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Benthic Survey of Inner Dowsing, Race Bank and North Ridge cSAC, and of Haisborough, Hammond and Winterton cSAC

Authors: Christopher Barrio Froján, Alex Callaway
Paul Whomersley, David Stephens & Koen Vanstaen

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Project Manager:	Paul Whomersley/Sonia Kirby
Report compiled by:	Christopher Barrio Froján
Quality control by:	Paul Whomersley
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Head office

Centre for Environment, Fisheries & Aquaculture Science

Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK

Tel +44 (0) 1502 56 2244 Fax +44 (0) 1502 51 3865

www.cefas.defra.gov.uk

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Executive Summary

This report describes the results from an interdisciplinary field survey aimed at identifying the location, extent and condition of Annex I habitat features in two candidate Special Areas of Conservation: the Inner Dowsing, Race Bank and North Ridge (IDRBNR) cSAC, and the Haisborough, Hammond and Winterton (HHW) cSAC. The habitat features of interest are (i) sandbanks slightly covered by sea water all the time, and (ii) biogenic reefs.

Acoustic sidescan and multibeam data were acquired from within both cSACs, together with groundtruthing samples representative of targeted habitat types. Groundtruthing techniques included the acquisition of video and still images of the seabed, and of sediment and faunal samples.

Delineation of the entire sandbank feature at both cSACs was not possible due to the chosen survey design based on acoustic data corridors. However, where these corridors did intersect the sandbank features, comparisons between newly acquired data and modelled full-coverage bathymetry data revealed discrepancies in the precise location of sandbank boundaries. Such discrepancies, most noticeable at the HHW cSAC, could be interpreted as the sandbanks having migrated by as much as 200 m in places.

Analysis of collected faunal datasets revealed several distinct faunal assemblages; the differences amongst them were likely influenced by localised differences in environmental conditions. At a broad scale, however, differences were most evident between assemblages present in sites representing reefs and sandbank troughs, and those representing sandbank crests and flanks. No differences were observed in assemblage composition within each of these two groups of habitats.

Biogenic reef structures, built primarily by the tube-dwelling polychaete *Sabellaria spinulosa*, were observed, sampled and characterised, but due to their very patchy distribution and relatively low elevation, the overall extent of reef habitat could not be measured with any certainty.

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1 Background and Introduction

Natural England (NE) and The Joint Nature Conservation Committee (JNCC), in partnership with Cefas, have conducted field surveys to investigate the condition of Annex I habitat features within two candidate Special Areas of Conservation (cSAC): the Haisborough, Hammond and Winterton (HHW) cSAC, and the Inner Dowsing, Race Bank and North Ridge (IDRBNR) cSAC. Surveys were designed to acquire data to assess the present condition of Annex I features and to contribute to the development of a baseline for future long-term monitoring of Annex I feature condition within the cSACs.

The Haisborough, Hammond and Winterton cSAC lies off the north east coast of Norfolk, whereas the Inner Dowsing, Race Bank and North Ridge cSAC is located off the south Lincolnshire coast in the vicinity of Skegness, extending eastwards and north from Burnham Flats on the North Norfolk coast (Figure 1). Both cSACs contain a series of sandbanks which meet the Annex I habitat description 'Sandbanks slightly covered by sea water all the time'. Other habitats and features of conservation interest include biogenic reefs such as those created by the Ross worm *Sabellaria spinulosa* which are also a designated feature of the site.

This report describes the findings from the dedicated surveys of both cSACs and, together with the cruise reports submitted previously (Whomersley et al., 2011) and additional information from the Humber and East Coast Regional Environmental Characterisation (REC) reports (Tappin et al., 2011; Limpenny et al., 2011), provide both the necessary detail on the assessment process and the best available evidence on which to build a robust baseline.

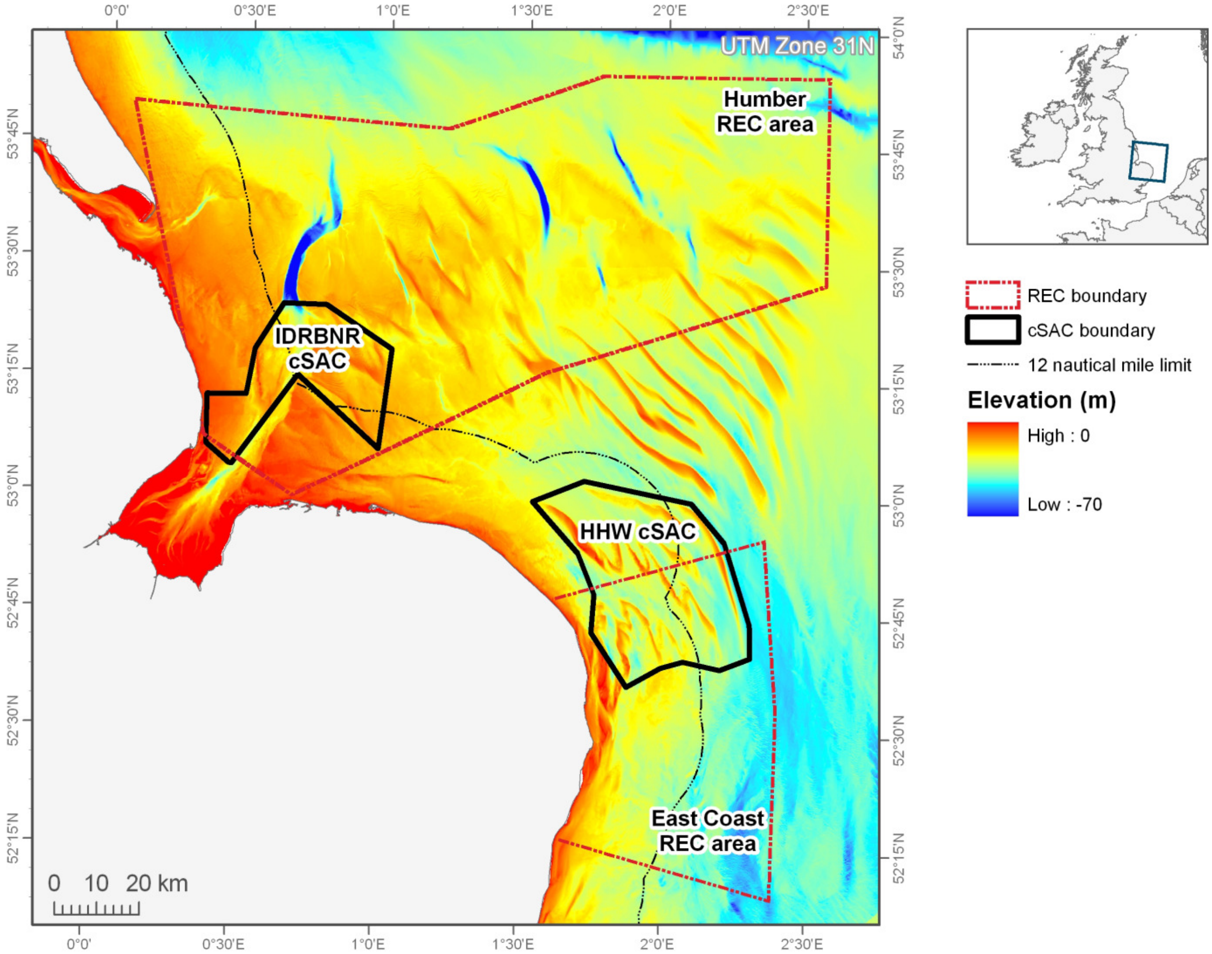

Figure 1. Location of the IDRBNR and HHW cSACs in relation to the Humber and East Coast REC areas. Elevation is derived from the Defra Digital Elevation Model (Astrium, 2011).

1.1 Links to Action Plan

The Plan of Action (PoA) document, drafted by all parties, agreed on a number of Work Packages to ensure the attainment of the project's objectives. These included:

1. To develop and deliver a comprehensive and fit for purpose field sampling design – objective achieved and sampling design implemented successfully. Details of the sampling design presented in Section 2.
2. To acquire high quality acoustic and biological data – objective achieved, with all data processed and analysed. Results from analyses are given in Sections 3 and 4.
3. Establish a baseline for long-term monitoring of the condition of Annex I sandbank and biogenic reef features in the area of study – objective partially achieved, with assemblage composition for each habitat type presented in Sections 3 and 4, together with descriptions of associated physical parameters. Newly acquired acoustic data did not allow for the accurate calculation of sandbank and reef extent.

In addition to the above Work Packages, a number of hypotheses were included in the PoA document to provide a framework for the analyses on the acquired biological datasets. These hypotheses were (*sic*):

1. Different communities are associated with crests and with flanks of the sandbanks.
2. There is a difference between the sandbank flank communities located on the more wave- and tidally-exposed outer sandbanks compared to the communities found on inner banks.
3. Communities subject to high anthropogenic pressures are different to communities subject to no/low pressure.
4. The Haisborough Gat reef and the Docking Shoal reef are receiving direct [anthropogenic] impacts.

2 Survey Design and Methods

2.1 Planning, including sampling site selection

The HHW and the IDRBNR cSACs both span the 12 nautical mile inshore-offshore boundary. Because of this cross-boundary location, the characterisation of both cSACs was a cross-agency venture involving NE (responsible for the area of the site inside the 12 nautical mile limit), the JNCC (responsible for the area of the site outside the 12 nautical mile) and Cefas, who provided the research platform (*RV Cefas Endeavour*) and operational expertise. All project partners (NE, the JNCC and Cefas) were represented at all planning meetings and were involved in determining the overall direction of the survey plan.

A Geographic Information System (GIS) project was created which contained all available and relevant data layers (see Appendix II for a list of data sources used). Using this GIS project, acoustic survey lines were planned and mapped based on the typical operational capabilities of the survey vessel. Areas not previously surveyed by the REC programme were prioritised, as well as groundtruthing stations which would enable the testing of the predefined hypotheses. Subsequently, conditions encountered during the survey meant that some of the planned survey lines had to be substituted with new lines when *in situ* observations indicated that some of the proposed lines would take the vessel beyond its navigational safety limits. Additional acoustic and benthic sampling surveys were later commissioned to complete the original survey design using the Environment Agency's (EA) research vessel, the *Humber Guardian*, to acquire data from the sections of the sand bank complex that were shallower than 15 m and inaccessible to *RV Cefas Endeavour* (Figure 2).

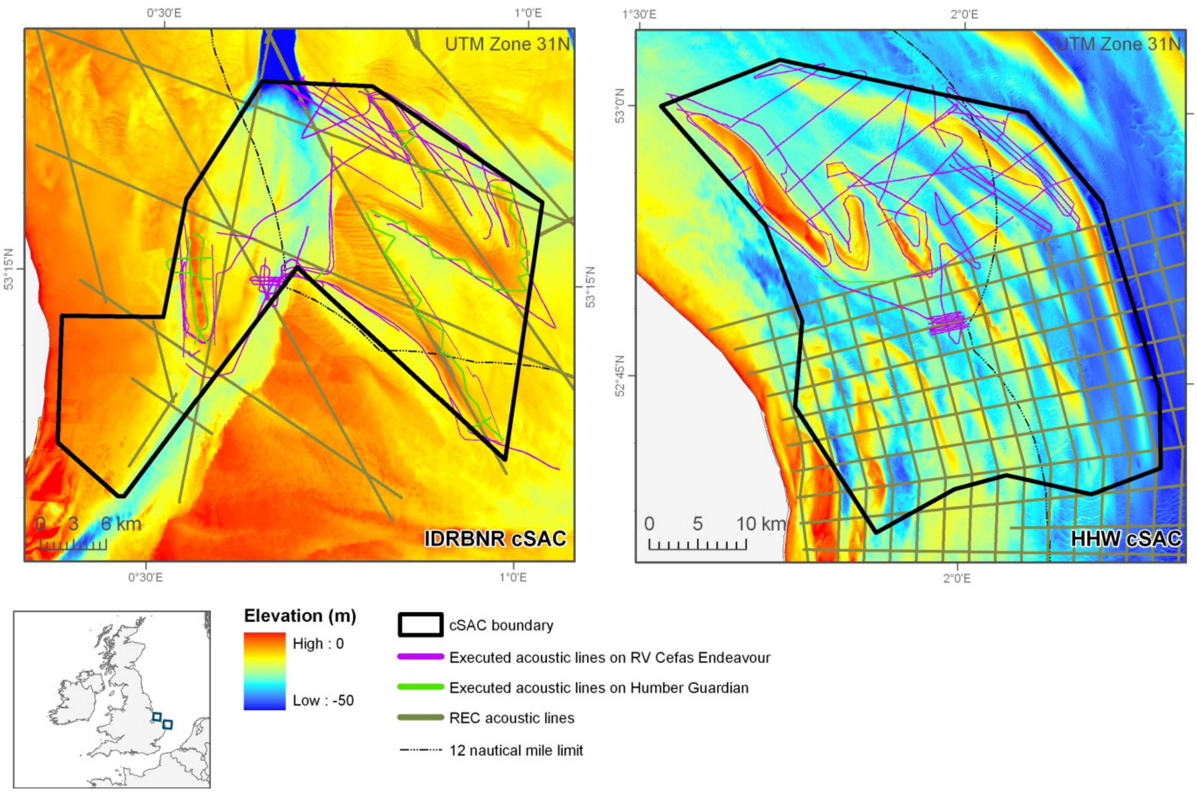

Figure 2. Executed acoustic survey lines within the IDRBNR and HHW cSACs, shown in relation to acoustic survey lines surveyed under the REC programme.

To enable the testing of the proposed hypotheses, statistical guidance on the grab sampling survey design was sought from a Cefas statistician. A power analysis was performed to ascertain the optimum number of grab samples necessary to detect a significant change in selected infaunal assemblage parameters (see Appendix III for detailed rationale on determining appropriate sampling effort). This analysis revealed that 15 replicate grab samples per sampling site would be sufficient to capture the variance of selected assemblage parameters within a site and enable statistically robust comparison of these parameters to be made between sites. Such level of replication would also enable the statistical comparison of assemblages living on selected sandbank features, such as the crest, trough and flank of sandbanks (i.e., between statistical treatments). Several sites representing each treatment were sampled; treatment designation of sites was based on assessment of best available evidence. *Sabellaria spinulosa* reef was also sampled following the same guidance on sample replication to make datasets from all treatments compatible.

Within each cSAC, 10 sites were sampled successfully for infauna using a mini-Hamon grab (Table 1), representing all four treatments (sandbank crest, flank, trough and *S. spinulosa* reef) (Figure 3). Not all planned sites were sampled, as bad weather and forced downtime due to equipment failure consumed some of the total survey time available. Because of this, insufficient replication of flank features at different levels of exposure to predominant currents (i.e., seaward vs. landward flanks) prevented the testing of Hypothesis 2 (see Section 1.1).

Table 1. Sampling sites at each of the cSACs with details of sampling effort at each site.

	Treatment	Grab Samples	Camera tows
IDRBNR cSAC			
East North Ridge	Trough	15	5
Dudgeon Shoal Trough	Trough	15	1
Dudgeon Shoal Flank	Flank	15	2
North Dudgeon Shoal	Reef	15	-
West Dudgeon Shoal	Flank	15	-
Silver Pit East	Reef	15 + 3 supplementary	2
Docking Shoal	Reef	15	5
Inner Dowsing East	Crest	15	1
Inner Dowsing West Trough	Trough	15	1
Inner Dowsing West Crest	Crest	15	1
HHW cSAC			
Southern Hewett Ridge Crest	Crest	15	-
Southern Hewett Ridge Flank	Flank	15	-
East Hammond Knoll	Trough	15	-
Winterton Ridge	Crest	15	3 (Reef)
Haisborough Gat Reef	Reef	15	3
Haisborough Sandbank West	Crest	15	-
Haisborough Tail Bight	Trough	15	1
Haisborough Tail Deep	Trough	15	1
Northern Hewett Ridge*	Flank	-	2
West Smiths Knoll	Trough	15	-
Smiths Knoll	Flank	20**	-
Total	4	308	28

* Only sampled for epifauna with camera, not for infauna with grab.
** Five replicates at four points down flank slope to investigate potential change in benthic assemblage along depth gradient.

Not all sites sampled for infauna were sampled for epifauna using an underwater camera (see Figure 4). The rationale for collecting underwater video and stills was to perform one tow within each survey box of the designated trough, flank and crest treatments. Additional tows were carried out if features of interest were identified (i.e., reef). Within reef areas additional camera tows were carried out to gather additional information relating to the extent and quality of the reef.

Within some areas it was not possible to perform camera tows due to strong tides and poor visibility. During the additional survey work carried out on the *Humber Guardian,* grab sampling was prioritised over collecting underwater video and stills, therefore no further camera tows were performed.

Smiths Knoll in the HHW cSAC was sampled differently to all other sites due to time constraints during the survey. It was not feasible to collect 15 replicates from each of the designated treatments, therefore, in discussion with the JNCC customer representative it was decided to collect 5 samples at four points along a survey line transiting the slope of the bank.

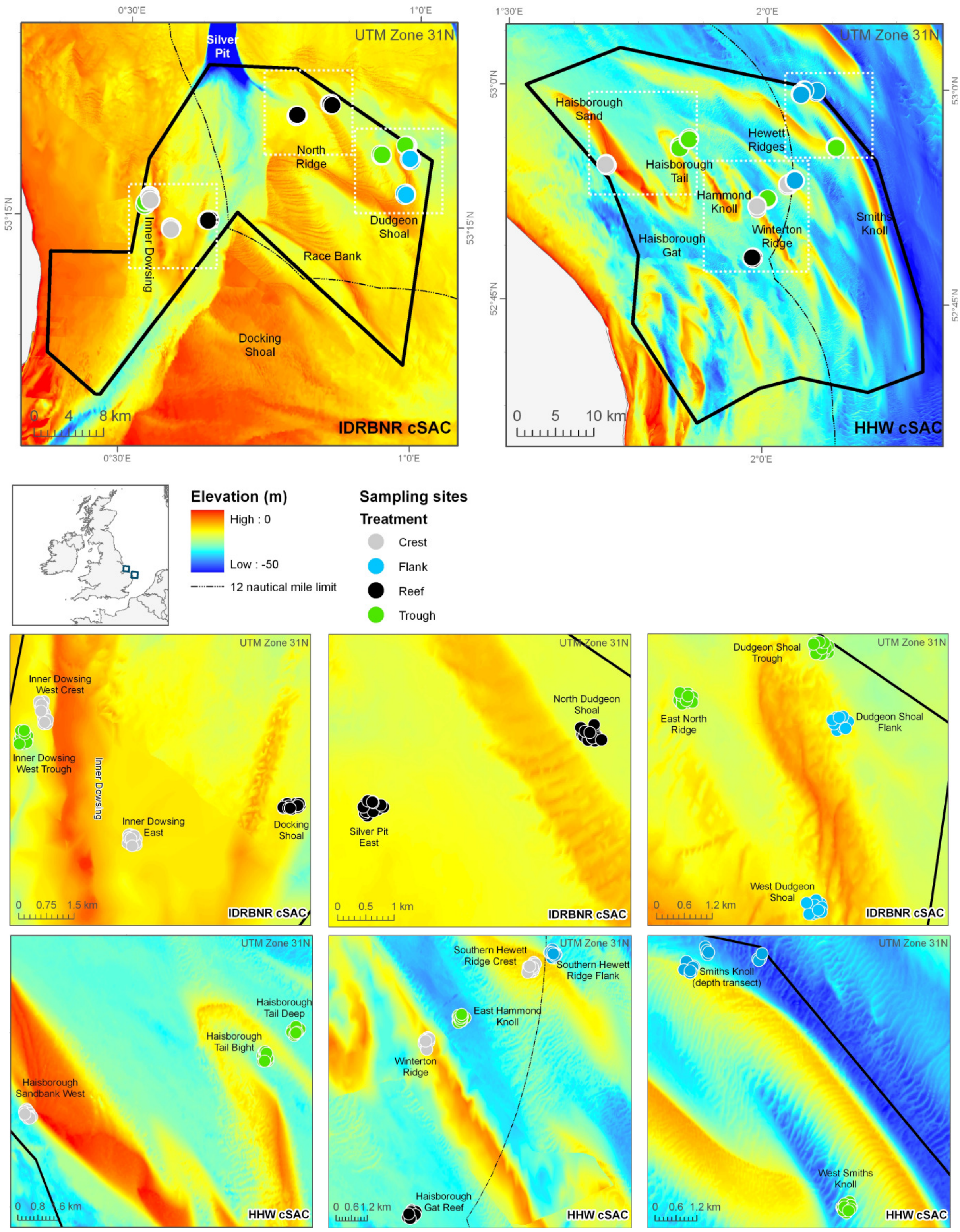

Figure 3. Location of each infaunal sampling site within the IDRBNR and HHW cSACs – the location of each insert (ordered west to east) is indicated by a dashed white box in the main map. Sampling points are colour coded by treatment.

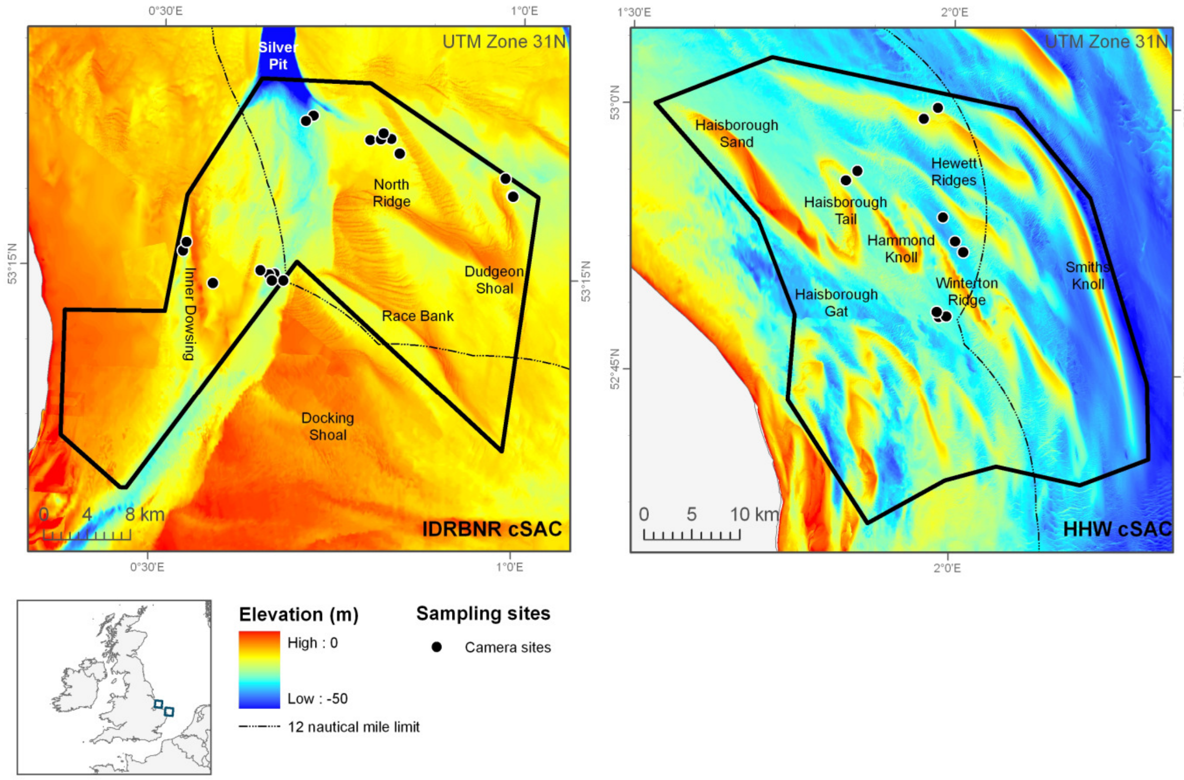

Figure 4. Location of each epifaunal sampling site in the IDRBNR and HHW cSACs – sites were sampled with underwater camera only.

2.2 Acoustic and geophysical methods

RV Cefas Endeavour

A Kongsberg EM3002 dual head multibeam echosounder (MBES) was used to collect high resolution multibeam bathymetry and backscatter data. The MBES transducers were mounted on a retractable drop keel to reduce acoustic noise and this was lowered 1 m below the hull of the vessel. Sound velocity measurements were taken near the transducer heads using a Reson sound velocity sensor. In addition, regular conductivity, temperature and depth (CTD) casts were taken using a Saiv SD-204, to obtain profiles of the sound velocity through the whole water column. The draft of the vessel was obtained before and after the end of the survey using a Druck PTX1830 depth/level sensor located on the hull near the drop keel. Prior to the start of the survey, a navigation check and full system calibration was undertaken.

Kongsberg SIS software was used for all data acquisition during the survey and for real-time quality control of acquired data. All bathymetry data processing was undertaken using the Caris HIPS software. The data were corrected for tidal elevations using GPS-derived height measurements from a C-Nav 3050 with real-time Ordnance Survey corrections. Basic smoothing was applied to the GPS height data. To normalise the bathymetry data to Chart Datum, local offset values were obtained from the UKHO's Vertical Offshore Reference Framework (VORF) model. Final outputs were provided as fully corrected GSF files, ASCII XYZ data and GeoTiff images.

Backscatter data were processed using QPS Fledermaus Geocoder Toolkit (FMGT). Final outputs were a fully compensated backscatter mosaic presented as a GeoTiff and derived statistical GIS layers as raster files.

During survey operations, an Edgetech FS-4200 sidescan sonar was deployed to acquire high resolution seabed backscatter data. Both low (300 kHz) and high (600 kHz) frequency data were collected and were found to be effective for the identification of spatially restricted seabed features, such as potential biogenic reefs. All sidescan sonar data were processed using Triton Imaging ISIS and DelpMap software into full georeferenced GeoTiff images for further expert analysis.

RV Humber Guardian

A GeoAcoustics GeoSwath interferometric bathymetry system was used to collect high resolution multibeam bathymetry and backscatter data. The MBES transducers were mounted on a gunnel mounted support pole. Sound velocity measurements were taken near the transducer heads using a Valeport sound velocity sensor. Prior to the start of the survey, a navigation check and full system calibration was undertaken.

The data were corrected for tidal elevations using GPS derived height measurements from a C-Nav 3050 with real-time Ordnance Survey corrections. Tidal corrections were made using RINEX files derived from C-Nav 3050 data. Final outputs were provided as fully corrected GSF files, ASCII XYZ data and GeoTiff images.

All data visualisation and analysis was undertaken using ESRI's ArcGIS 9.3.1.

2.3 Sampling methods (grabs and seabed imagery)

2.3.1 Underwater video and still photography

On *RV Cefas Endeavour*, underwater video footage and still photographs were acquired using a Kongsberg camera and flash setup (models OE14-208 and 11-242, respectively) mounted on a lightweight aluminium frame (DropCam). High power LED strip lights and a four point laser system (17 cm apart, to provide scale) were also mounted on the DropCam. A video camera attached to a mini Hamon grab (HamCam) was also used to inspect the seabed before sampling. A live feed from the camera to the deck of the survey vessel allowed for direct observation of the seabed during sample acquisition and ensure suitable data quality.

The MESH 'Recommended operating guidelines for underwater video and photographic imaging techniques[1]' were followed during video sample acquisition. At each sampling site, the vessel's dynamic positioning (DP) system was used to set the course and speed of the tow. Video footage of the seabed was recorded for approximately 10 minutes at each sampling site. Photographs were taken at approximately one minute intervals and, in addition, opportunistically at particular features of interest. All video footage and still photographs have been digitised and were delivered to NE and the JNCC in January 2012.

The position of the drop camera frame during the survey was logged using the starboard gantry offset. This position assumes that the drop camera frame was always directly beneath the starboard winch point. As this may not always be the case (due to strong tides) the position logged for the drop camera frame must be considered approximate. However, it is thought that the size of error associated with the positions used did not affect the potential for delineation of *Sabellaria spinulosa* reef.

2.3.2 Sediment and faunal sample acquisition

A mini-Hamon grab (sampling area: 0.1 m^2) was used to acquire sediment and infaunal samples following the guidance set out in Ware and Kenny (2011). Upon retrieval, each sample was assessed for suitability (i.e., sampled volume > 5 litres). A sediment subsample (approx. 500 ml) was taken for particle size distribution analysis (PSA), the remaining sediment was washed over a 1 mm mesh sieve, and the material retained stored in buffered 4% formalin solution to fix the infauna.

2.4 Sample and data processing – analysis methodologies

2.4.1 Acoustic data analysis

Newly acquired MBES corridor survey data were overlaid on the digital elevation model (DEM; Astrium, 2011) in ArcGIS to enable comparison of elevation changes between the two datasets. A polyline shapefile was created for each cSAC and areas where no consensus was observed between the data were marked across the corridor survey line. These polylines were orientated along the elevation change visible in the data rather than always perpendicular to the survey line. In addition, a difference plot was created using the Raster Math toolbox 'minus' function within ArcGIS9.3. The bathymetric values from the corridor survey data were subtracted from the DEM bathymetric values in coincident cells. This resulted in a plot illustrating the difference in depths between data sets (see Section 3.1). Thus, a positive difference indicates that corridor survey data were deeper than the

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[1] Reference URL: http://www.searchmesh.net/PDF/GMHM3_Video_ROG.pdf

DEM and a negative difference indicates the corridor data were shallower than the DEM. Sandbanks have the potential to be mobile, therefore, where it was possible to infer a direction of travel, arrows indicating the direction of travel have been drawn.

2.4.2 Video and stills analysis

Video footage and still photographs acquired at each camera sampling site were sent to a specialist sub-contractor for processing. Sub-contractors are required to participate in the National Marine Biological Analytical Quality Control Scheme. Each video tow was analysed by viewing several times, first to detect and record any changes in biotope across the entire transect, and second, to describe physical features and quantify the epifauna characterising each biotope. Physical features recorded included the proportion of different substrate types, inclination, texture, stability, formations and evidence of bioturbation. Epifauna were quantified according to the Marine Nature Conservation Review (MNCR) SACFOR abundance scale (S = Superabundant, A = Abundant, C = Common, F = Frequent, O = Occasional, R = Rare). A maximum of three representative photographic stills were analysed from each of the different biotopes identified in the video transect. Epifauna were also recorded using the SACFOR scale after identification to the lowest possible taxonomic level. All information extracted from the video and stills samples was recorded on the MNCR Habitat recording forms before being entered into the Marine Recorder database. Biological data extracted from video are at best semi-quantitative and as such, do not lend themselves to classical algebraic functions and statistical treatment. Such data are primarily used as supplementary information to the patterns observed in the results from quantitative analyses of grab sample data. Positional data from video footage has been plotted on maps to assist in the delineation of different habitats.

2.4.3 Faunal sample analysis

All infaunal samples were sent to a specialist sub-contractor for processing. Sub-contractors are required to participate in the National Marine Biological Analytical Quality Control Scheme and follow the sample processing recommendations described in the Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites (Ware & Kenny, 2011). After inspection, the resulting taxon-by-sample matrix was subjected to standard univariate and multivariate analyses using the PRIMER software package (Clarke & Gorley, 2006). Metrics per sample calculated included the total number of individuals (N), number of species (S), an index of species diversity (N1) and one of dominance/evenness (N21’) (Hill, 1973). Multivariate analyses were performed to investigate patterns in benthic community structure and to compare assemblage composition between the different sampling treatments. Colonial taxa were excluded from analyses that require species abundance values. All data are to be entered into Marine Recorder.

2.4.4 Particle size distribution analysis (PSA)

PSA methodology was based on recommendations made by the National Marine Biological Analytical Quality Control Scheme[2] (Mason, 2011). A subsample of the sediment collected, screened at 1 mm, was analysed using the Malvern Mastersizer 2000 laser sizer. The remaining sediment was split at 1 mm by wet sieving. Sediment greater than 1 mm was dry sieved at 0.5 phi intervals, from 1 mm to 63 mm. The dry sieve and laser results were combined to give the full particle size distribution at half phi intervals, between 0.1 µm and 63,000µm (11.5 phi to 6 phi). All sediment samples except for those collected at Smiths Knoll, IDRBNR cSAC (n = 20) were analysed for PSA.

2.5 Data QA/QC

All activities in the field were performed according to the recommendations in the following documents:

- Biological Monitoring: General Guidelines for Quality Assurance document (ICES, 2004)[3]
- Quality Assurance in Marine Biological Monitoring[4] (Addison, 2010)
- Recommended operating guidelines for underwater video and photographic imaging techniques[1]

Video, photographic stills, faunal and sediment samples have been processed and results checked following the recommendations of the National Marine Biological Analytical Quality Control Scheme. A taxonomic reference collection has been prepared for archive.

3 Data Analysis and Results

3.1 MBES (bathymetry & backscatter) & sidescan data

Bathymetric data were obtained from a British Isles Continental Shelf digital elevation model (DEM) (Astrium, 2011) and recent MBES corridor surveys that targeted the sandbanks at both cSACs. The DEM comprised data from multiple surveys of varying resolution; these data were combined and interpolated where necessary, to create a bathymetric model of 1 arc second (approx. 30 m) horizontal resolution (Astrium, 2011). Bathymetric data from MBES corridor surveys were gridded at 2 m horizontal resolution and used to validate analysis of the DEM. The bathymetric DEM was

[2] Reference URL: http://www.nmbaqcs.org/scheme-components/particle-size-analysis/reports.aspx

[3] Reference URL: http://www.searchmesh.net/PDF/GMHM3_Video_ROG.pdf

[4] Reference URL: http://www.nmbaqcs.org/qa-standards/qa-in-marine-biological-monitoring.aspx

cropped within the mapping application ArcGIS 9.3 to cover an area that encompasses both cSACs (Figure 1).

MBES corridor surveys were carried out to determine the dimensions and limits of the sandbanks. Elevation data from these surveys ranged from -3 m to -50 m at the HHW site with a mean elevation of -28 m. At the IDRBNR site, elevation data ranged from -3 m to -71 m, with a mean elevation of -14 m. Both DEM and MBES corridor data indicate the presence and dimension of sandbanks, sand waves and mega-ripples within the cSACs. However, the DEM benefits from more comprehensive high-resolution data coverage over HHW cSAC than at IDRBNR cSAC, since a greater density of MBES data (acquired from the East Coast REC surveys) was available off the East Anglian coast to inform the model. The difference in DEM resolution is evident in angular artefacts of DEM creation around IDRBNR cSAC (see Inner Dowsing insert in Figure 3), and in the disparity between the DEM and the MBES corridor survey data in the form of offsets in the location of sandbanks at HHW cSAC (Figure 5). The offset at some locations shown in Figure 5 is of approximately 200 m. It is not possible with the data available to determine the exact cause the offset between data sets; it may be due to either sandbank migration or positional discrepancy of the datasets. Such observed differences highlight the need for a robust, objective technique to delineate sandbank features. Selecting certain features and the surrounding areas for a full coverage survey rather than resurveying the entire area may enable the cause of the offset to be identified.

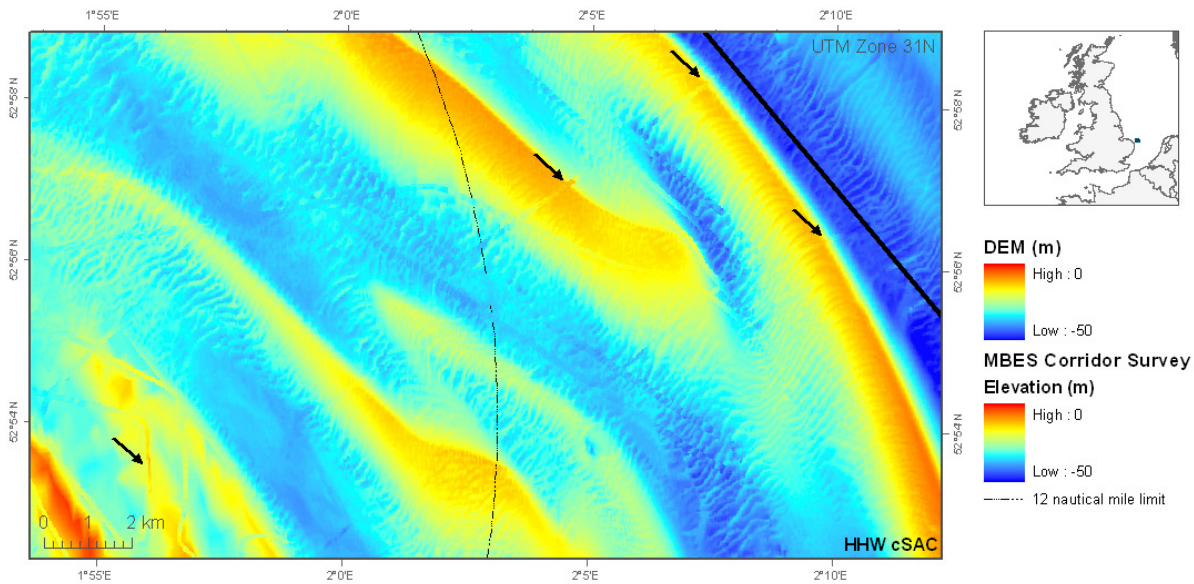


Figure 5. Arrows pointing at offset observed between Digital Elevation Model (DEM) and multibeam echosounder (MBES) corridor survey data.

Sidescan data were acquired at the same time as MBES data, georeferenced as geotiff images, and plotted on the dedicated GIS project. Expert judgement has been used to interpret any pattern observed within the data in combination with other lines of evidence (i.e., data from video footage).

3.2 Video and still sample analysis (for epifauna)

From the analysis of underwater video footage 66 taxa were identified; 77 taxa were identified from still photographs. In combination, a total of 80 epifaunal taxa were recorded over 28 camera sampling sites.

Although relative abundance data extracted from video footage and still photographs can be considered semi-quantitative (i.e., SACFOR scale), only limited analyses can be performed on them in this format. To elucidate a basic spatial pattern in the sampled epifaunal assemblage across both sampling areas, presence/absence data for each sampling site (taxa from video and still images combined) have been analysed. Multivariate analyses identified 8 distinct epifaunal assemblages, labelled a-h (Figure 6). Five of the distinct assemblages identified were represented at only one or two sites, therefore reflecting site-specific, localised environmental conditions; however, the remaining three assemblages (e, f and g) were more widespread, and harboured the greatest number of taxa. The location of these three assemblages coincided with areas of *S. spinulosa* reef and sandbank troughs, and did not include sampling sites representing sandbank crests or flanks. Only one assemblage identified spanned both cSACs (assemblage c), represented by a single site in each area. Statistical testing did not, however, detect a significant difference in overall epifaunal assemblage composition between cSACs. The patterns outlined above are therefore purely indicative and any detail must not be relied upon precisely. Appendix IV contains a list of taxa representing the three most widespread assemblages identified, namely e, f and g.

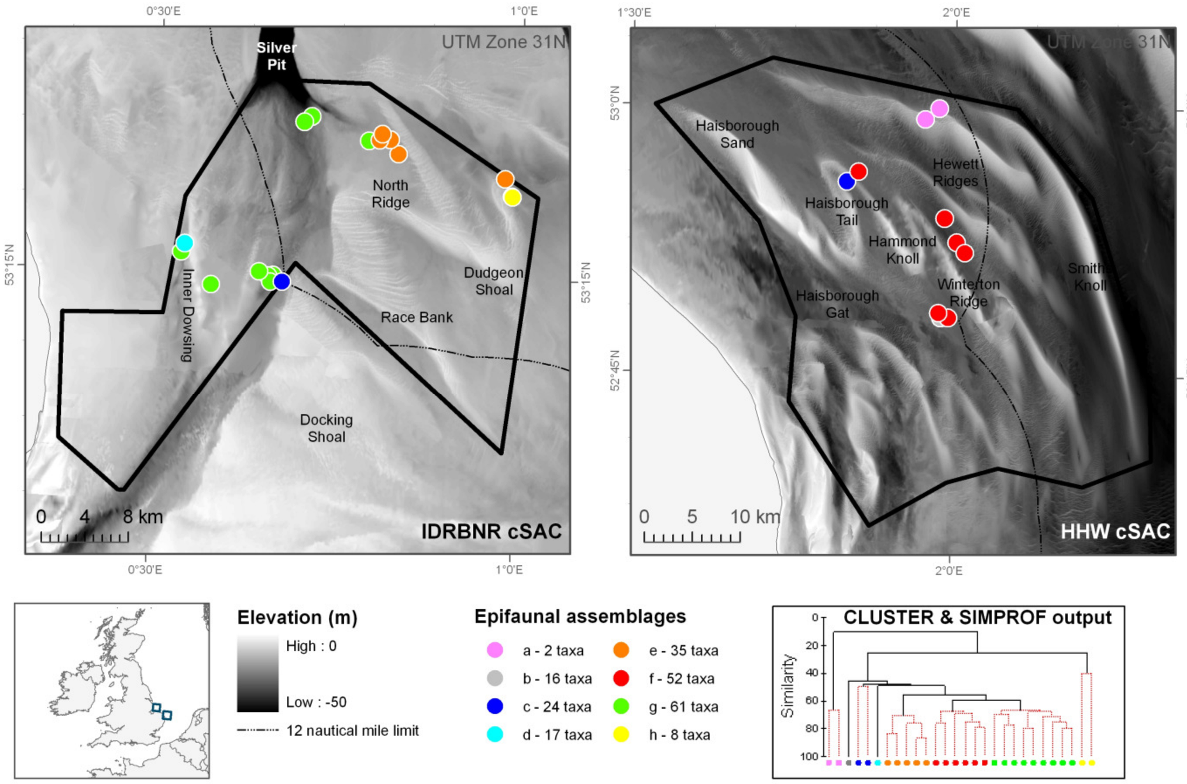


Figure 6. Distribution of each of the distinct epifaunal assemblages identified through multivariate analyses (see similarity dendrogram insert bottom right).

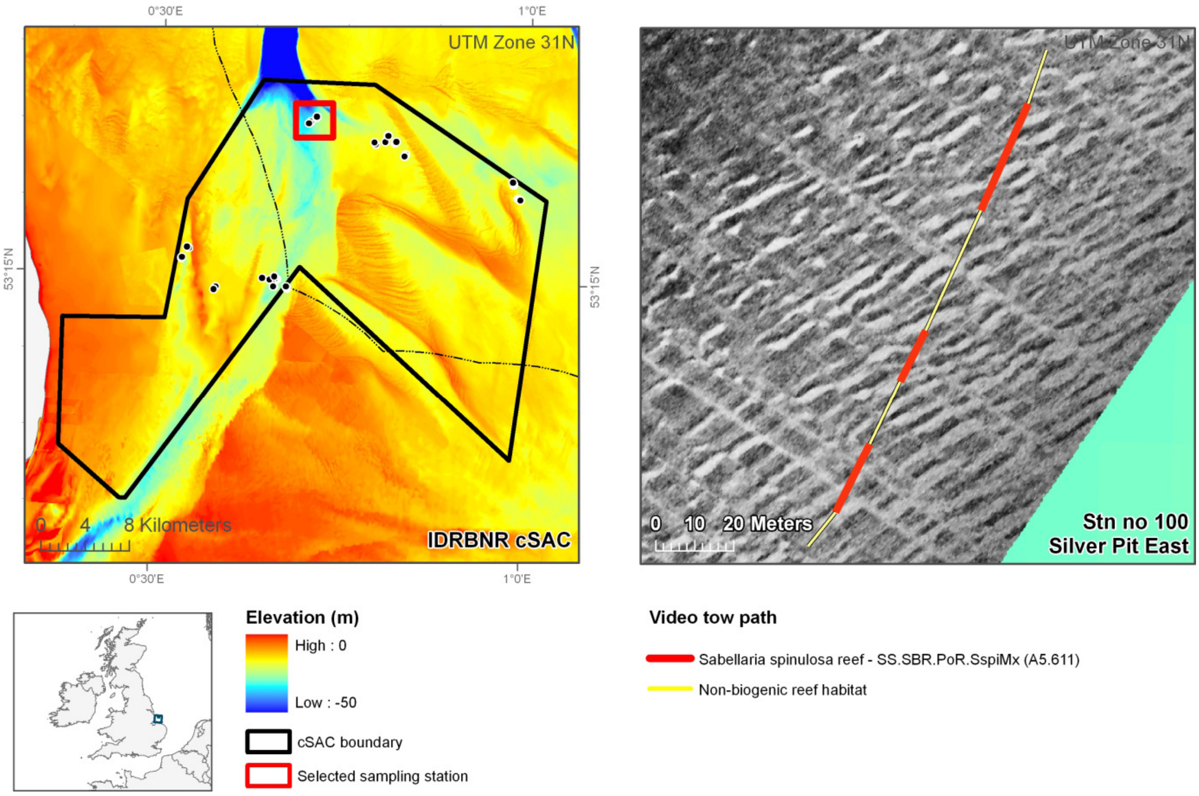
Sampling sites representing sandbank flanks harboured just nine epifaunal taxa. Epifaunal assemblages representing reef, troughs and sandbank crests were statistically indistinguishable (although the allocation of samples to represent crests at the time of sampling may be questionable (see below)). A poor balance of sampling effort amongst treatments also complicates direct comparison between them (see Table 2), as most of the available sampling effort was directed at characterising the more faunally rich reef and trough habitats (weather downtime prevented the balanced survey plan to be completed). Depth constraints on the survey vessel directly above sandbank crests also prevented comprehensive sampling of crest habitats.

Table 2. Comparison of epifaunal sampling effort directed at each targeted seabed feature.

	Crest	Flank	Reef	Trough
Number of sites sampled	2	4	15	7
Total number of taxa observed	31	9	72	55
Average number of taxa observed per site	16	2	5	8

The location of habitat designated from the video footage as *Sabellaria spinulosa* reef (biotope: SS.SBR.PoR.SspiMx – A5.611) is illustrated over the following pages (Figure 7). Selected video tow tracks are overlaid on a backdrop of sidescan sonar data, and the tow track itself is classified into either *S. spinulosa* reef or other non-reef habitat. Only six video sampling sites captured a significant (> 5 m) extent of reef (sites 95 and 100 in the north of IDRBNR cSAC and sites 315, 316, 317 and 319 in the centre of HHW cSAC). Reef at stations 97 and 98 (around Silver Pit East in IDRBNR cSAC) was observed over less than 5 m due to the video tow starting or ending midway through the reef extent, so reef may be more extensive than recorded at those sites. Patchiness of reef, where observed, was variable across sites, ranging between 10% and 60% coverage. There appears to be no indication on the sidescan sonar data which would assist in the accurate delineation of reef habitat beyond the tracks of the video tows.

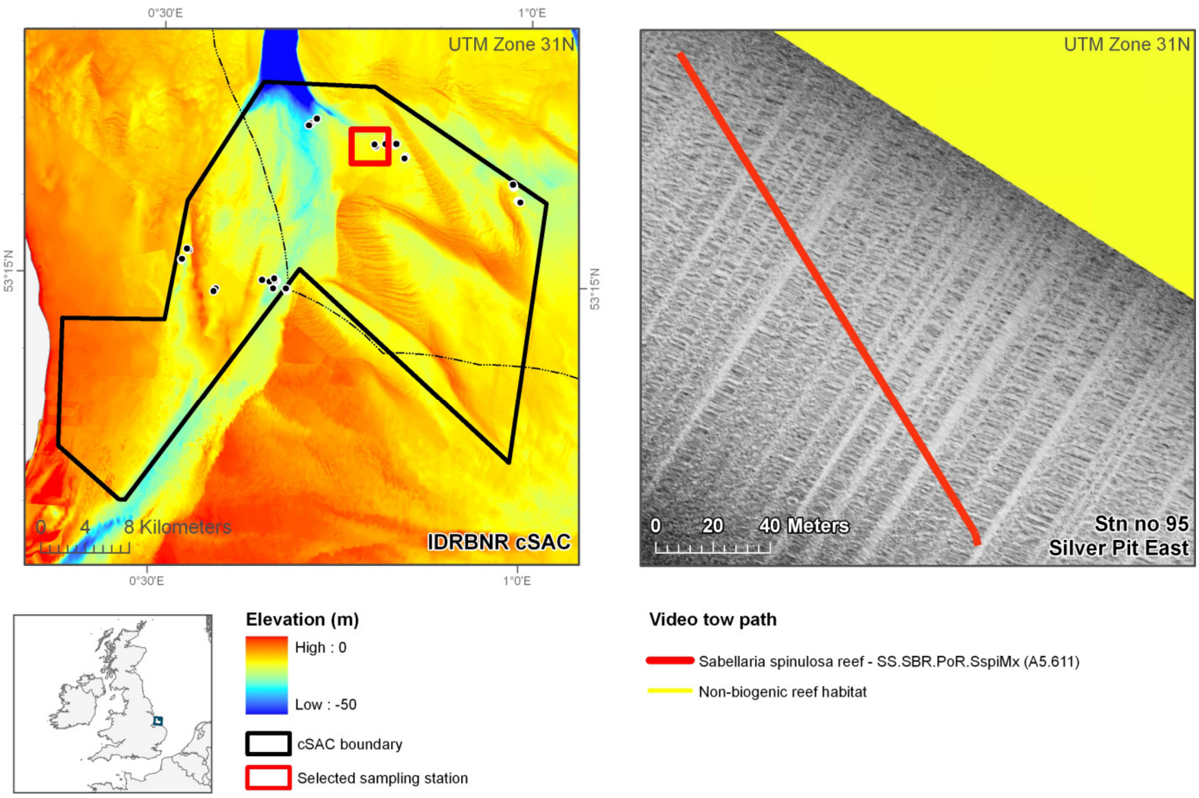
At station 316 in the East Hammond Knoll, dense aggregations of brittlestars (Ophiuroidea) were observed.



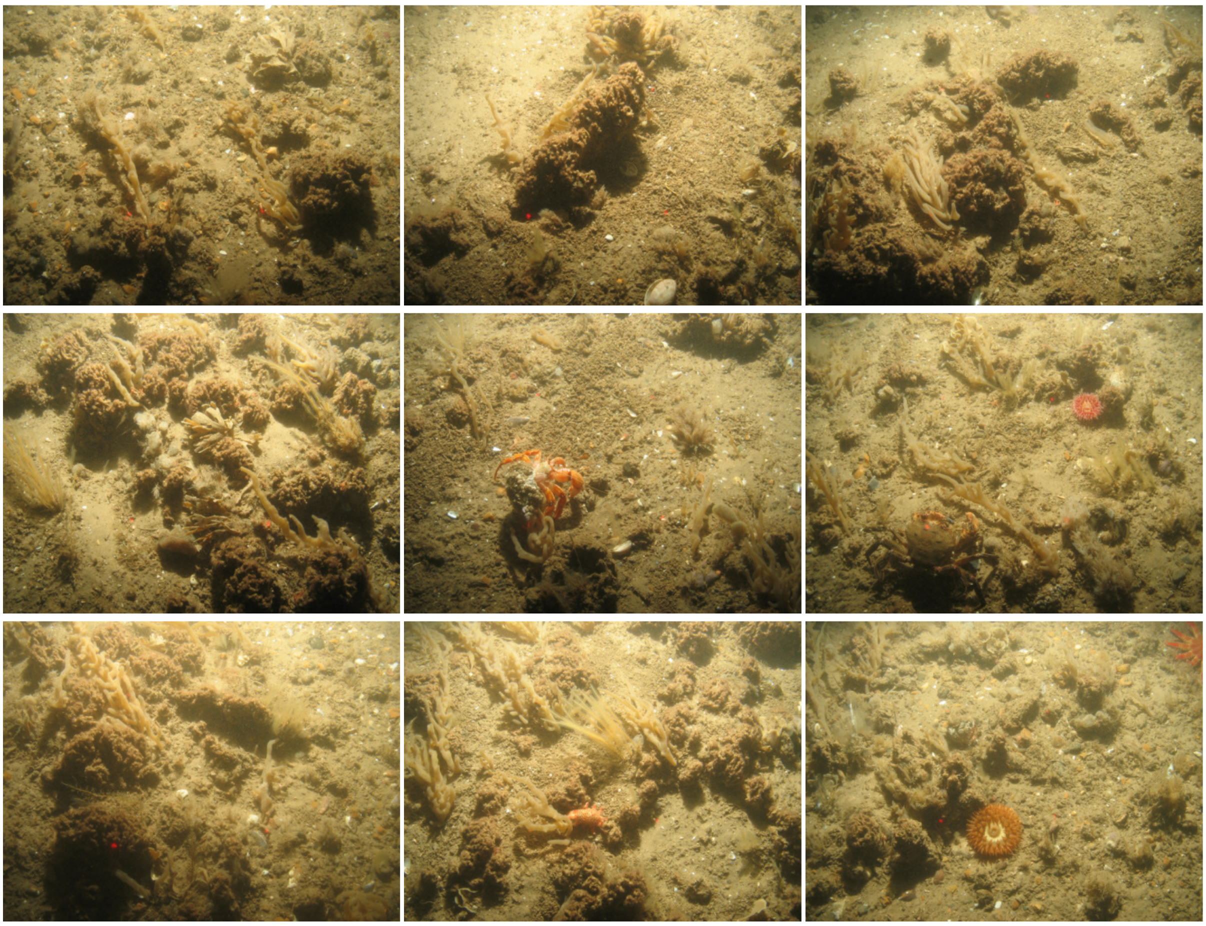
Example photographs from reef areas.

Field description: "Sabellaria spinulosa reef (20-35%) with some broken tubes and gravel."

Figure 7 (composite). Location of *Sabellaria spinulosa* reef identified from video footage. The background to each video tow is sidescan sonar data.

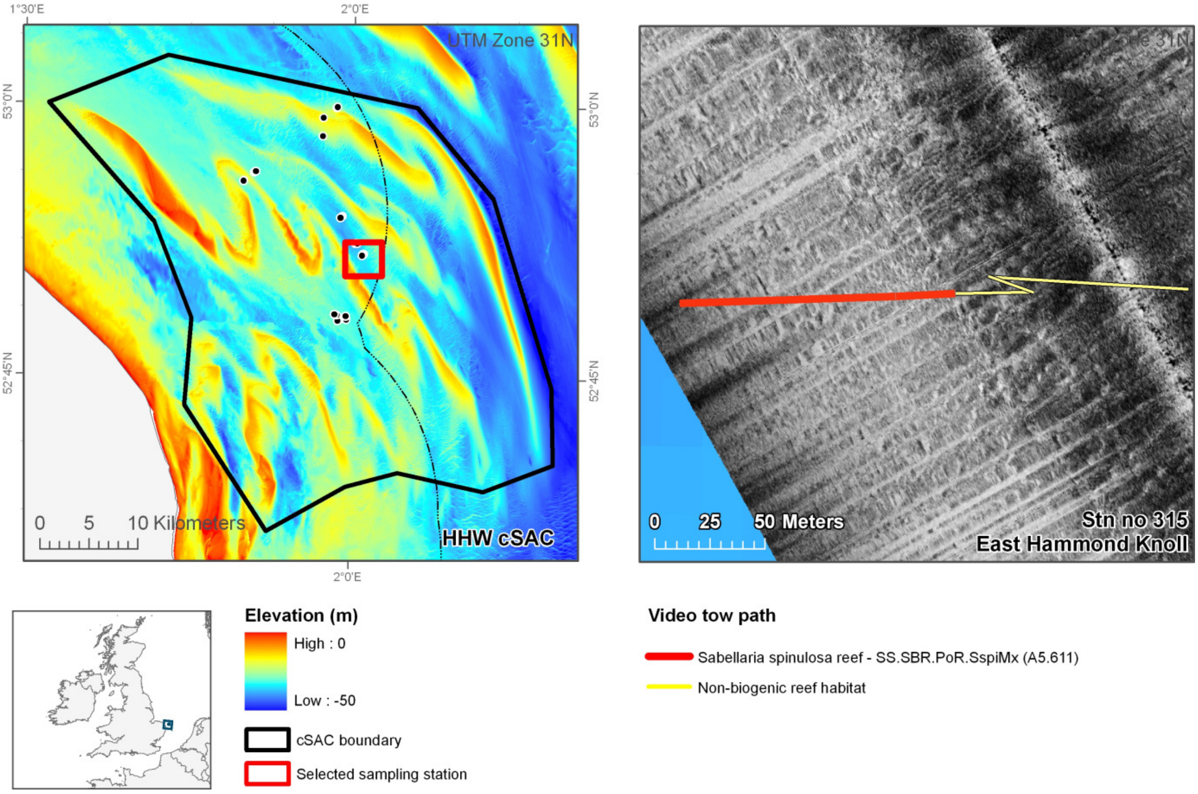


Example photographs from reef areas.

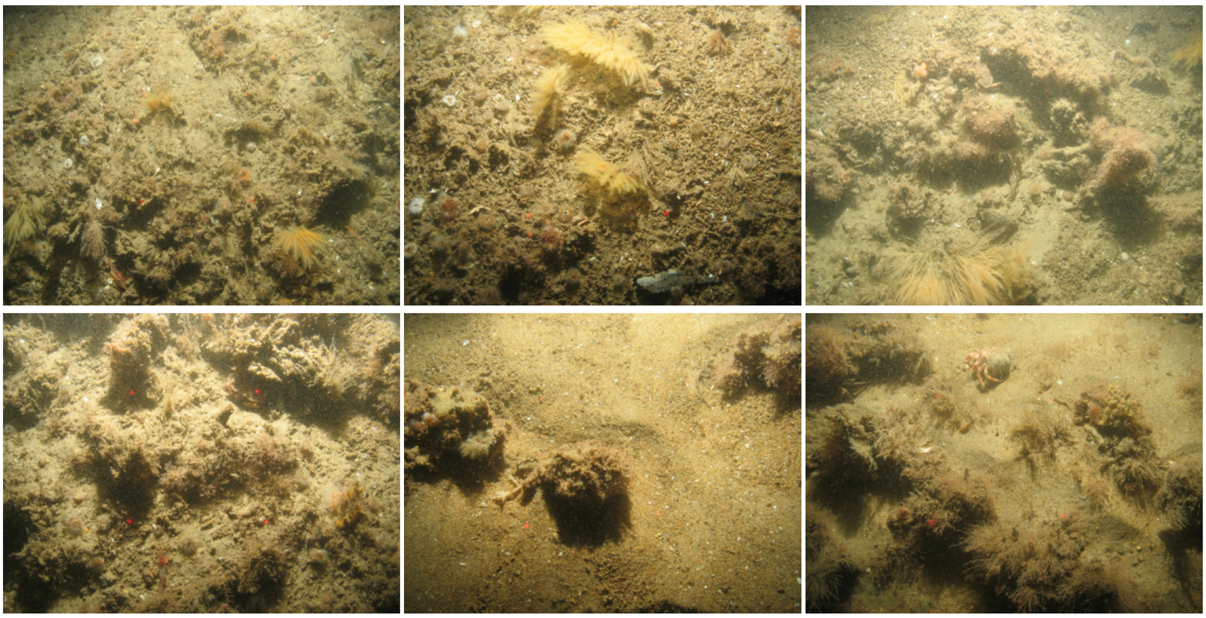


Field description: "Mixture of varying proportions of Sabellariid reef (30%), broken tubes (35%), patches of gravel, sand and Bryozoa and Hydrozoa (15%)."

Figure 7 (composite). Location of *Sabellaria spinulosa* reef identified from video footage.

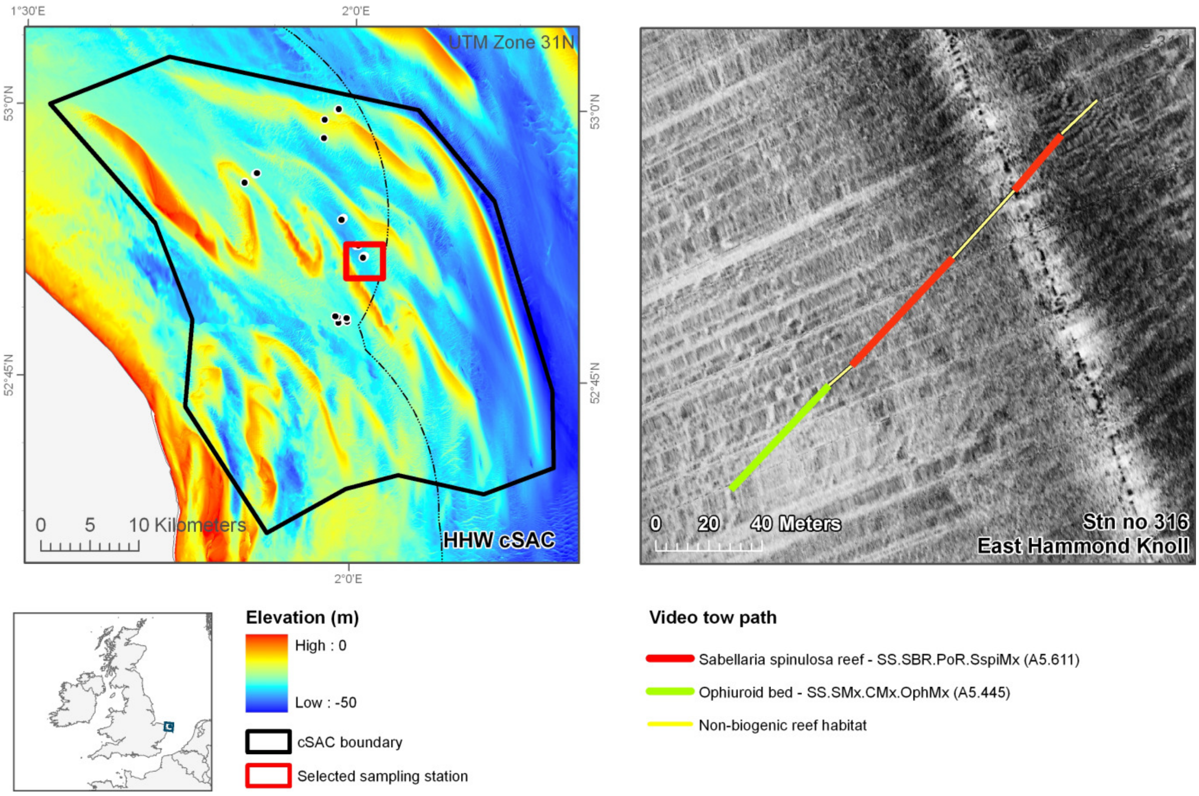


Example photographs from reef areas.

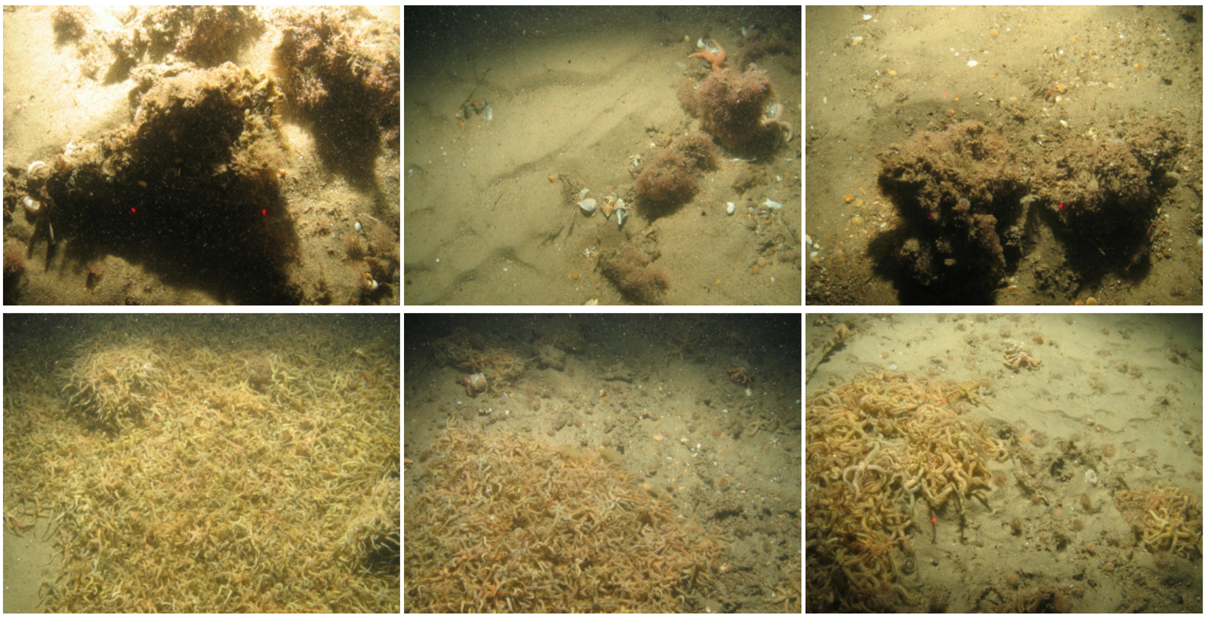


Field description: "Sabellaria reef (60%) with pebbly gravel, brozoans/hydroids (20%) and minimal sand" and "Sabellaria reef (20%), sand, bryozoans and hydroids (10%)".

Figure 7 (composite). Location of *Sabellaria spinulosa* reef identified from video footage. The background to each video tow is sidescan sonar data.

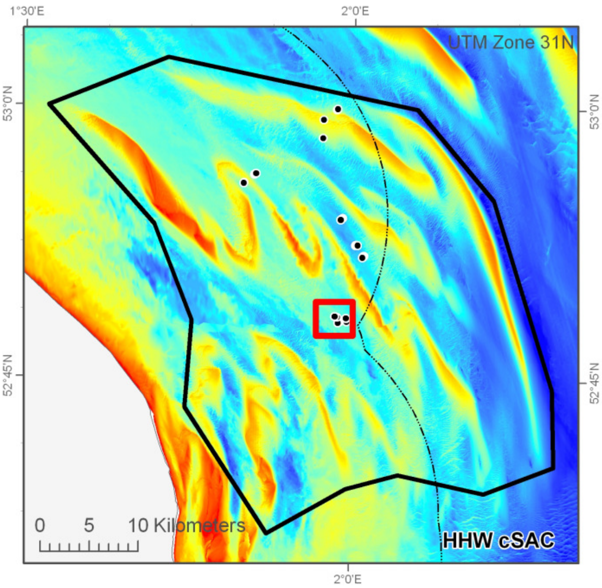


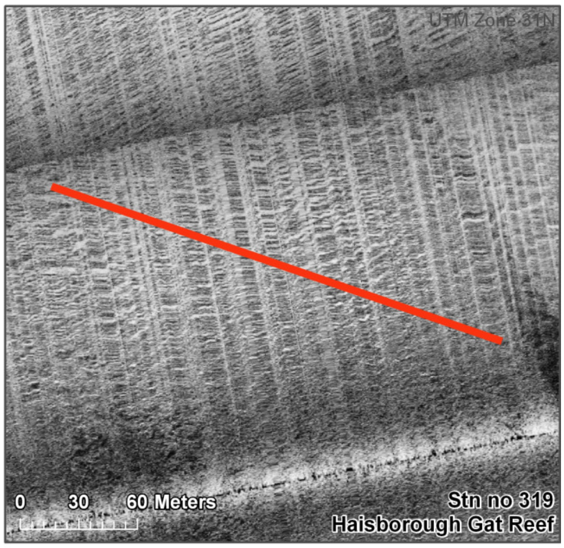
Example photographs from reef areas.



Field description: "Rippled sand with sabellaria reef (10%), occasional pebbles and clay fragments." and "Sand and brittlestar mass".

Figure 7 (composite). Location of *Sabellaria spinulosa* reef identified from video footage. The background to each video tow is sidescan sonar data.

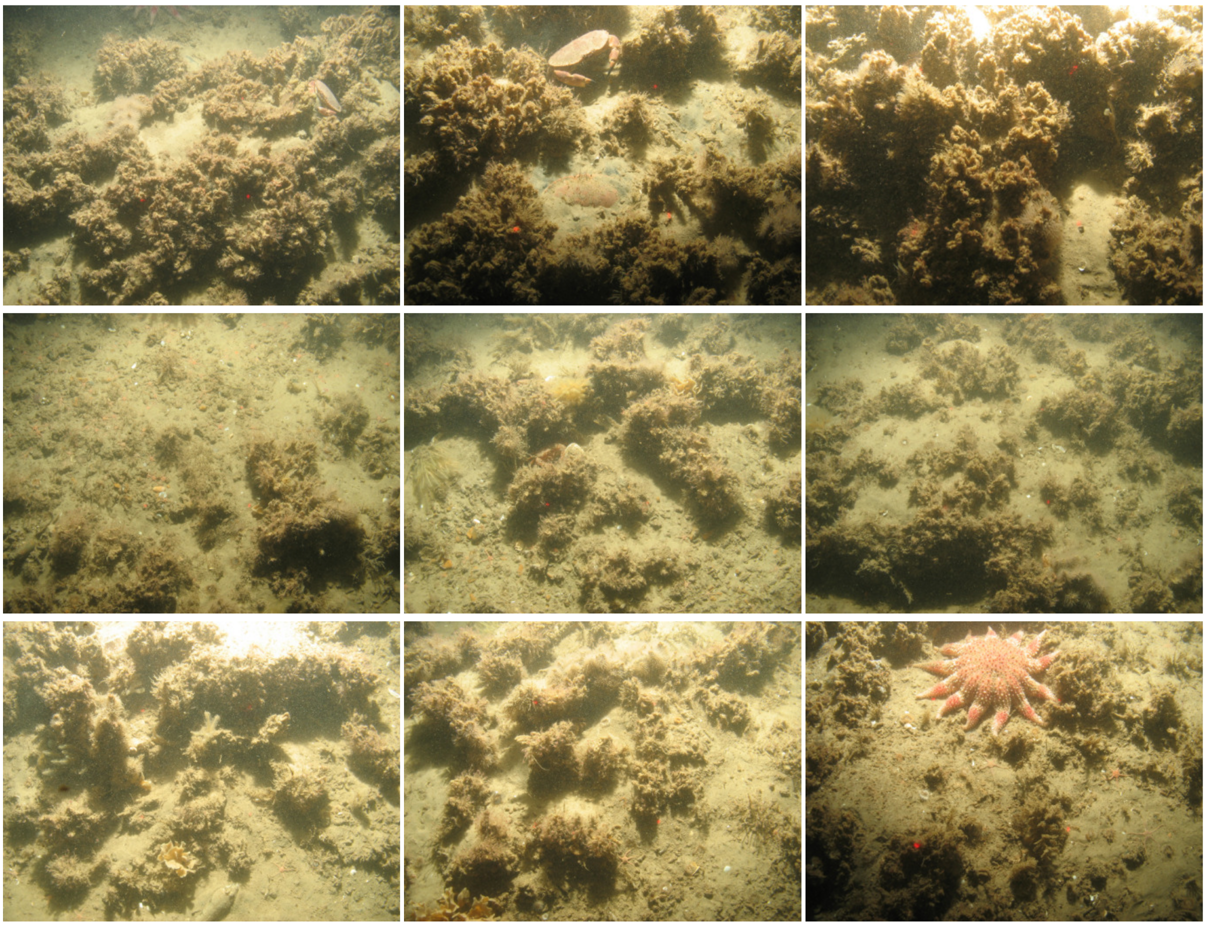




Elevation (m)
High : 0
Low : -50
cSAC boundary
Selected sampling station

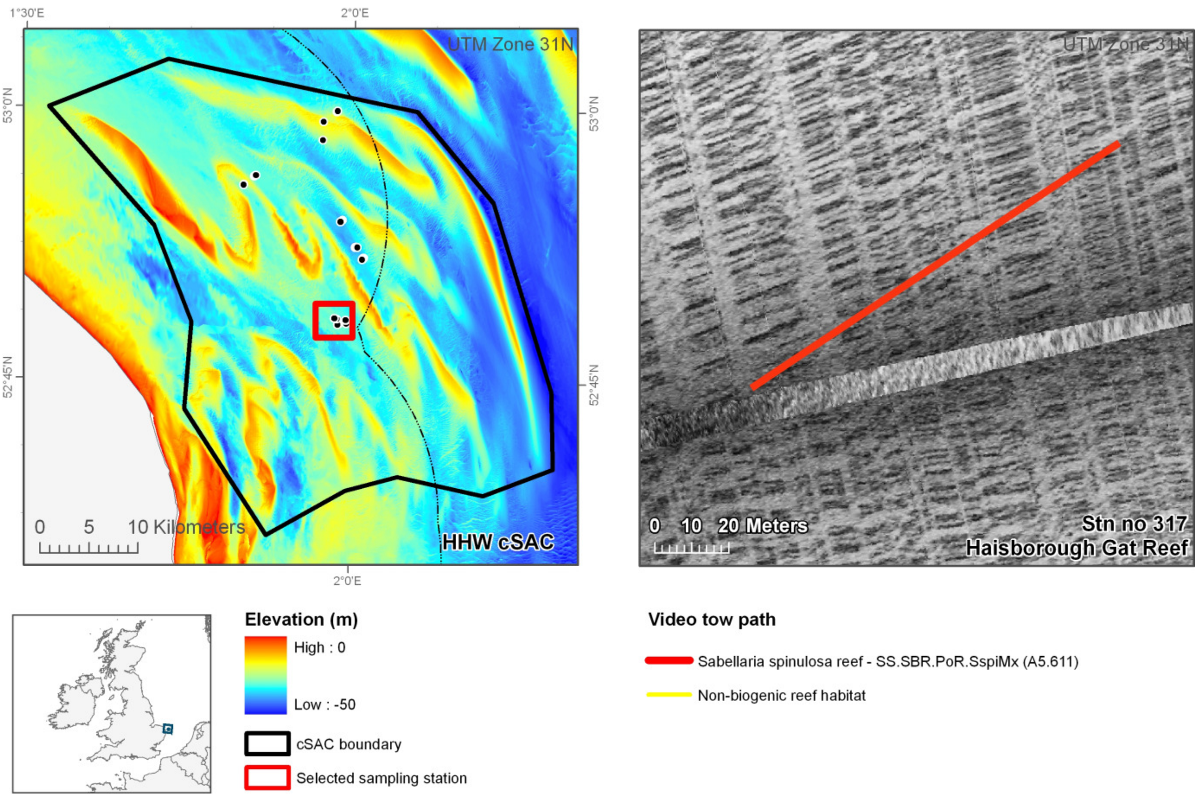
Video tow path
Sabellaria spinulosa reef - SS.SBR.PoR.SspiMx (A5.611)
Non-biogenic reef habitat

Example photographs from reef areas.



Field description: "Sabellaria reef (55%) and sand. Bryozoans / hydroids (10%)".

Figure 7 (composite). Location of *Sabellaria spinulosa* reef identified from video footage. The background to each video tow is sidescan sonar data.



Example photographs from reef areas.

[No stills available]

Field description: "Sabellaria reef (60%) with sand".

Figure 7 (composite). Location of *Sabellaria spinulosa* reef identified from video footage. The background to each video tow is sidescan sonar data.

3.3 Grab sample analysis (for infauna)

In total, 308 infaunal samples were collected from 20 sites representing four treatments (reef, sandbank crest, flank and trough). From these samples, 571 taxa were identified, 93 of which were colonial. Colonial organisms which cannot be enumerated have been excluded from analyses that rely on taxon abundance information, leaving 478 solitary taxa for most analyses.

Overall, samples taken from sandbank flanks showed a consistently low number of individuals, few taxa, low diversity and high evenness (i.e., infaunal assemblages on flanks were not represented primarily by many individuals from a small number of taxa, instead most organisms were evenly spread amongst all taxa) (Figure 8). Samples representing reef contained a high number of individuals, many taxa, high diversity and low evenness (i.e., the sampled assemblage was dominated by large numbers of a few species – mainly *S. spinulosa*). Samples taken from sandbank troughs showed the highest variability of all, with some samples containing very few infauna and others very many, but on the whole, mean values for each of the measured assemblage metrics were intermediate between those of flanks and reef (Figure 8). Mean values of assemblage metrics from samples representing sandbank crests were lowest of all; however, outlying points (see Figure

8) indicate that in some instances, some samples contained individuals and taxa in quantities similar to those observed in reef and troughs. This could be an example of misclassification of sampling site at the time of sampling site designation[5]. Outlying samples originally classified as crests are those taken immediately east from the Inner Dowsing sandbank (station codes: IDEON01 to IDEON15, Inner Dowsing East site), towards the west of the IDRBNR cSAC (see Figure 3).

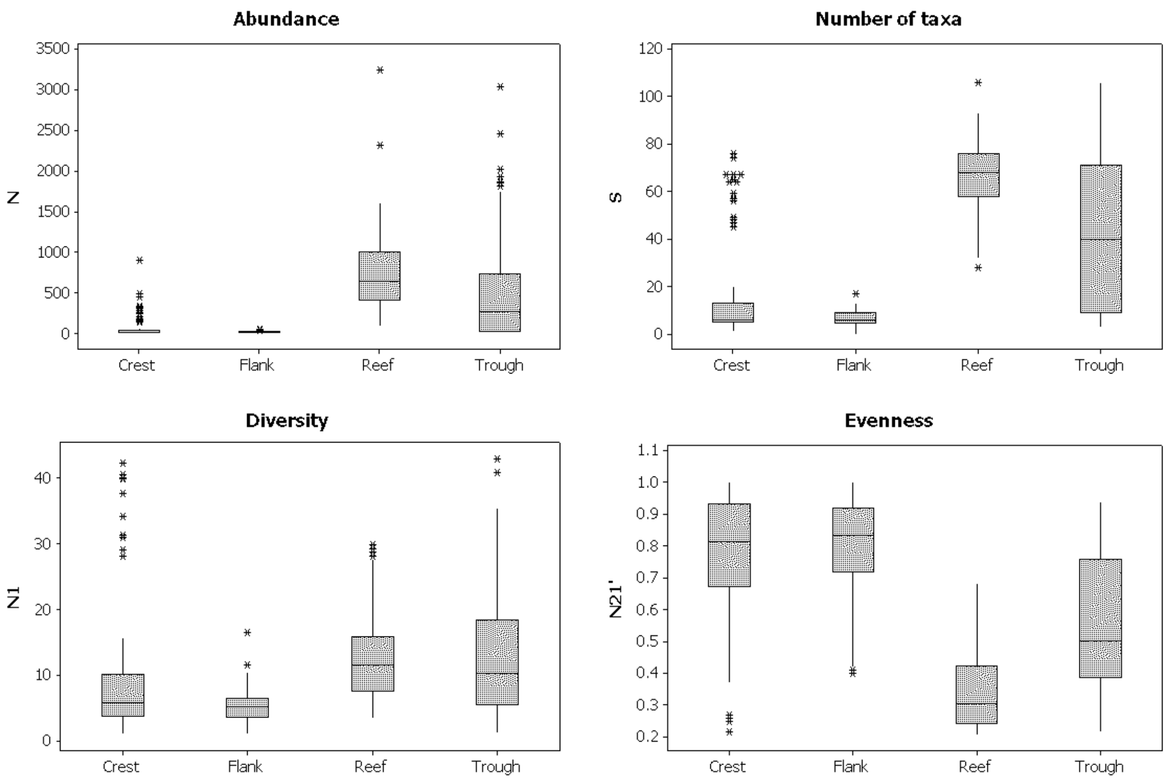


Figure 8. Comparison of the distribution of all univariate assemblage metric values per sample across sampling treatments.

The discrepancy in the designation of the Inner Dowsing East sampling site as representative of a sandbank crest is evidenced further with the plotting of the number of taxa from each sample on a map (Figure 9). The number of taxa identified at Inner Dowsing East was comparable to other sites that were designated as reef or trough (see Figure 3 for sampling site treatment designation). All other sites designated as sandbank crest displayed much smaller numbers of taxa.

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[5] Explanatory note: Sampling sites were allocated to each treatment as a desk study on land, before survey, based on available information. The site ‘Inner Dowsing East’ appears to be at a depth and in a location which could be considered on paper to represent a sandbank crest (as does Inner Dowsing West Crest nearby). Only after sampling and sample analysis do the data acquired suggest otherwise. This finding does not compromise designation of other sites into their respective treatments, it simply means that appearances can be deceptive on paper, and criteria used for initial sample allocation of Inner Dowsing East to the ‘crest’ treatment were not (could not) be rigorous enough to foresee the result obtained. Factors other than those considered in the initial treatment designation criteria are influencing the assemblage at the Inner Dowsing East site.

Inspection of the taxon composition of samples from Inner Dowsing East reveals that *S. spinulosa* was present in six out of all 15 samples. It is unlikely that this species would inhabit sandbank crests due to their dynamic instability at short temporal scales; this evidence further supports the possibility of misclassification of this site at the time of survey.

One last piece of evidence in support of the misclassification of Inner Dowsing East can be observed in a non-metric multidimensional scaling (MDS) plot of all samples following multivariate analysis (Figure 10). In the plot, samples representing reef cluster tightly, together with some samples representing troughs. Most samples representing crests are widely scattered and distinct from the cluster of reef and trough samples, except a few crest samples which cluster tightly with those from reef and troughs. These exceptions belong to samples collected at Inner Dowsing East, indicating that the assemblage at this site is more similar to that found at reef and trough sites. In all further statistical comparisons of assemblage composition across treatments, samples from Inner Downing East have been reclassified to represent a sandbank trough[6].

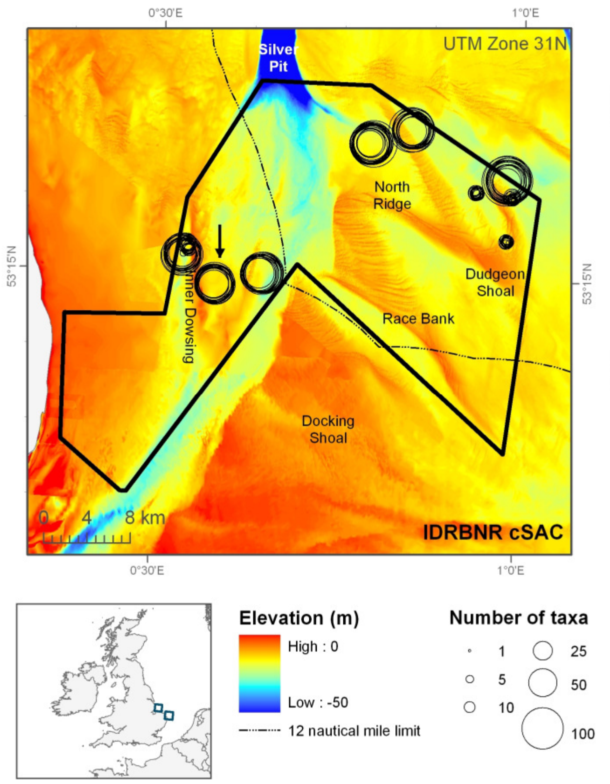

Figure 9. Plot of all grab samples with circles proportional to the number of infaunal taxa identified in each. Arrow in IDRBNR cSAC points at Inner Dowsing East sampling site.

[6] Explanatory note: Re-designation means there are three sampling sites designated as crest, which is still a relatively balanced design when comparing these with four or five sites representing each of the other treatments.

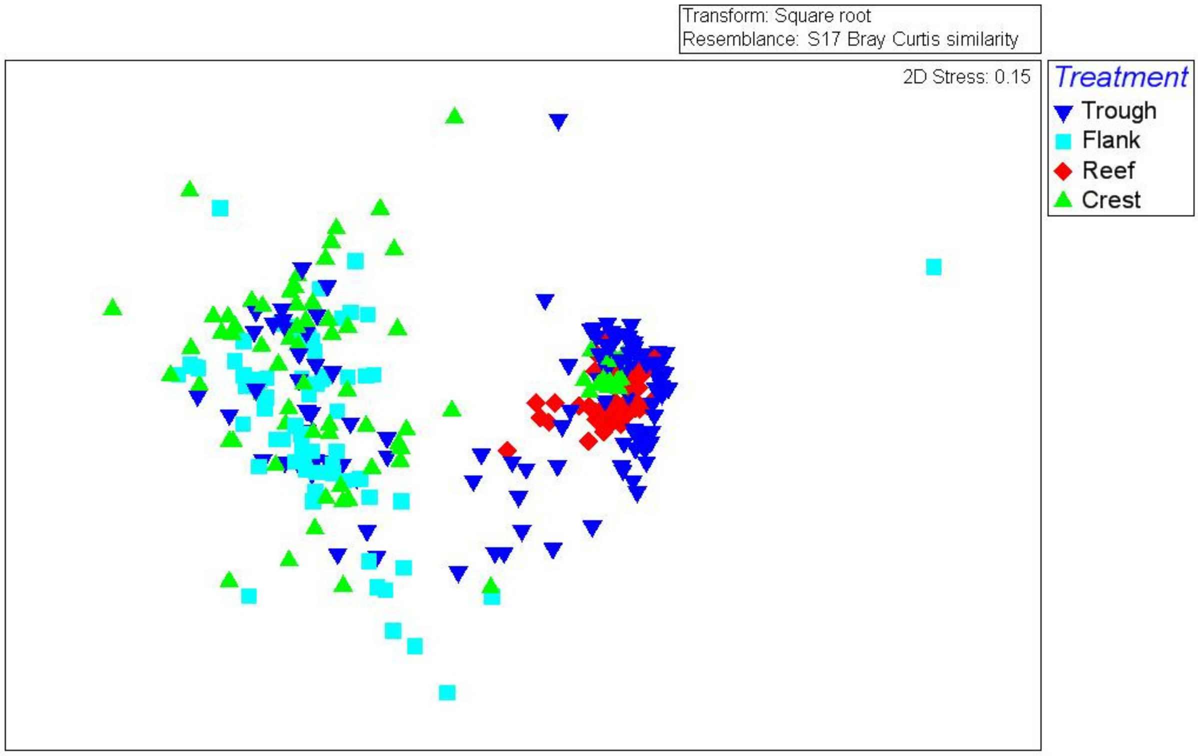

Figure 10. Non-metric multidimensional scaling (MDS) plot of all infaunal samples colour-coded by treatment.

Multivariate statistical comparisons between assemblages pertaining to each treatment revealed that there was an overall difference in assemblage composition amongst treatments (Table 3). However, comparison of assemblage composition between pairs of treatments revealed that assemblages inhabiting reef and sandbank troughs were statistically indistinguishable. In fact, the negative value of the R Statistic between these two habitat types (see Table 3) suggests that the difference *amongst* samples representing reef or troughs was greater than the difference *between* both those treatments. A complete list of taxa characterising each habitat type (treatment), together with their relative abundance, is presented in Appendix IV. All other pairwise comparisons of treatments revealed statistically significant differences between them (Table 3), although the apparent difference between sandbank crests and flanks is doubtful (i.e., the R value is very close to zero).

Table 3. Results from a one-way ANOSIM test between samples representing each treatment (reef, crest, flank and trough).

	R Statistic	Significance Level %
Global Test	0.356	0.1
Pairwise Tests		
Trough vs. Flank	0.363	0.1
Trough vs. Reef	-0.016	70.4
Trough vs. Crest	0.381	0.1
Flank vs. Reef	0.822	0.1
Flank vs. Crest	0.064	0.1
Reef vs. Crest	0.847	0.1

Multivariate analyses were also performed to detect natural patterns in the dataset (instead of testing for differences between pre-defined treatments). Analysis of all 308 samples revealed that they fell into 68 statistically distinct groups (data not shown). Single sampling sites (most represented by 15 replicate samples) were able to contain more than one statistically distinct group of samples. Distinct groups of samples harboured a mean number of taxa per sample between 6 and 193. This result highlights the high level of variability between samples, which in turn reflects the high degree of infaunal assemblage heterogeneity even at small spatial scales (i.e., within sampling sites and beyond).

Since individual samples were replicates of their target sampling site, taxon abundance data per replicate have been averaged across each site and subjected to further multivariate analyses. The results of these analyses are illustrated in Figure 11. Eleven statistically distinct infaunal assemblages were identified from the analyses, six of which represented by a single sampling site. The largest group (assemblage g) was represented at 6 sampling sites and harboured 86 taxa. The highest number of taxa was recorded within assemblage f, followed by assemblage d, each containing 2 and 3 sites, respectively (Figure 11), and representing reef and trough habitat types. Distinct assemblages denoted by a single site also containing a high number of taxa (e.g., assemblages a, b, c and e) were also representing reef or trough habitat types. No distinct assemblage spanned both cSACs.

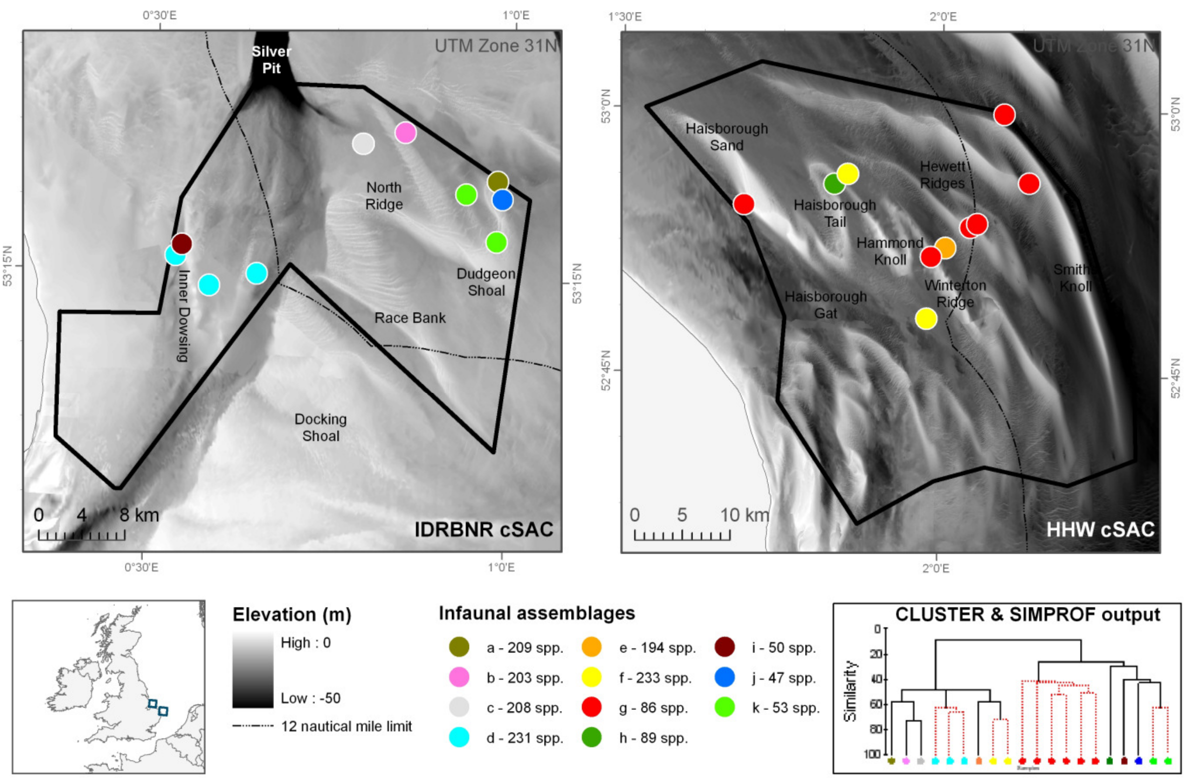

Figure 11. Distribution of each of the distinct infaunal assemblages identified through multivariate analyses of sample data averaged by site (see similarity dendrogram insert bottom right).

The pattern in relative similarity amongst sampling sites and treatments is best appreciated in an MDS plot (Figure 12). Again, sites representing reef clustered tightly, together with most sites representing sandbank troughs, irrespective of the cSAC to which the site belongs. The other two clusters observed were mostly representative of each cSAC and contain sites representing sandbank flanks, crests and troughs. Despite such apparent distinction in samples taken at different cSACs, there was no statistically significant difference in assemblage composition between cSACs. There was, however, a statistically significant difference between assemblages taken from different treatments: reef and trough assemblages being indistinguishable from one another, but each was different from crest and flank assemblages. Flank and crest assemblages were also indistinguishable from one another.

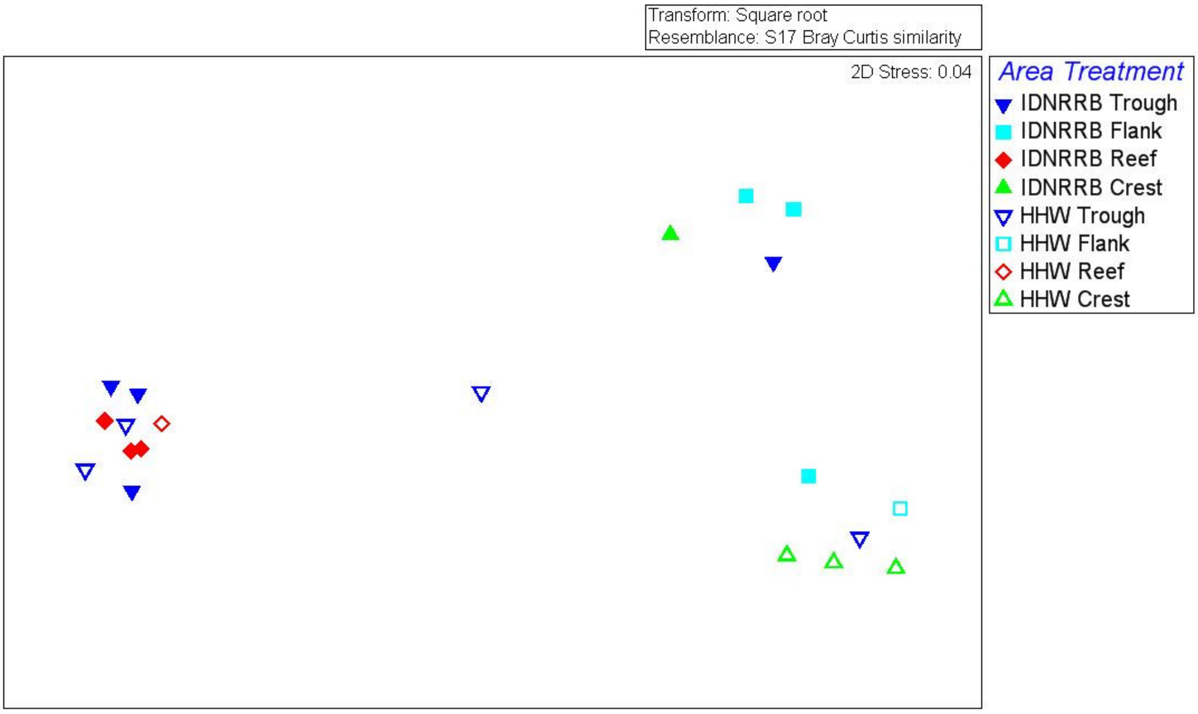

Figure 12. MDS plot of sampling sites coded by treatment and cSAC.

Lastly, investigation of variation in assemblage composition down the depth gradient of a sandbank flank (afforded by the 5 replicates that were taken at increasing depth intervals at Smiths Knoll, HHW cSAC) did not reveal any discernible or statistically significant pattern (data not shown).

3.4 Species and habitats of conservation importance

Sabellaria spinulosa is not itself designated as a species of conservation importance, but the reef it constructs when present in dense aggregations is considered a habitat of conservation importance. Hendrick & Foster-Smith (2006) provide broad guidelines on how to define reefiness, citing elevation, patchiness, extent, density and stability amongst the features that can be assessed (see Appendix I). Not all of these measurements were possible to obtain from the collected data, but those that were acquired are presented in Table 4. Based on the absence of important relevant information and on the limitations of the available data, an overall reefiness score has not been attempted for each of the sites where reef was observed.

Table 4. Summary of measurements available to conduct reefiness assessment based on Hendrick & Foster-Smith (2006) criteria.

	IDRBNR cSAC		HHW cSAC			
Video Stn No	95	100	315	316	317	319
Elevation	-	-	-	-	-	-
Consolidation	-	-	-	-	-	-
Area	-	-	-	-	-	-
Patchiness	20-35%	30%	60%	10%	60%	55%
Density*	-	High	High	-	Low-High	-
Diversity*	-	7.6	26.0	26.0	16.6	16.6
Biotope	A5.611	A5.611	A5.611	A5.611	A5.611	A5.611
Longevity	-	-	-	-	-	-

* Values based on grab sample data collected at same site.

In addition to the sites where *S. spinulosa* reef was observed on the video footage (see Figure 7), other sites also harboured notable populations of *S. spinulosa*, which have the potential to develop into reef. If density of *S. spinulosa* can be considered an indicator of reef building potential, more sites than those in which reef was observed could be of specific conservation interest. Thresholds between low, medium and high density of *S. spinulosa* were derived from Hendrick & Foster-Smith (2006) before being mapped (Figure 13).

As expected, sites with highest density of *S. spinulosa* coincided with sites where a large number of infaunal taxa were collected (see Figure 9). In addition to the sites which were originally designated as reef and where reef was observed on video footage, some sites originally designated as sandbank trough and crest also harboured high a high density of *S. spinulosa* (see Figure 3). Notably, Inner Dowsing East, which consistently displayed attributes uncharacteristic of its original crest designation, contained samples with low and high density values.

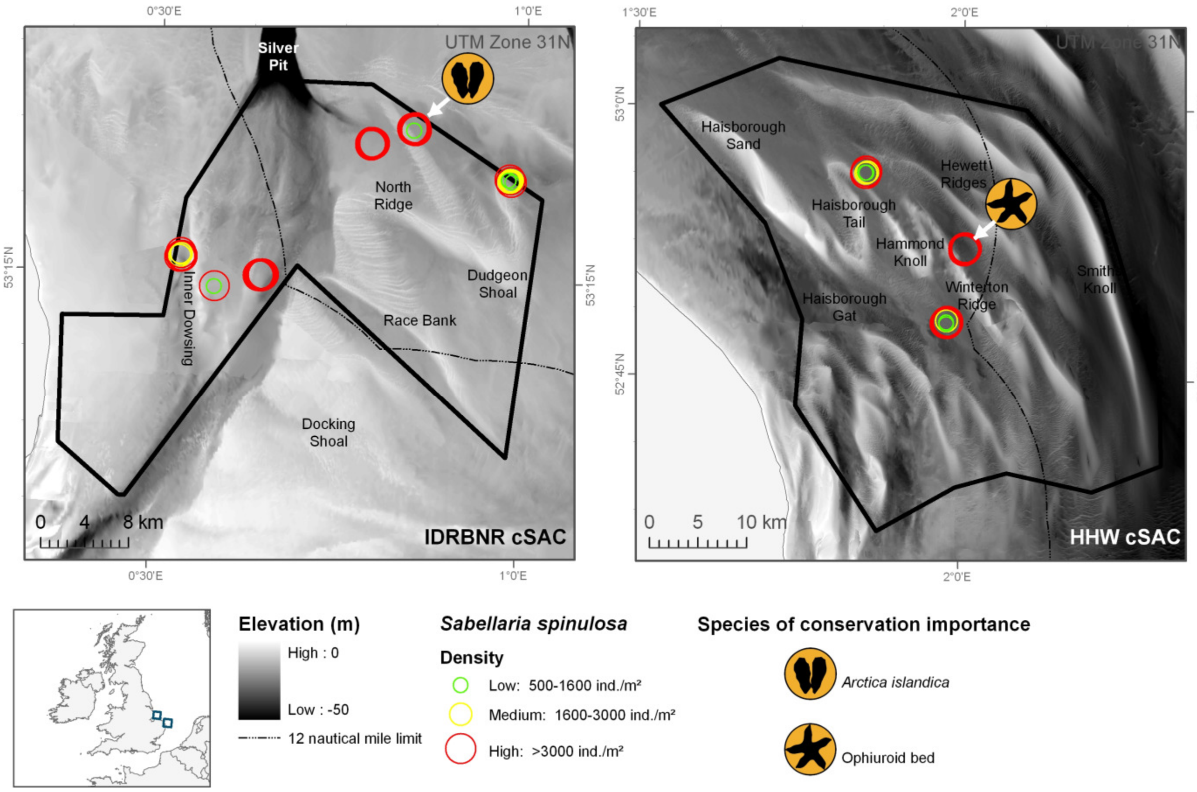

Figure 13. Location of samples containing species and habitats of conservation importance. Gradations of reefiness based on selected criteria by Hendrick & Foster-Smith (2006).

Mussels (*Mytilus edulis*) also have the capacity to form biogenic reef, however, the highest number of members of this species were found primarily together with *S. spinulosa* (i.e., at reef designated sites), therefore their distribution has not been mapped separately.

The ocean quahog (*Arctica islandica*) is the only species of designated conservation importance identified from the infaunal samples collected. One juvenile individual of *A. islandica* was recorded at the North Dudgeon Shoal sampling site (Figure 13). In addition, dense aggregations of brittlestars (Ophiuroidea) were observed at one sampling site in the HHW cSAC (see also Figure 7). Although not designated as a feature or species of conservation importance, such beds may play a significant role in the ecological functioning of coastal seas.

3.5 Sediment sample PSA

PSA of sediment samples has enabled the classification of each sample according to the Folk and EUNIS sediment classification systems (Appendix V).

Data from replicate samples of each site have been averaged by site and plotted on a triangular graph with a backdrop of the Folk sediment classification system (Figure 14). Sites representing reef were characterised as being predominantly 'slightly gravelly sand'. Sites representing sandbank flanks and crests were constituted primarily of 'sand'. Sites representing sandbank troughs had a sedimentary profile which spanned several sediment classes, from 'sand' to 'gravelly muddy sand' in varying proportions.

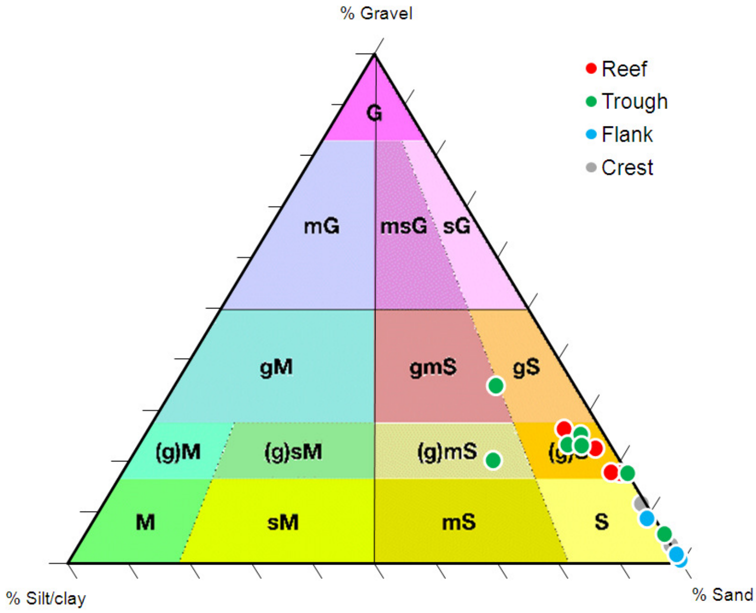

Figure 14. Triangular plot of averaged sediment particle size data by sampling site, set against the Folk sediment classification system.

A multivariate comparison of sediment attributes between each of the different sampling treatments revealed an overall difference in sediment properties between treatments when viewed together, but those apparent differences becoming less or more pronounced after comparisons between pairs of treatments (Table 5).

Table 5. Results from a one-way ANOSIM test of PSA-derived data between samples representing each treatment (reef, crest, flank and trough).

	R Statistic	Significance Level %
Global Test	0.149	0.1
Pairwise Tests		
Reef vs. Trough	-0.074	99.9
Reef vs. Crest	0.656	0.1
Reef vs. Flank	0.650	0.1
Trough vs. Crest	0.159	0.1
Trough vs. Flank	0.124	0.3
Crest vs. Flank	0.044	2.9

Sediment attributes were similar between reef and trough treatments (i.e., R value close to 0 and statistically not significant), whereas differences in sediment attributes between reef and crest or flank treatments were the most pronounced (i.e., R value close to 1 and statistically significant). Differences in sediment attributes were less pronounced between trough and crest or flank treatments, but were still statistically significant. Lastly, although differences between crest and flank treatments appear statistically significant, the R value close to 0 would suggest that they were not.

Shared sediment attributes between treatments are best appreciated in Table 6. Crest and flank treatments share a relatively high proportion of sand and a low proportion of silt/clay and gravel. They also shared similar attributes relating to the sediment particle size profile of the samples. In contrast, reef and troughs share relatively low proportions of sand and higher proportions of silt/clay and gravel, as well as similar values pertaining to the other measured sediment parameters. Such a distinction (made clearer by the colour coding of values in Table 6) reinforces the similarities observed between reef and trough habitats, and between crest and flank habitats, as well as the differences between those two groups of treatments.

Table 6. Relative contribution (normalised values) of each sediment attribute to each sampling treatment. Cells are colour-coded according to high (red), medium (yellow) and low (green) values.

	Treatment			
	Crest	**Flank**	**Reef**	**Trough**
Sand (%)	0.766	0.781	-0.410	-0.461
Mean (Phi)	0.196	0.326	-0.154	-0.140
Kurtosis	0.398	0.241	-0.471	-0.042
Skewness	-0.318	-0.479	0.266	0.199
Silt/Clay (%)	-0.437	-0.399	-0.024	0.381
Gravel (%)	-0.740	-0.781	0.541	0.378
Sorting	-0.883	-0.836	0.549	0.467

Information derived from sediment PSA was used to describe each sample using EUNIS level 3 habitat classifications (Appendix V). Classifications given to sediment samples ranged from coarse through mixed to sand and muddy sand.

3.6 Surficial sediments

The sparse areal coverage of acoustic data relative to the total area of each cSAC, together with the targeted and selective sampling of localised features, prevents meaningful extrapolation of surficial sediment information across the large expanse covered by the cSACs. Therefore, maps of surficial sediments for each of the cSACs have not been produced.

4 Data Interpretation

4.1 Delineation of Annex I habitats

'Sandbanks slightly covered by sea water all the time' and '*Sabellaria spinulosa* reef' were the two Annex I habitats targeted for investigation in the present study. Each habitat requires a different approach to detecting and delimiting its extent.

4.1.1 Sandbank delineation

The newly acquired corridor survey data offer limited evidence with which to assess the size and extent of sandbanks present in the cSAC. The spacing between survey lines is too large, and too few lines bisect the sandbanks to enable unequivocal delineation of the extent and topography of these features. However, some insights are discernible from the available data.

Within ArcGIS, corridor survey data were overlaid on the DEM. The corridor survey data consistently displayed lower elevations (greater depths) than the DEM. At HHW cSAC the difference between topography and location of sand bank features illustrated by the DEM and corridor survey data was more obvious and substantial than at IDRBNR cSAC (Figure 15). This may be because the sandbanks at HHW cSAC are more mobile than those at IDRBNR, or could be due to discrepancies in the datasets. At HHW cSAC, the DEM appears to have less interpolation in the model than in areas at IDRBNR, in which case the more accurate data informing the DEM at HHW provides clear elevation changes for comparison. At IDRBNR cSAC, where fewer data points were available for the DEM, changes in elevation will be less severe and restrict comparison between datasets because the same features are not evidenced in both.

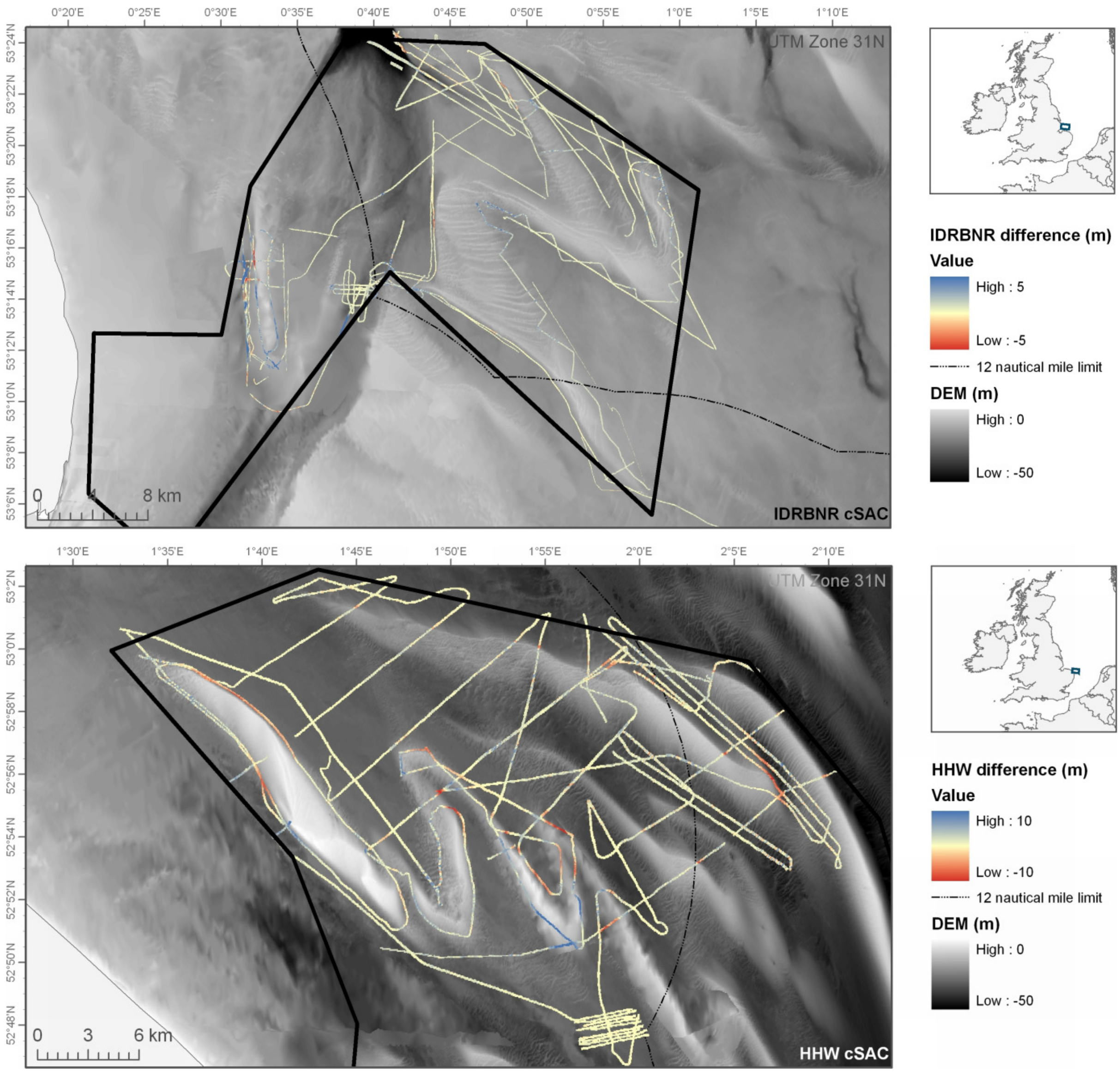

Figure 15. Difference plot between DEM data and corridor survey data.

At HHW cSAC, some movement of the sandbanks could be occurring. Using the available data, it is not possible to estimate the magnitude of this movement or if the whole complex is mobile. In some areas where corridor survey lines bisect the sandbanks, it can be seen that elevations differ between the DEM and corridor data which could be interpreted as bulk movement of a feature by up to 200 m in a lateral direction. This displacement seems to be in a general north easterly direction with some areas indicating up to ±10 m elevation difference between datasets (Figure 15), although some areas may be moving south westerly whilst others show no indication of movement.

At IDRBNR cSAC there is less difference between the DEM and corridor survey data with an elevation difference of ±5 m in some areas (Figure 15) which may be due to the lack of information on the cross section topography of sandbanks. This lack of survey lines crossing sandbank features rather than running parallel to them over the majority of the sandbanks also makes it impossible to infer any mobilisation of features.

4.1.2 Delineation of Sabellaria spinulosa reef

Sabellaria spinulosa is a gregarious tube-building polychaete which, in dense aggregations is capable of forming crusts or reefs that can, in turn, attract other residents leading to a localised increase in biodiversity. Hendrick and Foster-Smith (2007) describe a scoring system for 'reefiness' which has been applied as far as possible to the available data (see Table 4).

In terms of delineation of *Sabellaria spinulosa* reef, two sites (Docking Shoal in IDRBNR cSAC and Haisborough Gat Reef in HHW cSAC) were surveyed acoustically more intensively than the rest in an attempt to enable the delineation of reef boundary known to occur there, and to calculate the extent of the reef. Close inspection of sidescan sonar data from both sites did reveal a pattern which could be indicative of small and patchy *S. spinulosa* reef clusters. This pattern was used with some success to direct sampling with underwater cameras at reef-designated sites. However, no obvious or diagnostic acoustic signature was observed that may be classified unequivocally as reef or that could enable the precise differentiation or delineation of reef habitat from surrounding sediments on the acoustic data record.

When all video tow tracks showing *S. spinulosa* reef were overlain onto a backdrop of sidescan sonar data (Figure 7), there still was no obvious change in acoustic signature on the sidescan data over the transition between reef and its surroundings. It is likely that the combination of the high degree of patchiness of reef features (< 1 m clumps) and their relatively low elevation against a background of unconsolidated sediment presents an acoustic return that is too indistinct to be captured precisely on sidescan sonar data.

4.2 Biotopes to describe assemblages at each site

Biotope designation was achieved through the collation of information available for each sampling site including: the total number of taxa, the overall sediment description, the allocated sampling treatment, and the assemblage identified at each site through multivariate analysis of infaunal abundance data (excluding colonial taxa). All of this information is summarised in Table 7.

Table 7. Summary of information used to inform biotope designation for each sampling site. Colour coding shows shared characteristics for each column heading.

	S*	Folk symbol	Treatment	Assemblage	Reef observed	MNCR Biotope	EUNIS Code
IDRBNR cSAC							
Dudgeon Shoal Trough	278	(g)S	Trough	a – 209 spp.	-	SS.SBR.PoR.SspiMx	A5.611
North Dudgeon Shoal	244	(g)S	Reef	b – 203 spp.	-	SS.SBR.PoR.SspiMx	A5.611
Silver Pit East	256	(g)S	Reef	c – 208 spp.	Yes	SS.SBR.PoR.SspiMx	A5.611
Docking Shoal	219	(g)S	Reef	d – 231 spp.	-	SS.SBR.PoR.SspiMx	A5.611
Inner Dowsing East	194	gmS	Trough	d – 231 spp.	-	SS.SBR.PoR.SspiMx	A5.611
Inner Dowsing West Trough	198	(g)mS	Trough	d – 231 spp.	-	SS.SBR.PoR.SspiMx	A5.611
Inner Dowsing West Crest	70	S	Crest	i – 50 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
Dudgeon Shoal Flank	65	S	Flank	j – 47 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
East North Ridge	50	S	Trough	k – 53 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
West Dudgeon Shoal	47	S	Flank	k – 53 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
HHW cSAC							
East Hammond Knoll	226	(g)S	Trough	e – 194 spp.	Yes	SS.SBR.PoR.SspiMx	A5.611
Haisborough Gat Reef	210	(g)S	Reef	f – 233 spp.	Yes	SS.SBR.PoR.SspiMx	A5.611
Haisborough Tail Deep	214	(g)S	Trough	f – 233 spp.	-	SS.SBR.PoR.SspiMx	A5.611
Southern Hewett Ridge Crest	37	S	Crest	g – 86 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
Southern Hewett Ridge Flank	24	S	Flank	g – 86 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
Winterton Ridge	21	S	Crest	g – 86 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
Haisborough Sandbank West	46	S	Crest	g – 86 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
West Smiths Knoll	28	S	Trough	g – 86 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
Smiths Knoll	45	S	Flank	g – 86 spp.	-	SS.SSa.IFiSa.IMoSa	A5.231
Haisborough Tail Bight	117	(g)S	Trough	h – 89 spp.	-	SS.SSa.IFiSa	A5.23

* Total number of taxa (including colonial taxa) recorded at each site. The number of taxa within each assemblage identified through multivariate analysis excludes colonial taxa.

Sites individually harbouring a relatively high number of taxa on slightly mixed sediment, belonging to reef and trough treatments and representing assemblages with relatively high overall taxon richness have been designated to the biotope SS.SBR.PoR.SspiMx – *Sabellaria spinulosa* on stable circalittoral mixed sediment (A5.611). Multivariate analyses revealed no difference in assemblage composition between reef and trough treatments, and although some sites representing troughs may have harboured only a few individuals of *S. spinulosa*, and at some sites representing reef, reef itself was not observed on video footage, the overall taxon richness of those sites was equivalent or higher than sites where *S. spinulosa* reef was observed.

In contrast, sites individually harbouring a low number of taxa inhabiting clean sandy sediments, representing sandbank crests and flanks at relatively shallow depths, and grouped by multivariate analysis into assemblages with reduced taxon richness, have been designated to the biotope SS.SSa.IFiSa.IMoSa – Infralittoral mobile clean sand with sparse fauna (A5.231). Lastly, a single site, Haisborough Tail Bight, representing a shallow trough of slightly gravelly sand with no notable presence of *S. spinulosa* but with an intermediate number of taxa (higher than that indicated by the definition of SS.SSa.IFiSa.IMoSa) has been designated as SS.SSa.IFiSa (infralittoral fine sand – A5.23). For this site there was no suitable match at Level 4 of the marine habitat classification system.

5 Discussion

5.1 Summary of habitats recorded

The number of different habitats recorded during the present investigation, and the variation between them, very much depends on which datasets are used to inform the assessment. Inspection of acoustic data could not be relied upon to differentiate with confidence between habitat types beyond those separated by obvious changes in bathymetry (i.e., sandbank vs. not sandbank). Multivariate statistical analysis of epifaunal data revealed several distinct epifaunal assemblages (Figure 6), as did the analysis of infaunal data (Figure 11). Similar analysis of particle size distribution data revealed broad similarities and differences between habitat types (Table 5 Table 6) and joined sampling sites into a different number of distinct groups (e.g., Figure 14). Comparison of infaunal assemblage composition between the four sampling treatments revealed one distinct assemblage characteristic of reefs and sandbank troughs which was shown to be statistically very different to that inhabiting sandbank crests and flanks (Table 3; Figure 10). Although the two cSACs did not share any of the identified distinct infaunal assemblages, statistical analysis did not show any overall area-specific difference in assemblage composition between the two sites. Combining all this information to inform the designation of a biotope for each site resulted in the identification of two biotopes at Level 4 and one biotope at Level 3 in the classification hierarchy (see Table 7).

For the sake of simplicity, three communities can be distinguished from the present datasets, with the potential for some localised, site-specific variation in taxon composition within each:

1. Community inhabiting patchy biogenic reef habitat with *S. spinulosa* contributing – but not essential – to the elevated diversity observed in this community (elevated diversity levels also observed where reef itself was not encountered, but *S. spinulosa* was present). This community occurs in sheltered areas between sandbanks where sediments are relatively mixed and stable, and afford some accumulation of organic matter. Sites hosting this community in the present study represented reef and trough treatments.
2. Sparse community with relatively low taxon diversity inhabiting exposed, high-energy, clean, mobile sand representing sandbank crests and flanks.
3. A community with an assemblage richness intermediate between the two previous communities and without a significant presence of *S. spinulosa*. This community may be representative of the wider seabed sediments beyond the direct influence of sandbanks.

Communities similar to those described above were identified during the Humber and East Coast REC surveys. In the Humber REC survey, four 'Functional Biological Communities' (FBC) were described: (1) Barnacles, ascidians and tube worms, (2) Infaunal polychaetes with burrowing bivalves and amphipods, (3) *Sabellaria spinulosa* reef, and (4) Sparse fauna (see Chapter 6 in Tappin et al. (2011) for full FBC descriptions). The last two FBCs listed bear a strong resemblance to the first two communities identified in the present investigation. The distribution of each of these two communities over the whole Humber REC survey area is illustrated in Figure 16. The third distinct community of intermediate diversity identified in this study was not observed within the IDRBNR cSAC, but might be considered an equivalent community to the other two FBCs identified in the Humber REC survey report.

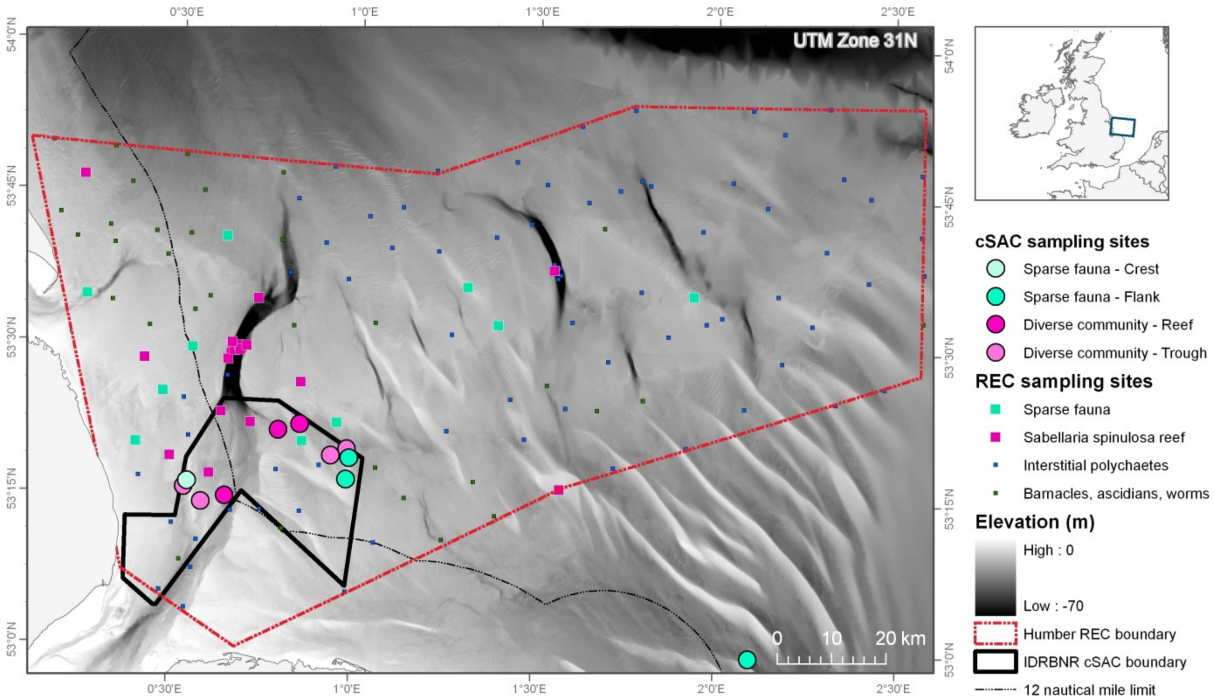

Figure 16. IDRBNR cSAC and Humber REC sampling sites colour coded by 'Functional Biological Community' (REC study) or equivalent (cSAC study). Equivalent communities between studies share the same colour.

The diverse community identified is distributed mostly within the cSAC area – where it has been fully characterised in the present investigation – and in the deeper reaches sampled within the Humber REC survey area. It appears that the locations where this community is found are also characterised by relatively mixed and stable sediments with elevated levels of organic matter, and where *S. spinulosa* is present. In contrast, the location of the sparse faunal community both inside and outside the IDRBNR cSAC corresponds with areas of clean sand and gravel, with no mud or organic content and an absence of *S. spinulosa*. Other communities identified in the Humber REC survey are spread throughout the area and reflect subtle differences in sediment composition and stability (Tappin et al., 2011).

In the East Coast REC survey, equivalent communities to those in the HHW cSAC can be inferred from combinations of the statistically distinct assemblages identified: (1) Diverse reef community = REC assemblages E, H, G and I, (2) Sparse faunal community = REC assemblages A, D and Q, and (3) intermediate diversity community = REC assemblages C and R (see Chapter 7 in Limpenny et al. (2011) for a full description of each assemblage). The distribution of these communities over the whole East Coast REC survey area is illustrated in Figure 17.

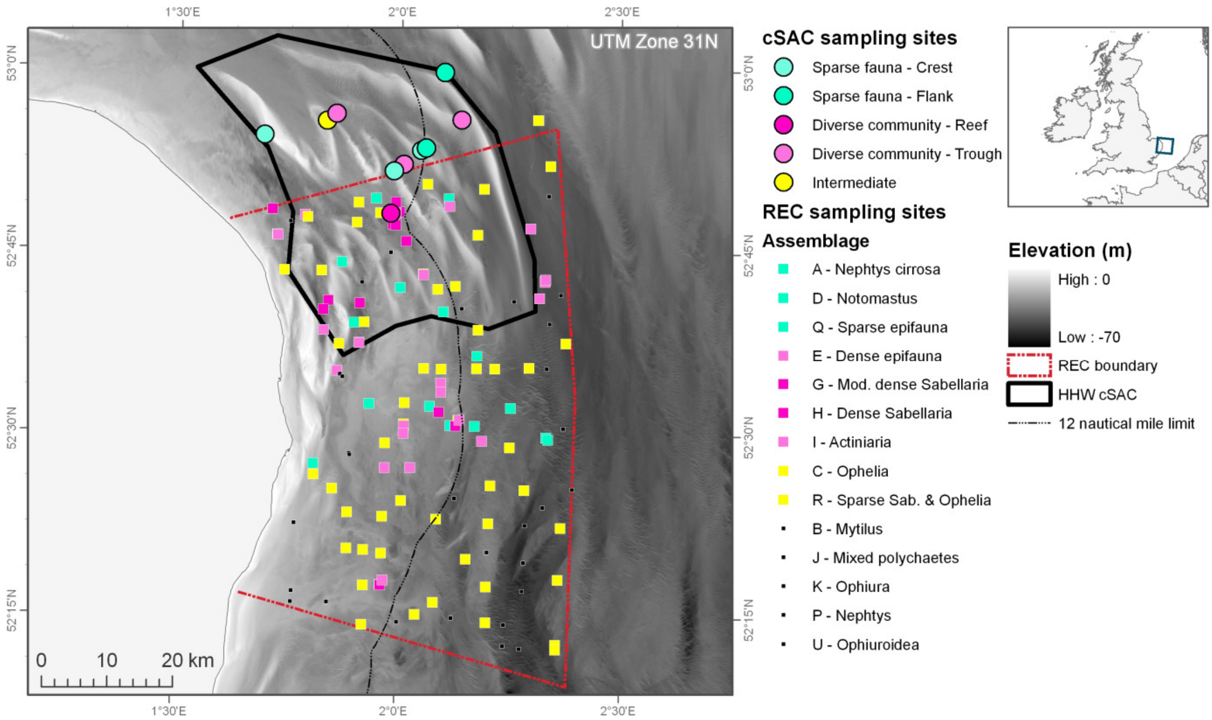

Figure 17. HHW cSAC and East Coast REC sampling sites colour coded by community type (diverse, sparse and intermediate) identified in cSAC study. Equivalent communities between studies share the same colour.

The location of the diverse community identified from the East Coast REC survey coincides with areas in which it has been identified in the HHW cSAC study, especially in the areas between sandbanks in the Haisborough Gat. It is also present in trough areas either side of the Middle Cross Sand sandbank (southwest corner of cSAC area), in deeper waters east of Smith's Knoll (just outside cSAC eastern boundary), and centrally, close to the 12 nm territorial water limit. The distribution of the sparse faunal community appears to be restricted to the northern half of the East Coast REC survey area, interspersed amongst the other communities identified. The equivalent assemblages to the intermediate diversity community identified in the cSAC study also appear to be spread all over the REC survey area. This community, in all its localised variations, might be the predominant community backdrop present in most shallow shelf waters in the southern North Sea, against which are pockets of very diverse communities reflecting the effects of localised aggregations of habitat engineers such as *S. spinulosa*, and areas of sparse fauna where sediments are too unstable and devoid of organic matter to accommodate a diverse assemblage.

5.2 Annex I features within sites

5.2.1 Sandbanks

The presence and broad-scale extent of sandbanks in both cSACs in this study coincides with that presented in the Site Assessment Documents (JNCC & NE, 2010a and 2010b). The discrepancies in bathymetry readings between acquired acoustic data from multibeam corridor surveys and modelled data (DEM) could be interpreted as evidence of sandbank mobility. Such discrepancies were more apparent at the HHW cSAC, where much of the sandbank complex could have migrated up to 200 m in a north easterly direction. This interpretation however should not be relied upon too heavily because of the variable quantity and density of data points that underlie the DEM.

5.2.2 Biogenic reef

Biogenic reef clusters built by *S. spinulosa* were observed, sampled and characterised during the present investigation. It is likely, however, that their low elevation and high degree of patchiness against a backdrop of unconsolidated mixed sediments prevented the detection of reef at a broad spatial scale on the acquired acoustic sidescan data, thus preventing the delineation of any reef feature and the calculation of reef extent. Several sampling sites, whether targeting biogenic reef or sandbank troughs, harboured high numbers of *S. spinulosa*, which resulted in those same sites harbouring a diverse and abundant infaunal assemblage. Some of the sampling sites chosen to represent sandbank troughs, and which did not harbour high numbers of *S. spinulosa,* could also maintain equally diverse and abundant infaunal assemblages as sties representing *S. spinulosa* reef. It is possible that the small-scale physical heterogeneity of these trough habitats, with some coarse components stabilising the sediment (e.g., gravel or small aggregations of *S. spinulosa* tubes), increased shelter from the strongest currents afforded by surrounding sandbanks, and the possibility of organic matter to accumulate, results in a patchwork of conditions which as a whole enable the establishment of a diverse assemblage with a collectively wide set of habitat requirements.

5.3 Identification of appropriate indicators to assess state of features

Sandbanks are a topographic feature which, in the case of those targeted under the present investigation, are relatively stable at a decadal time scale. Appropriate indicators to assess the state of such features would therefore be its presence and extent, which when observed over time, would indicate whether the physical state of the feature was changing. At present, broad-scale acoustic surveys, with the required level of data accuracy and resolution, provide the best way of determining sandbank presence and extent. However, other technologies such as LIDAR or remote bathymetry measurements from orbiting satellites may become more effective at overcoming the present technical limitations posed by opaque, sediment laden water masses and shallow water which may hinder access.

Appropriate indicators for assessing the quality of biogenic reef are already available (i.e., published reefiness assessment methodologies). However, the lower the quality of the reef (i.e., the more patchy and that with lesser elevation), the harder it is to detect, differentiate and measure its extent using conventional video and acoustic techniques. Acoustic data coverage can provide an accurate measure of reef extent over the area of data coverage, but only when the reef is of sufficient reefiness to be differentiated and delineated against the background acoustic signature of the surrounding sediments. Groundtruthing techniques such as those used for the present investigation are still required to detect the presence of live and viable *S. spinulosa*, even from areas where the acoustic data suggests no discernible presence of reef.

5.4 Survey limitations

The original survey designed to support this investigation was suitable for the assessment of sandbank features. However, because of the adoption of more stringent safety measures during the survey itself, it was not possible to steer the survey vessel along all the proposed sampling corridors, as these would have taken the vessel beyond its updated safe operational capabilities. As a consequence, some of the shallower reaches of the survey area had to be revisited with a smaller vessel of shallower draft, with its own set of operational capabilities. Since both the cSACs surveyed are exposed even to slight changes in sea and weather conditions, there is a trade-off between using larger, more stable vessels able to operate in poor conditions, and using smaller vessels which can only operate in a very small weather window before the quality of the data they collect starts to deteriorate.

Large amounts of time (resource) were spent mobilising for survey, as well as on weather downtime and standby. This is true for both the acoustic survey on the *Cefas Endeavour* and the additional groundtruthing survey carried out on the *Humber Guardian*. Further consideration must also be given to the ability of the smaller vessel to deploy the equipment needed to collect samples from sandbank habitats (i.e. the mini Hamon grab and camera sledge/drop camera) and the ability to hold position while the sample is collected (grab) or follow a specific survey line during camera deployments. In comparison, no weather downtime was experienced during the survey carried out on *Cefas Endeavour* and all gears were successfully deployed as per the Standard Operating Procedures. The use of *Cefas Endeavour* also provided the flexibility to swap between gears if conditions at the time favoured a specific gear. This is something that is not possible on smaller research vessels due to the limited amount of deck space. A further consideration is the hours of operations capable on each vessel. On the smaller vessel, operations were limited to long days due to the restrictions of hours of work imposed on the crew and the limited amount of accommodation on the vessel. *Cefas Endeavour*, on the other hand, operated for 24 hours a day resulting in no time being lost during transits to and from port.

5.5 Data limitations

Overall, the data quality gathered for the present investigation was good. Where data quality could have been better was where poor visibility due to increased suspended sediment hindered the view of the seafloor at some video sampling sites. Use of a fresh water lens camera in the future would minimise the effects of poor visibility.

Acoustic data gridded at 1 m bin sizes (each cell is 1 m^2) will not resolve features that can be averaged out over a 1 m^2 unit. This, combined with a 0.1 m deviation accepted in gridding, will result in features with dimensions lower than these characteristics being unresolved. As a consequence, the coverage and spatial resolution of acquired acoustic data was insufficient to delineate the biogenic reef present in the areas surveyed. This could be because of the low elevation of the reef itself and/or because of its high degree of patchiness. Neither of these reef properties was known in detail before the survey was conducted, therefore, parts of the survey specifically aimed at the delineation of biogenic reef were not as successful as anticipated. To maximise the potential for reef detection and delineation, future surveys may have to collect 100% coverage of very high-resolution data (e.g., 0.5 m bin size), although this would still not guarantee the detection and accurate delineation of low elevation and very patchy reef against a background of coarse sediments (i.e., reef with topographic expression less than 10 cm high and a footprint <2 m^2). Again, a trade-off would be necessary between total survey extent and detailed spatial resolution of discrete features, both constrained by a limited pool of resource.

5.6 Anthropogenic impacts

No evidence of anthropogenic activity was observed on the newly acquired acoustic or video data. However, various commercial fishing activities are known to occur in certain areas in and around the cSACs (Figure 18, Figure 19, Figure 20). Vessel Monitoring System (VMS) data from UK fishing vessels recorded during 2011 and 2012 revealed a very low level of fishing intensity across the cSACs. Elevated levels of fishing intensity by large vessels have been detected immediately to the south and west of IDRBNR cSAC and to the east of HHW cSAC (Figure 18). The activity of vessels <15 m is not captured with VMS data, however, sightings of vessels have been standardised to provide a measure of fishing intensity by these smaller vessels around the UK (Vanstaen, 2010). Highest levels of fishing activity by small vessels using fixed or mobile gear appear at the mouth to The Wash, in the southwest corner of IDRBNR cSAC (Figure 19).

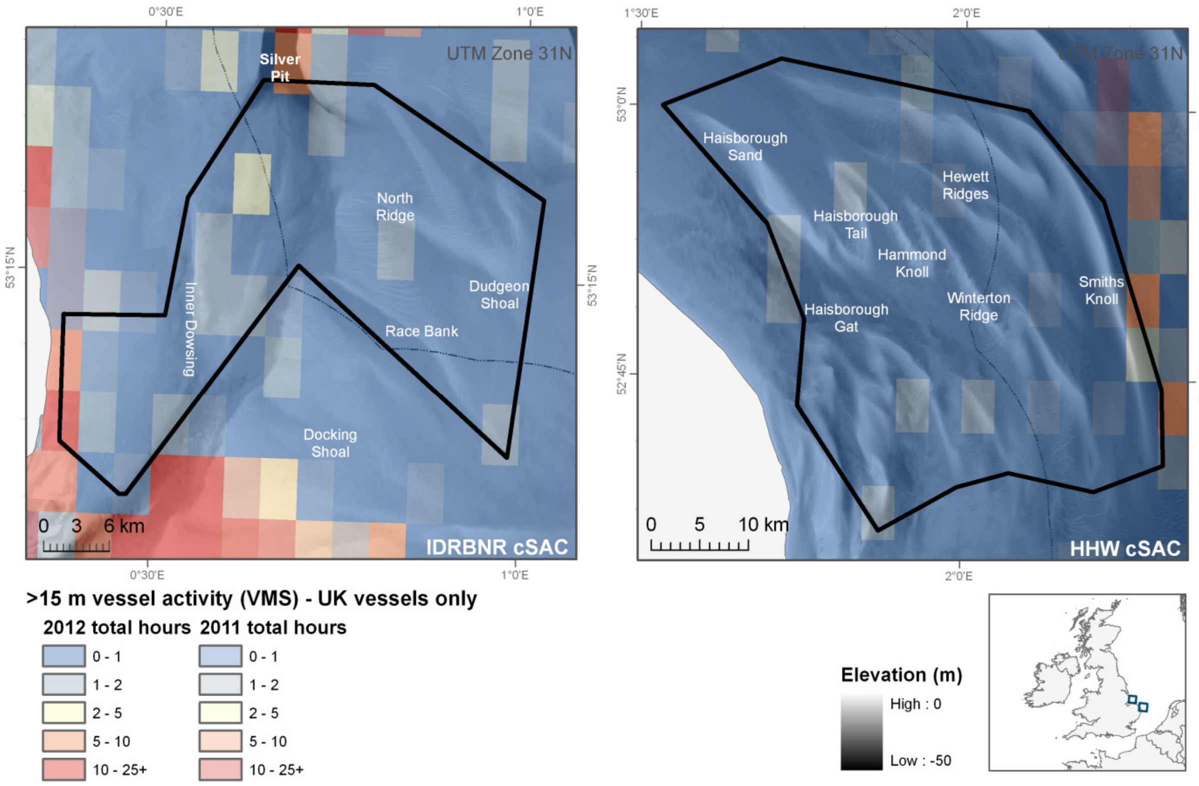

Figure 18. Intensity of fishing activity in 2011 and 2012 by vessels >15 m according to VMS data records.

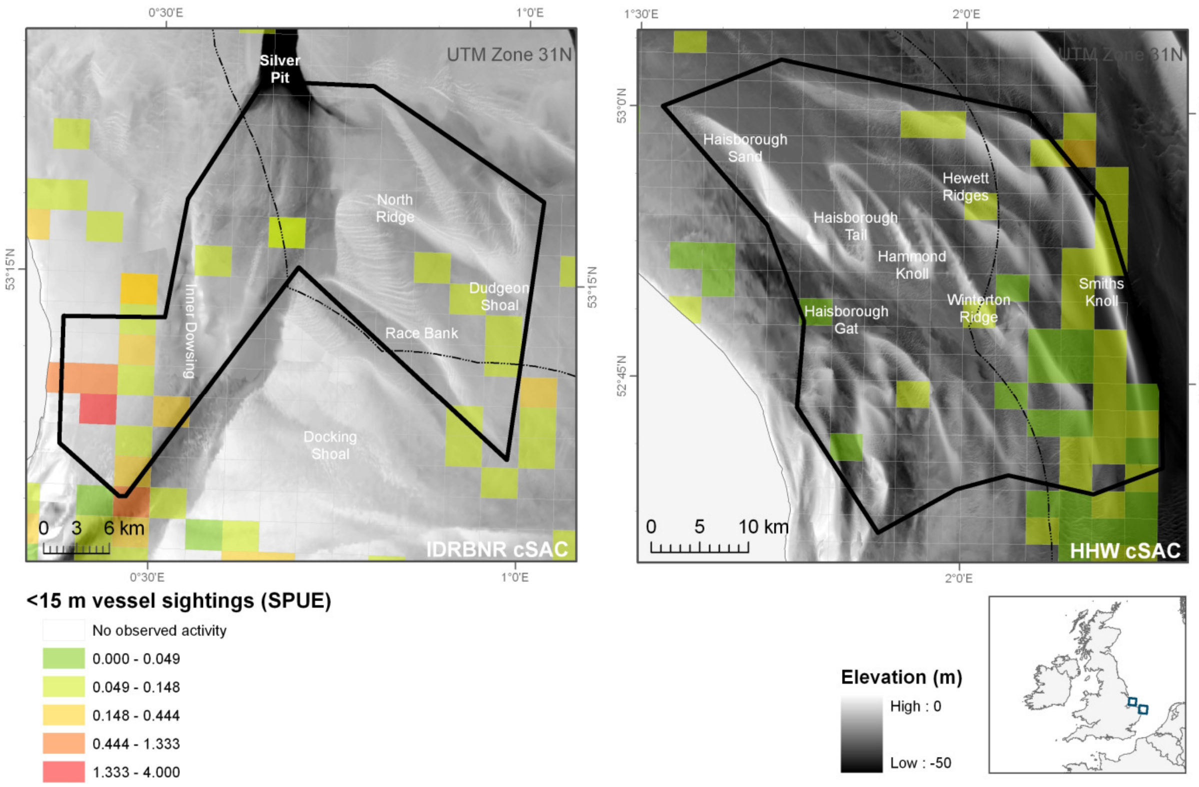

Figure 19. Intensity of fishing activity (static and mobile gears between 2007 and 2009) by vessels <15 m (from Vanstaen, 2010).

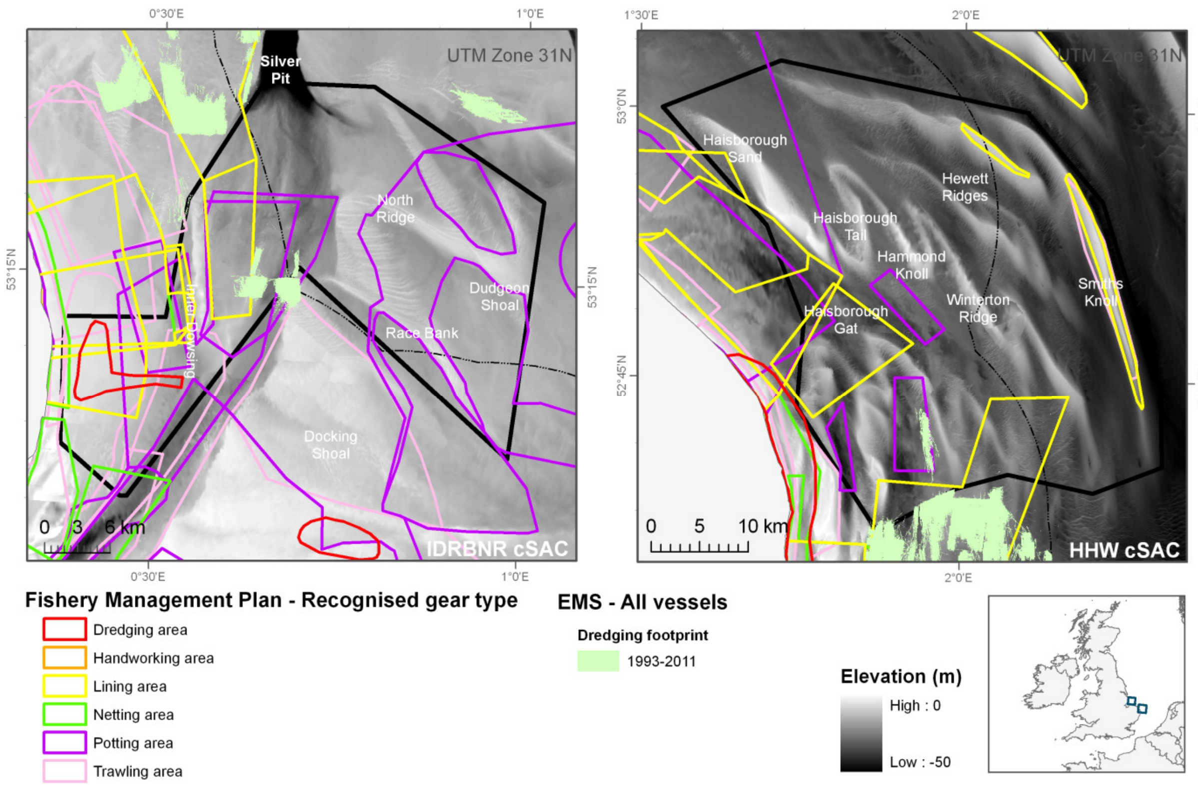

Figure 20. Map depicting the Fishery Management Plan areas by different gear type, together with the aggregate dredging footprint which takes place in and around the cSACs.

Historic electronic monitoring system (EMS) data from the aggregate extraction industry shows a footprint of activity within the IDRBNR cSAC north of the Docking Shoal (Figure 20). This area coincides with the area targeted during this study for intensive sampling of *Sabellaria spinulosa* reef (see Figure 2, Figure 3 and Figure 4). Although high density values of *S. spinulosa* were sampled from this area (see Figure 13), no reef structures were observed in the video footage obtained. The infaunal assemblage sampled at this site displayed an elevated number of taxa, no different to other sites where reef was observed (see Figure 11). Limpenny et al. (2010) reports similar observations in this area made in 2005, identifying discontinued agglomerations of *S. spinulosa* on the sidescan sonar record that were not always captured by the video and grab samples. No inference can be made at present between the historical occurrence of aggregate dredging and the observed absence of *S. spinulosa* reef north of the Dudgeon Shoal.

6 Conclusions

The present investigation has enabled the following conclusions to be made:

1. Sandbanks at both the HHW and IDRBNR cSACs appear to be in a stable condition, although spatial discrepancies between acquired MBES corridor data and modelled bathymetry (DEM)

data could be interpreted as evidence of sandbank migration of up to 200 m at HHW cSAC. Future surveys and comparison of temporally extended datasets should enable the verification of this interpretation.

2. There are differences in faunal assemblage composition between the treatments sampled; reef and sandbank trough assemblages were statistically similar; sandbank crest and flank assemblages, although distinct statistically, were also similar in the benthic communities they hosted. Other differences observed between groups of sampling sites were due to local differences in environmental conditions. There was no overall difference in faunal assemblage composition between the two cSACs.
3. Detection, delineation and the calculation of extent of biogenic reef was not possible using the newly acquired acoustic datasets. It is likely that the reef habitat observed during groundtruth sampling was of too low elevation and/or too patchy to be differentiated and delineated accurately from the surrounding coarse sediments using the resolution of the acoustic data acquired. Reefiness of sampling sites harbouring *S. spinulosa* was determined using suitable available data. Nine out of 20 sampling sites contained samples with high reefiness score.

The outcome of testing the predefined hypotheses in the PoA is as follows:

1. Different communities are associated with crests and with flanks of the sandbanks – Hypothesis supported statistically but the difference observed between faunal assemblages inhabiting sandbank flanks and crests is likely to be ecologically unimportant.
2. There is a difference between the sandbank flank communities located on the more wave- and tidally-exposed outer sandbanks compared to the communities found on inner banks – Hypotheses not tested due to lack of replication of samples in either treatment (i.e., exposed vs. sheltered flanks).
3. Communities subject to high anthropogenic pressures are different to communities subject to no/low pressure – Hypothesis not tested due to lack of measureable differences in anthropogenic pressures across the survey sites.
4. The Haisborough Gat reef and the Docking Shoal reef are receiving direct [anthropogenic] impacts. Hypothesis not tested due to lack of evidence of anthropogenic pressure in these areas.

6.1 Future monitoring scheme

Due to the size of the cSACs and the features of interest within them, resource constraints, and the variability and unpredictability in environmental conditions (e.g., weather, sea state, feature condition) there will always be a trade-off between using the most effective and reliable survey platform, the spatial extent of a monitoring survey, and the use to which the datasets acquired can be put. Data from corridor surveys allow for a greater areal extent to be covered, whilst 100% spatial coverage of a feature of interest can increase confidence in the assessment of quality of that feature. Targeted groundtruthing will always be necessary to verify any inferences obtained from remotely acquired data. Future monitoring surveys must ensure they identify the exact nature of what is to be monitored, and design a survey which will optimise the acquisition of good quality data to enable a meaningful assessment of site condition. Based on recent experience on the present investigation, it might be useful in the future to target resources to specific tasks instead of spreading resources over several different objectives. For example, should a measure of sandbank feature extent be required, or a more localised biogenic reef feature require delineating, separate focused surveys could be dedicated to each task, rather than sharing a single general survey to cover both tasks, with the inherent compromises such sharing brings.

Whilst indicative costs can be calculated for separate elements of a particular survey (based on known prices for staff time, equipment running costs, predicted duration of certain processes, etc.) the total expected cost of a monitoring survey cannot be finalised until the exact purpose of the survey is known. More often than not, however, it is the resource available and the multiple objectives of the resource provider which determine the scope a survey. To date, Cefas has always endeavoured to maximise the return from any available resource, however, it might be of interest to explore a change of approach, focusing to resolve a single targeted objective rather than to maximise the return across several objectives with diverse or conflicting technical requirements.

Acknowledgements

This work was conducted within the JNCC/Cefas MoU and NE/Cefas partnership agreement. We would like to thank the JNCC and Natural England, in particular Neil Golding, Chris Pirie, Ian Reach, Jen Ashworth and Ian Saunders for their valued input during the planning and execution of the offshore surveys. Jessica Woo from the Eastern IFCA was the Fisheries Liaison Officer during the data acquisition cruise. We would also like to thank Claire Mason and Briony Silburn (Cefas) for ensuring that all sediment samples were successfully processed. Royal Haskoning DHV provided EMS footprint data.

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Vanstaen, K. 2010. Development of an integrated fishing activity data layer for English and Welsh waters, and development of a GIS toolbox for future inshore fishing activity data analysis. Report No 5 for Department for Environment, Food and Rural Affairs, 108pp

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Appendix I

Sabellaria spinulosa reef assessment

Sabellaria spinulosa **reef structure determination matrix**

Reef Structure matrix			Elevation (cm)			
			<2	2 to 5	5 to 10	>10
			Not a reef	Low	Medium	High
Patchiness – (% coverage)	<10%	Not a reef	NOT A REEF	NOT A REEF	NOT A REEF	NOT A REEF
	10-20%	Low	NOT A REEF	LOW	LOW	LOW
	20-30%	Medium	NOT A REEF	LOW	MEDIUM	MEDIUM
	>30%	High	NOT A REEF	LOW	MEDIUM	HIGH

Sabellaria spinulosa **reef conservation quality matrix**

Reef Structure vs. area		Area (m^2)			
		<25	25 - 10,000	10,000 - 1,000,000	> 1,000,000
		Not a reef	Low	Medium	High
-Reef Quality (incl. Patchiness and Elevation)	Not a reef	NOT A REEF	NOT A REEF	NOT A REEF	NOT A REEF
	Low	NOT A REEF	LOW	LOW	LOW
	Medium	NOT A REEF	LOW	MEDIUM	MEDIUM
	High	NOT A REEF	MEDIUM	HIGH	HIGH

Appendix II

Data sources for IDRBNR cSAC

Reference	Description
AMEC, 2007. Docking Shoal Environmental Statement: Ecology Baseline Report.	Baseline survey of windfarm site
CEFAS, 1998. Annual monitoring of the Phase 2 dredging uplift at Area 107 aggregate extraction site (year 3).	Monitoring data from aggregate site
CEFAS, 1999. Annual monitoring of the Phase 2 dredging uplift at Area 107 aggregate extraction site (year 4).	Monitoring data from aggregate site
CENTRICA, 2007. Lincs Offshore Windfarm Environmental Statement	Baseline survey of windfarm site
CENTRICA, 2008. Docking Shoal Offshore Windfarm Environmental Statement: Volume 1 Offshore.	Baseline survey of windfarm site
CENTRICA, 2009a. Race Bank Offshore Windfarm Environmental Statement: Volume 1 Offshore.	Baseline survey of windfarm site
CENTRICA, 2009b. Docking Shoal and Race Bank Supplementary Environmental Information.	Supplementary environmental survey data in support of Environmental Statements for two windfarm sites
DFR, 1996a. Annual Monitoring of the Phase 2 Dredging Uplift at Area 107 Aggregate. Directorate of Fisheries Research, Burnham-on-Crouch.	Monitoring data from aggregate site
DFR, 1996b. Environmental Status Report of North East Area 107 Aggregate Extraction Site: Post Dredging Phase 1 Uplift, Directorate of Fisheries Research, Burnham-on-Crouch.	Monitoring data from aggregate site
DFR, 1997. Annual Monitoring of the Phase 2 Dredging Uplift at Area 107 Aggregate Extraction Site (Year 2), Directorate of Fisheries Research, Burnham-on-Crouch.	Monitoring data from aggregate site
EASTERN SEA FISHERIES JOINT COMMITTEE, 2008. Unpublished *Mytilus edulis* and *Sabellaria spinulosa* resource survey data.	Survey of Inner and Outer Wash
EMU Ltd, 2006. Lincs Offshore Windfarm Baseline Benthic Survey 2005. REPORT No. 06/J/I/03/0813/0603. Report to RES.	Baseline survey of windfarm site
EMU Ltd, 2005a. Lynn & Inner Dowsing Offshore Wind Farm Monitoring Programme (inc. Lincs. Baseline Surveys) Mussel Survey Draft Report No. 05/J/1/03/0685/0548 and EMU Ltd, 2005b. Lynn & Inner Dowsing Offshore Wind Farm Monitoring Programme (inc. Lincs. Baseline Surveys) Fisheries & Epibenthos surveys Final Report No. 05/J/1/03/0685/0508	Baseline survey of windfarm site
ENTEC UK LTD, 2003. Area 481 Benthic and Epibenthic Survey Report. Report to United Marine Aggregates Ltd and Van Oord ACZ.	Survey of aggregate site
INSTITUTE OF ESTUARINE AND COASTAL STUDIES, 1999. Biological baseline survey of Inner Dowsing (Area 439) & North Dowsing (Area 400). Report prepared for Entec UK for Hanson Aggregates Marine Ltd.	Survey of aggregate site

Reference	Description
MARINE AGGREGATE LEVY SUSTAINABILITY FUND (MALSF), 2010. Humber Regional Environmental Characterisation preliminary data. www.marinealsf.org.uk	Survey data to set an environmental characterisation of the seafloor at a large regional scale
MARINE ECOLOGICAL SURVEYS (MES) LTD, 2003. Marine Aggregate Extraction Application Area 106 (480). Environmental Statement. Report prepared for Hanson Aggregates Marine Ltd.	EIA of aggregate site
MARINE ECOLOGICAL SURVEYS (MES) LTD, 2000. Benthic biological resources in and adjacent to Triton Knoll (Area 440) and Outer Dowsing (Area 441). Report prepared for Coastline Surveys Ltd, Gloucestershire.	Survey of aggregate site
Defra (2011) 1 arc second Digital Elevation Model	Bathymetric data used to map base of sandbanks
UNICOMARINE, 2000. Analysis of macroinvertebrate samples taken in 1999 from the Docking Shoal, Race Bank and Area 107. Report 107X9 to CEFAS.	Survey of fishing grounds

HHW data sources cSAC

Reference	Description
COOPER, K., BOYD, S., ALDRIDGE, J., & REES, H., 2007. Cumulative impacts of aggregate extraction on the seabed macroinvertebrate community in the area off the east of the UK. Journal of Sea Research, 57, 288-302.	Scientific study of aggregate site.
ENTEC UK LTD., 2007. Summary of report on the data acquisition phase of the characterisation of possible marine SACs (outer Wash sandbanks and outer Thames Estuary). Report to Natural England as part of Contract FST20-18-030, April 2007.	Surveys to specifically identify Annex I interest features.
ENTEC UK LTD, 2008c. SAC selection Assessment: Outer Wash Sandbanks. Report to Natural England as part of Contract FST20-18-030.	Surveys to specifically identify Annex I interest features.
GARDLINE ENVIRONMENTAL LTD. 2010. Bacton to Baird Pipeline Route and Environmental Survey, October and November 2009, Habitat Assessment Report. 1578-0709-BSCL. February 2010.	Seafloor environmental characterisation survey data used to support an assessment of environmental impacts of planned gas pipeline installation.
HANSON AGGREGATE MARINE LTD (HAML). 2009. Licence Area 436/202 Cross Sands Monitoring Report.	Impact assessment monitoring data associated with 10 year review of aggregate dredging activity. Comparative multibeam bathymetry analyses of Cross Sands banks.
MARINE AGGREGATE LEVY SUSTAINABILITY FUND (MALSF). 2010. East Coast Regional Environmental Characterisation preliminary data. www.marinealsf.org.uk.	Survey data to set an environmental characterisation of the seafloor at a large regional scale.
Defra (2011) 1 arc second Digital Elevation Model	Bathymetric data used to map base of sandbanks

Reference	Description
SEIDERER, L.J., 2005. Government View Application - Area 202: Cross Sands Extension. An update of the Environmental Statement - 5 years post-dredging. Prepared for Hanson Aggregates Marine Limited by Marine Ecological Surveys Ltd.	Survey of aggregate site.
WORSFORD, T.M. & DYER, M.F., 2005. Benthic ecology of Scroby Sands windfarm site: results of July 2005 (post-construction) survey and comparison with 1998 (pre-construction) survey. Unicomarine Report EONSCR05 to E.On UK Renewables Offshore Wind Ltd.	Offshore windfarm monitoring report.

Appendix III

Power analysis of grab samples from sandy sediments – by Jon Barry (Cefas statistician)

The idea is to compare the diversity of communities in a sandy area with those in a 'peaks and troughs' area. I have chosen to use abundance and richness (number of species) per grab as parameters of diversity.

I have data from 158 grabs collected from a sandy area. For each grab I have calculated the abundance and richness. To calculate the power of detecting differences in abundance or diversity between the sandy area and the peaks and troughs area, I have assumed that data from the peaks and troughs area would be increased / decreased by some factor difference, but that the shape of the distribution would be the same apart from this. I have had to make this assumption as there is no data from the peaks / troughs area.

Figures A1 and A2 show power plots for richness and abundance per grab as a function of sample size (this is the number of grabs taken from each area – e.g. six from one area and six from the other); there are separate lines for different values of the difference between the means of the two distributions.

The power is calculated as follows (I have used abundance to illustrate this, but the same procedure applies for richness). A random sample with replacement of size N is taken from the abundance per grab data. A second random sample of size N with replacement is then taken, but a value "difference" is added to each of these observations. The two samples are then compared using a Wilcoxon non-parametric test using the function *wilcox.test* in the statistical package R. This whole procedure is repeated 1000 times. The power is the proportion of times that the Wilcoxon test is statistically significant at the 5% level (two-sided test).

I used a Wilcoxon test and sampling from the actual data because both sets of data had a skewed distributed and so I thought it best to sample from the actual distribution rather than from some theoretical distribution.

Figure A1 shows the power plots for richness. Thus, for example, if sample size was about 12, then you would have a 90% chance of detecting a difference of 30. Figure A2 shows the power plots for abundance. Here, we need a sample size of 15 in each area to have a 90% chance of detecting a difference of 200.

A summary of richness and abundance per grab is shown below.

	Richness	Abundance
Minimum	1	2
1st quartile	9	15
Median	15	31
Mean	23.9	198.6
3rd quartile	29.8	154
Maximum	103	4678

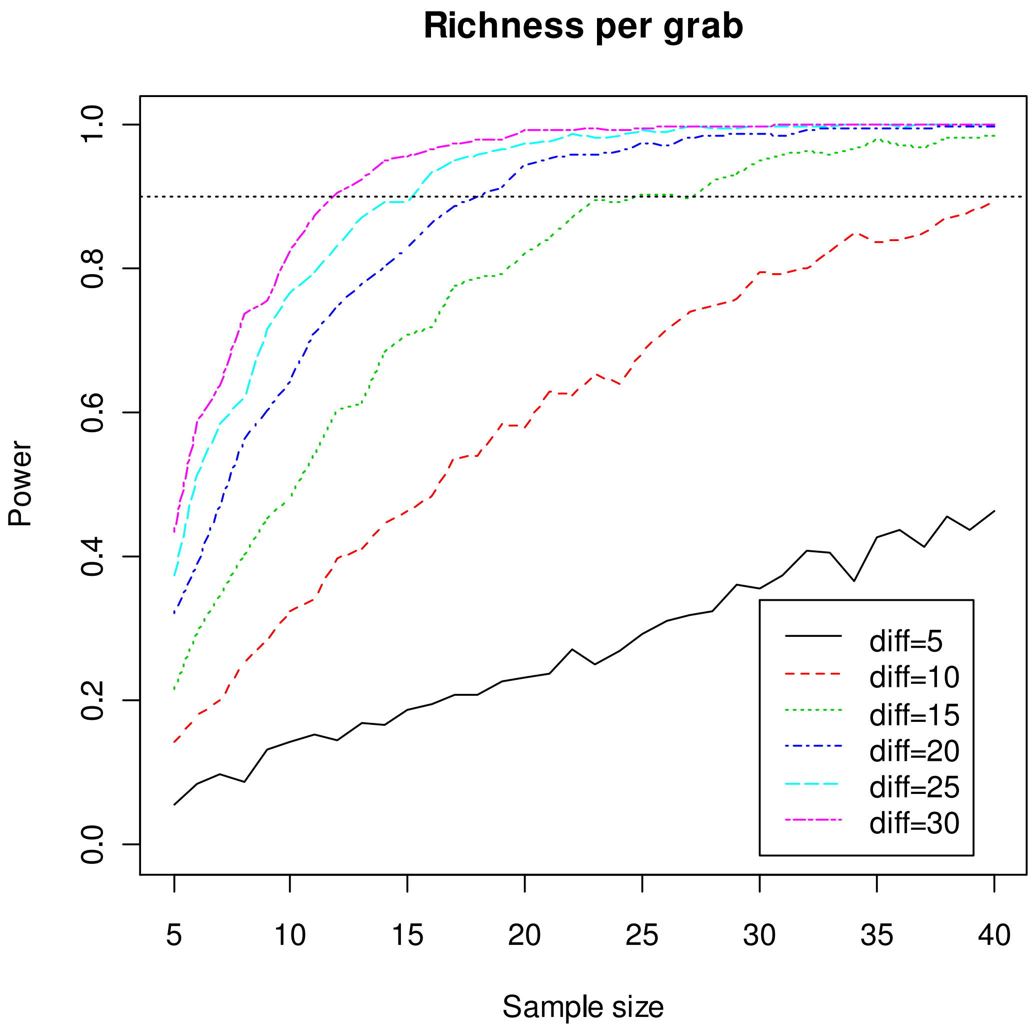

Figure A1: Power probabilities as a function of levels of mean difference (diff) and sample size for richness per grab.

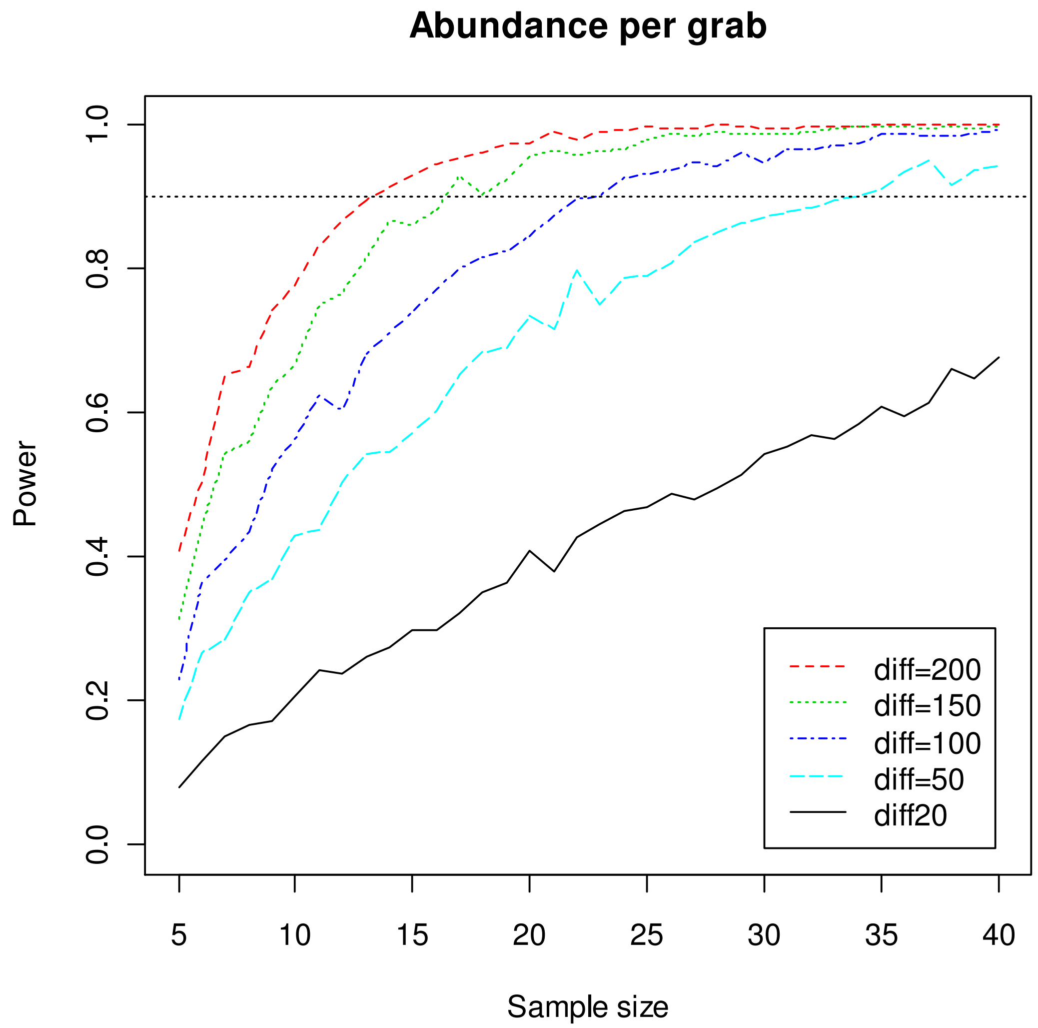

Figure A2: Power probabilities as a function of levels of mean difference (diff) and sample size for abundance per grab (soft substrate).

Appendix IV

Relative contribution of taxa to the similarity within each of the three principal epifaunal assemblages identified across HHW and IDRBNR cSACs, as produced by a SIMPER routine. Assemblages represented by a single sample cannot be displayed as part of this output. Colour coding denotes relative contribution to similarity (red: high; yellow: medium; green: low).

	Epifaunal assemblage		
Taxon	**e**	**f**	**g**
BRYOZOA	1.0	1.0	1.0
Flustra foliacea	1.0	1.0	1.0
Pagurus bernhardus	0.4	1.0	1.0
Alcyonidium diaphanum	1.0	0.5	0.9
Halecium	1.0	0.7	1.0
Balanus	0.6	0.7	0.2
Urticina	1.0	1.0	1.0
CONICA	1.0	0.8	1.0
Asterias rubens	0.4	1.0	1.0
Bowerbankia	1.0	0.8	1.0
Sabellaria spinulosa	0.8	1.0	1.0
Sertularia	1.0	1.0	0.7
Lanice conchilega	1.0	0.3	0.6
Sagartia troglodytes		1.0	0.8
Crossaster papposus	0.4	0.7	1.0
Tubulariidae	0.2	0.8	0.8
Liocarcinus	1.0	0.8	1.0
ASCIDIACEA	1.0	0.7	0.7
Nemertesia antennina	1.0	1.0	0.3
Carcinus maenas		0.8	0.4
Hydrallmania falcata	1.0		0.4
Cancer pagurus	0.4	0.7	0.8
PORIFERA	0.2	0.8	0.8
Vesicularia spinosa	0.2	0.7	0.9
Necora puber	0.6	0.5	0.4
Nemertesia ramosa	0.6	0.7	0.2
Callionymus lyra	0.4		0.6
Limanda limanda	0.2	0.7	
Ophiura	0.2	0.5	0.7
Pandalus montagui	0.2	0.3	0.7
Gadidae		0.3	0.3
Agonus cataphractus	0.2		0.3
Spirobranchus	0.2	0.2	0.6
Sagartia elegans		1.0	0.8
Nemertesia			0.8
Sabella pavonina	0.4		0.8
Cerianthus lloydii		1.0	0.1
Hydroides		0.8	0.2
NUDIBRANCHIA	0.8		0.1
Henricia			0.3
Ammodytidae		0.2	
Aeolidia papillosa			0.1
Sagartiogeton undatus		0.3	0.2
Ebalia		0.2	0.2
Macropodia		0.2	0.2
Lacuna crassior	0.2		0.1

	Epifaunal assemblage		
Taxon	**e**	**f**	**g**
Mya truncata		0.2	0.1
Alcyonium digitatum		1.0	
Acanthodoris pilosa	0.6		
Galathea intermedia			0.6
Eucratea loricata		0.5	
Trigla lucerna		0.5	
Cereus pedunculatus			0.3
Electra pilosa		0.3	
Flabellinidae		0.3	
Halichondria		0.3	
Ophiothrix fragilis		0.3	
Taurulus bubalis		0.3	
Gibbula tumida			0.2
Inachus			0.2
Mytilus edulis			0.2
Corallinaceae	0.2		
Aequipecten opercularis		0.2	
Doto		0.2	
Hyas		0.2	
Pholis gunnellus		0.2	
Scyliorhinus canicula		0.2	
Suberites		0.2	
Aulactinia verrucosa			0.1
Botryllus schlosseri			0.1
Crangon crangon			0.1
Gibbula cineraria			0.1
Gobiidae			0.1
Homarus gammarus			0.1
Janolus cristatus			0.1
Nucella lapillus			0.1
Pisidia longicornis			0.1
Plumularia setacea			0.1
Scypha ciliata			0.1

Relative abundance of infaunal taxa (square-root transformed) to the similarity within each of the treatments sampled across HHW and IBRDNR cSACs as produced by a SIMPER routine. Colour coding denotes relative contribution to similarity (red: high; yellow: medium; green: low).

	Treatment			
Taxa	Crest	Flank	Reef	Trough
Sabellaria spinulosa	0.12	0.02	16.86	3.91
Mytilus edulis	0.21	0.03	5.95	2.50
Polycirrus	0.05	0.17	4.22	3.19
Abra alba	0.04	0.05	3.51	2.09
NEMERTEA	0.14	0.09	3.30	1.85
Lumbrineris gracilis	0.17	0.11	3.02	1.94
Dipolydora caulleryi		0.02	3.21	1.60
Harmothoe impar	0.08		2.95	1.52
Lanice conchilega	0.02	0.03	2.60	1.83
Balanus crenatus		0.02	0.22	3.88
Amphipholis squamata	0.03	0.07	2.16	1.66
Ophiura albida	0.14	0.43	1.63	1.63
Pholoe baltica	0.05	0.02	2.10	1.25
Spio armata	0.31	0.38	1.85	0.86
Mya truncata	0.02		1.97	1.19
Eumida sanguinea			1.74	1.18
Kurtiella bidentata	0.02		0.99	1.90
Golfingia elongata			1.63	1.27
Protodorvillea kefersteini			1.89	0.97
Mediomastus fragilis	0.02		1.53	1.28
Nucula nucleus	0.02		0.99	1.80
Nephtys cirrosa	1.09	1.21	0.08	0.37
Aonides paucibranchiata			1.90	0.77
Nymphon brevirostre		0.02	1.57	1.08
Scoloplos armiger	0.09	0.16	1.25	1.06
Ampelisca diadema	0.05		1.52	0.87
NEMATODA	0.06		0.91	1.44
Urothoe elegans	0.06	0.12	1.83	0.37
Ophelia borealis	0.73	0.78	0.34	0.53
Bodotria scorpioides	0.02	0.02	1.67	0.58
Glycera lapidum		0.03	1.51	0.74
Pholoe inornata	0.02		1.29	0.97
ASCIDIACEA	0.02	0.02	1.13	1.06
Pisidia longicornis		0.05	1.13	1.03
Autolytus			1.08	1.11
Anaitides maculata		0.02	1.34	0.63
Eunereis longissima	0.05		1.24	0.69
Lagis koreni	0.02		1.17	0.74
Notomastus	0.17	0.02	0.60	1.03
Spiophanes bombyx	0.31	0.18	0.57	0.56
Cirriformia tentaculata			0.94	0.59
Achelia echinata			0.69	0.83
Lepidonotus squamatus			0.93	0.59
Syllis armillaris		0.02	1.15	0.32
Scalibregma inflatum	0.02		0.57	0.89
Caulleriella alata			0.86	0.56
Sabellidae	0.02		0.38	0.99
Dipolydora coeca		0.02	0.60	0.75
Phoronis			0.67	0.68
Lacuna crassior	0.07	0.05	1.08	0.10
Caprella linearis	0.02		0.43	0.85
Spio martinensis	0.03		0.64	0.62
Nephasoma minutum			0.58	0.64
Leptocheirus pectinatus			1.00	0.20
Nephtys caeca	0.11	0.07	0.65	0.36
Bathyporeia elegans	0.32	0.51	0.03	0.30
Sphaerosyllis taylori			0.97	0.19
Eteone longa	0.07	0.03	0.46	0.58
Urothoe brevicornis	0.31	0.53	0.02	0.27
Eulalia bilineata			0.55	0.58
Nereimyra punctata			0.56	0.56
Thelepus cincinnatus			0.68	0.40
Gastrosaccus spinifer	0.46	0.32	0.16	0.12
Nicolea venustula			0.78	0.28

	Treatment			
Taxa	Crest	Flank	Reef	Trough
Galathowenia oculata	0.02		0.82	0.21
Gibbula tumida		0.02	0.56	0.47
Dendrodoa grossularia			0.17	0.87
Galathea intermedia			0.59	0.45
Psamathe fusca			0.43	0.61
Unciola crenatipalma			0.59	0.42
Stenothoe marina			0.50	0.50
Asteroidea			0.65	0.33
Cirratulus incertus			0.91	0.07
Sabella pavonina		0.02	0.63	0.33
Parapleustes bicuspis	0.03		0.71	0.23
Ampelisca spinipes	0.04	0.02	0.61	0.28
Laonice bahusiensis			0.66	0.28
Hiatella arctica			0.54	0.36
Exogone naidina			0.61	0.27
Malmgreniella arenicolae			0.43	0.42
Rissoa interrupta			0.75	0.09
Pomatoceros lamarcki			0.23	0.59
Owenia fusiformis	0.02		0.58	0.19
Exogone verugera			0.73	0.05
Nereis zonata			0.60	0.18
Tanaopsis graciloides			0.32	0.46
Crossaster papposus			0.31	0.46
Onoba semicostata			0.29	0.48
TURBELLARIA			0.26	0.51
Crepidula fornicata			0.38	0.38
Pseudoprotella phasma			0.27	0.49
Goodallia triangularis		0.56	0.03	0.16
Anoplodactylus petiolatus	0.03		0.13	0.59
Golfingia vulgaris			0.52	0.22
Aphelochaeta marioni			0.34	0.39
Axionice maculata			0.48	0.24
Cuthona			0.41	0.31
Glycera oxycephala	0.20	0.34		0.17
Amphicteis midas			0.50	0.21
Callipallene			0.22	0.49
Ensis	0.56		0.05	0.08
Haustorius arenarius	0.47	0.11		0.11
Harmothoe extenuata	0.02		0.44	0.21
Gnathia oxyuraea			0.54	0.12
Poecilochaetus serpens	0.02		0.40	0.23
Sthenelais boa			0.40	0.23
Clymenura			0.45	0.16
Ascidiella scabra			0.55	0.05
Leptocheirus hirsutimanus		0.04	0.34	0.19
Molgula			0.50	0.07
Pilumnus hirtellus			0.33	0.24
Gattyana cirrhosa			0.18	0.37
Harpinia pectinata			0.33	0.21
Jupiteria minuta			0.46	0.07
Ampharete lindstroemi	0.02		0.20	0.30
Doto			0.22	0.30
Eurydice spinigera	0.19	0.18	0.05	0.09
Phtisica marina			0.08	0.43
Gammaropsis maculata			0.09	0.41
Gibbula cineraria			0.24	0.25
Musculus discors			0.36	0.13
Syllis			0.46	0.02
Monocorophium sextonae				0.47
Pseudopolydora pulchra	0.02		0.17	0.27
ENTEROPNEUSTA			0.29	0.17
Molgula manhattensis			0.29	0.17
Eumida bahusiensis		0.03	0.17	0.25
Abra prismatica	0.03	0.03	0.30	0.09

Taxa	Treatment			
	Crest	Flank	Reef	Trough
Spirobranchus lamarcki			0.12	0.31
Spio goniocephala	0.17	0.10		0.15
Eulalia viridis			0.07	0.34
Syllides			0.29	0.12
Chaetozone zetlandica			0.16	0.24
Goniada maculata			0.21	0.19
Grania			0.34	0.06
Lucinoma borealis			0.37	0.03
Scalibregma celticum			0.19	0.21
Sphaerodorum gracilis			0.21	0.18
Syllis variegata			0.30	0.07
Ensis arcuatus		0.02	0.32	0.02
Malmgrenia arenicolae		0.02	0.11	0.23
Ophiothrix fragilis			0.23	0.12
Polycarpa fibrosa			0.16	0.19
Pagurus bernhardus	0.02	0.02	0.17	0.13
Aphelochaeta			0.19	0.15
Tapes rhomboides			0.16	0.18
Nicolea				0.33
Rissoa parva			0.22	0.11
Amphilochus neapolitanus			0.21	0.12
Modiolus modiolus			0.13	0.19
Nymphon hirtum			0.26	0.06
Praxillella affinis			0.15	0.17
Eusyllis blomstrandi			0.21	0.10
Noemiamea dolioliformis			0.25	0.06
Eulalia mustela			0.15	0.14
Gammaropsis cornuta			0.23	0.05
Procerastea			0.09	0.19
COPEPODA		0.03	0.20	0.03
Exogone hebes			0.21	0.05
Nephtys kersivalensis	0.02		0.04	0.20
Scolelepis bonnieri	0.20	0.05		0.01
Verruca stroemia	0.03		0.04	0.19
Cancer pagurus	0.02		0.19	0.04
Magelona johnstoni	0.02	0.22		0.01
Onchidoris muricata			0.03	0.22
Chaetozone christiei	0.02	0.09	0.08	0.05
Crassicorophium crassicorne			0.23	
Phisidia aurea			0.23	
Nephtys longosetosa	0.11	0.07		0.05
Bathyporeia pelagica	0.10	0.07	0.02	0.03
Cheirocratus assimilis		0.02	0.11	0.09
Euzonus flabelligerus		0.13		0.09
Fabricia stellaris			0.02	0.20
Leptochiton asellus				0.22
Montacuta substriata			0.09	0.13
Orchomenella nana		0.02	0.17	0.03
Anomiidae			0.05	0.16
Anaitides groenlandica			0.12	0.09
Mysta picta			0.12	0.09
Syllis cornuta			0.17	0.03
Travisia forbesii	0.02	0.03	0.03	0.12
Asterias rubens			0.02	0.18
Demonax			0.18	0.02
Buccinum undatum			0.13	0.06
Minuspio cirrifera			0.18	0.01
Paraonis fulgens	0.17	0.02		
Anaitides mucosa	0.02		0.13	0.03
Aphelochaeta sp.A			0.13	0.05
Hypereteone foliosa		0.02	0.03	0.13
Proceraea			0.08	0.10
Spisula solida		0.09	0.08	0.01
Timoclea ovata			0.11	0.07
Terebellides stroemi			0.14	0.03
Eulalia expusilla			0.09	0.08
Harmothoe pagenstecheri			0.09	0.08
Hydroides norvegica	0.02			0.15
Venerupis senegalensis			0.08	0.09

Taxa	Treatment			
	Crest	Flank	Reef	Trough
Aricidea minuta		0.02	0.10	0.04
Atylus falcatus	0.03	0.11		0.02
Pandalus montagui			0.12	0.04
Tryphosella sarsi			0.09	0.07
Parvicardium ovale	0.02		0.10	0.03
Pseudopotamilla reniformis			0.05	0.10
Hinia incrassata				0.15
Photis pollex			0.11	0.04
Caprella septentrionalis				0.14
Eunereis sp.A			0.05	0.09
Jassa				0.14
Philine			0.13	0.01
Asclerocheilus intermedius			0.02	0.12
Ebalia tuberosa			0.10	0.03
Gammarellus homari	0.02		0.06	0.05
Liocarcinus depurator			0.03	0.10
Serpulidae			0.03	0.10
Melinna elisabethae	0.02		0.05	0.05
Oenopota rufa			0.10	0.02
Paradoneis lyra			0.05	0.07
Dendronotus frondosus			0.09	0.03
Nicolea zostericola			0.09	0.03
Pusillina inconspicua				0.12
Schistomeringos neglecta			0.03	0.09
Epitonium clathratulum			0.07	0.04
Harmothoe clavigera			0.07	0.04
Amphilochus manudens			0.03	0.08
Anobothrus gracilis			0.10	0.01
Atylus swammerdamei	0.03	0.03	0.05	
Ericthonius punctatus				0.11
Inachus	0.02			0.09
Jasmineira elegans			0.09	0.02
Trichobranchus glacialis			0.09	0.02
Cirriformia				0.10
Euspira pulchella		0.03	0.03	0.04
Jassa pusilla			0.05	0.05
Paguridae				0.10
Pherusa flabellata			0.05	0.05
Pherusa plumosa			0.03	0.07
Scolelepis squamata	0.07	0.02		0.01
Spisula elliptica			0.10	
Thoralus cranchii			0.02	0.08
Thracia villosiuscula			0.06	0.04
Urothoe marina				0.10
Pseudoparatanais batei			0.02	0.07
Acidostoma obesum			0.06	0.03
Aeolidiidae				0.09
Aora gracilis				0.09
Ensis ensis			0.08	0.01
Maldanidae	0.03		0.06	
Pygospio elegans			0.05	0.04
Spio filicornis		0.05	0.03	0.01
Tharyx killariensis			0.05	0.04
Tmetonyx			0.03	0.06
Abludomelita obtusata		0.02	0.02	0.04
Amaeana trilobata			0.08	
Anaitides lineata			0.08	
Aonides oxycephala			0.02	0.06
Ebalia tumefacta			0.06	0.02
Harpinia crenulata			0.08	
Macropodia rostrata			0.05	0.03
Pleurocrypta porcellanae			0.07	0.01
Tapes				0.08
Cheirocratus intermedius				0.07
Cheirocratus sundevallii			0.04	0.03
Chone filicaudata			0.05	0.02
Cirratulus			0.02	0.05
Echinidea			0.05	0.02
Eurydice truncata	0.07			

Taxa	Treatment			
	Crest	Flank	Reef	Trough
Maerella tenuimana	0.02	0.02		0.03
Notodelphys			0.07	
SPATANGOIDA		0.07		
Tellimya ferruginosa		0.07		
Terebellidae		0.05	0.02	
Urothoe pulchella		0.07		
Corystes cassivelaunus		0.03	0.03	0.01
Echinocardium cordatum		0.06		0.01
Macropodia parva			0.06	0.01
Edwardsiidae		0.02	0.03	0.01
Pontocrates arenarius	0.03	0.02		0.01
Cerianthus lloydii			0.02	0.04
Chone			0.06	
Chrysallida interstincta			0.06	
Nebalia herbstii			0.02	0.04
Ophelina acuminata			0.02	0.04
Tubificoides amplivasatus				0.06
Cancerilla tubulata			0.03	0.02
Demonax cambrensis			0.02	0.03
Eudorella truncatula			0.03	0.02
Hippomedon denticulatus		0.03		0.02
Leucothoe incisa				0.05
Magelona mirabilis	0.02	0.02		0.01
Microphthalmus				0.05
Parapleustes assimilis			0.02	0.03
Podarkeopsis capensis	0.02		0.02	0.01
Prodajus ostendensis	0.02	0.03		
THORACICA			0.02	0.03
Tubificoides pseudogaster			0.02	0.03
Acidostoma neglectum			0.02	0.02
Anoplodactylus pygmaeus				0.04
Bathyporeia guilliamsoniana		0.02	0.02	
Bodotria arenosa	0.02			0.02
Chrysallida pellucida			0.03	0.01
Circeis spirillum			0.04	
Cucumariidae			0.02	0.02
Dosinia			0.02	0.02
Dyopedos monacanthus			0.02	0.02
Eubranchus			0.02	0.02
Eulalia ornata			0.04	
Glycinde nordmanni			0.02	0.02
Levinsenia gracilis		0.02	0.02	
Limnodriloides			0.03	0.01
Megaluropus agilis		0.03		0.01
Odontosyllis fulgurans			0.03	0.01
Ophiopholis aculeata			0.03	0.01
Ophryotrocha			0.02	0.02
Orbinia sertulata		0.02	0.02	
Parametaphoxus fultoni			0.03	0.01
Perioculodes longimanus			0.03	0.01
Polydora ciliata			0.03	0.01
Portumnus latipes	0.02			0.02
Retusa obtusa			0.02	0.02
Scolelepis foliosa			0.03	0.01
Semierycina nitida			0.02	0.02
Sepiolidae				0.04
Socarnes erythrophthalmus				0.04
Spiophanes kroyeri			0.02	0.02
Synchelidium maculatum			0.02	0.02
Amblyosyllis formosa				0.03
Anapagurus hyndmanni			0.03	
Aphrodita aculeata			0.03	
Astarte sulcata			0.02	0.01
Atherospio guillei				0.03
Bopyridae				0.03
Capitella				0.03
Caprella tuberculata				0.03
Diastylis bradyi		0.03		
Dodecaceria				0.03

Taxa	Treatment			
	Crest	Flank	Reef	Trough
Eualus pusiolus			0.02	0.01
Eurynome				0.03
Flabellinidae			0.02	0.01
Gammaropsis palmata			0.03	
Goniodoris nodosa				0.03
Heteranomia squamula				0.03
Hippolyte varians			0.02	0.01
Hippolytidae			0.02	0.01
Iphimedia minuta			0.02	0.01
Liocarcinus pusillus			0.02	0.01
Marphysa bellii			0.02	0.01
Medicorophium affine			0.03	
Modiolarca tumida			0.03	
Nereididae				0.03
Pachypygus gibber			0.03	
Palliolum striatum			0.02	0.01
Pirimela denticulata			0.03	
Pseudocuma longicornis			0.02	0.01
Sphaerosyllis bulbosa		0.02		0.01
Sphaerosyllis erinaceus			0.03	
Sphenia binghami			0.02	0.01
Spio decorata			0.02	0.01
Stenula rubrovittata			0.02	0.01
Thyone fusus			0.02	0.01
Tritonia				0.03
Anaitides rosea			0.02	
Anapagurus laevis			0.02	
APPENDICULARIA				0.02
Arctica islandica			0.02	
Arenicolidae				0.02
Argissa hamatipes			0.02	
Ascidicola rosea			0.02	
Atylus vedlomensis				0.02
Bonnierilla			0.02	
Caprella acanthifera			0.02	
Chaetoderma nitidulum			0.02	
Chaetozone setosa			0.02	
Cirratulus cirratus			0.02	
Cressa dubia				0.02
Ebalia cranchii			0.02	
Ehlersia ferrugina			0.02	
Embletonia pulchra				0.02
Eudorellopsis deformis			0.02	
Eulalia aurea				0.02
Eusyllis assimilis			0.02	
Fabulina fabula		0.02		
Facelina				0.02
Flabelligera affinis				0.02
Gammaridae			0.02	
Glycera alba			0.02	
Hyala vitrea			0.02	
Hyas coarctatus			0.02	
Kellia suborbicularis				0.02
Lacuna vincta			0.02	
Laonome			0.02	
Leptopentacta elongata			0.02	
Luidia sarsi			0.02	
Lysianassa ceratina				0.02
Malacoceros vulgaris			0.02	
Malmgrenia mcintoshi			0.02	
Microprotopus maculatus			0.02	
Monticellina	0.02			
Myodocopida			0.02	
Mysta barbata			0.02	
Neopentadactyla mixta			0.02	
Neotaenioglossida	0.02			
Nymphon gracile			0.02	
Oenopota turricula			0.02	
Ophiodromus pallidus				0.02

	Treatment			
Taxa	Crest	Flank	Reef	Trough
Opisthodonta pterochaeta		0.02		
Orbinia			0.02	
Palio dubia			0.02	
Paramunna bilobata				0.02
Pariambus typicus			0.02	
Partulida pellucida			0.02	
Parvicardium scabrum			0.02	
Pectinidae			0.02	
Phaxas pellucidus			0.02	
Photis longicaudata				0.02
Phoxocephalus holbolli			0.02	
Pisione remota				0.02
Polygordius	0.02			
Pontocrates altamarinus			0.02	
Psammechinus miliaris				0.02
Pseudomystides limbata			0.02	
Pseudonotomastus southerni		0.02		
Pterocirrus macroceros			0.02	
Pycnogonum littorale			0.02	
Raphitoma linearis			0.02	
Saccocirrus papillocercus		0.02		
Schistomeringos rudolphi		0.02		
Scolelepis korsuni				0.02
Sphaerosyllis tetralix			0.02	
Syllis gracilis				0.02
Tornus subcarinatus				0.02
Trichobranchus roseus			0.02	
Velutina velutina				0.02
Acanthodoris pilosa				0.01
Aequipecten opercularis				0.01
Ammodytes				0.01
Antalis entalis				0.01
Aricidea cerrutii				0.01
Ascidiella aspersa				0.01
Baffinia hesslei				0.01
Barnea candida				0.01
Callianassa subterranea				0.01
Cochlodesma praetenue				0.01
Coryphella				0.01
Dipolydora quadrilobata				0.01
Ebalia				0.01
Endeis spinosa				0.01
Ericthonius				0.01
Eupolymnia nebulosa				0.01
Eupolymnia nesidensis				0.01
Gari tellinella				0.01
Hyas araneus				0.01
Iphimedia obesa				0.01
Lamellaria perspicua				0.01
Maera othonis				0.01
Myriochele				0.01
Nebalia reboredae				0.01
Neoamphitrite figulus				0.01
Nephtys hombergii				0.01
Ocenebra erinacea				0.01
Ocnus planci				0.01
Ophiactis balli				0.01
Phascolosoma granulatum				0.01
Procerastea halleziana				0.01
Pseudopolydora paucibranchiata				0.01
Pyura tessellata				0.01
Schistomysis				0.01
Scoletoma magnidentata				0.01
Siphonoecetes kroyeranus				0.01
Spirobranchus triqueter				0.01
Spisula				0.01
Stenopleustes nodifer				0.01
Stenothoe tergestina				0.01
Streptosyllis websteri				0.01
Tridonta montagui				0.01
Trivia				0.01
Trypanosyllis coeliaca				0.01
Upogebia deltaura				0.01
Websterinereis glauca				0.01
Total no. of taxa	**86**	**90**	**346**	**393**
Total relative abundance	**8.69**	**9**	**141.41**	**99.24**

Appendix V

Classification of sediments from available sampling sites according to the Folk and EUNIS sediment classification systems.

Sample code	Folk symbol	EUNIS classification
DSHG01	gS	coarse
DSHG02	gmS	mixed
DSHG03	gS	coarse
DSHG04	gS	coarse
DSHG05	sG	coarse
DSHG06	gS	coarse
DSHG07	gS	coarse
DSHG08	gS	coarse
DSHG09	gS	coarse
DSHG10	msG	mixed
DSHG11	msG	mixed
DSHG12	sG	coarse
DSHG13	gmS	mixed
DSHG14	gmS	mixed
DSHG15	gS	coarse
ENR01	gS	coarse sediment
ENR02	(g)S	sand and muddy sand
ENR03	(g)S	sand and muddy sand
ENR04	(g)S	sand and muddy sand
ENR05	gS	coarse sediment
ENR06	gS	coarse sediment
ENR07	(g)S	sand and muddy sand
ENR08	S	sand and muddy sand
ENR09	gS	coarse sediment
ENR10	gS	coarse sediment
ENR11	gS	coarse sediment
ENR12	(g)S	sand and muddy sand
ENR13	gS	coarse sediment
ENR14	(g)S	sand and muddy sand
ENR15	gS	coarse sediment
HGR1-01	gS	coarse
HGR1-02	gS	coarse
HGR1-03	gS	coarse
HGR1-04	sG	coarse
HGR1-05	gS	coarse
HGR1-06	gS	coarse
HGR1-07	gS	coarse
HGR1-08	gS	coarse
HGR1-09	gS	coarse
HGR1-10	gS	coarse
HGR1-11	gS	coarse
HGR1-12	gS	coarse
HGR1-13	gS	coarse
HGR1-14	gS	coarse
HGR1-15	gS	coarse
HHW001	gS	coarse sediment
HHW002	(g)S	sand and muddy sand
HHW003	S	sand and muddy sand
HHW004	S	sand and muddy sand
HHW005	gS	coarse sediment
HHW006	S	sand and muddy sand
HHW007	gS	coarse sediment
HHW008	S	sand and muddy sand
HHW009	(g)S	sand and muddy sand
HHW010	S	sand and muddy sand
HHW011	S	sand and muddy sand
HHW012	S	sand and muddy sand
HHW013	S	sand and muddy sand
HHW014	S	sand and muddy sand
HHW015	S	sand and muddy sand
HHW016	S	sand and muddy sand
HHW017	(g)S	sand and muddy sand
HHW018	gS	coarse sediment
HHW019	S	sand and muddy sand
HHW020	S	sand and muddy sand
HHW021	S	sand and muddy sand
HHW022	S	sand and muddy sand
HHW023	S	sand and muddy sand
HHW024	S	sand and muddy sand
HHW025	S	sand and muddy sand
HHW026	S	sand and muddy sand
HHW027	S	sand and muddy sand
HHW028	S	sand and muddy sand
HHW029	S	sand and muddy sand
HHW030	S	sand and muddy sand
HHW031	sG	coarse sediment
HHW032	gS	coarse sediment
HHW033	gmS	mixed sediments
HHW034	gS	coarse sediment
HHW035	gmS	mixed sediments
HHW036	msG	mixed sediments
HHW037	gS	coarse sediment
HHW038	gS	coarse sediment
HHW039	gmS	mixed sediments
HHW040	gmS	mixed sediments
HHW041	gS	coarse sediment
HHW042	gS	coarse sediment
HHW043	gS	coarse sediment
HHW044	gS	coarse sediment
HHW045	gS	coarse sediment
HHW076	S	sand and muddy sand
HHW077	S	sand and muddy sand
HHW078	(g)S	sand and muddy sand
HHW079	S	sand and muddy sand
HHW080	S	sand and muddy sand
HHW081	S	sand and muddy sand
HHW082	S	sand and muddy sand
HHW083	S	sand and muddy sand
HHW084	(g)S	sand and muddy sand
HHW085	S	sand and muddy sand
HHW086	S	sand and muddy sand
HHW087	S	sand and muddy sand
HHW088	S	sand and muddy sand
HHW089	S	sand and muddy sand
HHW090	S	sand and muddy sand
HHW091	(g)S	sand and muddy sand

Sample code	Folk symbol	EUNIS classification
HHW092	S	sand and muddy sand
HHW093	S	sand and muddy sand
HHW094	S	sand and muddy sand
HHW095	S	sand and muddy sand
HHW096	S	sand and muddy sand
HHW097	gS	coarse sediment
HHW098	S	sand and muddy sand
HHW099	S	sand and muddy sand
HHW100	S	sand and muddy sand
HHW101	S	sand and muddy sand
HHW102	(g)S	sand and muddy sand
HHW103	S	sand and muddy sand
HHW104	S	sand and muddy sand
HHW105	(g)S	sand and muddy sand
HSWON01	S	sand and muddy sand
HSWON02	S	sand and muddy sand
HSWON03	S	sand and muddy sand
HSWON04	S	sand and muddy sand
HSWON05	S	sand and muddy sand
HSWON06	S	sand and muddy sand
HSWON07	S	sand and muddy sand
HSWON08	S	sand and muddy sand
HSWON09	S	sand and muddy sand
HSWON10	S	sand and muddy sand
HSWON11	S	sand and muddy sand
HSWON12	S	sand and muddy sand
HSWON13	S	sand and muddy sand
HSWON14	S	sand and muddy sand
HSWON15	(g)S	sand and muddy sand
HTB01	gS	coarse
HTB02	gS	coarse
HTB03	S	sand and muddy sand
HTB04	sG	coarse
HTB05	sG	coarse
HTB06	gS	coarse
HTB07	gS	coarse
HTB08	gS	coarse
HTB09	gS	coarse
HTB10	(g)S	sand and muddy sand
HTB11	(g)S	sand and muddy sand
HTB12	sG	coarse
HTB13	gS	coarse
HTB14	(g)S	sand and muddy sand
HTB15	gS	coarse
HTD01	gS	coarse
HTD02	gS	coarse
HTD03	sG	coarse
HTD04	gS	coarse
HTD05	sG	coarse
HTD06	gS	coarse
HTD07	gS	coarse
HTD08	gS	coarse
HTD09	msG	mixed
HTD10	gS	coarse
HTD11	sG	coarse
HTD12	sG	coarse
HTD13	gS	coarse
HTD14	gS	coarse
HTD15	gS	coarse
IDEON01	msG	mixed
IDEON02	msG	mixed

Sample code	Folk symbol	EUNIS classification
IDEON03	gS	coarse
IDEON04	msG	mixed
IDEON05	sG	coarse
IDEON06	gM	mixed
IDEON07	msG	mixed
IDEON08	sG	coarse
IDEON09	sG	coarse
IDEON10	gmS	mixed
IDEON11	msG	mixed
IDEON12	gmS	mixed
IDEON13	msG	mixed
IDEON14	sG	coarse
IDEON15	gmS	mixed
IDWOFF01	gmS	mixed
IDWOFF02	msG	mixed
IDWOFF03	gmS	mixed
IDWOFF04	gM	mixed
IDWOFF05	gmS	mixed
IDWOFF06	gmS	mixed
IDWOFF07	gS	coarse
IDWOFF08	gS	coarse
IDWOFF09	gmS	mixed
IDWOFF10	gmS	mixed
IDWOFF11	gmS	mixed
IDWOFF12	msG	mixed
IDWOFF13	gmS	mixed
IDWOFF14	gM	mixed
IDWOFF15	gmS	mixed
IDWON01	gS	coarse
IDWON02	gS	coarse
IDWON03	(g)S	sand and muddy sand
IDWON04	S	sand and muddy sand
IDWON05	S	sand and muddy sand
IDWON06	S	sand and muddy sand
IDWON07	sG	coarse
IDWON08	S	sand and muddy sand
IDWON09	sG	coarse
IDWON10	(g)S	sand and muddy sand
IDWON11	S	sand and muddy sand
IDWON12	S	sand and muddy sand
IDWON13	(g)S	sand and muddy sand
IDWON14	sG	coarse
IDWON15	S	sand and muddy sand
OFFB01	gS	coarse sediment
OFFB02	gS	coarse sediment
OFFB03	gS	coarse sediment
OFFB04	gS	coarse sediment
OFFB05	gS	coarse sediment
OFFB06	gS	coarse sediment
OFFB07	gS	coarse sediment
OFFB08	gS	coarse sediment
OFFB09	sG	coarse sediment
OFFB10	gS	coarse sediment
OFFB11	gmS	mixed sediments
OFFB12	gS	coarse sediment
OFFB13	gS	coarse sediment
OFFB14	sG	coarse sediment
OFFB15	gS	coarse sediment
ONB01	(g)S	sand and muddy sand
ONB02	gS	coarse sediment
ONB03	(g)mS	mud and sandy mud

Sample code	Folk symbol	EUNIS classification
ONB04	gS	coarse sediment
ONB05	(g)S	sand and muddy sand
ONB06	gS	coarse sediment
ONB07	(g)S	sand and muddy sand
ONB08	gS	coarse sediment
ONB09	gS	coarse sediment
ONB10	gS	coarse sediment
ONB11	gS	coarse sediment
ONB12	gS	coarse sediment
ONB13	gS	coarse sediment
ONB14	gS	coarse sediment
ONB15	gS	coarse sediment
ONR01	gS	coarse sediment
ONR02	gS	coarse sediment
ONR03	gS	coarse sediment
ONR04	gS	coarse sediment
ONR05	gS	coarse sediment
ONR06	gS	coarse sediment
ONR07	gS	coarse sediment
ONR08	gS	coarse sediment
ONR09	gS	coarse sediment
ONR10	gS	coarse sediment
ONR11	gS	coarse sediment
ONR12	gS	coarse sediment
ONR13	gS	coarse sediment
ONR14	gS	coarse sediment
ONR15	gS	coarse sediment
SPEHG01	gS	coarse sediment
SPEHG02	gS	coarse sediment
SPEHG03	gS	coarse sediment
SPEHG04	gS	coarse sediment
SPEHG05	gS	coarse sediment
SPEHG06	gS	coarse sediment
SPEHG07	gS	coarse sediment
SPEHG08	gS	coarse sediment
SPEHG09	gS	coarse sediment
SPEHG10	gS	coarse sediment
SPEHG11	gS	coarse sediment
SPEHG12	gS	coarse sediment
SPEHG13	gS	coarse sediment
SPEHG14	gS	coarse sediment
SPEHG15	gS	coarse sediment
SPESAB01	gS	coarse sediment
SPESAB02	gS	coarse sediment
SPESAB03	gS	coarse sediment
WDS01	(g)S	sand and muddy sand
WDS02	(g)S	sand and muddy sand
WDS03	(g)S	sand and muddy sand
WDS04	(g)S	sand and muddy sand
WDS05	(g)S	sand and muddy sand
WDS06	(g)S	sand and muddy sand
WDS07	S	sand and muddy sand
WDS08	(g)S	sand and muddy sand
WDS09	(g)S	sand and muddy sand
WDS10	(g)S	sand and muddy sand
WDS11	(g)S	sand and muddy sand
WDS12	(g)S	sand and muddy sand
WDS13	S	sand and muddy sand
WDS14	S	sand and muddy sand
WDS15	S	sand and muddy sand

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Head office
Centre for Environment, Fisheries & Aquaculture Science
Pakefield Road, Lowestoft,
Suffolk NR33 0HT UK

Tel **+44 (0) 1502 56 2244**
Fax **+44 (0) 1502 51 3865**

Web **www.cefas.defra.gov.uk**

Centre for Environment, Fisheries & Aquaculture Science
Barrack Road, The Nothe
Weymouth, DT4 8UB

Tel **+44 (0) 1305 206600**
Fax **+44 (0) 1305 206601**

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