produced were used to select suitable sites for ground truthing.

Matching faunal characteristics and habitat data to the acoustic properties of the sea floor enables the distribution of communities to be shown. The aim of the matching process is to find a combination of acoustic properties that are characteristic of a particular habitat, community or biotope. The ground truth points are superimposed on separate maps of E1, E2 and depth. The values of these acoustic properties in which these data points lie are then noted and a range ascribed to each habitat or life form category. Each habitat, community or biotope is then assigned characteristic ranges of acoustic values for E1, E2 and depth which can then be used to re-classify the track data. However, it cannot be expected that each life form or habitat recognised will have its own, exclusive combination of acoustic properties for a number of reasons:-

1. In many cases acoustic 'signatures' overlap considerably and a distinction cannot be made between two life form or habitat categories. In such cases, categories have to be amalgamated. However, such categories usually resemble each other and may represent somewhat arbitrary points along a continuum.
2. There is a limit to the accuracy with which ground truth data points can be located and this can place in the 'wrong' part of the acoustic map. Allowances need to be made for position where a ground truth data point lies close to but outside of its expected range.

3. The track spacing is variable, but often quite widely separated. If the ground is heterogeneous at a scale below the resolution of the acoustic map, then the component life forms or habitats can only be represented together as a mixture.

The relationship between acoustic ground characteristics and life forms should be seen as the best model based on available data.

2.5. Incorporation of previous survey results

The data from the two recent comprehensive surveys of the Wash were entered into spreadsheets for importing into *MapInfo*. This required, in many cases, a re-interpretation of the different datasets to achieve a common denominator for comparative purposes that carries useful information.

3. Acoustic survey results

3.1. Track records for acoustic data

Map 1 shows the extent of the track data collected on *Surveyor*. The tracks have been coloured according to values for E2 (an indicator of hardness) and the points represent the average of three consecutive data points in order to reduce the volume of data presented. Most of the Wash has been surveyed using the ground discrimination system and some sections were intensively tracked which were representative of similar sites or where it was thought possible that there were sublittoral mussel beds.

3.2. Continuous coverage of acoustic data

The values for Echoes 1 and 2 and bathymetry have been used to produce a continuous coverage of the ground. Comparison of these coverages with the raw track data will indicate areas where such coverages must be treated with a degree of caution. The E1 and E2 data has been rescaled so that the maximum value (after eliminating obvious outliers) is 1. This is necessary when the survey equipment has been repositioned with respect to the vessel during the survey resulting in a shift in the range of values over similar ground. Such shifts appear due to changes in depth of the sounder and the deviation of the sounder pole from vertical. Standardisation also aids the comparison of patterns of E1 and E2.

Depths have been corrected to chart datum by applying corrections for Hunstanton on a half-hourly basis. Tidal corrections were calculated from the tidal prediction program using the simplified harmonic method produced by the UK Hydrographic Office (Anon, 1991).

The following procedure was used in the preparation of the maps showing continuous coverage. The track data were first gridded within *Surfer* using a kriging algorithm for calculating the grid node values. The grid node values were then imported into *MapInfo* as a table. *Vertical Mapper* (an application written for use within *MapInfo*) was used to produce raster and contoured maps of the grid node values. The raster maps are presented (Map 2) to show the spread of values over the survey area using a standard colour scheme were blue indicates low values and red high values. These raster maps are not used in further analysis: contouring the grid node values is a separate process carried out within *Vertical Mapper*.

Contours (Maps 3, 4 & 5), although more interpretable, are prone to spurious detours when the contouring process is automated. Also, contour lines and choice of colours may over-accentuate the apparent definition of boundaries between adjacent ranges. **Contours, therefore, must be viewed with some caution.** Raster maps are a useful comparative display since they emphasise that the values are continuously variable over the survey area.

In general E1 and E2 values are closely correlated so that the patterns in the distribution of E1 and E2 show strong similarities. However, there were significant areas, particularly in the deeper water in the entrance to the Wash, where the re-scaled values of E1 are higher than the E2 values, indicating ground which might be rough.

The bathymetry of the Wash as determined acoustically during the present survey accords well with the Hydrographic charts. The NRA report states that the 15m contour forms a natural break between communities (probably due to wave effects and sedimentation characteristics) and much of the Wash lies shallower than this whilst there are areas deeper than 20m in the Boston and Lynn Deeps.

The acoustic data has been classified according to combinations of four ranges of values for E1 and E2 (low, moderately low, moderately high and high) and two depth bands (shallow (<15m) and deep (>15m)). The categories are displayed in Map 6 and form a useful backdrop for the visual inspection of the ground truth data.

4. Ground truth data and comparison with previous survey data

The three surveys (NRA, CSD and the current BMP project) have employed different methodologies for collecting data. The NRA survey was based on grab samples taken on a regular grid whilst the CSD project employed divers, grabs, dredges and trawls in a more irregular survey pattern. The present survey used video, grab and trawls to ground truth the acoustic maps (i.e., the sample stations were chosen to investigate different acoustic ground types).

Sediment characteristics obtained using trawls, dredges and, to some extent, video and diver observation, may tend to accentuate the coarser components such as shell. Again, epifauna and large, conspicuous and well dispersed infauna will also be accentuated. Diversity measures are limited by the nature of the data obtained by these methods to presence/absence or abundance ratings of a limited range of epifaunal species. However, sediment heterogeneity (e.g., cobble/sand mixtures) and patchiness of colonial macrofauna (e.g., mussels, *Sabellaria spinulosa* reefs) can only be assessed using sampling techniques, such as those described above, that cover large areas of ground.

Grab samples, on the other hand, will accentuate finer sediment (grabs that misfire or collect very small amounts of soft sediment due to the presence of cobbles tend to be disregarded) and inconspicuous infauna. The data collected is easily quantifiable and are amenable to multivariate statistical techniques and the calculation of numerical indices of diversity. However, unless numerous replicates are taken, little idea of spatial heterogeneity at each location can be obtained.

Table 1. Sediment analysis from the Broadscale Mapping survey (1996)

Sample type			Position		Particle size								Ground type
Grab	Video	Trawl	Latitude	Longitude	Tot. weight	<2mm	<1mm	<0.5mm	<0.25mm	<0.125mm	<0.063mm	>0.063mm	
1			0.35605	53.1625	197.3	2.6	1.6	2.4	11.3	164.5	14.5	0.4	fine sand
2			0.36348	53.1641	195.9	59.1	13.8	29.8	75.8	16.2	0.7	0.5	crs. sand
3	3		0.38508	53.164	152.1	137.6	3.7	1.8	6.5	1.8	0.4	0.3	cob/grav
4	4		0.4049	53.1532	380.8	337.5	11.1	6.7	19.4	5.2	0.6	0.3	shell/grav/sand
5	5		0.42768	53.1462	360	258.5	18.3	13.7	46.2	19	2.6	1.7	grav/silt/sand
6	6		0.45738	53.136	195.8	106.7	16.3	14.9	32.7	16.7	4.4	4.1	grav/clay
7	7		0.49493	53.1258	233.2	139.3	11.1	9.9	37	29.5	3.5	2.9	grav
8			0.52082	53.1121	411.4	238.5	36.9	36.1	47.6	37	9.3	6	shell/grav
9	9		0.5491	53.0925	207.4	0.2	1.2	6	186.7	11.5	1.5	0.3	crs. sand
	10		0.4413	53.0952									grav/sand
11	11		0.41468	53.0968	287.3	138.6	21.3	22.9	50.2	49.6	3.1	1.6	cob/grav
12	12		0.47428	53.0204	158.1	2.8	2	11.7	133.1	7.4	1	0.1	crs. sand/shell
13	13		0.42985	52.9527	195.6	14.2	7.8	16.1	72.8	74.6	7.6	2.5	crs. sand/shell
14	14		0.2318	52.8954	155.5	35.8	5.5	5.9	45.6	34.8	16.2	11.7	shell/clay
15			0.23408	52.9047	182.6	18.1	5.2	8.1	69.5	39.6	22	20.1	shell/clay
		1	0.21743	52.9066									shell
		2	0.22917	52.8965									
16			0.199	52.9348	120	8.5	5	17.4	73.6	15	0.4	0.1	crs. sand/shell
		3	0.23112	52.8963									
17	17		0.34682	52.965	188.4	103.2	14.2	7.6	16.6	18.6	17	11.2	fine sand/cob
18			0.36555	52.9801	231.5	68.6	20	20.8	40.9	63.9	10.9	6.4	shell
19			0.30322	52.9153									shell/clay
20			0.30177	52.8737	222.5	79.7	6	5.5	71.2	52.2	4.2	3.7	grav/shell
21			0.2975	52.8596	119.9	0	0.2	0.8	1.6	18.3	50.6	48.4	sand/mud
22			0.30623	52.8479	138.2	0	0.7	1.9	74.2	60.4	1	0	
23			0.25472	52.997	137	14.1	1.9	1.5	16.6	54.2	26.2	22.5	shell/sand/mud
24			0.20698	52.983	207.8	0	0	0.3	0	27.9	102.8	76.8	sand/mud
25			0.29525	53.0189	152.8	0.1	0.3	1	49.2	100.5	1.7	0	grav/cob
		4	0.34142	52.9545									
			0.32168	52.9474									

Table 2. Conspicuous species from samples from the Broadscale Mapping survey (1996) (p = present; ab = abundant)

Sample type	Sample number																												
Grab	1	2	3	4	5	6	7	8	9		11	12	13	14	15			16		17	18	19	20	21	22	23	24	25	
Video			3	4	5	6	7		9	10	11	12	13	14						17									
Trawl																1	2		3										4
hydroids			p		p		ab	p			p		p	p	p	p	p		p	p								p	
Flustra																													p
Alcyonium																p													p
encrusting bryozoans			p		p									p	p													p	
Sabellaria		p	p	p	p	p	p				p	p										p							
Lanice		p			p	p					p	p		p	p							p					p		
Ophiura ophiura															p	ab	p												
Ophiura albida									p						ab	p	p			p	p						ab		
Sagartia		p	p																										
Asterias														ab		ab	p		p									p	p
Psammechinus																	ab		ab										ab
Scolelepis												p																	
Nephtys sp.												p																	
Pectinaria													p																
Spionid tubes?													p									p							
Aphrodite														p															
Shrimp/prawns																p	ab		p										
Modiolus live																													p
Mytilus shell																ab					ab								
Modiolus shell								p							p														
Ensis shell													p		p														
Cockle/Macoma shell																										p			

4.1. Sediment characteristics

The sediment characteristics of the samples obtained during the BMP survey are given in Table 1. The types of data and terminology used to describe sediments in the three surveys varies and some attempt to standardise the descriptors has been made (Map 7). To simplify the presentation of the sediment characteristics further, the descriptors have been generalised to six terms based on the Folks triangle (see Map 7b) which have been overlain on the acoustic ground types. The picture presented is complex with samples taken on different surveys from similar locations sometimes indicating very different sediments. Whether this demonstrates spatial or temporal heterogeneity (or both) cannot be ascertained. However, the coarser sediment sites from the NRA and the BMP survey appear to accord well with acoustic hardness. Many of the CSD samples from the Lynn Deep fit poorly into this picture and this might indicate a temporal change since 1985-6.

The general pattern of sediments indicates hard, cobble/sand ground off Gibraltar Point, coarse sand with substantial waves (as indicated by sidescan sonar) off the Sledway and progressively finer sediments further into the Wash. Shell banks, returning a strong signal, occur in shallow sheltered areas (e.g., off Gat Sands and the Roaring Middle) whilst scoured coarse sand, also returning a strong signal, are found in the river channels.

4.2. Biotope and community characteristics

The fauna collected at the sample sites during the BMP survey are listed in Table 2.

Difficulties were encountered in finding a common basis for categorising community descriptions from the three sets of survey data owing to the superficial nature of many of the records and the lack of epifauna in the grab sample data from the NRA report. Many of the community types, although some are based on multivariate analysis, are dependant ultimately on some degree of subjective interpretation. An attempt has been made to match sample descriptions with biotopes according to the most recent MNCR classification handbook (Connor *et al.*, 1996). This proved to be difficult owing to the relatively undeveloped state of the sublittoral sediment biotopes as compared to other parts of the MNCR classification system: there are not enough biotopes to adequately describe the range of sediment biotopes present.

However, provisional biotope categories have been identified based on conspicuous characteristics and they are described below. It must be pointed out that many of these provisional biotopes are very broadly based both in terms of species composition and type of substratum and a large degree of overlap is to be expected. The main biotope categories described below were, however, more likely to be found in various combinations than separately. The biotopes assigned to the sample data from all three surveys are summarised on Map 11 superimposed on the raster image of acoustic ground type.

1. *Sabellaria spinulosa/Lanice conchilega* on cobble/sand substratum. See also:-
   (a) MNCR type MCR.Sab.C: *Sabellaria spinulosa* crusts on silty turbid circalittoral rock (bedrock and boulders); tideswept; few other species. (The substratum in this description does not match the provisional biotope description).
   (b) CSD Report community types 1) *Sabellaria spinulosa* and 2) *Lanice conchilega* (although separately described, they were often found together); muddy sand with pebbles at about 10m.

(c) NRA group A1: *Sabellaria spinulosa* on mixed sediments below 15m. High species diversity.

The polychaete *Sabellaria spinulosa* binds sand grains into rigid tubes built one joined to another to form reefs over the surface of rocks and sand. The tube-reefs were patchy and low-lying in the Wash and did not form substantial reefs, as is the case with the related species *Sabellaria alveolata* in locations on the west coast of Britain. *Sabellaria* was widely distributed throughout the Wash whilst the highest abundance was to be found at the entrance of the Wash. This trend is even more accentuated when the BMP 1996 data is included (which extends the area surveyed further to the east). It would appears that *Sabellaria* is found on mobile sand in wave exposed locations especially where there are pebbles. The distribution of *Sabellaria spinulosa* from all three surveys is shown on Map 8.

The descriptions of the *Sabellaria* reefs and associated species diversity vary widely between the various Wash reports. The association between areas where *Sabellaria* was abundant and high species diversity is not clear (see Map 10b) and the epifauna associated with this habitat might be more dependant upon the presence of pebbles than on the hard surfaces created by *Sabellaria*. Indeed, a case could be made that the epifauna might even suffer because of smothering of *Sabellaria* colonisation.

The supposed dependence of shrimp upon *Sabellaria* (NRA) is challenged by Warren (1973) and trawls with large numbers of shrimps/prawns were not found to be associated with *Sabellaria* in the present survey, although few samples were taken. The significance of *Sabellaria* for the natural heritage and fisheries interests of areas within the Wash are unclear since much of the relationship between this species and other species and its habitat are somewhat speculative.

Lanice conchilega creates deep parchment tubes that have a sand frill projecting from the sediment surface. They do not bind sand into reefs nor consolidate loose stones as does *Sabellaria*. They are found in sand and pockets of sand between stones, although their tubes can encrust stones to a limited extent. *Lanice* has been found either on its own or together with *Sabellaria spinulosa* in the Wash.

2. Epifaunal biotopes (hydroid and bryozoans) on cobble mixed with finer sediment.
   (a) MNCR type MCR.Flu: *Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock and mixed substrata; boulders and bedrock; moderately wave exposed.
   (b) CSD Report community types; 1) *Flustra foliacea;* 2) Hydroid/bryozoan; 3) *Alcyonium digitatum*; pebbles in waveswept and sand scoured areas. Extent probably limited by available hard substrata.
   (c) NRA: No epifaunal communities described.

Although it is possible to describe different types of epifaunal communities for the Wash, it is considered for the purposes of the present study that most are variations of a limited range of epifaunal species. Epifaunal communities encompass both encrusting bryozoans and bryozoan/hydroid turf. Many of the species were small and probably characteristically ephemeral although *Flustra foliacea* and occasionally *Alcyonium digitatum* were also recorded. These epifaunal communities were not particularly species rich compared with open coast epifaunal communities on the east coast. It is likely that these communities extend further eastwards from the Wash and a broader geographic context might be needed before

an assessment of the importance of the epifaunal communities to the Wash ecosystem can be made.

3. Shell and muddy sand with *Ophiura* spp., *Psammechinus miliaris*, shrimps and *Asterias rubens*.
   (a) MNCR type: no equivalent recognised.
   (b) CSD Report community/habitat type; Muddy sand with shell gravel and pebbles (?)
   (c) NRA Report: Possibly A2; bivalves, *Ophiura albida*, and *Lanice conchilega*; mixed sediment; less than 15m.

Ophiura ophiura and *Ophiura albida* are conspicuous brittlestars that have overlapping but generally well defined distributions (Map 9). The brittle stars were found on a variety of substrata but *Ophiura albida* was often associated with silty substrates with a variable shell component (*Ensis, Cerastoderma, Mytilus*) and associated mobile fauna. These biotopes may be associated with dense shrimp populations and other scavengers including flatfish. Their importance to the fisheries interest in the Wash is unclear.

4. Sparse fauna on coarse sand which may form extensive plains or pronounced ridges many metres high.
   (a) MNCR type: IGS.Mob: Sparse epifauna on clean mobile infralittoral sand; mobile fauna (crabs, *Asterias rubens, Buccinum undatum*); coarse sand; moderately exposed.
   (b) CSD Report habitat type: Sand.
   (c) NRA Report: C; Coarse sands; polychaete/ bivalve mix.

Large areas of the outer part of the Wash were of clean sand with large features that result from the mobility of the sediment. Although the MNCR description limits this biotope to the infralittoral (<10m) this was recorded in greater depths in the circalittoral in the Wash.

5. Medium fine/muddy sands with inconspicuous infauna. This is a broad catch-all category which can only be properly investigated using detailed analysis of grab/core samples.
   (a) MNCR type: no types exist that clearly equate with the infaunal communities described in the NRA Report.
   (b) CSD Report community/habitat type: Soft mud with numerous small unidentified polychaetes.
   (c) NRA Report: Many groups cover this category that vary as to their particle size and species composition; B1, B2, B3 and D. The reasons for separating these groups are not clear and they are all found close inshore and especially close to the river channels.

Species distributions:
Apart from *Sabellaria spinulosa* and *Ophiura albida*, some other species deserve mention because of their importance to species diversity and fisheries:-

1. *Sabella pavonina*: This species has been found to the south east of the Roaring Middle, around Sunk Sand and also (in the CSD report) the north eastern end of the Boston Deeps.

It is thought to favour areas of enhanced tidal currents which might be found at these sites.

2. *Modiolus modiolus*: A few live mussels have been trawled up during both the present survey and in 1982 (CSD report) and recorded in low numbers in the NRA report. *Modiolus* beds, if they exist, were elusive and their contribution to the diversity of the Wash remains an unknown quantity.
3. *Mytlius edulis*: Beds of this intertidally commercially important mussel have not been detected acoustically or by diect sampling on the sublittoral sand banks.

4.3. Species and habitat diversity

It is likely that the distribution of diversity as compared with biotope distribution might aid the interpretation of the Wash. Map 10 shows measures of diversity based on number of taxa or conspicuous species derived from the three surveys. There would appear to be a correlation between species diversity and hardness of ground and further analysis might be rewarding.

5. Discussion

This report had, as one of its aims, the description of the sublittoral environment of the Wash in terms of the distribution of biotopes (habitats and faunal communities). The assumption in the planning stages of the project was that biotopes would be identified and their extent and distribution mapped. An important objective for English Nature was to map *Sabellaria spinulosa* reefs with the view that this biotope could be managed to maintain its integrity and diversity. However, it was clear during the progress of the survey that describing the Wash in general terms using biotopes posed many difficulties and that this had implications for scientific underpinning of resource management in the Wash.

5.1. Biotopes

Habitats and their associated communities are together termed 'biotopes' and, in principle, they can be categorised according to the classification derived by the MNCR. Mapping biotope categories is now an established technique and is particularly successful in revealing biotope diversity and pattern when applied to areas where the range of biotopes is very diverse. However, where the range of biotopes is not great the maps will appear over simplified. This is particularly the case with the biotope classification of the sublittoral sediments as the system stands at the present time.

Nevertheless, if there is sufficient choice to adequately discriminate between samples biotopes, provide a basis for a broadscale, general picture of an area. Biotopes also can provide a framework for the comparison of sites on a national or international scale. Biotopes can also form a useful common denominator for the comparison of two or more sets of data. In order to avoid forcing a 'square peg into a round hole', new biotope types have been created for the purposes of this survey. These biotopes have been arranged into main biotopes and variations upon them (see Map 11). These biotopes are provisional and it should be pointed out that (a) they lack a full integration of infauna with epifauna and (b) the importance of mobile scavengers and carnivores has not been fully considered. More

complete data is required before a full analysis can be undertaken to formulate and justify the biotopes proposed.

The biotope approach to the sublittoral sediments may not be appropriate in the situation encountered in the Wash. Indeed, the 'biotopes' might be better regarded as composed of overlapping distributions of key conspicuous species, many of which can exploit a wide range of sediment types. The lack of clear boundaries between assemblages of species together with a lack of fidelity to a particular ground type makes any biotope categories somewhat arbitrary and, therefore, difficult to apply consistently to sample records: biotopes may be variously categorised and there is a risk of misclassification.

This has quite profound implications for the scientific basis for site management of the Wash: can a biotope category represent a consistently identifiable community that can be mapped, monitored and, possibly, be subject to a specific form of management?

Other characteristics can be measured as variables independently of biotopes, such as species richness and taxonomic diversity, habitat feature diversity, median particle size and selected species of particular interest which may cross biotope categories. These characteristics can be mapped and provide the spatial information required to underpin management. For example, areas of high diversity can be identified and monitored for change, perhaps stimulating specific measures to maintain or restore diversity. Links between diversity and the distribution of habitat features, single species or human activities (such as fisheries, effluent inputs) can be investigated spatially without being constrained by biotope categories.

However, maps showing features as continuous variables are often difficult to act upon and there is a need to draw boundaries, albeit somewhat arbitrarily. Biotopes at least ensure that there is a consistency in mapped units into which other attributes (such as diversity) can be placed.

It is suggested that a proper understanding of the Wash ecosystem requires separate spatial layers showing species and habitat distributions. Faunal analysis should remain flexible to derive statistics on diversity and community clusters as revealed through multivariate analysis. Categorisation into biotope types is, at this stage, premature and likely to lead to poor management decisions because of the scope for misclassification and the drawing of arbitrary boundaries.

However, it is recognised that biotopes will be useful to assess the Wash in terms of a national standard and to derive a general picture of broad biological features which can be viewed in a wider context than simply the Wash itself.

5.2. Sampling sediments and fauna

Very different impressions of the Wash are gained depending upon the sampling methodology used. There is a particularly marked difference between grab survey, with the emphasis on infauna, and other types of survey that emphasise the epifauna. Both infauna and epifauna require sampling from approximately the same location and time to be able to fully assess the range of biotopes found in the Wash. Video and diver observation gives the most accurate representation of the epifauna allowing some assessment to be made of spatial heterogeneity whilst dredges and trawls provide samples for accurate species identification.

Unfortunately, use of video and divers is restricted by poor visibility in the Wash, but should be considered in any sampling programme.

Intensive sampling is expensive and, unless sampling is stratified based on some prior knowledge of the sea floor, can lead underepresentation of some habitats. For example, the regular grid sampling undertaken by the NRA appears to have missed many of the restricted areas of hard ground around the Roaring Middle. Acoustic remote sensing can provide a sufficient knowledge of habitat types to stratify sampling.

It is recommended that a comprehensive stratified sampling programme involving epifaunal and infaunal sampling be undertaken based on acoustic ground types. Further acoustic work may be needed to supplement the map of ground type.

5.3. Spatial heterogeneity and temporal change

Are differences between surveys real or apparent? The positions given for samples may have been poor estimates and even with GPS the sample may be 100 metres or more away from the stated position (bearing in mind the lay-back of a dredge, video and even a grab). This uncertainty is of little consequence if the ground is homogenous over large areas, but can be very misleading over heterogenous ground.

However, sediments can be very fluid habitats subject to sedimentation and redistribution by waves and tidal currents. Where sand mixes with hard substrata, sediment movement may drastically affect epilithic communities through scour and periodic covering.

Should we expect biotopes in such situations to be stable spatially and temporally? If change occurs, what is the nature of the dynamics and what implications does this have for management? Perhaps a parallel can be drawn with the more obviously fluid pelagic habitats and space be allowed for the process of fluctuating habitats and communities involving colonisation and recruitment. Clearly, special measures to conserve a community that is highly dynamic needs to take the wider view than more stable, geographically conservative communities.

Sabellaria spinulosa is of particular interest because it has been singled out as being of significance to species diversity and associated with the prawn fishery. Indeed, the reef-building worms (*S. spinulosa* and *S. alveolata*) have formed a theme in the LIFE programme promoting management of the cSACs. It is important, therefore, to test many of the assumptions about the importance of this species to the overall pattern of species diversity and richness in the Wash.

It is recommended that a measure of species diversity and richness for the whole of the Wash is one of the objectives of a broadscale comprehensive survey and that an assessment is made of the association of *Sabellaria spinulosa* with diversity and richness. Specific studies may be undertaken to investigate the dynamics of species such as *Sabellaria spinulosa* in order to ascertain the best ways to conserve these biotopes.

5.4. Productivity and population studies

The Wash is an area under some pressure from fisheries (mussel, cockle and prawn) as well as from anthropogenic inputs from rivers (agricultural run off, sewage and industrial waste).

Anecdotal evidence suggests a recent decline in populations of certain marine invertebrates (including shellfish stocks) and shore birds. Many studies are being or have been conducted in the Wash and yet, despite this, showing change and decline to have taken place unequivocally remains elusive. This is an area of research likely to attract much interest (from MAFF, for example) and requires intensive long-term sampling.

However, few organisations are well placed to perform broadscale and regular surveys. This spatial perspective is needed to interpret different measures of change throughout the Wash and is, therefore, complementary to productivity and population studies.

It is suggested that the Eastern Joint Sea Fisheries Committee is best placed to perform broadscale, regular survey which would provide a sound context for the interpretation of all other studies on productivity and populations in the Wash.

5.5. Links between Eastern Joint Sea Fisheries Committee and English Nature

One of the aims of this project was to assist the EJSFC in the use of *RoxAnn* in remote survey for assessing and monitoring the status of particular shell fish stocks and habitats. It is hoped that English Nature and the EJSFC will work closely with monitoring the cSAC and that this project will facilitate the growth of this partnership.

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

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

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

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

Grids generated from the track data allow far greater scope for analysis than is possible within *Microplot* with, potentially, the benefits of a less subjective approach to interpolation and the combination of data into a single map. However, processing the data can be intensive in terms of computation and the resulting images still require careful interpretation. It is

likely that continued support to both English Nature and the EJSFC will be required for this, dependant upon the critical requirements of maps.

The EJSFC should build up their experience of *RoxAnn* to discriminate between ground types on a localised basis within *Microplot*. The EJSFC may wish to liaise with Newcastle University and English Nature to continue to build skills in post processing and biotope map production.

Acknowledgements

The Wash survey was funded by English Nature and supported by the Eastern Joint Sea Fisheries Committee, who supplied the vessels from which the survey was conducted. The BMP project would like to thank the crew of the fisheries vessels *Protector 3* and *Surveyor*. We would like to thank Bill Watson in particular for the long hours at the helm and for allowing us to stay at his house.

We would like to thank Matt Mander from the EJSFC, and Ian Patterson and Helen Vine from English Nature for their input into the survey and their useful comments of the report.

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Map 1. Track of survey vessel showing Echo 2 values.

The acoustic data is obtained from a patch of ground under the survey vessel for each pulse of sound emitted by the transducer. The return signal (echo) is analysed and three values derived; echo 1 (roughness), echo 2 (hardness) and depth. The average value over 4 seconds is saved together with the position from the GPS and time from the computer's clock. The raw track data, therefore, consists of a series of points along the ship's track with associated data.

The strength of echo 1 is dependant not only on the ability of the ground to reflect sound (hard, smooth surfaces reflect strongly) but also on the duration of the echo (rough ground reflects sound from further afield and extends the duration of the echo). The duration and strength of echo 1 is argued to be linked to ground roughness.

The strength of echo 2 is similarly dependant upon the ability of the ground to reflect sound. However, signal strength is greatly attenuated since the pulse must reflect back from the water surface and reflect a second time from the ground before registering as a second echo. It is, for this reason, considered to be more sensitive to variation in hardness than the strength of the first return.

The size of the patch covered by the sound pulse is determined by the beam angle of the transducer (approximately 17 degrees) and depth. Thus, the single echo 1 and 2 values will be returned from, potentially, a substantial area of the sea floor and will in themselves be an 'average' over the different types of ground that could occur in the patch.

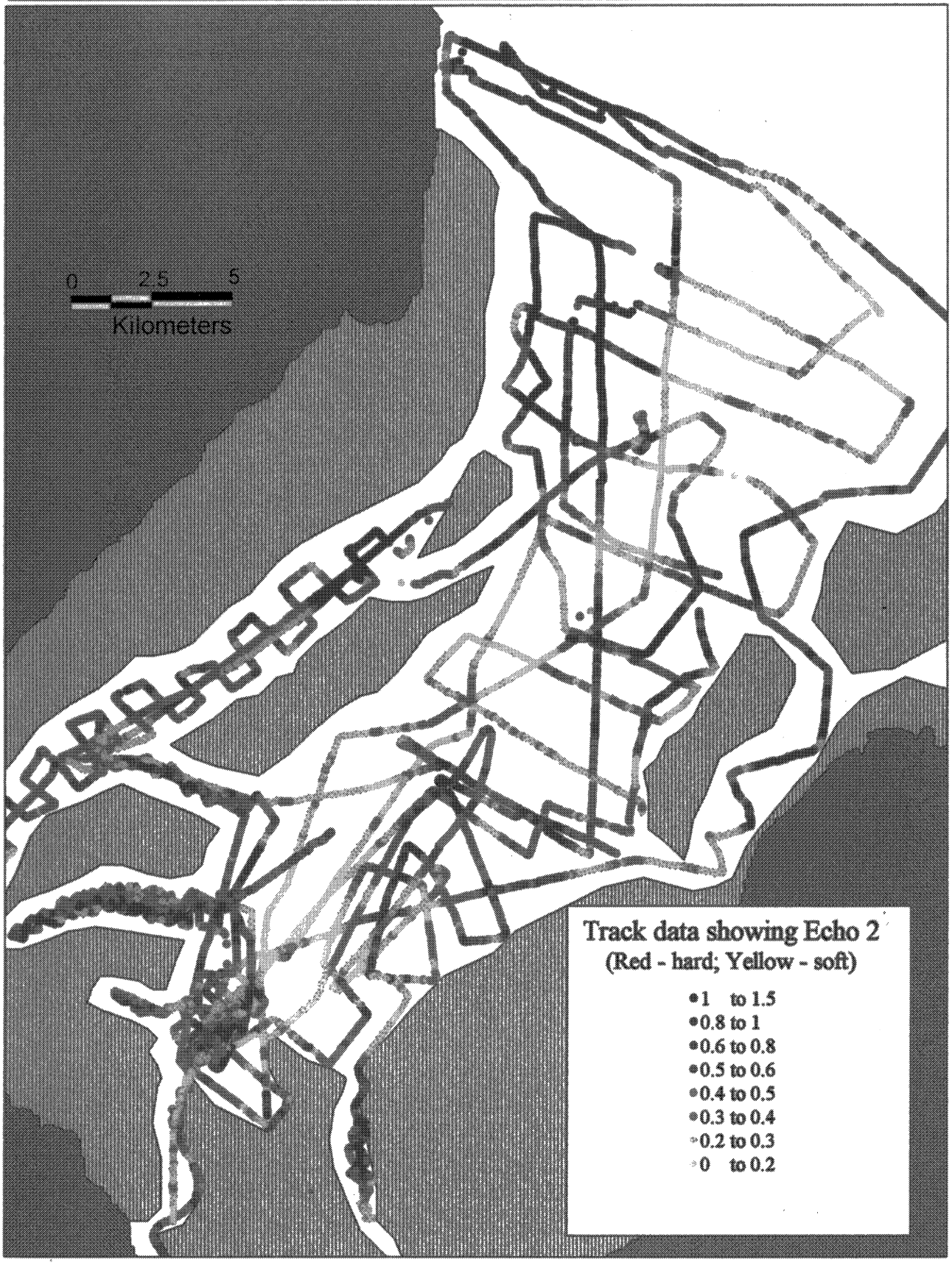
It must be stressed that these simple values for echoes 1 and 2 do not measure either roughness or hardness, but are only loosely linked to these sediment characteristics. For the purposes of analysis, they are simply considered to be two properties of the signal and that distribution patterns of these properties must be ground truthed before they can be interpreted in terms of ground type. Nevertheless, the terms hardness and roughness are used as a tag for E1 and E2 for convenience.

The nature of the track data needs to be borne in mind when viewing the continuous coverages generated from it. (a) Track spacing varies: some areas are densely covered by tracks and the coverages can be viewed with more confidence than is the case for wide track spacings. (b) Adjacent tracks may differ markedly in values for E1, E2 or depth: there is always the possibility that one of the tracks might be spurious and cross-tracks may not be available for double checking.

In summary:
(1). E1 and E2 are indicators of different ground types, but not a direct measure of roughness and hardness .
(2). Do not put too much faith in the fine scale variations in E1, E2 and depth distributions as shown in the continuous coverages, especially wheretrack spacing is wide or there are discrepancies between adjacent tracks.

Map 1. Track of survey vessel showing Echo 2 values (hardness)

Author: EFS
Date: 5th February, 1997
File: Wash, track.wor



Map 2. Raster images of depth, E1 and E2.

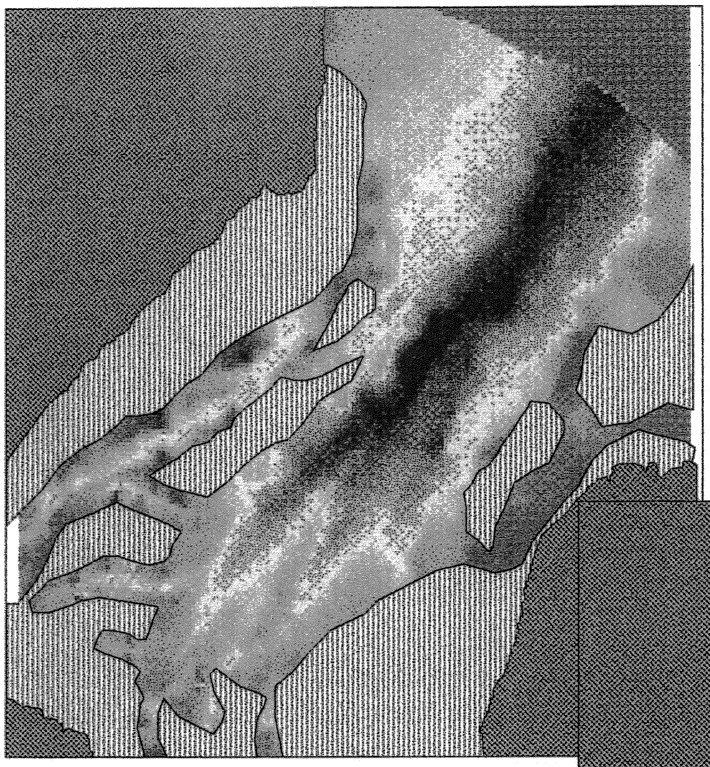
The generation of a continuous coverage from the track data requires new values to be calculated at grid nodes over the entire area. In this case a grid of about 200 rows and 340 columns was 'placed' over the track data and new values calculated at each node. These values were calculated automatically from a search of surrounding track data using *Surfer* and *Vertical Mapper.*

The raster map displays these node values by placing them in the centre of a small pixel (representing an area approximately 100m x 100m) which are then coloured according to the node value.

The grid values can be used to generate contours (as in Maps 3, 4 & 5) or can be used in other forms of analysis, such as image processing, in which latter case the 'pixel' nature of the resulting image is retained (e.g., Map 6). Raster images convey a greater sense of continuous change than do contour maps.

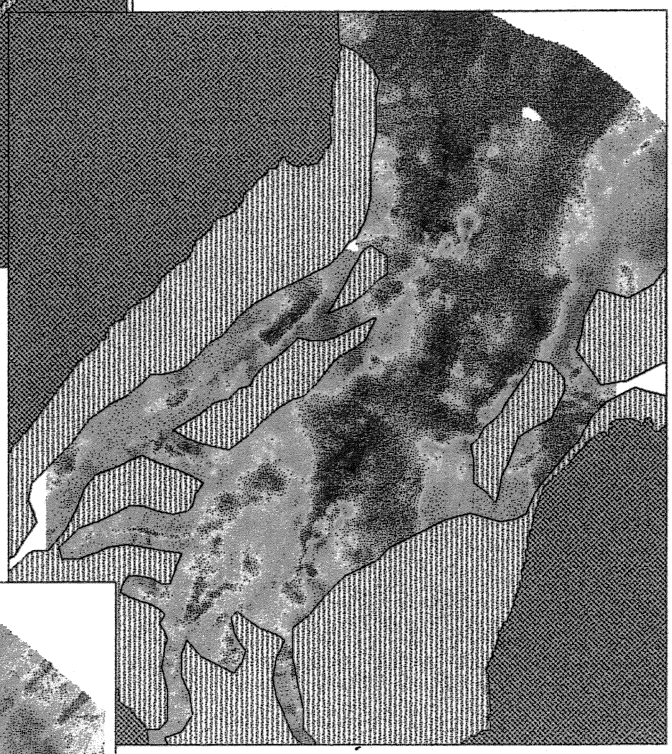
Map 2. Raster images of depth, E1 & E2

Author: BFS
Date:5th Feb, 1997
File: Wash, raster.wor



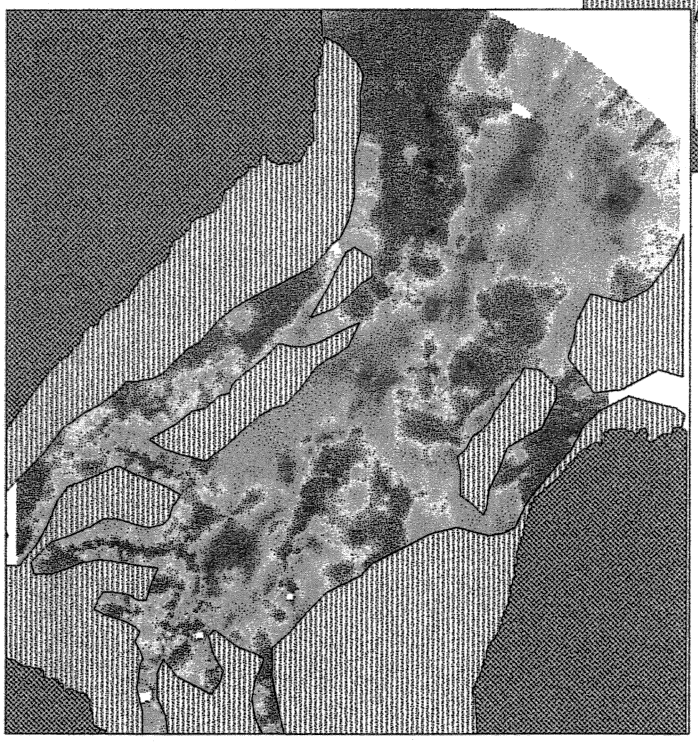
Map 2a. Depth.

Shallow is blue; deep water is red



Map 2b. Echo 1 (roughness)

Rough is red; smooth is blue



Map 2c. Echo 2 (hardness)

Hard is red: soft is blue

Maps 3, 4 & 5. Acoustic signal strength of Echoes 1 & 2, bathymetry.

The maps have been generated by contouring grid values. They give a clear picture of the distribution of E1, E2 and depth, although the boundaries between the ranges must not be considered to be as definitive as they might appear.

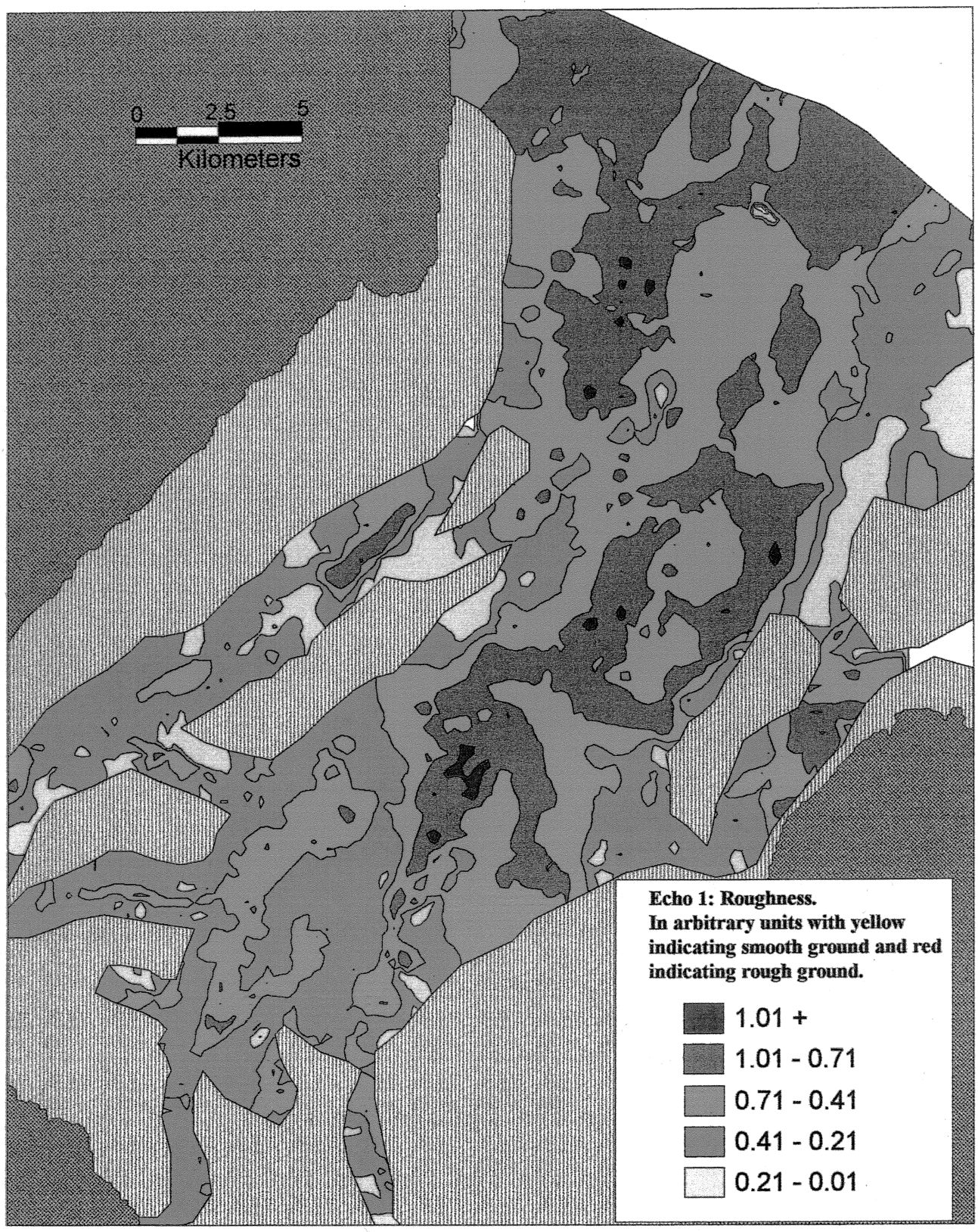
In general, the patterns of E1 and E2 are similar. Clearly, ground likely to generate strong E2 values are likely to also lead to strong E1 values.

There were extensive areas of hard ground off Gibraltar Point, Sunk Sand, in the channel between Sunk Island and Hunstanton, Roaring Middle and in Boston Deep and smaller areas off Gat Sand and in the various channels. Particularly soft ground was found in the Old Lynn Channel and the Lynn Deeps.

However, E1 values can also be elevated above what might be expected if E1 was directly correlated with E2 in situations where the ground is rough. The deeper ground at the entrance to Wash and extending south east along the southern edge of the Lynn Deep was just such an area of elevated E1 values (ground of elevated roughness).

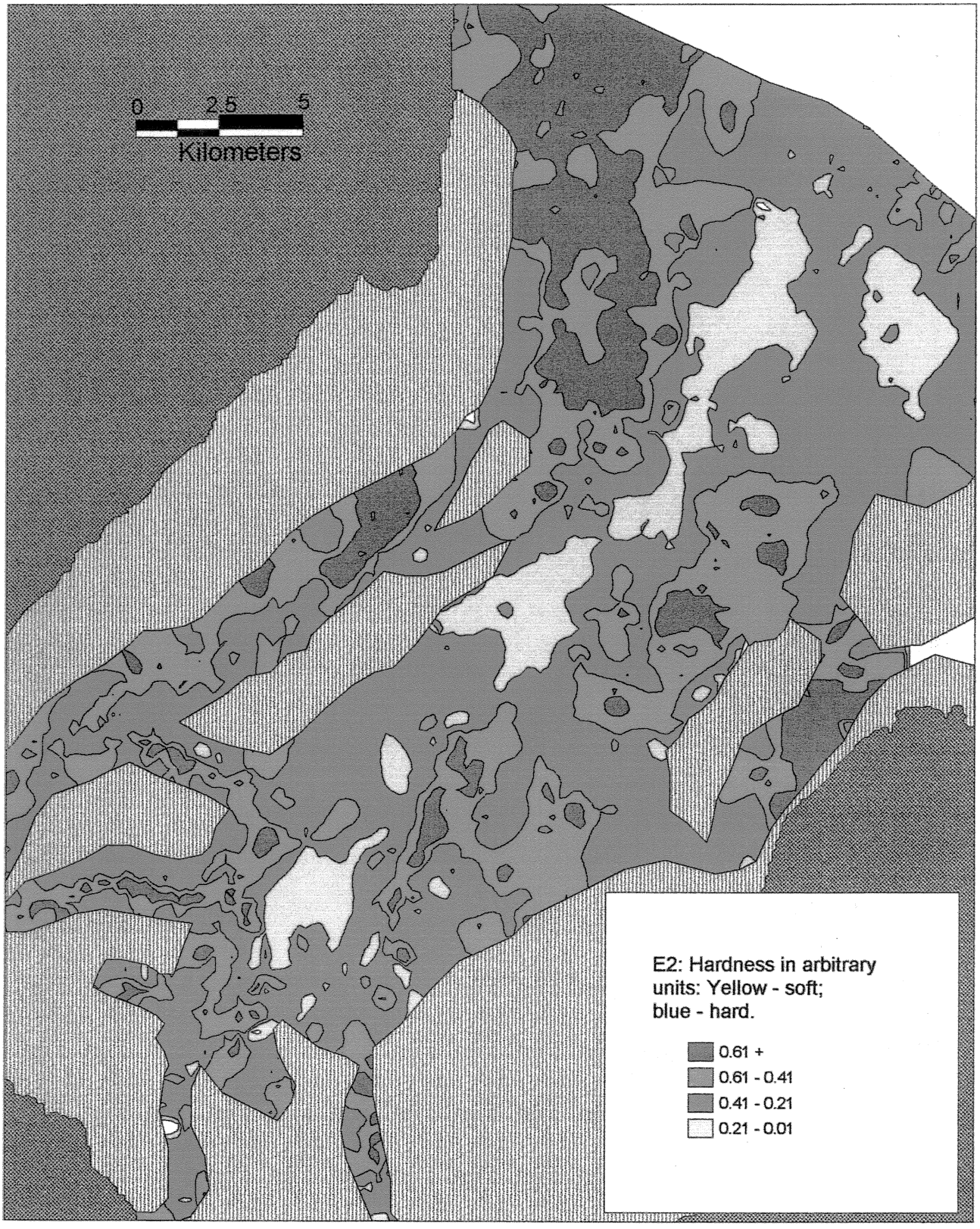
Map 3. Acoustic signal strength of Echo 1 (hardness)

Author: BFS
Date:5th February, 1997
File: Wash, e1cont.wor



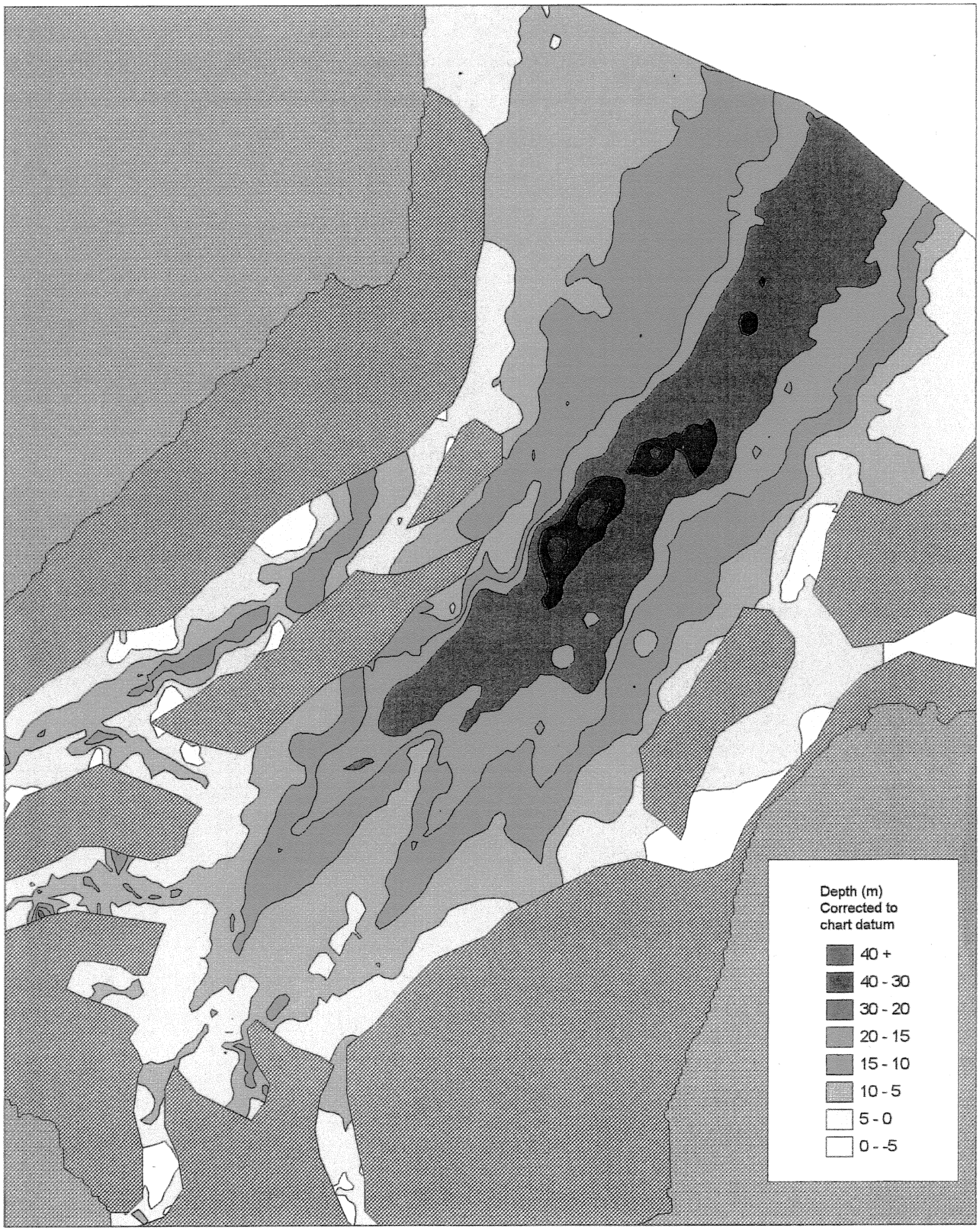
Map 4. Acoustic signal strength of Echo 2 (hardness)

Author: BFS
Date:5th February, 1997
File: Wash, e2cont.wor



Map 5. Bathymetry (from echo sounder readings)

Author: BFS
Date: 5th February, 1997
File: Wash, Dp3.wor



Map 6. Acoustic ground types.

The three acoustic parameters (E1, E2 and depth) can be categorised based on the description in the text accompanying Maps 3, 4 &5. Firstly, the grid values for E1 and E2 can be separately divided into ranges (low, moderately low, moderately high and high) which are then combined (forming a possible 16 categories). Many of the possible combinations are either not found or are only rarely found. The majority of grid values lay along a trend showing E1 and E2 to be correlated and these have been coloured along a scale of yellow, green, blue and red. Note that low E1/E2 values are not well represented.

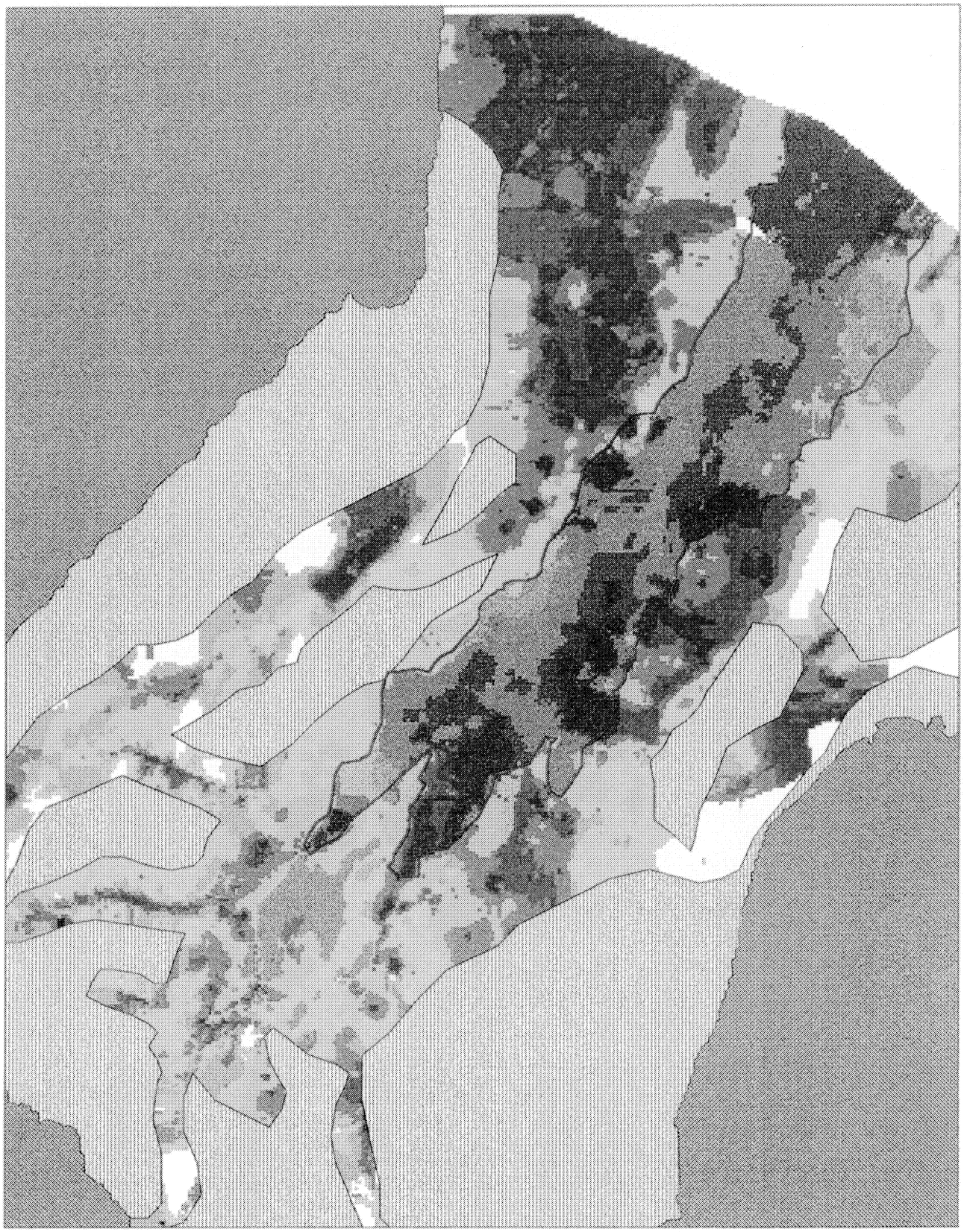
However, there are significant areas where high E1 values are elevated above E2 values and these are coloured shades of orange.

These categories have been further divided into shallow and deep versions with 15m below chart datum as being the division between the two depth ranges. The shallow water ground types are brightly coloured whilst the deeper ground is indicated by darker tones. A red line showing the 15m contour is also included.

This raster map was produced using the image processing utilities in *Idrisi* and imported into *MapInfo* for display. It has been used as a backdrop for some of the other maps as a useful reference to ground type.

Map 6. Acoustic Ground Types

Author: BFS
Date: Feb 5th, 1997
File: Wash, groundtp.wor

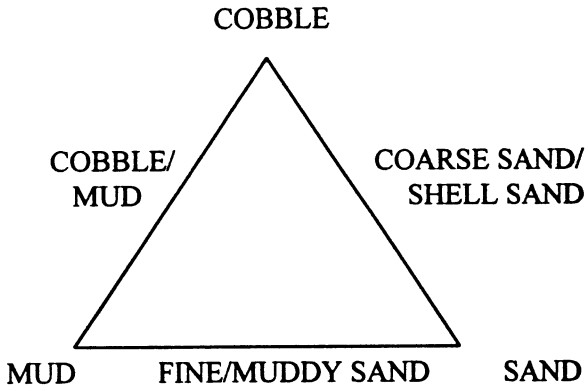


Map 7. Sediment characteristics from three surveys.

The comparison of results from sediment samples taken from different surveys is problematic because of different sampling methods and descriptive terminology. An attempt has been made in Map 7 to use a limited descriptive terminology and choice of colour for the symbols.

Map 7b. Sediment type from three surveys combined (reduced to 6 types).

The sediments can be described in terms of a modified Folks triangle:



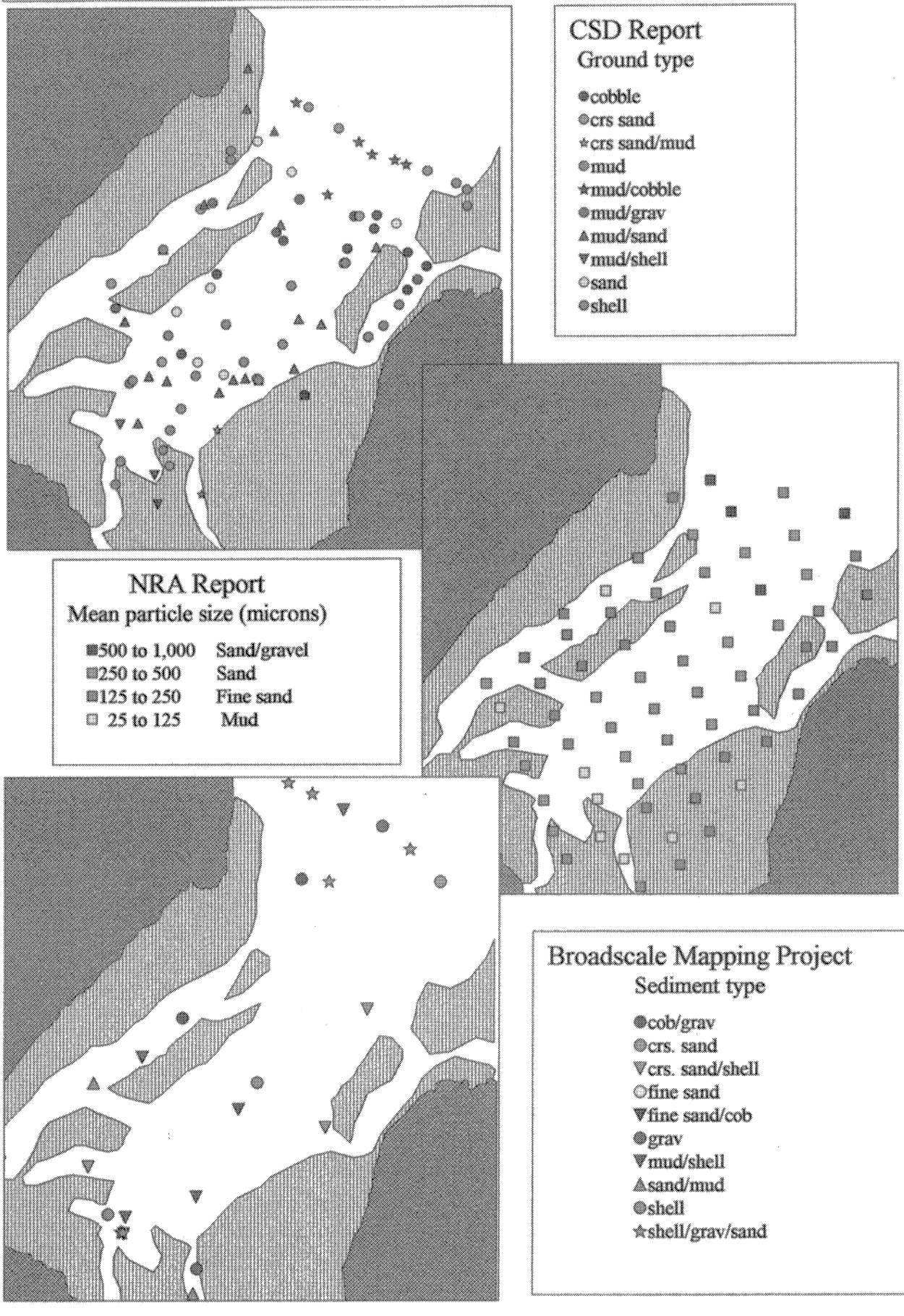
The sediment types have been further reduced to the six types above to facilitate combining the data from the three surveys and comparison with the acoustic ground types.

In general, there is quite good accord between harder ground and the stronger acoustic ground type. The hard ground near Gat Sand was largely composed of shell whilst the hard ground off Gilbraltar Point had a larger component of cobble. The Lynn Deeps had a mixture of moderately hard/rough ground and soft ground: the harder ground appears to correlate with cobble/mud.

There are many samples which would appear not to fit into the acoustic picture (mismatches). However, it must be remembered that misclassification, positional error and possible changes over time would all contribute to mismatches.

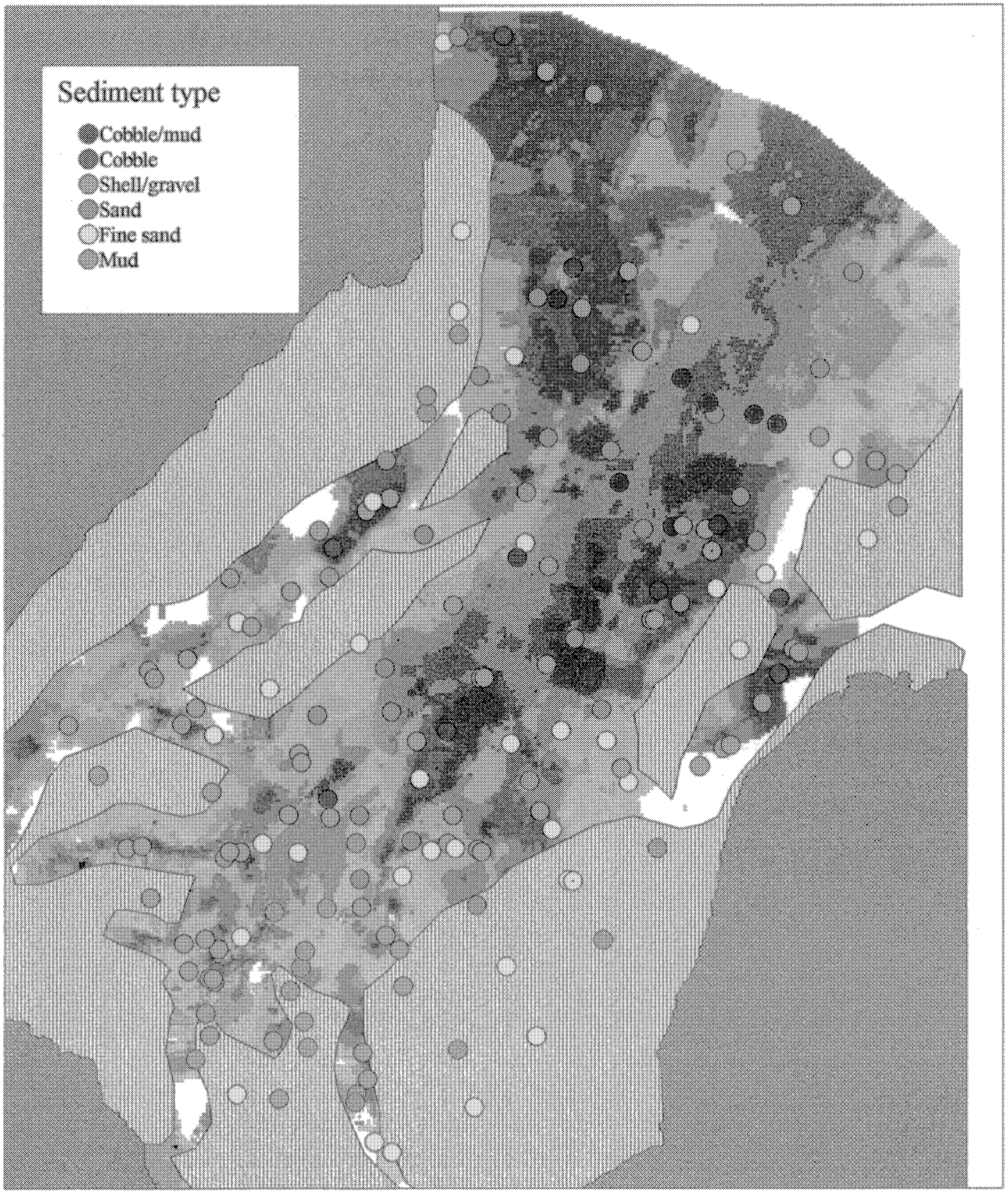
Map 7. Sediment characterstics from the three surveys

Author: BFS
Date:5th Feb, 1997
File: Wash, sediment.wor



Map 7b. Sediment type of three surveys combined (reduced to 6 types).

Author: BFS
Date: 5th Feb, 1997
File: Wash, allsed.wor



Map 8. The distribution of *Sabellaria spinulosa*.

The reef-building worm *Sabellaria spinulosa* has been found throughout the Wash in all three surveys and would appear to be very catholic in the range of sediments on which it can live. These points raise the question as to whether *Sabellaria spinulosa* is a suitable conspicuous species for the characterisation of a biotope whose distribution can be mapped and might form the basis of a management unit.

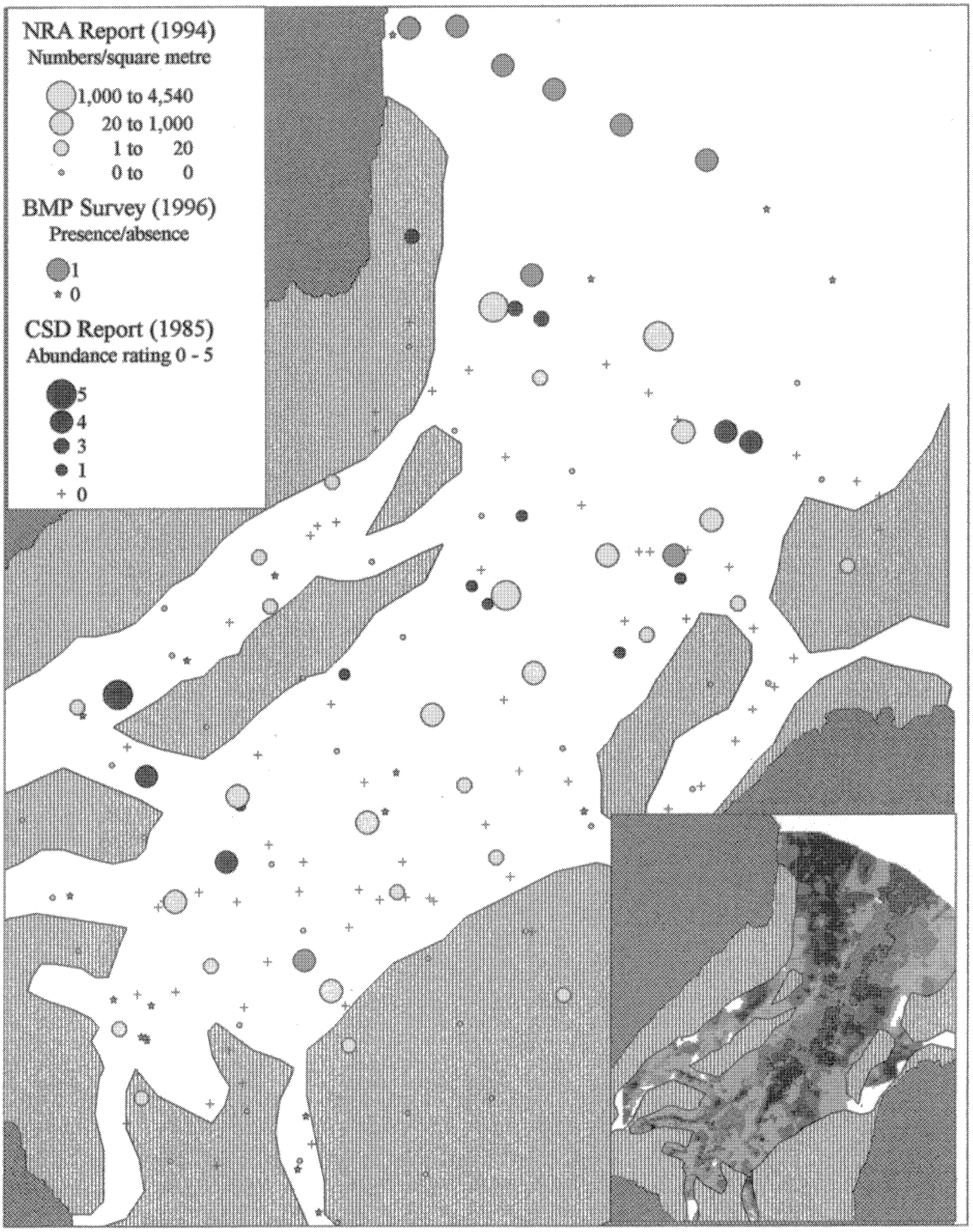
The differences in distribution between the three surveys are of doubtful significance and are probably accountable by the different sampling techniques used. However, the distribution was patchy over much of the inner Wash area whilst *Sabellaria spinulosa* was consistently recorded over much of the outer Wash, particularly the hard ground off Gibraltar Point.

Map 9. Distribution of two species of brittle star.

The issues raised by the reef-building worm (Map 8) are echoed by the distributions of the brittle stars. Both species of brittle star were found over different types of ground although *Ophiura ophiura* was restricted to the inner south-east corner of the Wash.

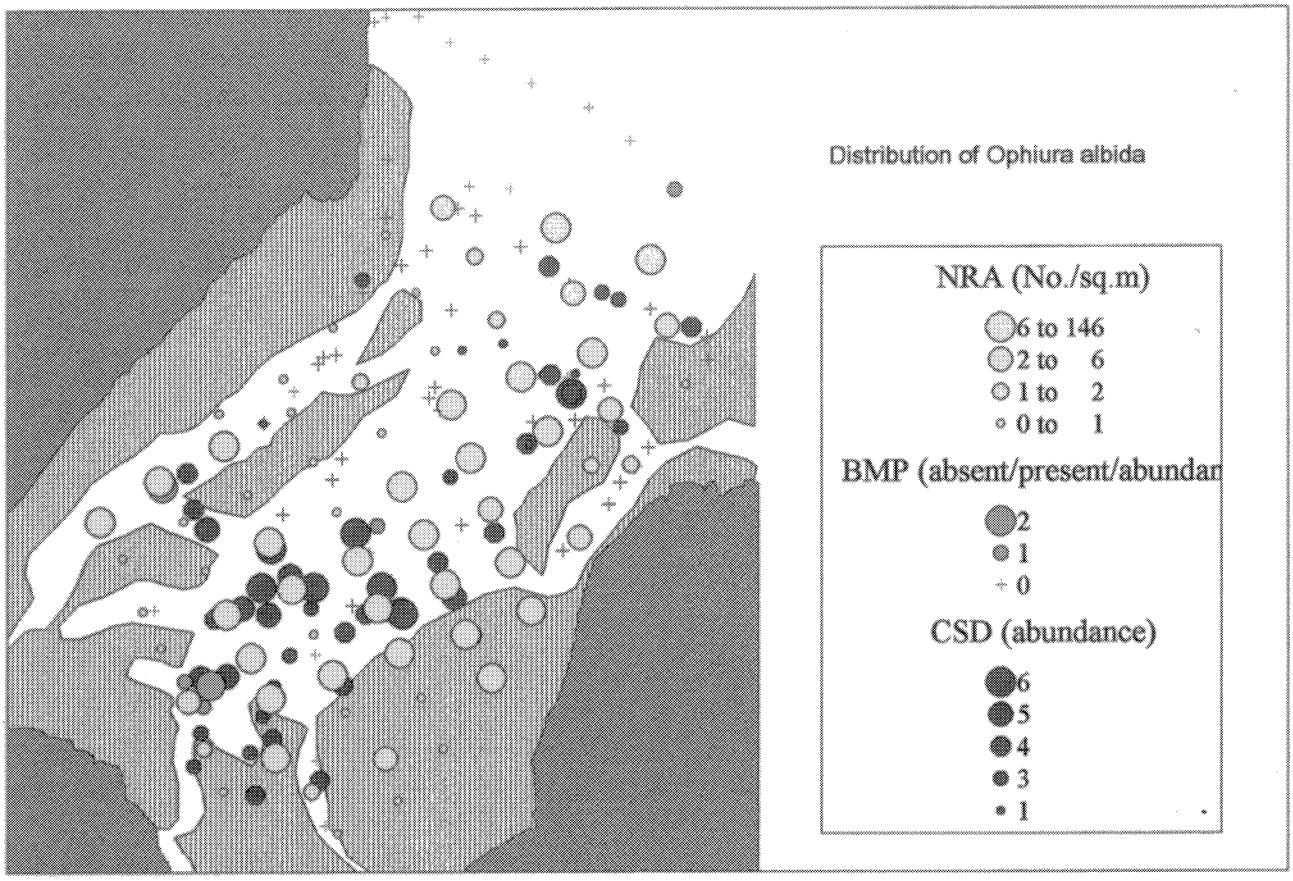
Map 8. The distribution of Sabellaria spinulosa (inset shows raster image of acoustic ground type)

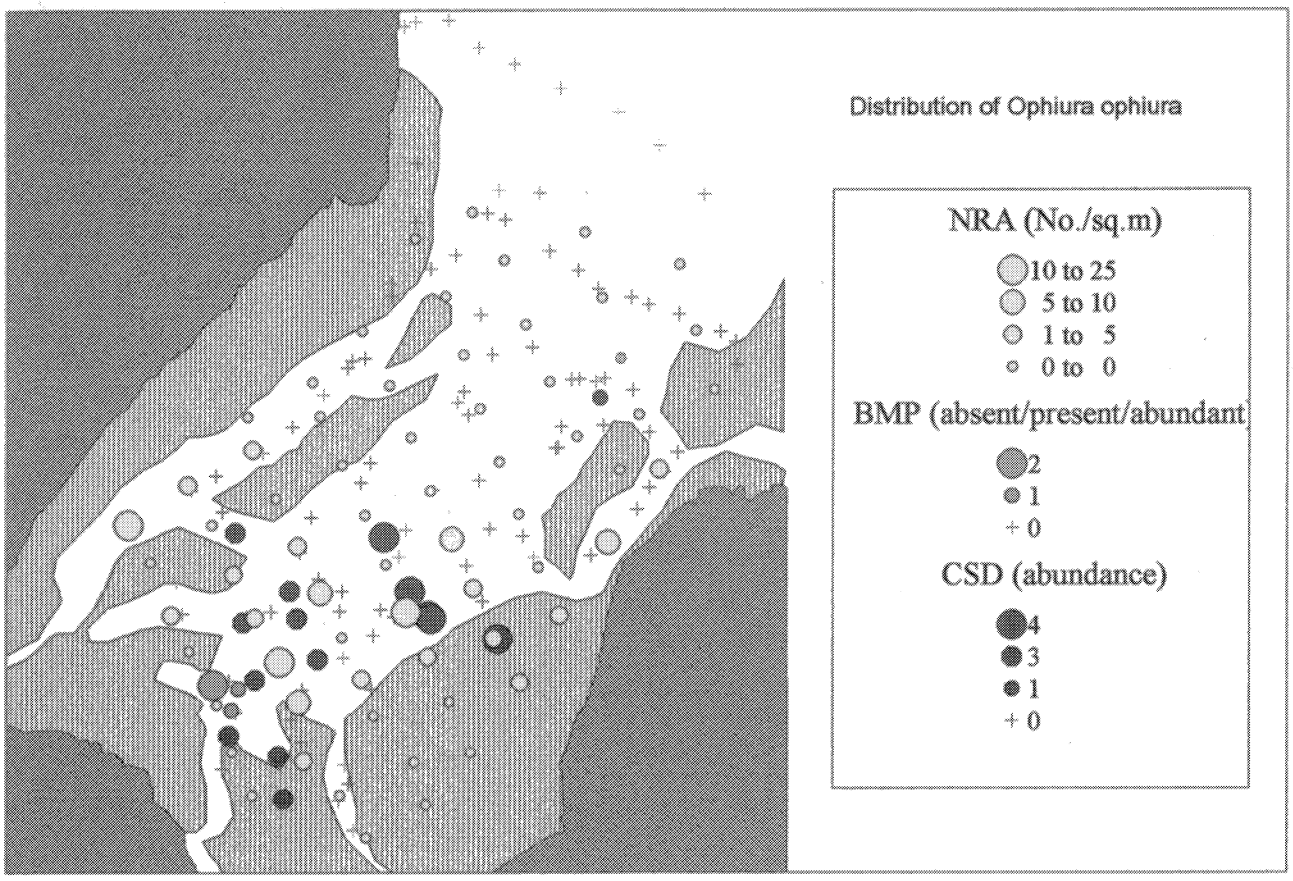
Author: BFS
Date: 5th February, 1997
File: Wash, sabspin.wor



Map 9. Distribution of two species of brittle star

Author: BFS
Date: 5th February, 1997
File: Wash, ophiura.wor





Map 10. Diversity

A consistent measure of diversity for the three surveys cannot be used due to the different nature of the data and sampling methods. However, a four-point diversity measure has been derived for each survey to show variation over the Wash. The diversity measure for both the CSD and BMP surveys are based on very few, conspicuous species and is subject to poor recording (e.g., through poor underwater visibiltiy). Diversity measures for these surveys are also weighted towards the epifauna.

The NRA report supplies a more robust measure of diversity, but neglects the epifauna.

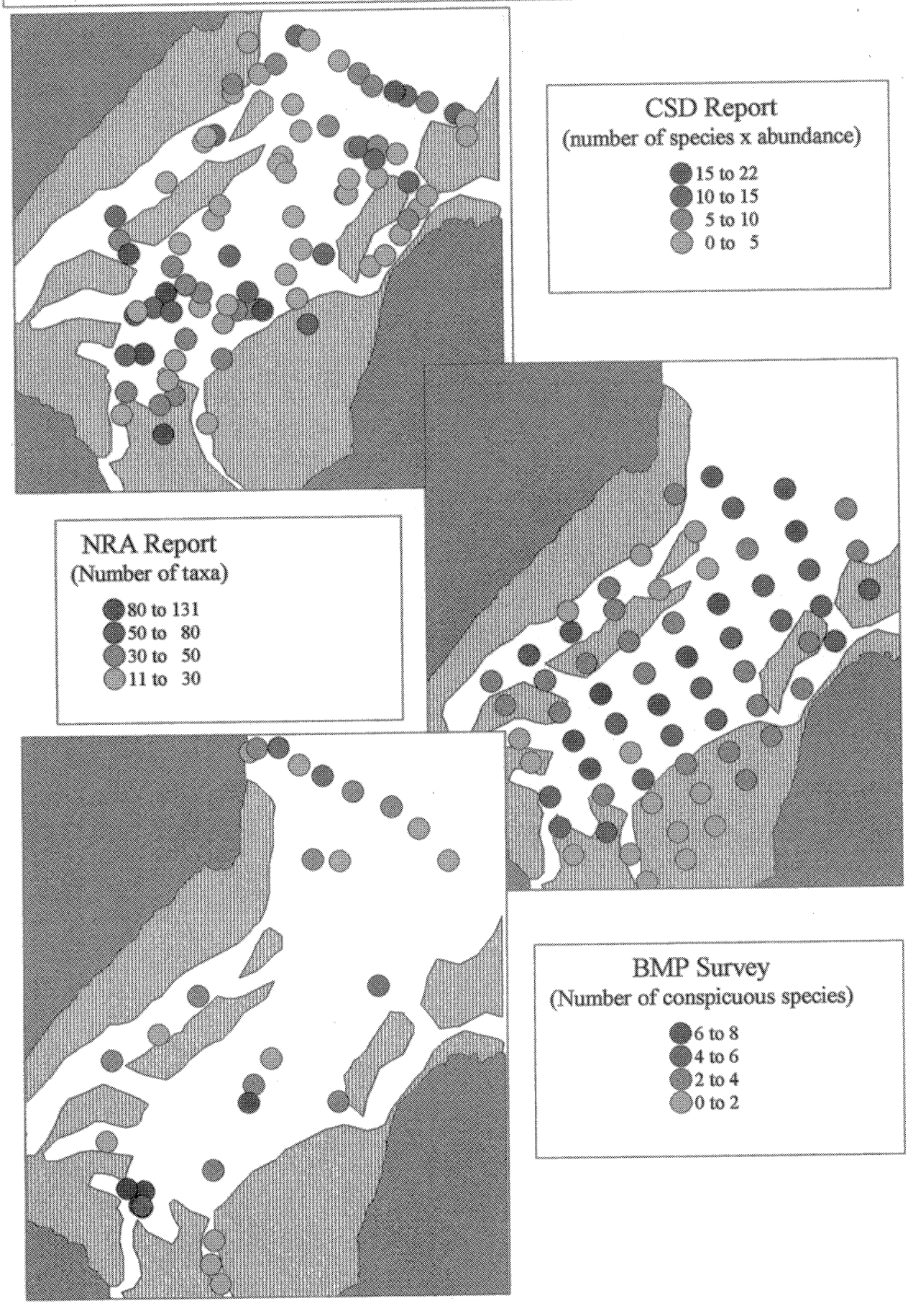
Map 10b. Diversity from three surveys combined.

The diversity measures from the three surveys have been combined and overlain on the raster image of acoustic ground type. There is broad agreement between the surveys that high diversity was associated with the shell banks of the Roaring Middle and Gat Sand and low diversity was associated with softer ground.

However, the picture is more uncertain on the hard ground off Sunk Sand and Gibraltar Point. The variation in diversity may be entirely due to sampling; but there is the possibility that the hard ground in these wave exposed shallows was different in nature (sandier and with a less open structure than the shell banks). There is no clear support for the view that ground most likely to have significant populations of *Sabellaria spinulosa* also has the highest diversity.

Map 10. Diversity

Author: BFS
Date:5th Feb, 1997
File: Wash, diversity.wor



Map 10b. Diversity from three surveys combined

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Map 11. Biotopes from all three surveys.

An attempt has been made to characterise the faunal assemblages from the various samples. These are described in more detail in the text of the report as 'biotopes'. There are five main biotope categories:- (1) *Sabellaria spinulosa* and/or *Lanice conchilega*; (2) epifauna; (3) *Ophiura albida*; (4) incon-spicuous infauna; (5) Scavengers (*Asterias rubens, Crangon* and *Buccinum undatum*). However, they do not form distinct biotopes but represent types that were more often found in various combinations.

(1) *Sabellaria spinulosa* and/or *Lanice conchilega*:
- (1.1) *Sabellaria spinulosa*
- (1.2) *Sabellaria spinulosa/Lanice conchilega*/epifauna/*Ophiura albida*
- (1.3) As above with *Asterias rubens* and *Crangon*
- (1.4) *Lanice conchilega*
- (1.5) *Lanice conchilega*/epifauna
- (1.6) *Lanice conchilega/Asterias*

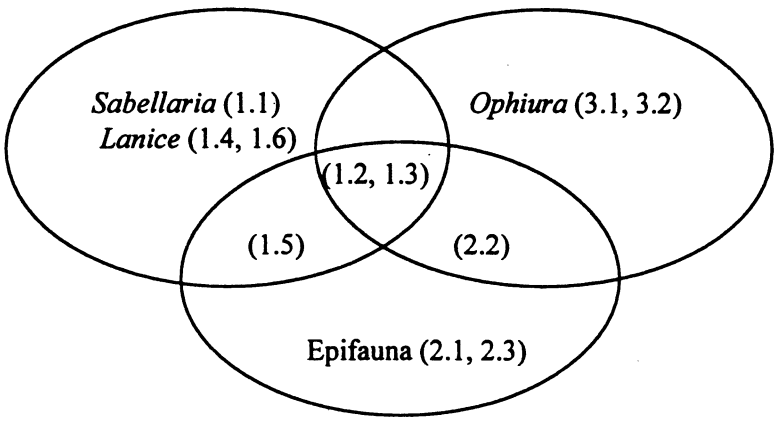
(2) Epifauna
- (2.1) Epifauna
- (2.2) Epifauna/*Ophiura*
- (2.3) Epifauna/*Asterias*

(3) *Ophiura albida*
- (3.1) *Ophiura albida*
- (3.2) *Ophiura albida/Asterias*

(4) Inconspicuous infauna

(5) Scavengers (included as conspicuous component of the above biotopes)

It might be more helpful to the understanding and interpretation of biotope distribution to regard the conspicuous species to have separate but overlapping distributions with the possible presence of scavengers in almost any biotope. Infauna have been excluded from the scheme below as the relationship between epifauna and infauna is not known. It is likely that the distribution of infaunal assemblages might be somewhat independent of the epifaunal biotopes.



Map 11. Biotopes from all surveys

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