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Sabellaria spinulosa reef in The Wash and North Norfolk Coast cSAC and its approaches: Part I, mapping techniques and ecological assessment

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Sabellaria spinulosa reef in The Wash and North Norfolk Coast cSAC and its approaches: Part I, mapping techniques and ecological assessment

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A report for the Eastern Sea Fisheries Joint Committee and English Nature

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Summary

The use of acoustic ground discrimination systems (AGDS) and sidescan sonar for mapping *Sabellaria spinulosa* reefs were compared and contrasted. AGDS was moderately successful in discriminating between different biotopes, including *Sabellaria spinulosa* reefs. The project benefited from the trial of the *QTC* AGDS for comparison with *RoxAnn*. Both systems performed to similar levels of accuracy. However, the differences between interpretations of the data sets underlines that AGDS map likely distributions of biotopes and there is considerable uncertainty attached to maps. It is concluded that, whilst AGDS can map probable distribution of *Sabellaria spinulosa* biotopes moderately successfully, they cannot map fine scale distribution with high levels of accuracy.

Sidescan sonar can give direct images of sea floor features. However, direct detection of *Sabellaria spinulosa* reefs by sidescan sonar was unsuccessful. Although the opportunity for repeat surveys using sidescan sonar was thwarted by poor weather, it is unlikely that the system used would be capable of imaging reefs. It is recommended that other acoustic imaging techniques be tested, such as scanning sonar.

Direct observation using video confirmed that reefs existed in Area 107 in locations where they were previously seen in 1997. They were not observed in the area near Longsands within The Wash. The apparent absence of reefs at the latter site added to the difficulty in trailing mapping techniques. Possible temporal variability and spatial heterogeneity is discussed in relation to monitoring.

The distinctiveness of *Sabellaria spinulosa* reefs as a community separate from other biotopes in which *Sabellaria spinulosa* was found at low to moderate densities has been discussed. Whilst *Sabellaria spinulosa* biotopes merge into each other, there is some evidence that reefs are sufficiently distinct from other biotopes to justify a definition in terms of density ($>500/0.1m^2$) and associated fauna.

A number of options for future survey of *Sabellaria spinulosa* reefs are discussed.

Contents

1. Background and aims of the programme

The programme is a joint project between English Nature (EN) and the Eastern Sea Fisheries Joint Committee (ESFJC). It aims to establish the spatial and temporal distribution of *Sabellaria spinulosa* reefs within the area of The Wash and North Norfolk Coast Special Area of Conservation (cSAC) and to develop techniques for monitoring reef condition and fishery impacts. The latest moderation exercise by EN has elevated *Sabellaria spinulosa* to the status of an interest feature in its own right as a biogenic reef. This survey is the first stage of a project to study the extent and variability of *Sabellaria spinulosa* reefs, to study their local ecosystem and identify the impacts, if any, of current fishing practices on these features. This survey concentrates on fine scale mapping of the spatial and temporal distribution of the reefs.

The mapping surveys based on acoustic data collected during the Broadscale Mapping Project (BMP), as summarised in Foster-Smith and Sotheran (1999), predicted the most likely distribution of *Sabellaria spinulosa* together with a range of other biotopes found within the area. The maps were based on all acoustic data and ground truth samples collected over three years. The maps indicated that high densities of *Sabellaria spinulosa* within The Wash were most likely to be located on the northern side of the Lynn Deeps near Longsands, and also on the opposite side near Hunstanton. The predicted distribution extended along the sides of the Lynn Deeps north east to Scott Patch near the licensed sand extraction area 107, and well developed reef was confirmed here. However, although high density samples were actually taken from both sites, error assessments indicated that *Sabellaria spinulosa* reef was predicted with an internal accuracy of about 58%. A more recent camera survey undertaken by the ESFJC suggested that *Sabellaria spinulosa* reef was seen in the former location although sampling was not sufficiently extensive to definitively confirm the distribution of reefs. Thus, questions remain as to the effectiveness of acoustic ground discrimination systems (AGDS) for detecting and mapping *Sabellaria spinulosa* reefs. Other techniques, such as sidescan sonar, may be more appropriate for detecting reefs.

Part of the reason for the apparently poor acoustic discrimination is the real problem of deciding what constitutes a reef as opposed to other biotopes characterised by lower densities of *Sabellaria spinulosa* (see Holt and others 1995 for a discussion on *Sabellaria spinulosa*). Most of the acoustic confusion between the reef biotopes occurred between *Sabellaria spinulosa/Lanice* biotopes: If these two similar biotopes are amalgamated, then the accuracy increases to 87%. Where should the line be drawn between reef biotopes and other similar biotopes? This has not been helped by the lack of opportunity to visually confirm the presence of reefs within The Wash since many of the previous surveys have coincided with periods of poor visibility. Thus, the only site where reefs have been confirmed lies just outside the SAC (within the licensed sand extraction area 107). This site, therefore, makes a useful reference site to test the methodology for the detection of reefs.

There is uncertainty as to the spatial patchiness and temporal stability of reefs (Holt and others 1995). Previous surveys (Dipper and others 1989; NRA, 1994; Foster-Smith and Sotheran, 1999; Foster-Smith 2000) have all shown very variable densities of *Sabellaria spinulosa* with only moderate numbers recorded on some surveys and very dense *Sabellaria spinulosa* recorded on others. Samples taken in similar locations on different surveys show very marked changes in *Sabellaria spinulosa* densities. Foster-Smith (2000) illustrated large changes in the overall proportion of some key species between 1997 and 1999 and there appeared to be a decline in the relative abundance of *Sabellaria spinulosa* (Figure 1).

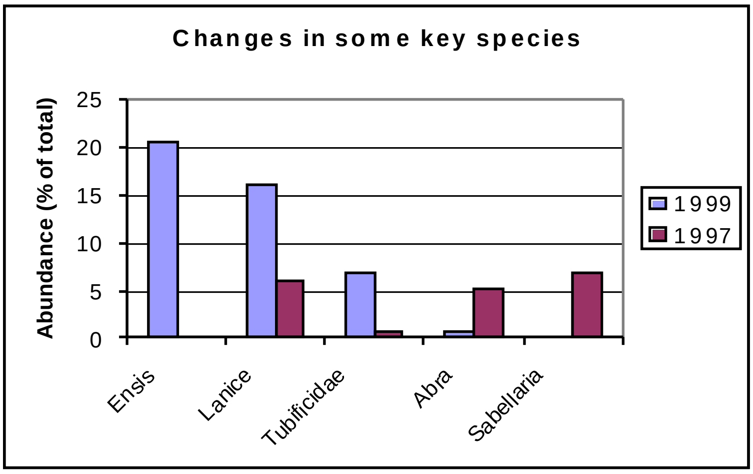


Figure 1. The relative abundance of five species commonly found in samples in either 1997 or 1999.

Note that all the samples from each year have been pooled. The positions of the sampling stations for the two surveys were not coincident and the differences and changes in relative abundance may be due to chance.

This *may* indicate widespread changes in *Sabellaria spinulosa* over time. However, the apparent decline may have been due to small differences in position of the samples between the two surveys coupled with a naturally patchy distribution. Assessing temporal change may be complicated by patch dynamics of the reef system including reef build-up and break-down involving other related *Sabellaria spinulosa* biotopes.

The ability to monitor the status of *Sabellaria spinulosa* reef requires that (a) reefs form a real entity that can be defined in such a way as to separate this *Sabellaria spinulosa* community from other similar biotopes; (b) reefs can be detected through field observation; (c) their distribution can be mapped repeatedly with sufficient accuracy to detect significant changes in reef distribution.

The objectives of the survey were:-

1. To identify the distribution of *Sabellaria spinulosa*:

   a. To map the likely distribution of *Sabellaria spinulosa* in the selected survey boxes in the mouth of The Wash (where recent ESFJC observations gave tentative confirmation of the presence of *Sabellaria spinulosa* reef) and to compare this to the reference site in area 107 (Figure 2).
   b. To test techniques by assessing the application of different acoustic survey and field sampling methods for identifying and measuring *Sabellaria spinulosa* reefs at different stages in development. If reefs form very small patches, then acoustic ground discrimination systems (with their poor spatial resolution) may not be the most appropriate tool for mapping the reefs.

2. To asses natural change in *Sabellaria spinulosa*: To gauge the short term stability and seasonality of *Sabellaria spinulosa* reefs by measuring changes in reef extent over space and time using repeat surveys. Short term stability was to be assessed by repeating the initial summer survey in the following autumn. Ultimately, these techniques should be used to assess long term stability.

The effect of fishing on the *Sabellaria* reefs, undertaken by the ESFJC, is a further objective of the overall project, but is not the part of the survey reported here.

2. Methods

2.1 Survey strategy

There were three main components of the survey:

1. Broad scale acoustic survey of the trial areas using the *RoxAnn* AGDS on board *Surveyor* to map variations in substrate and identify smaller areas of reef systems. There arose an opportunity to compare *RoxAnn* with *QTC Impact,* another proprietary AGDS.

2. Detailed sidescan survey over the selected sections of the trial areas run in conjunction with *RoxAnn* to provide high-resolution topographic and sediment surface feature images.

3. Use of underwater video and Day grab for field sampling. These data were to be used to categorise the *Sabellaria spinulosa* communities and for the ground-truthing of the acoustic data. The grab samples were to be preserved and stored for sediment and faunal analysis should this be required at a later stage in the project. In the event, the samples were sorted and the *Sabellaria spinulosa* counted since this was felt to be required for the description of the samples in terms of *Sabellaria spinulosa* composition. The infaunal analysis remains to be done but, due to time constraints, reporting on the results will be the subject of a supplementary report (estimated completion date May 2001).

2.2 Acoustic ground discrimination

The following account is taken from the draft JNCC guidelines on the use of AGDS. It is given as background information on both *RoxAnn* and *QTC*.

Acoustic ground discrimination systems (AGDS) are based on single beam echo sounders and are designed to detect different substrata by their acoustic reflectance properties. An echo sounder generates a short pulse of sound at a single frequency that travels through the water and rebounds off the seabed. The mechanical energy of the echo is received by the transducer and converted into an electrical signal that is displayed on a screen. The transducer shapes the pulse of sound into an approximate cone directed towards the sea floor. The area ensonified (analogous to the term 'illuminated') by the echo sounder directly under the vessel is approximately circular, although sounders produce many side-lobes that make the footprint a more complex shape in practice. The area depends upon the beam angle (angle of the apex of the cone of sound) and depth of the sea floor.

Sound waves travelling in the centre of this cone will hit the seabed first (assuming the seabed is level) and depth is measured from time taken for this returning sound energy to be detected by the transponder. The strength of the echo and the way it decays with time produces a complex signal whose shape depends to a large degree on the nature of the sea floor and this is the basis upon which echo sounders have been used for sea floor classification. The extent to which sound is absorbed or reflected by the sea floor depends upon the hardness of the seabed: Hard surfaces produce strong echoes whilst soft surfaces (and this may include rock substrata that are acoustically softened by overgrowth of biota) results in a weak signal. The sound energy that spreads away from the centre of the cone produces a weaker echo. This wave energy takes slightly longer to reach the seabed because of the extra distance travelled and this time lag increases with increasing angular distance away from vertical axis of the transmission pulse. Rough surfaces will produce an echo that decays slowly since sound spreading some distance from the vertical may reflect off inclined surfaces angled towards the transducer (a property termed ‘backscatter’) whilst flat surfaces will reflect sound away from the transducer. The decaying echo may also contain an element that depends on the reflectance of sound from subsurface features. This is particularly the case for low frequency sounders where there is greater penetration through soft surface sediment.

Additionally, there may be multiple echoes as the returning sound energy bounces off the water surface and rebounds from the sea floor a second (or third) time. The significance of the second echo (first multiple echo) for ground discrimination is debatable, but it has been considered to be more sensitive to hardness than the initial reflectance of the first echo.

The *RoxAnn* system uses analogue signal processing hardware to select two elements from the echo and measure signal strength (in millivolts) integrated over the time. The first selected segment of the echo is the decaying echo after the initial peak. This measure of time/strength of the decaying echo is termed ‘Echo 1’ (or ‘E1’) and is taken to be a measure of roughness of the ground. The beam width of the sounder is important for E1 since a wide beam will give greater scope for measuring signal decay away from the perpendicular than a narrow beam. For this reason it is recommended that AGDS operate with a sounder of moderate beam width (15∀– 25∀). The second segment is the whole of the first multiple echo and is measured by the *RoxAnn* processor as ‘Echo 2’ (or ‘E2’).

The two paired variables (E1 and E2) can be displayed on a Cartesian XY plot, and this is the basis of the *RoxAnn* real-time display as used in the data logging and display systems *Microplot*™ and *RoxMap*™. Rectangular areas on the Cartesian plot can be marked out so that records lying within that section of the plot can be colour-coded and displayed on the track plot.

QTC View operates in a very different way to *RoxAnn*. The echo is converted from analogue to digital form and is then subjected to analysis using a large number of algorithms for wave-form analysis (Collins and others 1996; Collins and McConnaghey 1998). The *QTC* choice of algorithms and the way they are applied to the echo is considered commercially sensitive. However, the second echo is not used. The system is designed to be calibrated by positioning the vessel over known ground types and a sample dataset collected. The exercise is repeated for different ground types and the combined datasets subjected to Principle Components Analysis (PCA) and the data displayed on a three-dimensional plot of the first three principal components, termed ‘*Q space*’. The *Q* space is then divided up into regions that relate to the ground type classes. This catalogue can then be applied to future survey data to classify the tracks in real time.

QTC Impact offers a greater scope for survey without calibration and use of post-processing: the signal is subjected to the algorithms as with *QTC View* but all variables are logged and principle components analysis run on the complete dataset. This identifies ‘natural’ clusters within the dataset that can be attributed to ground types as dictated by the field sample data. The clusters can be further split by running PCA again. The process of finding 'natural' clusters is termed 'unsupervised classification'

The *RoxAnn* unit used was installed on the ESFJC vessel *Surveyor* and the *QTC Impact* was on trial. Both units were linked into the vessel's echo sounder operating at 200kHz.

2.3 Sidescan sonar

Two transducers (one port one starboard) are usually housed in a 'fish' that is towed behind a vessel. Each transducer emits pulses of sound that are 'fan-shaped' in that they are very wide in the port/starboard plane but very narrow fore/aft. A single pulse results in an echo from the seabed that is more distant as the slant angle (the angle at which the sound meets the seabed) increases. The first part of the echo to be picked up by the transducer is the reflection from the sea floor directly under the fish and time taken for the rest of the echo to return to the transducer is a measure of the distance from the fish. The surface unit displays the vessel's position centre-screen and the return signal to the right or left (starboard/port) at a distance from centre screen which is in proportion to the time taken for the return signal to be picked up by the transducer. The trace on the screen (or paper trace) advances with each new pulse until an image of the sea floor is built up line by line.

The intensity of the echo is also measured so that an image can be produced that looks like a strongly side-illuminated black and white photograph. The intensity of the echo depends on reflectance that in turn depends upon topography. Surfaces angled towards the fish produces a strong echo whilst surface hidden from the 'line of sight' of the fish results in a sound shadow. Intensity is also dependant upon absorption of sound on the sea floor, so that some idea of sea floor sediments can be visualised but it is not a straightforward measurement. Sidescan sonars have a good spatial resolution and produce an image that covers a swath (200m either side of the fish in this survey). However, bathymetric data are limited and the image, whilst giving excellent information on topographic features has little measurable point data on sediment characteristics. The images require careful interpretation (usually by eye).

SeaMap operate a *Geo Acoustics / SS490* side scan sonar which can switch between 100kHz and 500kHz and was linked to an *EOSCAN* digital acquisition system (Polaris Imaging Inc) which provided full geo-referenced data capture and post-processing capability. SeaMap also used an *EOMAP* system (Polaris Imaging Inc) for combining individual sonar lines into a mosaic to create a map of the survey area.

2.4 Comparing techniques

It is important to compare the characteristics of the two types of acoustic systems. They 'see' the sea floor in very different ways and the data they produce are complementary: AGDS gives moderately good powers of discrimination, but at low resolution whilst sidescan gives high resolution images with limited powers to discriminate between sediment types (Table 1). Although the sidescan images can be overlaid to give continuous coverage, the positional accuracy across the swath will depend upon estimates of distance and subject to yaw of the fish (as became apparent in The Wash).

Table 1. Comparison of capabilities of AGDS and sidescan sonar as used in the study.

	AGDS	Sidescan
Topography	Very broad scale features only	Fine scale features
Bathymetry	Precise under vessel	Poor
Coverage	Along tracks only	Swaths that can be mosaiced to form a continuous coverage of large areas
Resolution	Poor: dependent largely on track spacing although acoustic 'footprint' is also limiting. Typical resolution 25-100m	About 1m
Sediment characteristics	Moderate powers of discrimination	Usually limited to visual interpretation of 'black and white' image
Scope for analysis	Can easily be subjected to image processing and multivariate analysis	Usually interpreted by eye
Positional accuracy	Data under vessel can be precisely located if required	Centre of swath estimated from ship's position and layback of fish. Extremities of swath estimated from ship's direction of travel and times of echoes

2.5 Field sampling

Field sampling using video was the preferred sampling technique because (1) the reefs could be assessed visually directly and (2) the sampling was considered to be less destructive of the reef than grab sampling. However, The Wash and its environs are prone to periods of extremely poor visibility and, unless conditions are ideal, the identification of non-reef *Sabellaria spinulosa* is difficult since other tubes (eg, those of *Lanice* and *Sabella discifera*) may be confused with *Sabellaria.* Video is also difficult to control in the high tidal streams that are often encountered in The Wash.

Additionally, high diversity that is associated with *Sabellaria spinulosa* is one of the characteristics of reefs that make them important to the natural history interest of the area. This can only be determined through the analysis of infauna. For these reason a limited program of grab sampling was agreed. The primary purpose was to ascertain the level of *Sabellaria spinulosa* present at the stations although many of the samples were processed on board by passing over a 0.5mm sieve and preserved for future analysis. In all, 5 stations with 5 replicate samples were grab-sampled in the survey areas during the initial survey in July and they were supplemented by further 6 stations which were sampled (not replicated: 6 samples in total) in The Wash trial area in October. Further grab samples were taken during November, but these were assessed for *Sabellaria* content on board and not processed or preserved.

2.6 Analysis

Analysis of the AGDS data requires the track data (after QA procedures) to be interpolated to create a digital continuous coverage of the variables (E1, E2 and depth; Q1, Q2 and Q3). These can then be imported into the image processing package *IDRISI* for classification (interpretation). Supervised classification is routinely used, although unsupervised classification can be instructive. With supervised classification, the field samples are used to ground truth the acoustic data: AGDS values in the vicinity of the field samples are associated with the habitat or biotope category of the field sample and these data used to create an acoustic signature for each category. The whole image is then classified by assigning each pixel to a habitat (or biotope) category on the basis of the match between the pixel's acoustic values and the signatures.

Unsupervised classification uses multivariate statistics to find 'natural' clusters of acoustic data within the data set to form the basis of categories. However, no reference is made to the field samples until after the analysis.

3. Survey summary

The survey encountered problems related to the weather and sea conditions and, in the event, some parts of the survey could not be completed. The main initial survey took place between July 24 and 28. The repeat survey was attempted in October but was abandoned after carrying out field sampling in The Wash only. The Wash trial area was, however, comprehensively re-surveyed in November and the surveyors took advantage of the *QTC* system that was on trial by the ESFJC. No further work was possible in area 107 nor was any follow-up sidescan carried out in either October or November.

Despite the constraints of the weather, many of the tasks were completed and the project has benefited from the comparative survey between *RoxAnn* and *QTC*. Table 2 is a summary of the survey log and the tasks carried out. The primary datasets and the analyses performed are summarised in Figure 3.

Table 2. Summary of survey.

Date	Sea conditions	Survey tasks	Analyses
June, 2000	Rough; survey of Wash trial area abandoned; 107 not attempted		
July, 2000	Fair	1. *RoxAnn* surveys of Wash trial area and 107. 2. Sidescan/*RoxAnn* surveys of 'reef' sections within trial areas. 3. Video samples and five replicate Day grabs at two stations in Wash trial area and three stations at 107. Samples preserved.	1. Supervised and un-supervised classification of *RoxAnn* data. 2. Mosaic sidescan. 3. Categorisation of all field sample data (used in supervised classification). 4. Grab samples analysed for *Sabellaria*.
October, 2000	Rough; Grab and video sampling in Wash trial area; sampling in 107 abandoned.	Grab and video data collected for Wash: Infauna preserved for future analysis.	Categorisation of all field data
November, 2000	Short period of fair weather with no opportunity to survey 107.	1. *QTC* and *RoxAnn* surveys of the intensely surveyed area within The Wash trial area. 2. Habitat data from grab samples: no samples retained for infaunal analysis.	1. Unsupervised and supervised classification of *RoxAnn* and *QTC* data. 2. Samples categorised.

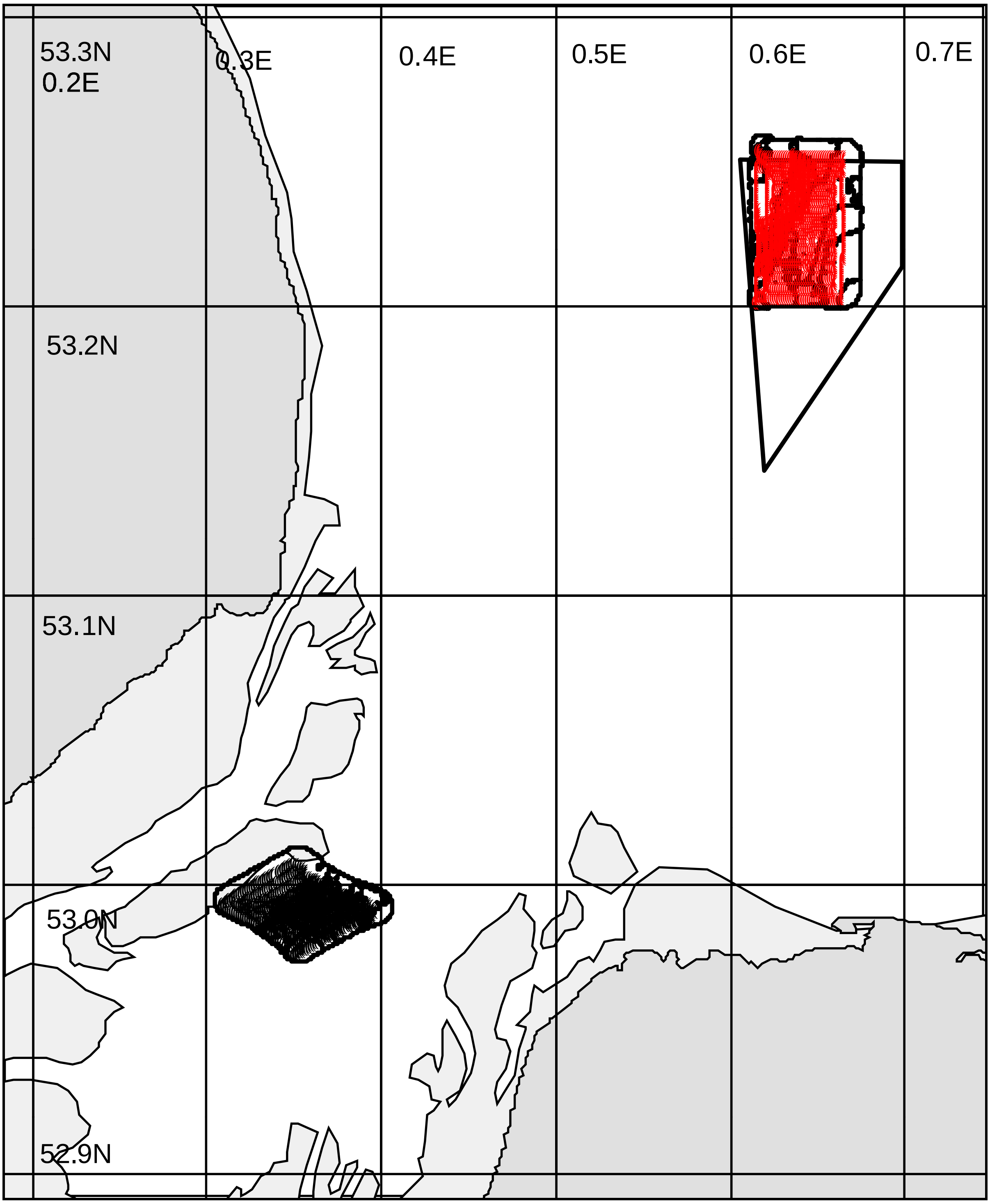


Figure 2. Site map of area with trial sites marked by the track lines run on the July survey.

Area 107 is also shown for reference. The coordinates and projection of this map is in decimal degrees WGS84 to facilitate location of the sites on Hydrographic charts. However, all analysis has been done after the data have been converted to metres and OSGB36. All subsequent maps have used the latter coordinate system and datum.

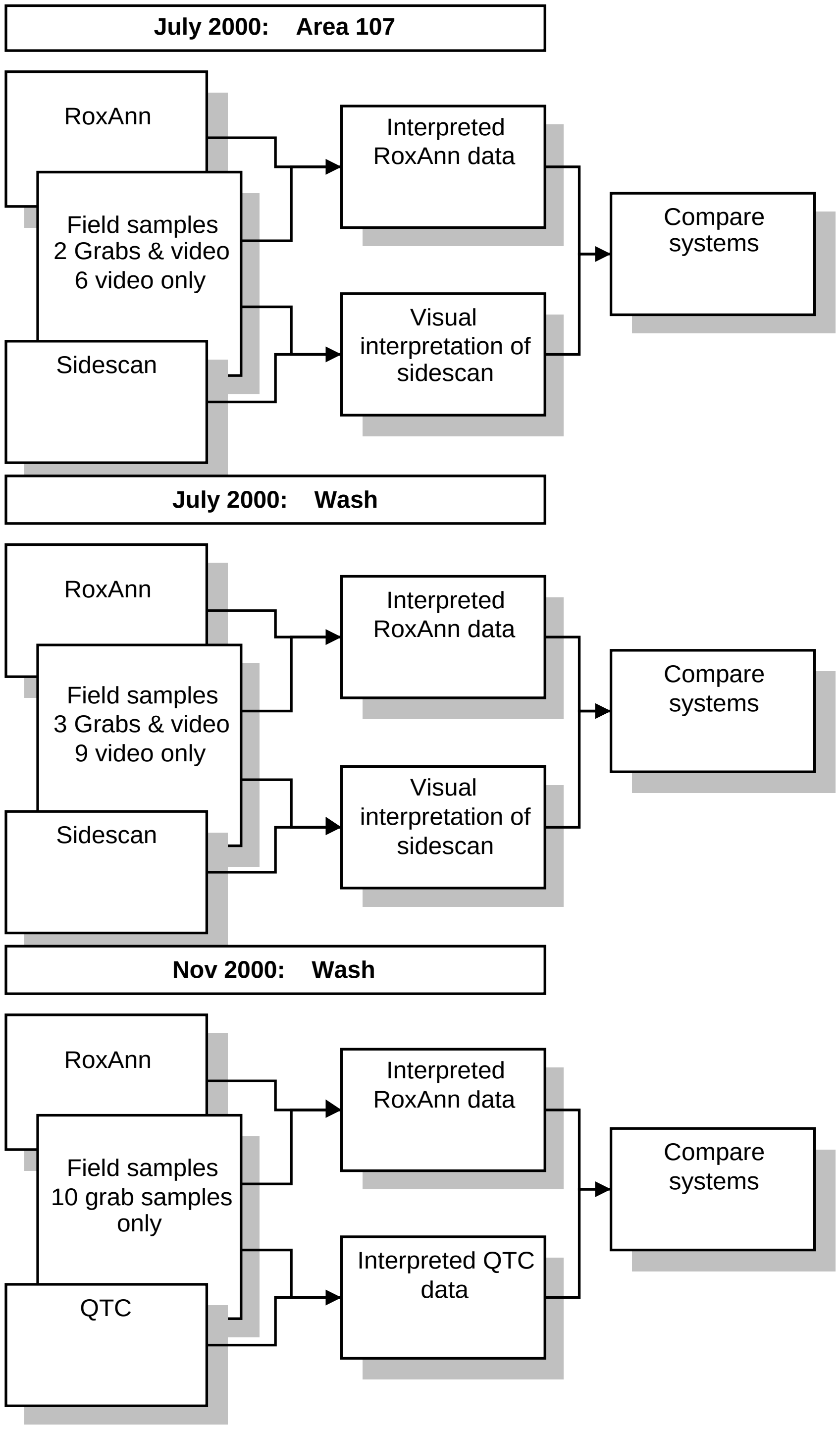


Figure 3. Main data sets and analyses performed using them.

4. The initial (July) survey

4.1 Longsands *RoxAnn* data

The track data and the location of the samples are shown in Figure 4 below. The area selected for sidescan is indicated by the closely spaced *RoxAnn* tracks.

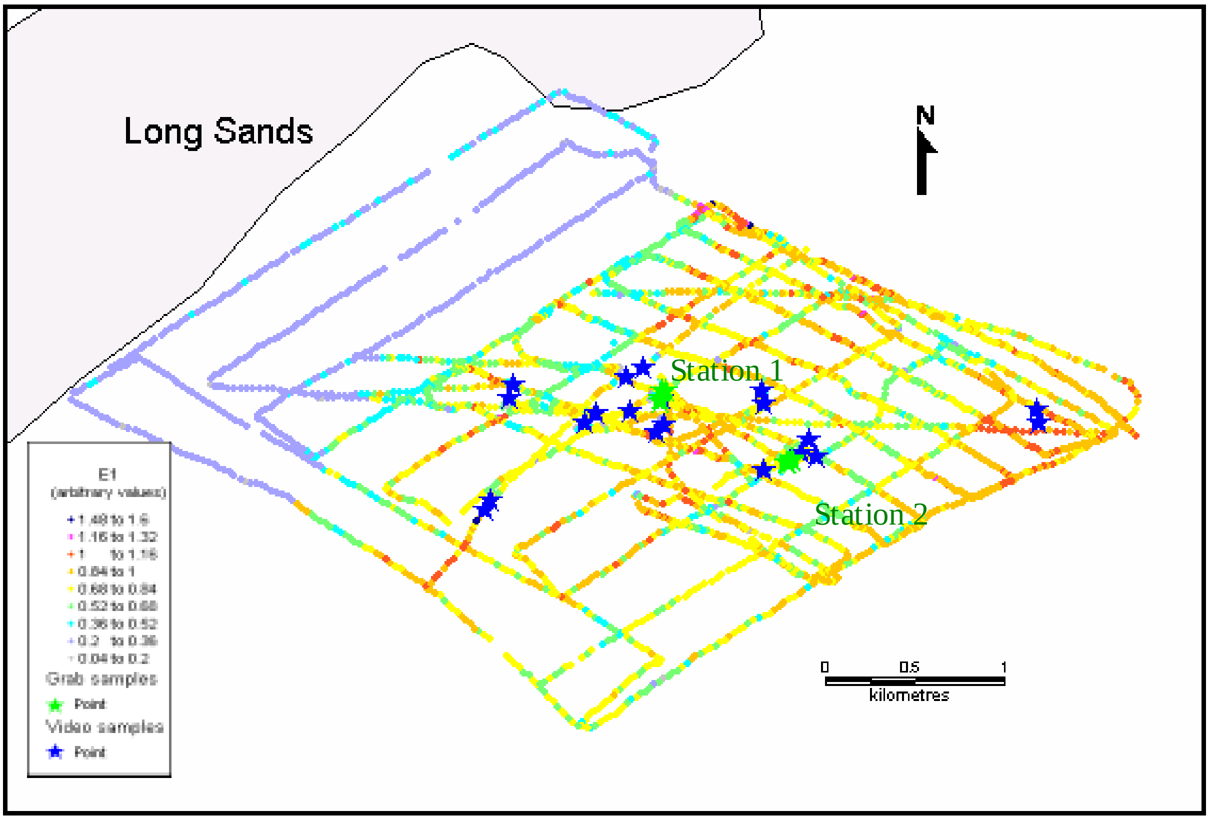


Figure 4. *RoxAnn* tracks over the Longsand site coloured according to E1 values.

The green stars give the positions of the grab stations detailed in Table 3, whilst the blue stars indicate the positions of video samples.

4.2 Longsands sidescan and field sample data

The sidescan traces have been mosaiced and the composite image shown in Figures 5 and 6 with samples coded according to sediment and biotope respectively. There was little visual evidence of *Sabellaria spinulosa* in any of the video samples and infaunal analysis of the grab samples showed that densities (number per $0.1m^2$) were low to moderate (Table 3).

Table 3. Numbers of *Sabellaria* in the 0.1m^2 grab samples from Longsands. Note two stations were sampled: 1 (samples 1-5), 2 (samples 6-10).

Station	Grab	Lat	Long	*Sabellaria*
1	1	52.9943	0.359733	19
	2	52.99427	0.360017	32
	3	52.9938	0.359467	10
	4	52.99433	0.359767	6
	5	52.99392	0.359517	3
2	6	52.99048	0.369967	8
	7	52.99052	0.369917	10
	8	52.99048	0.370033	8
	9	52.99068	0.370333	1
	10	52.9906	0.370283	14

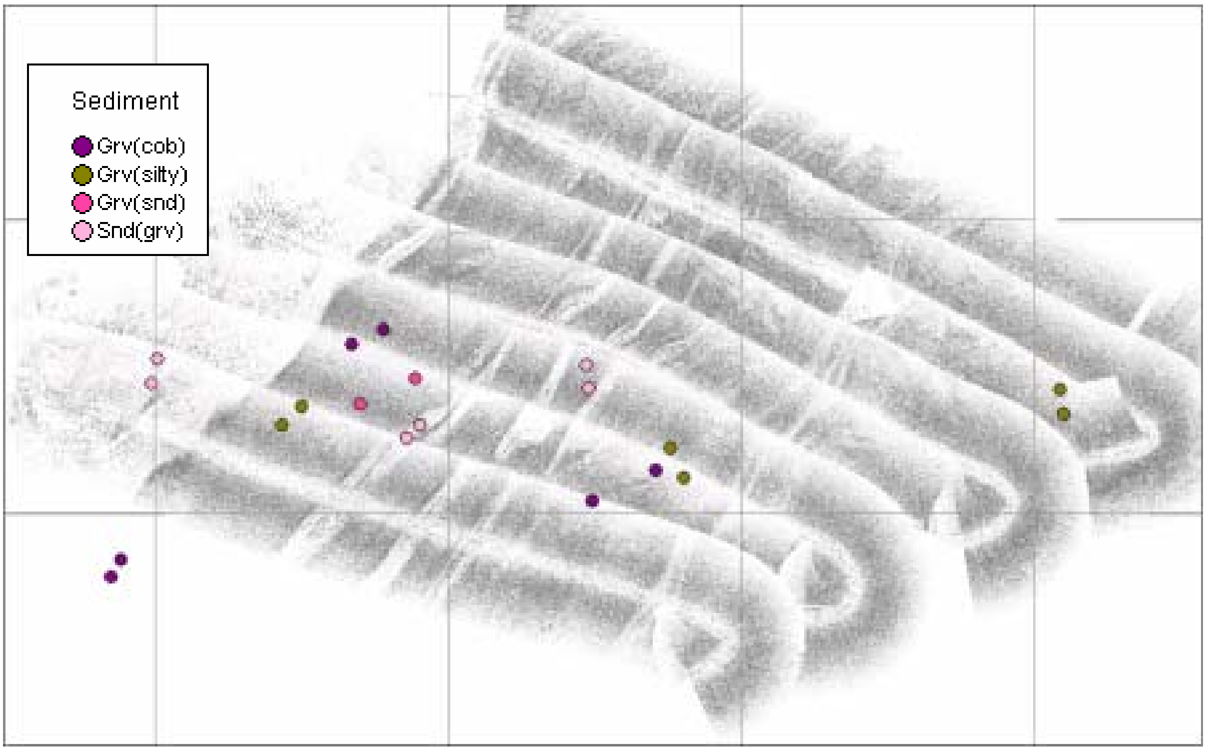


Figure 5. Mosaic of several sidescan tows over the Longsand site with sediment samples superimposed.

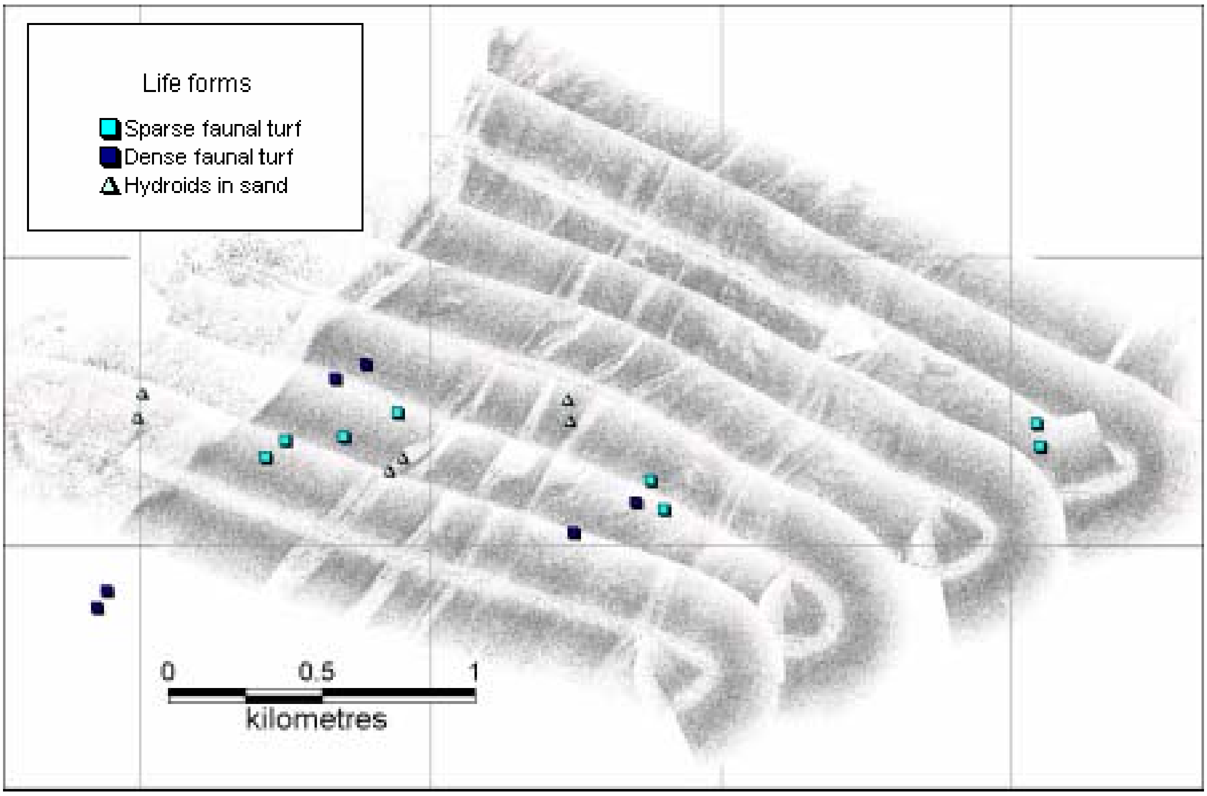


Figure 6. The sidescan mosaic of Longsand with biotope superimposed.

The sidescan images have not mosaiced satisfactorily with obvious positional problems at the edges of the swaths. It is likely that the high tidal currents that crossed the direction of tow caused the fish to yaw. This would introduce errors into the estimates for the position of the swaths which are based on the assumption that the fish is pointing along the direction of travel of the survey vessel.

The sidescan could distinguish sand from gravely sediments, but the gravel/cobble sediments were indistinguishable. The floor of the Lynn Deeps is fairly level at about 30m, but strips of sand overlying gravel and cobble run south-east/north-west. The sidescan on its own gave no obvious indication of reefs. The apparent absence of *Sabellaria* reefs was a disappointment, considering the grab sample sites and accompanying video samples were in positions reported to have reef by the ESFJC. It is clearly impossible to assess the capability of the survey techniques to detect reefs, let alone map them without definite reef being confirmed (even if they were, in fact, present but unsampled).

4.3 Area 107 *RoxAnn* data

The track data and the location of the samples are shown in Figure 7 below. The area selected for sidescan is indicated by the closely spaced *RoxAnn* tracks.

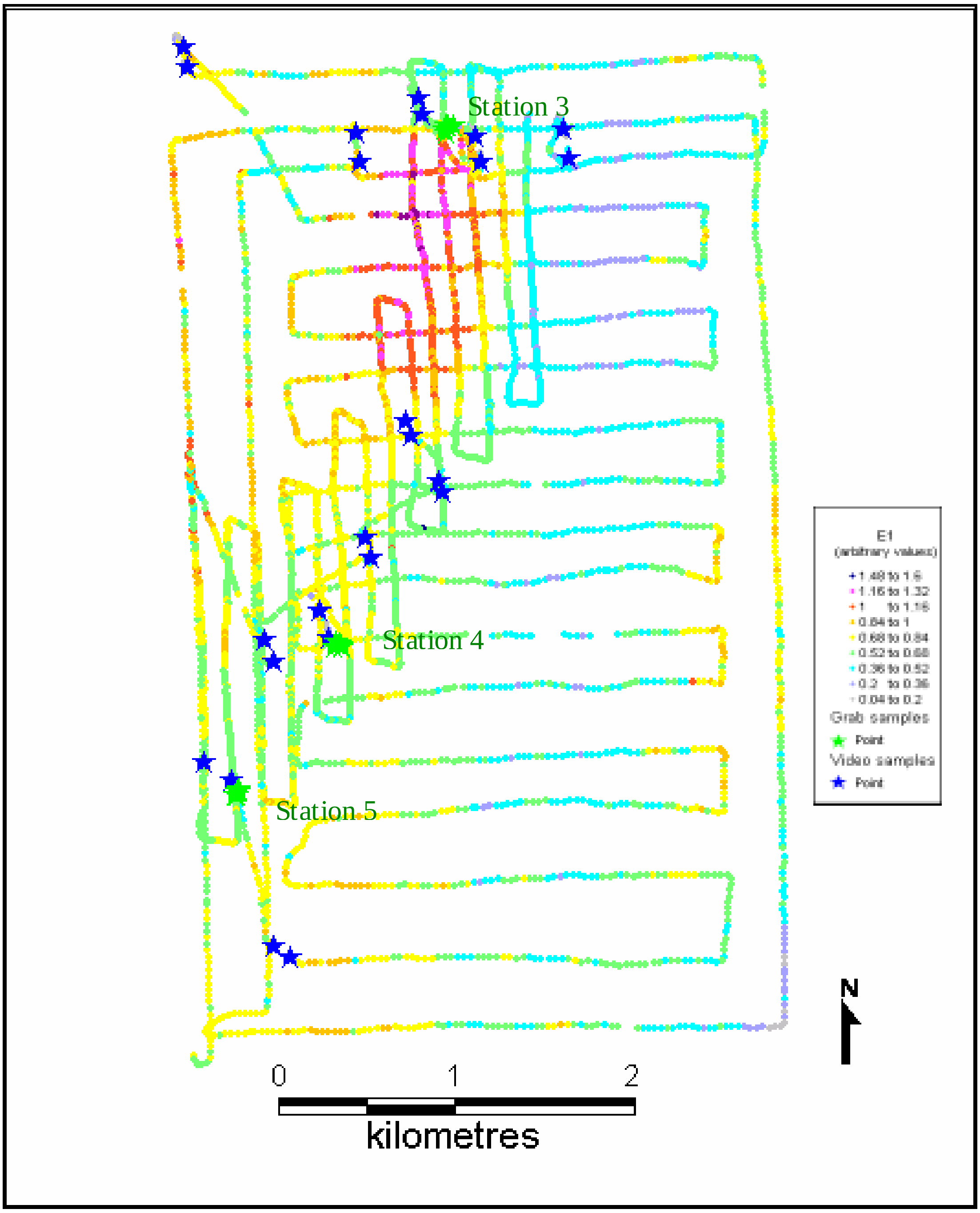


Figure 7. ***RoxAnn*** **tracks over the Area 107 site coloured according to E1 values.**

The green stars give the positions of the grab stations detailed in Table 4, whilst the blue stars indicate the positions of video samples.

4.4 Area 107 sidescan and field sample data

The sidescan traces have been mosaiced and the composite image shown in Figures 8 and 9 with samples coded according to sediment and biotope respectively. Unlike the Longsands site, *Sabellaria* reef was confirmed in the same locations that were sampled in 1997.

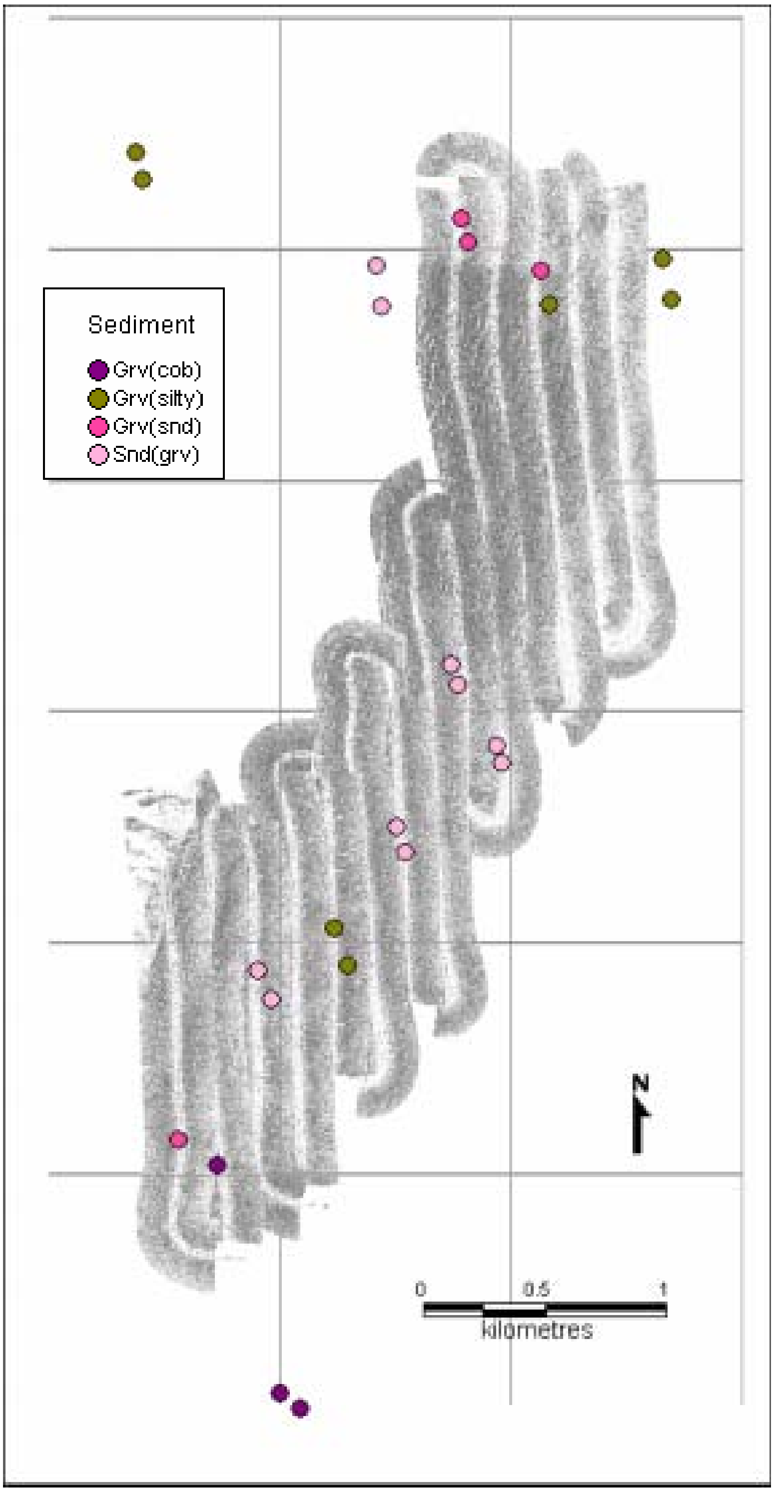


Figure 8. Mosaic of several sidescan tows over the Area 107 site with sediment samples superimposed.

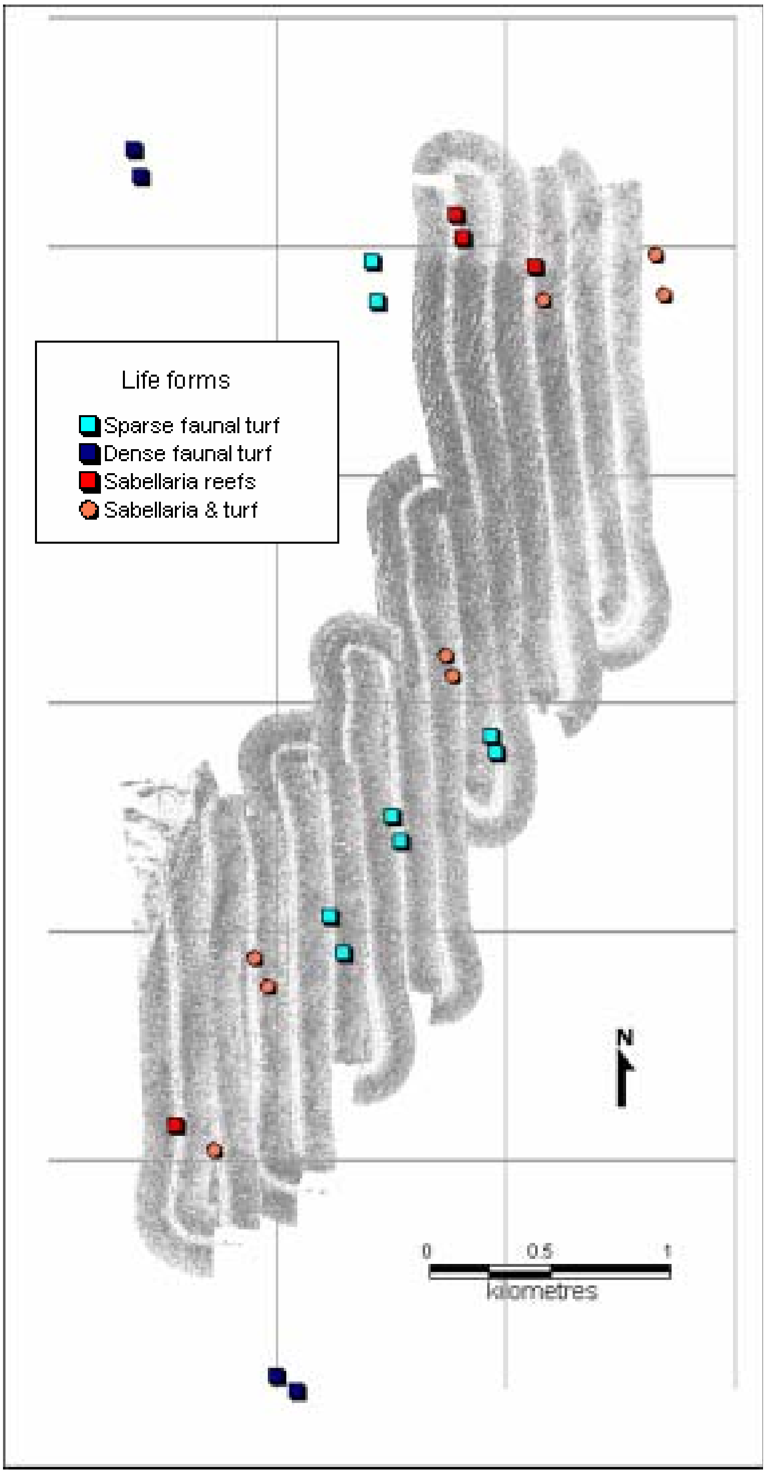


Figure 9. The sidescan mosaic over the Area 107 site with biotope superimposed.

The *Sabellaria* densities were far higher in many of the grab samples in the 107 area than were found in the Longsands area in The Wash. Table 4 gives the number of *Sabellaria* counted in the grabs from area 107.

Table 4. Numbers of *Sabellaria* in the 0.1m^2 grab samples from Area107. Note three stations were sampled: 1 (samples 11-15), 2 (samples 16-20) and 3 (samples 21-25).

Station	Grab	Lat	Long	*Sabellaria*
3	11	53.21693	0.62105	12
	12	53.21712	0.621333	665
	13	53.21718	0.6213	632
	14	53.21693	0.621217	176
	15	53.2171	0.621167	12
4	16	53.22427	0.63045	0
	17	53.22428	0.629933	2
	18	53.22433	0.630483	3
	19	53.22455	0.630033	1
	20	53.22438	0.630267	0
5	21	53.25038	0.6407	11
	22	53.25058	0.641517	27
	23	53.25062	0.641	60
	24	53.25003	0.64095	4
	25	53.25058	0.641033	868

Detailed examination of parts of the coverage with reef indicate that there is a marked difference between cobble with hydroid turf and sandy/gravel sediments, but nothing in the patterning of the reef ground that might confidently be used to distinguish this from other sandy/gravel sediments (Figures 10 and 11).

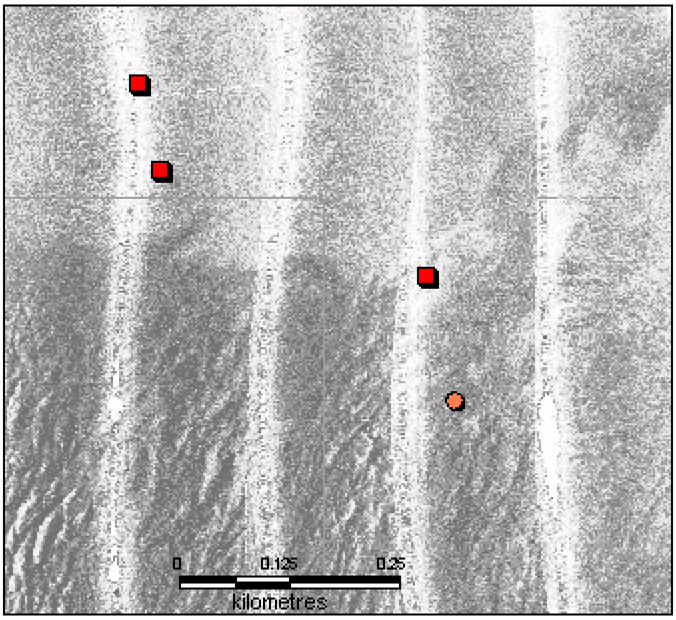


Figure 10. Area at the north of 107 showing a sharp delineation between reef (red squares) and faunal turf and sparse *Sabellaria* on silty gravel.

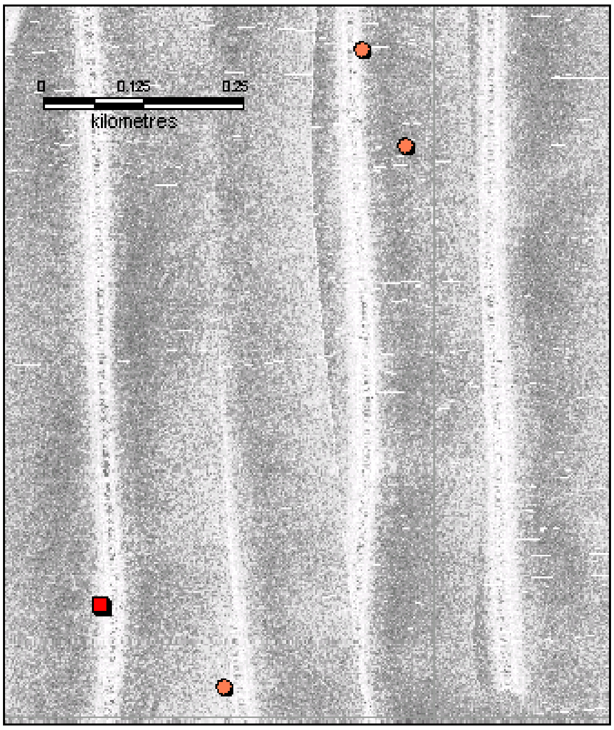


Figure 11. Area at the western edge of 107 showing a gradual change between ground with reef and faunal turf and sparse *Sabellaria* on silty gravel.

In passing, it is worth showing the marks on the hard cobble and faunal turf ground that are presumed to be caused by some heavy towed (fishing?) gear (Figure 12).

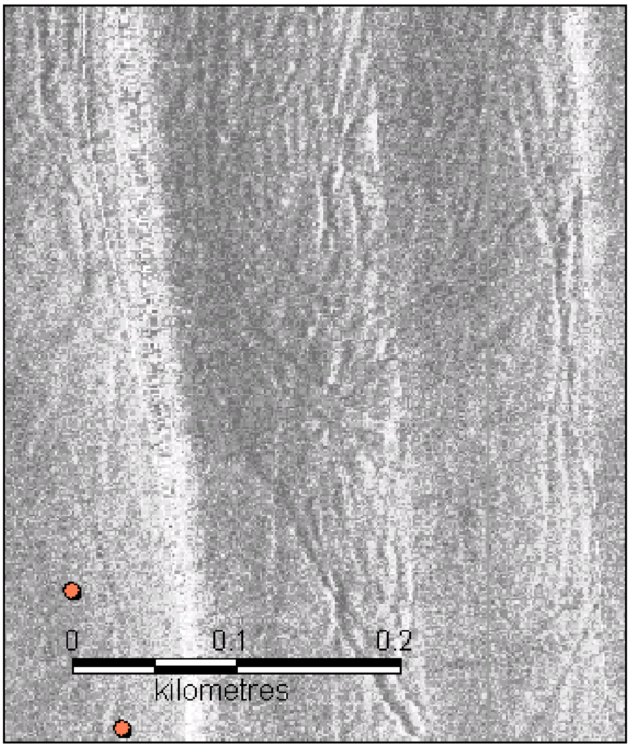


Figure 12. Numerous marks of fishing (?) gear being towed across the cobble and turf banks in the north western area of 107.

4.5 Interpretation of the July data sets

The interpolated *RoxAnn* data were classified using the broad categories that summarised the video and grab sample data. The two sites were classified separately so that, since no *Sabellaria* biotopes were found at the Longsand site, these biotopes could not be predicted on the basis of the acoustic values alone. It is possible that if the data from both Longsand and 107 were amalgamated, then *Sabellaria* might have been predicted somewhere in the Longsand site. However, it is not good practise to interpret two widely separated sites together.

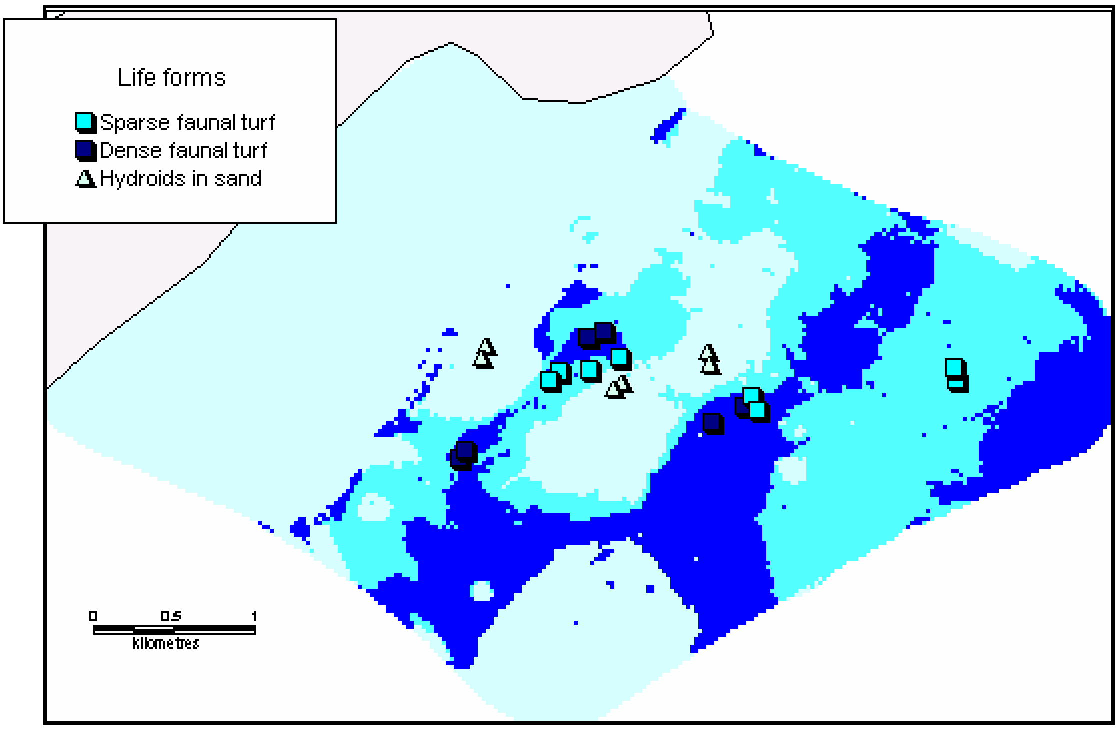


Figure 13. Supervised classification of the *RoxAnn* data from the July survey of Longsands. The field samples have been superimposed shown as biotopes. See Figure 14 for legend for classification.

In both cases there is good agreement between the field samples and the classified images, which is not unexpected since there are a relatively small number of samples to fit to the data. The predicted distribution of *Sabellaria* reef and the related sparse *Sabellaria* and faunal turf in area 107 seem to coincide with the transition zone between shallow cobble (primarily with a faunal turf community) and sandy gravel sediment (often with no conspicuous fauna) seen on the sidescan images. The distribution of the biotopes in relation to topography is probably best seen in 3-D images and these are shown for both the Longs Sand and area 107 in Figures 15 - 18.

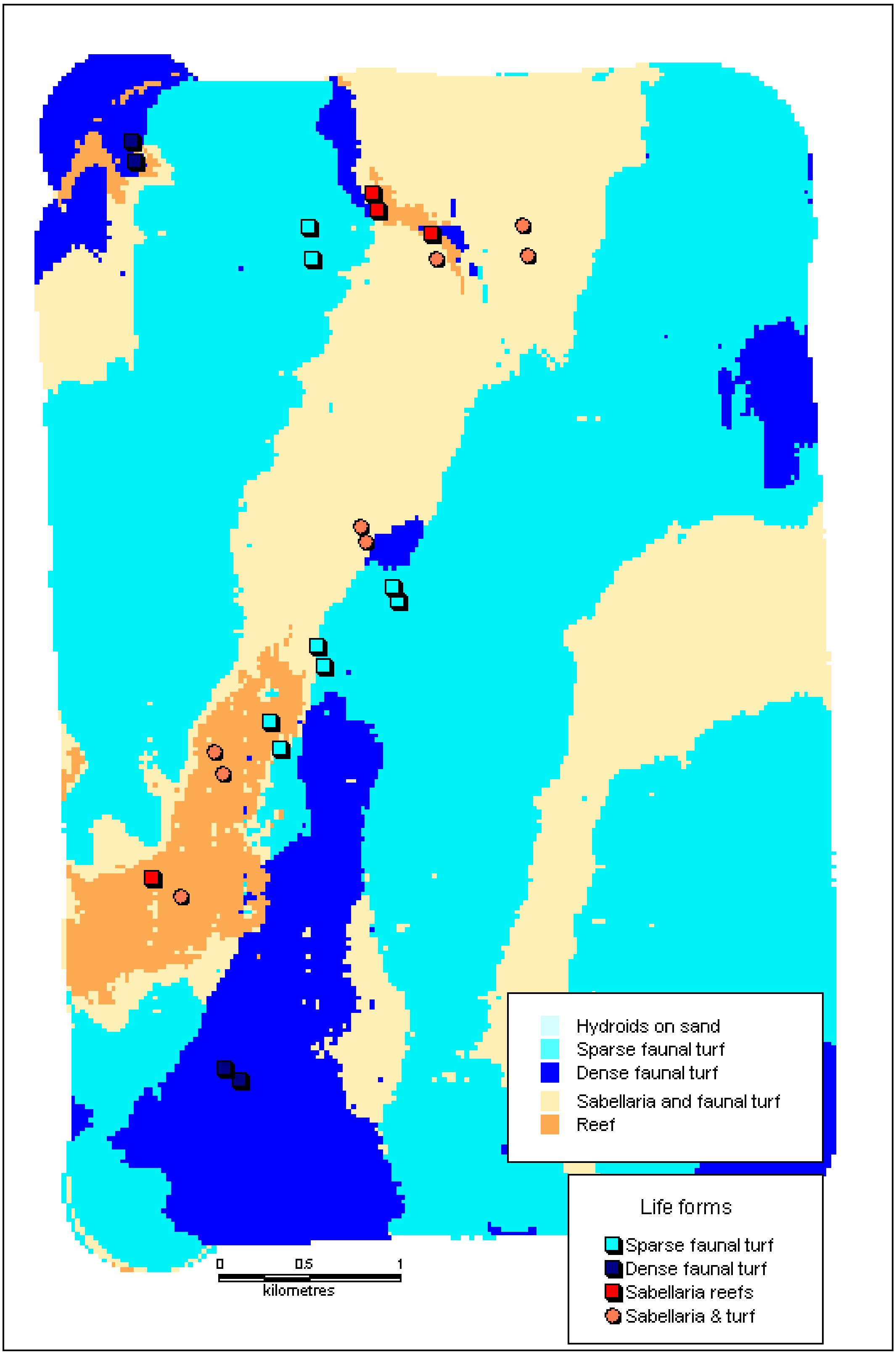


Figure 14. Supervised classification of the *RoxAnn* data from the July survey of area 107. The field samples have been superimposed shown as biotopes.

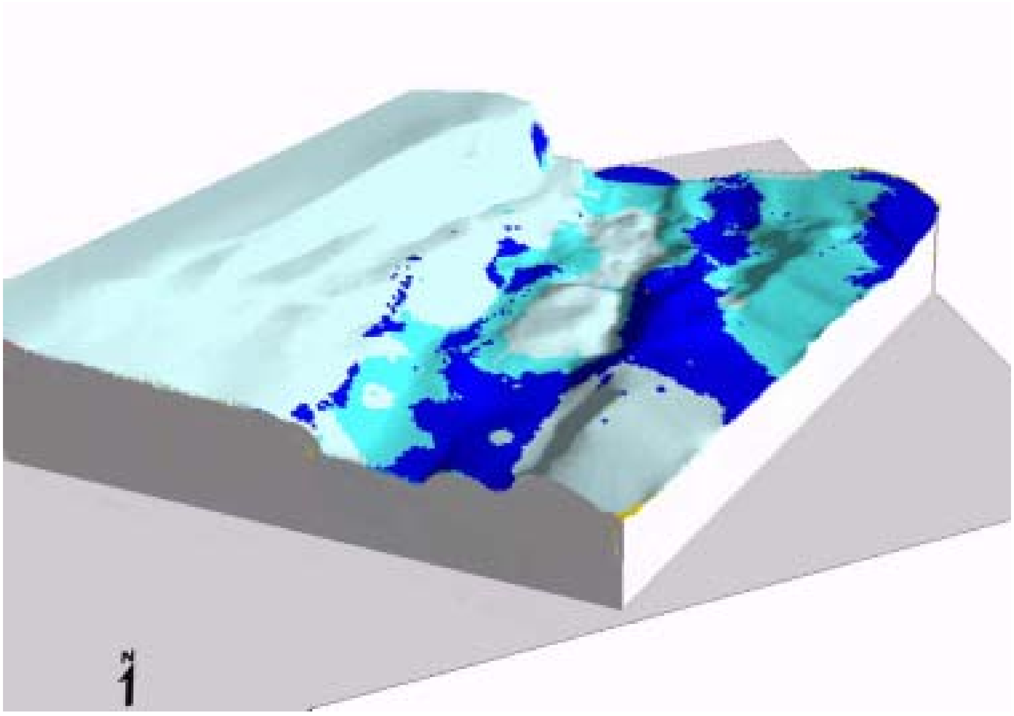


Figure 15. Drape of biotopes on bathymetric model of Longsands.

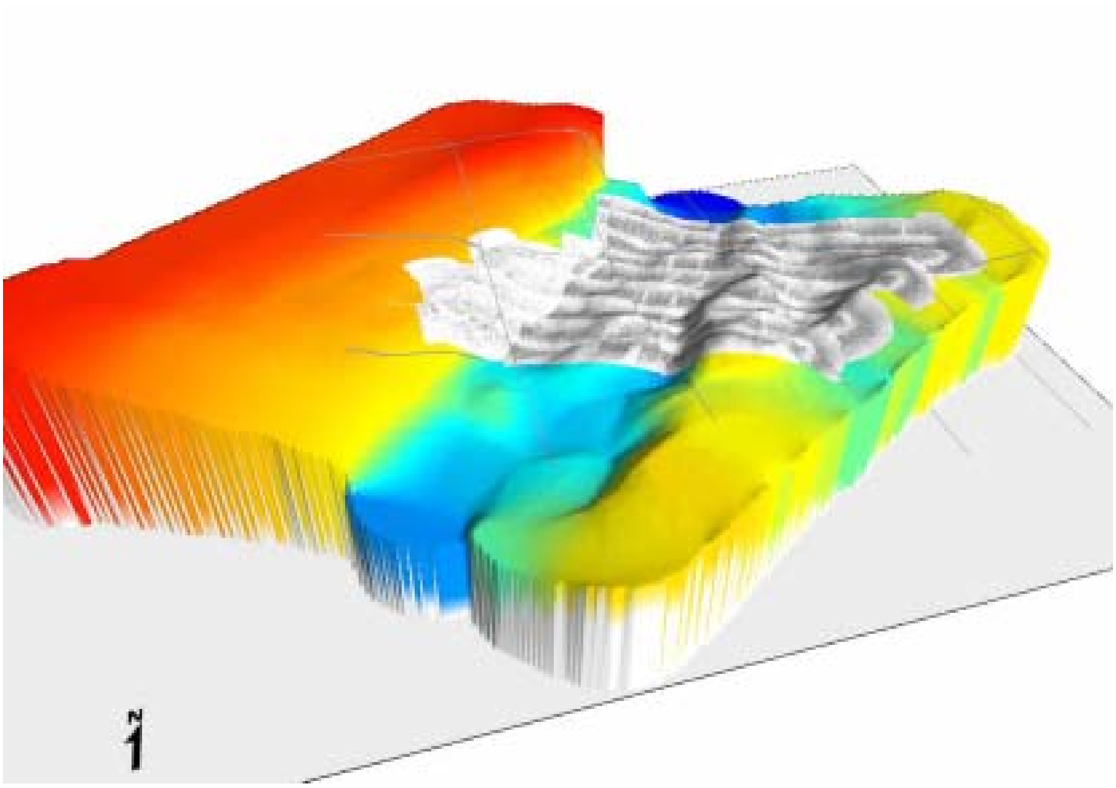


Figure 16. Drape of sidescan mosaic on bathymetric model of Longsands.

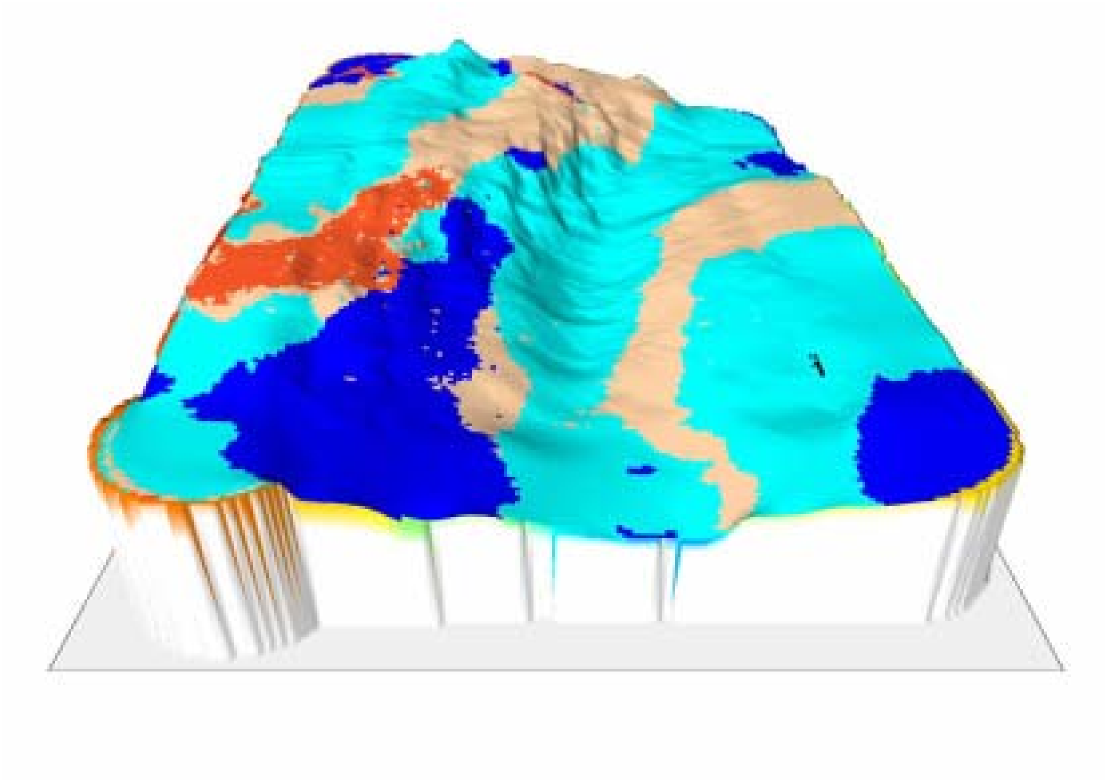


Figure 17. Drape of biotopes on bathymetric model of area 107.

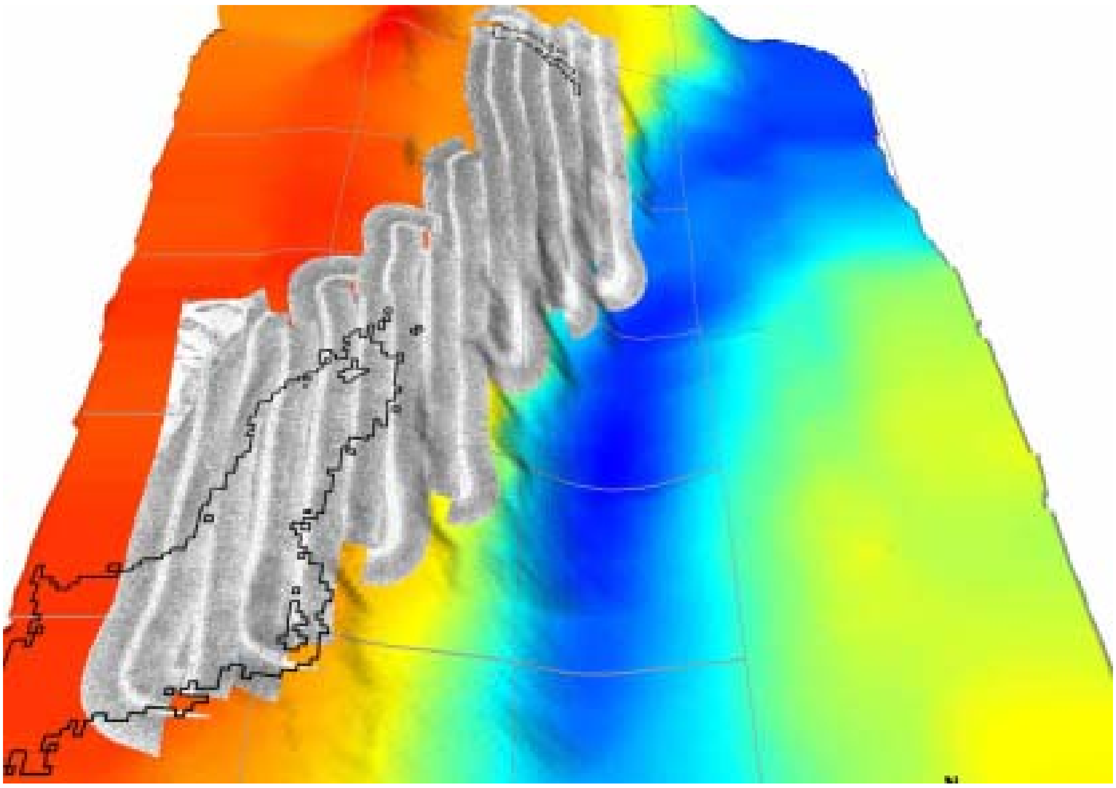


Figure 18. Drape of sidescan on bathymetric model of area 107.

The areas predicted to be *Sabellaria* reef are also shown marked by the black polygons. Note that for clarity this view has zoomed in to show just the area covered by the sidescan.

4.6 Summary of the July survey

1. *Sabellaria* reef was positively identified only at the reference site of 107.
2. Reef was not clearly distinguishable from other sandy gravel habitats using sidescan sonar, although this may not be considered the final verdict since there is a possibility that differences in sidescan deployment might show the reefs. There was no opportunity to deploy the sidescan after the July survey.
3. *RoxAnn* appeared to be able to predict the distribution of reef but, again, there was no further opportunity to test the predicted distribution by further field sampling.
4. Neither sidescan nor *RoxAnn*, for different reasons, can be considered to give accurate positional data over the full coverage of the map.
5. Thus, at best it is only possible to map the likely distribution of the reef within the resolution of the *RoxAnn* system.
6. This may be sufficient for monitoring coarse changes in distribution but cannot be used to map small changes in distribution at a fine scale with a comprehensive coverage.
7. Doubt remains as to the integrity of the reef system as distinct from other related biotopes in which *Sabellaria* is a characteristic species.
8. Reefs might be distinguished from video samples, but this method is limited by visibility and the handling capability of the drop down system in strong currents.
9. It is likely that the full range of *Sabellaria* biotopes can only be defined with confidence with infaunal analysis of grab samples.
10. Neither sampling system is highly precise in terms of position on the sea floor.

5. Repeat survey of the Longsands site

5.1 Introduction

It is worth revisiting the initial requirements of the repeat survey and matching these to the actual outputs from the initial survey. The purpose of the repeat survey was primarily to test the methodologies for the detection of *Sabellaria* reefs by re-mapping the reefs and assessing whether the techniques were capable of measuring change (in this case short term changes perhaps due to seasonality).

However, sidescan proved not to be capable of distinguishing between reef and sandy gravel habitats (if, indeed, there are sharp boundaries between these related habitats). The apparent ability of *RoxAnn* to distinguish reef has not been tested and, in any event, it is unlikely that this systems would be sensitive to fine scale changes in boundary conditions. Thus, the original aims for repeat survey could not be met in their entirety and, indeed, the priorities had to change.

1. Did the initial survey correctly represent the Longsands site as being without *Sabellaria* reef? Further sampling was required to explore the possibility that the initial survey missed the reef. In particular, the initial survey was constrained from sampling at the eastern edge of the area due to static fishing gear.

2. Would re-survey of the areas using AGDS produce comparable results?

3. One of the major obstacles to the acceptance of AGDS, such as *RoxAnn*, is that they do not 'see' the benthic habitats directly (in the same way that sidescan produces a highly visual image of the sea floor). Instead, the data require interpretation. Different systems, surveys and procedures for analysis can all result in different interpretations. The opportunity to use another AGDS (*QTC*) simultaneously with *RoxAnn* was fortuitous and allowed the two systems to be compared. Would they produce comparable interpretations?

4. Other aims also included testing the predicted distribution of reef in area 107 and the re-deployment of sidescan for reef detection. Unfortunately neither of these two objectives were achieved due to poor weather.

5.2 Analysis of the AGDS data sets

A detailed description of the analyses of the *RoxAnn* and *QTC* data sets is available as a separate report. This is useful to those wishing to follow the processes in some detail. Only the main results are presented here.

Both AGDS were run simultaneously using the same echo sounder. Thus, the data sets are exactly comparable. The Q values were treated in the same ways are the E values in that they were considered to be continuous variable that could be subjected to interpolation and analysis using image processing.

5.3 Unsupervised classification

Unsupervised classification is a process that attempts to find 'natural' groupings of within a data set. These groups are derived with no input from the field sample data and any association between the groups and the biotope or habitat categories is made after the classification. Figure 19 shows the unsupervised classification of the two data sets. The colours have been selected by eye to draw out potential similarities.

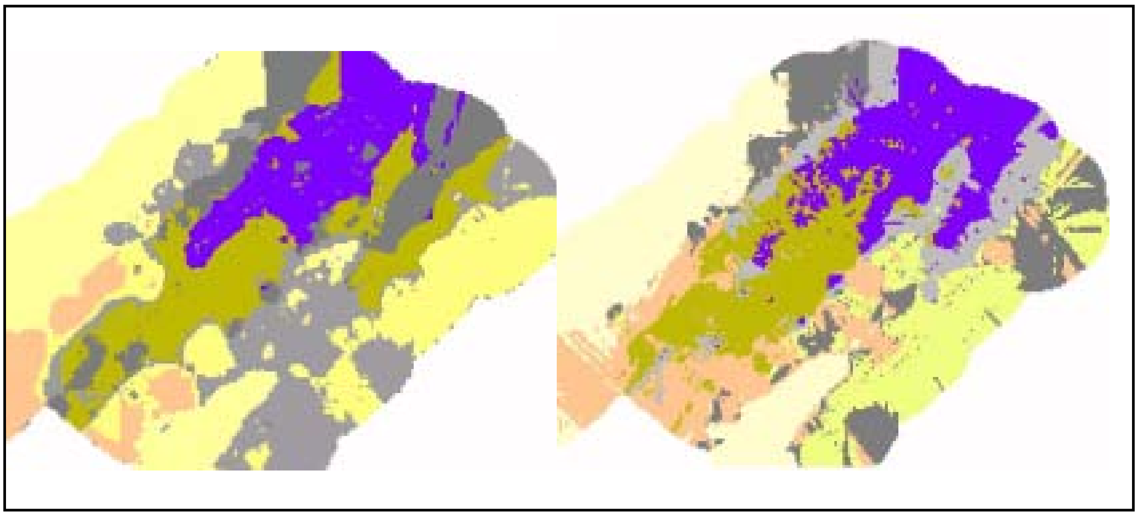


Figure 19. Unsupervised classification of (left) *RoxAnn* and (right) *QTC* data.

There are some clear similarities, such as the separation of the major deep ground into a north-east and south-west section (purple vs. green). Other boundaries between the groupings are also similar, although the groupings may not be exactly analogous. This type of classification is of limited interest, but does reveal if the two systems are responding to the ground in similar ways. There is sufficient visual similarity between some of the unsupervised ground types to suggest that this is the case.

5.4 Supervised classification

This is the more informative and standard approach to interpretation. The field samples from October and November were used as ground truth points for the classification.

Biotope classification: Although the two interpretations (Figures 20 and 21) look generally similar, there are substantial differences in the distribution of the biotopes. The overall accuracy of the two maps are similar as judged by the proportion of ground truth samples that lay on top of the appropriate biotope class (approximately 37% match). However, the *RoxAnn* interpretation has underestimated the sparse faunal turf whilst the *QTC* has underestimated the *Lanice* community. The important biotope is the *Sabellaria* gravel and *RoxAnn* has predicted distribution more in keeping with the ground truth samples than the *QTC* interpretation.

Sediment classification: There is a greater dissimilarity between the sediment classifications, with *RoxAnn* having a slightly better overall accuracy (approximately 40% match compared with 32% for *QTC*). The main differences are in the distribution of sand (underestimated by *RoxAnn*) and cobble and gravel (underestimated by *QTC*).

It is an inescapable conclusion that AGDS mapping is dependent upon the ground truth samples (since it does not 'see' the benthic habitats directly) and also upon the AGDS system used. However, the interpretation is bound to be problematic because (1) the ground appears to be highly heterogeneous and (2) the biotopes and habitat types are all very similar and grade into each other. These topics are discussed in the next section.

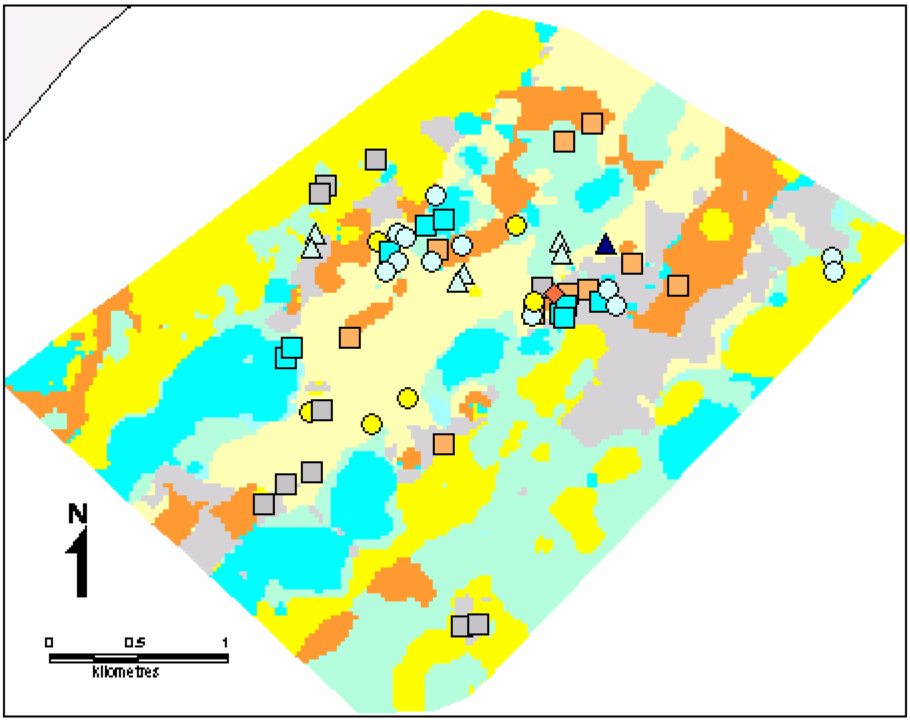


Figure 20. Supervised classification of the November *RoxAnn* data using field samples coded to biotopes as the ground truth data.

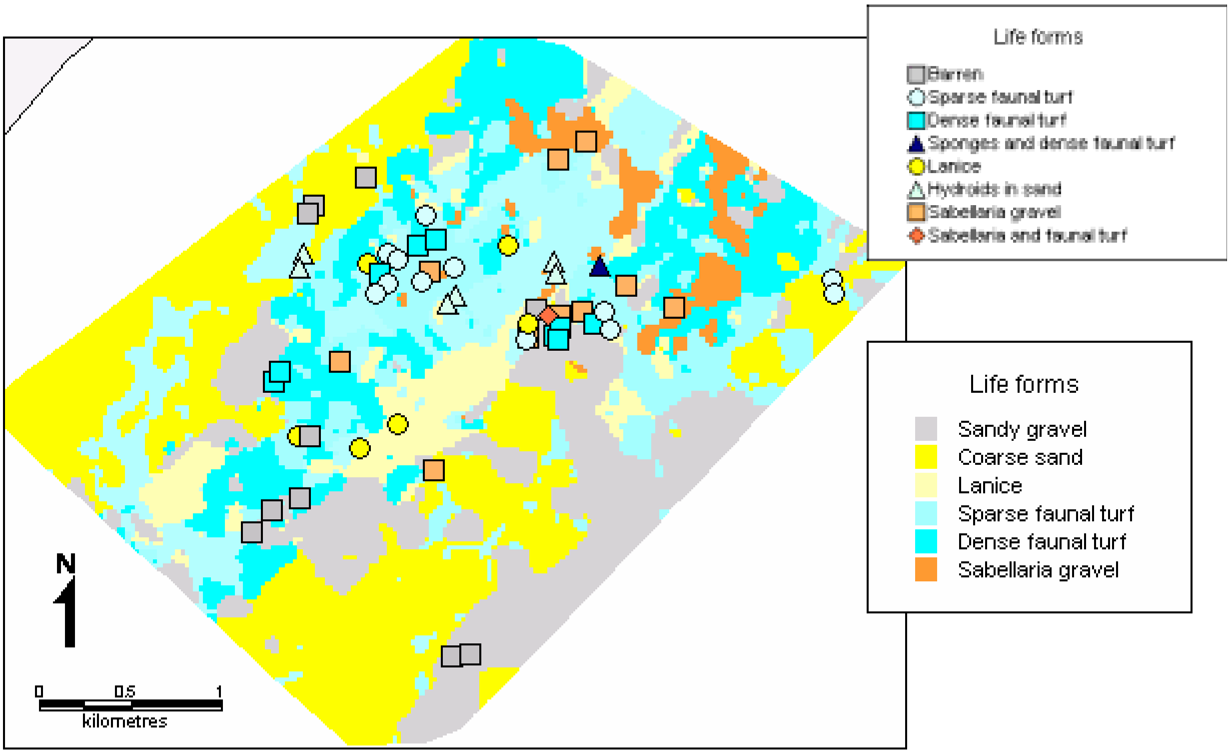


Figure 21. Supervised classification of the *QTC* data using field samples coded to biotopes as the ground truth data.

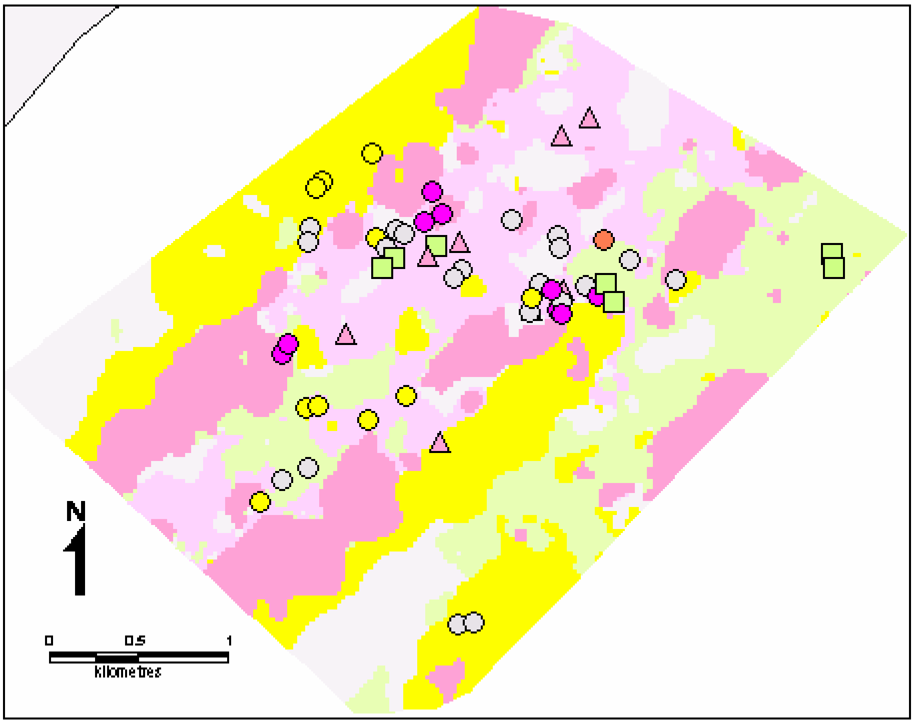


Figure 22. Supervised classification of the November *RoxAnn* data using field samples coded to sediment type as the ground truth data.

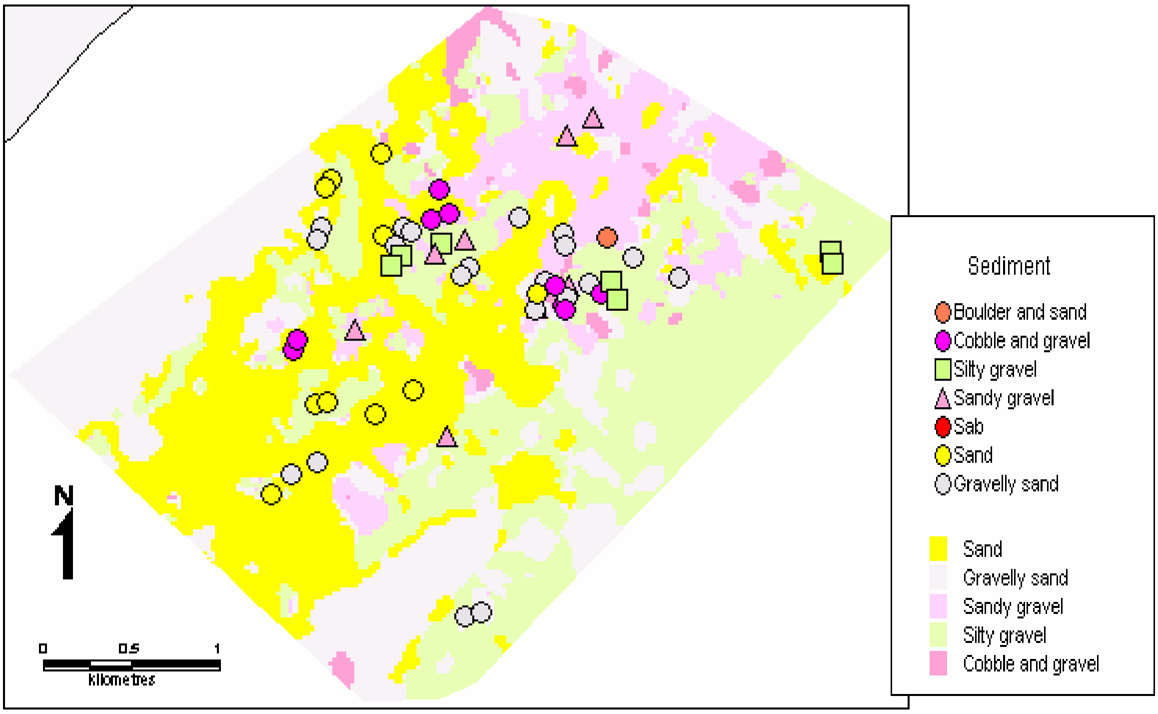


Figure 23. Supervised classification of the *QTC* data using field samples coded to sediment type as the ground truth data.

5.5 Field sampling: a summary

Further field sampling was undertaken in October and also in November, although the nature of the sampling was different (see Table 2). The initial project outline did not require any infaunal analysis, although analysis has since been sanctioned. Thus infaunal analysis is, at the time of writing, incomplete. The current status of the field sample data is shown in Table 5. The only common denominator that would allow all the field samples to be combined is the visual assessment of the habitat and biotope. The more detailed infaunal data either have been or will be incorporated into the analyses on the description of the *Sabellaria* reef (together with previous survey data) which is described in the next section.

Table 5. Current status of analysis of the field sample data collected in all the surveys for 2000.

Samples	Visual assessment	*Sabellaria* count	Full species list
July grab samples	Yes	Yes	Pending
July video	Yes	N/A	N/A
October grab samples	Yes	Pending	Pending
October video	Yes	N/A	N/A
November grab samples	Yes	Not retained	Not retained

Clearly, the field sample data for area 107 comprises wholly of that collected in July and have already been shown (Figures 8 – 14). It remains to present the complete field data set for Longsands and to explore if the spatial relation between the biotopes can tell us anything about the expected patchiness of the biotopes.

Figure 24 shows all the field samples for the Longsands site coded according to biotope. The first point of importance is that *Sabellaria* tubes were observed (especially in the grabs) on a gravely substrate or as encrustations on gravel and small cobbles. However, no well developed reef was observed.

If it is assumed that there was no significant temporal change in the distribution of the biotopes during the period of the survey, then it is apparent from a visual inspection that there is a high degree of spatial heterogeneity.

This heterogeneity can be analysed by determining the pair-wise similarity/ dissimilarity over increasing separation distance (termed ‘lag’). If the area were homogeneous, then it would be expected that the similarity between samples would be high where samples lie close to each other. If, on the other hand, the area were heterogeneous, it would be expected that the similarity would be low. Figure 25 illustrates the relationship between similarity and lag, and even at the closest spacing (within 200m) the similarity is low (0.2), compared with the frequency that would be expected if the samples were completely randomly distributed (similarity = 0.11 – the red horizontal line).

Intriguingly, the frequency has a second peak at a lag of about 1000m. This coincides with the distance across the deeps and may represent a repeated pattern in this direction. However, the main point is that the biotopes are probably very patchily distributed, which would make accurate and detailed mapping very difficult. The problem is compounded because the various biotopes are not clearly distinct even from the field samples. They have many of the same component habitat features and conspicuous species, but in varying proportions. The distinctive nature of the reef biotope is discussed in the next section.

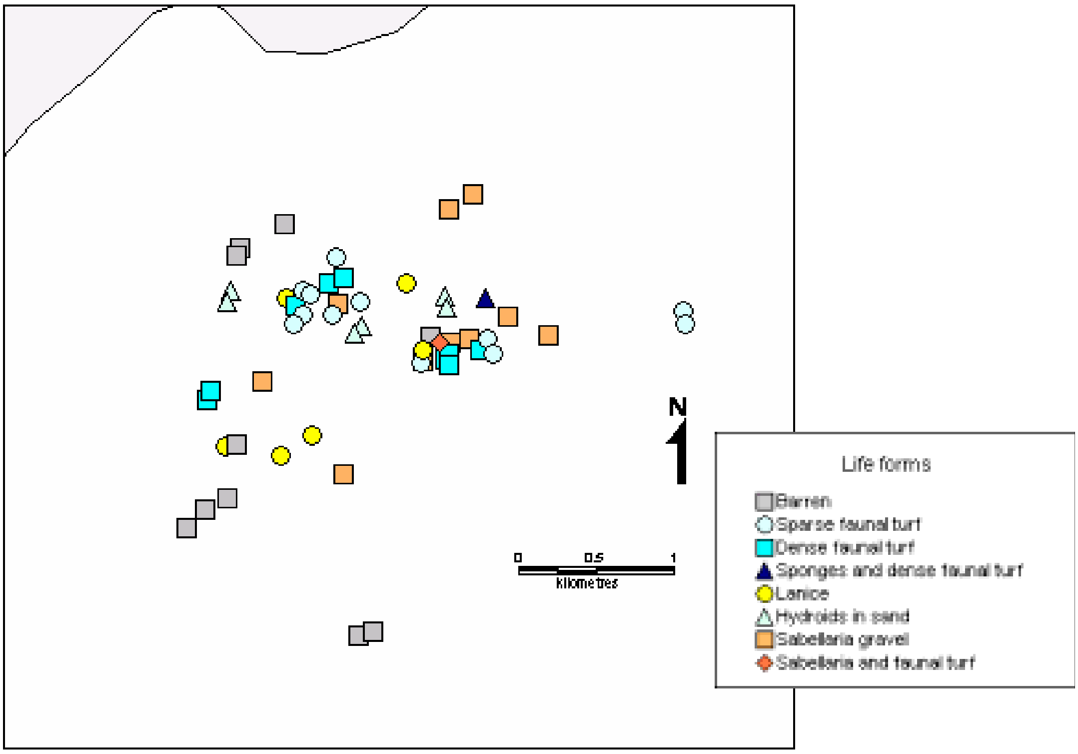


Figure 24. All field samples from the Longsands site colour coded to biotope.

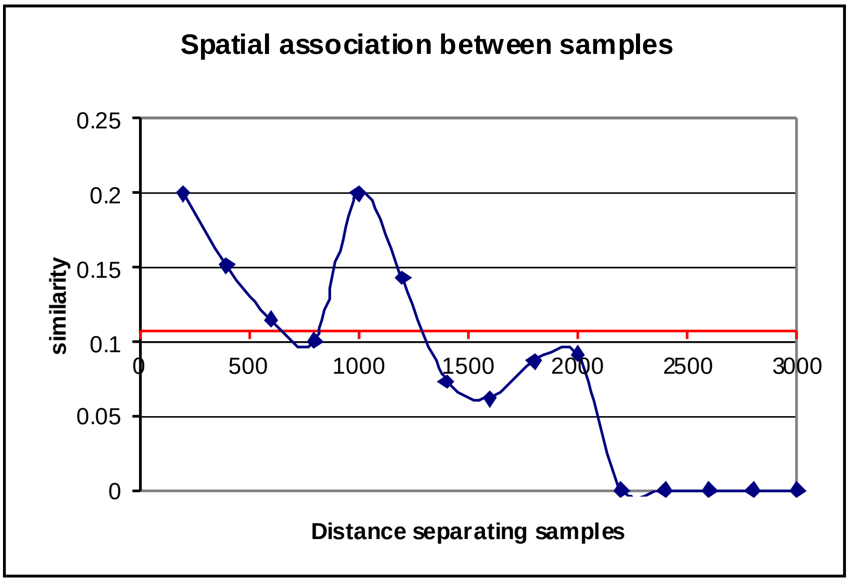


Figure 25. The frequency with which samples are of similar biotopes with increasing separation distance (lag). The red horizontal line indicates the frequency expected by chance.

6. What constitutes a *Sabellaria spinulosa* reef?

Video of *Sabellaria spinulosa* reefs would seem to leave no doubt about what should constitute a reef: They show intertwined tubes growing upwards away from the sea floor forming biogenic mounds up to 30cm tall that extend over large areas. However, grab and trawled samples also show that *Sabellaria* can also form low encrustations on cobbles or be mixed with gravel as part of other communities. Previous SeaMap reports of analysis of grab and video samples and suggested that the reef form of *Sabellaria spinulosa* was one extreme expression of the *Sabellaria* community and that various other communities overlapped with reefs in terms of both *Sabellaria* density and species composition. The analyses were summarised in a schematic diagram (Figure 26) illustrating how the communities overlapped and this is reproduced below.

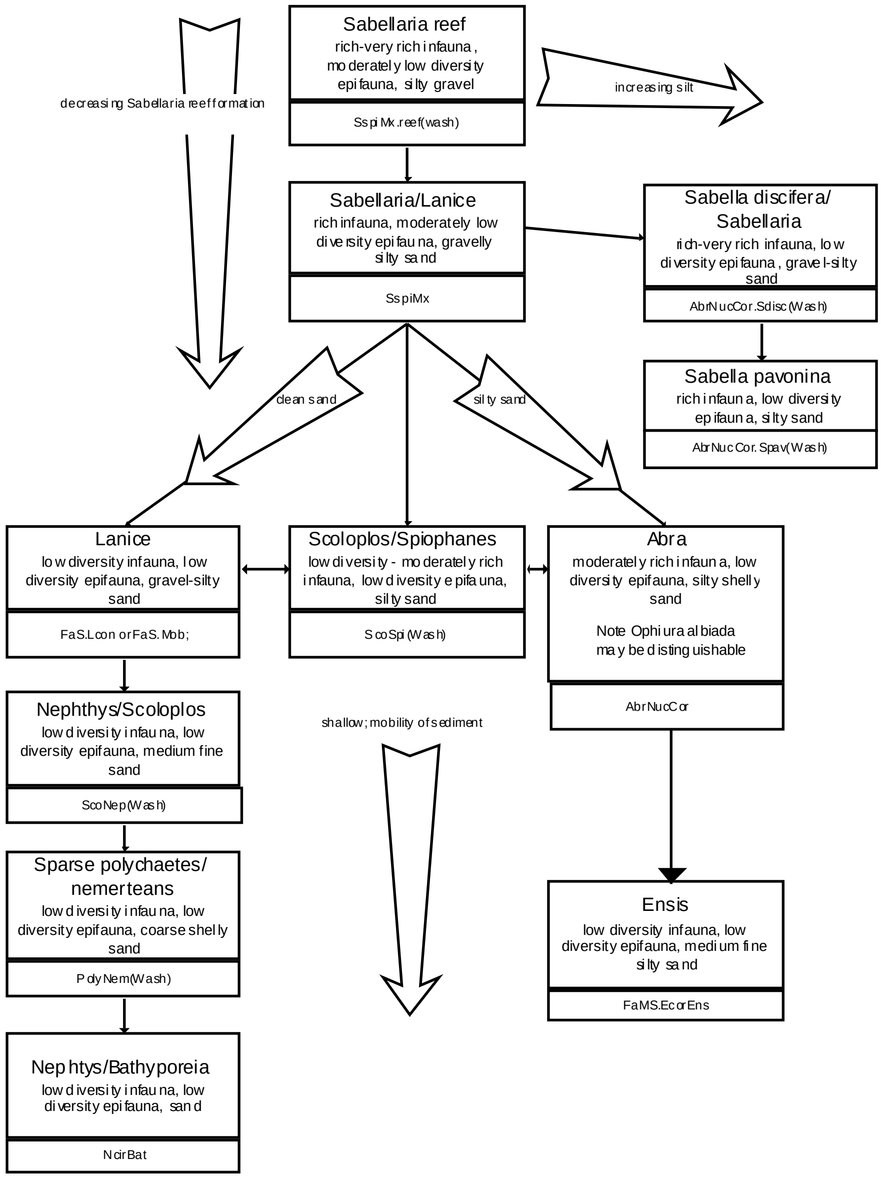


Figure 26. Schematic representation of the relationship between the main infaunal biotopes.

The requirement to monitor the status of *Sabellaria* reefs, however, has meant that the distinctive nature of reefs/dense *Sabellaria* communities as compared with other communities in which *Sabellaria* appears in lower densities needs to be re-examined.

6.1 Population structure

Firstly, do high density *Sabellaria* communities lie at one end of a continuum that can be explained by a simple mathematical description of the population structure or is there any evidence of a significant departure from distribution models (ie, an unexpected peak in the frequency distribution) that might indicate that reef populations are somewhat distinct from the continuum model? Figure 27 suggests that there is an exponential decrease in *Sabellaria* densities for most of the population that accords with the continuum model. However, there is a slightly elevated frequency of high density *Sabellaria* samples that might indicate that reef communities may show some distinction from the continuum model. This must be viewed with caution since the result might also be due to biased sampling in favour of reefs.

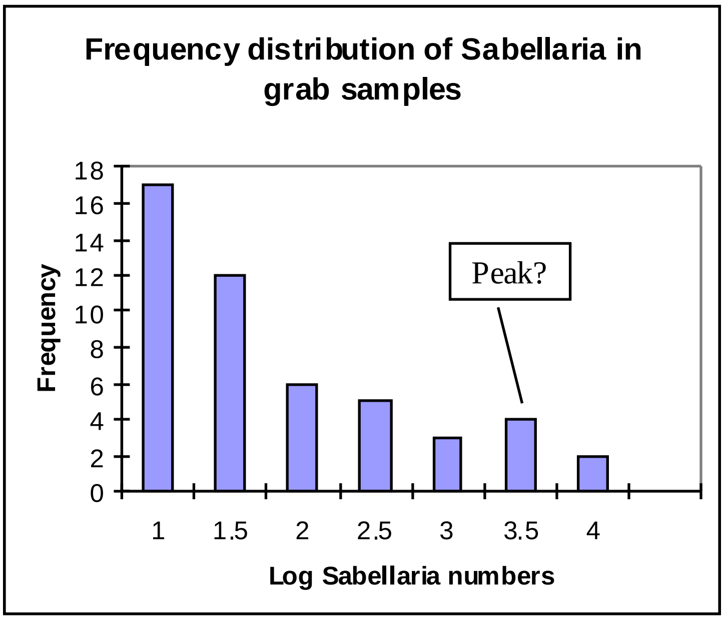


Figure 27. Frequency histogram of the density of *Sabellaria* in all sample records available.

The frequency distribution gives no clear evidence that reefs are distinct from other less dense *Sabellaria* communities although the data might be taken to indicate that densities of about 1000 per 0.1m^2 grab sample (and above) might indicate a 'reef'.

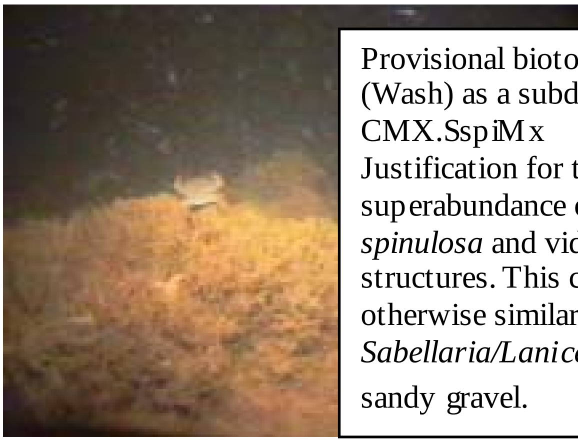
6.2 Community composition

Are there distinctive features about the species composition of *Sabellaria spinulosa* communities that set them apart from other communities? Although multivariate techniques can be used to distinguish communities, care must be taken to perform the analyses on data sets from different years separately since the species composition appears to change from year to year. An example from 1997 is shown in Figure 28 which clearly demonstrates that the dense *Sabellaria* communities can be distinguished by using Principal Components Analysis (PCA). Note that in this example the counts for *Sabellaria* have not been included in the PCA (ie, the *Sabellaria* communities can be distinguished by their associated fauna). However, the species that most contribute to the distinctiveness of *Sabellaria* communities are quite common. Thus, *Sabellaria* communities are associated with *Scoloplos armiger* (a deposit feeding orbinid polychaete) and *Pholoe inornata* and *Harmothoe* spp (both carnivorous scale worms). It is possible that dense *Sabellaria* creates a complex and open structure suitable for crawling carnivores. One group of actively burrowing carnivorous polychaetes, *Nephthys* sp, are conspicuously not found in association with *Sabellaria* communities. Distinctive reef communities have also been reported for the NRA dataset and the same species seem to be associated with the *Sabellaria* communities.

Box 1. The original description of the reef (Foster-Smith & Sotheran, 1999) is included below and this serves as a basis for a definition of a reef:

Sabellaria (super-abundant, including reefs)

Species	Abundance
Sabellaria spinulosa	SA
Pholoe inornata	A
Pisidia longicornis	A
Scoloplos armiger	A
Harmothoe indet.	C-A
Mytilus edulis	C-A
Autolytus prolifera	C
Eulalia ornata	C
Eumida ockelmanni	C
Exogone hebes	C
Mediomastus fragilis	C
Nereis longissima	C
Abra alba	O-C
Ampharete lindstroemi	O-C
Caulleriella zetlandica	O-C
Protodorvillea kefersteini	O-C



Provisional biotope CMX.SspiMx.reef (Wash) as a subdivision of CMX.SspiMx
Justification for this biotope is based on superabundance of *Sabellaria spinulosa* and video evidence of reef structures. This community is otherwise similar in composition to the *Sabellaria/Lanice* community. Silty sandy gravel.

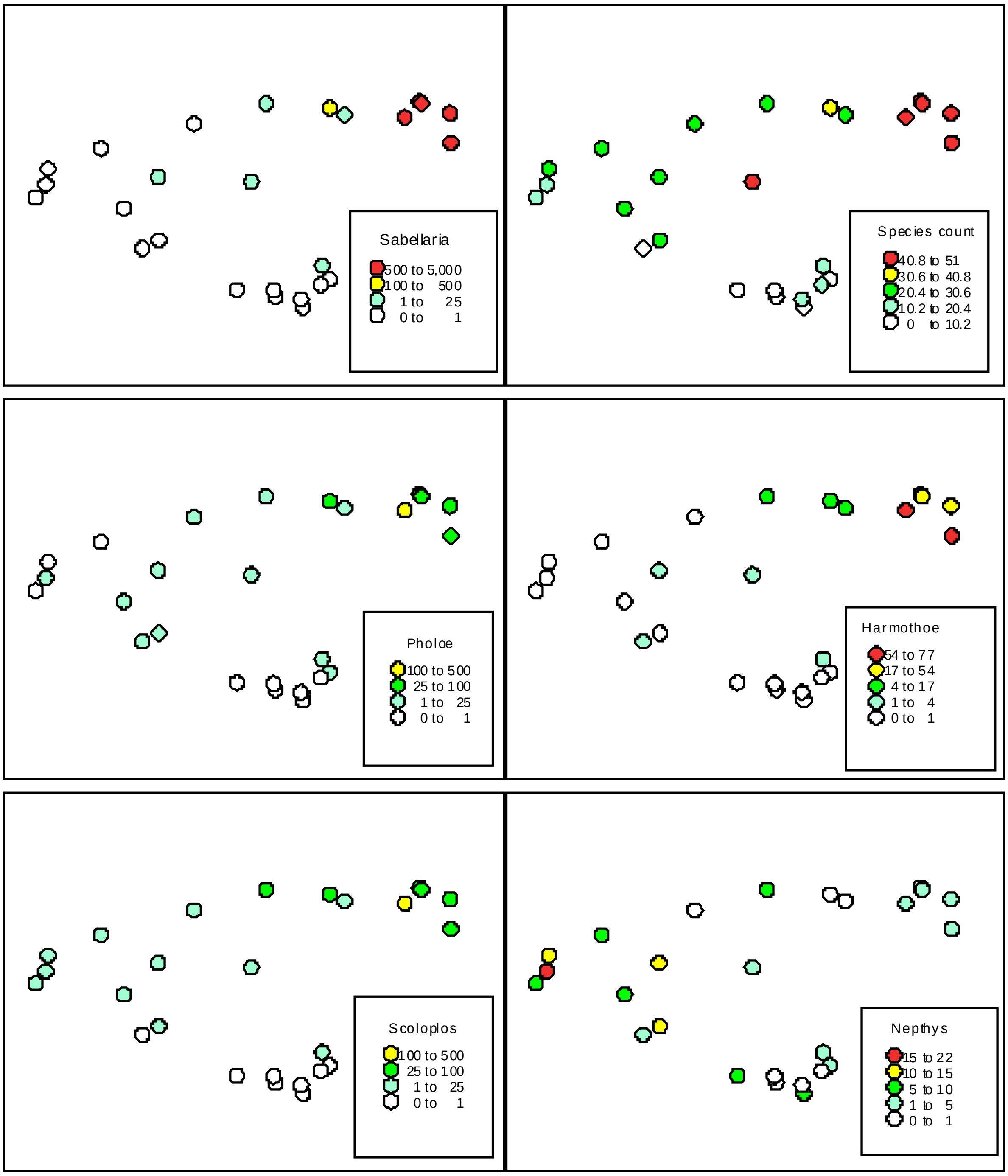


Figure 28. Principal components analysis of a data set from 1997.

The PCA has been performed on a species/abundance matrix with *Sabellaria* excluded. The samples have then been labelled according to the abundance *Sabellaria*, species counts and four key species identified in the PCA.

Figure 28 also shows that there is an association between species richness (as measured by a simple species count) and *Sabellaria* communities and the relationship between *Sabellaria* abundance and diversity is explored in the following section.

Species diversity

The relationship between *Sabellaria* communities and species diversity would appear from the example dataset to be quite straightforward: There is a trend for dense *Sabellaria* to be associated with high species diversity although there are examples of high diversity not associated with *Sabellaria* (Figure 29).

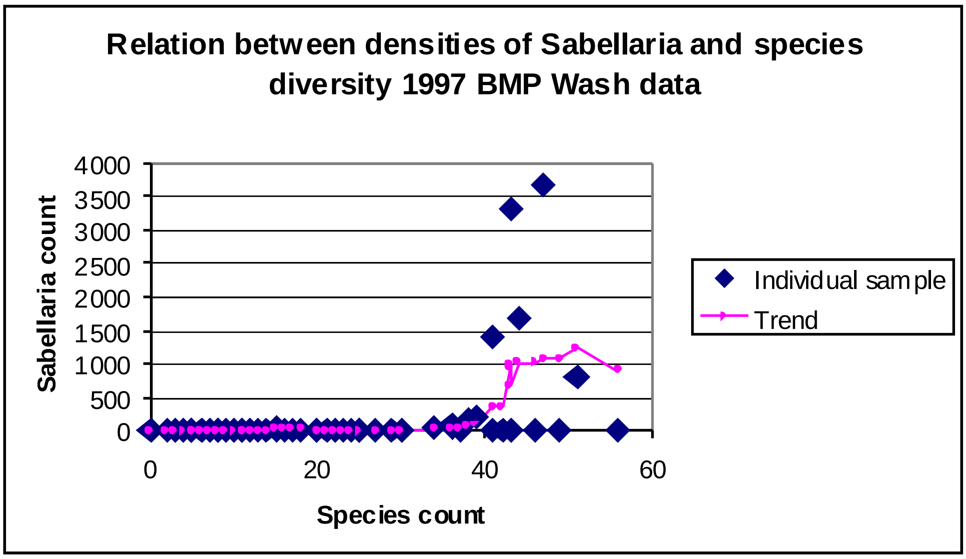


Figure 29. Density of *Sabellaria* plotted against species diversity as measured by total species count in the BMP samples (Foster-Smith and others. 1999).

The trend has been calculated as the running mean of five consecutive samples arranged in order increasing species counts.

The NRA data set shows a very similar pattern (Figure 30) and the same major species appear to be associated with the *Sabellaria* communities in this study as with the BMP data sets.

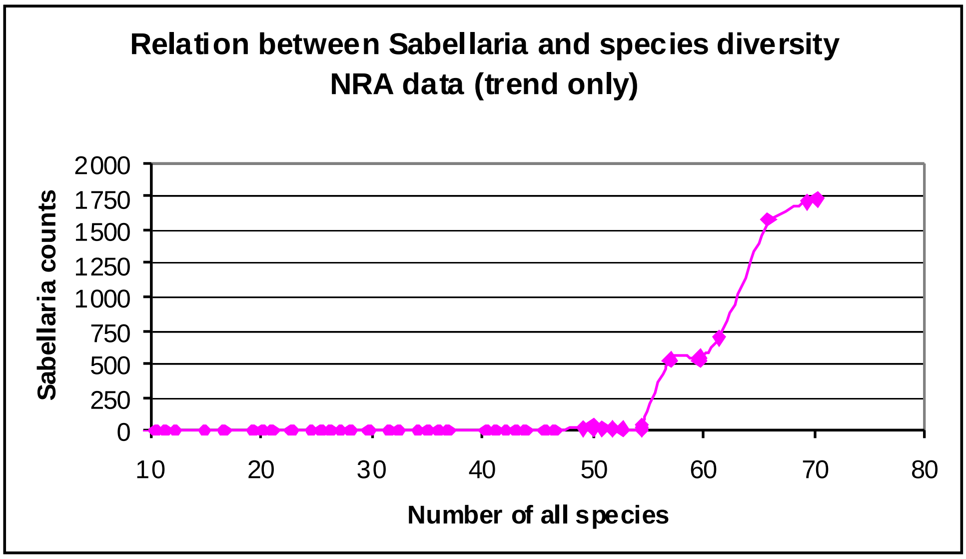


Figure 30. Density of Sabellaria plotted against species diversity as measured by the trend of total species count in the NRA samples (NRA, 1994).

Holt and others (1995) cite the NRA report as making the distinction between '*S. spinulosa* sites' and 'low or no *S. spinulosa*' at densities equivalent to about 33/ 0.1m^2 and that the former have twice as many species and three times the number of individuals (excluding *S. spinulosa*) as the latter. The graphs of the NRA data indicate that this is an extreme interpretation of their data and no such sharp distinction can be made although it is clear that even low densities of *Sabellaria* were associated with high species diversity (see Figure 31). The data from the BMP 1997 survey are less supportive of the conclusion that the presence of *Sabellaria* necessarily indicates high species diversity since many samples with *Sabellaria* at densities of less than 100/0.1m^2 have only moderate species diversity. The differences between the NRA and the BMP surveys may in part be due to differences in the sampling procedure used: The NRA survey took 3 samples per site as compared with the single samples of the BMP survey (and this would give the higher species counts in the NRA survey).

It must be borne in mind that many of the very low diversity sites are of mobile sand with *Nephthys* and are unlikely to be suitable for *Sabellaria*. It is not surprising, therefore, that the presence of *Sabellaria* even in low numbers might indicate slightly more stable conditions that would suit a wide range of species. It cannot be concluded from this that *Sabellaria* is structuring the community in these low numbers.

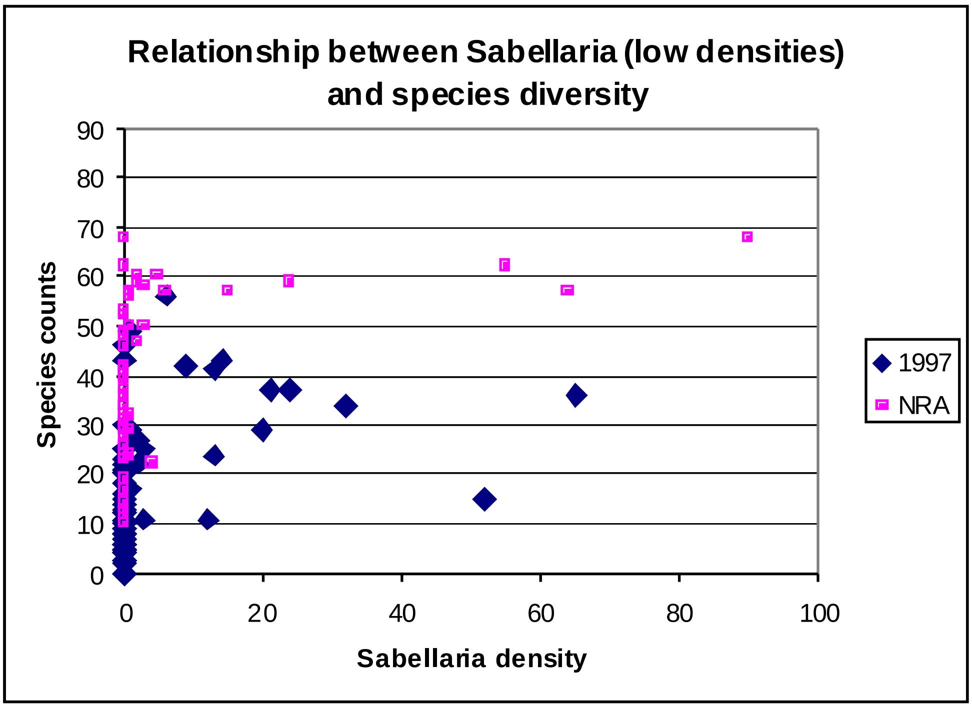


Figure 31. Samples with low densities (<100/0.1m^2) of *Sabellaria* have been selected to show the relationship with species diversity (number of species).

There appears to be little relationship in the BMP 1997 data set whilst even small numbers of *Sabellaria* were associated with high species diversity in the NRA data set. However, the converse is not true: high species diversity is not always associated with *Sabellaria*.

In summary, it is doubtful if *Sabellaria* densities less than 100/0.1m^2 are a good indicator of species diversity whilst densities above 500-1000/0.1m^2 are always associated with high species diversity. These high density *Sabellaria* communities appear to have a distinctive associated fauna which may be due to the biogenic reef structure. There is some weak evidence that there is a cluster of samples with high densities that might not be entirely due to a purely exponentially distributed population structure (ie, the actual population structure differs slightly from a purely mathematical population model predicting that the number of samples decrease exponentially with increasing sample density). Taken together, the evidence suggests that there *may* be a real clustering of high density *Sabellaria* communities that indicates a qualitative difference between these and lower density *Sabellaria* communities.

However, high diversity infaunal communities from The Wash also occur without high densities of *Sabellaria*, particularly some *Abra/Ophiura* communities, although species composition is different (Foster-Smith and Sotheran, 1999).

6.3 Broad scale trends in *Sabellaria* distribution

Fine scale spatial (and possibly temporal) heterogeneity seems to be characteristic of all biotopes in The Wash, including *Sabellaria* biotopes. However, there may be broad scale trends in *Sabellaria* distribution that transcends fine scale variability. All the *Sabellaria* data (from the NRA, CSD and BMP surveys and the 1999 and 2000 monitoring surveys) have been summarised using a five point abundance scale and the point data interpolated to create a continuous coverage to illustrate spatial trends. The analysis was performed in *Surfer* using an inverse distance square algorithm and the trends illustrated in Figure 32 by shades of violet. The samples are also shown as points of graduating colour. Three main points can be made from this analysis:-

1. The data is spatially very variable with high densities of *Sabellaria* lying close to samples with low densities;
2. There are clearly areas where *Sabellaria* has not be observed in any of the surveys and other areas where *Sabellaria* has been observed at moderate to high abundance levels quite frequently.
3. The trend confirms the predicted distribution from the Lynn Deeps to Scott Patch, but there may also be lower densities extending well into The Wash.

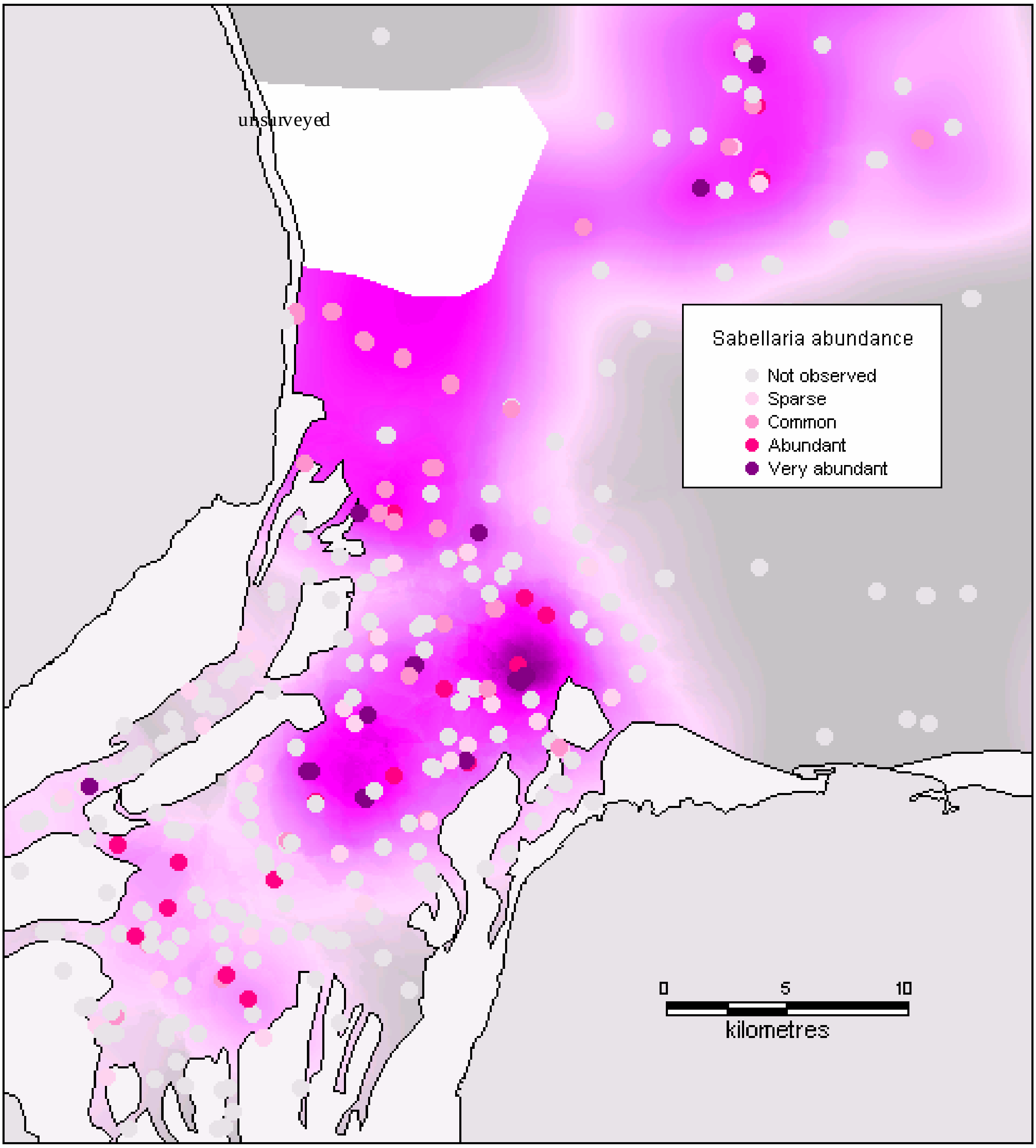


Figure 32. Trends in Sabellaria distribution. The data is a summary of all records available. The abundances of individual point samples are shown on an interpolated surface.

7. Conclusions and recommendations

Many of the underlying issues that need to considered in designing a strategy for monitoring the status of *Sabellaria* reefs involve questions about the inherent spatial and temporal patchiness in distribution of *Sabellaria*. The spatial heterogeneity indicated in the video tows over reefs (see also Foster-Smith and others 1999) indicates that reef structure can vary between well formed structures and sandy patches within short distances. At a larger scale, it seems that the reefs in area 107 are persistent (although they might vary in the precise location of patches) whilst those in The Wash may fluctuate.

Well developed *Sabellaria* reefs can be visually recognised. Whilst direct observation using video or divers might seem to be the best field method for the detection of reefs, such techniques may be unreliable as monitoring tools in The Wash because of the unpredictable (but often poor) visibility in this region. Perhaps more fundamentally, there is no clear distinction between *Sabellaria* reefs and related *Sabellaria* biotopes either visually or through analysis of sample data. *Sabellaria* reefs may be characterised by high species diversity and densities greater than about 500 per $0.1m^2$. However, the population structure of *Sabellaria* in all samples gives no more than a hint that reefs have a distinctive population structure. If future monitoring of reefs is to rely on a statistical analysis of grab samples to define reefs (rather than visual confirmation) then more work may be considered necessary to place more precise limits on *Sabellaria* densities than has been possible in this study. The use of community composition and diversity measurements for this purpose is not recommended for the for the following reasons:-

1. Determination of species diversity is dependent on the expertise of the person carrying out the infaunal analysis and variability might be expected due to this reason alone. Detailed infaunal analysis is also expensive.
2. Species composition and diversity may change over time depending on the recruitment of species other than *Sabellaria* and this may not mirror fluctuations in *Sabellaria*.
3. Community structure is an attribute of the reef that might be important to measure and the relationship between community structure and reef development investigated. Using community structure to define a reef would involve circularity in the argument which would preclude such analyses.

Additionally, it may be important to assess the status of related but non-reef *Sabellaria* biotopes. Thus, the disappearance of well-developed reefs might not indicate that the *Sabellaria* communities have been eliminated from an area. They may well recover from an existing local population of *Sabellaria*. It would seem unwise, therefore, to rely entirely on direct observation and sampling (such as grab samples) might be considered necessary to assess the status of the *Sabellaria* population and associated diverse infauna.

If *Sabellaria* populations (and reef development) were very dynamic, then a technique for ‘seeing’ the reefs would be invaluable in mapping the way reefs fluctuate. Such detailed maps could be used to evaluate the significance of changes in the reef at any precise point (is change due to fine scale dynamics or some broader scale trend?). However, no clear choice for the remote surveying *Sabellaria* reefs emerges from this study. It is unlikely that either sidescan sonar or AGDS would be successful in mapping small reef features with precision (to remind the reader; the sidescan sonar studies failed to 'see' reefs and AGDS has a resolution greater than 25m). The accuracy and repeatability required for mapping small reefs could be achieved by use of other sonar techniques, but these are untried. For example, scanning acoustic 'cameras' may be able to achieve the high definition required, but would be limited to the survey of small areas (eg, *Imagenex* digital imaging scanning sonar).

Precision location of divers (using sonar beacons) may also be feasible. However, the cost of such precision surveys, whilst of scientific interest for the study of *Sabellaria* dynamics, might be hard to justify for monitoring the status of reefs.

AGDS were more likely to be able to discriminate between *Sabellaria* reefs and other sandy gravel biotopes than sidescan sonar, but the technique is too prone to variability to be able to use the maps without extensive field sampling for use as an accurate repeat survey tool. AGDS is best used for broad scale and indicative survey.

In summary, neither the field sampling techniques nor the remote mapping techniques employed in this survey are likely to be sufficiently precise enough to permit the assessment of fine scale changes. However, how important are fine scale changes to the overall status of the *Sabellaria* biotopes (reef and non-reef)? By concentrating expensive survey effort on fine scale variability there is a risk that significant broad scale changes may go undetected. There does appear to be a pattern to the broad scale distribution which suggests that *Sabellaria* is more likely to be found in the channel running from the Lynn Deeps to Scott Patch. It is less likely to occur well within The Wash, although the earlier surveys indicate some low – moderate densities of *Sabellaria* in the inner Wash.

The surveys are not sufficiently comparable to test any temporal changes in these broad trends. However, the spatial trends taken together with apparently recent low diversity of *Sabellaria* in the Lynn Deeps and the persistence of reefs offshore might suggest that the penetration of dense *Sabellaria* communities into The Wash might vary over time. Whether or not this is the case, there is certainly not enough evidence to indicate if such variations are cyclical or if there is a continuous downward trend in *Sabellaria* numbers in The Wash.

Thus, broad scale fluctuations in population at the mouth of The Wash in relation to the more stable populations outside The Wash may indicate the operation of broad scale processes that are more important to the management of the status of the reefs. Do the results of this survey (and previous survey surveys) help in the formulation of a broader scale monitoring strategy?

7.1 Future survey strategies

Choosing the scale for sampling and the area for survey for The Wash and its environs must be matched to the priority questions that need to be addressed for monitoring the status of the reefs and related *Sabellaria* biotopes (as well as the techniques available and survey cost). Some example options are given in Table 6 with reference to Figure 32.

Table 6. Examples of options for monitoring the status of reefs in The Wash.

Scale	Techniques	Positioning precision	Cost/effort	Issues addressed	Issues not addressed
Quadrat (25m x 25m)	Continuous coverage: Videography, photography and diver sampling	Very precise: DGPS and acoustic beacons	High for sample quadrat; prohibitive for large survey area	Patch dynamics of reef; sequence of reef construction and decline	Significance of change hard to assess in broader context
Box (500m x 500m)	AGDS; random sampling within box: videography, grab samples, diver – collected samples	GPS (assuming no selective availability)	Videography low; grab low to moderate depending on infaunal analysis	Statistics of box used to assess change	Hard to extrapolate change to whole area; little information on patch dynamics
Box (500m x 500m)	As above plus acoustic imaging	As above	As above; Imaging unknown	As above plus boundary changes within box associated with patch dynamics	Hard to extrapolate change to whole area
Whole area	AGDS survey plus selected sampling using videography and grabs	As above	High to achieve adequate coverage and sample intensity for repeat survey; Moderate if indicative only	Broad scale changes mapped; comprehensive statistic for whole area	Even intensive survey is imprecise for measurement of change; If indicative then statistics unreliable
Box and belt transect	AGDS for belt; as option 2 & 3 for boxes	As above	Moderate to high depending on number of boxes and sampling	Broad scale changes along preselected gradient	Changes outside transect not assessed, changes between samples extrapolated and therefore imprecise (indicative only)

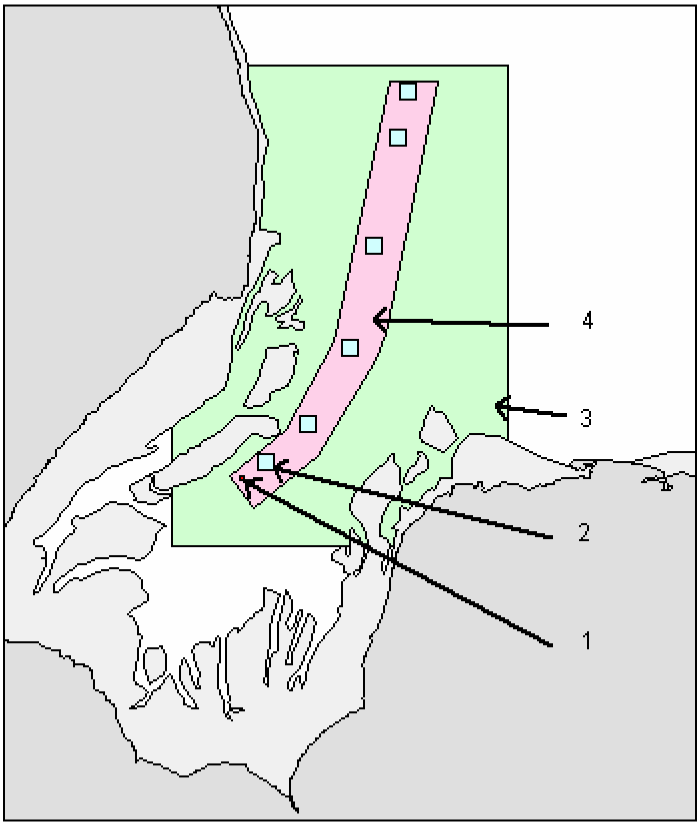


Figure 33. Examples of sampling scales and survey sizes for monitoring the status if reefs in The Wash.

Some of the issues raised above are discussed in more detail:-

1. **Detailed assessment of patch dynamics of *Sabellaria* reef.**
   The need for this information must be justified for this expensive survey strategy. The nature of the dynamics might be of value for the understanding of the conditions needed for reef build-up and decline as well as the natural cycles in this process that might be needed before appreciating the significance of change.

2. **Experimentation with other forms of remote sensing.**
   Fine scale imaging could, if techniques such as acoustic cameras prove themselves, be used to map the above monitoring areas and greatly add to the knowledge of variability and dynamics of reefs/*Sabellaria* biotopes. It is recommended that such techniques should be investigated and trailed (manufacturers demonstration).

3. **AGDS survey of the whole area**
   Whilst this would produce results which would help assess the changes in distribution patterns over the whole area, intensive survey would be required if changes in these distribution patterns were to be relied upon. It is unlikely that this survey strategy would justify the expense on a yearly basis. However, a six-yearly repeat baseline survey might be considered.

4. Random sampling within monitoring areas that follow a broad environmental gradient.

It is clear that limited sampling in an area is insufficient to be able to sample the full range of biotopes (eg, *Sabellaria* biotopes were not sampled at the Longsands site in July). A larger number of samples would allow an assessment to be made of the *Sabellaria* population within a sampling area and the spatial heterogeneity (dispersion) of the population. These sampling areas might be about 500m x 500m and arranged following the northern flank of the Lynn Deeps/Scott Patch feature. The analysis would produce summary statistics for each site that could be used to detect broad scale spatial and temporal trends.

Video and grab samples are the recommended field sampling techniques: Grab samples may not require detailed infaunal analysis to reduce expense. However, the samples could provide information on the population structure of the polychaetes. Video, despite the problems of poor visibility, can be rapidly deployed and many records can be collected in a short time. Experimentation with downward-facing digital video in a fixed frame may reduce the problems of poor visibility that affects forward-facing videography.

AGDS could be used to help plan and focus the random stratified sampling and could be used in two ways:-

1. AGDS data can be collected over the trial areas. This would add very little to the cost of the survey and analysis of the data may produce information on changing acoustic properties that could be used to help interpret any spatial variability found within the samples.
2. A detailed initial survey could be carried out over the strip of seabed that encompasses the monitoring sites to provide a good baseline and bathymetric model for displaying other data. A detailed knowledge of the topography is likely to be important in the understanding of the habitat requirements of the *Sabellaria* biotopes.

5. Modelling and specific survey to test hypotheses

Existing data on topography and *Sabellaria* habitat requirements could be used to predict where other reefs might be located. Deterministic models are based on linking distribution to certain features: For example, *Sabellaria* reefs might be linked to areas with moderately high seafloor currents and shear stress, depths and transitional zones between cobble and sand. The presence of any of these conditions in an area might be expected to raise the likelihood of *Sabellaria* being present. These deterministic models can be tested by sampling new areas and this type of study can make use of opportunistic sampling or be tested by sampling specifically selected sites. Deterministic models can prove very powerful tools in explaining the natural history of an organism. However, whilst they can be formulated to explain the results of surveys *post hoc* they must be tested in a predictive capacity to become reliable models.

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