East Coast Marine Aggregate Regional Environmental Assessment

Benthic Ecology Survey

Job No.: J/1/03/1671

TECHNICAL REPORT

A Report for:

Anglian Offshore Dredging Association

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CONTENTS **Page**

1.0 INTRODUCTION 1

1.1 STUDY BACKGROUND 1
1.2 ANGLIAN MAREA BENTHIC SURVEY OBJECTIVES 1
1.3 REGIONAL CONTEXT 2
2.3.1 Aggregate extraction and the MAREA process 2
2.3.2 Hydrodynamics (waves, tides and currents) 3
2.3.3 Sediment processes and seabed character 3
2.3.4 Distribution of seabed habitat types 3
2.3.5 Nature conservation features 5

2.0 METHOD 6

2.1 SURVEY DESIGN 6
2.2 CURRENT SURVEY 14
2.3.1 General 14
2.3.2 Survey dates 14
2.3.3 Positioning 14
2.3.4 Drop down video 14
2.3.5 Grab sampling and onboard sampling treatment 15
2.3.6 2m beam trawling 16
2.3.7 Laboratory sample analyses 17
2.3.8 Sabellaria spinulosa video analysis 18
2.3 INTEGRATED DATASET ANALYSES 21
2.3.1 Primer analyses 21
2.3.2 Data distribution plots 23

3.0 RESULTS AND DISCUSSION 24

3.1 CURRENT AND INTEGRATED SURVEY ARRAYS 24
3.2 SEDIMENT GRAB DATA 24
3.3 MACROFAUNAL GRAB DATA40
3.4 MULTIVARIATE ASSESSMENT OF MACROFAUNAL GRAB DATA 53
3.5 ASSESSMENT OF ABIOTIC- BIOTIC RELATIONSHIPS 63
3.6 ATTRIBUTION OF BIOTOPES CLASSIFICATIONS TO GRAB SAMPLE DATA 66
3.7 VIDEO ANALYSES AND *SABELLARIA* REEF ASSESSMENT 81
3.8 2M BEAM TRAWL DATA 87

4.0 NATURE CONSERVATION 100

4.1 SPECIES AND HABITATS OF CONSERVATION IMPORTANCE 100
4.2 OTHER INTEREST FEATURES 109

5.0 CONCLUSION 112

6.0 REFERENCES 113

APPENDICES (Electronic copy only)

Appendix A	East Coast MAREA Benthic Review and Survey Plan
Appendix B	Current survey grab log and sample details
Appendix C	Current survey daily progress reports
Appendix D	Integrated dataset grab log and sample details
Appendix E	Integrated dataset particle size data
Appendix F	Current survey hyperdigital camera log
Appendix G	Current survey static image positions
Appendix H	Current survey grab deck photos
Appendix I	Current survey underwater stills
Appendix J	Current survey video footage
Appendix K	Integrated dataset infaunal raw data
Appendix L	Integrated dataset epifaunal raw data
Appendix M	Integrated dataset biomass
Appendix N	Grab diversity indices distribution plots
Appendix O	Integrated dataset grab diversity indices
Appendix P	Grab multivariate sample dendrogram
Appendix Q	Infaunal mulivariate sample groupings outliers
Appendix R	Biotope level explanation
Appendix S	Current survey video analysis (non *Sabellaria*) summary table
Appendix T	Integrated dataset trawl log and sample details
Appendix U	Integrated dataset trawl quantitative raw data
Appendix V	Integrated dataset trawl presence-absence data
Appendix W	Current survey trawl deck photos
Appendix X	Current survey trawl log and sample details
Appendix Y	Current survey trawl fish species measurements
Appendix Z	Current survey trawl shellfish species measurements
Appendix AA	Integrated dataset trawl diversity indices
Appendix AB	Trawl multivariate sample dendrogram
Appendix AC	Trawl multivariate sample groupings outliers

FIGURES

Figure 1.1	Locations of aggregate licences and application areas within the Anglian MAREA region.
Figure 2.1	Current survey positions in context of pre-existing sample locations.
Figure 2.2	Current and historic sample positions overlain on MESH habitats, Anglian MAREA region.
Figure 2.3	Current and historic samples overlain on predicted admiralty tidal extents, Anglian MAREA region.
Figure 2.4	Current and historic sample positions overlain on Electronic Monitoring System (EMS) data, Anglian MAREA region.
Figure 3.1	Current AODA survey array, Anglian MAREA region.
Figure 3.2	Integrated survey array and dredging impact zones, Anglian MAREA region.
Figure 3.3	Principal Components Analysis of selected sediment variables as indicated.
Figure 3.4	Principal sediment components distribution, Anglian MAREA region.
Figure 3.5	Sediment type distributions, based on Folk classifications, Anglian MAREA region.
Figure 3.6	MDS ordination of PSD data. Samples classified according to impact zone.
Figure 3.7	MDS ordination of PSD data. Samples classified according to depth.
Figure 3.8	MDS ordination of PSD data. Samples classified according to year.
Figure 3.9	Major taxonomic groups relative contributions to total species diversity, abundance and biomass, Anglian MAREA region.

Figure 3.10a-l Densities of selected macro-invertebrates species against Eastings, and distribution plots, Anglian MAREA region.
Figure 3.11 Total species distribution, grab data, Anglian MAREA region.
Figure 3.12 Total individuals distribution, grab data, Anglian MAREA region.
Figure 3.13 Infaunal biomass distributions, grab data, Anglian MAREA region.
Figure 3.14a Average number of grab species in each impact zone.
Figure 3.14b Average number of grab individuals in each impact zone.
Figure 3.14c Diversity indices averages for each impact zone (grab data).
Figure 3.15 MDS ordination, enumerated macrofaunal sample data, Anglian MAREA region.
Figure 3.16 Infaunal group distributions, grab data primer analyses, Anglian MAREA region.
Figure 3.17 MDS macrofaunal data ordination, samples classified according to impact zone.
Figure 3.18 Macrofaunal data MDS ordination, samples classified to year.
Figure 3.19 Dissimilarity matrix macrofaunal data MDS ordination for repeat year surveys; samples classified according to survey.
Figure 3.20 Dissimilarity matrix PSD data MDS ordination for repeat years surveys; samples classified according to survey.
Figure 3.21 Macrofaunal data MDS ordination, samples classified to Folk sediment type.
Figure 3.22 Macrofaunal data MDS ordination, samples classified to depth bands.
Figure 3.23 Non-transformed species abundance overlaid on MDS sediment grab ordination sample data.
Figure 3.24 Infaunal group biotope distributions, Anglian MAREA region.
Figure 3.25 *Sabellaria* reef distribution and sites with potential for future reef development, Anglian MAREA region.
Figure 3.26a Average number of trawl species in each impact zone.
Figure 3.26b Average number of trawl individuals in each impact zone.
Figure 3.26c Diversity indices averages for each impact zone (trawl data).
Figure 3.27 MDS ordination of the trawl faunal data for the Anglian MAREA region.
Figure 3.28 Faunal groups distribution, trawl data primer analyses, Anglian MAREA region.
Figure 3.29 MDS trawl faunal data ordination, samples classified according to survey.
Figure 3.30 MDS trawl faunal data ordination, samples classified according to impact zone.
Figure 3.31 MDS trawl faunal data ordination, samples classified according to year.
Figure 4.1 Location of *Ammodytes marinus*, Anglian MAREA region.
Figure 4.2 Location of *Clupea harengus*, Anglian MAREA region.
Figure 4.3 Location of *Gadus morhua*, Anglian MAREA region.
Figure 4.4 Location of *Raja clavata*, Anglian MAREA region.
Figure 4.5 Location of *Raja montagui*, Anglian MAREA region.
Figure 4.6 Location of *Merlangius merlangus*, Anglian MAREA region.
Figure 4.7 Location of *Obelia bidentata*, Anglian MAREA region.
Figure 4.8 Location of *Pleuronectes platessa*, Anglian MAREA region.
Figure 4.9 Location of *Solea solea*, Anglian MAREA region.
Figure 4.10 Location of *Rissoides desmaresti*, Anglian MAREA region.

Figure 4.11 Sandbank distribution within the Anglian MAREA region.

PLATES

Plate 2.1 Sea bed photographic stills equipment
Plate 2.2 Combined digital underwater video and freshwater reservoir system. 15
Plate 2.3 0.1m2 Mini-Hamon grab. 15
Plate 2.4 Deployment of the 2m beam trawl.
Plate 2.5 On board processing of the 2m beam trawl catch. 16
Plate 3.1 a-f Example sediments from the video analysis 39

Plate 3.2 a-h Typical polychaete, mollusc, echinoderm and crustacean species, Anglian MAREA region. 44
Plate 3.3 a-c Typical conspicuous fauna associated with a range of sediments within the Anglian MAREA region. 81
Plate 3.4 a-b Typical trawl samples from the current MAREA survey. 89

TABLES

Table 1.1 Marine landscape classifications and MESH habitats within the East Coast MAREA area.......... 4
Table 2.1 Historic datasets post 2002 within the Anglian MAREA integrated with data from the current AODA survey........ 7
Table 2.2 Distribution of grab and trawl sampling effort and the types of dredging impacts represented within the Anglian MAREA study area........ 13
Table 2.3 Abundance scales used for sublittoral taxa, taken from Hiscock (1996). 17
Table 2.4 Summary of *Sabellaria* characteristics based on Hendrick & Foster-Smith (2006). 19
Table 2.5 Analysis of *Sabellaria* Characteristics and Score Allocated for the Current Survey within the Anglian MAREA........ 19
Table 2.6 Range of figures proposed by participants of the JNCC 2007 workshop to be used together as a measure of reefiness........ 20
Table 2.7 Summary of test routines undertaken in PRIMER. 22
Table 3.1 Classifications of sediment samples within the Anglian MAREA survey area and summary sediment data........ 27
Table 3.2 Combined grab and trawl surveys overall taxa counts for the Anglian MAREA region. 40
Table 3.3 Grab species/higher taxa number and occurrence frequency, within major taxonomic groups, Anglian MAREA region. 41
Table 3.4 Top 30 most abundant infauna (enumerated data) and frequently occurring grab fauna (including epifaunal presence/absence data), Anglian MAREA region........ 43
Table 3.5 Summary of total species, abundance and biomass of each grab survey used for the analysis of historical data presented in this report. Abundance is the total per m^2, whilst the biomass is exprtessed as Ash free dry weight (AFDW)........ 47
Table 3.6 Multivariate sample groupings summary, enumerated grab data........ 56
Table 3.7 Results of the BIOENV analysis between abiotic variables and infaunal data. 65
Table 3.8 Biotopes within the Anglian MAREA region and associated (European Nature Information System) EUNIS codes........ 67
Table 3.9 Classification of observed biotopes from Connor *et al.* (2004)........ 68
Table 3.10a-h Physical and biological attributes of the biotopes identified........ 70
Table 3.12 Trawl species/higher taxa number and occurrence frequency, within major taxonomic groups, Anglian MAREA region. 87
Table 3.13 Top 30 most abundant and frequently occurring (combined enumerated and presence/absence data) trawl species. 88
Table 3.14 Top 30 most abundant shellfish and fish from the 2m beam trawl, showing their frequency of occurrence within the data set. 89
Table 3.15 Simper analysis summary for 2m beam trawl sample groups (square root transformed data). 95
Table 4.1 Species and habitats of importance in the Anglian MAREA region. 100

1.0 INTRODUCTION

1.1 Study background

The Anglian Offshore Dredging Association (AODA), a consortium of aggregate companies operating along the east coast, initiated a Marine Aggregate Regional Environmental Assessment (MAREA). Through establishment of baseline descriptions of the biological and physical conditions across the east coast group of aggregate licences, a process has been initiated that will inform assessment of potential cumulative and in-combination benthic impacts relating to aggregate licence applications and renewals.

Emu Ltd. undertook a Benthic Data Review and Survey Plan for AODA (Emu Ltd. 2010, report number 09/J/1/0/1469/0897) which considered available data for the region and recommended a subsequent approach to address the gaps in data and knowledge identified. Accordingly, AODA commissioned Emu Ltd. to undertake a benthic ecological survey to address the data gaps and to enhance knowledge and understanding of seabed areas that may be subject to the direct and indirect effects of current and future dredging activities.

This report details the 2010 survey undertaken in the MAREA region and presents the baseline information acquired. These data were combined with suitable historic datasets to further enhance interpretation of benthic ecological conditions in the Anglian MAREA region.

Although MAREAs are not statutory processes, the survey design has been developed in consultation with Cefas, JNCC and Natural England to ensure best practice and sufficient coverage of areas of particular interest.

Figure 1.1 below presents the extents of the Anglian region for which baseline benthic information were collected together with the locations of licensed aggregate areas and those under application.

1.2 Anglian MAREA benthic survey objectives

The surveys' principal aim was to provide a broad-scale description of the benthic communities within the potential influences of dredging, which will support a detailed regional assessment of dredging activities on benthic habitats and species within the East Coast MAREA study area.

The key objectives of the MAREA benthic ecological survey were to:

- Re-sample a limited number of historic stations for data validation purposes;
- Identify where aggregate extraction may have affected benthic species and habitats , based on data from individual licence areas, a combination of licence grounds and cumulatively over time;
- Characterise benthic communities in possible impact zones based on proposed new dredging areas;
- Establish a consistent regional benthic species and habitats dataset, based on analysis of existing and newly acquired data across the region, to assist identification of potential future change informing site-specific environmental impact assessments.

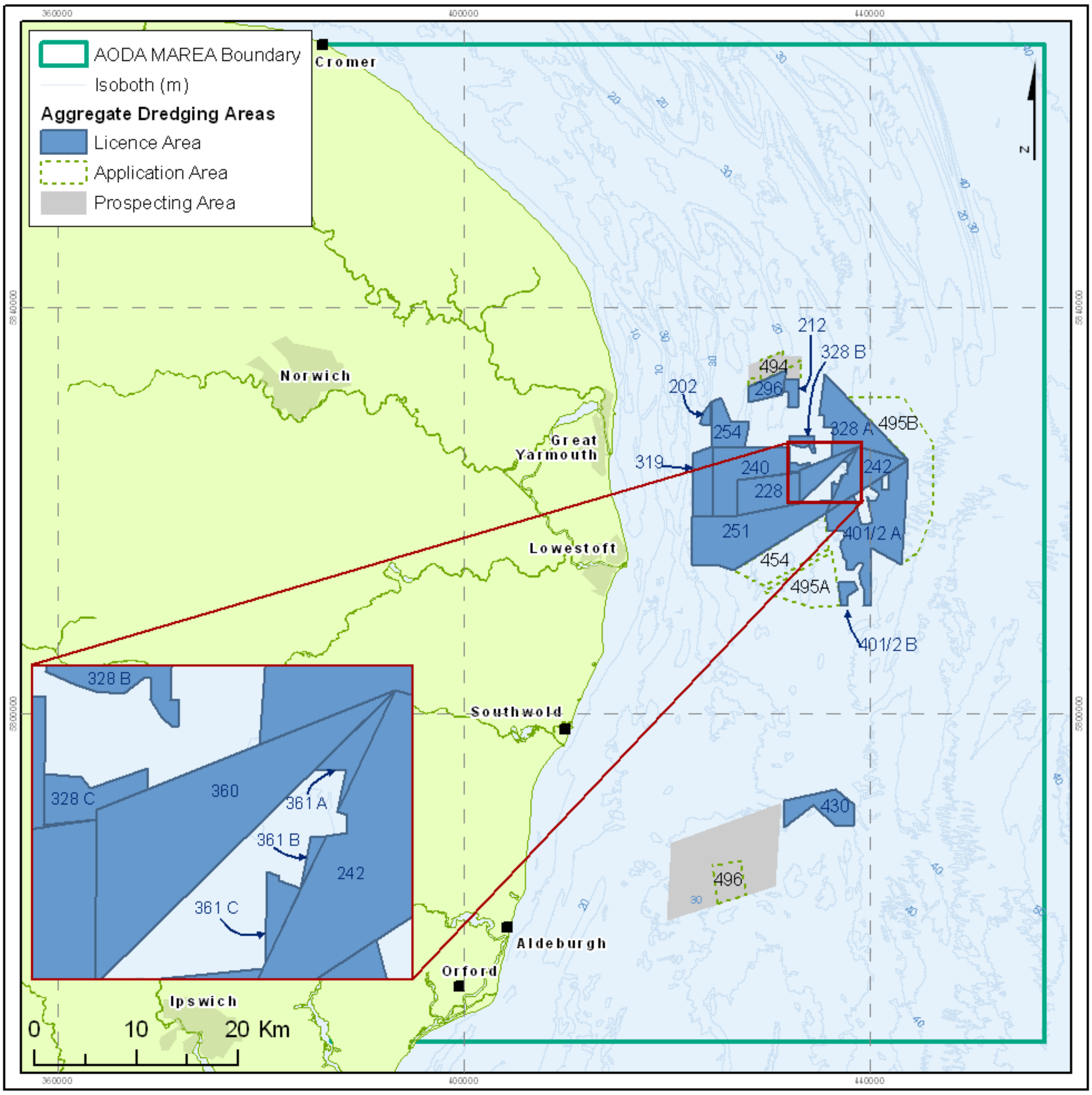


Figure 1.1 Locations of aggregate licences and application areas within the Anglian MAREA region.

1.3 Regional context

The Benthic Review and Survey Plan Report (Emu Ltd., 2010, report number 09/J/1/03/1469/0897, Appendix A) gave a detailed review of benthic environmental data in the Anglian region. In addition, the AODA MAREA Scoping Report (Emu Ltd., 2008a, report number 08/J/1/06/1302/0838) presented a regional overview of environmental data. To provide a regional benthic context, the following summarises relevant key information contained within these reports.

2.3.1 Aggregate extraction and the MAREA process

Sand and gravel have been extracted from the Anglian Offshore Region since the 1960's. Currently there are 14 licensed areas providing between eight and nine million tonnes of aggregate material each year, which comprise 30-40 per cent of total UK production (Emu Ltd., 2008b). The extraction areas will require licence renewal within the next 3 to 4 years and a further 4 applications are in progress.

It is acknowledged that aggregate extraction has potential adverse direct and indirect impacts on marine environments. Extraction licences have historically been awarded through the Government View process, with new licences subject to site specific environmental assessment procedures. However, on a regional level, where a number of individual licences are awarded and, with a history of aggregate resource winning in the region, there is concern that no effective process is in place to assess cumulative and in combination impacts. To this end, the Regional Environmental Assessment for marine aggregates (REA) process is being developed as a method comparable to Environmental Impact Assessment (EIA), but undertaken at a regional scale. Within this context, impact assessment and implications of aggregate extraction within the whole region are considered.

The East Coast has been identified as a strategic area given the timing and spatial extent of new and renewal licences. The process aims to provide a strategic level assessment as well as improving the evidence base for individual applications.

2.3.2 Hydrodynamics (waves, tides and currents)

Controlled by the narrowing of the North Sea from north to south and the marked change in coastline orientation, wave conditions vary considerably over the Anglian Offshore Region (AOR). To the North West coastal region, winds from between 325º N and 70º N can generate waves over fetch lengths of greater than 200km. Conversely, on the south west coastal region such fetch lengths can only be generated over a much narrower range of wind directions of between 20º N and 60º N.

Tidal level variations along the coastline between Lowestoft and Great Yarmouth are relatively small, with mean spring tides having a range of about 1.9m. Although weakening to the north and south, tidal currents are strong, regularly reaching in excess of 3 knots over much of the offshore part of the region.

2.3.3 Sediment processes and seabed character

At the eastern edge of the study area, the depth to seabed attains a maximum value of 30-40m. Much of the regional coastline comprises glacial till cliffs, eroding since the end of the last Ice Age (7,500 to 10,000 years B.P.). In recent centuries these cliff edges have receded at a rate of approximately 1m per year (HR Wallingford, 2008), producing substantial sediment quantities. This has subsequently been transported generally eastwards and southwards along the coastline forming barrier beaches across the valleys and areas of low land between the cliffs.

While sediment has accumulated at some locations along the coastline, producing wide beaches, much of the sand has been transported offshore to form large sandbanks (McCave, 1978), which are commonly treated as two groups, the Inner and Outer Great Yarmouth Banks. Sediments found in the Norfolk section of the AOR are mainly created from the erosion and transportation of rock material, whereas off the coast of Suffolk around 30% or more of the sediment is composed of shell material.

Importantly, the Southern North Sea Sediment Transport Study (HR Wallingford, 2002) found that the existing dredging licences in the AOR were located further offshore than the coastal sediment transport pathways.

2.3.4 Distribution of seabed habitat types

The Anglian MAREA study area is dominated by sandy sediments supporting typical mobile sand species (Cooper *et al.*, 2007). Sand sediment fauna are naturally impoverished due to the perturbed benthic environment resulting from large-scale, wave and tidally induced sand movements and related smothering and scouring (Millner *et al.*, 1977; Kenny *et al.*, 1991). Acoustic seabed imaging of a number of aggregate sites within the East Coast MAREA revealed the presence of mobile bedforms together with sandwaves and megaripples indicating mobile and unstable environments. Typical species associated with impoverished mobile sand substrates include the polychaetes *Ophelia borealis* and *Nephtys cirrosa* and the mysid shrimp *Gastrosaccus spinifer*.

Some "hotspots" of greater macrofaunal richness and diversity exist (Cooper *et al.,* 2007). These correspond with coarser gravel areas and patches of *Sabellaria spinulosa* (Ross worm) reef where microhabitat seabed conditions may be comparatively stable allowing settlement and colonisation by a wider range of less disturbance tolerant species (Unicomarine Ltd., 1994; Marine Ecological Surveys Ltd., 2001; Worsfold & Dyer, 2005; Emu Ltd., 2005; 2007). Consequently, there are likely to be specific locations at which the macrofaunal community deviates from that which typically occurs across the region, thus highlighting that it is not appropriate to extrapolate observations made during site specific studies.

Typical species associated with coarser gravel areas include the polychaetes *Pholoe baltica, Lagis koreni*, *Spiophanes bombyx* and *Scalibregma inflatum, Pomatoceros* spp. (keel worm), *Ophiura albida* (brittlestar), *Mysella bidentata* (bivalve), *Echinocyamus pusillus* (sea urchin), Bryozoans (sea mats) including *Electra monostachys* and *Flustra foliacea,* Hydroids (sea firs) such as *Sertularia argentea* and Actinaria (sea anemones).

An overall picture of the distribution of sediment habitat types is given in Cooper *et al*. (2007) in which a broad pattern of sediment coarsening with increasing southerly distance across the MAREA study area was indicated:

- Northern survey area - fine and medium sands dominate;
- Central zones - coarse sand prevalent;
- Southern survey area – gravel dominates.

UKSeaMap and MESH habitats

Connor *et al*. (2006) introduced the concept of marine landscape classifications as part of the development of the UKSeaMap. The Anglian MAREA encompasses a number of different marine landscape types, assigned on the basis of a variety of benthic and water column environmental datasets. These are summarised in Table 1.1 together with the principal Mapping European Seabed Habitats (MESH) identified within the region. The MESH project infers habitat types based on existing knowledge of relationships between main physical factors and selected hydrographic and biological data.

Table 1.1 Marine landscape classifications and MESH habitats within the East Coast MAREA area.

UKSeaMap Marine landscape classifications	MESH habitats
Shallow sand plain under both moderate and strong tidal current stress	Circalittoral and deep circalittoral coarse sediment
Shallow coarse sediment plains under both moderate and strong tidal current stress	Circalittoral fine sand or circalittoral muddy sand
Shallow mixed sediment plain under moderate tidal current stress	Deep circalittoral sand
A relatively small area classified as shelf mud occurs north and east of the study area	A small area of deep circalittoral mud
Linear subtidal sediment bank features are present to the north	Inshore areas and the linear sand bank features to the north are classified as infralittoral fine sand or infralittoral muddy sand
Discrete small inshore mixed sediment plain areas	Small patches of inshore infralittoral and circalittoral mixed sediments

Coastal habitats

Norfolk coastal habitats are comprised of mobile sands with some shingle, backed by defensive dune systems. Wave exposed sandy shores are mostly devoid of fauna, but in wetter low shore areas sand mason worm, *Lanice conchilega* and lug worm *Arenicola marina* aggregations are common (Irving, 1995). Much of the Suffolk coastline near-shore seabed comprises coarse and fine muddy sand with some clay deposits. Conspicuous taxa include the bivalves *Nucula* spp and *Macoma balthica* together with polychaete *Spiophanes bombyx*, the urchin *Echinocardium cordatum* and robust amphipods (Irving, 1998). In places behind the shingle and sand barrier there are saline lagoons fed by seawater percolation or via overtopping (See Barnes, 1989).

2.3.5 Nature conservation features

Data collected as part of the Anglian MAREA benthic review indicated the presence of two potential Annex I habitats as defined within the EU Habitats Directive (92/43/EEC). These were:

- 'Reefs' – *Sabellaria spinulosa*, a small tube building polychaete worm. A biogenic reef is created when certain species aggregate forming a hard substratum which allows a community of other species to develop (see section 1.3.4);
- 'Sandbanks' which are slightly covered by seawater all the time.

2.0 METHOD

2.1 Survey design

Following identification of data and knowledge gaps in the benthic data review (Emu Ltd., 2010) a comprehensive programme of seabed sampling and underwater video was planned. This was based on the following hypotheses regarding the expected effects of dredging on benthos;

- Benthic fauna will be adversely affected, as a consequence of physical sediment changes attributable to the extraction of marine aggregate in the immediate vicinity of dredging;

- The benthic fauna at secondary or cumulative impact zones outside of the immediate licence area will demonstrate changes potentially attributable to dredging activity both singly and cumulatively with other dredging areas;

- Benthic fauna within dredging activity areas will be adversely affected, but where dredging has ceased, will initially re-colonise relatively rapidly (i.e. within months). This initial colonisation will be due to opportunistic fauna and r-strategy invertebrates (i.e. highly fecund species of small body size with potential for rapid dispersal). The community is likely to be structurally comparable to adjacent non-affected assemblages within 2-3 years, possibly longer for comparatively stable gravel environments, such as those found in the southern areas of the region. It should be noted, however, that although the more impoverished habitats may recolonise more rapidly, a number of recent studies suggest that recolonisation can take months, they may not achieve the same community but rather an alternative stable state following extraction (Demie *et al*., 2003; Boyd *et al*., 2005).

Addressing the hypotheses above, the benthic survey array aimed to infill the discussed data gaps. The resultant regional benthic dataset will enhance the decision making process for sustainable management of aggregate resources. The survey design was based on the following factors:

- Distribution of existing data;
- Distribution of habitats;
- Hydrodynamic conditions;
- Dredging activity patterns.

For this survey, the design comprised 55 grab samples, analysed for both fauna and particle size distribution (PSD), 20 trawl sites and an extra 13 grab samples for PSD only, to *groun*d-truth inshor*e* *MAR*EA geophysical survey lines.

Presented below are details of the complete dataset considered within this study which was combined to establish a consistent and integrated format for the region (Table 2.1). Prior to analysis all data were reconciled by returning them to a common taxonomic level and nomenclature, checked using the WoRMs database (Appeltans *et al.*, (2011). Datasets available only at family level were rejected as not supporting appropriate analysis. Data from a total of 672 grabs and 203 trawls were assessed as part of this MAREA.

Table 2.1 Historic datasets post 2002 within the Anglian MAREA integrated with data from the current AODA survey.

Data set	Prefix	Year of survey	Total number of sites (incl. replicates)
REC (2010)	A10_	2009	155 grabs and 128 trawls *151 grabs with PSA, epifaunal and infaunal data* *4 grabs with just epifaunal and infaunal data*
Emu (2005) Area 401/2	B05_	2004	49 grabs and 5 trawls *46 grabs with PSA, epifaunal and infaunal data* *3 grabs with just PSA and infaunal data*
Emu (2009) Area 401/2	B09_	2009	49 grabs and 5 trawls *49 grabs with PSA, epifaunal and infaunal data*
Emu (2004) Area 436/202	C04_	2003	37 grabs and 4 trawls *37 grabs with PSA, epifaunal and infaunal data*
Emu (2007) Area 436/202	C07_	2006	37 grabs and 5 trawls *37 grabs with PSA, epifaunal and infaunal data*
Emu (2002) Area 254	D02_	2002	46 grabs and 5 trawls *46 grabs with PSA, epifaunal and infaunal data*
Emu (2008) Area 254	D08_	2008	46 grabs and 6 trawls *46 grabs with PSA, epifaunal and infaunal data*
MES ALSF (2007) Area 328	E07_	2007	10 grabs *10 grabs with PSA, epifaunal and infaunal data*
MES ALSF (2007) Area 401	F07_	2007	10 grabs *10 grabs with PSA, epifaunal and infaunal data*
MES ALSF (2007) Area 430	G07_	2007	10 grabs *10 grabs with PSA, epifaunal and infaunal data*
MESL (2006) Area 430	H06_	2006	113 grabs and 19 trawls *112 grabs with PSA, epifaunal and infaunal data* *1 grab with just epifaunal and infaunal data*
Emu (2010) AODA	I10_	2010	68 grabs and 20 trawls *41 grabs with PSA, epifaunal and infaunal data* *13 Ground Truthing grabs (just PSA)* *13 grab with just PSA and infaunal data* *1 grabs with just epifaunal and infaunal data*
Emu (2009) Area 202	J09_	2009	42 grabs and 6 trawls *39 grabs with PSA, epifaunal and infaunal data* *2 grabs with just epifaunal data* *1 grab with just PSA and infaunal data*
TOTAL			***672 grabs and 203 trawls*** ***634 with PSA, epifaunal and infaunal data*** ***13 Ground Truthing grabs (just PSA)*** ***17 grabs with just PSA and infaunal data*** ***6 grabs with just epifaunal and infauanl data*** ***2 grabs with just epifaunal data***

*** Within each data set, grabs are prefixed with G, trawls with T and Ground Truth sites with GT e.g. REC (2010) grab #100 = A10_G100**

Figures 2.1 to 2.4 illustrate the site selection rationale. Figure 2.1 shows the grab, camera and trawl arrays for the current survey within the context of the existing benthic data locations. Given that for some licence areas suitable data already exist, providing coverage for a number of impact types at the site level, a high density benthic sampling survey of the entire East Coast region was not considered necessary. In particular, for the MEPF-ALSF Regional Environmental Characterisation (REC) programme a number of samples were collected which fell outside of the predicted aggregate area sediment plume extents and usefully serve as reference samples for the MAREA.

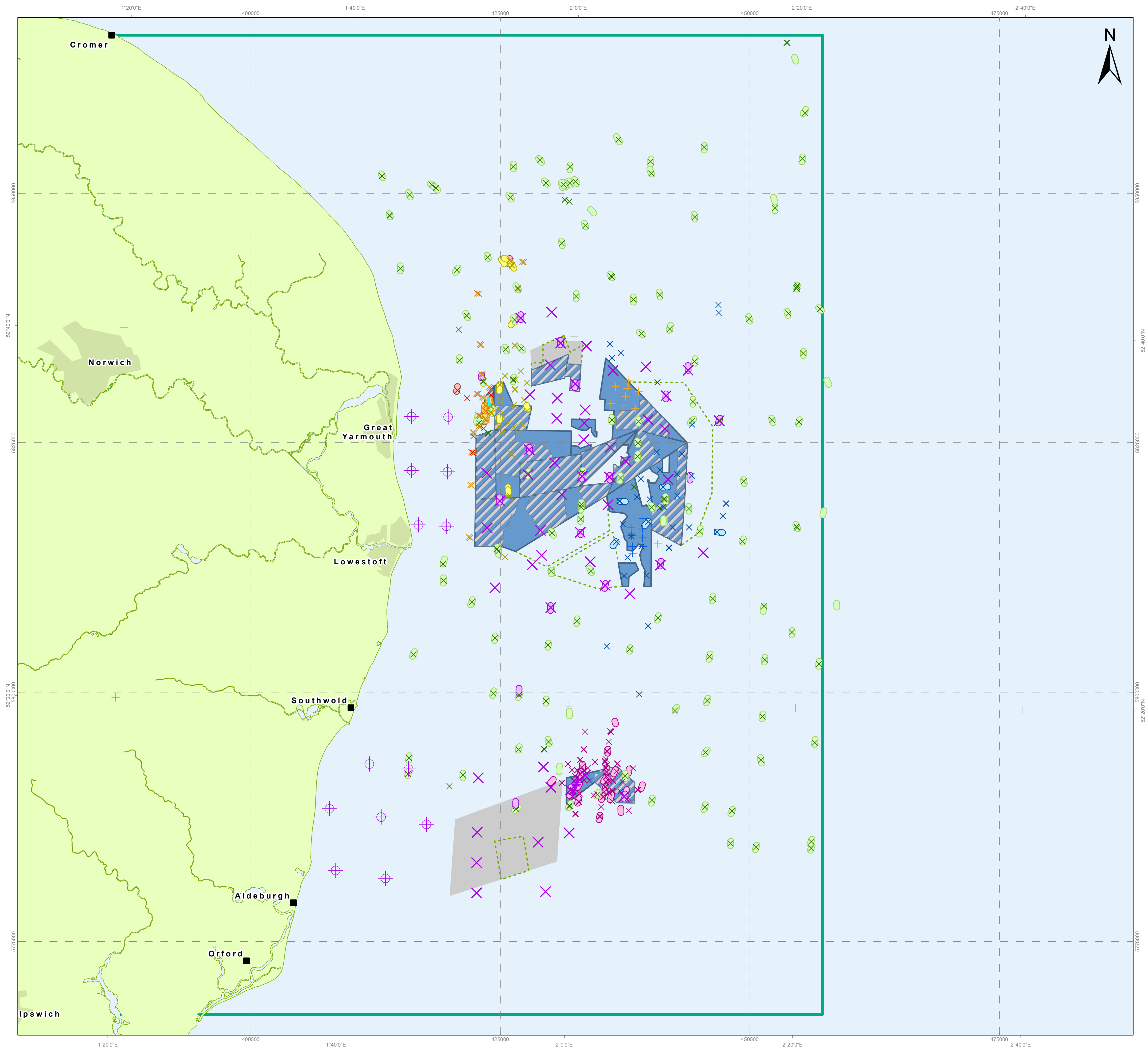
In addition to the REC data, a number of sites from the other historic datasets utilised also fell outside of the predicted primary and secondary influences of dredging, thereby acting as additional regional controls. Only those data collected post 2002 and following current guidelines (Boyd, 2002) were selected and combined as part of the Anglian MAREA array.

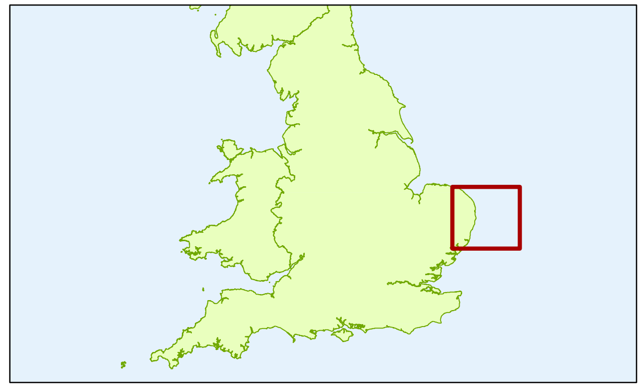
Figure 2.2 shows the distribution of MESH (see section 1.3.4) habitat types overlain with the locations of both the existing and current survey sites. This demonstrates the coverage of the predicted habitats present within the region.

Sediment modelling outputs for the region, indicating plume excursions and potential cumulative effect areas, were provided by Cefas and were considered within the proposed benthic array design. In addition, tidal diamond data were used to predict maximum spring tide sediment movements when disturbed by dredging and to further help identify potential cumulative effect areas. Figure 2.3 presents the historic and current survey sample locations overlain onto predicted Admiralty diamond data indicating maximum extents based on spring tides and modelled sediment transport from aggregate licence areas (Cooper *et al*, 2007). These indicate areas that could potentially be affected by dredging related fine sediment redistribution. Within each group of aggregate licences there is potential for cumulative effects on benthos to occur as a result of the interaction of two or more sediment plumes arising from different dredging activities.

Historic and current survey sample locations have been overlain onto Electronic Monitoring System (EMS) data (10 year cumulative footprint of aggregate extraction activity) and are presented in Figure 2.4. These data enabled identification of Active Dredge Zones (ADZs) across the east coast (AODA) region and the different dredging intensities within them.

New benthic sample locations for the current survey were positioned, as far as practicable; to coincide with both REC and new proposed geophysical survey lines so that the biological data could be related to the physical seabed conditions. Furthermore, to allow for any aggregate licences granted in the future, benthic surveying was also undertaken within and around areas currently under application. It is intended that these data will help inform the environmental characterisation during any subsequent site specific EIAs.





Legend

MAREA Study Boundary

Aggregate Areas

- Active Dredge Zone
- Licence Area
- Application Area
- Prospecting Area

Current Survey Array

- Hamon Grab Site
- Groundtruth Site
- 2m Beam Trawl

Historic Sample Locations

- REC Hamon Grab (2009)
- REC Trawl (2009)
- Area 254 Hamon Grab (2002, 2008)
- Area 254 Trawl (2002)
- Area 436 & 202 Hamon Grab (2004, 2007)
- Area 436 & 202 Trawl (2004, 2007)
- Area 202 Hamon Grab (2009)
- Area 202 Trawl (2009)
- Area 401/2 Hamon Grab (2005, 2009)
- Area 401/2 Trawl (2005, 2009)
- Area 430 Hamon Grab (2006)
- Area 430 Trawl (2006)
- Area 328 Hamon Grab (2007)
- Area 401 Hamon Grab (2007)
- Area 430 Hamon Grab (2007)

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010

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Kilometres

Coordinate System: WGS84 UTM Zone 31 North

Scale: 1:375,000

Sheet Size: A3

Client: Anglian Offshore Dredging Association

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Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

Current Survey Positions in Context of Pre-Existing Sample Locations

Figure No. 2.1

Drawn By:	Checked By:	Issued On:	Job Number:	Rev:
MXP	EMP	26/03/12	J/1/03/1671	1

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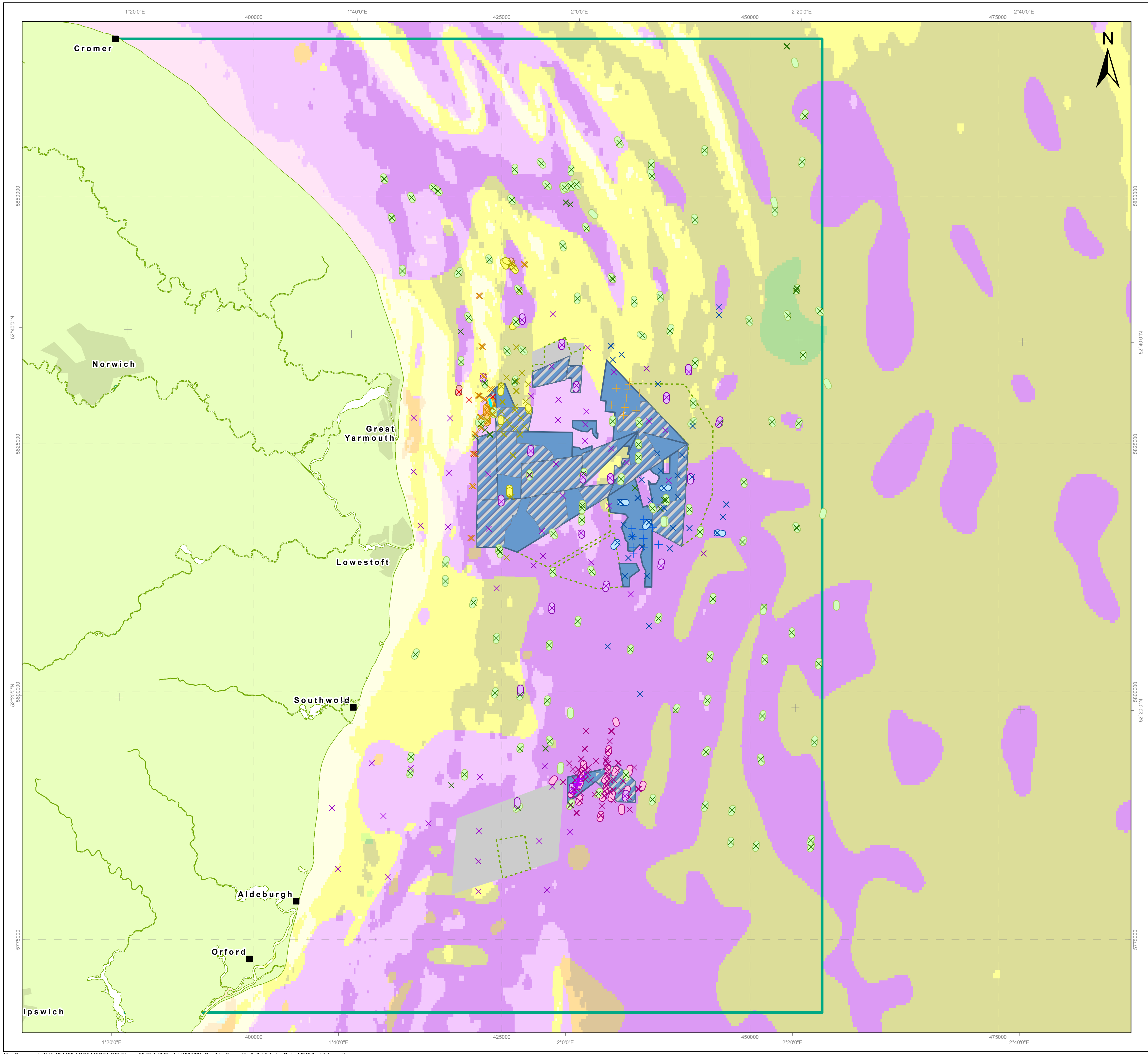

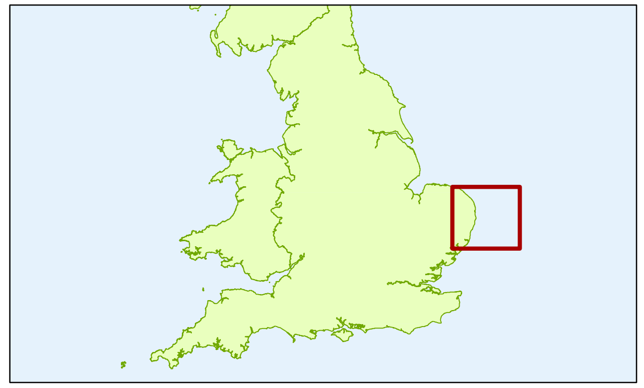

Legend

MAREA Study Boundary

Aggregate Areas

- Active Dredge Zone
- Licence Area
- Application Area
- Prospecting Area

Sample Locations

- REA Hamon Grab (2010)
- REA Trawl (2010)
- REC Hamon Grab (2009)
- REC Trawl (2009)
- Area 254 Hamon Grab (2002, 2008)
- Area 254 Trawl (2002)
- Area 436 & 202 Hamon Grab (2004, 2007)
- Area 436 & 202 Trawl (2004, 2007)
- Area 202 Hamon Grab (2009)
- Area 202 Trawl (2009)
- Area 401/2 Hamon Grab (2005, 2009)
- Area 401/2 Trawl (2005, 2009)
- Area 430 Hamon Grab (2006)
- Area 430 Trawl (2006)
- Area 328 Hamon Grab (2007)
- Area 401 Hamon Grab (2007)
- Area 430 Hamon Grab (2007)

Predicted EUNIS Habitats

- Infralittoral Coarse Sediment
- Circalittoral Coarse Sediment
- Deep Circalittoral Coarse Sediment
- Infralittoral Mixed Sediments
- Circalittoral Mixed Sediments
- Deep Circalittoral Mixed Sediments
- Infralittoral Fine or Muddy Sand
- Circalittoral Fine or Muddy Sand
- Deep Circalittoral Sand
- Infralittoral Sandy or Fine Mud
- Circalittoral Sandy or Fine Mud
- Deep Circalittoral Mud

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010

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Kilometres

Coordinate System: WGS84 UTM Zone 31 North

Scale: 1:375,000

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Client: Anglian Offshore Dredging Association

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Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title: Current and Historic Sample Positions Overlain on MESH Habitats, Anglian MAREA Region

Figure No. 2.2

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MXP	EMP	26/03/12	J/1/03/1671	1

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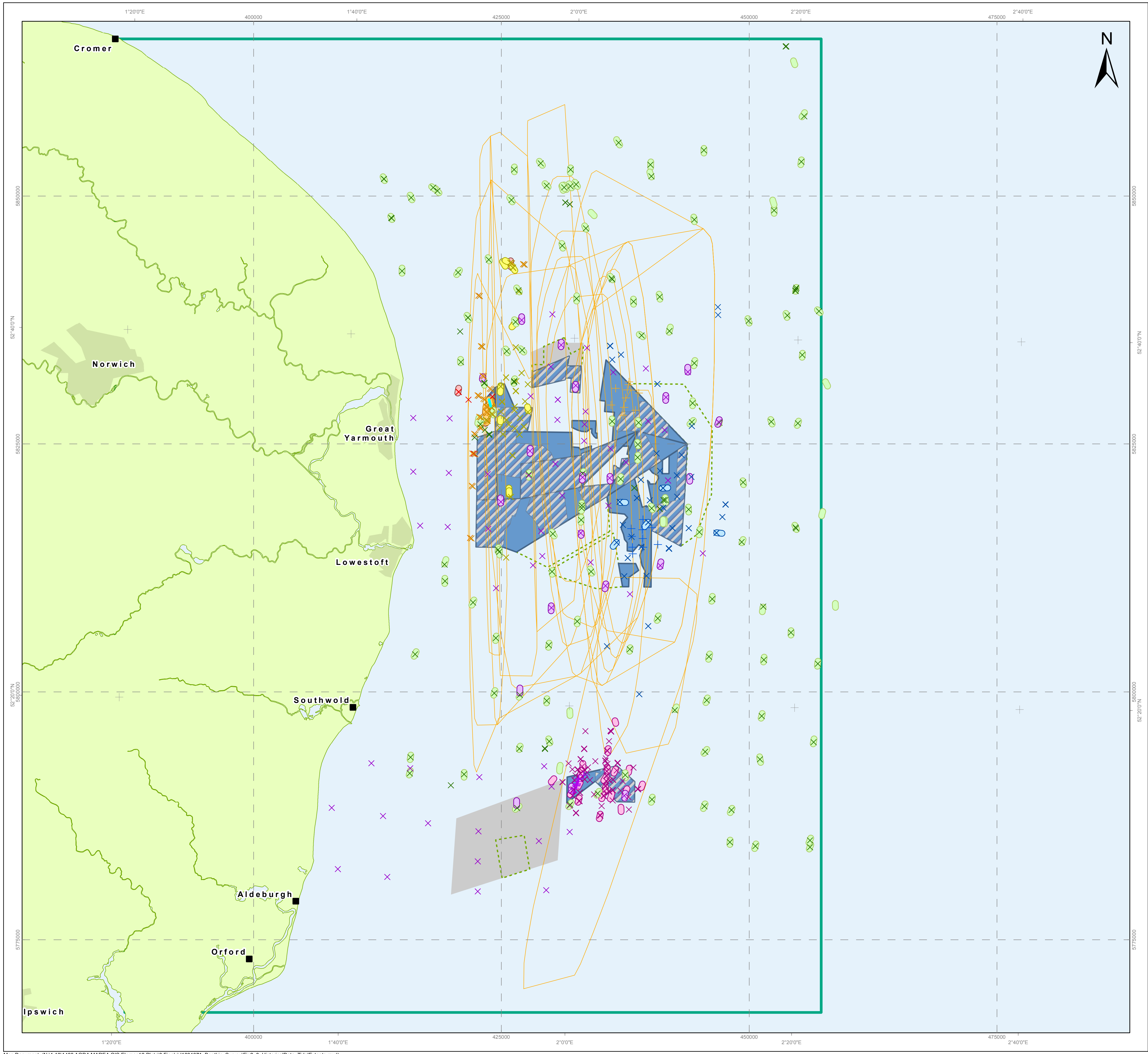

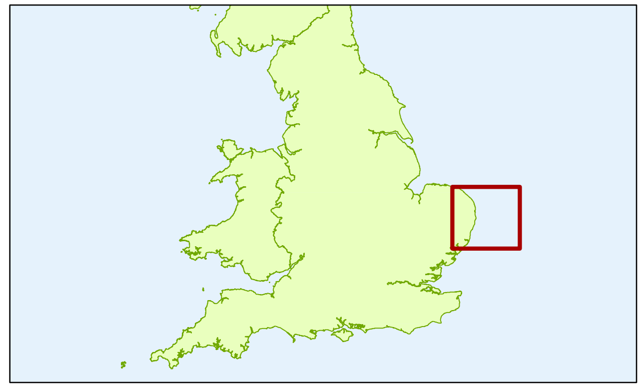

Legend

MAREA Study Boundary

Aggregate Areas

Active Dredge Zone

Licence Area

Application Area

Prospecting Area

Tidal Extent

Based on Tidal Diamonds

Sample Locations

REA Hamon Grab (2010)

REA Trawl (2010)

REC Hamon Grab (2009)

REC Trawl (2009)

Area 254 Hamon Grab (2002, 2008)

Area 254 Trawl (2002)

Area 436 & 202 Hamon Grab (2004, 2007)

Area 436 & 202 Trawl (2004, 2007)

Area 202 Hamon Grab (2009)

Area 202 Trawl (2009)

Area 401/2 Hamon Grab (2005, 2009)

Area 401/2 Trawl (2005, 2009)

Area 430 Hamon Grab (2006)

Area 430 Trawl (2006)

Area 328 Hamon Grab (2007)

Area 401 Hamon Grab (2007)

Area 430 Hamon Grab (2007)

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010

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Coordinate System: WGS84 UTM Zone 31 North

Scale: 1:375,000

Sheet Size: A3

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Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title: Current and Historic Sample Positions Overlain on Predicted Admiralty Tidal Extents, Anglian MAREA Region

Figure No. 2.3

Drawn By:	Checked By:	Issued On:	Job Number:	Rev:
MXP	EMP	26/03/12	J/1/03/1671	1

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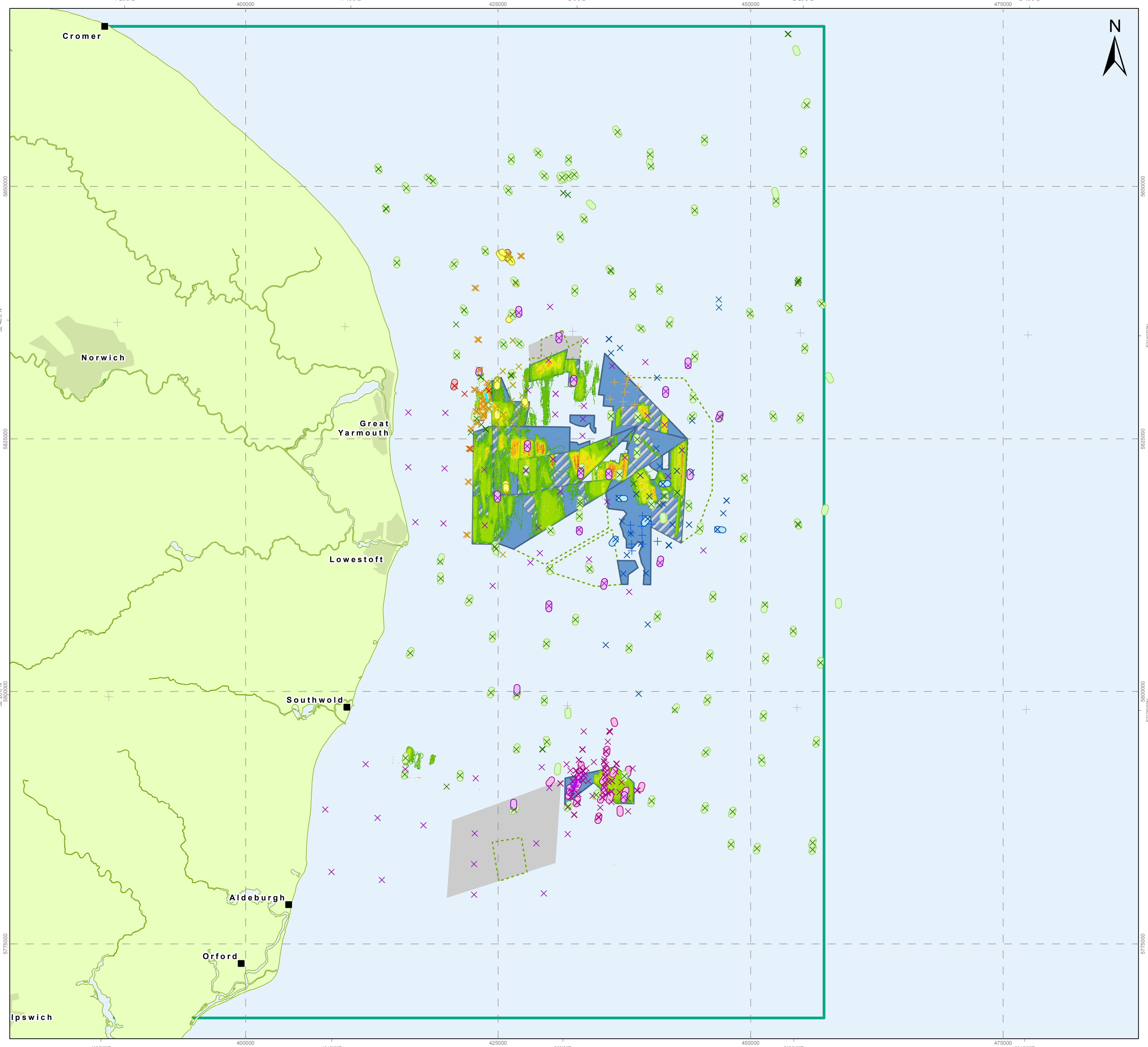

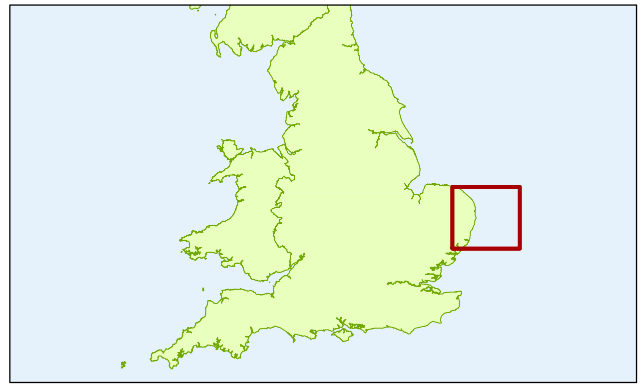

Legend

MAREA Study Boundary	**Sample Locations**
Aggregate Areas	REA Hamon Grab (2010)
Active Dredge Zone	REA Trawl (2010)
Licence Area	REC Hamon Grab (2009)
Application Area	REC Trawl (2009)
Prospecting Area	Area 254 Hamon Grab (2002, 2008)
Dredging Intensity (99-09)	Area 254 Trawl (2002)
0 - 1 Minute	Area 436 & 202 Hamon Grab (2004, 2007)
1 - 15 Minutes	Area 436 & 202 Trawl (2004, 2007)
15 Minutes - 2.5 Hours	Area 202 Hamon Grab (2009)
2.5 Hours - 5 Hours	Area 202 Trawl (2009)
5 Hours - 10 Hours	Area 401/2 Hamon Grab (2005, 2009)
10 Hours - 15 Hours	Area 401/2 Trawl (2005, 2009)
15 Hours - 20 Hours	Area 430 Hamon Grab (2006)
More Than 20 Hours	Area 430 Trawl (2006)
	Area 328 Hamon Grab (2007)
	Area 401 Hamon Grab (2007)
	Area 430 Hamon Grab (2007)

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010

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Kilometres

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Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

Current and Historic Sample Positions Overlain on Electronic Monitoring System (EMS) Data, Anglian MAREA Region

Figure No. 2.4

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The objectives, indicated in section 2.1 with respect to potential benthic community impacts due to aggregate extraction, were considered in relation to specific sampling effort (Table 2.2), including a consideration of historic benthic ecological data.

As part of the benthic survey a limited number of benthic samples were collected along the planned MAREA geophysical survey lines running east-west and into the shore. These samples were intended for the ground-truthing of geophysical sediment type data and will only be processed for biological content in the event that a link between coastal processes and offshore dredging is indicated.

Table 2.2 Distribution of grab and trawl sampling effort and the types of dredging impacts represented within the Anglian MAREA study area.

Title and Character of Impact	No. grab samples	No. trawl samples	Anticipated Effect on Benthos
Primary Impact Zone (PIZ) Seabed encompassed within boundary of licensed aggregate area which has potential to be dredged within licence life	*Current sites: 21* *Historic sites: 206* Total: 207	*Current sites: 6* *Historic sites: 42* Total: 48	Complete/near complete macrofauna loss coupled with changes in sediment composition in current or recent active dredging areas. Areas in which dredging has ceased may be in a state of partial recovery characterised by high 'opportunist' species densities. Any recovery dependent on habitat restitution rate and severity of any residual secondary sediment effects arising from dredging activities elsewhere within the licence.
Secondary / Cumulative Impact Zones (SIZ/CIZ) Area falling outside licensed aggregate sites, but within influence of mobilised fine sediments arising from dredging activities. Area may be influenced by several aggregate sites.	*Current sites: 26* *Historic sites: 304* Total: 330	*Current sites: 12* *Historic sites: 72* Total: 84	Partial fauna loss, primarily epifauna, in response to deposition and/or seabed sediment mobilisation and associated smothering, scour and destabilisation effects. Fining of the sediments due to fine sediment deposition via dredging disturbance or from on-board screening processes. Noted decreasing impact gradient with increasing distance from dredging to where no detectable effects are observed over and above reference conditions. If affected by multiple aggregate zones, effects severity and longevity may be increased.
Reference Zone (RefZ) Area outside predicted primary and secondary dredging activity influences. Representative of physical environmental conditions in primary and secondary impact zones. * Includes the 13 Ground Truth sites.	*Current sites: 21* *Historic sites: 97* Total: 118	*Current sites: 2* *Historic sites: 67* Total: 69	No change in sediment habitat or biological community attributes due to dredging activity will occur. Any change reflecting natural temporal variance or other anthropogenic activity, e.g. demersal fishing.

2.2 Current survey

2.3.1 General

Mini-Hamon grab sampling (0.1m²), 2m beam trawling, drop-down stills, videoing and the subsequent laboratory and data analyses for the current survey were carried out by Emu Ltd. All field and laboratory methods employed by Emu Ltd. conformed to in-house operating guidelines and/or ISO9001 control procedures, where appropriate, and are detailed in the text below.

The sediment PSD analyses were undertaken at Emu's UKAS accredited sediment laboratory. This included particle sizing via a Malvern laser diffractor on samples containing 5%, or more, fine (silt/clay) sediments.

Analyses of macrofaunal grab and 2m beam trawl samples (including fish and epifaunal species) were undertaken by Emu Ltd., long term participants in the National Marine Biological Analytical Quality Control Scheme (NMBAQC) scheme. This scheme is an independent, national QC scheme designed to assess the quality of marine benthic taxonomy between laboratories in the UK. Emu Ltd. have participated since 1996 consistently achieving >95% compliance with the scheme. The subsequent phylum level biomass analysis was also completed at the Emu laboratory.

2.3.2 Survey dates

The current survey was completed over 8 days in July 2010, from 10/07/2010 to 11/07/2010 on board the vessel *MV Shannon*, and between 25/07/2010 to 30/07/2010 on the *FV Arie Dirk*. The initial vessel operated from Great Yarmouth port and the latter from Lowestoft.

2.3.3 Positioning

Sample positions generated during survey design were used to guide the vessel to within 10m of each sample location (grab, trawl and video). Actual grab sample positions were recorded in WGS84 UTM Zone 31 North every time the grab touched the seabed; as indicated by the winch wire slackening. During survey operations the positions were fixed using a Hemisphere Crescent V110 series Differential Global Positioning System (DGPS) giving a positional accuracy <60cm (95% of the time).

The HYDROpro™ navigational software package was also used during positioning and for the sequential recording (fixing) of each sample location and field event. In addition, HYDROpro™ generated a series of continuous fixes every 5 seconds between the start and end of the trawls to record each tow track. Fixed offsets in relation to the vessel plan and DGPS antenna position were used in HYDROpro™ to determine the position of the drop down video, 2m beam trawl and Mini-Hamon grab. Appropriate lay-backs to trawl positions on the seabed were made, as indicated by the length of warp deployed during each trawl.

2.3.4 Drop down video

Prior to sampling, static seabed photos and video images were acquired at each faunal grab location (Plates 2.1-2.2). Depending on turbidity levels, a Kongsberg combined digital stills and video camera was used, either attached to a sledge or mounted within a water filled clear view box frame; illumination was provided by two 150W LED lights.

A minimum of 3 minutes seabed video footage and 3 seabed images were obtained. The camera frame position on the seabed was recorded using HYDROproTM, with each image position fixed within HYDROproTM navigation software at the moment of capture. Video images were digitally overlain with dGPS position and recorded in digital format to 5 MB quality or better.

Plate 2.1 Sea bed photographic stills equipment

Plate 2.2 Combined digital underwater video and freshwater reservoir system.

Video footage and stills images were later analysed to assist the appraisal of sediment habitat types and provide a wider context within which the results of the grab sampling can be placed. For all sites containing *Sabellaria* reef a detailed assessment of the level of 'reefiness' was conducted based on 'elevation' and 'patchiness' measures (see section 2.2.8).

2.3.5 Grab sampling and onboard sampling treatment

For determination of macrofaunal content and particle size distribution, quantitative seabed samples were collected using a 0.1 m^2 Mini-Hamon grab (Plate 2.3). Upon grab sample recovery, a sample volume assessment was made, before the sample was placed in a plastic container. Photographic records were taken for all samples and brief descriptions (sediment type, conspicuous fauna, etc.) were made.

Sub-samples were taken from grab samples and placed in pre-labelled plastic bags (with internal waterproof label) for subsequent PSD analysis. The volume taken depended upon the sediment nature (see Eleftheriou and McIntyre, 2004) and was either 300 cm^3 or 500 cm^3.

The remaining sample was sieved over a 1 mm mesh to remove the majority of finer sediment. Sieve contents were then transferred to a labelled 10 litre plastic bucket (with internal waterproof labels) and the sample fixed using a 4% buffered formalin solution. Samples were subsequently returned to the Emu Ltd. laboratories, at Trafalgar Wharf in Hampshire, for laboratory sorting.

Plate 2.3 0.1m2 Mini-Hamon grab.

2.3.6 2m beam trawling

Larger mobile epibenthos were collected utilising a Lowestoft 2m scientific beam trawl fitted with a 5 mm aperture mesh liner and towed for approximately 500m. The 2m beam trawl method of biological sampling attempts to identify the mobile and low density epibenthos which may not be sampled using grab techniques (Plates 2.4 and 2.5).

Plate 2.4

Plate 2.4 Deployment of the 2m beam trawl.

Plate 2.5

Plate 2.5 On board processing of the 2m beam trawl catch.

Upon recovery, each trawl sample was initially spread out within a large shallow box to assess overall character of conspicuous fauna and substrate material; photographs of each sample were taken.

Notes were made of sediment characteristics, shell material content and algal abundance. Fish length measurements from head tip to tail end were made rounding down to the nearest whole centimetre. For rays, the length between wingtips and total length from head tip to tail end were recorded to the nearest whole centimetre. Carapace length in millimetres was measured for shellfish.

Prior to sorting and processing the contents into fish crates, catch total volume (minus fish species) was measured using a graduated fish box. A 5 litre sub sample was taken to complete taxonomic analyses on return to the laboratory. The rest of the trawl catch was largely identified and enumerated on site with representative specimens returned to Emu's laboratories, for reference collection purposes and to confirm field identification. Data from the field and lab were later combined allowing for differences in quantification methods to give the total trawl species composition.

Large sediment material, i.e. cobbles and pebbles, were washed over a 5 mm grid mesh on a sorting table to remove mobile fauna. Solitary attached fauna were then enumerated from the cobbles and pebbles whilst the abundance of any identifiable encrusting fauna was estimated based on the whole sample and using the percentage element of the SACFOR scale (Table 2.3).

Table 2.3 Abundance scales used for sublittoral taxa, taken from Hiscock (1996).

Growth form			Size of individuals/colonies				Density
% Cover	Crust / meadow	Massive / turf	<1cm	1-3cm	3-15cm	>15cm	
>80%	S		S				>1/0.001m^2
40-79%	A	S	A	S			1-9/0.001m^2
20-39%	C	A	C	A	S		1-9/0.01 m^2
10-19%	F	C	F	C	A	S	1-9/0.1 m^2
5-9%	O	F	O	F	C	A	1-9/ m^2
1-5% or density	R	O	R	O	F	C	1-9/10 m^2
<1% density		R		R	O	F	1-9/100 m^2
					R	O	1-9/1000 m^2
						R	<1/1000 m^2

Key: S = Superabundant, **A** = Abundant, **C** = Common, **F** = Frequent, **O** = Occasional, **R** = Rare, **P** = present (used when the abundance of an organism could not be estimated accurately).

For highly numerous taxa such as sea urchins, sub samples were taken in the field from which an estimate of abundance was calculated. Abundance estimates were based on the known numbers of individuals which occupy a particular volume so that the overall species densities could be scaled up to calculate the applicable overall catch density.

2.3.7 Laboratory sample analyses

Laboratory particle size distribution (PSD) analyses

Sediment samples collected in the field were analysed for PSD following the Emu Ltd. in-house procedures (Emu, 2005) based on BS1377; part two; 1990. On return to the Emu laboratory, representative sub-samples of each sediment sample were initially wet split before being oven dried to constant weight and sieved through a series of mesh apertures corresponding to whole phi units. The weight of the sediment fraction retained on each mesh was measured and recorded.

Macrobenthic taxonomic analysis

Faunal grab samples were washed over a 1 mm sieve to remove all remaining fine sediment and fixative. Fauna were sorted by elutriation with final sorting by hand under a binocular microscope to ensure no fauna remained. Fauna were preserved in 70% Industrial Denatured Alcohol (IDA). Residual sediment fractions were retained following sorting for future quality control auditing as required; detailed in Emu's In-house Methods (MET/07) for the Processing, Identification, Enumeration and Recording of Marine Benthic Macro-invertebrates.

Macro-invertebrates collected from grab samples were identified to species level, where possible, and enumerated. Colonial sessile epifauna were also identified to species level where possible, but were recorded as presence/absence data only. Following identification, all biological faunal material was returned to 70% IDA for long term storage. A faunal reference collection was prepared with examples of each species identified retained. This will be permanently housed at Emu Ltd and will allow future checks on taxonomic classification to be made in assessing comparative monitoring data. Emu undertook QC checks on a representative number of whole samples, as well as the entire reference collection in compliance with internal analytical quality control criteria.

Biomass determination

Biomass analyses were performed on the faunal grab samples including the reference specimens. Fauna from each sample were sorted into standard biomass phyla groupings (Polychaeta, Crustacea, Mollusca, Echinodermata and Others (Nemerteans, Phoronids, flatworms, etc) with biomass analyses conducted using the standard wet blot method employed within the National Marine Biological Association Quality Control Scheme. Subsequently, the appropriate corrections were applied to this data to provide equivalent dry weight biomass data (Eleftheriou & Basford, 1989). The conversion factors applied are given below. Colonial sessile and solitary encrusting epifauna were not submitted to the biomass analysis.

- Polychaeta: 15.5%
- Crustacea: 22.5%
- Echinodermata: 8.0%
- Mollusca: 8.5%
- Others: 15.5%.

2.3.8 *Sabellaria spinulosa video analysis*

Accurate *S. spinulosa* reef assessment is presently difficult and the subject of much debate, however, Hendrick and Foster-Smith (2006), Gubbay (2007) and Limpenny (2010) offer a number of criteria to aid reef structure determination. Further development of these criteria has been undertaken by Emu Ltd. (Emu Ltd., 2008c) to enable the interpretation of *Sabellaria* aggregations through the following three stage process:

Stage 1 – Sediment description and *Sabellaria* form present

Video footage from each site was reviewed and checked against the *in-situ* video records. Video analyses were supplemented by static images. The following information was assessed:

1. Substrate type; and
2. Presence of *S. spinulosa* was classified into the following categories where possible:
   - Absent;
   - Moribund loose tubes (loose tubes not attached to the seabed);
   - Crusts (low lying tubes);
   - Clumps (nodules of reef <10cm in diameter); and
   - Potential Reef (continuous, i.e. not clumped, erect *Sabellaria* tubes with height >2cm)

Stage 2 – *Sabellaria* reef characteristics

Hendrick & Foster-Smith (2006) described a multi-criteria scoring system which can be used to give an overview of various characteristics considered important to the 'reefiness' of *S. spinulosa* aggregations.

It has been suggested (Hendrick & Foster-Smith, 2006) that each of the characteristics can be scored as Low, Medium or High, and be weighted according to the perceived importance of that characteristic. Table 2.4 summarises the characteristics indicated as determinable by video survey.

Table 2.4 Summary of *Sabellaria* characteristics based on Hendrick & Foster-Smith (2006).

Characteristic	Measurement via video footage
Elevation	Elevation can be estimated from video imagery. Alternatively it is possible to get an indication of the reef elevation from remote sensing techniques such as high frequency sidescan sonar or swath bathymetry, although such surveys were not conducted by Emu Ltd. as part of the current MAREA.
Patchiness	A rough indication of the patchiness of the reef can most easily be estimated from videography.
Consolidation	As with elevation, an indication of the degree of sediment consolidation can be derived from vertical photography and video footage.
Density	Biogenic reef characteristics are all linked to the density of the aggregation. For instance it has been suggested, that the growth morphology of *S. spinulosa* maybe influenced by density, such that an upright growth form is a reflection of competition for space (Schwartz, 1932; Schafer, 1972). A rough density estimate can be derived from videography.

Whilst an overall score of these characteristics is an oversimplification, the approach attempts to encourage a structured consideration of each characteristic. For the purpose of this current survey, where areas of potential reef have been identified, the characteristics specified in Table 2.5 were scored, where possible. In addition, notes were also made on other conspicuous species present.

Table 2.5 Analysis of *Sabellaria* Characteristics and Score Allocated for the Current Survey within the Anglian MAREA.

Characteristic	Analysis of characteristics and score allocated
Elevation	A rough estimate of the height of the reef can be obtained utilising known information on the height of the camera from the ground when the video sledge is landed on the seabed.
Patchiness	The video footage obtained from the present survey were not video transects and as such the position and the number of seabed drops varies between sites due to the nature of each site. Therefore, patchiness is determined on a site by site basis and is quantified as a percentage and was calculated as follows: $\frac{\text{Total percentage of } \textit{Sabellaria} \text{ cover over the whole site}}{\text{Total number of video drops for the site (i.e the total area surveyed)}} \times 100$

Characteristic	Analysis of characteristics and score allocated
Consolidation	A score for this characteristic is difficult to ascertain from the video footage obtained for this survey. For the purpose of this survey, a brief description of the nature of the reef will be given, but descriptive terms used do not relate to the Hendrick & Foster-Smith (2006) scoring system.
Density	A score for this characteristic is difficult to ascertain from the video footage obtained for this survey. For the purpose of this survey, a brief description of the nature of the reef will be given, but descriptive terms used do not relate to the Hendrick & Foster-Smith (2006) scoring system.

Stage 3 – Measure of 'reefiness'

Whilst Hendrick & Foster-Smith (2006) provided a starting point in evaluating reefiness, JNCC have since conducted a workshop (2007) and produced '*Defining and managing Sabellaria spinulosa reefs: Report of an inter-agency workshop*' (JNCC Report 405, Gubbay, 2007). The main focus of the workshop was seeking agreement on a definition of *Sabellaria spinulosa* reefs.

Participants agreed that the simplest definition of *S. spinulosa* reef in the context of the Habitats Directive was considered to be an area of *S. spinulosa* which is elevated from the seabed and has a large spatial extent (two of the characteristics presented by Hendrick & Foster-Smith, 2006). Colonies may be patchy within an area defined as reef and show a range of elevations. In addition the report states that, regardless of extent, patchiness appears to be a feature of reefs and therefore 100% coverage should not to be expected within an area defined as a *S. spinulosa* reef (Gubbay, 2007).

In seeking to provide greater guidance, the workshop participants attempted to assign figures to the characteristics of elevation and patchiness which could be used in combination to determine whether an area might qualify as a reef. The best, but not unanimous, agreement which could be reached on the day is given below in Table 2.6.

Table 2.6 Range of figures proposed by participants of the JNCC 2007 workshop to be used together as a measure of reefiness.

Measure of 'reefiness'	NOT a REEF	LOW	MEDIUM	HIGH
Elevation (cm) (average tube height)	<2	2-5	5-10	>10
Patchiness (% cover)	<10%	10-20%	20-30%	>30%

Note that the figures presented in the table are a starting point for wider discussion rather than accepted and fully agreed thresholds for *Sabellaria* reef identification. The above 'traffic light' system was utilised in the analysis of *Sabellaria* reef for the current survey.

For this study, Sabellaria elevation is an estimation of average tube height (see Table 2.5). Accordingly the base of the video system was set to 6cm above the seabed enabling an estimation of elevation in relation to distance from the base of the system. For the majority of sites assessed, elevation is defined as a range of values thus the confidence of the exact elevation is "moderate" as it is based on an average (see below). However, confidence that the elevation falls within the range is "high". Lower elevations are more difficult to ascertain, although where it is evident that the Sabellaira present is more than thick crusts, i.e. with a visible elevation, albeit low, an estimation of 2cm was assigned.

The average estimates were obtained following the survey effort which comprised a minimum of 3 minutes of video footage and 3 stills images were collected throughout the survey. However, at sites where potential *S. spinulosa* reef was recorded in-situ, additional video footage and stills were collected (up to 7 minutes with 16 stills images).

A detailed *S. spinulosa* reef assessment for the entire integrated dataset was outside the scope of this regional assessment. Furthermore, in the absence of video footage for all the historic datasets utilised the necessary information for such an assessment was unavailable. The above reef assessment was therefore only done for the current survey sites.

2.3 Integrated dataset analyses

2.3.1 Primer analyses

An important component of the Anglian MAREA project was the refinement and reconciliation of historic datasets with the current survey data to create an overall benthic dataset for the Anglian region. Although this may be achieved via sub-routines within PRIMER or UNICORN, experience suggests that manual intervention is usually the most effective method to achieve compatibility across datasets. Such intervention included re-classification of some taxa to higher taxonomic levels to overcome data truncation, elimination of sp. and spp. suffixes and "juvenile" classification and ensuring consistency of species nomenclature and taxonomic discrimination. SIMPER, the similarity percentages routine within Plymouth Marine Laboratories PRIMER v6 statistical package (Clarke & Gorley, 2006; Clarke & Warwick, 2001) acted as an effective 'check' on combined datasets highlighting any species responsible for spurious divisions for immediate corrective action as necessary.

Data drawn from the faunal and sediment analyses were analysed to describe community and seabed sediment structure and distribution. This allowed analysis to elucidate relationships between faunal assemblages and physical variables within the Anglian group of aggregate licences. PRIMER v6 suite of statistical routines was further used to investigate community structure and relationships with abiotic factors with a number of univariate and multivariate statistical measures utilised. Table 2.7 contains a summary of each Primer routine utilised together with a description of what each test encompasses.

Table 2.7 Summary of test routines undertaken in PRIMER.

Analysis	Description
Hierarchical Cluster Analysis	Cluster analysis aims to find "natural groupings" of samples with similar physical and faunal characteristics. The most commonly used clustering techniques are the hierarchical agglomerative methods. These start with a similarity matrix and "fuse" the samples into groups and the groups into larger clusters, starting with the highest mutual similarities then gradually lowering the similarity level at which groups are formed until all of the samples are contained in a single cluster. The results of hierarchical clustering are represented by a tree diagram or dendrogram, with the x axis representing the full set of samples and the y axis representing the similarity level at which the groups are considered to have fused.
Multidimensional Scaling (MDS) Ordination	This technique allows the construction of a "map" or configuration of the samples in multidimensional space. This configuration attempts to position the samples as accurately as possible to reflect similarity. For example, if sample 1 has a greater similarity to sample 2 than it does to sample 3 it will be displayed more closely to sample 2 than sample 3. This "map" of the relative similarities is plotted in two dimensions. It is important to remember that this two-dimensional plot is a representation of a multidimensional picture. When large sample numbers are analysed, or datasets including highly differentiated samples, the accuracy of the two-dimensional plot may be reduced. An accuracy measure (stress) is given on the MDS plot. Stress values <0.1 correspond to a good ordination; values <0.2 give a useful 2-dimensional picture, but one should not place too much reliance on the fine details of the plot; stress >0.3 indicates that the samples are close to being positioned in an arbitrary manner and should not be regarded as necessarily similar to one another, particularly in the upper half of this range.
Principal Components Analysis (PCA)	PCA is a technique for finding patterns in highly variable data. Data are presented as a "cloud" of points and are rotated to show the maximum variability within the samples. The first principal component (axis) explains as much of the data variability as possible, the second axis the second most important variability factor and so on. PCA is highly useful in allowing informed opinion on factors affecting the distribution of observed results.
The SIMPER Routine	The SIMPER routine allows the comparison between groups of samples from one site to another to be made. Species (or particle size fractions) responsible for the dissimilarity between the two sites are then listed in decreasing order of importance in the discrimination of the two regions. This routine also provides information on which species are responsible for the within-site similarities and their contribution to the internal similarity of the group.
BIOENV	BIOENV finds relationships (rank correlation) between environmental variables and observed community patterns. In this way, community distribution can be related to the environmental variable which may be the most important factor and, if desired, relationships can then be tested with statistical significance.
ANOSIM	This is a significance test for groups previously assigned (*a priori*) through analysis of the faunal data set. The routine tests for whether the assigned groups are meaningful, using significance levels to show results of within and between group comparisons; i.e. if groups are valid, samples within groups should be more similar in composition than samples from different groups.

Faunal data were square root transformed, which serves to down-weight the dominant species taking a much greater account of the less frequently occurring species and allowing the underlying community structure to be assessed.

Transformed data were subjected to hierarchical clustering during which the relative similarities between every pair of samples were calculated. Macrofaunal data were compared using the Bray-Curtis similarity measure whilst physical data were compared using the Euclidean distance measure of similarity. The calculated pair-wise similarities were then used to group the faunal and sediment samples based on the group averages and to construct Multi Dimensional Scaling (MDS) and PCA sample ordination plots. These analyses enabled the identification of any clusters within the dataset.

The similarity percentages routine (SIMPER) was used to identify those species and sediment fractions that were most responsible for both the “within” sample group similarity and for the “between” sample group dissimilarity. ANOSIM was used to identify the significance of any relationships between groups. BIOENV was then employed to reveal those environmental variables which best matched the observed clustering of faunal samples.

2.3.2 Data distribution plots

The large size of the dataset analysed for the Anglian MAREA affected the ability to clearly display all results within plots. To increase clarity and enhance plot interpretation, for those surveys repeated over several years, only the most recent year’s results were displayed. For a full list of temporal data see the relevant appendices.

3.0 RESULTS AND DISCUSSION

3.1 Current and integrated survey arrays

The current survey array is presented in Figure 3.1. As discussed in section 2.1, the current survey sites were integrated with a suite of historic sites for the Anglian MAREA. The integrated array is illustrated in Figure 3.2 which also depicts the impact zone that sites are located within. All sites falling within licensed aggregate areas are located within the primary impact zone and those sites situated outside of the aggregate areas, but within the influence of mobilised fine sediments that have arisen as a result of dredging activities are located within the secondary/cumulative impact zone. Sites situated outside the predicted primary and secondary influences of dredging activity served as reference sites.

Appendices B and C respectively, contain a grab log and inventory and daily progress reports for the current survey. Appendix D contains grab positions, depths, impact zones, infaunal groups and biotopes for all sites within the integrated dataset.

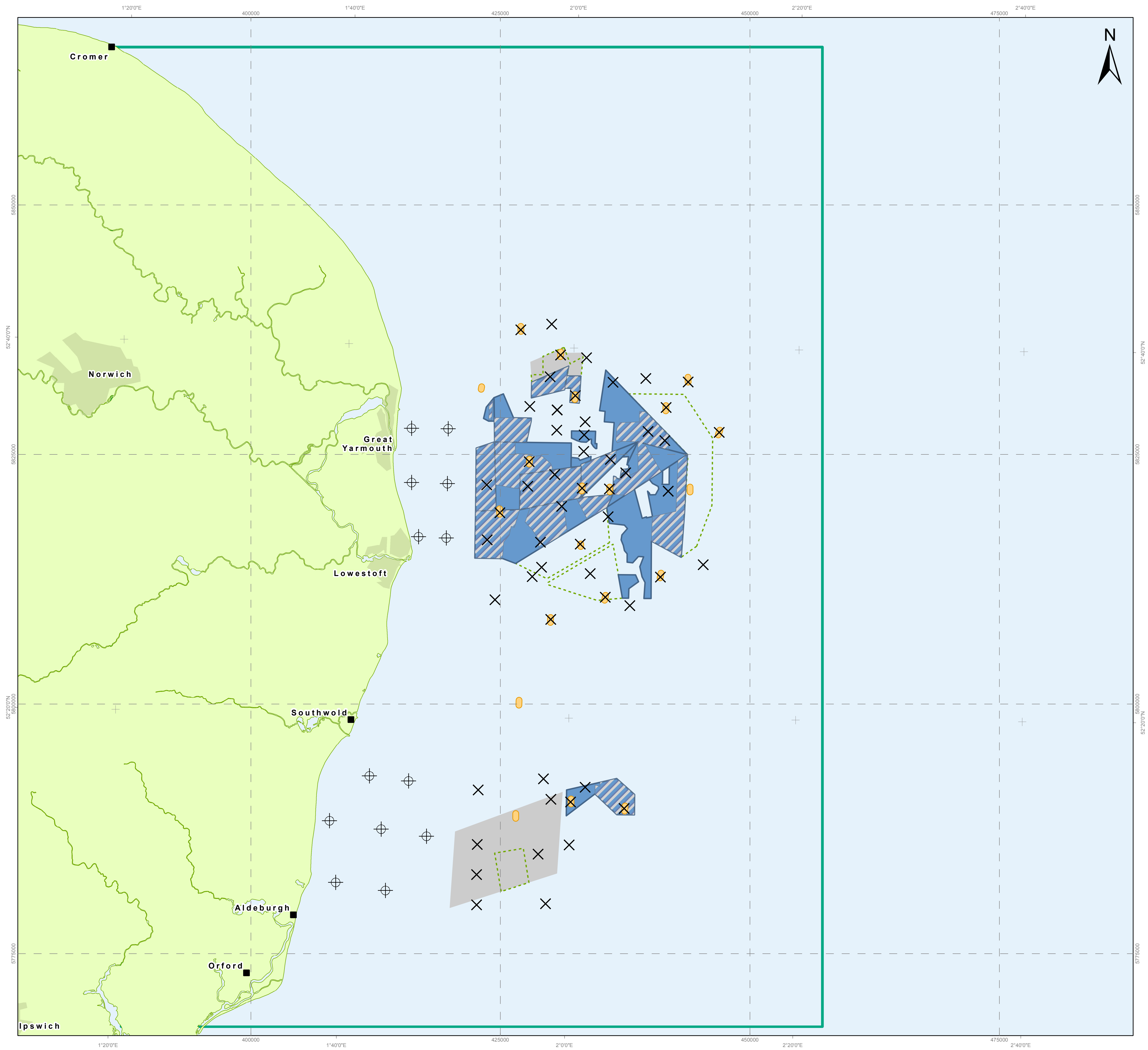
3.2 Sediment grab data

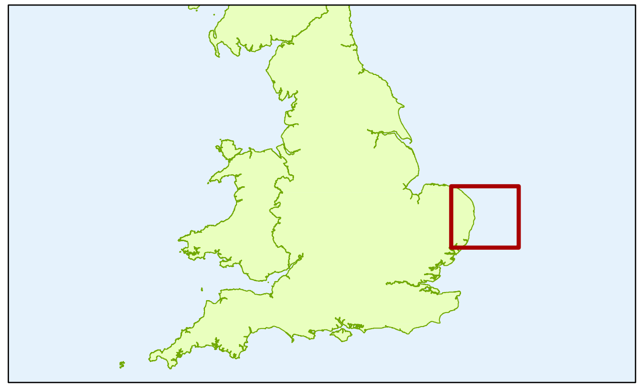
Sediment classification

PSD results, comprising sieve fractions, gravel/sand/fines percentages, sorting coefficients and Folk and Wentworth classifications for the entire integrated dataset, are included in Appendix E.

A total of eleven different sediment types were classified following PSD analyses - see Table 3.1 for summary data. Sediment classification nomenclature was based on the Folk (1954, 1974) classification system which uses the Wentworth (Wentworth, 1922) class size scale to impart physical descriptive information in relation to physical size.

Results demonstrate the homogenous nature of the sediment within the Anglian MAREA region, with 60% of the sites comprising slightly gravelly to gravelly sands and a further 26% classified as sandy gravel. These dominant sediment types ranged from moderately to very poorly sorted. The remaining 14% of sites were primarily composed of sand or varying degrees of gravelly muddy sand/muddy sandy gravel with just three locations dominated by mud and one classified as gravel.





Legend

- MAREA Study Boundary

Aggregate Areas

- Active Dredge Zone
- Licence Area
- Application Area
- Prospecting Area

Survey Array

- Hamon Grab Site
- Groundtruth Site
- 2m Beam Trawl

Notes:

Source: The Crown Estate, 2010

0 5 10 20
Kilometres

Coordinate System: WGS84 UTM Zone 31 North

Scale: 1:375,000

Sheet Size: A3

Client: Anglian Offshore Dredging Association

Consultant: Emu Limited
Ph: +44 (0) 1489 860050
Fax: +44 (0) 1489 860051
website: www.emulimited.com
email: mail@emulimited.com

Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

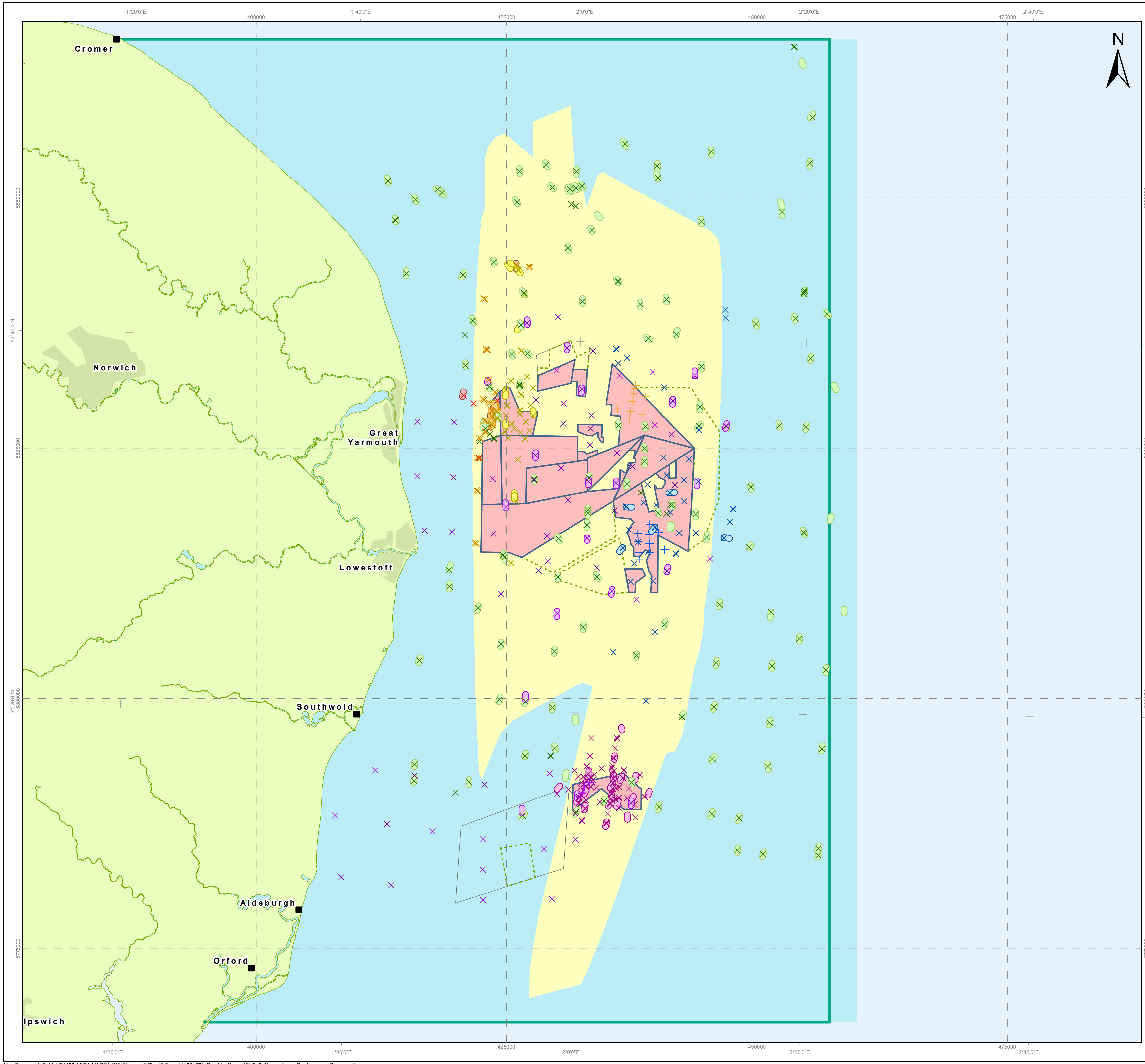
Current AODA Survey Array, Anglian MAREA Region

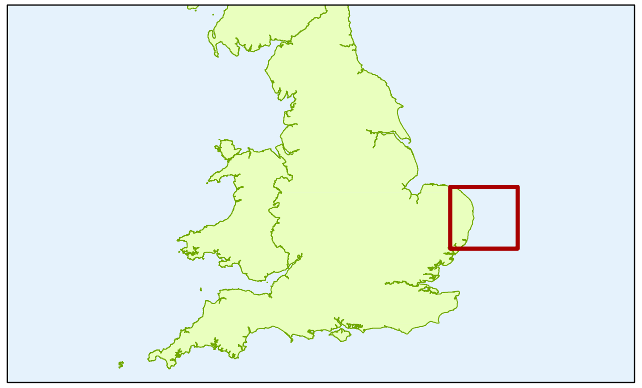
Figure No. 3.1

Drawn By:	Checked By:	Issued On:	Job Number:	Rev:
MXP	EMP	26/03/12	J/1/03/1671	1

Map Document: (N:\1.13\1463 AODA MAREA GIS Element\3.Plots\3.Finals\J1031671_Benthic_Survey\Fig3_1_SurveyArray.mxd)
26/03/2012 -- 09:54:31

Commercial in Confidence





Legend

MAREA Study Boundary

Aggregate Areas
- Licence Area
- Application Area
- Prospecting Area

Dredging Impact Zone
- Primary
- Secondary/Cumulative
- Reference Zone

Sample Locations
- REA Hamon Grab Site (2010)
- REA 2m Beam Trawl (2009)
- REC Hamon Grab Site (2009)
- REC Trawl (2010)
- Area 254 Hamon Grab Site (2002, 2008)
- Area 254 Trawl (2002)
- Area 436 & 202 Hamon Grab (2004, 2007)
- Area 436 & 202 Trawl (2004, 2007)
- Area 202 Hamon Grab (2009)
- Area 202 Trawl (2009)
- Area 401/2 Hamon Grab (2005, 2009)
- Area 401/2 Trawl (2005, 2009)
- Area 430 Hamon Grab (2006)
- Area 430 Trawl (2006)
- Area 328 Hamon Grab (2007)
- Area 401 Hamon Grab (2007)
- Area 430 Hamon Grab (2007)

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010

0 5 10 20 Kilometres

Coordinate System: WGS84 UTM Zone 31 North

Scale: 1:375,000

Sheet Size: A3

Client: Anglian Offshore Dredging Association

Consultant: Emu Limited
Ph: +44 (0) 1489 860050
Fax: +44 (0) 1489 860051
website: www.emulimited.com
email: mail@emulimited.com

Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

Integrated Survey Array and Dredging Impact Zones, Anglian MAREA Region

Figure No. 3.2

Drawn By:	Checked By:	Issued On:	Job Number:	Rev:
MXP	EMP	26/03/12	J/1/03/1671	1

Table 3.1 Classifications of sediment samples within the Anglian MAREA survey area and summary sediment data.

<table>
<tr><th>Folk classification</th><th>Samples
Historic data sets identified by prefix</th><th>Mean sediment composition</th><th>Example typical photographs of samples and in situ</th></tr>
<tr>
<td>Slightly gravelly sand

(g)S

(n=208)</td>
<td>Current sites:
1, 4, 7, 16, 25, 30, 31, 34, 40, 41, 42, 43, 46, 48, 49, GT5, GT8, GT9, GT10, GT12.
Historic sites:
See Appendix E.</td>
<td>
<table>
<tr><th></th><th>Mean</th><th>s/d</th></tr>
<tr><td>% Gravel</td><td>1.47</td><td>1.36</td></tr>
<tr><td>% Sand</td><td>97.32</td><td>6.25</td></tr>
<tr><td>% Fines</td><td>1.20</td><td>6.05</td></tr>
<tr><td>Sorting</td><td>0.79</td><td>0.27</td></tr>
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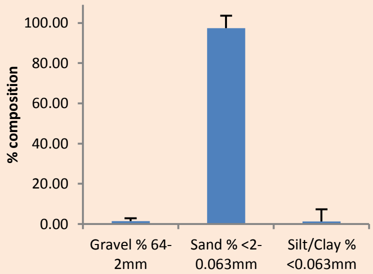

Grains sizes typical of (g)S group, contributing to 94.8% of the total similarity of 843.79:

250µm (58.9, 41.79%)
125µm (16.9, 31.37%)
500µm (15.4, 21.62%)
Grain size (av.value,contrib.%)</td>
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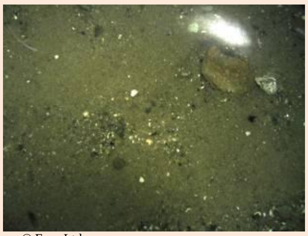
© Emu Ltd

© Emu Ltd</td>
</tr>
<tr>
<td>Gravelly sand

gS

(n=187)</td>
<td>Current sites:
2, 3, 5, 6, 19, 22, 23, 24, 29, 32, 37, 39, 51, 52, 55, GT6.
Historic sites:
See Appendix E.</td>
<td>
<table>
<tr><th></th><th>Mean</th><th>s/d</th></tr>
<tr><td>% Gravel</td><td>15.57</td><td>7.55</td></tr>
<tr><td>% Sand</td><td>83.08</td><td>7.69</td></tr>
<tr><td>% Fines</td><td>1.35</td><td>2.15</td></tr>
<tr><td>Sorting</td><td>1.86</td><td>0.51</td></tr>
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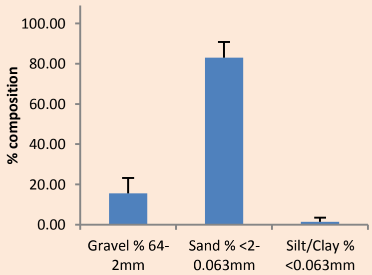

Grains sizes typical of gS group, contributing to 83.7% of the total similarity of 713.05:

250µm (40.3, 38.75%);
125µm (15.2, 24.07%)
500µm (15.6, 20.87%)
Grain size (av.value,contrib.%)</td>
<td>
© Emu Ltd

© Emu Ltd</td>
</tr>
</table>

<table>
<tr><th>Folk classification</th><th>Samples
Historic data sets identified by prefix</th><th>Mean sediment composition</th><th>Example typical photographs of samples and in situ</th></tr>
<tr>
<td>Sandy gravel

sG

(n=175)</td>
<td>Current sites:
8, 9, 10, 11, 12, 13, 14, 17, 20, 26, 28, 33, 44, 47, 54.

Historic sites:
See Appendix E.</td>
<td>
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<tr><th></th><th>Mean</th><th>s/d</th></tr>
<tr><td>% Gravel</td><td>47.23</td><td>11.88</td></tr>
<tr><td>% Sand</td><td>51.55</td><td>11.48</td></tr>
<tr><td>% Fines</td><td>1.23</td><td>1.74</td></tr>
<tr><td>Sorting</td><td>2.63</td><td>0.34</td></tr>
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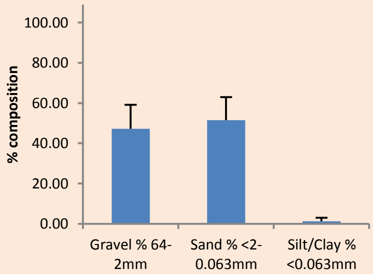

Grains sizes typical of sG group, contributing to 84.5% of the total similarity of 491.57:

250µm (21.7, 22.41%)
16000µm (16.2, 20.64%)
31500µm (4.24, 16.92%)
125µm (12.8, 13.94%)
8000µm (17.1, 10.55%)
Grain size (av.value,contrib.%)
</td>
<td>
© Emu Ltd

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</tr>
<tr>
<td>Sand

S

(n=29)</td>
<td>Current sites:
27, 35, 36, 38, 45, 50, 53, GT1.
Historic sites:
See Appendix E.</td>
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<tr><th></th><th>Mean</th><th>s/d</th></tr>
<tr><td>% Gravel</td><td>0.04</td><td>0.00</td></tr>
<tr><td>% Sand</td><td>99.69</td><td>0.73</td></tr>
<tr><td>% Fines</td><td>0.30</td><td>0.73</td></tr>
<tr><td>Sorting</td><td>0.57</td><td>0.13</td></tr>
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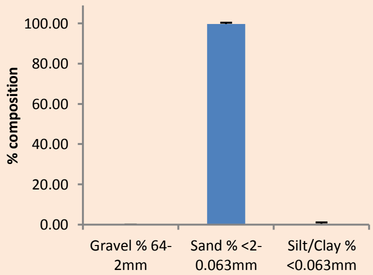

Grains sizes typical of S group, contributing to 99.7% of the total similarity of 1453.23:

250µm (60.9, 42.97%)
125µm (27.1, 36.41%)
500µm (10.1, 20.31%)
Grain size (av.value,contrib.%)
</td>
<td>
© Emu Ltd

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</tr>
</table>

<table>
<tr><th>Folk classification</th><th>Samples
Historic data sets identified by prefix</th><th>Mean sediment composition</th><th>Example typical photographs of samples and in situ</th></tr>
<tr>
<td>Gravelly muddy sand

gmS

(n=21)</td>
<td>Current sites:
21, GT7.
Historic sites:
See Appendix E.</td>
<td>
<table>
<tr><th></th><th>Mean</th><th>s/d</th></tr>
<tr><td>% Gravel</td><td>18.62</td><td>7.38</td></tr>
<tr><td>% Sand</td><td>62.14</td><td>11.01</td></tr>
<tr><td>% Fines</td><td>19.24</td><td>9.21</td></tr>
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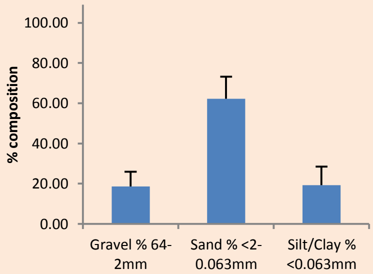

Grains sizes typical of gmS group, contributing to 83.1% of the total similarity of 491.57:

250µm (26.0, 30.06%)
125µm (17.5, 20.44%)
<63µm (18.5, 20.22%)
16000µm (3.22, 7.6%)
4000µm (6.95, 4.82%)
Grain size (av.value,contrib.%)
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<td>
© Emu Ltd

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</tr>
<tr>
<td>Slightly gravelly muddy sand

(g)mS

(n=17)</td>
<td>Current sites:
15, GT2, GT11.
Historic sites:
See Appendix E.</td>
<td>
<table>
<tr><th></th><th>Mean</th><th>s/d</th></tr>
<tr><td>% Gravel</td><td>1.17</td><td>1.21</td></tr>
<tr><td>% Sand</td><td>76.34</td><td>9.80</td></tr>
<tr><td>% Fines</td><td>22.49</td><td>10.27</td></tr>
<tr><td>Sorting</td><td>1.40</td><td>0.25</td></tr>
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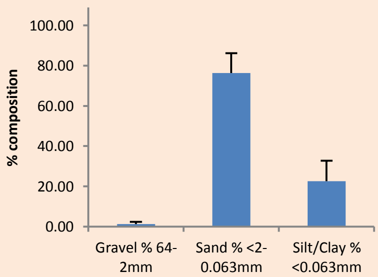
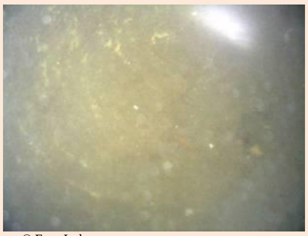


Grains sizes typical of (g)mS group, contributing to 91.5% of the total similarity of 651.35:

250um (32, 38.05%)
125um (23.5, 24.38%)
<63um (21.6, 15.57%)
63um (10.6, 13.52%)
Grain size (av.value,contrib.%)
</td>
<td>
© Emu Ltd

© Emu Ltd</td>
</tr>
</table>

Folk classification	Samples *Historic data sets identified by prefix*	Mean sediment composition	Example typical photographs of samples and *in situ*

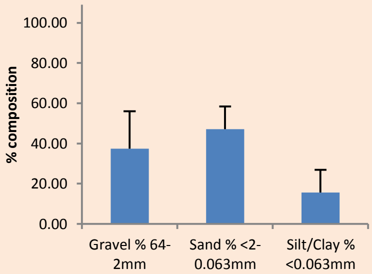
Muddy sandy gravel

msG

(n=16)

Current sites:
18, GT3, GT4, GT13.
Historic sites:
See Appendix E.

	Mean	s/d
% Gravel	35.75	18.61
% Sand	47.04	11.33
% Fines	15.60	11.25
Sorting	-	-



Grains sizes typical of msG group, contributing to 80.7% of the total similarity of 627.16:

<63µm (17.1, 22.9%)
31500µm (6.38, 18.92%)
250µm (17.1, 14.11%)
63µm (5.85, 13.99%)
8000µm (13.4, 10.8%)
Grain size (av.value,contrib.%)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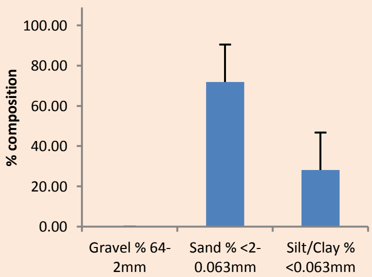
Muddy sand

mS

(n=3)

Current sites:
None.
Historic sites:
See Appendix E.

	Mean	s/d
% Gravel	0.00	0.00
% Sand	71.92	18.60
% Fines	28.08	18.60
Sorting	1.04	0.19



Grains sizes typical of mS group, contributing to 92.2% of the total similarity of 1886.51:

250µm (21.4, 46.19%)
125µm (37.5, 27.68%)
<63µm (28.1, 18.35%)
Grain size (av.value,contrib.%)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No *in situ* photograph avalaible.

<table>
<tr><th>Folk classification</th><th>Samples
Historic data sets identified by prefix</th><th>Mean sediment composition</th><th>Example typical photographs of samples and in situ</th></tr>
<tr>
<td>Slightly gravelly sandy mud

(g)sM

(n=2)</td>
<td>Current sites:
None.

Historic sites:
See Appendix E.</td>
<td>
<table>
<tr><th></th><th>Mean</th><th>s/d</th></tr>
<tr><td>% Gravel</td><td>2.03</td><td>0.40</td></tr>
<tr><td>% Sand</td><td>39.73</td><td>8.20</td></tr>
<tr><td>% Fines</td><td>58.24</td><td>8.60</td></tr>
<tr><td>Sorting</td><td>1.55</td><td>0.18</td></tr>
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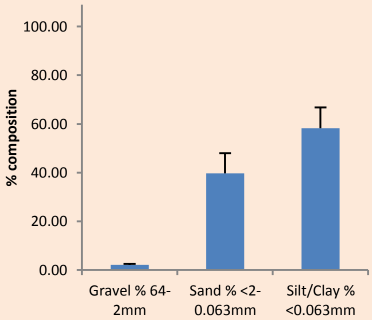

Grains sizes typical of (g)sM group, contributing to 93.6% of the total similarity of 220.27:

63µm (15.2, 59.97%)
<63µm (58.2, 33.58%)
Grain size (av.value,contrib.%)
</td>
<td>
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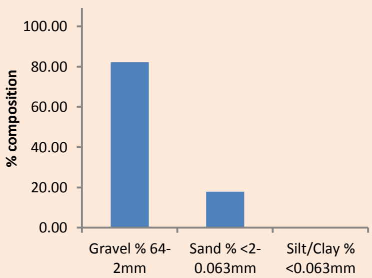
</tr>
<tr>
<td>Gravel

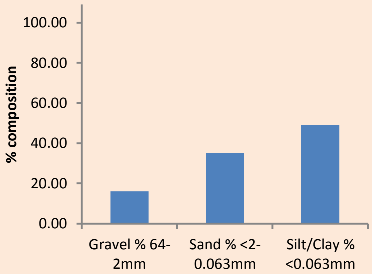
G

(n=1)</td>
<td>Current sites:
None.
Historic sites:
See Appendix E.</td>
<td>
<table>
<tr><th></th><th>Mean</th></tr>
<tr><td>% Gravel</td><td>82.16</td></tr>
<tr><td>% Sand</td><td>17.83</td></tr>
<tr><td>% Fines</td><td>0.01</td></tr>
<tr><td>Sorting</td><td>2.21</td></tr>
</table>


Grains sizes typical of G group, contributing to 85.3% of the total:

16000µm (29.3%)
31500µm (24.38%)
8000µm (21.07%)
250µm (10.54%)
Grain size (contrib.%)
</td>
<td>
© Emu Ltd

No in situ photograph avalaible.</td>
</tr>
</table>

Folk classification	Samples *Historic data sets identified by prefix*	Mean sediment composition	Example typical photographs of samples and *in situ*
Gravelly mud gM (n=1)	***Current sites:*** None. ***Historic sites:*** See Appendix E.	Mean % Gravel 16.10 % Sand 34.95 % Fines 48.95 Sorting 3.02  Grains sizes typical of gM group, contributing to 84.2% of the total: <63µm (48.95%) 125µm (12.09%) 250µm (11.82%) 8000µm (6.40%) 16000µm (4.89%) *Grain size (contrib.%)*	 © Emu Ltd No *in situ* photograph avalaible.

A Principal Components Analysis (PCA) ordination of the PSD data (Figure 3.3), according to the Folk sediment classifications given in Table 3.1, indicated that samples formed discrete clusters.

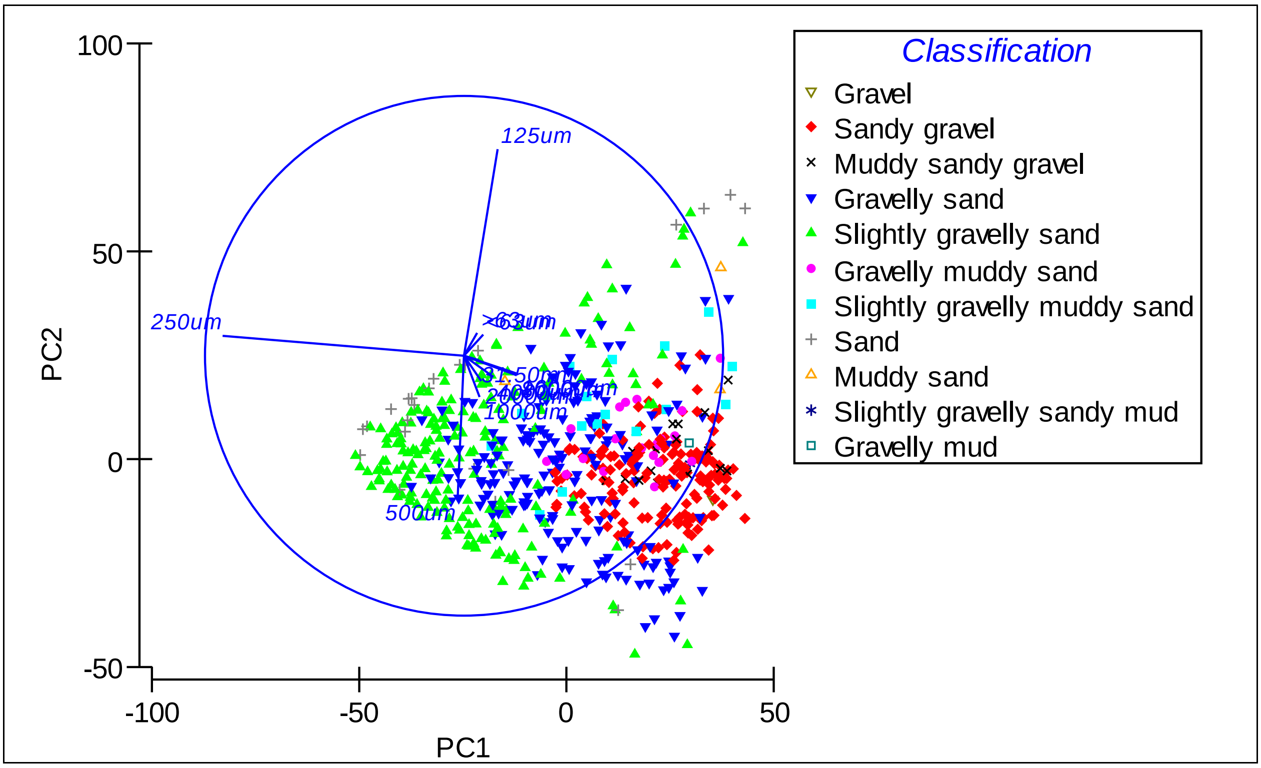


Figure 3.3 Principal Components Analysis of selected sediment variables as indicated. Samples are symbolised according to Folk sediment classifications.

It is apparent that several different size classes are responsible for the differences between sediment groups. The 250um fraction, classified as fine sand, was correlated with PC axis 1 which accounted for 50% of the variation between samples. A further 23% of the variation within the dataset was accounted for by PC axis 2 which was mainly correlated with two fractions, 125µm and 500µm, fine sand and medium sand respectively.

Geographical trends

The distribution of the principal sediment components and the Folk sediment classifications for all sites are illustrated within Figures 3.4 and 3.5 respectively. These figures illustrate the homogenous sediment nature within the Anglian MAREA region. Within all of the aggregate extraction areas and over most of the survey area slightly gravelly to gravelly sand and sandy gravel predominates. To the north east of the region, an area of sediment with a higher silt component was noted which comprised slightly gravelly muddy sand and slightly gravelly sandy mud. In addition, along the western edge of the region, from midway down to the southern extent of the survey area, scattered sites with a higher silt component occurred; these were classified as slightly gravelly muddy sand, muddy sand or muddy sandy gravel. Within the centre of the southern extent of the array a small cluster of siltier sites was also located.

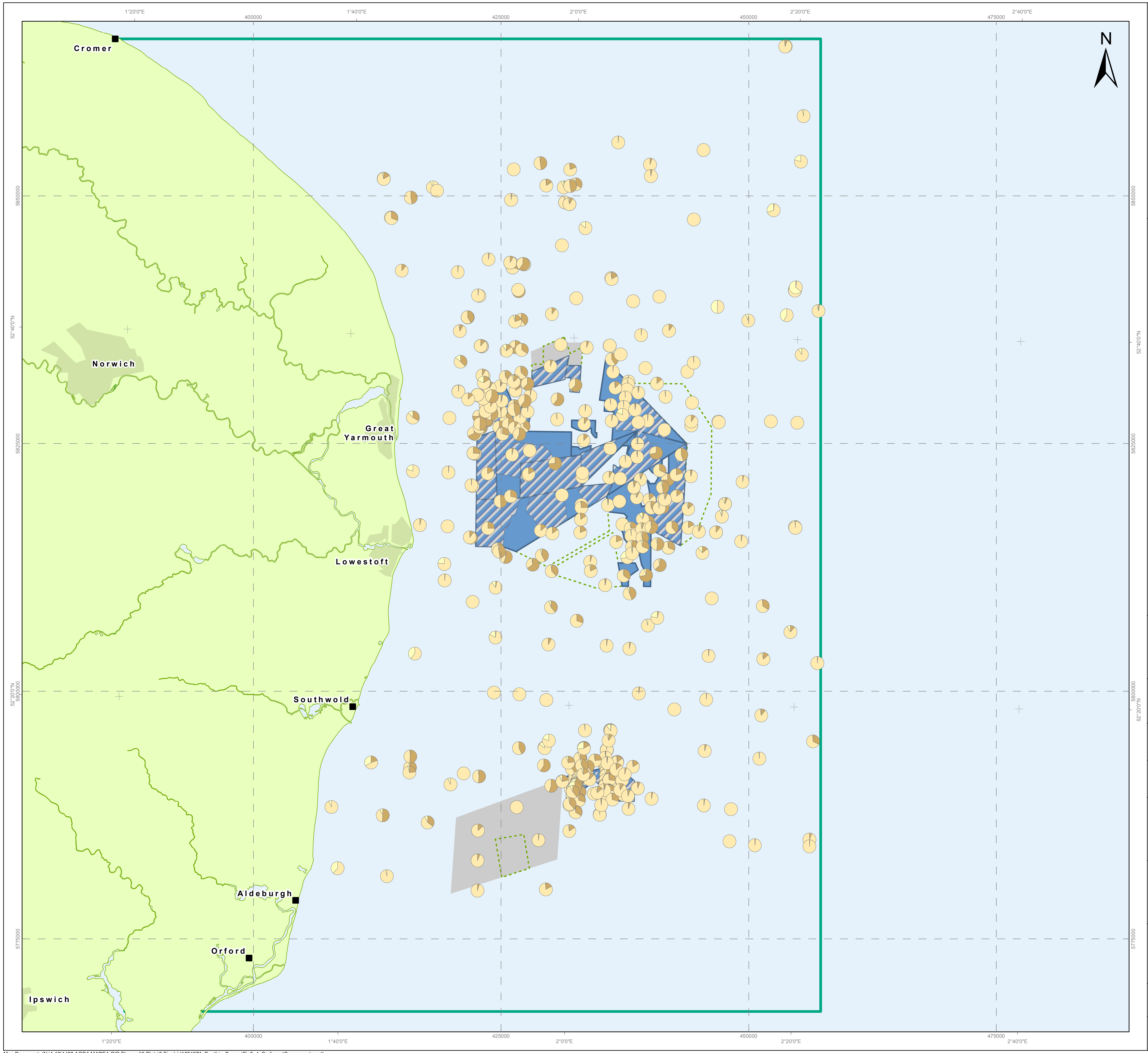
The general sediment coarsening with increasing southerly distance across the MAREA study area described by Cooper *et al.* (2007) was not observed in this study. Figure 3.4 indicates that clusters of sites with gravelly sediments were found within the aggregate licence areas.

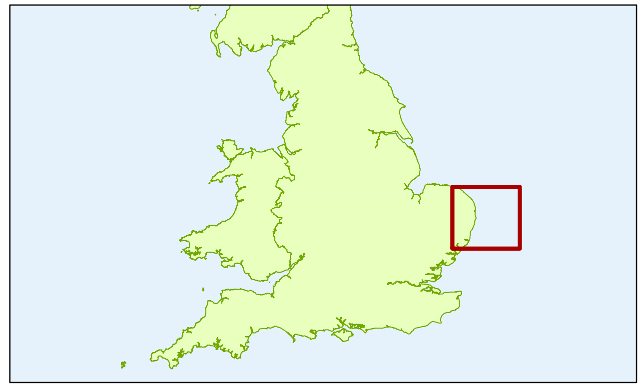
Further investigation into potential sediment data geographical trends were conducted using Primer. An MDS ordination of the PSD data, symbolised according to the suggested impact zone samples fell within, indicated no clear difference between zones (Figure 3.6). However, the result of an ANOSIM conducted on the data indicated that despite a very low Global R value of 0.035, suggesting no difference between impact zones, differences between the groups of data were possible based on a significance value of p=0.2%. This needs to be treated with some caution as R values below 0.2 usually represent no difference, but given the large size of the data set it is possible that differences exist somewhere within the overall data set.

On the basis of the ANOSIM a SIMPER analysis was conducted on the PSD data which revealed some broad between zone differences. It was found that 250µm, a fine sediment fraction, was the principal basis for similarity within the PSD data in all of the zones, with a contribution of 40-48%. However, the reference zone differed from both the primary and secondary/ cumulative impact zones due to a silt fraction contributing to the top 80% of similarity and a relatively lower contribution by gravel components. This corresponds with the pattern observed in Figures 3.4 and 3.5 in which two areas of sediment with a higher silt component were observed; the majority of these sites were located within the reference zone.

As the targeted resource for aggregates are coarser gravelly sands it may be expected that such fractions would be concentrated within or close to aggregate licence areas as they would be preferentially selected for extraction. In addition, due to the wide distribution of the sites in the reference area, it would be unlikely for these sites not to encompass the wider range of sediment type variation across the region.

The potential relationship between depth and PSD was also investigated through an MDS ordination (Figure 3.7) and an ANOSIM conducted on the data. The former indicated no relationship with depth, however, results from the ANOSIM suggested that despite a very low Global R value of 0.057, differences between the groups of data were possible based on a significance value of p=0.2%. This indicates that somewhere within the dataset a difference exits, although this should be treated with some caution as explained above. Assessment of the ANOSIM pairwise comparisons found that the 5-9.9m depth band was primarily responsible for the differences, with dissimilarity between shallow depths and all others revealed. SIMPER analyses revealed the 250µm fraction was the principal cause of dissimilarity between depths of 5-9.9m and all other depth bands, with the former generally containing a higher percentage of this fine sand component.





Legend

MAREA Study Boundary

Aggregate Areas

Active Dredge Zone

Licence Area

Application Area

Prospecting Area

Sediment Component (percentage)

Gravel

Sand

Fines

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010; MFA 2009
Emu Limited, 2002-2010

0 5 10 20

Kilometres

Coordinate System:

WGS84 UTM Zone 31 North

Scale:	*Sheet Size:*
1:375,000	A3

Client:

Anglian Offshore Dredging Association

Consultant:

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Ph: +44 (0) 1489 860050
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website: www.emulimited.com
email: mail@emulimited.com

Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

Principal Sediment Components Distribution, Anglian MAREA Region

Figure No. 3.4

Drawn By:	*Checked By:*	*Issued On:*	*Job Number:*	*Rev:*
MXP	EMP	26/03/12	J/1/03/1671	1

Map Document: (N:\1.13\1463 AODA MAREA GIS Element\3.Plots\3.Finals\J1031671_Benthic_Survey\Fig3_4_SedimentComponent.mxd)
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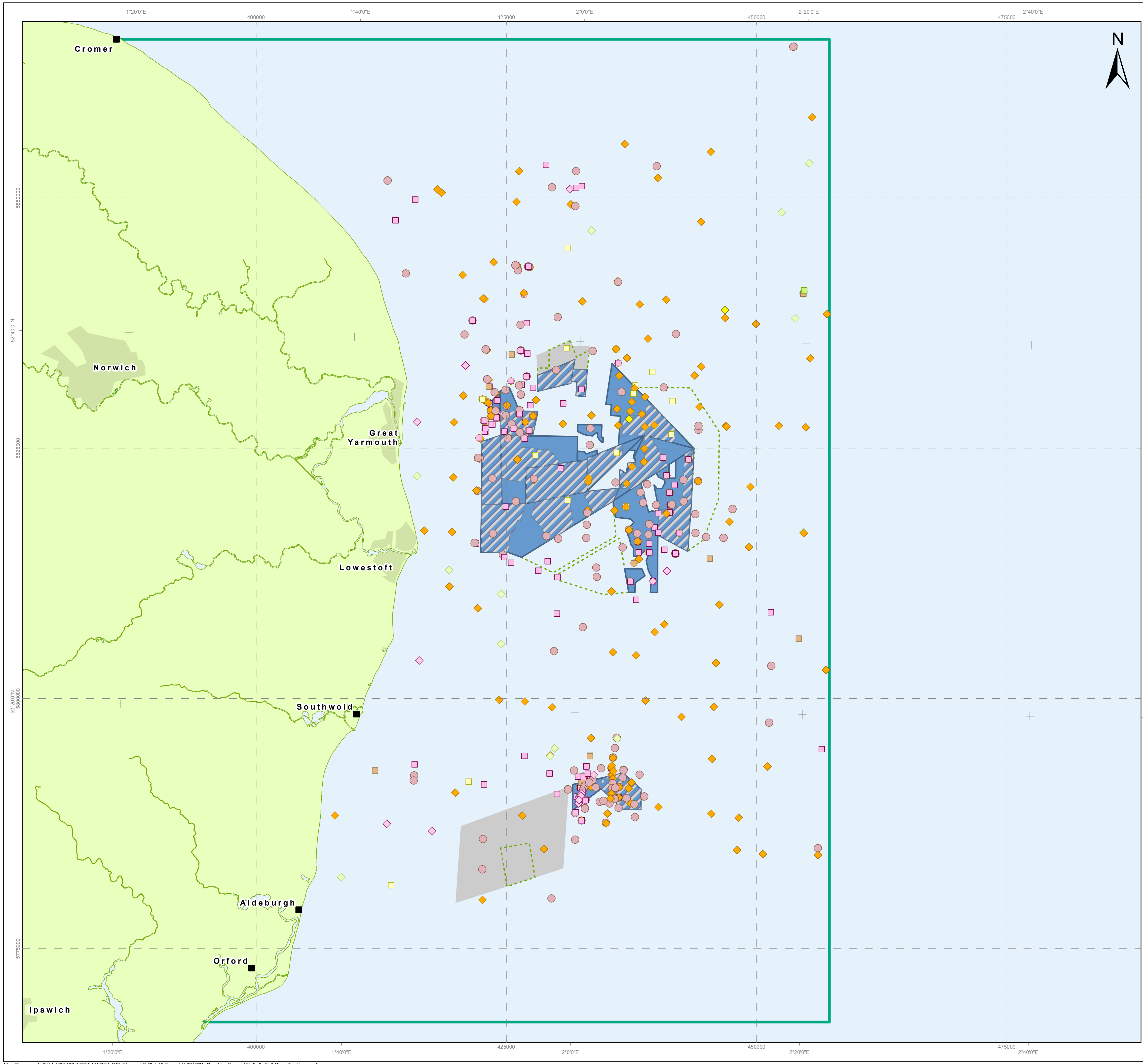

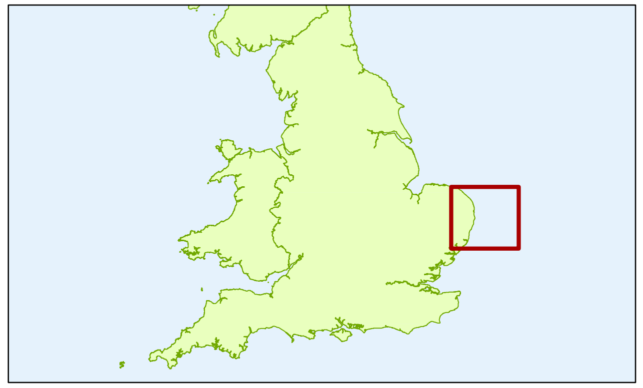

Legend

MAREA Study Boundary

Aggregate Areas

Active Dredge Zone
Licence Area
Application Area
Prospecting Area

Folk Classification

(g)S
(g)mS
(g)sM
G
S
gM
gS
gmS
mS
msG
sG

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010; MFA 2009
Emu Limited, 2002-2010

0 5 10 20
Kilometres

Coordinate System: WGS84 UTM Zone 31 North

Scale: 1:375,000

Sheet Size: A3

Client: Anglian Offshore Dredging Association

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website: www.emulimited.com
email: mail@emulimited.com

Project Title:
AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:
Sediment Type Distributions Based on Folk Classifications, Anglian MAREA Region

Figure No. 3.5

Drawn By:	Checked By:	Issued On:	Job Number:	Rev:
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Map Document: (N:\1.13\1463 AODA MAREA GIS Element\3.Plots\3.Finals\J1031671_Benthic_Survey\Fig3_5_FolkClassification.mxd)
26/03/2012 -- 10:20:07

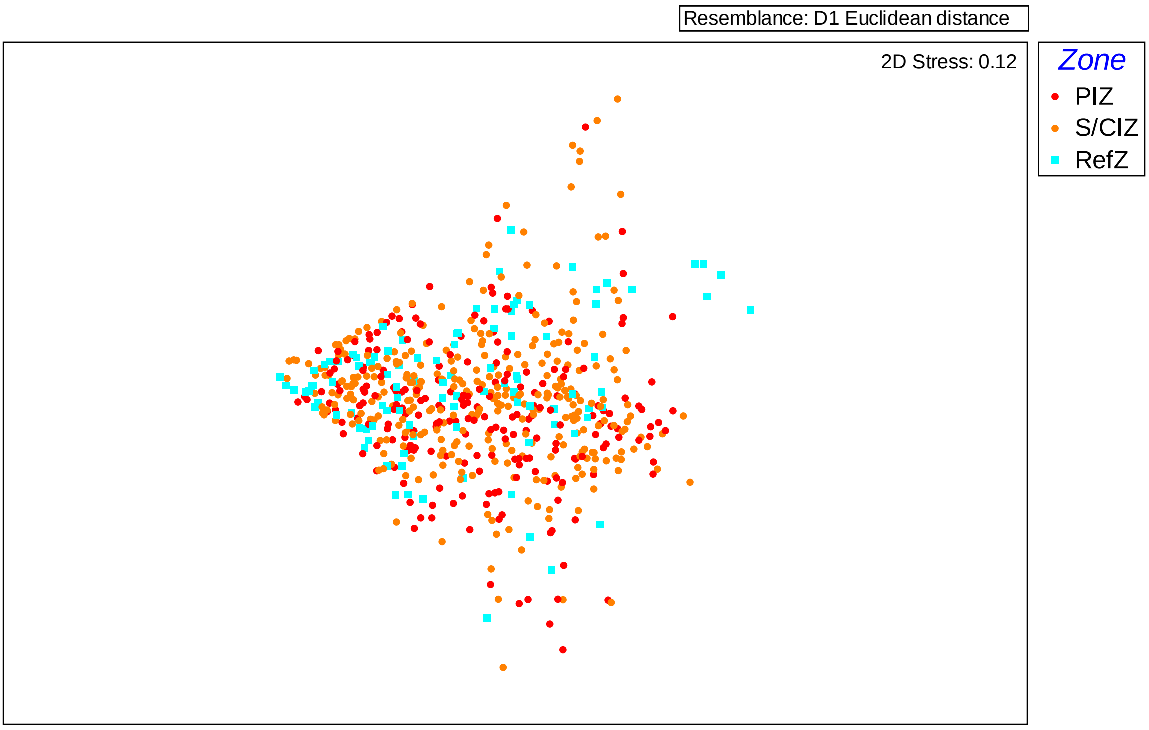


Figure 3.6 MDS ordination of PSD data. Samples are classified according to impact zone.

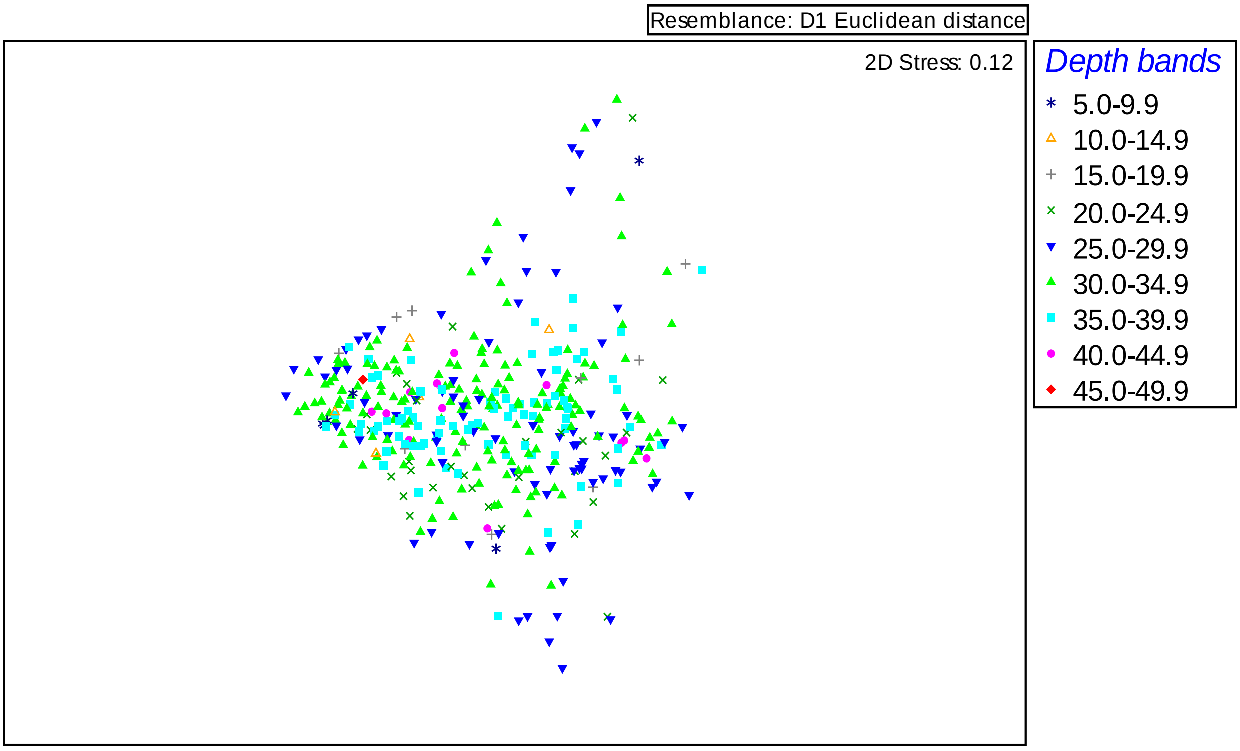


Figure 3.7 MDS ordination of PSD data. Samples are classified according to depth.

Temporal trends

Temporal trends in sediment type were explored through an MDS ordination of PSD data with samples classified according to the year they were collected (Figure 3.8). This indicated no correlation between year and PSD data, however a subsequent ANOSIM indicated that despite a very low Global R value of 0.046, suggesting no difference between years, differences between the groups of data were possible based on a significance value of p=0.1%. Assessment of the ANOSIM pairwise comparisons revealed differences between 2006 and other years (2002, 2003, 2008) were the principal cause of difference. An overall increase in the sand fraction (250µm) was observed between 2002 /2003 and 2006, however, between 2006 and 2008 a reduction in this fraction was found. These variations may be attributed to dredging effects, although natural variation cannot be dismissed.

To further elucidate any potential temporal trends in sediment type, between year analyses were conducted for datasets with repeat data. When examined in isolation, no correlation between year and sediment type was found for Areas 401/2 and 254 (Respectively: R=0.003, p=40.1%; R=0.008, p=22%). However, despite a low global R value of 0.078 Areas 436/202 data showed a significant difference (0.8%) between 2003 and 2006. A subsequent SIMPER analysis indicated that an increase in fine sediment fractions between these years was the principal cause of differences. A concomitant decrease in medium sand and gravel fractions was observed over the same period. Such a fining of sediment over time concurs with previous oberservations of sediment effects in dredged areas (Cooper *et al*., 2005; Desprez *et al*., 2009) although, again, natural variation cannot be dismissed.

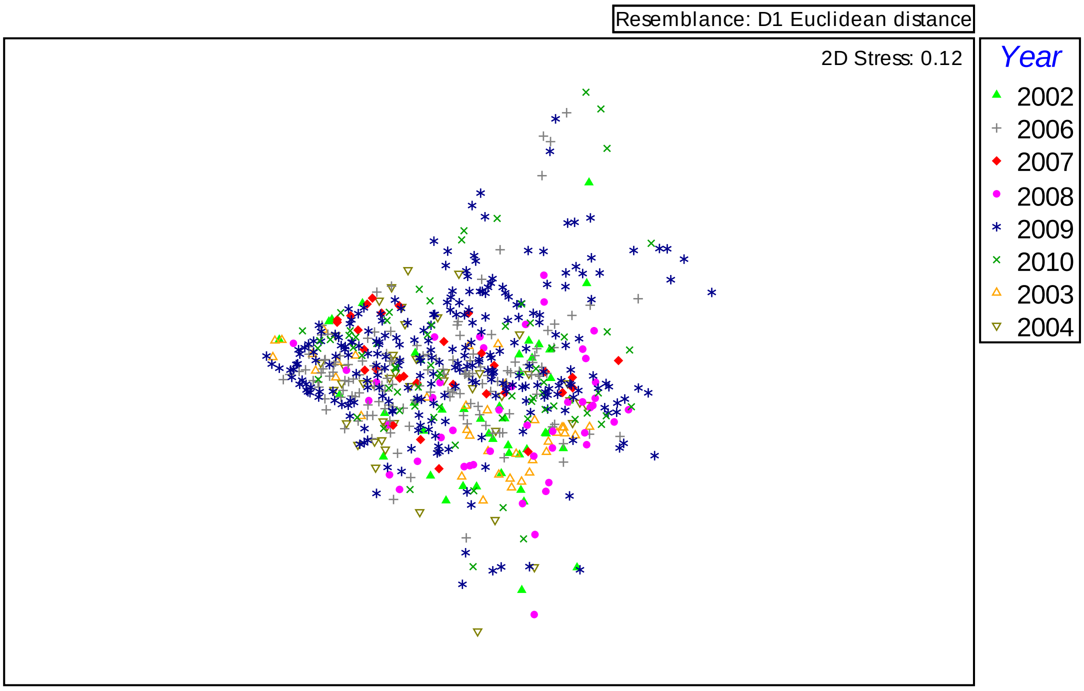


Figure 3.8. MDS ordination of PSD data. Samples are classified according to year.

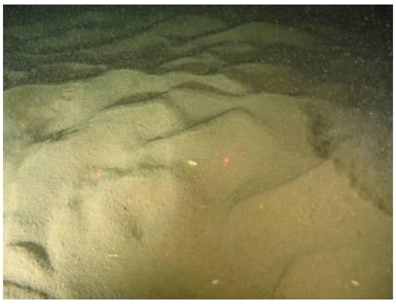
Palaeochannels and Geology

Archaeological work (Wessex Archaeology, 2010) in the Anglian MAREA region noted the presence of subtidal palaeochannels, infilled with sediment. These were also noted during the EC REC monitoring study and have been described as the geological evidence of early glaciations (Limpenny et al., 2011). In the South Coast MAREA (Emu Ltd., 2010) specific biotopes and species assemblages were associated with similar physical features and were therefore considered during analyses. However, the lack of surface expression of any of the palaeochannels in the Anglian MAREA region means they are unlikely to affect the biota, and thus they were not considered further. Therefore any relationships with fauna are unlikely to be explained by the underlying geology as it does not outcrop anywhere in the Anglian MAREA region and the majority of the Quaternary is clay-based (British Geological Society, 1984, 1991). From a geological aspect, the EC REC study highlighted discrete assemblages for the area. However, the region shows predominance for a sedimentary dominated seabed and associated characterising species. Their abundance distribution and variability has been linked to the proportional differences in sand and gravel proportions (Linpenny et al., 2011). Thus, only the sedimentary environment was explored for the current MAREA.

Video analyses

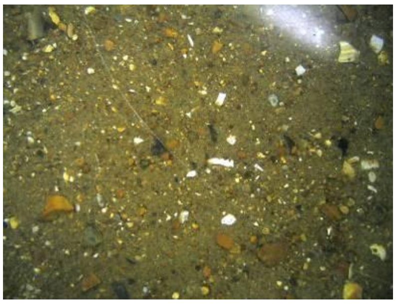
For the current video survey, a hyperdigital camera log, static image positions, deck photographs, underwater stills and video footage are presented within Appendices F to J respectively.

Video analyses for current data confirmed the dominance of gravelly sands within the Anglian MAREA region, but also illustrated the overall variability (Plates 3.1a-f). Video footage also indicated the presence of rippled sand at many of the sites, providing valuable information on the degree of sediment mobility within the area. In a number of the rippled sand areas, coarser sediment fractions and fragments of broken shell were seen to have accumulated in the troughs between ripples.



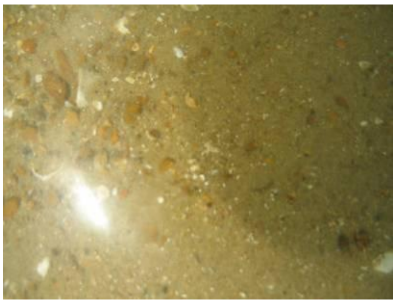
a. Rippled sand

b. Slightly gravelly, very shelly sand



c. Shelly gravelly sand

d. Rippled sand with patches of gravelly sand



e. Rippled shelly sand with patches of gravelly sand

f. Rippled silty sand

Plate 3.1 a-f Example sediments from the video analysis

3.3 Macrofaunal Grab Data

Grab Taxa Summary

Samples from the 0.1m² Mini-Hamon grab provided quantitative data for within substrate (infauna) macro-invertebrate species and qualitative (presence) results for sessile animals attached to the sediment surface (epifauna) (see Appendix K (enumerated infaunal species list), Appendix L (epifaunal species list) and Appendix M (Phylum biomass percentages) for the integrated AODA region dataset). Subsequent analyses incorporate both current survey and historic data.

Following faunal data rationalisation (see section 2.1), 759 taxa were found in both trawl and grab samples (Table 3.2). Overall, Annelida was the most species rich group, encompassing approximately a third of the taxa found within the Anglian MAREA study. The next most species rich groups, in order of dominance, were Crustacea, Molluscs, Cnidaria and Pisces (26.5%, 12.3%, 8.0% & 6.9% respectively).

Table 3.2 Combined grab and trawl surveys overall taxa counts for the Anglian MAREA region.

Taxonomic group	Overall number of unique species / higher taxa
Annelida (Polychaeta and Oligochaeta) (worms)	247
Bryozoa (Sea mats)	31
Crustacea (Shrimps, prawns, crabs, barnacles)	201
Chaetognatha (Arrow worms)	1
Chelicerata (Sea spiders)	17
Cnidaria (Sea firs, sea anemones)	61
Ctenophora (Sea gooseberries)	1
Echinodermata (Sea urchins, brittle stars, starfish)	24
Entoprocta (Goblet worms)	3
Enteropneusta (Acorn worm)	1
Mollusca (Bivalves, chitons)	93
Nemertea (Ribbon worms)	2
Nematoda (Round worms)	1
Other	2
Pisces (Fish)	52
Phoronida (Horseshoe worm)	1
Platyhelminths (Flat worms)	2
Porifera (Sponges)	5
Sipunculida (Peanut worms)	6
Tunicata (Sea squirt)	8

The number of species and the frequency of occurrence of the grab epifaunal and infaunal taxa within each of the major taxonomic groups are presented in Table 3.3. Figure 3.9 illustrates the relative taxonomic group contributions to total infaunal species diversity, abundance and biomass within the Anglian MAREA study area.

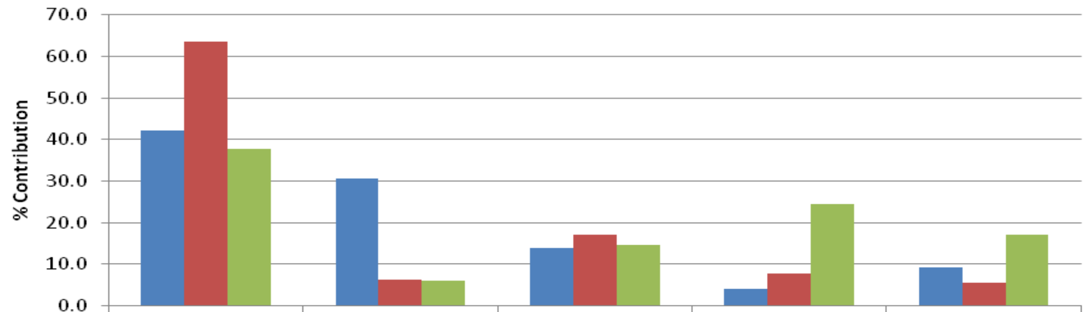
From grab samples, 668 taxa were identified with infauna encompassing 16 major taxonomic groups. For infauna Annelida were dominant, comprising 42% of infaunal taxa and occurring in 98% of samples. Annelids were also the largest contributors to total macrofaunal abundance at 63.5% and concurrently comprised a third of the total infaunal biomass. Crustacea were present in three quarters of the grab samples and were the next greatest contributors to infaunal species richness at 30.6%, but had a relatively low abundance (6.3%) and concomitantly low biomass (5.9%).

Although Echinodermata and 'other' taxa were comparatively poorly represented in terms of both species diversity and macrofaunal abundance, they accounted for 24.4% and 17.1% of the total biomass respectively. This may be attributed to the larger size of echinoderms and several of the taxonomic groups contained within 'others', including Pisces and Cnidaria, compared to polychaete or crustacean species.

All recorded grab epifauna were encompassed within five major taxonomic groups with over half classified as Cnidaria, occurring in 36% of samples. An additional 37% of epifaunal taxa were bryozoans, present within 30% of samples.

Table 3.3 Grab species/higher taxa number and occurrence frequency, within major taxonomic groups, Anglian MAREA region.

Taxonomic group	Epifauna		Infauna	
	No. species / higher taxa	Frequency of occurrence %	No. species / higher taxa	Frequency of occurrence %
Annelida (Polychaeta and Oligochaeta) (worms)	0	0	245	98
Bryozoa (Sea mats)	29	30	0	0
Crustacea (Shrimps, prawns, crabs, barnacles)	0	0	179	75
Chaetognatha (Arrow worms)	0	0	1	1
Chelicerata (Sea spiders)	0	0	17	18
Cnidaria (Sea firs, sea anemones)	41	36	10	25
Echinodermata (Sea urchins, brittle stars, starfish)	0	0	22	52
Entoprocta (Goblet worms)	2	1	0	0
Enteropneusta (Acorn worm)	0	0	1	0
Mollusca (Bivalves, chitons)	0	0	78	58
Nemertea (Ribbon worms)	0	0	2	39
Nematoda (Round worms)	0	0	1	15
Other	0	0	2	0
Pisces (Fish)	0	0	20	5
Phoronida (Horseshoe worm)	0	0	1	4
Platyhelminths (Flat worms)	0	0	2	2
Porifera (Sponges)	2	0	0	0
Sipunculida (Peanut worms)	0	0	6	5
Tunicata (Sea squirt)	5	4	2	1



	Annelida	Crustacea	Mollusca	Echinodermata	Others
Species	42.2	30.6	13.8	4.1	9.2
Abundance	63.5	6.3	17.0	7.6	5.6
Biomass	37.8	5.9	14.7	24.4	17.1

Figure 3.9 Major taxonomic groups relative contributions to total species diversity, abundance and biomass, Anglian MAREA region.
***Note: biomass for 'others' excludes colonial sessile epifauna.**

The top 30 most abundant infaunal species (enumerated data) highlights the numerical superiority of the Ross Worm *S. spinulosa* (Plate 3.2a) with 31,820 recorded; 45% of total grab infaunal individuals (Table 3.4). A bivalve species, *Abra alba* (Plate 3.2c), was the next most abundant organism, comprising 9% of individuals and the polchaete *Lagis Koreni*, brittlestar *Ophiura albida* and bivalve *Mytilus edulis* accounted for a further 10%.

The most frequently occurring taxa from grab samples (Table 3.4) incorporate presence/absence data for epifauna with the enumerated infaunal species data. Despite only accounting for 2% of total individuals *Ophelia borealis* (Plate 3.2b) had the highest frequency of occurrence in samples at 46.9%. The ribbon worm, Nemertea, and polychaetes *S. spinulosa* and *N. cirrosa* all occurred in approximately a third or more of the samples taken across the Anglian MAREA region.

The key epifaunal species occurring in grab samples included the hydroid *Sertularia* (21.1%), sea anemones Actiniaria (16.3%) and the bryozoans *Conopeum reticulum* (15.0%) and *Electra monostachys* (14.1%).

Table 3.4 Top 30 most abundant infauna (enumerated data) and frequently occurring grab fauna (including epifaunal presence/absence data), Anglian MAREA region.

Most abundant infaunal taxa					Most frequently occurring grab taxa		
Taxa	Type of organism	Total Abundance	Mean Abundance	Max Abundance	Taxa	Type of organism	% Frequency of occurrence
Sabellaria spinulosa	Worm	31820	48.8	3960	*Ophelia borealis*	Worm	46.9
Abra alba	Bivalve	6426	9.86	672	NEMERTEA	Ribbon worm	39.3
Lagis koreni	Worm	2704	4.15	278	*Sabellaria spinulosa*	Worm	37.4
Ophiura albida	Brittlestar	2283	3.5	106	*Nephtys cirrosa*	Worm	31.1
Mytilus edulis	Bivalve	2242	3.44	1078	*Glycera lapidum*	Worm	28.5
Abra	Bivalve	2231	3.42	289	*Spiophanes bombyx*	Worm	27.5
Scalibregma inflatum	Worm	1977	3.03	690	OPHIUROIDEA	Brittlestar	27.3
OPHIUROIDEA	Brittlestar	1966	3.02	121	*Lumbrineris gracilis*	Worm	25.6
ACTINARIA	Sea anemone	1860	2.85	335	*Lanice conchilega*	Worm	23.8
Lanice conchilega	Worm	1700	2.61	359	*Polycirrus*	Worm	23.0
Ophelia borealis	Worm	1544	2.37	58	*Nephtys*	Worm	22.7
Mytilidae	Bivalve	1245	1.91	515	*Gastrosaccus spinifer*	Shrimp	22.2
NEMERTEA	Ribbon worm	1172	1.8	58	*Abra alba*	Bivalve	21.5
Polycirrus	Worm	1164	1.79	158	*Sertularia*	Sea fir	21.1
Kurtiella bidentata	Bivalve	1115	1.71	352	*Notomastus*	Worm	21.0
Spiophanes bombyx	Worm	938	1.44	44	*Ophiura albida*	Brittlestar	19.9
Polydora caulleryi	Worm	932	1.43	138	*Lagis koreni*	Worm	19.6
Pholoe baltica (sensu petersen)	Worm	838	1.29	64	*Glycera oxycephala*	Worm	19.3
Pisidia longicornis	Crab	810	1.24	178	*Pholoe baltica (sensu petersen)*	Worm	16.6
NEMATODA	Roundworm	806	1.24	97	ACTINARIA	Sea anemone	16.3
Gastrosaccus spinifer	Shrimp	795	1.22	98	*Scalibregma inflatum*	Worm	15.5
Amphipholis squamata	Brittlestar	720	1.1	111	*Conopeum reticulum*	Bryozoan	15.0
Ophiura	Brittlestar	623	0.96	63	NEMATODA	Roundworm	14.6
Lumbrineris gracilis	Worm	541	0.83	27	*Electra monostachys*	Bryozoan	14.1
Glycera lapidum	Worm	424	0.65	8	*Ophiura*	Brittlestar	13.8
Polynoidae	Worm	416	0.64	48	*Polydora caulleryi*	Worm	13.3
Atylus swammerdamei	Amphipod	399	0.61	71	*Aonides paucibranchiata*	Worm	13.0
Notomastus	Worm	397	0.61	58	*Atylus swammerdamei*	Amphipod	13.0
CIRRIPEDIA	Barnacle	372	0.57	350	Mytilidae	Bivalve	13.0
Mediomastus fragilis	Worm	353	0.54	49	*Echinocyamus pusillus*	Sea urchin	12.9

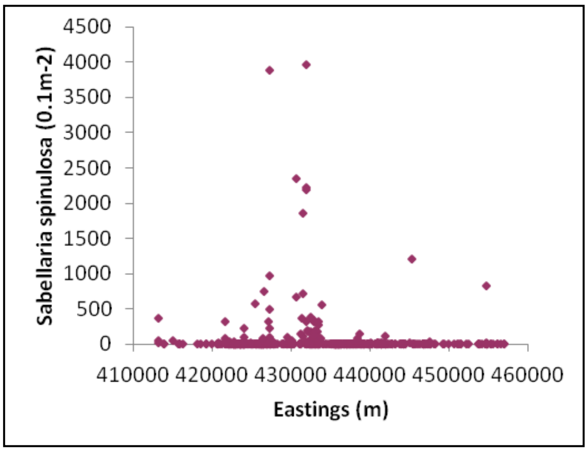
Plates 3.2a-h contain photographs of typical Annelid, Mollusc, Echinoderm and Crustacean species found within the Anglian MAREA study.

 © Emu Ltd	 © Emu Ltd
a) Ross worm *Sabellaria spinulosa*	**b)** Bristleworm *Ophelia borealis*
 © Emu Ltd	 © Emu Ltd
c) White furrow shell *Abra alba*	**d)** Common mussel *Mytilus edulis*
 © Emu Ltd	 © Emu Ltd
e) Serpent star *Ophiura albida*	**f)** Green sea urchin *Echinocyamus pusillus*
 © World Register of Marine Speices	 © World Register of Marine Speices
g) Opposum shrimp *Gastrosaccus spinifer*	**h)** Amphipod *Atylus swammerdami*

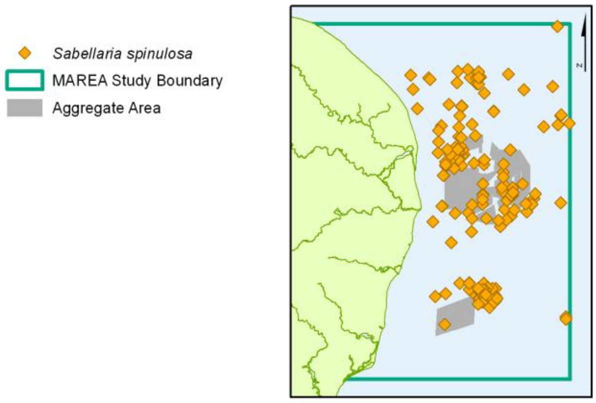
Plate 3.2 a-h Typical polychaete, mollusc, echinoderm and crustacean species, Anglian MAREA region.

Geographical Trends

Despite being numerically dominant, *S.spinulosa*, *A.alba*, *L.koreni* and *O.albida* occurred in <38% of grab samples, indicating the patchy distribution for these species. Species distributions and species-area relationships, using density against longitude (Eastings), were investigated, with an Easting of 460000 indicating sites further offshore (Figures 3.10a-l). These provided information on avoidance or aggregation in relation to position and general distribution within the Anglian MAREA.

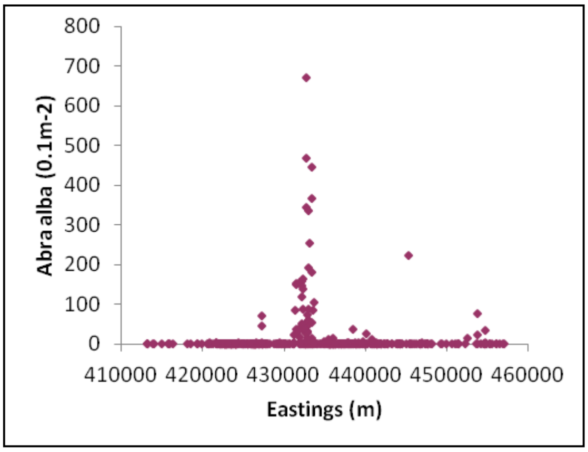


a)



b)

Sabellaria spinulosa



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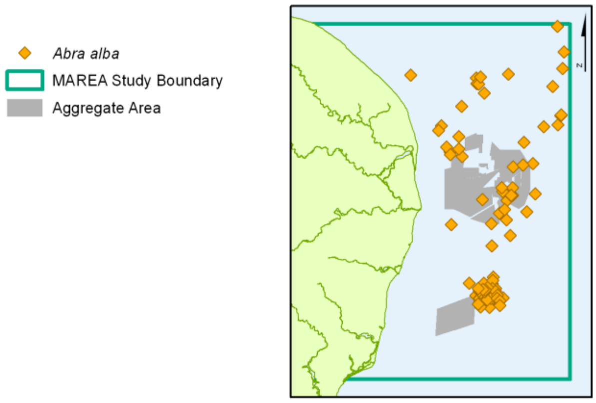

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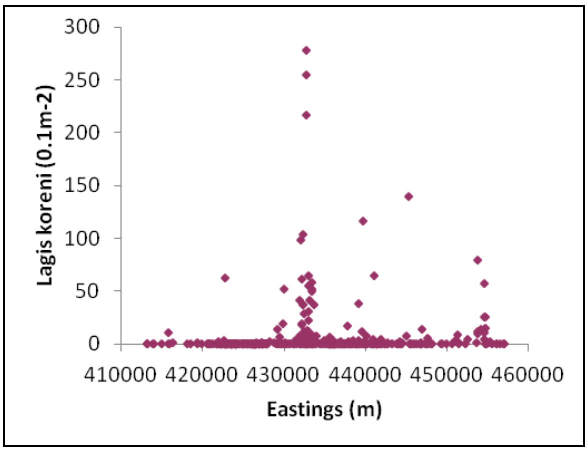
Abra alba



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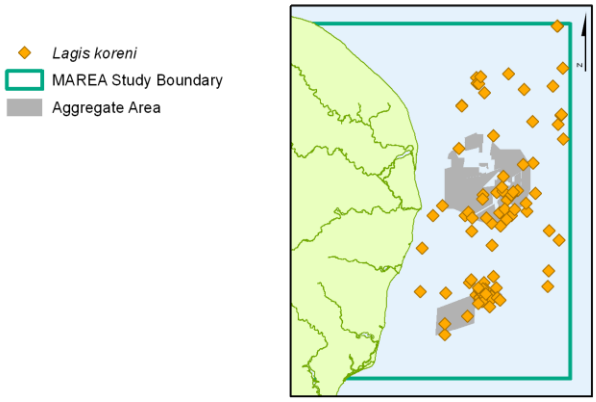
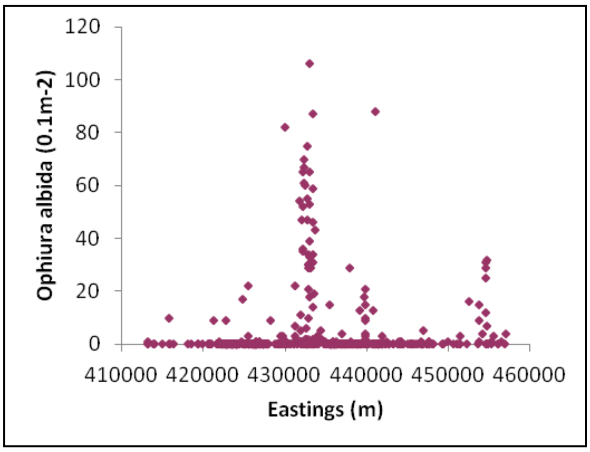
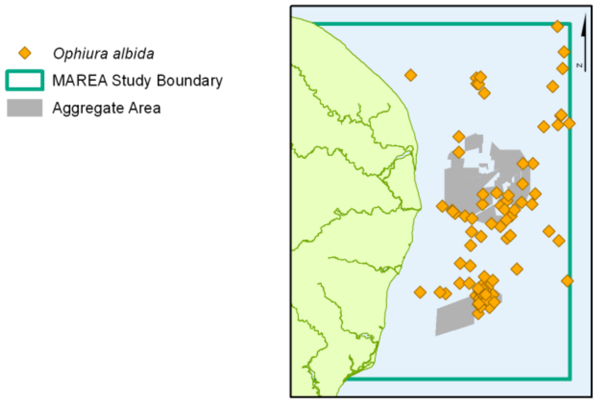


f)

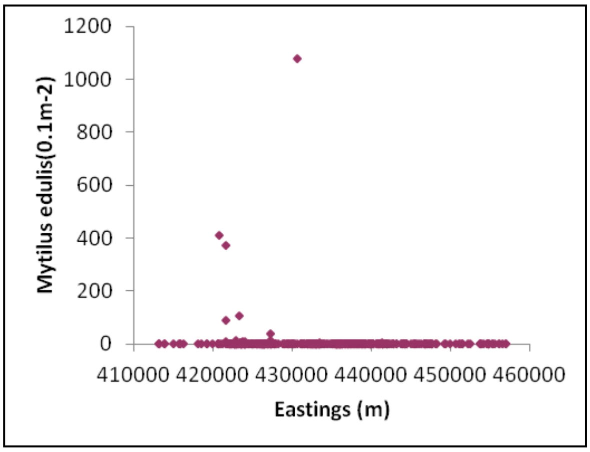
Lagis koreni

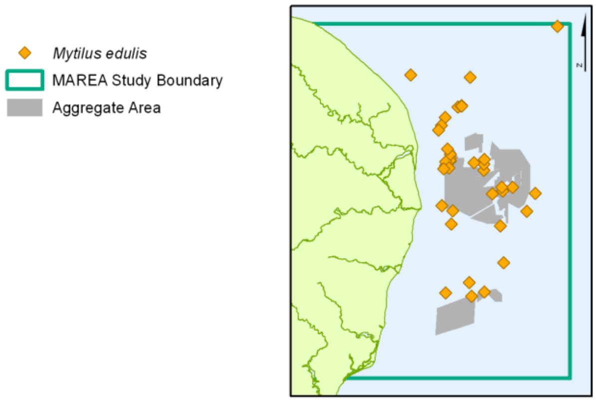




g) h)

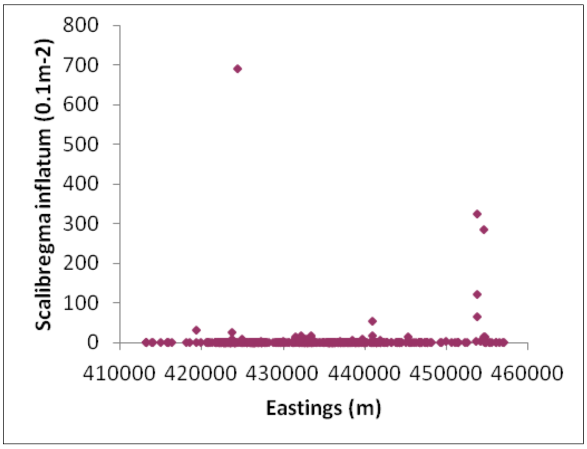
Ophiura albida

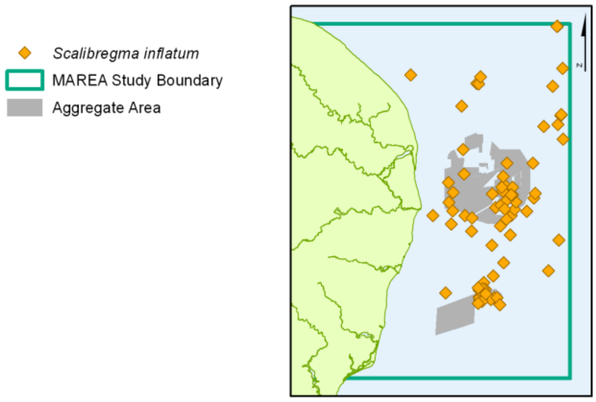




i) j)

Mytilus edulis





k) l)

Scalibregma inflatum

Figures 3.10a-l Densities of selected macro-invertebrates species against Eastings and distribution plots, Anglian MAREA region.

Abundances of all selected species (Figures 3.10a-l) were distributed unevenly across the study area. Peak *S. spinulosa*, *A. alba*, *L. koreni* and *O. albida* abundances were observed at longitudes corresponding approximately to the central portion of the Anglian MAREA region, reaching densities of 3960, 672, 278 and 106 individuals per $0.1m^2$ respectively. *S.spinulosa* and *A.alba* exhibited a similar density distributional pattern, with two lesser peaks to the west of the central section of the study area. Both species were present throughout the region, the former largely outside of aggregate extraction areas, and each with dense clusters within Area 430. *L.koreni* and *O.albida* were also found throughout the MAREA region, and both exhibited scattered abundance increases over the whole area, although primarily in the western portion.

M.eduilis and *S.inflatum* were scattered throughout the MAREA study region at low densities (<12 and <19 individuals per 0.1m² respectively). Both species exhibited peak abundances slightly to the east of the central portion of the study area. A lesser peak was observed further to the east for *M.eduilis* and in the western most reaches for *S.inflatum.*

The exact factors influencing the patchy distribution of these species across the Anglian MAREA region are unclear, however several generic factors have been suggested including sub-regional preferences and abiotic and biotic factors influencing dispersal. These may include suitable substrata, suspended sediment load and climatic conditions, or relate to specific species traits, such as the limited larval dispersal for *Sabellaria*.

Distributions for total species and individuals numbers and infaunal biomass respectively are shown (Figures 3.11 – 3.13) and Table 3.5. A range of diversity indices were also plotted to further elucidate potential macrofaunal geographical trends including Shannon-Weiner diversity (H'), Margalef's richness (d), Pielou's eveness (J) and Simpson's dominance (λ) indices (Appendix N). Appendix O contains diversity indices results for all grab sites.

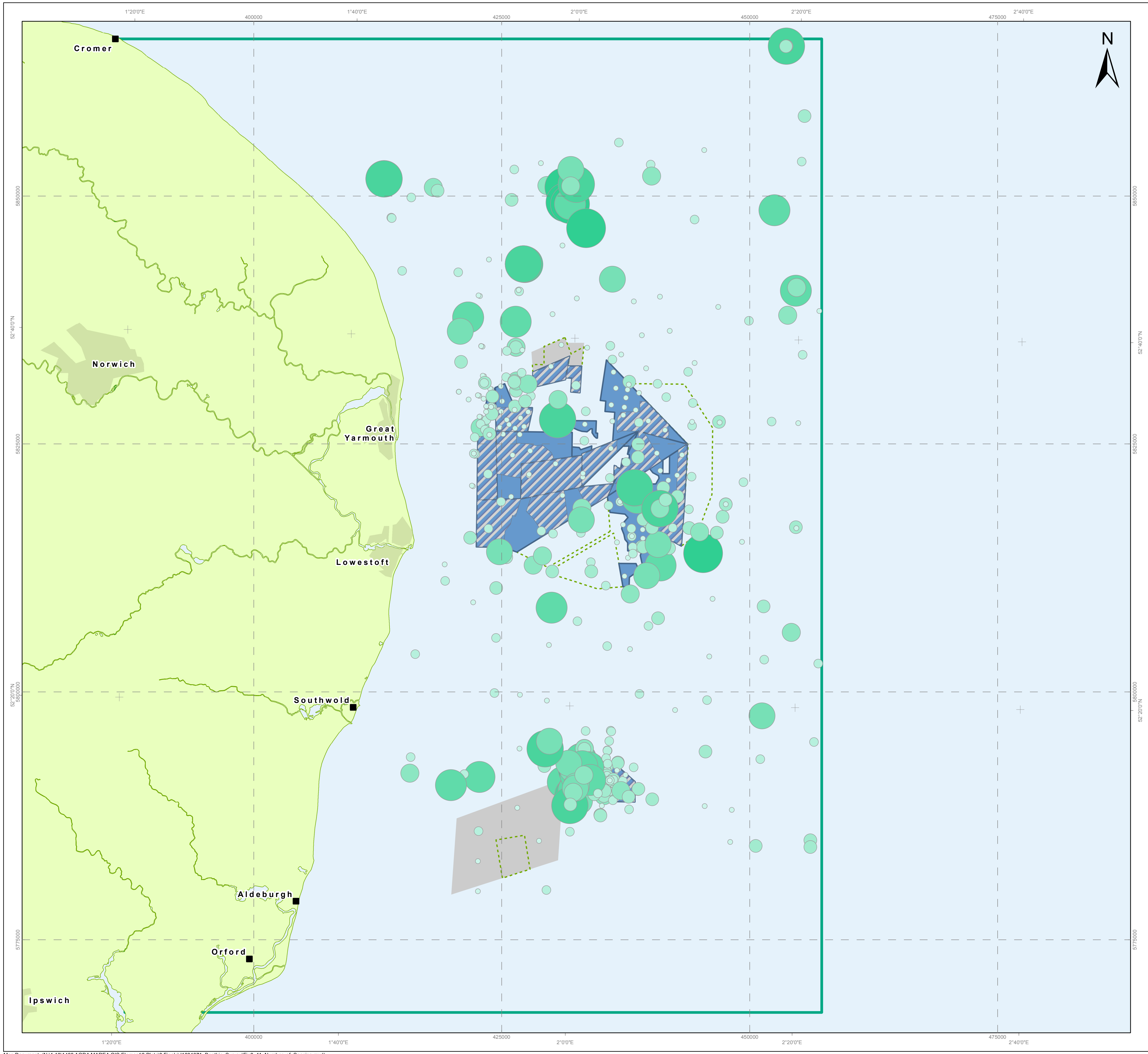
Table 3.5 Summary of total species, abundance and biomass of each grab survey used for the analysis of historical data presented in this report. Abundance is the total per m^2, whilst the biomass is exprtessed as Ash free dry weight (AFDW).

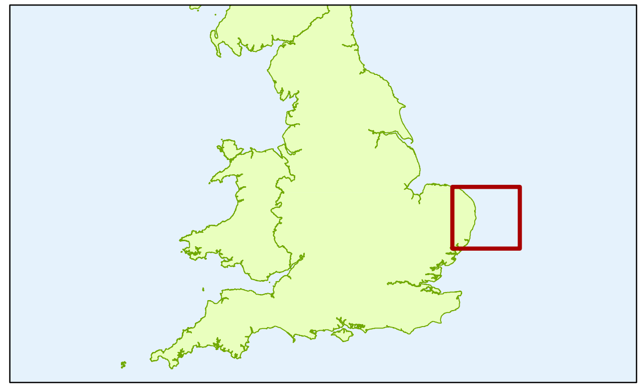
Survey	Nr of Taxa (S)	Nr of Individuals (N)	Biomass (AFDW/g)	
Area 401/2 (EMU, 2005)	182	8392	Annelida	14.4727g
			Crustacea	0.4995g
			Echinodermata	3.4777g
			Mollusca	0.2866g
			Others	0.0225g
Area 401/2 (EMU, 2009)	119	1833	Annelida	4.0991g
			Crustacea	0.2769g
			Echinodermata	0.9360g
			Mollusca	0.7667g
			Other	0.0361g
Area 436/202 (EMU, 2004)	95	1685	Annelida	1.9863g
			Crustacea	18.5077g
			Echinodermata	0.0107g
			Mollusca	0.0264g
			Other	4.7137g
Area 436/202 (EMU, 2007)	109	6097	Annelida	25.2189g
			Crustacea	1.5332g
			Echinodermata	0.9230g
			Mollusca	0.0257g
			Other	0.1727g
Area 202 (EMU, 2009)	122	2731	Annelida	19.5996g
			Crustacea	4.0702g
			Echinodermata	6.1467g
			Mollusca	0.4453g
			Others	0.2918g

Survey	Nr of Taxa (S)	Nr of Individuals (N)	Biomass (AFDW/g)	
Area 254 (EMU, 2002)	117	2631	Annelida	1.6416g
			Crustacea	0.4216g
			Echinodermata	0.1559g
			Mollusca	0.0079g
			Other	1.2537g
Area 254 (EMU, 2008)	112	1731	Annelida	1.5830g
			Crustacea	0.1360g
			Echinodermata	0.1440g
			Mollusca	0.1910g
			Other	2.8290g
Area 328 (MES ALSF, 2007)	34	108	Total biomass	2.3263g
Area 401 (MES ALSF, 2007)	70	631	Total biomass	13.952g
Area 430 (MESL, 2006)	237	23132	Annelida	200.7935g
			Crustacea	15.8805g
			Echinodermata	214.9741g
			Mollusca	93.3545g
			Others	13.3581g
Area 430 (MES ALSF, 2007)	81	628	Total biomass	31.0919g
REC (2010)	389	30764	Annelida	462.82g
			Crustacea	58.26g
			Echinodermata	31.51g
			Mollusca	147.79g
			Others	325.19g
AODA (EMU, 2010)	201	11953	Annelida	77.8127g
			Crustacea	8.4769g
			Echinodermata	54.9673g
			Mollusca	67.0268g
			Others	3.7108g

No patterns were discerned other than a general trend of lower values in sand dominated areas denoted as ‘sand/slightly gravelly sand’ on the sediment interpretation plot within the Anglian Offshore MAREA’s baseline report (Emu Ltd., 2010 – Chapter 7). No geographical difference or broad relationship with sediment type was observed for Pielou’s evenness or Simpson’s diversity indices.

To assess for differences in the above variables between impact zones, their average values within the Primary Impact Zone (PIZ), Secondary/Cumulative Impact Zone (S/CIZ) and Reference Zone (RefZ) are plotted in Figures 3.14a-c.





Legend

Number of Species
1 - 7
8 - 13
14 - 22
23 - 32
33 - 40
41 - 50
51 - 62
63 - 83

MAREA Study Boundary

Aggregate Areas
Active Dredge Zone
Licence Area
Application Area
Prospecting Area

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010; MFA 2009
Emu Limited, 2002-2010

0 5 10 20
Kilometres

Coordinate System:
WGS84 UTM Zone 31 North

Scale:	*Sheet Size:*
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Client: Anglian Offshore Dredging Association

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email: mail@emulimited.com

Project Title:
AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:
Total Species Distribution, Grab Data, Anglian MAREA Region

Figure No. 3.11

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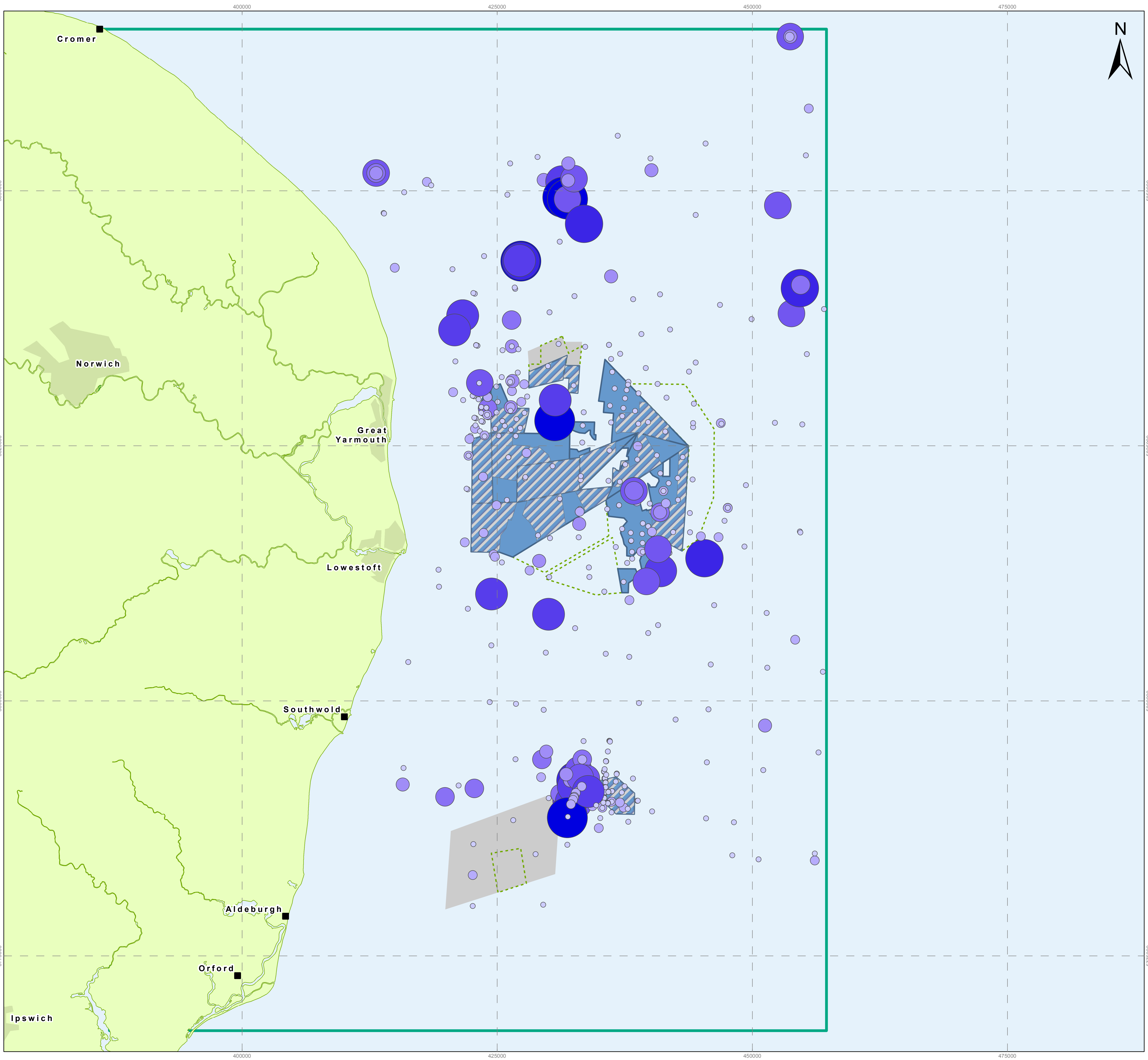

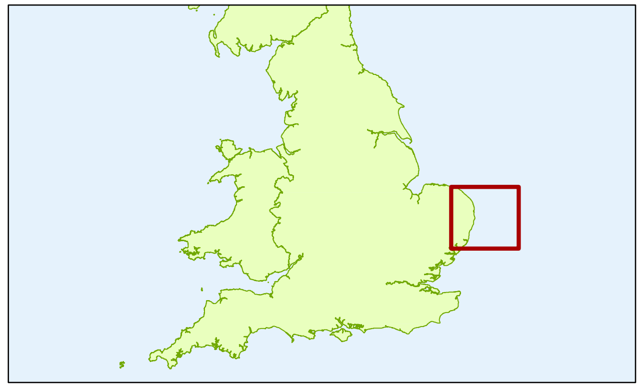

Legend

Number of Individuals

- 1 - 45
- 46 - 120
- 121 - 220
- 221 - 380
- 381 - 650
- 651 - 1150
- 1151 - 2400
- 2401 - 4656

MAREA Study Boundary

Aggregate Areas

- Active Dredge Zone
- Licence Area
- Application Area
- Prospecting Area

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010; MFA 2009
Emu Limited, 2002-2010

0 5 10 20
Kilometres

Coordinate System:
WGS84 UTM Zone 31 North

Scale:	*Sheet Size:*
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email: mail@emulimited.com

Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

Total Individuals Distribution, Grab Data, Anglian MAREA Region

Figure No. 3.12

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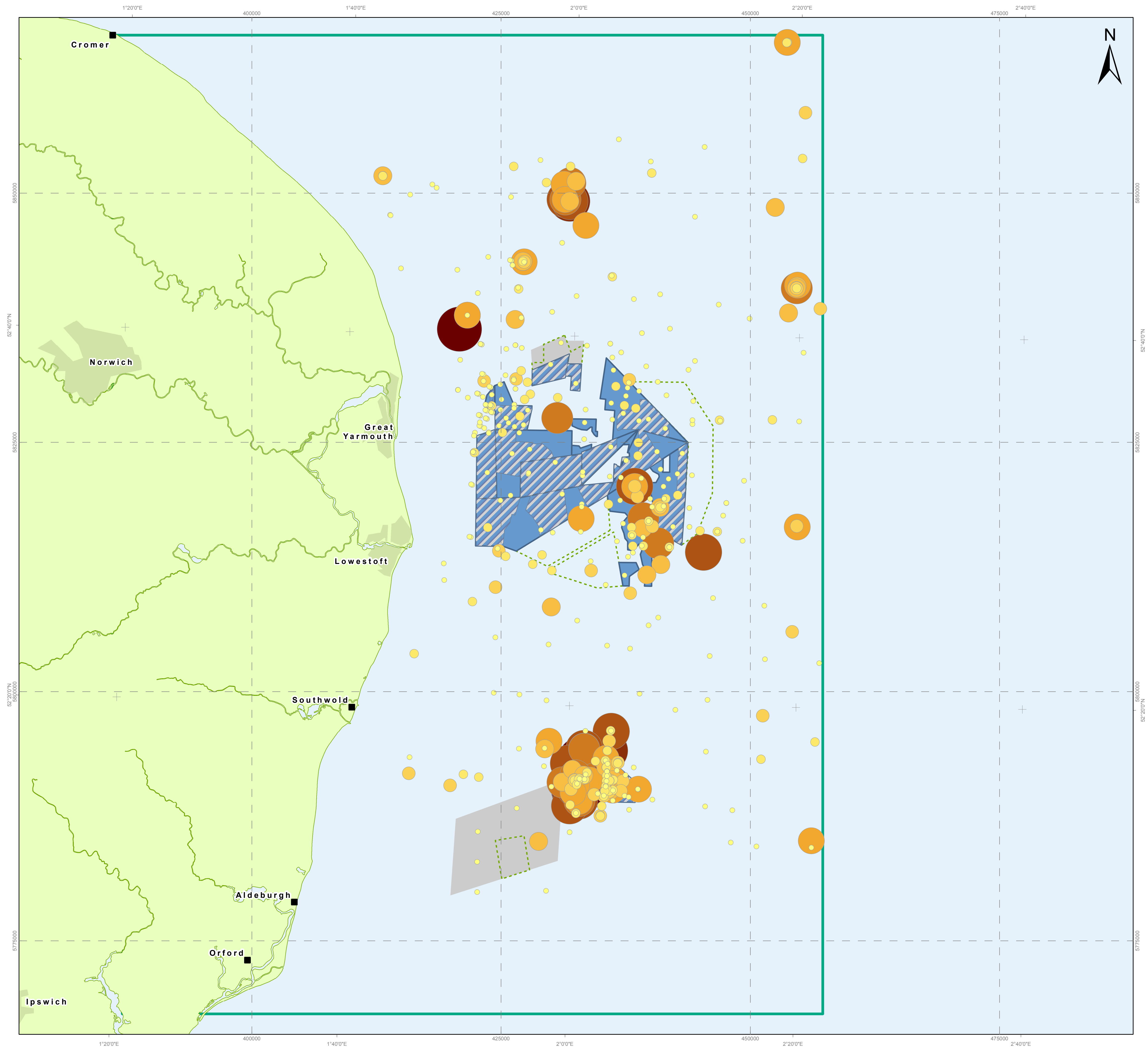

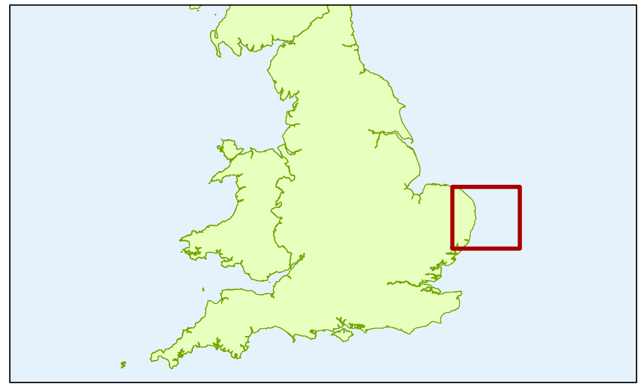

Legend

Total Infaunal Biomass
Ash Free Dry Weight (g/0.1m^2)

- 0.00 - 0.20
- 0.21 - 0.60
- 0.61 - 1.20
- 1.21 - 2.20
- 2.21 - 3.80
- 3.81 - 6.80
- 6.81 - 13.00
- 13.01 - 20.00
- 20.01 - 31.46

MARAEA Study Boundary

Aggregate Areas

- Active Dredge Zone
- Licence Area
- Application Area
- Prospecting Area

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010; MFA 2009
Emu Limited, 2002-2010

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Coordinate System: WGS84 UTM Zone 31 North

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EMU

Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

Infaunal Biomass Distribution
Grab Data, Anglian MAREA Region

Figure No. 3.13

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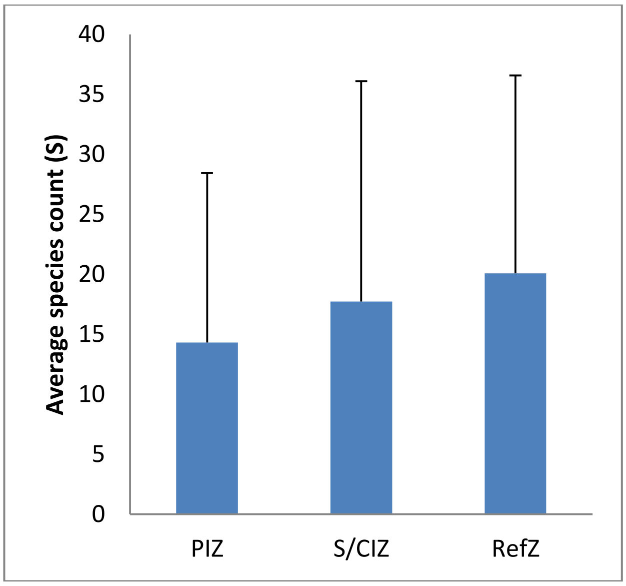


Figure 3.14a. Average number of grab species in each impact zone (+ 1 sd)

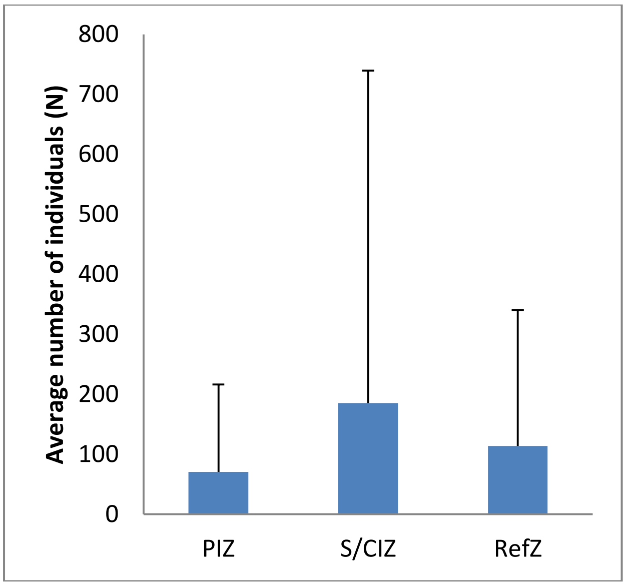


Figure 3.14b. Average number of grab individuals (quantitative infauna) in each impact zone (+ 1 sd).

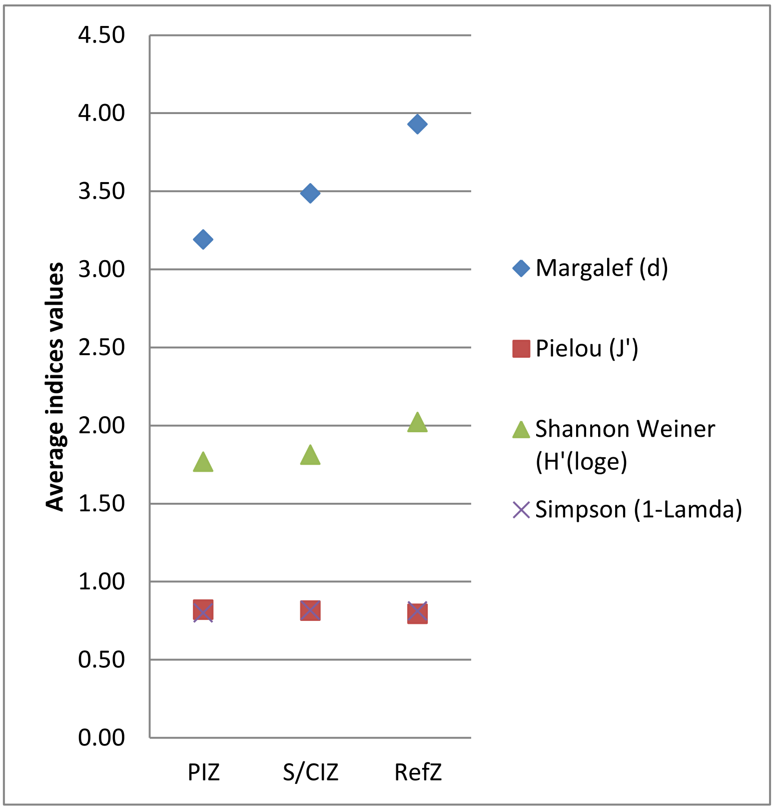


Figure 3.14c. Diversity indices averages for each impact zone (grab data).

Average species number broadly increased between the PIZ, S/CIZ and RefZ (Figure 3.14a), with the PIZ having the lowest (14) and the reference area, the highest (20). The PIZ also contained the lowest average number of individuals with less than a third of the S/CIZ (Figure 3.14b). However, the notable variability aroubnd mean values (Figures 3.14 a,b) indicates that there is highly unlikely to be any significant differences between zones. No clear zonal difference in Simpson diversity and Pielou's evenness was observed, however the reference zone contained higher values of both Shannon-Weiner diversity and Margalef richness indices (Figure 3.14c).

To further consider if aggregate extraction may be affecting faunal communities within the licensed areas, investigation into the relationship between impact zone and grab macrofaunal data was conducted utilising the multivariate analysis package Primer (see section 3.4).

3.4 Multivariate assessment of macrofaunal grab data

Infaunal clusters

Benthic community structure was investigated through multivariate analysis of the enumerated grab sample data (square root transformed). Appendix P contains the multivariate (group average sorting) sample dendrogram and Figure 3.15 presents the corresponding MDS ordination plot of the infaunal data. Single-site outliers are shaded grey to aid interpretation.

Cluster analysis of grab infaunal data (based on Bray-Curtis similarity of square root transformed data) defined thirty sample clusters including seven single-site outliers, based on a 14% similarity level cut off (Appendix P). Distributions for these infaunal groupings are presented in Figure 3.16 and the group assigned to each site is listed within the grab sample details Appendix (D). A biological and physical attribute summary for the multivariate sample groupings (infaunal data only) is given in Table 3.5 and Appendix Q for the single-site outliers (note: infaunal group symbols are those given on Primer plots). Species are identified and ranked according to internal group similarity contribution as derived from SIMPER analyses on both raw and square root transformed abundance data.

It should be noted that analysis of the characterising species of the Primer groups, outlined in Table 3.6, indicated that some of the clusters may have separated out spuriously on the basis of data differences (level of taxonomic definition) rather than real biological variation. Thus, some of the groups clustered, due to poorly defined taxa, needed to be merged based on the SIMPER outputs, as they were, in all likelihood, derived from the same community group and should not remain as standalone groups. The five pairs of groups identified as having potentially spurious differences, and which therefore could be merged, are identified in Table 3.6. Each group merged has been assigned the same colour in the MDS ordination (Figure 3.15) to aid interpretation.

When just one species characterised a group, merging was done on the basis of comparing key characterising species (Groups n and aa, d and w, e and s). Within group f, all taxa were identified to a low level of taxonomic resolution and the clusters similarity to group ac was revealed through direct comparison of the entire taxa array using SIMPER outputs. Group's v and y were merged on the basis of both *Nephtys* and *Glycera*, although there may have been a recent spat fall of *Mytilus* in group v (based on source data).

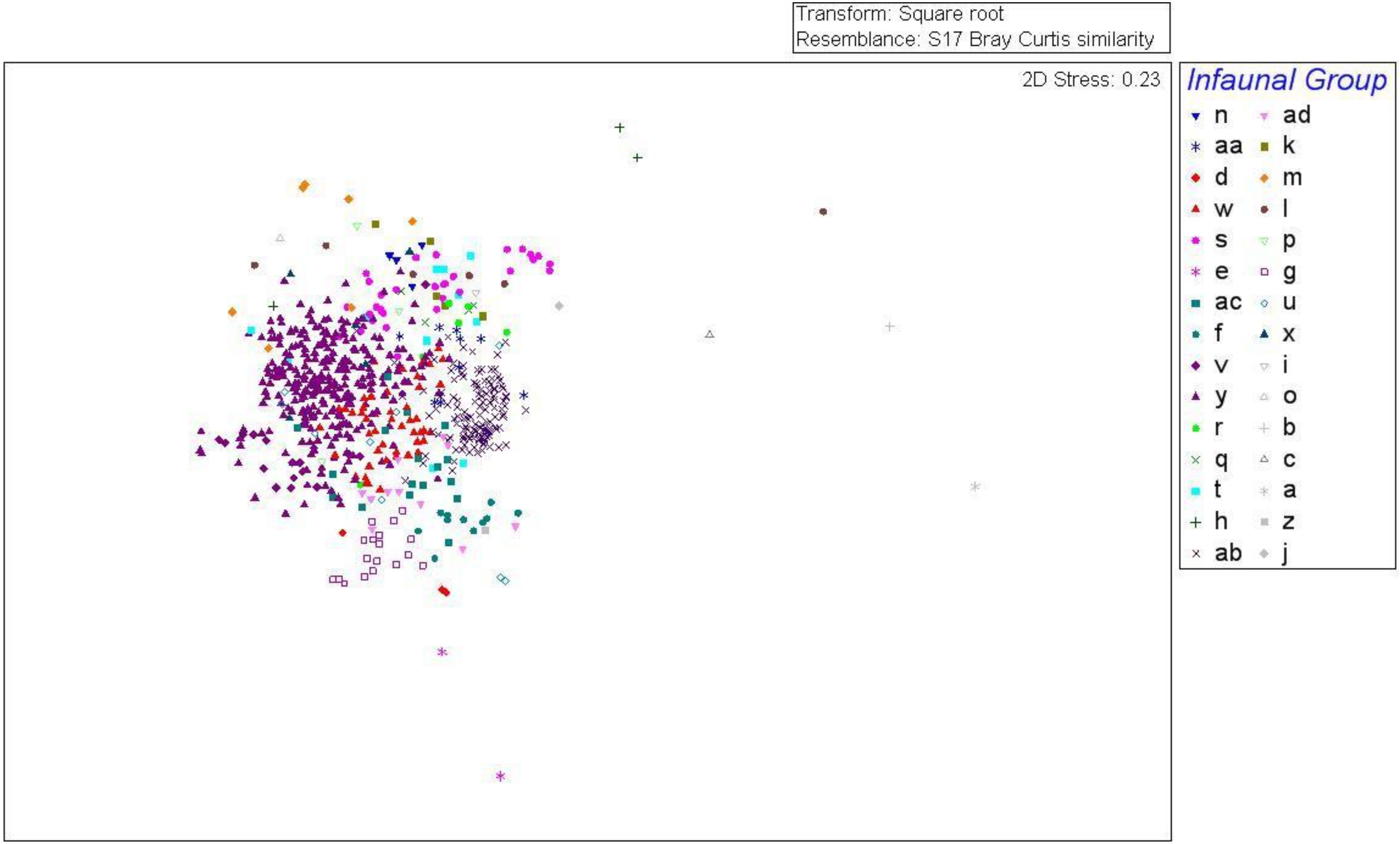
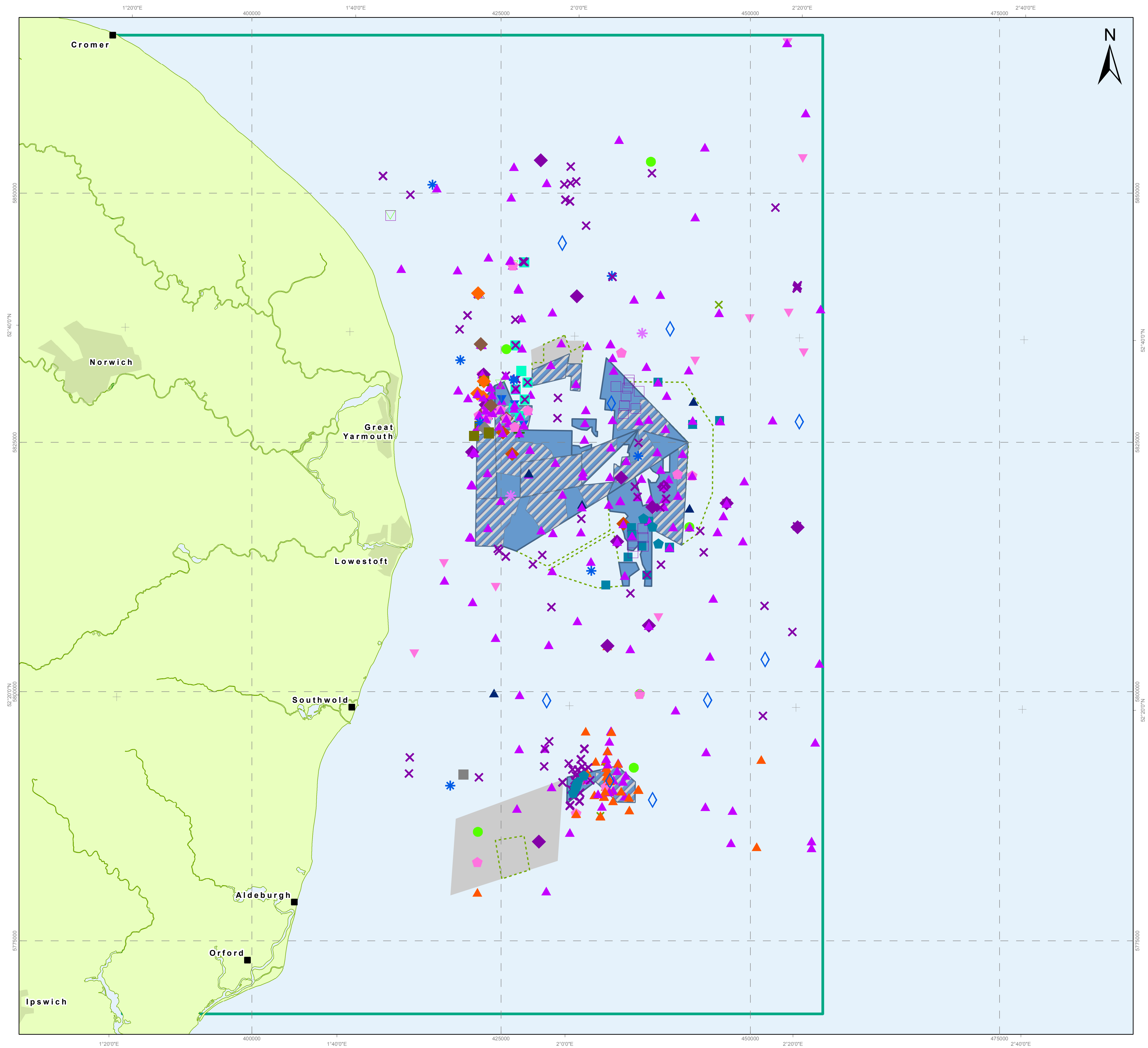
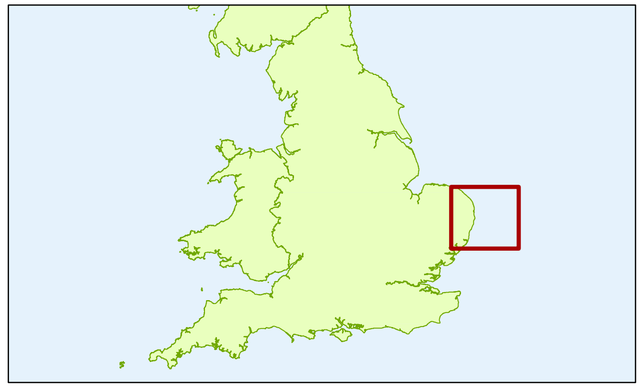


Figure 3.15 MDS ordination, enumerated macrofaunal sample data, Anglian MAREA region.





Legend

Infaunal Groups

- a
- aa
- ab
- ac
- ad
- b
- c
- d
- e
- f
- g
- h
- i
- j
- k
- l
- m
- n
- o
- p
- q
- r
- s
- t
- u
- v
- w
- x
- y
- z

MAREA Study Boundary

Aggregate Areas

- Active Dredge Zone
- Licence Area
- Application Area
- Prospecting Area

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010; MFA 2009
Emu Limited, 2002-2010

0 5 10 20
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Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

Infaunal Group Distribution Grab Data Primer Analyses, Anglian MAREA Region

Figure No. 3.16

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Table 3.6 Multivariate sample groupings summary, enumerated grab data.

Sample group	Main characterising species ranked abundance (top 50%)	Ranked contributionto top 50% of internal similarity (SIMPER)	Total no. species Mean no. Species (s/d)	Total no. individuals Mean no. individuals (s/d)	Average BCD depth m (s/d)	Mean % sand, gravel & fines and sorting coefficient (s/d) *Folk sediment classification(s)*
aa (n=9) Average similarity = 24.66	Mytilidae *Sabellaria spinulosa* ACTINARIA	Mytilidae *Sabellaria spinulosa* ACTINARIA *Polydora caulleryi*	**101** 20.00 (9.21)	**591** 101.00 (87.43)	-	Gravel = 13.96 (18.08) Sand = 81.71 (19.39) Fines = 4.33 (4.40) Sorting = 1.74 (0.90) *Slightly gravelly sand* *Gravelly sand* *Muddy sandy gravel* *Sandy gravel*
n (n=4) Average similrity = 46.27	*Sabellaria spinulosa*	*Sabellaria spinulosa*	**6** 2.25 (1.26)	**11** 6.00 (2.22)	**30.3** (8.9)	Gravel = 8.63 (8.80) Sand = 90.89 (9.41) Fines = 0.48 (0.94) Sorting = 1.34 (0.80) *Gravelly sand* *Slightly gravelly sand*
d (n=3) Average similarity = 52.22	*Spiophanes bombyx*	*Spiophanes bombyx*	**4** 2.00 (1.00)	**6** 4.00 (1.00)	**25.7** (1.6)	Gravel = 6.17 (3.84) Sand = 93.80 (3.85) Fines = 0.01 (0.01) Sorting = 1.02 (0.25) *Gravelly sand* *Slightly gravelly sand*
w (n=48) Average similarity = 26.57	*Abra alba* *Spisula elliptica* *Nephtys* *Spiophanes bombyx* *Glycera oxycephala* OPHIUROIDEA	*Abra alba* *Spisula elliptica* *Nephtys* *Spiophanes bombyx* OPHIUROIDEA *Glycera oxycephala* Nemertea	**127** 14.29 (3.98)	**1437** 127.00 (14.29)	**34.0** (2.3)	Gravel = 11.32 (12.34) Sand = 86.60 (13.15) Fines = 2.07 (3.01) Sorting = 1.38 (0.64) *Slightly gravelly sand* *Gravelly sand* *Sandy gravel* *Gravelly muddy sand* *Slightly gravelly muddy sand*
e (n=2) Average similarity = 66.67	*Glycera*	*Glycera*	**2** 1.50 (0.71)	**3** 2.00 (0.71)	**23.7**	Gravel = 15.05 (19.52) Sand = 84.85 (19.40) Fines = 0.10 (0.12) Sorting = 1.42 (0.91) *Gravelly sand* *Slightly gravelly sand*
s (n=31) Average similarity = 26.01	*Glycera lapidum*	*Glycera lapidum*	**67** 4.81 (2.79)	**322** 67.00 (14.45)	**30.7** (3.8)	Gravel = 25.59 (21.46) Sand = 74.23 (21.31) Fines = 0.17 (0.38) Sorting = 1.79 (0.71) *Sandy gravel* *Gravelly sand* *Slightly gravelly sand*
f (n=11) Average similarity = 34.24	*Ophiura* OPHIUROIDEA NEMERTEA *Echinocyamus* *Urothoe*	*Ophiura* OPHIUROIDEA *Echinocyamus* NEMERTEA *Urothoe* *Lumbrineris*	**86** 24.45 (8.93)	**1139** 86.00 (120.31)	-	Gravel = 36.03 (17.57) Sand = 56.37 (19.10) Fines = 0.10 (0.12) Sorting = 2.64 (0.51) *Slightly gravelly sand* *Slightly gravelly muddy sand* *Muddy sandy gravel*

Sample group	Main characterising species ranked abundance (top 50%)	Ranked contributionto top 50% of internal similarity (SIMPER)	Total no. species Mean no. Species (s/d)	Total no. individuals Mean no. individuals (s/d)	Average BCD depth m (s/d)	Mean % sand, gravel & fines and sorting coefficient (s/d) *Folk sediment classification(s)*
ac (n=17) Average similarity = 23.98	*Ophiura*	*Ophiura* *Lagis koreni*	**99** 13.65 (6.28)	**865** 99.00 (48.67)	**36.3** (2.7)	Gravel = 27.70 (21.45) Sand = 68.63 (19.11) Fines = 3.66 (7.29) Sorting = 2.06 (0.59) *Sandy gravel* *Gravelly sand* *Gravelly muddy sand* *Slightly gravelly sand*
v (n=17) Average similarity = 28.80	*Nephtys cirrosa*	*Nephtys cirrosa*	**34** 4.18 (2.35)	**90** 34.00 (3.37)	**30.6** (5.5)	Gravel = 22.54 (23.83) Sand = 76.92 (24.03) Fines = 0.54 (0.96) Sorting = 1.63 (1.03) *Sandy gravel* *Slightly gravelly sand* *Gravelly sand* *Sand*
y (n=286) Average similarity = 20.93	*Ophelia borealis*	*Ophelia borealis*	**263** 7.74 (4.56)	**6645** 263.00 (28.11)	**30.5** (5.7)	Gravel = 17.20 (21.48) Sand = 82.15 (21.44) Fines = 0.65 (1.70) Sorting = 1.49 (0.89) *Slightly gravelly sand* *Sandy gravel* *Gravelly sand* *Sand* *Gravel* *Gravelly muddy sand* *Slightly gravelly muddy sand*
q (n=4) Average similarity = 26.93	NEMERTEA	NEMERTEA	**18** 6.00 (3.56)	**33** 18.00 (4.57)	**35.3** (2.7)	Gravel = 16.95 (19.53) Sand = 70.01 (20.39) Fines = 13.05 (24.34) Sorting = 1.68 (0.86) *Gravelly sand* *Muddy sand* *Sandy gravel* *Slightly gravelly sand*
r (n=6) Average similarity = 21.45	*Notomastus* NEMERTEA	*Notomastus* NEMERTEA	**45** 11.17 (4.02)	**119** 45.00 (9.06)	**34.4** (2.3)	Gravel = 14.93 (12.08) Sand = 83.02 (12.72) Fines = 2.05 (4.16) Sorting = 1.69 (0.56) *Gravelly sand* *Gravelly muddy sand* *Sandy gravel* *Slightly gravelly sand*
g (n=18) Average similarity = 27.61	*Nephtys* *Ophelia*	*Nephtys*	**60** 7.39 (4.17)	**271** 60.00 (8.08)	-	Gravel = 11.98 (17.32) Sand = 85.16 (17.63) Fines = 2.86 (3.96) Sorting = 1.32 (0.83) *Slightly gravelly sand* *Gravelly sand* *Sandy gravel* *Sand* *Muddy sand*

Sample group	Main characterising species ranked abundance (top 50%)	Ranked contributionto top 50% of internal similarity (SIMPER)	Total no. species Mean no. Species (s/d)	Total no. individuals Mean no. individuals (s/d)	Average BCD depth m (s/d)	Mean % sand, gravel & fines and sorting coefficient (s/d) *Folk sediment classification(s)*
h (n=3) Average similarity = 42.19	*Pisione remota*	*Pisione remota*	**4** 2.00 (1.00)	**13** 4.00 (3.21)	**23.8** (3.2)	Gravel = 11.59 (17.32) Sand = 85.16 (17.63) Fines = 2.86 (3.96) Sorting = 1.32 (0.83) *Gravelly sand*
k (n=5) Average similarity = 23.19	Mytilidae	Mytilidae	**46** 13.80 (5.72)	**816** 46.00 (208.34)	-	Gravel = 41.32 (11.22) Sand = 56.96 (8.89) Fines = 1.72 (2.33) Sorting = 2.80 (0.06) *Sandy gravel*
l (n=6) Average similarity = 37.71	*Spio filicornis*	*Spio filicornis*	**12** 3.33 (1.21)	**23** 12.00 (1.47)	**25.2** (4.9)	Gravel = 21.60 (20.44) Sand = 78.39 (20.45) Fines = 0.01 (0.01) Sorting = 1.62 (0.52) *Gravelly sand* *Sandy gravel* *Slightly gravelly sand*
m (n=7) Average similrity = 45.84	*Atylus swammerdamei*	*Atylus swammerdamei*	**13** 3.14 (2.76)	**54** 13.00 (10.44)	**10.5** (28.2)	Gravel = 21.46 (28.85) Sand = 75.78 (30.77) Fines = 2.75 (3.98) Sorting = 1.86 (2.39) *Gravelly sand* *Sandy gravel* *Gravelly muddy sand* *Sand* *Slightly gravelly sand*
p (n=3) Average similarity = 34.14	*Spio armata* *Hesionura elongata*	*Spio armata* *Hesionura elongata*	**13** 6.00 (3.00)	**23** 13.00 (5.03)	**35.2** (2.8)	Gravel = 32.16 (19.56) Sand = 67.66 (19.73) Fines = 0.18 (0.28) Sorting = 2.28 (0.59) *Sandy gravel* *Gravelly sand*
t (n=11) Average similarity = 23.11	*Balanus crenatus*	*Balanus crenatus*	**62** 10.73 (5.60)	**309** 62.00 (20.69)	**29.4** (6.4)	Gravel = 36.74 (18.41) Sand = 62.97 (18.37) Fines = 0.30 (0.58) Sorting = 2.40 (0.42) *Sandy gravel* *Gravelly sand*
u (n=9) Average similarity = 26.95	OPHIUROIDEA	OPHIUROIDEA	**35** 6.89 (4.59)	**99** 35.00 (9.53)	**31.8**	Gravel = 6.21 (9.28) Sand = 92.90 (9.91) Fines = 0.89 (1.34) Sorting = 1.05 (0.68) *Slightly gravelly sand* *Gravelly sand* *Sand*

Geographical trends

Sixty-five percent of samples were clustered into two main groups, the merged groups y/v (44%/2%) and ab (19%). Group y/v was distributed across the whole of the MAREA region and was associated with a range of sediment types, although primarily found on the ubiquitous gravelly sands characteristic of the region. The group contained a low average number of species, as may be expected for the main infaunal group in a region dominated by a typically impoverished mobile sand substrate. *O. borealis* and *N. cirrosa*, polychaetes typical of depauperate communities, were the key characterising species of this group.

The generally low species richness and abundance of fauna throughout the Anglian MAREA is illustrated by over 60% of sites containing an average of <10 species and 40% of sites comprising <20 individuals. Previous studies have indicated that species richness is generally higher on hard stable substrates in comparison to mobile sediments (Hargrave *et al*., 2004).

Group ab contained the richest and most diverse macrofauna of any infaunal group, with an average of 39 species and 416 individuals across sites. The large standard deviation indicated within group variance and raw data assessment showed that 7 sites contained 1,204–3,960 individuals of *S. spinulosa*, the key characterising species. Additional species included the bivalve *Abra alba*, the echinoderm *Ophuira albida* and the polychaetes *Lumbrineris gracilis*, *Lanice conchilega* and *Lagis koreni*. The group was found associated with a range of sediment types including gravelly sand, sandy gravel and muddy sands/gravels; it was apparent throughout the region, although primarily outside of the aggregate extraction areas.

A further 8% and 5% of the samples were contained within the merged groups w(7.3%)/d(0.5%) and s(4.7%)/e(0.3%) respectively. Group w/d was found in the centre and south east of the region, with all sites falling within 'w' clustered in the latter area. This merged group occurred principally on gravelly sands and was characterised by *A. alba* and *Spiophanes bombyx*. Group s/e was scattered throughout the region on a range of sediment types encompassing sand, gravelly sand and sandy gravel and was characterised by *Glycera lapidum* / *Glycera*.

Although containing just 3% of samples, and characterised by the polychaete *Nepthys*, group g is worthy of note as it also exhibited a clear geographical pattern, being present solely in two clusters within the central portion of the MAREA region. These clusters do not appear to relate to a specific sediment type as they occur over a range of sediments including sand/slightly gravelly sand, gravelly sand and sandy gravel.

Further investigations of trends within impact zones, utilising MDS ordination of macrofaunal data (symbolised according to impact zone), indicated no clear differences between zone community composition (Figure 3.17), an ANOSIM result, R=0.007, p=22.3% also reflecting this.

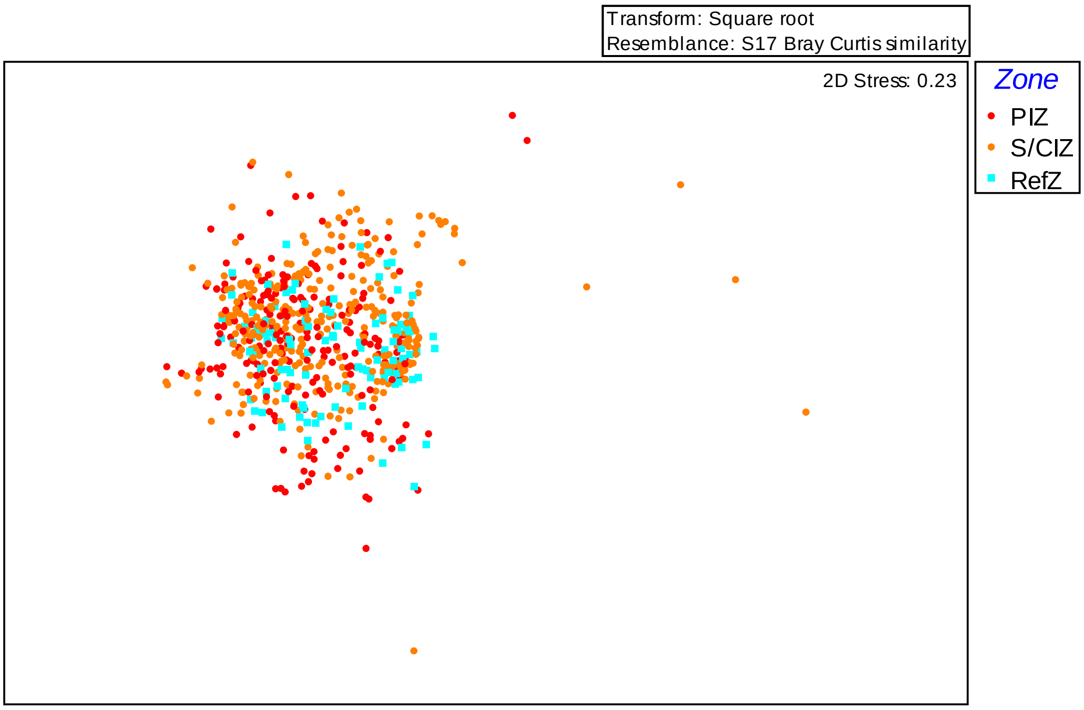


Figure 3.17 MDS macrofaunal data ordination, samples classified according to impact zone.

SIMPER analysis of macrofaunal data highlighted some broad community composition differences between zones. It was found that *O. borealis* was the principal species resulting in the similarity within the macrofaunal data for all zones, with a contribution of 18.52% - 30.89%. In addition to *O.borealis*, the species with the greatest contribution to the top 60% of similarity were largely the same within all zones, consisting of *N.cirrosa*, *Nemertea*, *Gastrosaccus spinifer* and *S. spinulosa* in differing orders of importance. However, within the reference zone a key difference was the inclusion of Ophiuroidea as the second greatest contributor to within group similarity. A number of additional species contributed to the top 60% of similarity, albeit to a lesser degree, in the reference zone sites. These included *Lagis koreni*, *Polycirrus* and *Ophiura albida*. Analyses of the dissimilarity results between groups indicated that variations in the abundances of *S.spinulosa* and *O.borealis* were the highest contributors to between zone differences.

Temporal trends

MDS ordination of all macrofaunal data, symbolised according to year, revealed that the 2007 datasets separated out (Figure 3.18). A subsequent SIMPER analysis indicated this was an artefact of inter-laboratory variability; specifically the taxonomic level that organisms were identified to, rather than a temporal trend. All data for 2007 were collected and analysed by one company and within this dataset none of the main characterising taxa were identified to species level. This highlights the difficulty with merging datasets from a range of sources as there is always likely to be inherent differences due to inter-laboratory variation, which need to be taken account of in addition to real biotic and abiotic differences.

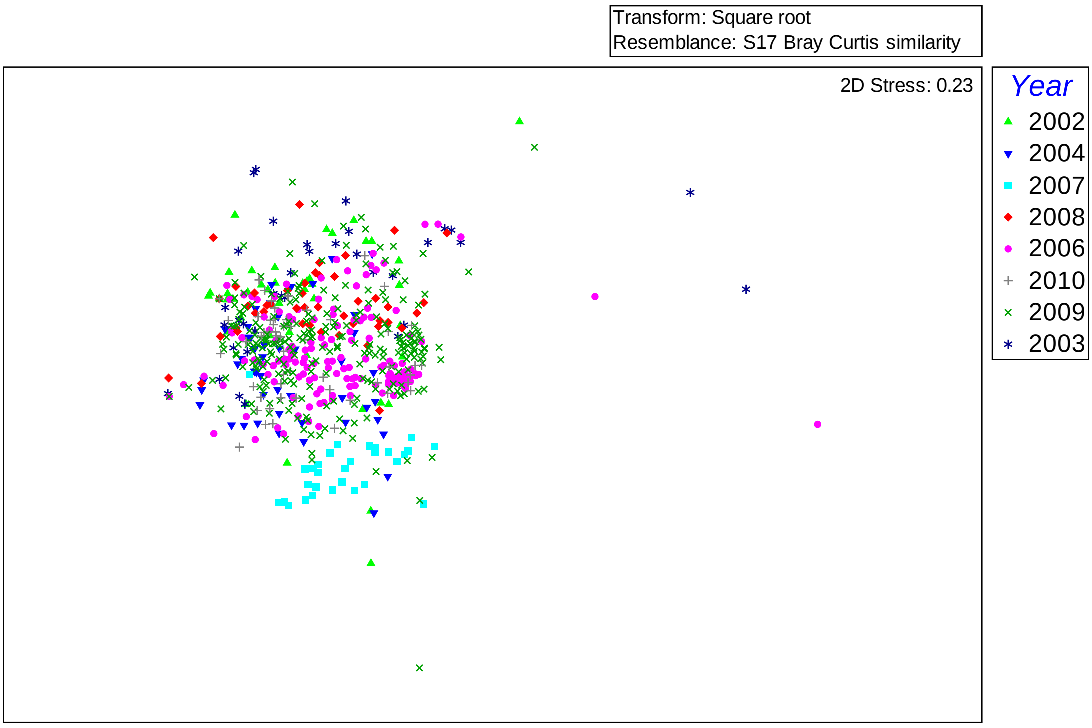


Figure 3.18 Macrofaunal data MDS ordination, samples classified to year.

To further investigate potential temporal trends, analyses were conducted solely on surveys which were repeated. These included: Area 401/2 (2004, 2009); Area 436/202 (2003, 2006) and Area 254 (2002, 2008). Although repeat years data was available for Area 430, investigations revealed no similar sample site locations between the years.

To investigate macrofaunal community temporal differences in a regional context, an MDS plot was constructed based on a dissimilarity matrix created for repeat year data and classified by survey (Figure 3.19). Ordination indicated that there was a greater difference in community composition between survey areas in earlier years, and that this became less over time; Area 202 exhibited the greatest change between years.

A potential theory for the observed macrofaunal differences between years was an overall fining of sediments potentially related to aggregate extraction. This theory was rejected following comparison of the faunal dissimilarity MDS ordination with an equivalent plot for PSD data (Figure 3.20), where no direct relationship is indicated.

A RELATE test conducted between the dissimilarity matrices for infauna and PSD data found there was no correlation between the datasets, indicating that faunal dissimilarity ordination variations were not explained by particle size data (Rho= -0.475, p=91.4%).

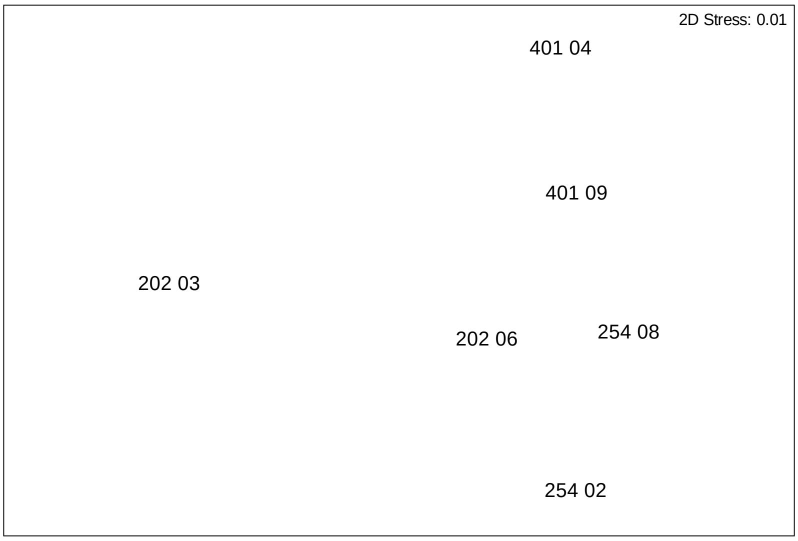


Figure 3.19 Dissimilarity matrix macrofaunal data MDS ordination for repeat year surveys; samples classified according to survey.

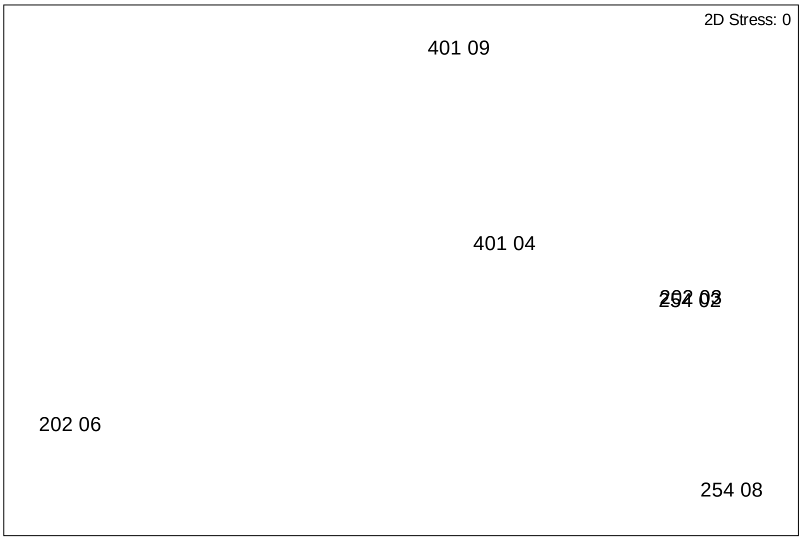


Figure 3.20 Dissimilarity matrix PSD data MDS ordination for repeat years surveys; samples classified according to survey.

To remove the geographical element from survey results and to help illuminate potential temporal trends, repeat year datasets were examined separately. Results from ANOSIM analyses suggested that despite low Global R values (R Values below 0.2), suggesting no macrofaunal community difference between years at Areas 401/2, 346/202 and 254, the low values calculated were all significant (respectively: R=0.169, p=0.1%; R=0.076, p=0.2%; R=0.146, p=0.1%), indicating potential differences within the data sets. Given the large size of the overall data set, it is likely that differences exist somewhere between some of the paired data sets.

On the basis of the ANOSIM outputs, SIMPER analyses were conducted on each of the repeat year datasets which revealed broad between years species differences. For all areas, an increase in the polychaete worm, *O. borealis,* was the main contributor to differences; the greatest increase, an average of 1.40 individuals, occurring in Area 401/2. *O. borealis* is a typical species of depauperate communties and its increase in all of these licence areas over time could be a result of dredging effects (see for example, Robinson *et al*., 2005) or a naturally induced change. When considered against a background of highly mobile sediments, limiting the development of stable environment communities, the impacts of aggregate dredging may not be clearly identified (see for example Dernie *et al*., 2003), as the naturally mobile habitat may mask or override anthropogenic effects. The next greatest contributors to between year differences showed abundance decreases in subsequent years, with a maximum reduction of 0.72 individuals (Area 401/2); these included *Ophiura*, *G. spinifer* and *S. spinulosa* (Areas 401/2, 436/202 & 254 respectively), all of which may have occurred as a result of natural and or anthropogenic effects.

3.5 Assessment of abiotic- biotic relationships

Superimposed sediment classification (Folk) and depth data, upon the faunal MDS ordinations, have initially been used to identify effects on macrofaunal communities. Depth information was not available for all sites thus only samples for which these data were obtained were included in the ordination. No clear correlation between community composition and either Folk classification or depth were illustrated in the MDS ordinations (Figures 3.21 & 3.22 respectively). However, subsequent ANOSIM analyses indicated some differences within the overall macrofaunal data set in relation to these variables, despite the low Global R values (Folk: R=0.084, p=0.1%. Depth: R=0.126, p=0.2%).

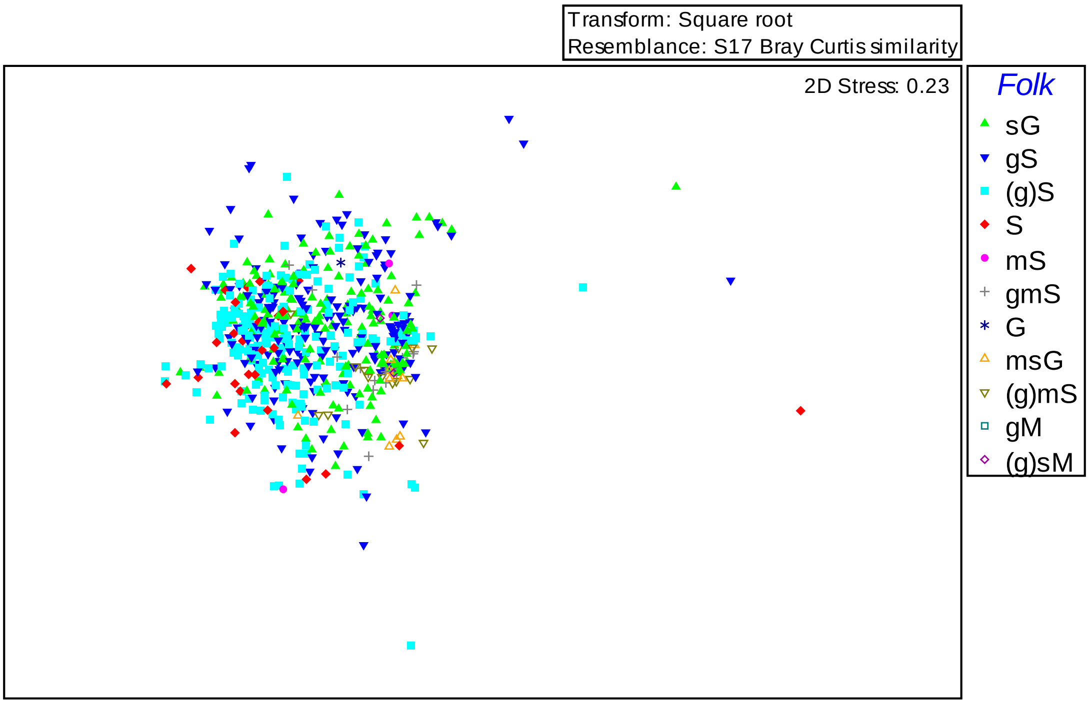


Figure 3.21 Macrofaunal data MDS ordination, samples classified to Folk sediment type.

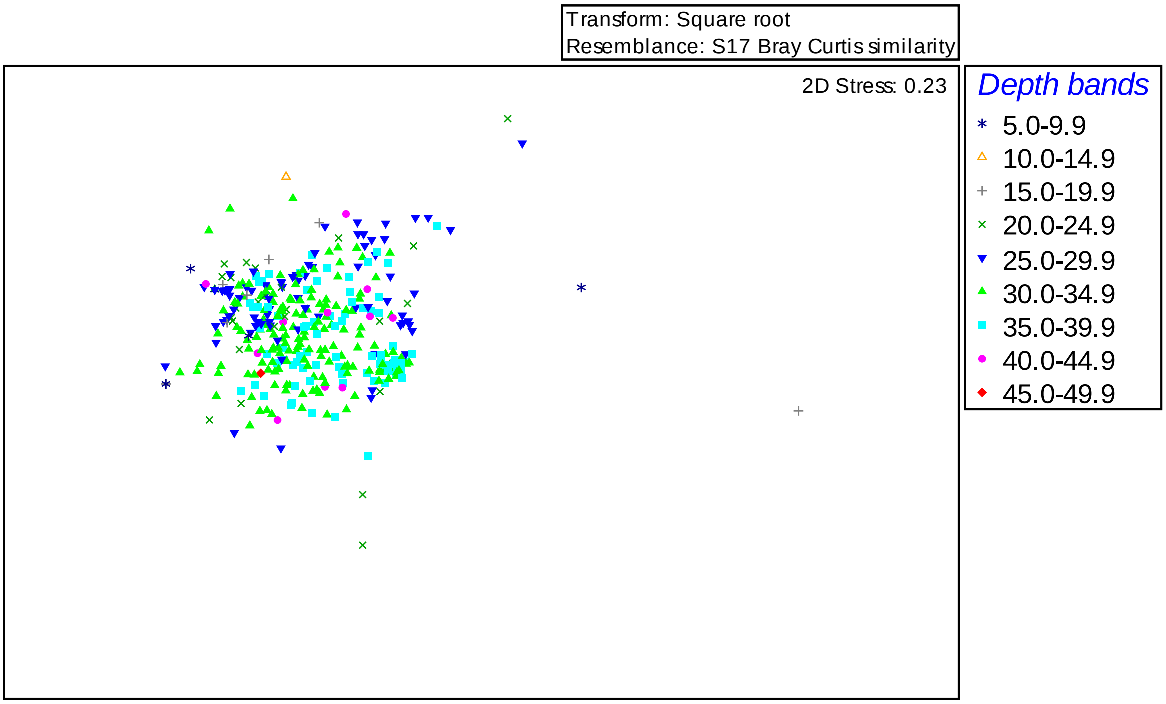


Figure 3.22 Macrofaunal data MDS ordination, samples classified to depth bands.

To further investigate the relationship between abiotic factors and macrofaunal distribution, as defined by multivariate analyses, a BIOENV was performed (Table 3.7). All abiotic factors, for which information was available, were used as input variables, including sediment fractions (31.50mm, 16000um, 8000um, 4000um, 2000um, 1000um, 500um, 250um, 125um, >63um, <63um), sorting coefficients, eastings and northings.

BIOENV results indicated a low correlation between biotic and abiotic variables suggesting that abiotic factors, other than those assessed, may be influencing macrofaunal distribution, though aspects of life history traits may also have a stochastic role. Of the variables examined, the <63um silt fraction was identified as the single abiotic variable assessed best explaining macrofaunal distribution across the Anglian MAREA region. The correlation (Table 3.7) was improved with the addition of fine to coarse sand fractions.

Increasing the maximum number of variables to 5 saw the inclusion of northings, although this only fractionally improved the correlation (Table 3.7). This indicates that neither location nor sediment particle size grading significantly influenced overall macrofaunal community composition, though localised patchy species distributions may be related (e.g. *S. spinulosa*). Sorting coefficient values may be employed as a proxy for sediment disturbance suggesting that between site variations in substrate mobility are not influencing macrofauna. For the Anglian MAREA region, research suggests that the entire area is largely comprised of mobile sediments thus indicating that all sites are subject to related effects.

Depth was not included in the BIOENV analysis as data were only available for less than 50% of sites thus would have significantly reduced usable sample numbers. This factor is noted as another limiting aspect when combining multiple source datasets. Instead, further investigations into the effect of depth were conducted using SIMPER analysis. The key difference highlighted was the inclusion of *O.borealis* as the key characterising species for all depth bands with greater than 2 samples in the group, excluding the deepest and shallowest bands (40.0-44.9m & 5.0-9.9m respectively). Instead, the top characterising species for these depth bands were *S. spinulosa* (40.0-44.9m) and *G. spinifer* (5.0-9.9m) with *O.borealis* the second highest contributor. Assessment of the ANOSIM pairwise comparisons revealed greatest differences in communities were found between depths of >30m and <15m.

Table 3.7 Results of the BIOENV analysis between abiotic variables and infaunal data.

Variables	Correlation coefficient (r)
Single variable	
% <63um (silt)	0.180
Multiple variables	
• 1000um (coarse sand), <63um (silt)	0.240
• 2000um (very coarse sand), >63um (very fine sand), <63um (silt)	0.247
• 2000um (very coarse sand), 1000um (coarse sand), >63um (very fine sand), <63um (silt)	0.260
• 2000um (very coarse sand), 1000um (coarse sand), >63um (very fine sand), <63um (silt), Northing	0.262

To establish any species-sediment relationships, the top contributing species abundances from five of the most abundant infaunal groups were overlaid onto sediment ordination data (Figure 3.23). This illustrated that polychaetes, *O. borealis*, *G. lapidum* and *N. cirrosa* were ubiquitous and did not exhibit any sediment preference for the range of sediments occurring in the area. *S. spinulosa* appeared to have a broad association with sandy gravels / gravelly sands and was infrequently found in sands with only a slight gravel element or in which gravel is absent. The bivalve *Abra alba* showed an apparent preference for sites with a silt component (Figure 3.23). This species is a detritus/phytoplankton feeder and as such it would be expected that this may occur in areas of increased silt and thus, organic materials.

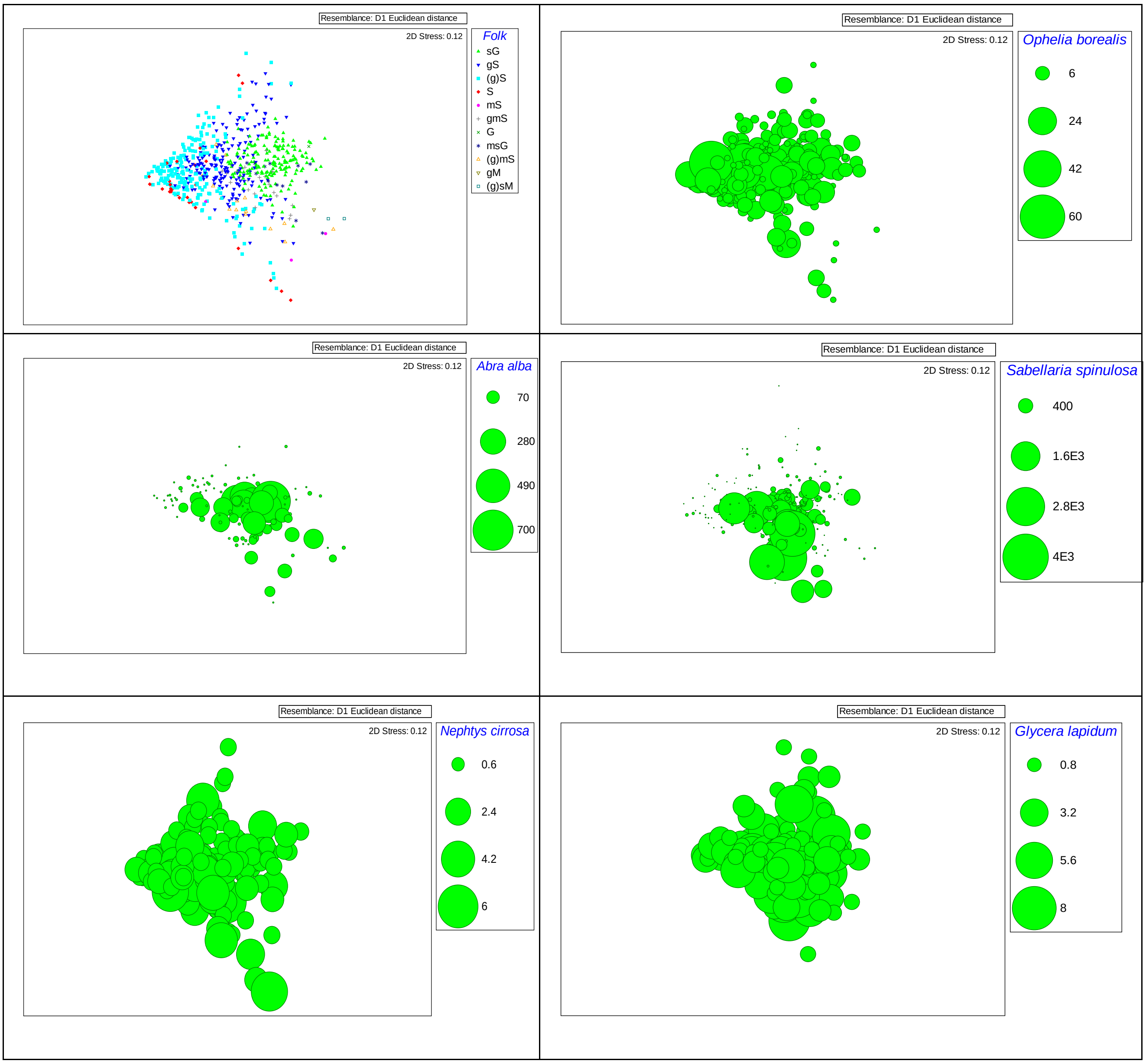


Figure 3.23 Non-transformed species abundance overlaid on MDS sediment grab ordination sample data.

3.6 Attribution of biotopes classifications to grab sample data

Infaunal groups identified through cluster analyses (section 3.4) were utilised to assign biotope classifications to the samples through comparison with the current Marine Habitat Classification for Britain and Ireland (Connor *et al*., 2004).

A total of one biotope, four biotope complexes, two habitat complexes and a habitat/biotope complex mosaic were identified within the Anglian MAREA region (Table 3.8, see grab sample details in Appendix D for all site biotope assignments and Appendix R for an explanation of biotope levels). To aid in biotope interpretation, a significant features description is given in Table 3.9.

Table 3.8 Biotopes within the Anglian MAREA region and associated (European Nature Information System) EUNIS codes.

Biotope level of classification	Biotope code	Bioptope name	EUNIS level	EUNIS 2006 code	EUNIS 2006 Name
Biotope (Level 5)	SS.SBR.PoR.SspiMx	*Sabellaria spinulosa* on stable circalittoral mixed sediment	5	A5.611	*Sabellaria spinulosa* on stable circalittoral mixed sediment
Biotope complex (Level 4)	SS.SCS.CCS	Circalittoral coarse sediment	4	A5.14	Circalittoral coarse sediments
	SS.SCS.ICS	Infralittoral coarse sediment		A5.13	Infralittoral coase sediments
	SS.SSa.CMuSa	Circalittoral muddy sand		A5.26	Circalittoral muddy sand
	SS.SSa.IFiSa	Infralittoral fine sand		A5.23	Infralittoral fine sand
Habitat complex (Level 3)	SS.SCS	Sublittoral coarse sediment (unstable cobbles and pebbles, gravels and coarse sands)	3	A5.1	Sublittoral coarse sediments
	SS.SSa	Sublittoral sands and muddy sands		A5.2	Sublittoral sand

***NOTE: Infaunal group 'u' was not accurately encompassed by any single biotope code; instead a mosaic of two codes, SS.SCS.CCS and SS.SSa, was assigned.**

Table 3.9 Classification of observed biotopes from Connor *et al.* (2004).

Biotope	Biotope description
S.SBR.PoR.SspiMx *Sabellaria spinulosa* on stable circalittoral mixed sediment	Consists of the tube-building polychaete *Sabellaria spinulosa* at high abundances on mixed sediment, typically forming low lying loose tube, sand, gravel, mud agglomerations on the seabed. Infauna comprise sublittoral polychaete species such as *Protodorvillea kefersteini*, *Pholoe synophthalmica, Harmothoe* spp, *Scoloplos armiger*, *Mediomastus fragilis*, *Lanice conchilega* and cirratulids, together with the bivalve *Abra alba,* and tube building amphipods such as *Ampelisca* spp. Epifauna comprise a variety of bryozoans including *Flustra foliacea*, *Alcyonidium diaphanum* and *Cellepora pumicosa*, in addition to calcareous tubeworms, pycnogonids, hermit crabs and amphipods. Consolidating sediment, *Sabellaria* reefs promote settlement patterns which may not be found in adjacent habitats thus enhancing epifaunal and infaunal diversity. Such reef development of reefs is assisted by the settlement behaviour of larval *Sabellaria* which are known to selectively colonise suitable sediment, particularly on existing *Sabellaria* tubes (Wilson 1929; Tait and Dipper, 1997). These reefs may be notably dredging or trawling affected when heavily disturbed an impoverished community may result (e.g. Pkef, an impoverished circalittoral mixed gravelly sand biotope), particularly disturbance is prolonged. However, it is likely that *S. spinulosa* reefs can recover quite quickly from short term or intermediate disturbance as found by Vorberg (2000). Notably recovery may be accelerated if some reef is left intact as *S. spinulosa* may be gregarious in favourable conditions (Davies, 2009).
SS.SCS Sublittoral coarse sediment (unstable cobbles and pebbles, gravels and coarse sands)	Coarse sand, gravel, pebble, shingle and cobble sediments, often unstable due to tides, currents and/or wave action. Generally on open coasts or tide-swept marine inlet channels. Typically low silt levels and no significant seaweed component; characterised by robust fauna including venerid bivalves.
SS.SCS.CCS Circalittoral coarse sediment	Tide-swept circalittoral coarse sand, gravel and shingle generally in depths >15-20m. May be noted in tidal marine inlet channels, along exposed coasts and offshore. As with shallower coarse sediments, may be characterised by robust infaunal polychaetes, mobile crustacea and bivalves. Certain sea cucumbers (e.g. Neopentadactyla) and the lancelet (*Branchiostoma lanceolatum*) may also be prevalent.
SS.SCS.ICS Infralittoral coarse sediment	Moderately exposed coarse and gravelly sands, shingle and gravel habitats in the infralittoral, are subject to tidal steam and wave action disturbance. Such habitats, found on the open coast or in tide-swept marine inlets, are characterised by robust fauna of infaunal polychaetes such as *Chaetozone setosa* and *Lanice conchilega*, cumacean crustacea such as *Iphinoe trispinosa* and *Diastylis bradyi*, and venerid bivalves.
SS.SSa Sublittoral sands and muddy sands	Clean medium to fine sands or non-cohesive slightly muddy sands on open coasts, offshore or in estuaries and marine inlets. Often subject to a degree of wave action or tidal currents restricting silt and clay content to <15%. Characterised by a taxa range including polychaetes, bivalve molluscs and amphipod crustacea.
SS.SSa.CMuSa Circalittoral muddy sand	Circalittoral non-cohesive muddy sands, silt content ranging from 5% to 20%. Habitat generally in depths >15-20m supporting animal-dominated communities characterised by a wide polychaete variety, bivalves such as *Abra alba* and *Nucula nitidosa*, and echinoderms such as Amphiura and Ophiura spp. and *Astropecten irregularis*. These circalittoral habitats tend to be more stable than their infralittoral counterparts thus support a richer infaunal community.
SS.SSa.IFiSa Infralittoral fine sand	Clean sands occuring in shallow water, either on open coast or tide-swept marine inlet channels. Typically lacks a significant seaweed component, characterised by robust fauna, particularly amphipods (Bathyporeia) and polychaetes including *Nephtys cirrosa* and *Lanice conchilega*.

For the infaunal groups, Tables 3.10a-h summarise the main physical and biological attributes encompassed within each biotope. Based on current classifications available, it was necessary to attribute two codes to infaunal group u (1.39% of sites, Table 3.10h) as the suite of macrofauna and sediment types could not be encompassed under one biotope code. In addition, the process of assigning biotopes resulted in the merging of a number of the infaunal groups identified through cluster analysis (see section 3.4), under the same biotope or habitat complex.

In severeal cases it was not possible to improve the level of biotope resolution beyond biotope / habitat complex (Table 3.8). This highlights a difficulty regarding the current paucity of classified circalittoral biotopes within the Marine Habitat Classification system, particularly with respect to disturbed, depauperate communities. The principal reason behind this is limited offshore field data within the present system on which biotope descriptions and subsequent classifications may be based. Instead, current classifications are largely based on historic survey information originally drawn from near-shore shallow water surveys and intertidal studies.

Further field data are required to update the Marine Habitats Classification system and to provide adequate coverage for offshore circalittoral biotopes. It is recommended that data from this MAREA, together with other aggregate studies targeting similar sediments, be made available to the Joint Nature Conservation Committee for expansion of the classification system and to aid future characterisation and assessment of marine aggregate sites.

A consequence of assigning biotope classifications to large groups of samples is a loss in biotope code resolution. This is because ‘between’ sample variability can be progressively diminished to satisfy the similarity requirements for increasing sample aggregation. Faunal data which is usually described at higher biotope coding levels were reduced in a number of cases to allow inclusion of all samples within each group. Coupled with the lack of suitable biotope codes within the current system this meant that at the level of the Anglian MAREA area many of the sample groups fell under broad habitat classifications, primarily tide-swept circalittoral coarse sediment (SS.SCS.CCS, 72% of sites).

Other coarse sediment assignments included the habitat complex sublittoral coarse sediment (SS.SCS, 0.15% of sites) and infralittoral coarse sediment (SS.SCS.ICS, 1%). Sublittoral sand classifications, including the habitat complex SS.SSa, circalittoral muddy sand (SS.SSa.CMuSa) and infralittoral fine sand (SS.SSa.IFiSa) derivatives accounted for a further 5.84% of sites.

Table 3.10a-h Physical and biological attributes of the biotopes identified.

Table 3.10a. Physical and Biological attributes of SS.SBR.PoR.SspiMx

SS.SBR.PoR.SspiMx

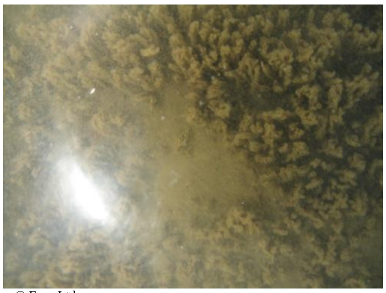
Sabellaria spinulosa on stable circalittoral mixed sediment

Infaunal group ab (n=127)

Characterising Species

Ranked contribution to top 50% of internal similarity SIMPER (Av. similarity 25.72%)	Main characterising species ranked abundance (top 50%)
Sabellaria spinulosa	Nemertea
Nemertea	*Sabellaria spinulosa*
Ophiuroidea	*Lumbrineris gracilis*
Abra alba	*Lanice conchilega*
Lumbineris gracilis	Ophiuroidea
Ophiura albida	*Glycera lapidum*
Lanice conchilega	
Lagis koreni	

Example of an *in situ* photograph



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Summary Species Data

Total No. Species	416
Mean No. Species/0.1m^2	39.46
Mean Abundance/0.1m^2	556.78
Mean Biomass/0.1m^2	5.43

Example photograph of the typical substrate

© Emu Ltd

Folk sediment classification(s): Sandy gravel, Gravelly sand, Slightly gravelly sand, Gravelly muddy sand, Muddy sandy gravel, Slightly gravelly muddy sand, Slightly gravelly sandy mud, Gravelly mud, Muddy sand

Summary physical attributes

µm	Mean %	s/d
64000	0.00	0.00
31500	1.85	6.69
16000	7.30	9.40
8000	9.28	7.91
4000	6.70	4.88
2000	4.39	2.84
1000	3.94	3.61
500	6.34	4.20
250	25.51	13.44
125	22.16	12.80
63	4.21	3.88
<63	8.32	11.43
Sorting	2.33	0.72
Depth (m)	33.67	4.15

Distribution within the East Coast REA Area

Table 3.10b Physical and biological attributes of SS.SCS.

SS.SCS

Sublittoral coarse sediment (unstable cobbles and pebbles, gravels and coarse sands)

Infaunal groups c and m (n=8)

Characterising Species

Ranked contribution to top 50% of internal similarity SIMPER (Av. similarity 34.38%)	Main characterising species ranked abundance (top 50%)
Atylus swammerdamei	*Polydora caulleryi*

Example of an *in situ* photograph

© Emu Ltd

Summary Species Data

Total No. Species	13
Mean No. Species/0.1m^2	2.88
Mean Abundance/0.1m^2	6.88
Mean Biomass/0.1m^2	<0.001

Example photograph of the typical substrate

© Emu Ltd

Folk sediment classification(s): Gravelly sand, Sandy gravel, Slightly gravelly sand, Gravelly muddy sand, Sand

Summary physical attributes

µm	Mean %	s/d
64000	0.00	0.00
31500	1.58	3.39
16000	4.30	5.37
8000	7.11	5.62
4000	5.96	5.45
2000	5.10	5.09
1000	5.24	4.67
500	19.34	5.79
250	38.12	26.58
125	8.79	6.36
63	2.04	5.15
<63	2.41	6.76
Sorting	1.71	0.92
Depth (m)	9.87	2.29

Distribution within the East Coast REA Area

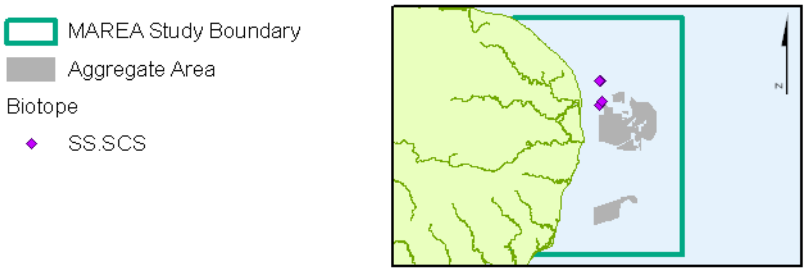


Table 3.10c Physical and biological attributes of SS.SCS.CCS.

SS.SCS.CCS

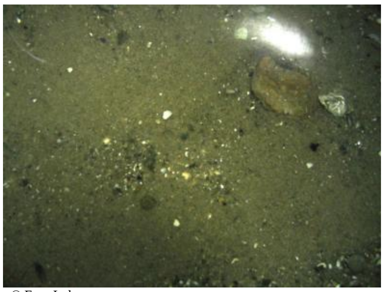
Circalittoral coarse sediment

Infaunal groups aa/n, f/ac, d/w, e/s, v/y, h, i, l, o, p, q, r, t, and x (n=468)

Characterising Species

Ranked contribution to top 50% of internal similarity SIMPER (Av. similarity 13.56%)	Main characterising species ranked abundance (top 50%)
Ophelia borealis *Nephtys cirrosa*	*Ophelia borealis* *Nephtys cirrosa* Nemertea *Gastrosaccus spinifer* *Sabellaria spinulosa* *Glycera oxycephala* *Spiophanes bombyx* *Glycera lapidum* *Nephtys* *Polycirrus* *Ophiura* *Notomastus* Ophiuroidea

Example of an *in situ* photograph



© Emu Ltd

Summary Species Data

Total No. Species	402
Mean No. Species/0.1m^2	8.83
Mean Abundance/0.1m^2	25.20
Mean Biomass/0.1m^2	0.29

Example photograph of the typical substrate

© Emu Ltd

Folk sediment classification(s): Slightly gravelly sand, Gravelly sand, Sandy gravel, Sand, Gravelly muddy sand, Muddy sandy gravel, Slightly gravelly muddy sand, Gravel, Muddy sand

Summary physical attributes

µm	Mean %	s/d
64000	0.06	1.39
31500	1.38	5.39
16000	5.45	8.96
8000	6.84	8.24
4000	4.67	4.61
2000	3.46	3.28
1000	3.95	5.55
500	13.76	12.68
250	44.33	22.68
125	13.96	13.73
63	0.93	1.76
<63	1.20	3.57
Sorting	1.58	0.85
Depth (m)	31.04	5.39

Distribution within the East Coast REA Area

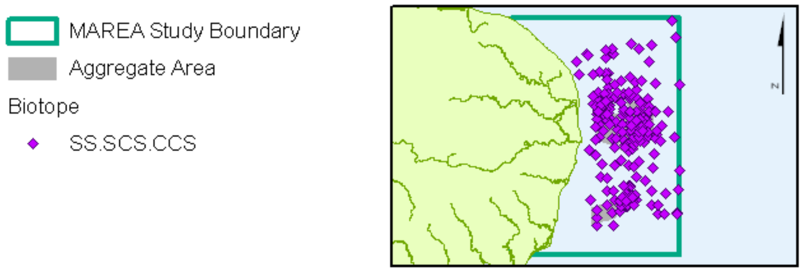


Table 3.10d Physical and biological attributes of SS.SCS.ICS.

SS.SCS.ICS
Infralittoral coarse sediment
Infaunal groups b, j and k (n=7)

Characterising Species

Ranked contribution to top 50% of internal similarity SIMPER (Av. similarity 14.10%)	Main characteristing species ranked abundance (top 50%)
Mytilidae	Mytilidae *Mytilus edulis* *Nymphon brevirostre* *Atylus swammerdamei* Actiniaria *Doto* *Balanus crenatus* *Barnea candida* *Autolytus* *Eusyllis blomstrandi* *Achelia longipes* *Cirriformia tentaculata* *Glycera lapidum*

Example of an *in situ* photograph

© Emu Ltd

Summary Species Data

Total No. Species	51
Mean No. Species/0.1m^2	11.43
Mean Abundance/0.1m^2	121.43
Mean Biomass/0.1m^2	0.56

Example photograph of the typical substrate

No substrate image available.

Folk sediment classification(s): Sandy gravel, Gravelly sand

Summary physical attributes

µm	Mean %	s/d
64000	0.00	0.00
31500	2.97	5.14
16000	15.99	13.63
8000	7.47	3.04
4000	8.61	6.31
2000	7.92	4.66
1000	7.36	4.33
500	14.27	7.69
250	25.34	7.08
125	7.84	4.08
63	1.06	0.88
<63	1.17	1.91
Sorting	2.47	0.56
Depth (m)	-	-

Distribution within the East Coast REA Area

MAREA Study Boundary
Aggregate Area
Biotope
SS.SCS.ICS

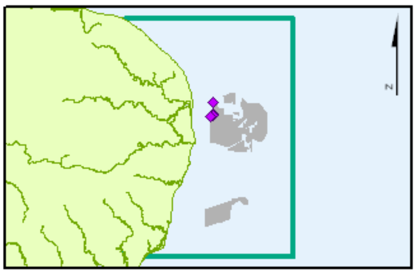


Table 3.10e Physical and biological attributes of SS.SSa.

SS.SSa
Sublittoral sands and muddy sands
Infaunal groups z (n=1)

Characterising Species		Example of an *in situ* photograph
Ranked contribution to top 50% of internal similarity SIMPER	Main characterising species ranked abundance (top 50%)	No *in situ* image available.
< 2 sampled	*Ophiura albida* *Pomatoceros lamarki* *Clymerura*	

Summary Species Data

Species/0.1m^2	13
Abundance/0.1m^2	33
Biomass/0.1m^2	0.21

Example photograph of the typical substrate

© Emu Ltd

Folk sediment classification(s): Sand

Summary physical attributes

µm	Mean %
64000	0.00
31500	0.00
16000	0.00
8000	0.00
4000	0.00
2000	0.23
1000	7.24
500	64.02
250	20.89
125	7.12
63	0.35
<63	0.15
Sorting	0.78
Depth (m)	-

Distribution within the East Coast REA Area

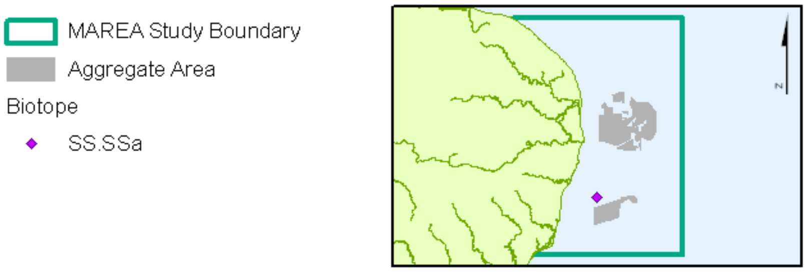


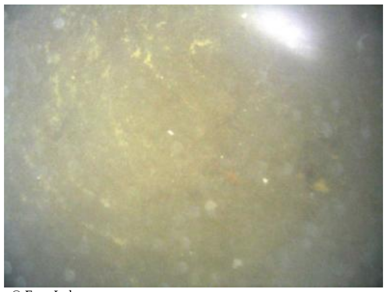
Table 3.10f Physical and biological attributes of SS.SSa.CMuSa.

SS.SSa.CMuSa
Circalittoral muddy sand
Infaunal group ad (n=11)

Characterising Species

Ranked contribution to top 50% of internal similarity SIMPER (Av. similarity 19.91%)	Main characterising species ranked abundance (top 50%)
Scalibregma inflatum *Lagis koreni* *Nephtys*	*Scalibregma inflatum*

Example of an *in situ* photograph



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Summary Species Data

Total No. Species	64
Mean No. Species/0.1m^2	12.18
Mean Abundance/0.1m^2	134.09
Mean Biomass/0.1m^2	0.37

Example photograph of the typical substrate

© Emu Ltd

Folk sediment classification(s): Slightly gravelly muddy sand, Slightly gravelly sand, Muddy sandy gravel

Summary physical attributes

µm	Mean %	s/d
64000	0.00	0.00
31500	0.00	0.00
16000	0.00	0.00
8000	0.35	0.64
4000	0.66	0.80
2000	0.99	1.36
1000	1.43	2.07
500	3.74	6.52
250	33.61	25.78
125	26.79	18.84
63	12.77	13.19
<63	19.66	13.32
Sorting	1.06	0.39
Depth (m)	34.50	-

Distribution within the East Coast REA Area

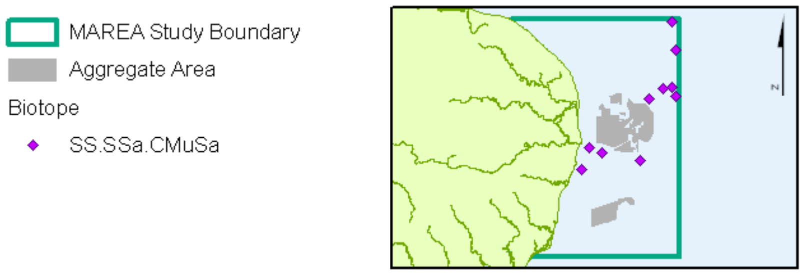


Table 3.10g Physical and biological attributes of SS.SSa.IFiSa.

SS.SSa.IFiSa

Infralittoral fine sand

Infaunal groups a and g (n=19)

Characterising Species

Ranked contribution to top 50% of internal similarity SIMPER (Av. similarity 24.71%)	Main characterising species ranked abundance (top 50%)
Nephtys	*Nephtys*
Ophelia	*Ophelia*
	Ophiuroidea
	Ophiura

Example *in situ* photograph

© Emu Ltd

Summary Species Data

Total No. Species	62
Mean No. Species/0,1m^2	7.11
Mean Abundance/0.1m^2	14.37
Mean Biomass/0.1m^2	0.35

Example photograph of the typical substrate

© Emu Ltd

Folk sediment classification(s): Slightly gravelly sand, Sandy gravel, Gravelly sand, Sand, Muddy sand

Summary physical attributes

µm	Mean %	s/d
64000	0.00	0.00
31500	0.00	0.00
16000	1.99	3.80
8000	5.93	8.91
4000	3.43	4.76
2000	1.99	2.10
1000	1.80	2.15
500	8.93	11.33
250	50.41	19.70
125	22.03	11.47
63	0.78	1.08
<63	2.71	3.91
Sorting	1.28	0.82
Depth (m)	15.70	-

Distribution within the East Coast REA Area

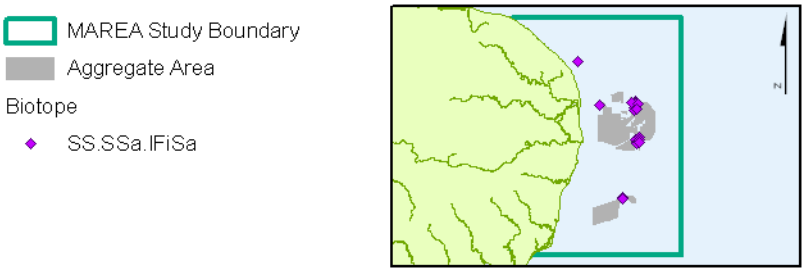


Table 3.10h Physical and biological attributes of SS.SCS.CCS/SS.SSa.

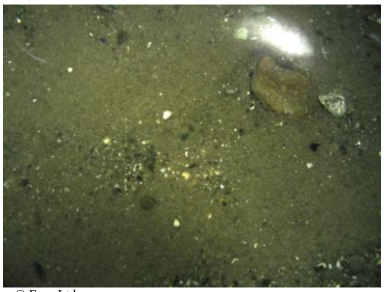
SS.SCS.CCS/SS.SSa

Circalittoral coarse sediment / Sublittoral sands and muddy sands

Infaunal groups u (n=9)

Characterising Species	
Ranked contribution to top 50% of internal similarity SIMPER (Av. similarity 26.95%)	Main characterising species ranked abundance (top 50%)
Ophiuroidea	Ophiuroidea *Ophelia borealis* *Pisione remota* EUMALACOSTRACA *Caulleriella alata*

Example *in situ* photograph



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Summary Species Data

Total No. Species	35
Mean No. Species/0,1m^2	6.89
Mean Abundance/0.1m^2	11.00
Mean Biomass/0.1m^2	0.07

Example photographs of the typical substrates

© Emu Ltd

© Emu Ltd

Folk sediment classification(s): Slightly gravelly sand, Gravelly sand, Sand

Summary physical attributes

µm	Mean %	s/d
64000	0.00	0.00
31500	0.00	0.00
16000	1.29	2.94
8000	1.83	3.44
4000	3.09	3.82
2000	3.65	4.74
1000	4.01	3.89
500	17.40	14.91
250	57.71	19.93
125	9.78	8.11
63	0.35	0.32
<63	0.89	1.34
Sorting	1.05	0.68
Depth (m)	31.79	-

Distribution within the East Coast REA Area

The only biotope to level 5 defined was *S. spinulosa*, SS.SBR.PoR.SspiMx, encompassing 19.54% of sites. *S. spinulosa*, as a dominant species on coarse sand mixed sediments, is poorly represented within the Marine Habitat Classification in terms of the range of biotopes it is found in. The *S. spinulosa* biotope classification available within the current system represents *Sabellaria* biogenic reef on mixed substrate. In this form, i.e. as a reef feature, the biotope was either not present, or not known to be present, at the majority of sites assigned this biotope (see section 3.7). However, it was still the most appropriate classification for the community composition of infaunal group ab (Table 3.9a), reflecting the high numbers of *Sabellaria* generally present and containing 39 of the key characterising species for the group identified through SIMPER analyses; these included *Nemertea*, *A. alba*, *Ophiura albida* and *Lagis koreni*.

As may be expected, sites within the *Sabellaria* biotope contained relatively high average species richness (39.46) and abundances (556.78) when considered against the overall Anglian MAREA area. Tubes built by this polychaete provide heterogeneous, relatively stable surfaces for organism colonisation and, when abundant or in reef form, consolidate sediments, resulting in increased community diversity and species abundance.

It is important that the relatively wide *Sabellaria* biotope distribution, within the Anglian MAREA, does not lead to a misinterpretation of the habitats conservation interest. *S. spinulosa* is a very common species in the UK and its presence alone is therefore not of conservation interest, it is clear in the international designations that the worm itself is not protected, only clearly distinct biogenic reef formations.

The ubiquitous circalittoral coarse sand biotope complex (SS.SCS.CCS) encompassed nineteen of the infaunal groupings, five of which were merged following analysis of the characterising taxa output by SIMPER (Table 3.10c). SIMPER analyses on the combined faunal data for the groups within SS.SCS.CCS revealed *Ophelia borealis* and *Nephtys cirrosa* to be the main characterising species in combination with species such as *S. spinulosa*, *Glycera oxycephala* and *Spiophanes bombyx*. This biotope complex occurred at an average depth of 31.04m within generally very poorly sorted sublittoral gravely sands. A key feature of all of the groupings encompassed within the SS.SCS.CCS complex was that they were faunistically poor which is generally indicative of physical instability or stress and which may occur in disturbed and transitional habitats. The mean number of species and individuals for this biotope complex were 8.83 and 25.20 per square metre respectively. The low number of characterising fauna for the various biotope options rendered the possibility of further discrimination, to biotope level, inappropriate.

Infaunal group ad (Table 3.10f) was classified to biotope complex level as circalittoral non-cohesive muddy sands (SS.SSa.CMuSa). The species composition of the biotope was appropriate to AalbNuc, however, the absence of a key characterising species, *Nucula nitidosa*, meant the assignment of this groups to AalbNuc could not be made with confidence. Species richness was generally low within CMuSa (12.18/ 0.1m^2) although average abundances were relatively high (134.09/0.1m^2). The main characterising species was *Scalibregm inflatum*, occurring on generally poorly sorted, sublittoral slightly gravely muddy sand, at an average depth of 34.50m.

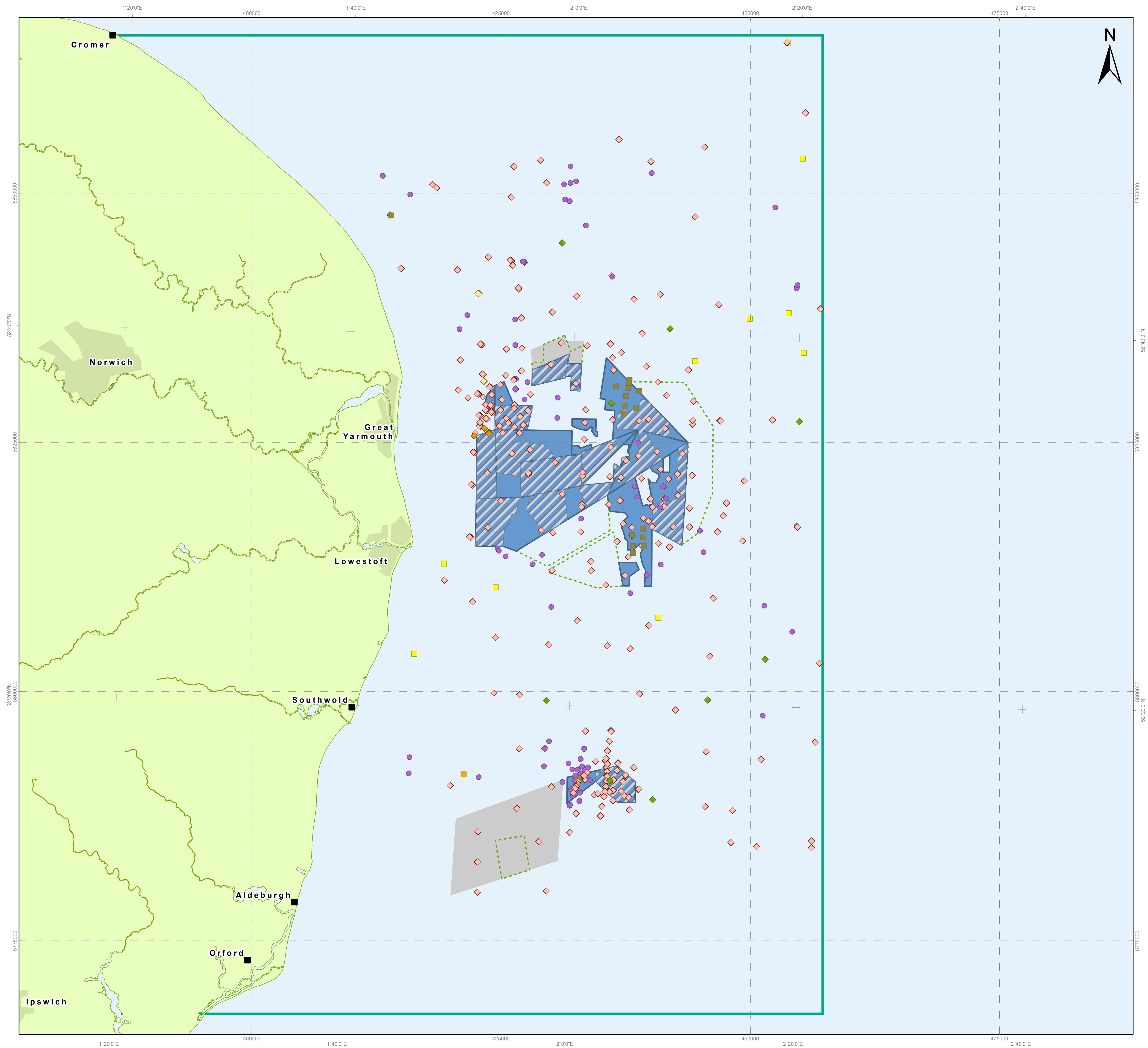
Infaunal groups a and g (Table 3.10g) corresponded well with the infralittoral fine sands biotope complex characterised by *Nephtys* and *Ophelia* within poorly sorted infralittoral gravelly sands at an average depth of 15.70m. Again, the classification could not be raised to biotope level due to the impoverished nature of the communities. The sites within this group and corresponding biotope are an extension of the SS.SCS.CCS described above, in this instance characterised by a greater proportion of fine sands in shallower water.

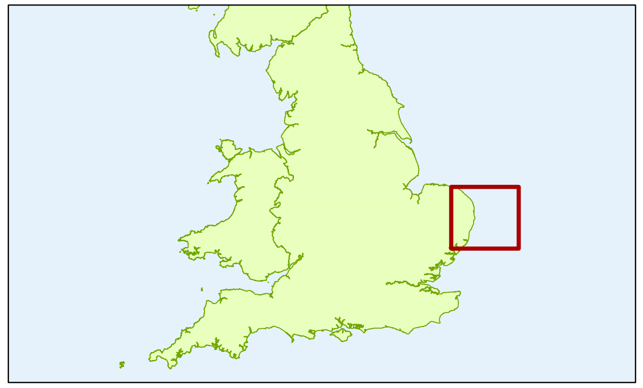
For group's b, j and k, (Table 3.10d), the biotope complex infralittoral coarse sand (SS.SCS.ICS) was ascribed with the key characterising species including *Mytilidae* and *Nymphon brevirostre*. Although bathymetry interpretation for the area revealed that not all sites were at typical depths for the infralittoral, the biotope complex assigned remained the best, based on the species array.

Due to the restricted number of species within group's z, c and m (Table 3.10e for the former group & 3.10b for the latter two groups), classifications had to remain at habitat complex level; clean medium to fine sands for the former group (SS.SSa) and coarse sediments (SS.SCS) for the latter two. Group z comprised one sample, found on sand, with *Ophiura albida* the main characterising species. Eight samples were contained within the SS.SCS group, encompassing highly impoverished communities (number of species and individuals 2.88 and 6.88/0.1m^2 respectively), primarily associated with gravelly sands, with *Atylus swammerdamei* as the main characterising species and *Polydora caulleryi* the most abundant.

The dominance of tide-swept circalittoral coarse sands throughout the MAREA area illustrated the relatively homogenous sediment nature and, by comparison, the small contributions from other biotopes Figure 3.24). *Sabellaria* biotope clusters were found throughout the study area, although generally outside of licensed aggregate extraction areas (Figure 3.24). Sites corresponding to the infralittoral fine sand biotope formed two discrete clusters within the central portion of the MAREA region and those corresponding to circalittoral muddy sand were generally found in the north east and western portions of the study area (Figure 3.24).

In general, results indicated a poor fit with predicted MESH habitats. Circalittoral coarse sand sites were located within a combination of both fine and coarse sand MESH habitat areas. The area of fine sediments noted in the north east of the MAREA area and the associated muddy sand biotopes roughly correlate with the MAREA circalittoral mud area delineated, although the boundaries differ. Unsurprisingly the *Sabellaria* biotope generally corresponded to coarser areas, the material of which is required for tube construction by this polychaete.





Legend

MAREA Study Boundary

Aggregate Areas

Active Dredge Zone

Licence Area

Application Area

Prospecting Area

Habitat Complex

SS.SCS

SS.SSa

Biotope Complex

SS.SCS.CCS

SS.SCS.ICS

SS.SCS.CCS/SS.SSa

SS.SSa.CMuSa

SS.SSa.IFiSa

Biotope

SS.SBR.PoR.SspiMx

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010; MFA 2009
Emu Limited, 2002-2010

0 5 10 20
Kilometres

Coordinate System:
WGS84 UTM Zone 31 North

Scale: 1:375,000

Sheet Size: A3

Client: Anglian Offshore Dredging Association

Consultant:
Emu Limited
Ph: +44 (0) 1489 860050
Fax: +44 (0) 1489 860051
website: www.emulimited.com
email: mail@emulimited.com

Project Title:
AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:
Infaunal Group Biotope Distributions
Anglian MAREA Region

Figure No. 3.24

Drawn By:	Checked By:	Issued On:	Job Number:	Rev:
MXP	EMP	26/03/12	J/1/03/1671	1

Map Document: (N:\1.13\1463 AODA MAREA GIS Element\3.Plots\3.Finals\J1031671_Benthic_Survey\Fig3_24_InfaunalBiotopes.mxd)
26/03/2012 -- 10:39:06

3.7 Video analyses and *Sabellaria* reef assessment

Video footage and stills images, collected as part of the current MAREA survey, assisted with sediment habitat type appraisal and provided a wider context within which grab sampling results could be placed. Temporal video datasets were not available, therefore historical analysis was not possible. Analysis of current video data were also considered not to add any value to the report as detaikled refining of the biotope classifications was not always feasible, thus complex or habitat level was ascribed. Moreover most of the area was characterised by infaunal communities, thus not possible to assess via video analysis. This included illustrating any variation in the generally homogenous sediments (see section 3.2).

Plates 3.3a-c show examples of conspicuous fauna associated with slightly differing gravelly sand sediments. Typical species observed within the video footage and stills included: Paguridae sp., hydroid sp., *Ophiura albida*, *Lanice conchilega* and *Asterias rubens*. A summary of video analyses results for all current survey sites is contained within Appendix S. Seabed imagery supported the grab sample data, confirming the dominance of coarse sediment biotopes described in section 3.6.

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a) Paguridae sp. on rippled sand, biotoped as SS.SCS.CCS.

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b) Hydroid spp., *Lanice conchilega* & *Ophiura albida* on shelly sand with a small area of sandy gravel, biotoped as SS.SCS.CCS.

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c) *Ophiura* sp., *Lanice conchilega*, Hydroid spp., Paguridae sp., *Asterias rubens*, *Euspira* sp. & an egg capsule on sandy gravel, biotoped as SS.SBR.PoR.SspiMx

Plate 3.3 a-c Typical conspicuous fauna associated with a range of sediments within the Anglian MAREA region.

For all sites containing *Sabellaria* reef in the current survey a detailed assessment of the level of 'reefiness' was conducted based on 'elevation' and 'patchiness' measures (Table 3.11, see section 2.2.8). *Sabellaria* reef is listed within Annex I of the EC Habitat Directive and is among habitats for which additional SACs must be designated as part of the UK's commitment to SACs across the EU Natura network.

Within the study area typical *S. spinulosa* observations include thin, low growing ephemeral crusts (e.g. Emu Ltd., 2008c), unlikely to constitute reef. However, several benthic ecology surveys have recorded discrete patches of dense *S. spinulosa* tubes with the potential to constitute biogenc reef under the Annex I 'reef' definition (e.g. MES, 2007; Emu Ltd., 2000, 2002, 2004, 2005, 2006, 2007, 2008b & c). In the current study, three reef sites were found with both elevation and patchiness scores: sites I10_G12, 21 and 44. These were associated with sandy gravels / gravelly sands which provide habitat suitable for *S.spinulosa* settlement and colonisation; the naturally mobile surficial sands afford worm tube construction and maintenance material (Holt *et al*., 1998). Four additional sites in the current survey had low-medium elevation scores, but were not classified as reef due to their high degree of patchiness (<10% cover) - see Section 2.28.

Reef sites identified in the current study were widely spaced within the Anglian MAREA region. One was located towards the north of the Anglian MAREA region, below Licence Area 296, east of Area 254, another in the central portion immediately outside of Area 401/2, and the last by Area 430 in the south. To provide an overview of *Sabellaria* reef distribution within the Anglian MAREA region, a plot was created (Figure

3.25) amalgamating the location of reef identified by previous benthic surveys in the region and the current survey reef sites. Figure 3.25 illustrates that the current reef sites are in the vicinity of previously recorded discrete dense *S.spinulosa* patches with potential to constitute Annex I biogenic reef.

Notably, for the East Coast REC, Limpenny *et al.* (2011) found that *S. spinulosa* reef habitat is likely to occur in moderately deep water and moderate tide with no clear sediment preference, although reef growth appeared to be negatiovely asoacietd with small and large sandwaves. It was considered that the highest likelihood of harbouring *Sabellaria* reef is recorded in a relatively small patch in the center of the far north of the East Coast REC Study Area.

Utilising acoustic imaging equipment and ground truthing with video, a number of reefs have been successfully mapped by Emu Ltd. (2005, 2006, 2008c) within the boundaries of Area 401/2 (Refer to Appendix A: Benthic Ecology Review, Section 3.7, Figure 12). In addition, a study by MESL (2007b) identified a '*Sabellaria* reserve' within the western part of Area 430. Erect reef structures have also been recorded 500m beyond the eastern boundary of Area 254, within Area 202 and to the north and west of the latter licence area (Emu Ltd., 2000, 2002, 2004b, 2007, 2008b) - Figure 3.25.

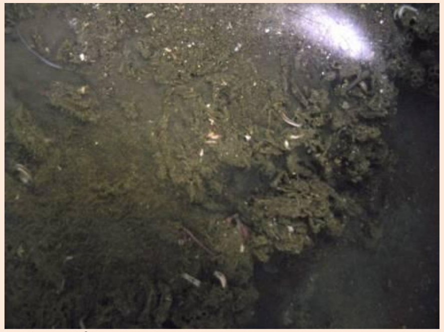
The combined current and previous survey (e.g. MES, 2007; Emu Ltd., 2000, 2002, 2004, 2005, 2006, 2007, 2008b & c) reef results indicate three main hotspots of *S. spinulosa* reef in the region (Figure 3.25), within and around the following licence areas:

- Area 430 to the south;
- Area 401/2 in the central portion; and
- Areas 202/254 to the north.

Whilst some studies have confirmed long-term presence of comparatively dense *S.spinulosa* populations and potential reef features in Areas 401/2 and 202 they have also recorded the development and decline of reef at other locations (MESL, 2001; Emu Ltd., 2007, 2008c). A known natural cycling of accretion and decay of *S.spinulosa* reef exists, although the process is poorly understood (Holt *et al*., 1998). JNCC (2007) suggest these reefs may be naturally ephemeral structures, building up over several years and then declining due to predation, by starfish for example. In addition to natural variability, trawl damage may be a factor affecting the disappearance of reef structures (Vorberg, 2000).

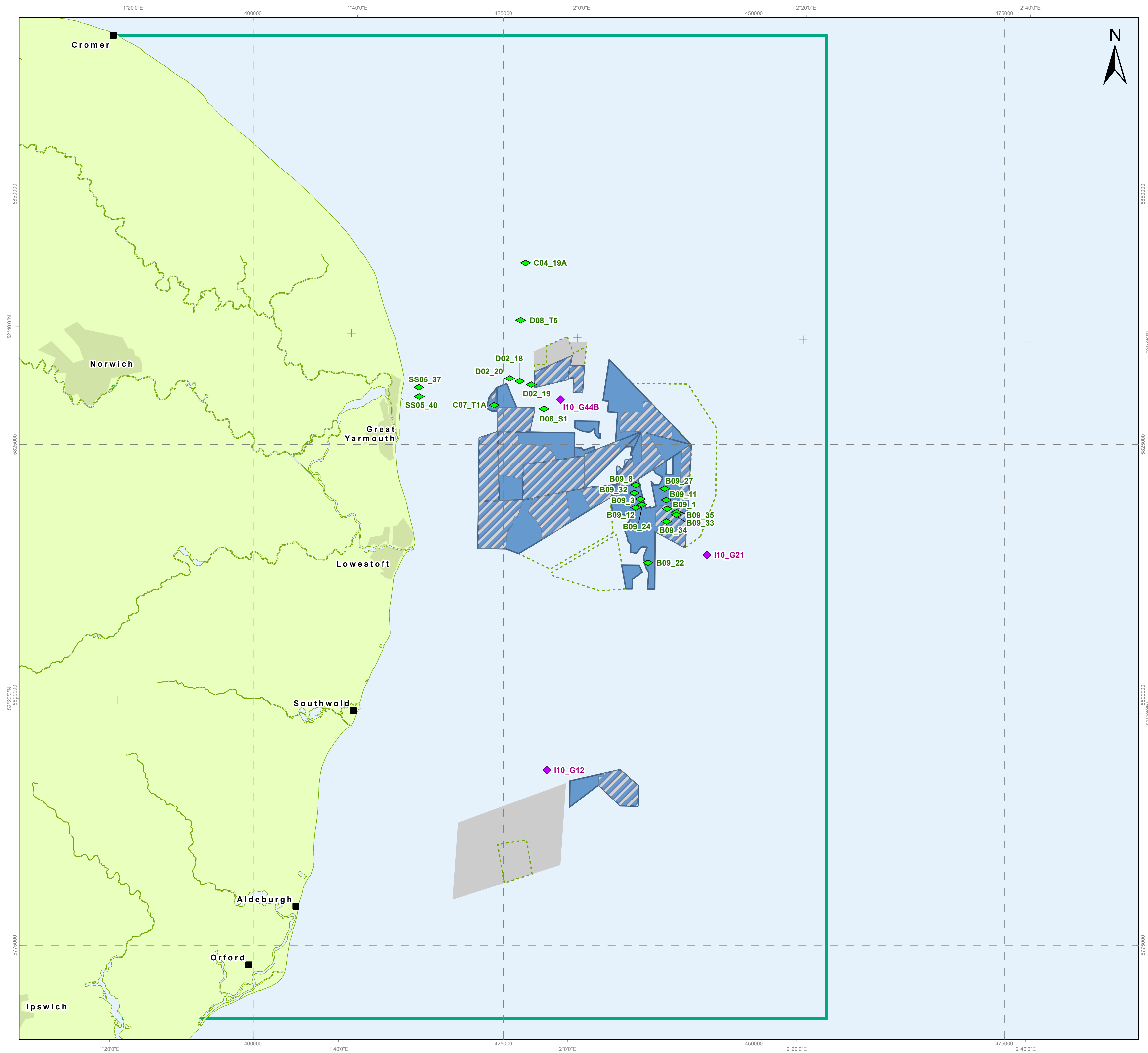
In the absence of video footage for the historic datasets assessed within this MAREA, the necessary information for an equivalent detailed assessment of the level of 'reefiness' at *Sabellaria* sites was unavailable. To fully assess and confirm *Sabellaria* reef structure abundance, a future comprehensive video and side scan sonar survey would be required. This would ascertain patchiness and elevation scores for all of the sites considered within the Anglian MAREA, and would accurately assess the extent of *Sabellaria* reefs throughout the region.

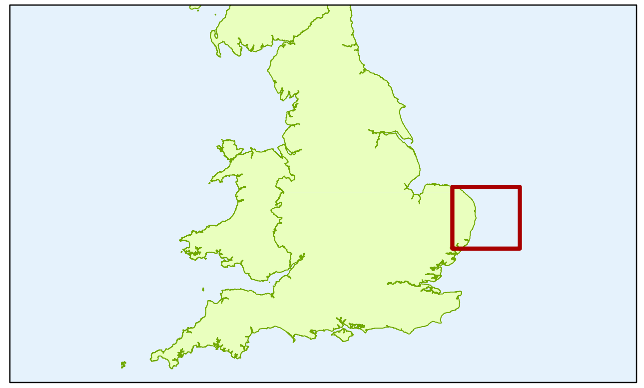
Table 3.11 Video analysis results and 3–stage analysis for *Sabellaria spinulosa* reef, current survey within the Anglian MAREA (site prefix I10_G).

		Stage 1 analysis					**Stage 2 analysis**					**Stage 3 analysis**	
Site	Sediment description	Sabellaria form present					Sabellaria characteristics				Image	Reef definition based on Elevation	Reef definition based on Patchiness
		Absent	Moribund loose tubes	Crusts	Clumps	Potential Reef	Elevation	Patchiness	Brief description of reef	Other conspicuous species			
12	Sand	×	✓ from grab sample	×	✓	✓	6-~10cm	70%	Discrete clumps and coherent live *Sabellaria spinulosa* reef	Hydroid spp.	 © Emu Ltd	**Medium**	**High**
21	Sand	×	×	×	✓	✓	6 - 10cm	45%	Discrete clumps and coherent live *Sabellaria spinulosa* reef	Hydroid spp. *Ophiura albida* *Asterias rubens*	 © Emu Ltd	**Medium**	**High**

Site	Sediment description	Sabellaria form present					Sabellaria characteristics				Image	Reef definition based on Elevation	Reef definition based on Patchiness
		Absent	Moribund loose tubes	Crusts	Clumps	Potential Reef	Elevation	Patchiness	Brief description of reef	Other conspicuous species			
22	Rippled sand with patches of gravelly sand	×	✓ from grab sample	×	✓	✓	~4 - 5cm	5%	Isolated clumps of *Sabellaria spinulosa*	*Lanice conchilega* Hydroid spp.	 © Emu Ltd	**Low**	**Not Reef**
42	Rippled sand with patches of gravelly sand	×	✓	×	✓	✓	7cm	2%	Isolated clumps of *Sabellaria spinulosa* with moribund tubes	Hydroid spp. *Asterias rubens*	 © Emu Ltd	**Medium**	**Not Reef**
44	Rippled sand with patches of sandy gravel	×	×	×	✓	✓	5 - 7cm	85%	Extensive coherent *Sabellaria spinulosa* reef with clumps of moribund tubes	Hydroid spp. *Asterias rubens*	 © Emu Ltd	**Medium**	**High**

Site	Sediment description	Sabellaria form present					Sabellaria characteristics				Image	Reef definition based on Elevation	Reef definition based on Patchiness
		Absent	Moribund loose tubes	Crusts	Clumps	Potential Reef	Elevation	Patchiness	Brief description of reef	Other conspicuous species			
47	Rippled sand with patches of gravelly sand	×	×	✓	✓	✓	2 cm	6%	Thick crusts and small clumps of *Sabellaria spinulosa*	*Lanice conchilega*	 © Emu Ltd	**Low**	**Not Reef**
55	Rippled sand with patches of gravelly sand	×	✓ from grab sample	×	✓	✓	2-4cm	2%	Isolated clumps with two small areas(<1m in diameter) of low lying coherent *Sabellaria spinulosa*	*Asterias rubens* Paguridae sp.	 © Emu Ltd	**Low**	**Not Reef**





Legend

MAREA Study Boundary

Aggregate Areas

- Active Dredge Zone
- Licence Area
- Application Area
- Prospecting Area

***Sabellaria* Reef Location**

- Previous benthic surveys *Sabellaria* reef observations

***Sabellaria* Reef Features within Current MAREA Survey**

- Site with both elevation and patchiness score

Notes: **Source:** EMU (2002) – Grab Data (D02_)
EMU (2004) – Grab Data (C04_)
EMU (2007) – Trawl Data (C07_)
EMU (2008b) – Grab and Trawl Data (D08_)
EMU (2008c) – Video Data (B09_)
EMU (2010) – Grab Data (I10_)
Worsley & Dyer (2005) – Grab Data (SS05_)
MES, 2006-07; CEFAS, 2009;
The Crown Estate, 2010; MFA 2009

0 5 10 20
Kilometres

Coordinate System: WGS84 UTM Zone 31 North

Scale: 1:375,000

Sheet Size: A3

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AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title: Distribution of *Sabellaria* Reef Based on Current and Previous Survey Data for the Anglian MAREA Region

Figure No. 3.25

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3.8 2m beam trawl data

Trawl taxa summary

Assemblages of larger, more mobile epibenthos together with communities of sessile colonial fauna, were collected using 2m beam trawls. Trawl positions, depths, impact zones and SIMPER groups for the integrated dataset are contained within Appendix T. Enumerated trawl taxa and presence/absence data for the integrated dataset are presented in Appendices U and V respectively. For the current survey, photographs of beam trawl samples, sampling details and fish and shellfish measurements are presented within Appendices W to Z respectively.

Encompassed within 14 major taxonomic groups, a total of 212 taxa were found in the trawl samples (Table 3.12). Occurring in all samples, the most species rich group was Crustacea, containing 26% of the trawl taxa. Pisces accounted for a further 22% of taxa, present in 98% of samples, these were followed by Mollusca, found in 85% of samples and encompassing 15% of taxa. Colonial sessile fauna mainly comprised Cnidaria, accounting for 15% of trawl taxa and occurring in 93% of samples.

Table 3.12 Trawl species/higher taxa number and occurrence frequency, within major taxonomic groups, Anglian MAREA region.

Taxonomic group	Trawl	
	No. species / higher taxa	Frequency of occurrence %
Annelida (Polychaeta and Oligochaeta) (worms)	6	43
Bryozoa (Sea mats)	12	50
Crustacea (Shrimps, prawns, crabs, barnacles)	55	100
Chelicerata (Sea spiders)	6	3
Cnidaria (Sea firs, sea anemones)	31	93
Ctenophora (Sea gooseberries)	1	1
Echinodermata (Sea urchins, brittle stars, starfish)	13	81
Entoprocta (Goblet worms)	1	0
Mollusca (Bivalves, chitons)	31	85
Pisces (Fish)	46	98
Platyhelminths (Flat worms)	1	1
Porifera (Sponges)	5	8
Sipunculida (Peanut worms)	1	1
Tunicata (Sea squirt)	3	8

Table 3.13 below presents the top 30 most abundant and frequently occurring trawl species recorded and Plates 3.4a-b illustrate some of the commonly occurring species found within the Anglian MAREA region. The numerical superiority of the brittlestar *Ophiura albida* is highlighted (Table 3.13) with a total of 109,895 found; 39% of total trawl individuals. Combined, brittlestars accounted for 60% of trawl individuals, encompassing *O. fragilis* and *O. ophiura* in addition to *O.albida*. The shrimp *Crangon allmanni* and polychaete *S.spinulosa* were also highly abundant, with over 20,000 individuals recorded for each.

Despite its numerical dominance, *O.albida* was present in under half of the samples (49.3%). The other brittlestar species were also clearly patchily distributed, with *O.ophiura* present in just 23.9% of samples and *O.fragilis* absent from the top 30 most frequently occurring species list. Work has shown that patchy distributions for these species may result from hydrodynamic forcing at the larval stage and in adult stage from a close association with fine material (Tyler and Banner, 1977).

Table 3.13 Top 30 most abundant and frequently occurring (combined enumerated and presence/absence data) trawl species.

Most abundant taxa			Most frequently occurring taxa		
Taxa	Common name	Total abundance	Taxa	Common name	% Frequency of occurrence
Ophiura albida	Serpent star	109895	*Crangon allmanni*	Shrimp	82.6
Ophiothrix fragilis	Common brittlestar	32522	*Pagurus bernhardus*	Common hermit crab	81.1
Crangon allmanni	Shrimp	26679	*Asterias rubens*	Common starfish	72.6
Ophiura ophiura	Serpent star	24275	*Liocarcinus holsatus*	Swimming crab	71.1
Sabellaria spinulosa	Ross worm	20621	*Agonus cataphractus*	Pogge	68.7
Pandalus montagui	Pink shrimp	18287	*Pandalus montagui*	Pink shrimp	58.7
Psammechinus miliaris	Sea urchin	13429	*Ammodytes*	Sandeel	54.7
Asterias rubens	Common starfish	8904	*Echiichthys vipera*	Lesser weever	54.7
Pagurus bernhardus	Common hermit crab	3954	*Sertularia argentea*	Sea fir	53.2
Mytilus edulis	Common mussel	2928	*Alcyonidium diaphanum*	Sechervil	52.2
Necora puber	Velvet swimming crab	2195	*Sepiola atlantica*	Little cuttlefish	51.7
Liocarcinus holsatus	Swimming crab	2180	*Ophiura albida*	Brittlestar	49.3
Schistomysis kervillei	Shrimp	1921	*Solea solea*	Sole	46.8
Crangon crangon	Brown shrimp	1385	*Flustra foliacea*	Greater hornwrack	45.3
Mysidacea	Opposum shrimp	980	Tubulariidae	Hydroid	44.3
Polinices pulchellus	Gastropod	914	*Hydrallmania falcata*	Sickle hydroid	40.3
Agonus cataphractus	Pogge	882	*Merlangius merlangus*	Whiting	39.3
Liocarcinus depurator	Blue-leg swimming crab	732	*Crangon crangon*	Brown shrimp	38.3
ACTINARIA	Sea anemone	711	*Macropodia*	Crab	37.8
Echiichthys vipera	Lesser weever	598	*Spisula elliptica*	Elliptical trough-shell	37.3
Sepiola atlantica	Little cuttlefish	561	*Limanda limanda*	Common dab	36.8
Gobiidae	Goby	546	*Pomatoschistus*	Goby	33.8
Spisula elliptica	Elliptical tough-shell	526	*Necora puber*	Velvet swimming crab	31.3
Ophiocten affinis	Brittlestar	469	*Psammechinus miliaris*	Sea urchin	30.3
Gastrosaccus spinifer	Shrimp	446	ACTINARIA	Sea anemone	28.4
Pilumnus hirtellus	Crab	423	*Liocarcinus depurator*	Blue-leg swimming crab	25.4
Macropodia	Crab	405	*Philocheras trispinosus*	Shrimp	24.4
Ammodytes	Sandeel	377	*Polinices pulchellus*	Gastropod	24.4
Merlangius merlangus	Whiting	371	*Callionymus lyra*	Common dragonet	23.9
Hinia reticulata	Netted dog whelk	364	*Ophiura ophiura*	Serpent star	23.9

Species occurring in greater than 68% of trawls included: the shrimp *C. allmanni* (82.6%), the crabs *Pagurus bernhardus* (81.1%) and *Liocarcinus holsatus* (71.1%), the starfish *Asterias rubens* (72.6%) and the fish *Agonus cataphractus* (68.7%). Trawl abundances and occurrence frequencies for larger fish and shellfish are given (Table 3.14). Results indicate that two species, the brown shrimp *C. allmanni* and the pink shrimp *Pandalus montagui* were the most abundant within the fish and shellfish caught within the Anglian MAREA (39 and 27% of individuals respectively) - Table 3.14. In addition to *A.cataphractus*, the most commonly occurring fish species were *Echiichthys vipera*, *Ammodytes* and *Solea solea*, occurring in greater than 46% of samples.

In common with the grab samples, beam trawls contained a variety of colonial sessile organisms, in particular the hydroids *Sertularia argentea* , *Hydrallmania falcata* and those within the family Tubulariidae (occurring in 53.2, 40.3 and 44.3% of samples respectively), and the bryozoans *Alcyonidium diaphanum* and *Flustra foliacea* (52.2 and 45.3% of samples respectively).

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a) Deck photo illustrating some of the key species found within Trawl 10 including: *Merlangius merlangus* (whiting); *Ammodytes* (sand eel); *Solea solea* (dover sole); *Limanda limanda* (dab); *Pagurus bernhardus* (hermit crab); *Asterias rubens* (starfish); and *Ophiura albida* (brittlestar).

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b) Deck photo illustrating some of the key species found within Trawl 5 including: *Asterias rubens* (starfish); *Liocarcinus depurator* (harbour crab); *Psammechinus miliaris* (sea urchin); *Merlangius merlangus* (whiting); *Agonus cataphractus* (pogge); *Limanda limanda* (dab); and *Solea solea* (dover sole).

Plate 3.4 a-b Typical trawl samples from the current MAREA survey.

Table 3.14 Top 30 most abundant shellfish and fish from the 2m beam trawl, showing their frequency of occurrence within the data set.

Taxa	Common name	Total abundance	% Frequency of occurrence
Crangon allmanni	Shrimp	26679	82.6
Pandalus montagui	Pink shrimp	18287	58.7
Pagurus bernhardus	Common hermit crab	3954	81.1
Mytilus edulis	Common mussel	2928	4.0
Necora puber	Velvet swimming crab	2195	31.3
Liocarcinus holsatus	Swimming crab	2180	71.1
Schistomysis kervillei	Shrimp	1921	4.0
Crangon crangon	Brown shrimp	1385	38.3
MSIDACEA	Opposum shrimp	980	2.5
Agonus cataphractus	Pogge	882	68.7
Liocarcinus depurator	Harbour crab	732	25.4
Echiichthys vipera	Lesser weever	598	54.7
Sepiola atlantica	Little cuttlefish	561	51.7
Gobiidae	Goby	546	15.9
Gastrosaccus spinifer	Shrimp	446	6.5
Pilumnus hirtellus	Crab	423	22.9
Macropodia	Crab	405	37.8
Ammodytes	Sandeel	377	54.7
Merlangius merlangus	Whiting	371	39.3
Anapagurus	Hermit crab	361	16.9
Solea solea	Sole	307	46.8
Buccinum undatum	Edible whelk	281	20.4
Limanda limanda	Common dab	281	36.8
Pomatoschistus	Goby	262	33.8
Pholis gunnellus	Butterfish	260	7.5
Philocheras trispinosus	Shrimp	218	24.4
Liparis	Snailfish	183	18.4
Cancer pagurus	Edible crab	179	18.4
Mytilidae	Bivalves	147	1.0
Pectinidae	Scallops	139	1.0

Summary information for diversity indices (Shannon-Weiner diversity, Margaelf's richness, Pielou's eveness and Simpson's dominance), total species and individual numbers for the integrated dataset trawl sites are given (Appendix AA). To assess these variables for differences between the impact zones, average values within the Primary Impact Zone (PIZ), Secondary /Cumulative Impact Zone (S/CIZ) and Reference Zone (RefZ) were plotted (Figures 3.26 a-c).

The RefZ contained the highest average species number (18) and individuals (1846), with over twice the number of individuals than the PIZ (Figure 3.26 a&b); no clear between zone differences for diversity indices were noted (Figure 3.26 c).

To further consider if licence area aggregate extraction may be affecting trawl faunal communities, investigation into the relationship between impact zone and trawl macrofaunal data was conducted utilising the statistical package Primer (see page 94).

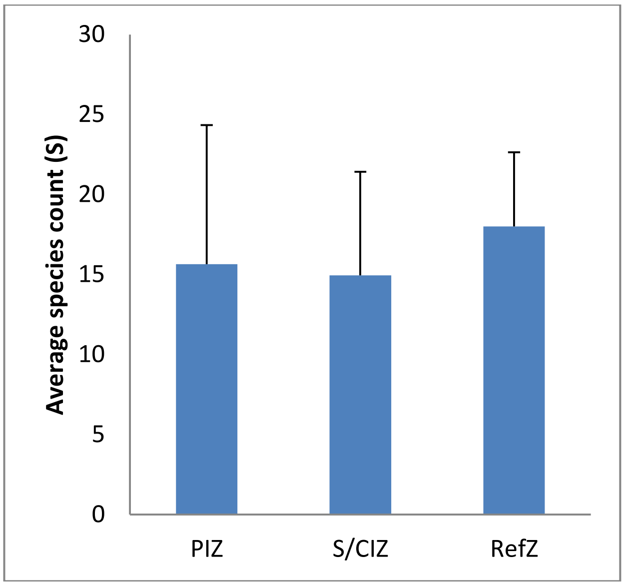


Figure 3.26a. Average Number of Trawl Species in each Impact Zone (+ 1 sd).

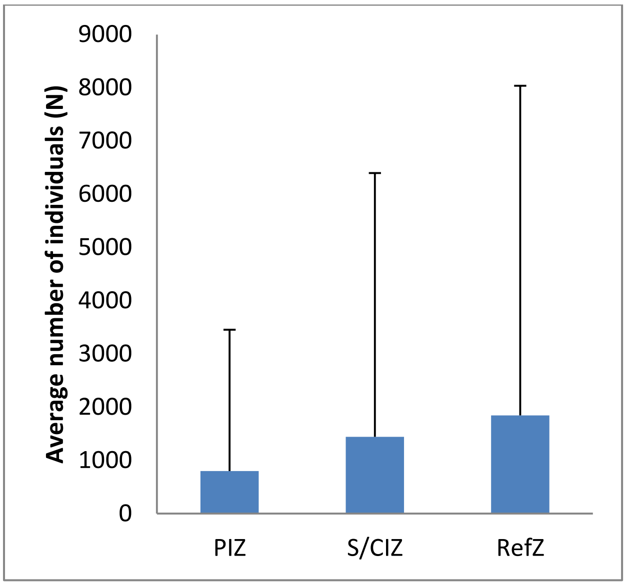


Figure 3.26b. Average Number of Trawl Individuals in each Impact Zone (+ 1 sd).

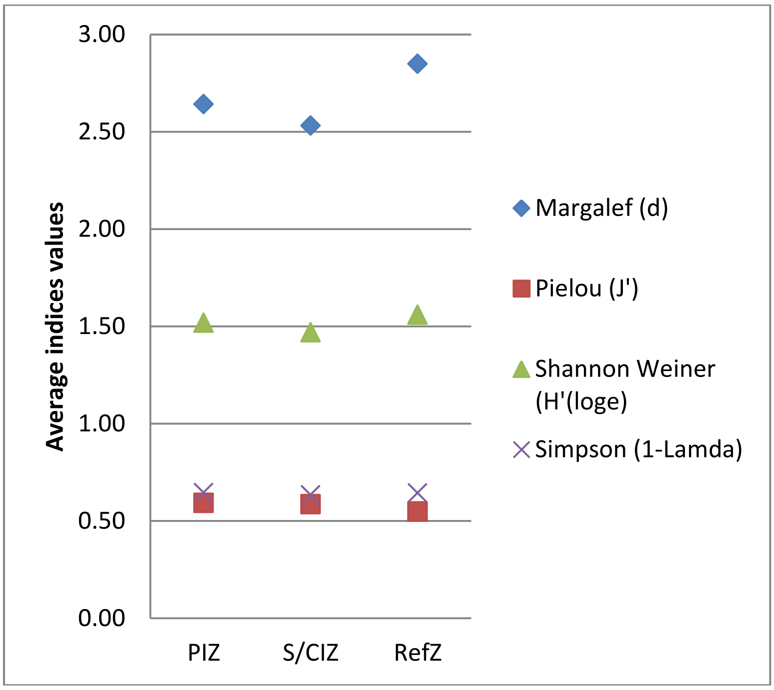


Figure 3.26c. Diversity Indices Averages for each Impact Zone (trawl data).

Multivariate assessment of trawl faunal data

The results of cluster analysis of beam trawl data (based on Bray-Curtis similarity of square root transformed data) and MDS ordination of trawl data are shown in Appendix AB and Figure 3.27 respectively. Fourteen sample clusters including five single-site outliers were defined from this analysis, based on a 27% similarity level cut-off. Distributions for these trawl groupings are presented in Figure 3.28 and the group assigned to each site is listed within the trawl sample spreadsheet in Appendix T.

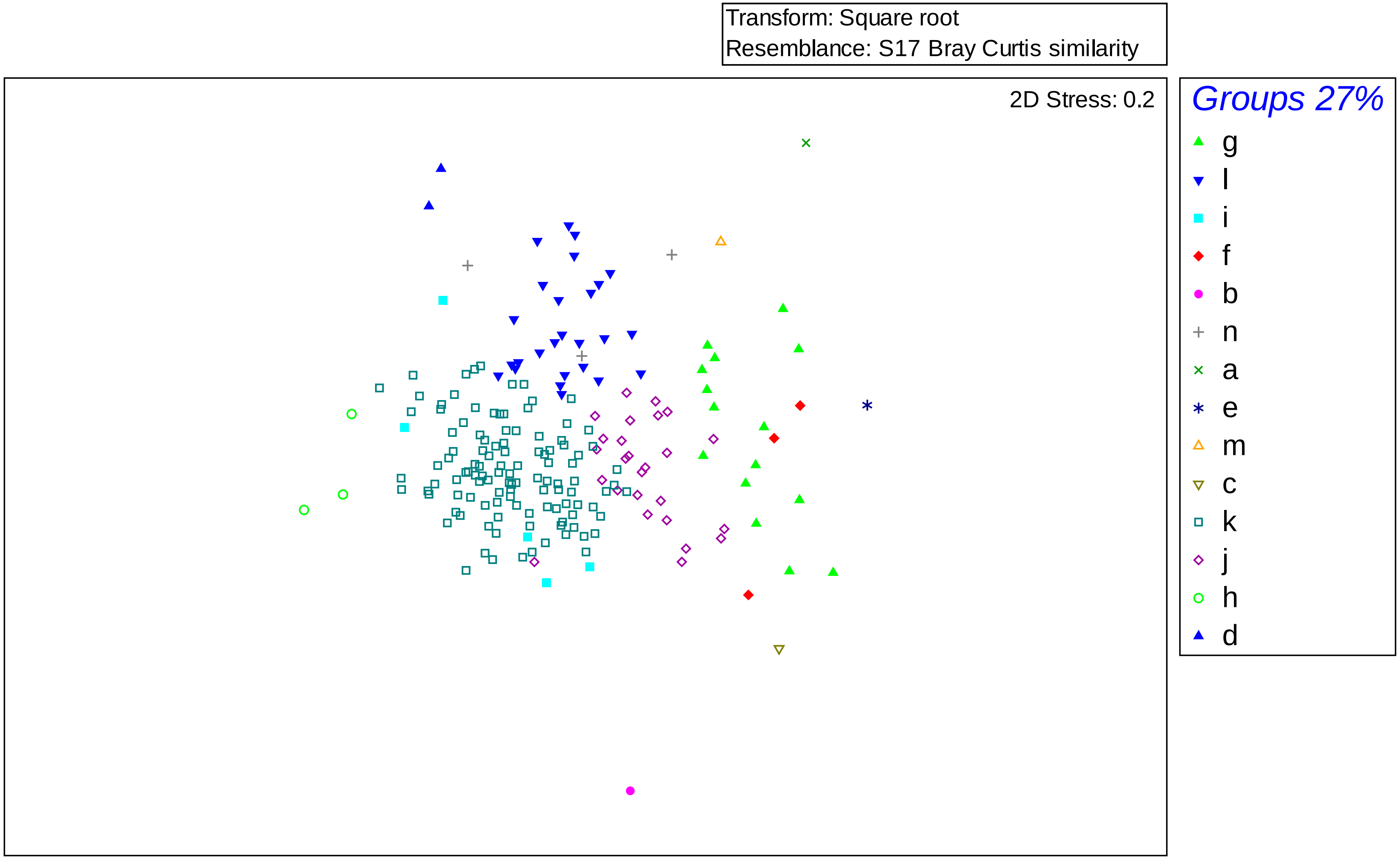


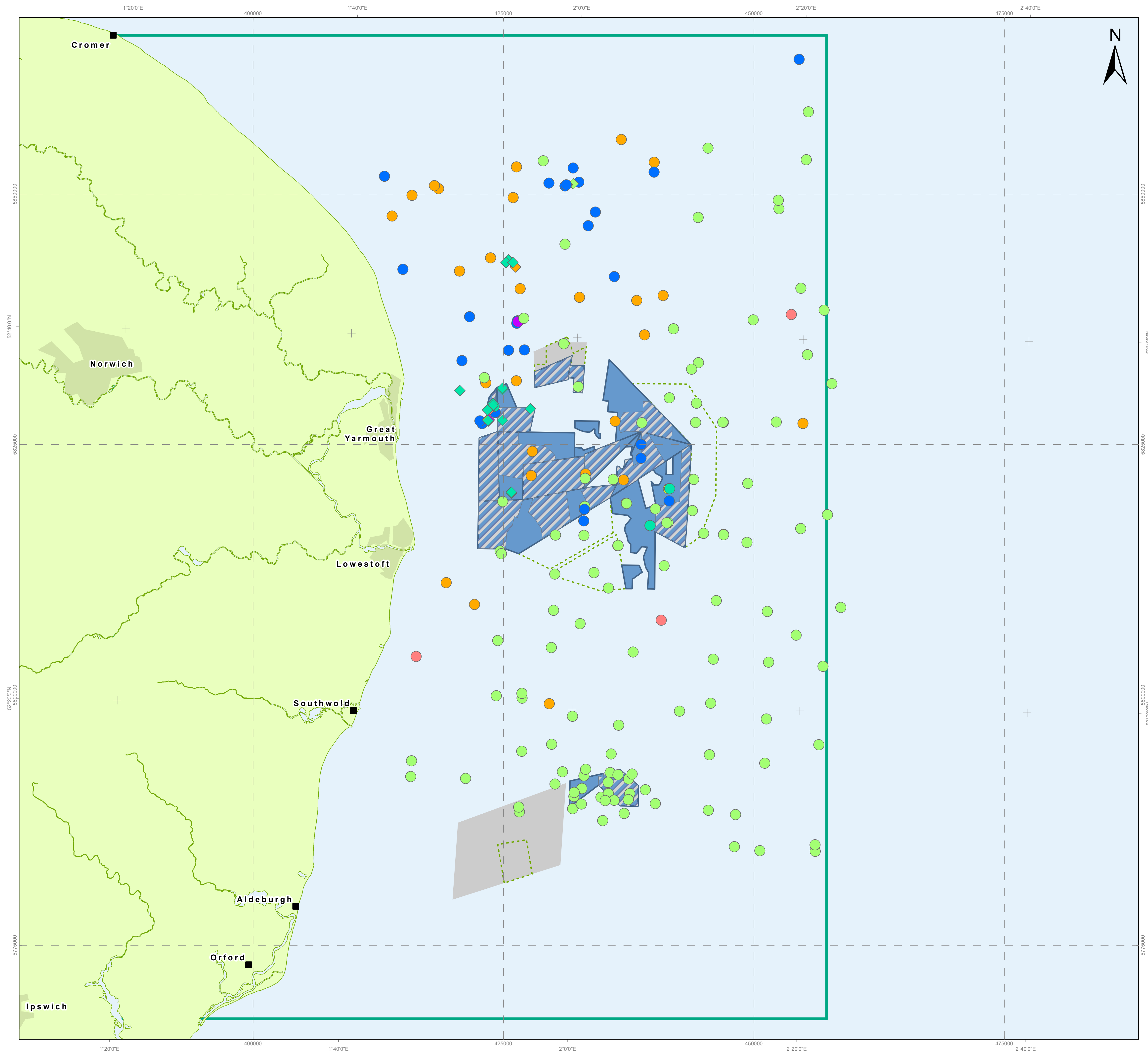
Figure 3.27 MDS ordination of the trawl faunal data for the Anglian MAREA region.

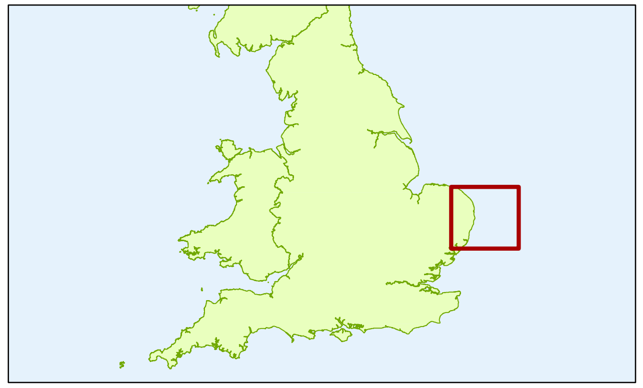
Following SIMPER analysis a characteristic fauna summary for the main trawl groups is presented in Table 3.15 and Appendix AC for the single-site outliers. The largest was Group k, incorporating 113 of the 203 trawl samples collected. This group was found throughout the MAREA study area, with the exception of the north western portion, associated with a range of gravelly sand/sandy gravel sediments. Characteristic epibenthos of this large grouping included *Crangon allmanni*, *Pagurus bernhardus* and *Ophiura albida*. The separation of this group from others was predominantly due to the higher abundance of *C.allmanni*.

Containing 26 samples each, Groups j and l were the second largest, together accounting for 13% of trawl records. Both were primarily found to the north of the survey area, excluding a few scattered sites within the central portion and towards the south. Commonly occurring epibenthic species within Group j included *P. bernhardus*, *C. crangon* and *Echiichthys vipera* found on varying proportions of gravelly sand. Within Group l, *P. montagui* and *A. rubens* were the key contributors, largely associated with sandy gravels and gravelly sands. Group g, clustered within the north western section of the MAREA region, comprised 15 samples characterised by *C. crangon* and *P. montagui*, found on gravelly sands/sandy gravels.

The remaining 10 groupings contained 5 or less samples, however, Groups n, d and m are worthy of note due to the relatively high abundances of species of interest within them. Group n comprised 3 sites situated within the central portion of the study area, corresponding with Licence Areas 202 and 401/2, with an average abundance of 6302 *S. spinulosa*. In its reef form this species is a BAP and OSPAR habitat and is also an Annex I Biogenic Reef habitat under the Habitats Directive (see Section 4.1). In the absence of video footage for these trawls the presence of *Sabellaria* reef cannot be confirmed, however, reef has previously been found within these licence areas (MESL, 2007b; Emu Ltd., 2008b).

The two sites encompassed within Group d, were located in the north of the MAREA area and contained an average of 16240 *O. fragilis*. Although not identified as a species of conservation importance nor with any corresponding legislative protection, dense *O. fragilis* aggregations equivalent to those found within Group d contain a wide range of epifauna and are considered key in coastal ecosystems (see Section 4.2). To the north of Licence Area 494, one sample with an average of 117 *Mytilus edulis* was found (Group m). This site is unlikely to comprise a mussel bed, protected as biogenic reef under the Habitats Directive, as these rarely form in water deeper than 10m (Holt *et al*., 1998). The site was actually recorded at 24m depth and no evidence of bed development was noted in the video footage for this location. Also, blue mussel beds were not identified during the EC REC survey, but only areas of large aggregation of this species (Limpenny *et al*., 2011). However, blue mussels are still important within the community (see Section 4.2) and it should be noted that Limpenny *et al.* (2011) suggest further investigation in order to assess the observed aggregations of blue mussels for possible inclusion in the Natura 2000 network.





Legend

Infaunal Group

- a
- b
- c
- d
- e
- f
- g
- h
- i
- j
- k
- l
- m
- n

MARAE Study Boundary

Aggregate Areas

- Active Dredge Zone
- Licence Area
- Application Area
- Prospecting Area

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010; MFA 2009
Emu Limited, 2002-2010

0 5 10 20
Kilometres

Coordinate System:
WGS84 UTM Zone 31 North

Scale:	*Sheet Size:*
1:375,000	A3

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Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

Faunal Groups Distribution, Trawl Data Primer Analyses, Anglian MAREA Region

Figure No. 3.28

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Table 3.15 Simper analysis summary for 2m beam trawl sample groups (square root transformed data).

Group d (n=2)		Average similarity: 70.07		Group f (n=3)		Average similarity: 32.06		Group g (n=15)		Average similarity: 35.15	
Species / higher taxa	Mean abund.	% Contrib.	% Cumul.	Species / higher taxa	Mean abund.	% Contrib.	% Cumul.	Species / higher taxa	Mean abund.	% Contrib.	% Cumul.
Ophiothrix fragilis	125.03	85.04	85.04	*Liocarcinus holsatus*	1.14	43.87	43.87	*Crangon crangon*	3.27	34.16	34.16
Asterias rubens	5.05	3.69	88.73	*Crangon allmanni*	0.94	22.21	66.08	*Pandalus montagui*	4.13	29.82	63.98
Modiolus modiolus	6.12	3.59	92.33	*Pandalus montagui*	1.05	19.64	85.72	Ammodytes	0.95	9.42	73.40
				Gobiidae	0.67	14.28	100.00	*Philocheras trispinosus*	1.22	8.29	81.69
								Crangon allmanni	1.49	6.62	88.31
								Liocarcinus holsatus	0.50	2.78	91.10

Group h (n=3)		Average similarity: 59.67		Group i (n=5)		Average similarity: 45.56		Group j (n=26)		Average similarity: 40.85	
Species / higher taxa	Mean abund.	% Contrib.	% Cumul.	Species / higher taxa	Mean abund.	% Contrib.	% Cumul.	Species / higher taxa	Mean abund.	% Contrib.	% Cumul.
Ophiura albida	152.26	60.25	60.25	*Crangon allmanni*	13.86	23.93	23.93	*Pagurus bernhardus*	4.01	23.83	23.83
Ophiura ophiura	74.79	23.69	83.94	*Schistomysis kervillei*	14.75	10.95	34.87	*Crangon crangon*	2.77	13.83	37.66
Crangon allmanni	22.03	6.97	90.91	Mysidacea	10.84	8.32	43.19	*Echiichthys vipera*	1.84	12.91	50.57
				Scyphozoa	5.37	7.89	51.08	*Pandalus montagui*	2.17	8.37	58.93
				Gastrosaccus spinifer	7.37	7.58	58.65	*Sepiola atlantica*	1.61	8.25	67.18
				Liocarcinus holsatus	5.21	7.38	66.03	*Asterias rubens*	1.32	8.18	75.37
				Gobiidae	6.96	6.63	72.66	Ammodytes	1.12	5.18	80.55
				Philocheras trispinosus	3.83	5.23	77.89	*Crangon allmanni*	1.29	4.30	84.84
				Pandalus montagui	3.44	2.28	80.18	*Agonus cataphractus*	0.67	2.46	87.30
				Nymphon brevirostre	1.69	2.27	82.44	*Philocheras trispinosus*	0.66	1.96	89.27
				Crangon crangon	2.31	2.04	84.48	*Spisula elliptica*	0.83	1.79	91.05
				Agonus cataphractus	2.20	1.86	86.34				
				Actiniaria	1.84	1.86	88.20				
				Merlangius merlangus	2.16	1.51	89.71				
				Pagurus bernhardus	1.81	1.45	91.16				

Group k (n=113)		Average similarity: 38.99		Group l (n=26)		Average similarity: 44.64		Group n (n=3)		Average similarity: 39.42	
Species / higher taxa	Mean abund.	% Contrib.	% Cumul.	Species / higher taxa	Mean abund.	% Contrib.	% Cumul.	Species / higher taxa	Mean abund.	% Contrib.	% Cumul.
Crangon allmanni	11.71	32.28	32.28	*Pandalus montagui*	17.03	25.77	25.77	*Sabellaria spinulosa*	63.97	48.69	48.69
Pagurus bernhardus	4.18	10.78	43.06	*Asterias rubens*	10.76	23.21	48.98	*Pandalus montagui*	11.58	14.85	63.54
Ophiura albida	8.82	10.07	53.13	*Necora puber*	5.22	8.58	57.56	*Crangon allmanni*	4.30	6.02	69.57
Liocarcinus holsatus	3.08	8.38	61.51	*Pagurus bernhardus*	3.35	7.68	65.23	Actiniaria	3.65	3.94	73.50
Asterias rubens	3.86	7.22	68.74	*Crangon allmanni*	3.35	5.10	70.34	*Macropodia rostrata*	2.52	3.53	77.03
Agonus cataphractus	1.98	5.20	73.94	Actiniaria	2.92	3.75	74.09	*Necora puber*	3.53	3.53	80.57
Echiichthys vipera	1.43	3.87	77.80	*Cancer pagurus*	1.95	3.33	77.41	*Liocarcinus holsatus*	2.10	2.71	83.27
Ammodytes	1.09	2.82	80.62	*Pilumnus hirtellus*	2.51	3.27	80.68	*Pandalina brevirostris*	2.04	1.91	85.19
Spisula elliptica	1.25	2.01	82.63	*Agonus cataphractus*	1.46	2.48	83.16	*Philocheras trispinosus*	1.14	1.91	87.10
Psammechinus miliaris	3.85	1.97	84.60	*Crangon crangon*	1.81	2.14	85.31	*Asterias rubens*	5.29	1.71	88.82
Sepiola atlantica	1.04	1.76	86.35	*Sepiola atlantica*	1.22	2.02	87.33	*Pisidia longicornis*	3.00	1.43	90.24
Merlangius merlangus	1.00	1.72	88.07								
Solea solea	0.92	1.56	89.63								
Macropodia	0.99	1.17	90.80								

Geographical trends

An MDS ordination of the macrofaunal data symbolised according to survey dataset (Figure 3.29) revealed that Areas 254 and 202 separated out from the other surveys. This may indicate a potential geographical trend as both areas are located within the north west of the MAREA region. These licence areas correspond with the main concentration of Group g, identified through cluster analyses of the trawl faunal data. The key characterising species identified through SIMPER analyses were the brown shrimp *C. crangon* and pink shrimp *P. montagui*. In addition, the brown shrimp *C. allmanni,* was present in low numbers in these areas, or absent in some years and was consistently a main contributor to the dissimilarity between these and other survey areas. A subsequent SIMPER analysis indicated that variation in the key shrimp species was the principal difference between Areas 202 and 254 and other survey areas.

Utilising an MDS ordination of trawl faunal data, with sites symbolised according to the suggested impact zone, further trend investigations indicated no clear differences between zone community composition (Figure 3.30); the ANOSIM result, R=0.016, p=13.7%, reflects this.

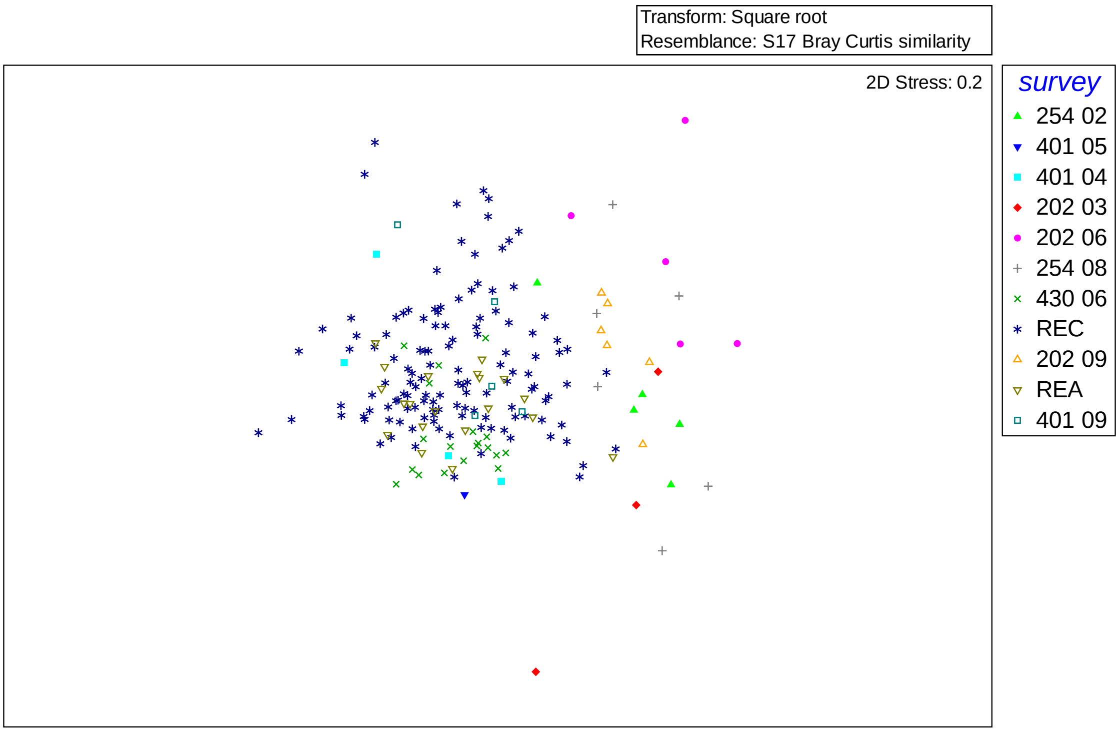


Figure 3.29. MDS trawl faunal data ordination, samples classified according to survey.

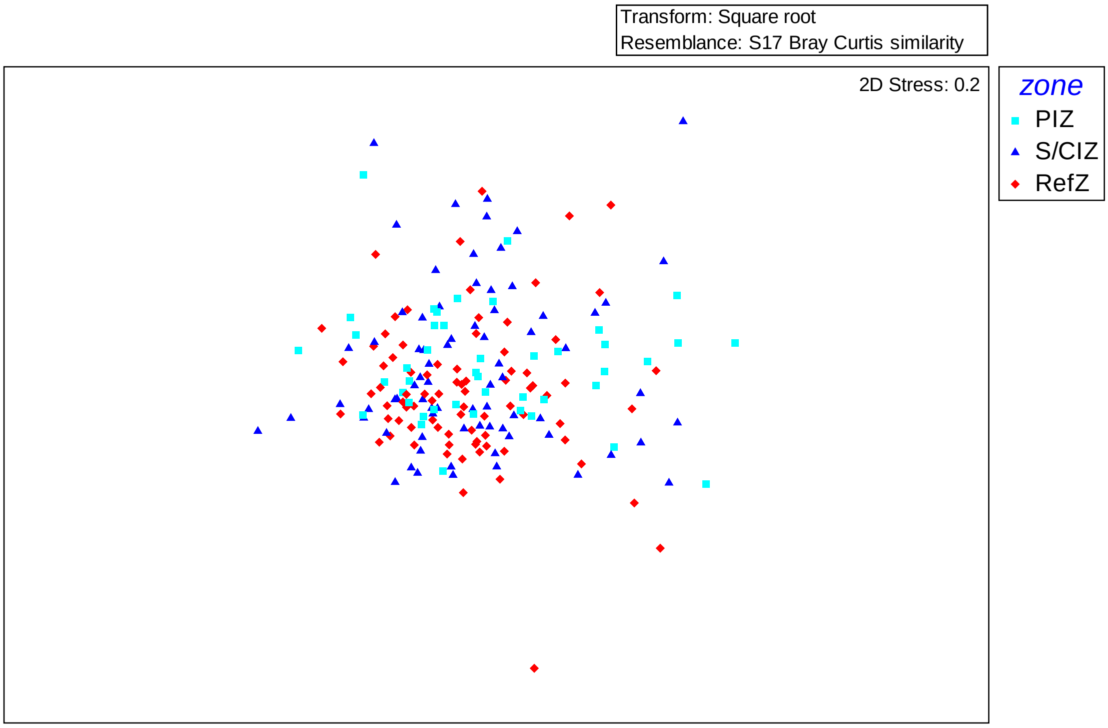


Figure 3.30. MDS trawl faunal data ordination, samples classified according to impact zone.

Temporal trends

Symbolised according to year, an MDS ordination of all trawl faunal data (Figure 3.31) showed that the 2002, 2008, 2003 and many of the 2006 and 2009 data points separate out. A subsequent ANOSIM based on comparison of years indicated a difference was evident somewhere in the community composition datasets (R=0.238, p=0.1%). On the pairwise comparison it was evident that the years separating out correspond with the Area 202 and 254 surveys and it is possible their separation was a result of the shrimp species trend discussed above. Whether the separation is due to geographical or ecological interaction factors cannot be clearly established through this work. This would require a targeted study to establish biotic and abiotic factors influencing shrimp species abundances in these licence areas.

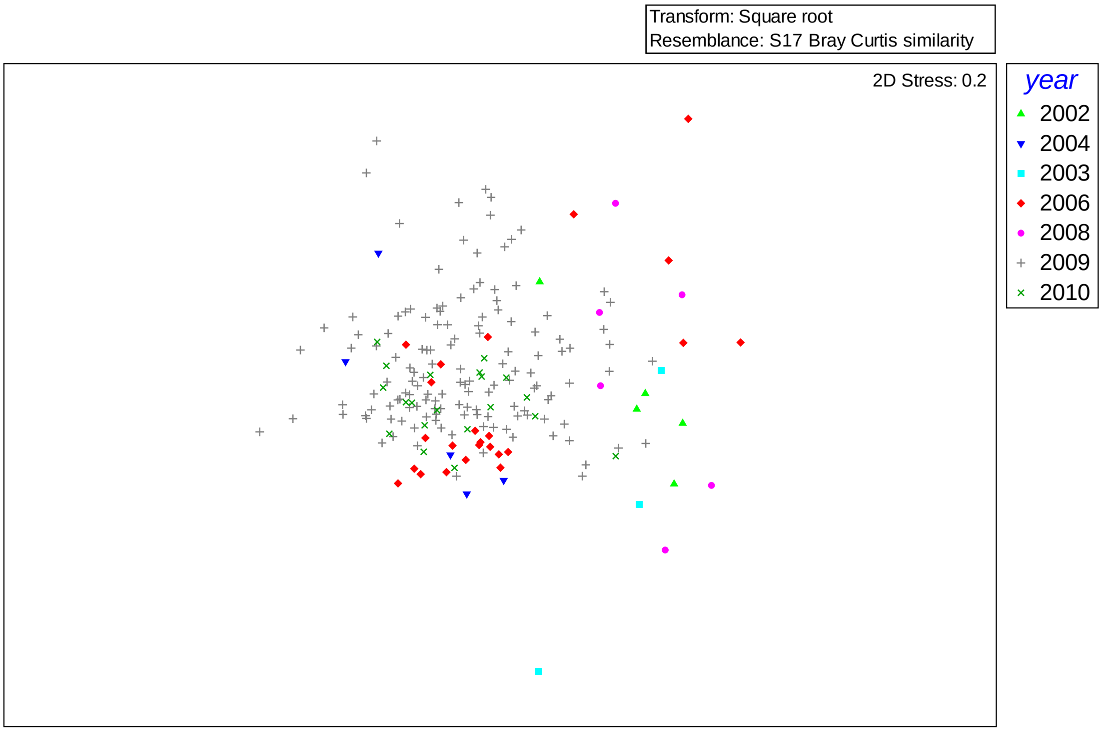


Figure 3.31. MDS trawl faunal data ordination, samples classified according to year.

To remove the geographical element from survey results and to identify potential temporal trends, repeat year datasets were examined separately. Those surveys with repeat year's data included: Area 401/2 (2004, 2009); Area 436/202 (2003, 2006) and Area 254 (2002, 2008).

ANOSIM results indicated no significant temporal macrofaunal community differences within Areas 254 (R=0.085, p=22.9%). However, differences were identified for Areas 401/2 and 436/202 (Respectively: R=0.576, p=0.8%; R=0.426, p=3.6%). SIMPER analyses on the latter two repeat year datasets revealed the species contributing to the difference. *S. spinulosa* made the greatest contribution in Area 401/2, increasing from an average of 338.40 individuals in 2004 to 3696.20 in 2009. It has been suggested that aggregate extraction activities may encourage *S. spinulosa* aggregations through provision of material needed for tube building (Thomas, pers.com). A reduction in the average number of *Schistomysis kervillei* and Mysidacea over the same period (Respectively: 383.00 to 1.20; 196.00 to 0) contributed to a further 15% of the difference between years.

For Area 436/202, an increase in average abundance of *P. montagui* contributed most to differences between 2003 and 2006 (0.67 to 60.80). Interestingly, over the same period *S. spinulosa*, on which *P. montagui* are known to predate (Kenny & Rees, 1994), also increased (0 to 85.60). A further 18% of the between year dissimilarity was attributed to an increase in Mytilidae between 2003 and 2006 (0 to 10.40) and a slight reduction in *Crangon allmanni* over the same period (1.67 to 1.60).

4.0 NATURE CONSERVATION

4.1 Species and habitats of conservation importance

Species of conservation interest, identified through benthic grab and trawl surveys in the Anglian MAREA area, are summarised in Table 4.1 and illustrated within Figures 4.1-4.11. In addition, several UK BAP habitats were identified including biogenic Ross worm reef and derivatives of subtidal sands and gravels (see Figure 3.24 for locations of biotopes within the region) and a number of sandbanks are known to be present within the Anglian MAREA region which might match the Annex I definition of 'sandbanks that are slightly covered by seawater all of the time' (Figure 4.12).

Table 4.1 Species and habitats of importance in the Anglian MAREA region.

Species or habitat of importance in the MAREA	National and international conservation designations	Example photographs
	Species	
Ammodytes marinus Lesser sand-eel	UK BAP Species	
Clupea harengus Atlantic herring	UK BAP Species	
Gadus morhua Atlantic cod	UK BAP Species (plus Global Red List status Vulnerable), OSPAR (threatened / declining species)	
Raja clavata Thornback skate/ray	OSPAR (threatened / declining species)	

Species or habitat of importance in the MAREA	National and international conservation designations	Example photographs
Raja montagui Spotted ray	OSPAR (threatened / declining species)	 © Emu Ltd 
Merlangius merlangus Whiting	UK BAP Species	 © Wikimedia commons
Obelia bidentata Double tooth hydroid	Nationally rare (based on Sanderson, W G. JNCC Report, No. 240. Published by JNCC, 1996). Provisional list of rare and scarce marine species. [not red list])	 © Emu Ltd
Pleuronectes platessa European plaice	UK BAP Species	 © Emu Ltd
Solea solea Sole	UK BAP Species	 © Wikimedia commons

Species or habitat of importance in the MAREA	National and international conservation designations	Example photographs
Rissoides desmaresti Mantis shrimp	Nationally scarce	 © Emu Ltd
Sabellaria spinulosa Biogenic ross worm reef ***(SS.SBR.PoR.SspiMx)***	UK BAP Habitat, OSPAR (threatened and/or declining habitat) Potential Annex I Biogenic Reef habitat (Habitats Directive)	 © Emu Ltd
Subtidal sands and gravels Includes biotope complexes: **SS.SCS.ICS** Infralittoral coarse sediment **SS.SCS.CCS** Circalittoral coarse sediment **SS.SSa.IFiSa** Infralittoral fine sand **SS.SSa.CMuSa** Circalittoral muddy sand	UK BAP priority habitats	 © Emu Ltd
Sandbanks that are slightly covered by seawater all of the time Includes biotope complex: **SS.SSa.IFiSa** Infralittoral fine sand	Potential Annex I habitat (Habitats Directive)	See Figure 4.12

Lesser sand eel *Ammodytes marinus*

The lesser sand eel (*Ammodytes marinus*) is a priority UK BAP species. Typically growing up to a length of 20-25cm, *A. marinus* have a close association with sandy substrates into which they burrow. This species has been recorded from mid-tide level to the shallow sublittoral to depths of 30m, and during winter bury in sediment at depths of 20-50cm.

A. marinus are subject to targeted fishing and may also be affected by climate change aspects which may have highlighted their role as a key species in North Sea ecosystems (Edwards and Richardson, 2004). Their decline and /or abundance changes have been suggested to be linked to seabird breeding failure in the region (Furness and Tasker, 2000). Recorded in the central and southern portions of the Anglian MAREA region, *A. marinus* catches were concentrated within Area 430 (Figure 4.1) and associated with the circalittoral coarse sediment biotope complex **SS.SCS.CCS**. This species was found in low abundances within the survey area; a single specimen was found at each of the 8 sites it was captured.

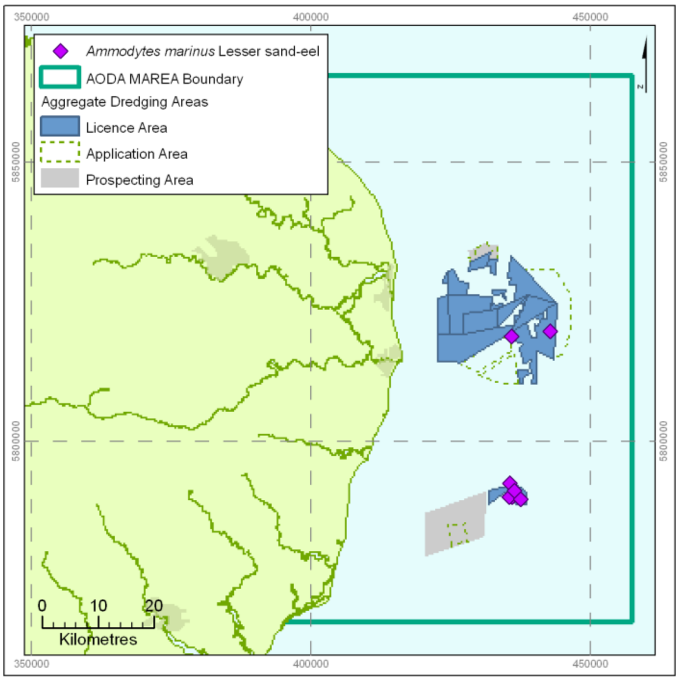


Figure 4.1 Location of *Ammodytes marinus*, Anglian MAREA region

Atlantic herring *Clupea harengus*

Atlantic herring (*Clupea harengus*) is designated as a UK BAP priority species. Reaching up to 40cm in length and 0.68 kg in weight, this pelagic species ranges from surface waters to 200m. When spawning has occurred, either inshore or offshore, millions of eggs sink to the bottom where they stick to gravel, shells and stones; outside of the spawning season Staying awaye from immediate coastal areas, *C. harengus* is widespread in UK and Irish waters where they were formerly found in large offshore near-surface shoals covering several square kilometres, although due to overexploitation numbers have significantly declined. Within the Anglian MAREA region two trawls in Area 430 to the south and a further two to the north, each yielded a single specimen (Figure 4.2).

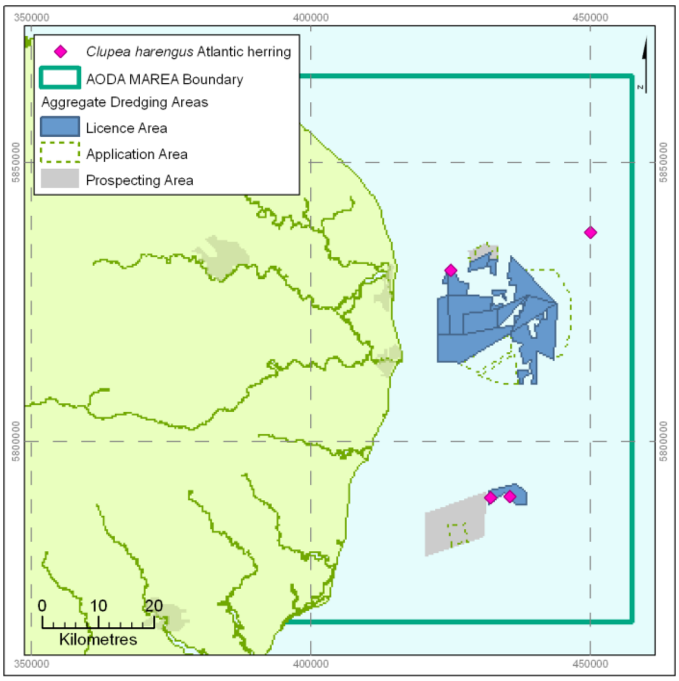


Figure 4.2 Location of *Clupea harengus*, Anglian MAREA region

Atlantic cod *Gadus morhua*

Atlantic cod (*Gadus morhua*) is a UK BAP priority species and has vulnerable status on the Global Red List. In addition, the species has been highlighted on the OSPAR list of threatened / declining species and habitats. They are commonly found on sandy bottoms around the coasts of Britain and Ireland, and have been recorded as far south as the Bay of Biscay and to the north Barents Sea. Cod prefer cold temperate waters and can be found from the shoreline down to depths of 600m, growing to 120 cm in length. Research suggests that they have been adversely affected by climate change with copepod prey species migrating northwards resulting in a predator/prey mismatch for foraging cod. Within the MAREA survey, *G. morhua* catches were concentrated in the south of the region within and around Area 430, with just one additional site to the west of Area 254 containing specimens (Figure 4.3). Recorded at 11 sites, an average abundance of 2.09 individuals were found. The majority of sites contained just 1 specimen, although higher catches at sites A10 T547 and A10 T551 (6 and 7 individuals respectively) were recorded.

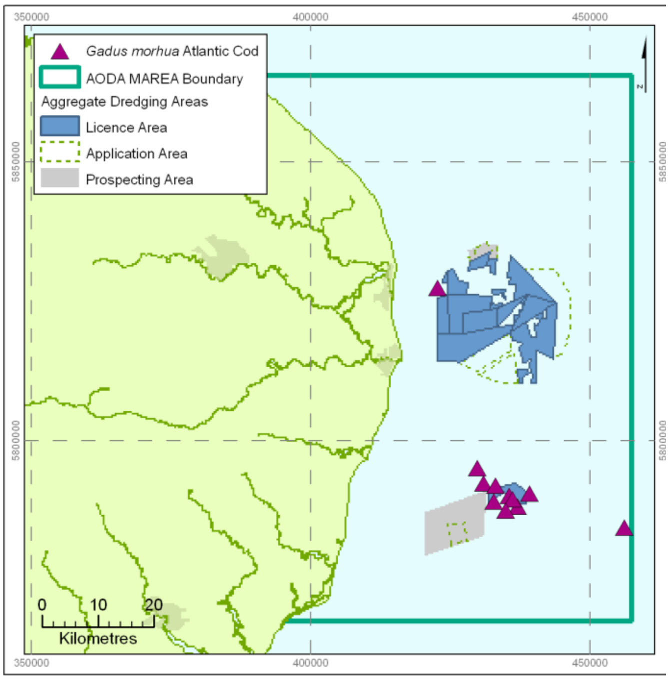


Figure 4.3 Location of *Gadus morhua*, Anglian MAREA region

Thornback skate/ ray *Raja clavata*

The Thornback ray (*Raja clavata*) is on the OSPAR list of threatened and / or declining species and habitats and has exhibited a decrease in numbers related to commercial exploitation (Rogers and Ellis, 2000). Growing up to 1m long, this species is common around the coasts of Britain and Ireland and is the most abundant ray in in-shore waters. Their distribution includes the Wash, Outer Thames Estuary, Solent, Carmarthen Bay, Cardigan Bay, Liverpool Bay and Solway Firth. *R. clavata* is generally found in depths ranging from 10-300m, on a wide variety of grounds including mud, sand, shingle and gravel. This species was found throughout the MAREA survey area, within and near to Areas 496 and 430 in the south and Area 401/2 in the central portion, and in the far north of the region (Figure 4.4). Recorded at 15 sites, uniformly low abundances were found, with 2 specimens caught at 1 site and the remaining sites each yielding 1 individual.

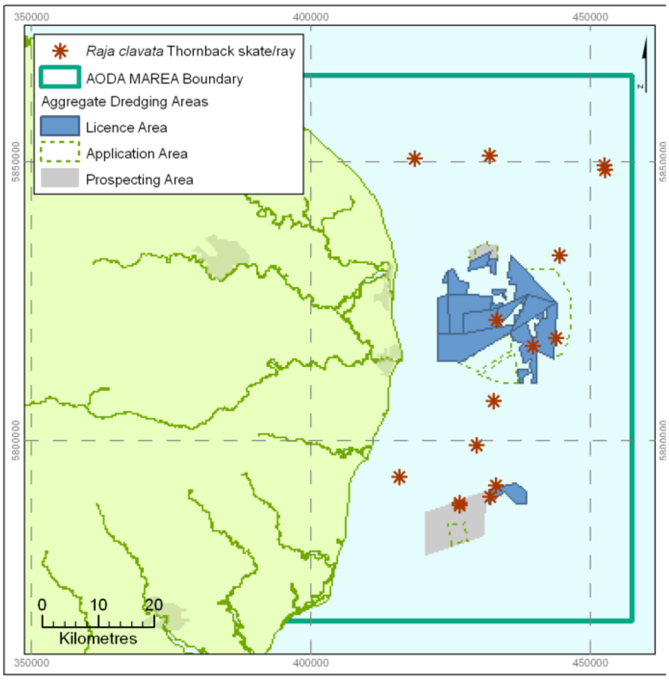


Figure 4.4 Location of *Raja clavata*, Anglian MAREA region

Spotted Ray *Raja montagui*

The spotted ray (*Raja montagui*) is included as a priority species under the OSPAR list of threatened and/or declining species and habitats. Associated with sandy grounds or muddy flats, where they deposit their eggs, this species is widespread around the coasts of Britain and Ireland, although appears to be rarely recorded from the east coast of England (Marinelife, 2010). Typically growing up to a length of 75cm and found in depths ranging from 25-120m, spotted rays mainly feed on crustaceans. This species appears to be locally uncommon in the MAREA study area, recorded at just three sites, two in the south of the region and one within Area 251 (Figure 4.5), each yielding a single specimen.

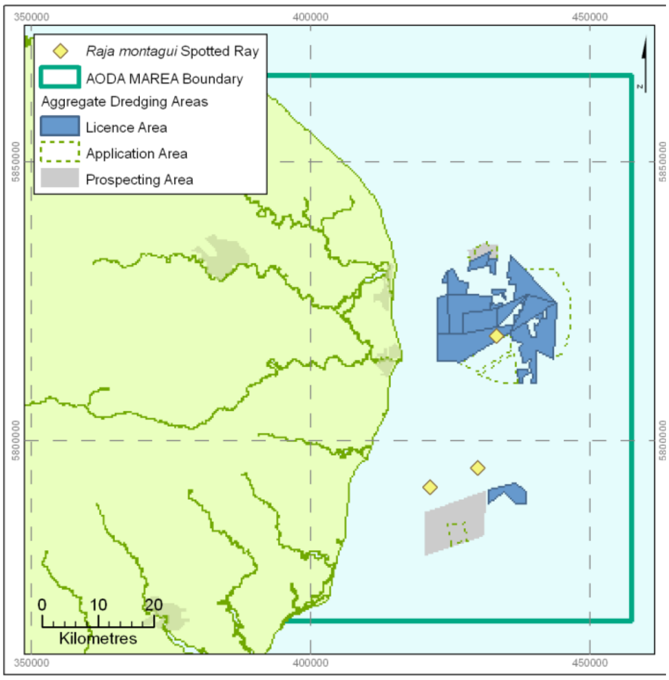


Figure 4.5 Location of *Raja montagui*, Anglian MAREA region

Whiting *Merlangius merlangus*

Whiting (*Merlangius merlangus*) has UK BAP priority species status. Associated with mud and gravel bottoms, but also found above sand and rock, *M. merlangus* are found off western Scotland, south-east England, the English Channel, and in the Irish Sea off the coasts of east England, Wales and Ireland. A benthopelagic species, usually found at depths of 30-100m, whiting can grow up to 70cm in length and feed on shrimps, crabs, molluscs, small fish, polychaetes and cephalopods. Results from the Anglian MAREA survey indicate this species is widely distributed throughout the region (Figure 4.6). Found in 79 trawl samples, the average *M. merlangus* yield was 4.70 with most sites containing fewer than 10 individuals, although scattered larger catches of up to 44 individuals were recorded.

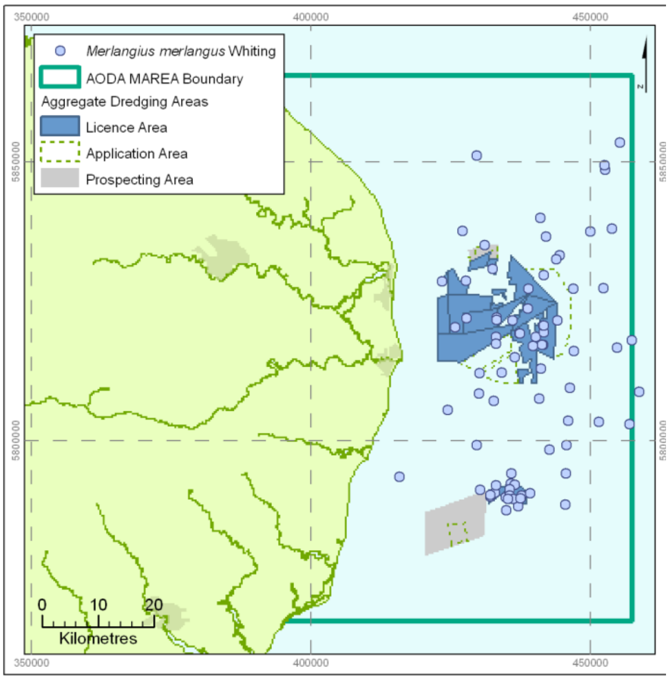


Figure 4.6 Location of *Merlangius merlangus*, Anglian MAREA region

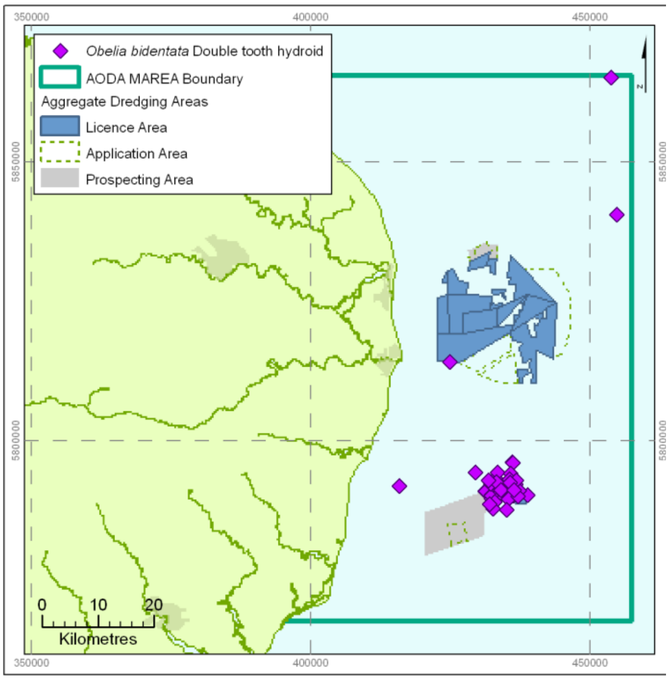


Figure 4.7 Location of *Obelia bidentata*, Anglian MAREA region

Double tooth hydroid *Obelia bidentata*

Regarded as nationally scarce (Sanderson, 1996), the double tooth hydroid (*Obelia bidentata*) is recorded around the British Isles, from the Wash to near Portsmouth (Hayward & Ryland, 1995). *O. bidentata* grows to 15cm tall and is characteristically found on inert substrata such as wood, shells, wrecks, and on sandy bottoms, sometimes algae. This hydroid is tolerant of brackish water, and is sublittoral to at least 200m, rarely in intertidal pools. The species was found at 60 sites, concentrated in and around Area 430 in the south east of the MAREA region. Scattered specimens were also found in the far north of the survey area and outside of Area 251 in the central portion (Figure 4.7). All sites yielded a single specimen.

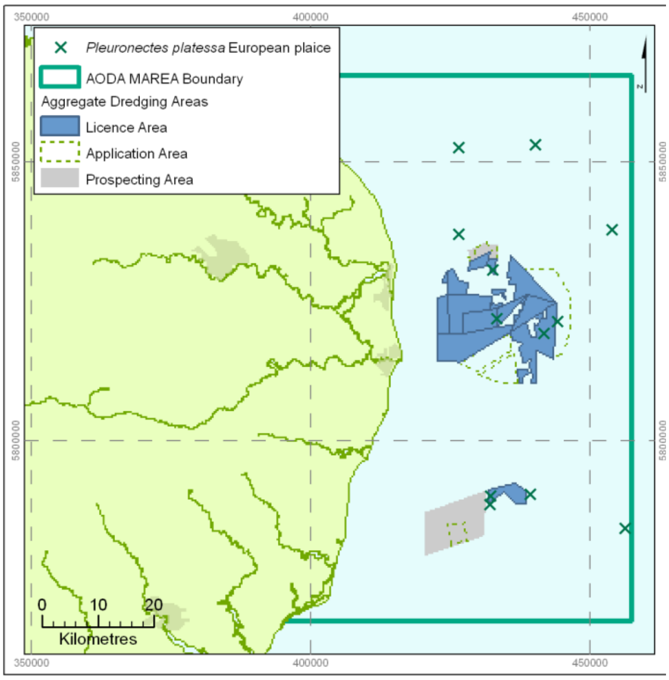


Figure 4.8 Location of *Pleuronectes platessa*, Anglian MAREA region

European plaice *Pleuronectes platessa*

European plaice (*Pleuronectes platessa*) are a UK BAP priority species. Common around the coasts of Britain and Ireland, this species primarily lives on sandy bottoms, although they are also found on gravel and mud, often partly buried, and in shelf waters on sandy patches in rocky areas. Occurring from 0-200m they are most common between 10-50m, feeding on bottom-living animals, particularly shellfish such as cockles and razor shells. *P. platessa* are usually 50-60cm in length, but exceptional specimens can reach 90cm. Recorded in 12 trawls at an average abundance of 1.5, ranging from 1 to 4 individuals, *P. platessa* was found in the north of the MAREA region, within Area 401/2 in the central portion and both within and near to Area 430 in the south (Figure 4.8).

Dover Sole *Solea solea*

Dover sole (*Solea solea*) is a UK BAP priority species. Widespread around the coasts of Britain and Ireland, although rare towards the north of Scotland, this species is primarily found on sandy, muddy and fine substrates in coastal waters, including estuaries. *S. solea* is mainly found between 10-60m and can reach 30-70 cm in length. Anglian MAREA results indicated *S. solea* as widely distributed throughout the region, recorded at 94 sites at an average abundance of 3, ranging from 1 to 22 individuals (Figure 4.9).

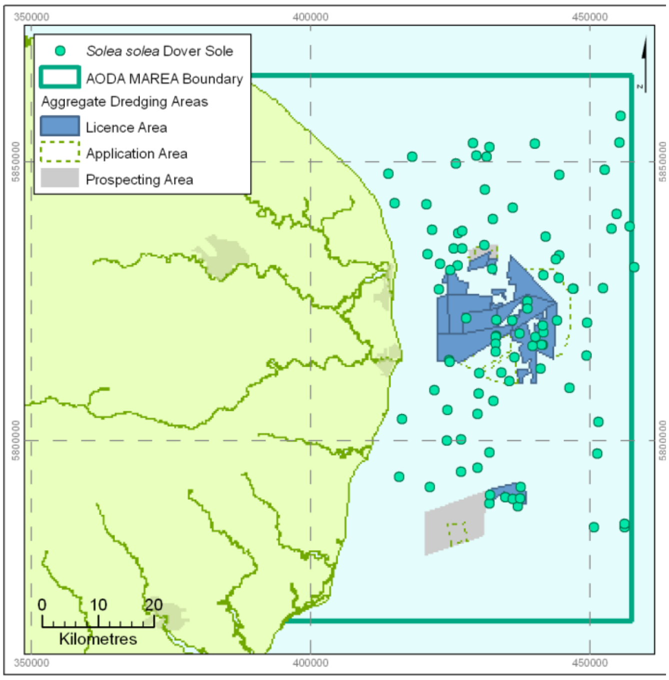


Figure 4.9 Location of *Solea solea*, Anglian MAREA region

Mantis shrimp *Rissoides desmaresti*

The mantis shrimp (*Rissoides desmaresti*) is regarded as nationally scarce (Sanderson, 1996), with low numbers previously recorded on the south and west coasts of the British Isles. An extensive bed of 25 hectares has recently been found in north Wales (Marlin, 2010) and the species has been recorded in the Plymouth area since 1900 including intertidally in Salcombe harbour. *R. desmaresti* grows to ~10cm long, creating simple burrow systems in sandy, gravely mud sediments from the lower shore down to 15-50m deep. This species was recorded within five locations within the Anglian MAREA survey: In the south west by Area 430; in the central portion below Area 401/2, and in the far north-eastern section of the region (Figure 4.10). Recorded average abundance was 4, encompassing 2 sites with 1 individual, and 5, 7 and 8 individuals respectively in the remaining 3. *R. desmaresti* is not commonly recorded, particularly off the east coast, implying the animal may have a greater range offshore than previously realised for this region. There have been suggestions that climate change aspects may be affecting and increasing the range and abundance of this, normally southerly, species (Herbert, 2001), thus records of its distribution may add to climate change knowledge in the region.

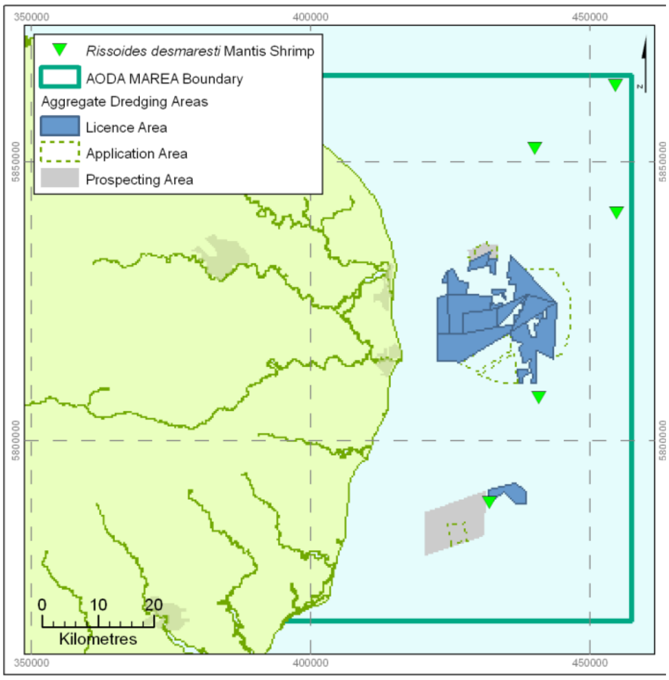


Figure 4.10 Location of *Rissoides desmaresti*, Anglian MAREA region

Ross worm, *Sabellaria spinulosa* reef habitat (SS.SBR.PoR.SspiMx)

The Ross worm *S. spinulosa* constructs sand or shell fragment tubes, which can be cemented onto suitable substrata (Hendrick and Foster-Smith, 2006). It may be solitary, as noted in the Plymouth region, or frequently colonial and may be gregarious in favourable conditions (Hendrick and Foster-Smith, 2006). Tube aggregations are found in loose formations, crusts and low lying biogenic reefs which may extend over several square kilometres (Hendrick and Foster-Smith, 2006). These may be patchy or continuous and may be highly ephemeral being broken up by natural effects such as storms, or mechanical damage such as trawling and dredging (Riesen & Riese, 1982).

S. spinulosa has historically been found throughout the Anglian MAREA region and is known to be common throughout the UK on suitable sandy mixed sediments. Typical *S. spinulosa* observations in the study area include thin, low growing ephemeral crusts (e.g. Emu Ltd., 2008c). However, several surveys have recorded discrete patches of dense S*. spinulosa* tubes with the potential to constitute biogenic reef (e.g. MES, 2007; Emu Ltd., 2000, 2002, 2004, 2005, 2006, 2007, 2008b & c).

It should be made clear that it is the reef formation alone, not the presence of the worms, which is the designated feature under the biogenic 'reef' category in Annex I of the EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora). Reef structures are also listed as a priority BAP habitat (UK Biodiversity Group, 1999) and as a threatened or declining habitat under OSPAR (Table 4.1).

Three *Sabellaria* reef sites were identified within the current survey (see section 3.7). These results were plotted with locations of *Sabellaria* reef identified through previous surveys (e.g. MES, 2007; Emu Ltd., 2000, 2002, 2004, 2005, 2006, 2007, 2008b & c) to provide an overview of the distribution of *Sabellaria* reef within the Anglian MAREA area (Figure 3.25). The combined results indicate three main hotspots of *Sabellaria* reef in the region, within and around the following licence areas: Area 430 to the south; Area 401/2 in the central portion and Areas 202/254 to the north.

Biotoping of infaunal clusters led to the assignment of **SS.SBR.PoR.SspiMx**, *S. spinulosa* on stable circalittoral mixed sediment, for the group characterised by generally high numbers of *S.spinulosa* (see section 3.6). Although reef was either not present, or not known to be present, at the majority of these sites this biotope allocation was still the most appropriate classification for the community composition of this infaunal group. **SS.SBR.PoR.SspiMx** was apparent throughout the region, although primarily outside of the aggregate extraction areas (see Figure 3.24).

With respect to Sabellaria reef, aggregate extraction is not considered to be a significant threat, provided that appropriate monitoring is undertaken to identify reef structures and aggregate extraction is zoned in relation to the proximity of these locations.

Sandbanks slightly covered by seawater all of the time

A number of sandbanks are present within the MAREA study area, which might match the Annex I definition of 'sandbanks that are slightly covered by seawater all of the time'. A natural general eastern movement of the Cross Sands bank and subsequent licence area encroachment has been documented (Emu Ltd., 2007). Thus, the sandbanks include a series of linear sand bank features located north of the study area at Hainsborough Sand, Hammon Knoll and Winterton Ridge together with a series of sand banks inshore of the block of aggregate licences at Cross, Scroby and Holm Sands. Figure 4.11 illustrates sandbank loctions within the Anglian MAREA, as defined by the MESH habitat classification for infralittoral fine or muddy sand.

Subtidal sand banks are usually found in high energy environments and may be characterised by well sorted sediments with a low organic content (Elliott *et al*., 1998). Large mega-ripples can also be produced in areas of strong current flow. Sandbank macrofauna is sparse because of the dynamic physical conditions associated with the mobile substrate. Typical sand fauna identified through grab sampling include: *O.borealis*; *N. cirrosa*; *Bathyporeia* spp., *Magelona mirabilis*; *G. spinifer* and *Spiophanes bombyx*. Larger mobile epibenthic species identified through beam trawling include: *C. crangon*; *C. allmanni*; *E.vipera*; *A.cataphractus* and *A. rubens*.

Biotopes associated with sandbank areas include SS.SSa.IFiSa.IMoSa, very low diversity mobile sands, and SS.SSa.IFiSa.NcirBat, describing impoverished mobile fine sand with typical sand fauna *N. cirrosa* and Bathyporeia sp. Due to the general absence of larger stable sediment particles, colonial sessile epifauna are absent or present in low abundances.

Subtidal sands and gravels

Subtidal sands and gravels and related derivatives recorded in the AODA MAREA region, are noted UK priority BAP habitats. The biotope derivatives recorded across the region at biotope and habitat complex levels are summarised in detail in Table 4.1.

Reported as the "*most common habitats found below the level of the lowest low tide*" (South East Biodiversity Strategy, 2008), UK subtidal sands and gravel sediments associated with the east coast are largely created from rock material rather than shell (West coast) (South East Biodiversity Strategy, 2008). It has been noted that "*the strength of tidal currents and exposure to wave action are important determinants of the topography and stability of sand and gravel habitats*" (South East Biodiversity Strategy, 2008). Research has shown that the AODA MAREA region is subject to strong tidal perturbations (Rees *et al*., 1999; Cooper, 2007) and the "*flora and fauna diversity living within the biotope*[s] *varies according to the level of environmental stress to which they are exposed*" (South East Biodiversity Strategy, 2008).

Tide-swept circalittoral coarse sand, **SS.SCS.CCS**, was ubiquitous within the MAREA region (Figure 3.24), encompassing over 70% of sites. All such designated sites were faunistically poor, indicative of disturbed communities.

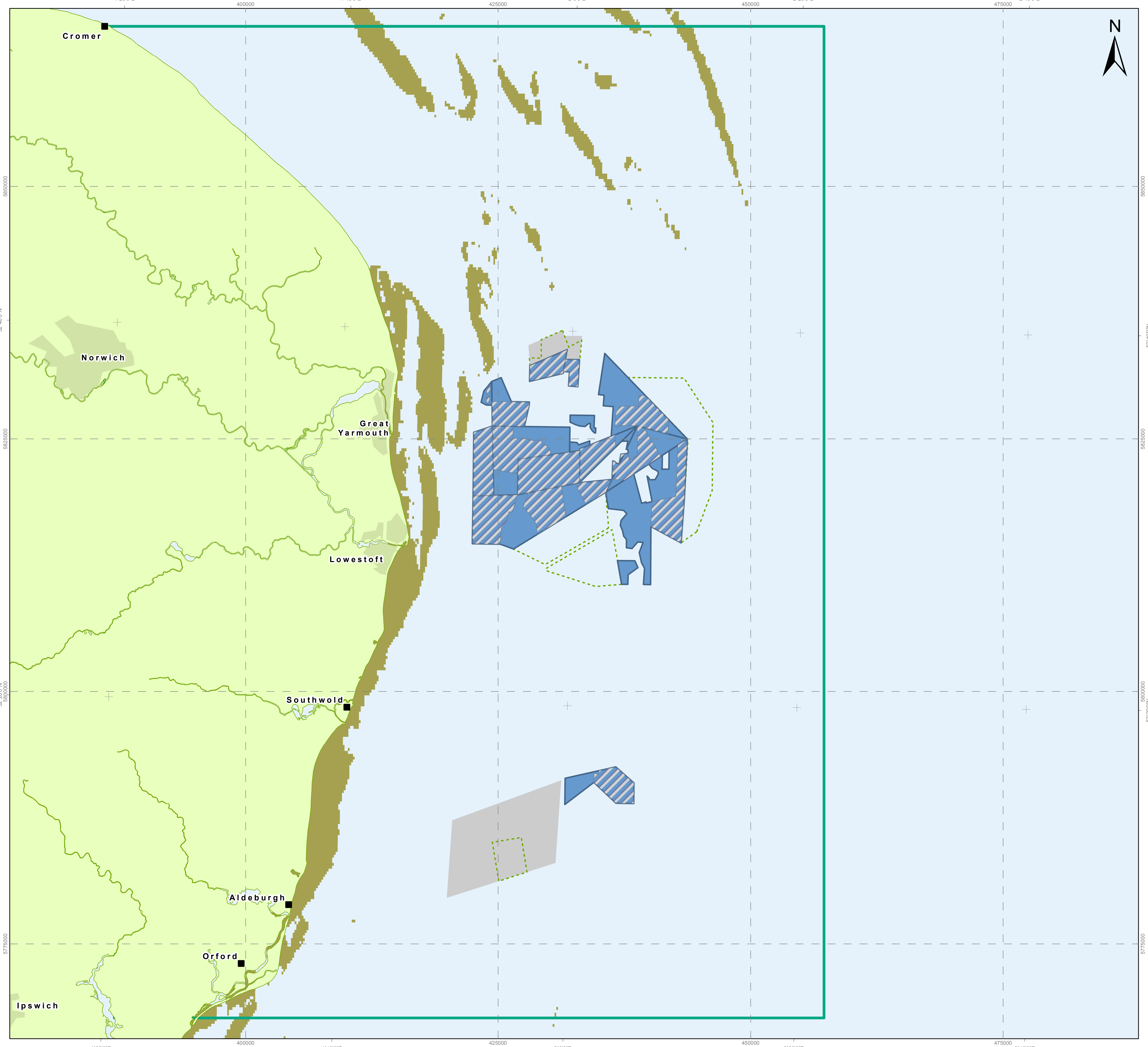
Although the **SS.SCS.CCS** biotope is listed under a UKBAP as are its derivatives, all these habitats are extremely well represented outside the licensed areas and characterise the whole area, and therefore they are not considered to be under any threat from localised dredging activities.

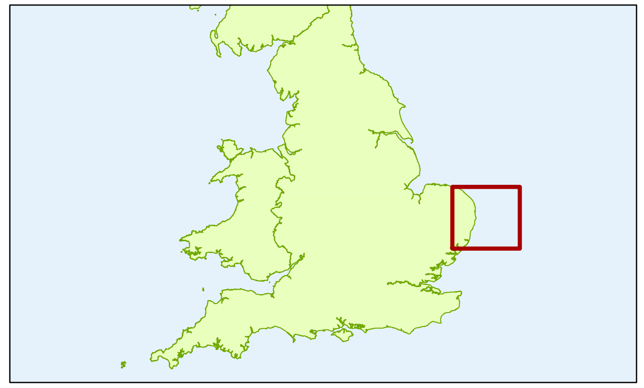
4.2 Other interest features

Despite not being identified as species of conservation importance nor afforded any corresponding legislative protection, the presence of brittlestars *O. fragilis* and blue mussels *M. edulis* within the MAREA survey area is worthy of note.

Although later removed from the list, *O. fragilis* beds were originally included as a candidate Nationally Important Marine Feature. Congregating to feed and breed, their numbers can reach thousands per square metre. For example, in the current survey 2 trawls contained >100,000 *O. fragilis,* and they were found in an additional 2 trawls and 3 grabs in similar, but lower, abundances. These aggregations are known to contain a wide range of epifauna and are considered key in the marine ecosystem (Davoult & Gounin, 1995). They are known to remove large amounts of suspended particulate matter from the water column (Davoult & Gounin, 1995) and they are important in the cycling of carbon dioxide (Migné *et al*., 1998). Previous research indicates that respiration of *O. fragilis* populations could supply up to 35% of phytoplankton carbon requirements (Migné *et al*., 1997).

Mytilus edulis were observed in 4% of trawls and 8% of grabs, with numbers over the whole dataset amounting to >5000. Mussel beds are protected as biogenic reefs under Annex I of the Habitats Directive, however these rarely form in water deeper than 10m (Holt *et al*., 1998) and therefore are unlikely to be present in a reef form at the sites surveyed. Mussels are still important as a non-reef feature within the community, providing a substratum for epifauna and epiflora, as well as engineering, stabilising and enriching habitats for infaunal species beneath mussel aggregations (Ragnarsson & Raffaelli, 1999; Holt *et al*., 1998).





Legend

MAREA Study Boundary

Aggregate Areas

Active Dredge Zone

Licence Area

Application Area

Prospecting Area

Predicted EUNIS Habitats

Infralittoral Fine or Muddy Sand

Notes:

Source: MES, 2006-07; CEFAS, 2009; The Crown Estate, 2010; MFA 2009
Emu Limited, 2002-2010

MESH Predicted EUNIS Habitats

0 5 10 20
Kilometres

Coordinate System: WGS84 UTM Zone 31 North

Scale: 1:375,000

Sheet Size: A3

Client: Anglian Offshore Dredging Association

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Project Title:

AODA Marine Aggregates Regional Environmental Assessment - Benthic Survey

Figure Title:

Sand Bank Distribution within the Anglian MAREA Region

Figure No. 4.11

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Map Document: (N:\1.13\1463 AODA MAREA GIS Element\3.Plots\3.Finals\J1031671_Benthic_Survey\Fig4_12_Sandbanks.mxd)
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5.0 CONCLUSION

One of the key outputs of this Anglian MAREA study has been the establishment of a consistent regional benthic species and habitat dataset, incorporating existing and newly acquired data from across the region, which can be utilised to inform future site specific environmental impact assessments and regional Strategic Environmental Assessments.

MAREA survey results indicate that the region is largely comprised of homogeonous gravelly sand / sandy gravel sediments. Generally impoverished communites typify the area, indicative of a physically disturbed environment. However, *S. spinulosa* populations are found throughout the region and where present in high densities or in a reef form result in local scale habitat consolidation with concomitant habitat heterogeneity encouraging increased species richness and community diversity.

Poor correlations were noted between abiotic data and benthic assemblages within the Anglian MAREA region. Previous studies have indicated a limited level of correlation between abiotic and biotic variables for the east coast aggregate sites, suggesting that other environmental factors or a complex combination of factors may be important in influencing faunal distributions. Potentially relevant factors may include the large scale movement of sand through the region together with the associated effects of sediment scouring, smothering and seabed instability, which have important consequences for the macrofauna, in general resulting in naturally impoverished communities.

A number of studies discuss the presence of a superficial mobile sand habitat within the region, typically associated with a sparse fauna, and surmise that although gravel may be present in grab samples it may not be available for colonisation at the seabed surface due to the presence of this surficial mobile sand.

At a regional level, differences in macrofaunal communities between control and primary / secondary impact sites are not apparent. Whether this is indicative of a lack of dredging impact in the region and instead attributed to high natural mobility in the area remains unclear. Conversely, the observed increase in *Ophelia borealis*, a species typical of depauperate communities, which has previously been idenitifed as an effect of dredging (e.g. see Robinson *et al*., 2005), could indicate aggregate extraction impacts. However, when considered against a background of highly mobile sediments limiting development of more complex communities typical of stable conditions, the identification of dredging impacts on benthic ecosystems is not clear (e.g. see Dernie *et al*., 2003), as the mobile habitat may mask or override anthropogenic impacts.

Recolonisation of a disturbed habitat to achieve baseline communities may depend on many factors. These may include the time of year, which will influence larval supply (Dernie *et al*., 2003) and the fact that the original sediment matrix is unlikely to be re-established. The faunal communities within disturbed sediments are the least static due to their inherent adaptations to unstable sediments, hence recovery to an identical community is unlikely to occur, although a community which is substantially of the form found originally is likely to be achieved (Emu, 2004). However, Boyd *et al*. (2005) have indicated that "*it is clear that re-establishment of a community similar to that which existed prior to dredging can only be attained if the topography and original sediment composition are restored*". Thus conclusions that dredging has no or little impact and that communities will recover against a background of naturally mobile sediments, should not be assumed.

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