Hornsea Project Three
Offshore Wind Farm

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Preliminary Environmental Information Report:
Annex 2.1 – Benthic Ecology Technical Report

Date: July 2017

Hornsea 3
Offshore Wind Farm

DONG energy

Environmental Impact Assessment

Preliminary Environmental Information Report

Volume 5

Annex 2.1 – Benthic Ecology Technical Report

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Glossary

Term	Definition
Annelid	Segmented worm, an invertebrate animal belonging to the phylum Annelida that includes polychaetes and oligochaetes (such as earthworms).
Benthic ecology	Benthic ecology encompasses the study of the organisms living in and on the sea floor, the interactions between them and impacts on the surrounding environment.
Biomass	The total quantity of living organisms in a given area, expressed in terms of living or dry weight or energy value per unit area.
Biotope	The combination of physical environment (habitat) and its distinctive assemblage of conspicuous species.
Circalittoral	The subzone of the rocky sublittoral below that dominated by algae (i.e. the infralittoral), and dominated by animals.
Crustacean	An invertebrate belonging to the subphylum of Crustacea, of the phylum Arthropoda. Includes crabs, lobsters, shrimps, barnacles and sand hoppers.
Echinoderm	An invertebrate animal belonging to the phylum Echinodermata that includes sea stars, brittle stars, feather stars, sea urchins and sea cucumbers.
Epibenthic	Organisms living on the surface of the seabed.
Epifauna	Animals living on the surface of the seabed.
European site	A Special Area of Conservation (SAC) or candidate SAC, a Special Protection Area (SPA) or potential SPA, a site listed as a Site of Community importance (SCI) or a Ramsar site.
Hamon grab	A tool for sampling the benthic macro-infauna that is particularly effective for sampling from coarse substrata.
Infauna	The animals living in the sediments of the seabed.
Infralittoral	A subzone of the sublittoral in which upward-facing rocks are dominated by erect algae.
Intertidal	An area of a seashore that is covered at high tide and uncovered at low tide.
Macrofauna	Organisms retained on a 0.5 mm mesh.
Mollusc	Invertebrate animal belonging to the phylum Mollusca that includes the snails, clams, chitons, tooth shells, and octopi.
Multivariate statistical analysis	Statistical analysis that includes the simultaneous observation and analysis of more than one statistical variable.
Polychaete	A class of segmented worms often known as bristleworms.
Spat	The spawn or larvae of shellfish, especially oysters.
Sublittoral	Area extending seaward of low tide to the edge of the continental shelf.
Subtidal	Area extending from below low tide to the edge of the continental shelf.
Univariate statistical analysis	A statistical analysis carried out with only one variable.

Acronyms

Acronym	Description
AL1	Cefas Action Level 1
AL2	Cefas Action Level 2
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIEEM	Chartered Institute of Ecology and Environmental Management
cSAC	Candidate Special Area of Conservation
CL	Carapace Length
CSEMP	Clean Seas Environment Monitoring Programme
CSQG	Canadian Sediment Quality Guideline
CW	Carapace Width
DCO	Development Consent Order
DDV	Drop-down Video
Defra	Department for Environment, Food and Rural Affairs
dGPS	Differential Geographical Positioning System
DTLR	Department of Transport, Local Government and the Regions
EcIA	Ecological Impact Assessment
ECR	Export Corridor Route
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ERL	Effect Range - Low
EUNIS	European Nature Information System
EWG	Expert Working Group
FOCI	Feature of Conservation Importance
GIS	Geographical Information System
HADA	Humber Aggregate Dredging Association
HRA	Habitats Regulations Assessment
ICES	Institute of Estuarine and Coastal Studies
JNCC	Joint Nature Conservation Committee
LNR	Local Nature Reserve
MALSF	Marine Aggregate Levy Sustainability Fund

Acronym	Description
MAREA	Marine Aggregate Regional Environmental Assessment
MCS	Marine Conservation Society
MCZ	Marine Conservation Zone
MDS	Multidimensional Scaling
MESH	Mapping European Seabed Habitats
MHWL	Mean High Water Spring
MLWS	Mean Low Water Spring
MMO	Marine Management Organisation
MNA	Marine Natural Area
MPA	Marine Protected Area
NMMP	UK National Marine Monitoring Programme
NOAA	National Oceanic and Atmospheric Administration, US Department of Commerce
NMBAQC	National Marine Biological Analytical Quality Control
NNR	National Nature Reserve
NPS	National Policy Statement
NSBP	North Sea Benthos Project
OSPAR	Oslo-Paris Commission
PAH	Polycyclic aromatic hydrocarbon
PEIR	Preliminary Environmental Information Report
PEL	Probable Effects Low
PRIMER	Plymouth Routines In Multivariate Ecological Research
PSA	Particle Size Analysis
QC	Quality Control
REC	Regional Environmental Characterisation
rMCZ	Recommended Marine Conservation Zone
SAC	Special Area of Conservation
SACFOR	Superabundant, Abundant, Common, Frequent, Occasional, Rare
SAD	Site Assessment Document
SCI	Site of Community Importance
SEA	Strategic environmental assessment
SIMPER	Similarity Percentages
SIMPROF	similarity profile analysis
TBT	Tributyltin
TEL	Threshold Effect Level
TN	Total Nitrogen
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbon
TPT	Triphenyltin
UKAS	United Kingdom Accreditation Service
UKBAP	UK Biodiversity Action Plan
UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States
VER	Valued Ecological Receptor
ZoC	Zone Characterisation
ZoI	Zone of Influence

Units

Unit	Description
%	Percent
µg/kg	Micrograms per kilogram
µm	Micrometre
cm	Centimetre
g	Grams
km	Kilometre
knot	Unit of speed equal to one nautical mile (1.852 km) per hour
m	Metre
MB	Mega Byte
mg/kg	Milligrams per kilogram
mm	Millimetre

1. Introduction

1.1 Project background

1.1.1.1 DONG Energy Power (UK) Ltd. (hereafter referred to as DONG Energy), on behalf of DONG Energy Hornsea Project Three (UK) Ltd. is promoting the development of the Hornsea Project Three Offshore Wind Farm (hereafter referred to as Hornsea Three). Hornsea Three is a proposed offshore wind farm with a total generating capacity of up to 2,400 MW and includes the associated offshore cable corridor and onshore infrastructure. The Hornsea Three array area is located in the east of the former Hornsea Zone, in the central region of the North Sea, approximately 121 km to the northeast Tringham, Norfolk, approximately 140 km to the east of the East Riding of Yorkshire coast and approximately 10.1 km west of the median line between UK and Netherlands waters (Figure 1.1).

1.1.1.2 RPS was commissioned to undertake a subtidal and intertidal benthic ecology characterisation study of the Hornsea Three site and surrounding area. This included a detailed desktop study of the benthic ecology of a defined study area (see section 3) surrounding Hornsea Three and a number of historic benthic ecology surveys across the former Hornsea Zone. This characterisation study has been supplemented with new data from site-specific surveys undertaken in 2016, including within the Hornsea Three array area, the Hornsea Three offshore cable corridor and the landfall area (section 4).

1.2 Aims and objectives

1.2.1.1 The aim of this study was to provide an up to date characterisation of the benthic ecological resources within a defined study area, which incorporates the Hornsea Three area and the zone of potential impact, as agreed with the relevant statutory consultees for this topic (i.e. Marine Management Organisation (MMO), Natural England, the Joint Nature Conservation Committee (JNCC) and the Centre for Environment, Fisheries and Aquaculture Science (Cefas)) through the Evidence Plan process (see section 2.2).

1.2.1.2 Based on this, and using existing data, historic benthic ecology survey data and the site-specific survey data, the objective was to give a general description of the subtidal and intertidal benthic communities within the southern North Sea regional benthic ecology study area. These were then compared with the subtidal and intertidal benthic communities found within the Hornsea Three benthic ecology study area (see section 2.1) to provide the basis for evaluating the importance of habitats, species, or groups of species, as 'valued ecological receptors' for consideration in the impact assessment. The subtidal and intertidal benthic characterisation was informed by:

- The identification of the subtidal and intertidal benthic communities that characterise the southern North Sea benthic ecology study area and describing ecological patterns and associations with physical parameters such as sediment types and bathymetry;
- The identification of the subtidal and intertidal benthic habitats, species and communities of conservation interest within the southern North Sea (e.g. Annex I habitats, United Kingdom (UK) Biodiversity Action Plan (BAP) priority species and habitats, OSPAR threatened and/or declining species); and
- The identification of subtidal and intertidal benthic features of ecological interest within the southern North Sea benthic ecology study area (e.g. species rich communities, reef habitats and sandbanks).

1.2.1.3 Guidance on the issues associated with offshore renewable energy developments in general have been obtained through reference to the Overarching National Policy Statement (NPS) for Energy (NPS EN-1; DECC, 2011a) and the National Policy Statement for Renewable Energy Infrastructure (NPS EN-3, DECC, 2011b) (for biodiversity: section 2.6.64 to 2.6.67; intertidal 2.6.81 to 2.6.83; subtidal 2.6.113 to 2.6.114). Further advice in relation to Hornsea Three specifically has been sought through consultation with the statutory consultees through the Evidence Plan process and from the scoping opinion received with respect to Hornsea Three (Planning Inspectorate (PINS), 2016).

1.2.1.4 This technical report describes the baseline benthic ecology of the Hornsea Three benthic ecology study area (section 2.1). Sensitive benthic ecology receptors at Hornsea Three are derived from this baseline information which informs the impact assessment in volume 2, chapter 2: Benthic Ecology. Volume 2, chapter 2: Benthic Ecology provides details on consultation and considers the potential significance and likely significance of effects of the maximum design scenario upon the receptors identified within this report.

1.2.1.5 Guidance on the Environmental Impact Assessment (EIA) process have been sought from the following resources:

- Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater and Coastal, Second Edition (CIEEM, 2016); and
- Guidelines for Ecological Impact Assessment in Britain and Ireland (IEEM, 2010).

1.2.1.6 In addition, the EIA will be informed by the legislative framework as defined by the Offshore Marine Conservation (Natural Habitats, & c.) Regulations 2007, the Conservation of Habitats and Species Regulations 2010 (Habitats Regulations), the Wildlife and Countryside Act 1981 (as amended), and the Marine and Coastal Access Act, 2009.

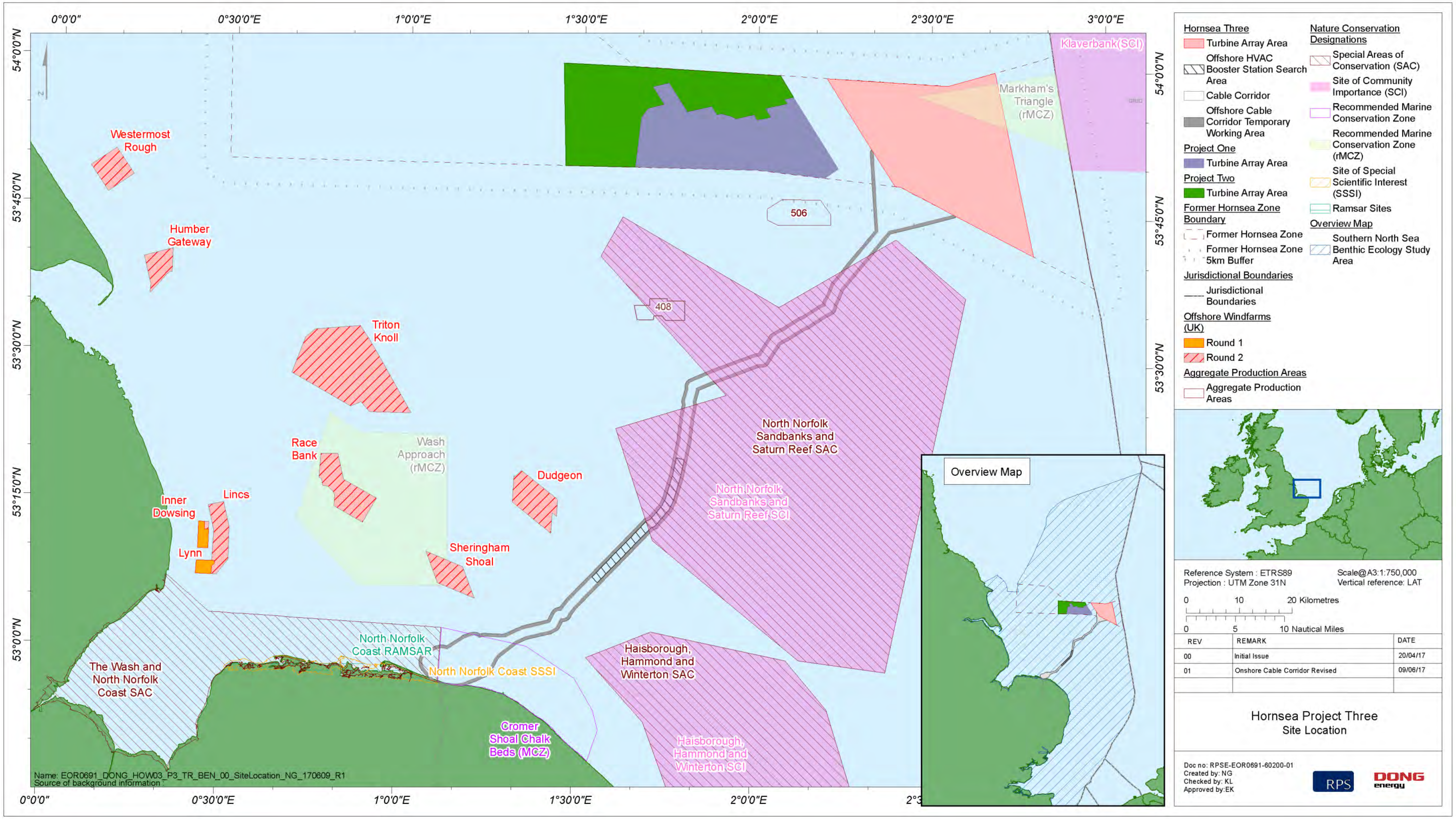

Figure 1.1: Location of Hornsea Three and the former Hornsea Zone, plus other offshore wind farm sites in the southern North Sea benthic ecology study area.

2. Methodology

2.1 Benthic ecology study area

2.1.1.1 For the purposes of the Hornsea Three benthic subtidal and intertidal characterisation, two study areas were defined:

- The Hornsea Three benthic ecology study area - this area encompasses Hornsea Three, which includes the Hornsea Three array area, Hornsea Three offshore cable corridor (i.e. encompassing subtidal benthic ecology), and landfall area (i.e. encompassing intertidal benthic ecology) (Figure 1.1). The subtidal section of the Hornsea Three benthic ecology study area also incorporates the former Hornsea Zone plus a 5 km buffer around the former Hornsea Zone, within which previous sampling campaigns were undertaken. Surveys undertaken across the former Hornsea Zone, including those for Hornsea Project One and Hornsea Project Two have been used to inform this Benthic Ecology Technical Report. At the landfall area, the Hornsea Three benthic ecology study area considers habitats up to the Mean High Water Spring (MHWS) mark. Habitats landward of MHWS have been considered in the onshore ecology assessment (see volume 3, chapter 3: Terrestrial Ecology); and
- The southern North Sea benthic ecology study area - this is the regional benthic ecology study area and was defined by the boundaries of the southern North Sea Marine Natural Area (Jones *et al*., 2004) (Figure 1.1). This southern North Sea benthic ecology study area provides wider context for the site-specific data and is the area assessed through the desktop review.

2.2 Evidence Plan

2.2.1.1 The purpose of the Hornsea Three Evidence Plan process (see Draft Envidence Plan (DONG Energy 2017)) is to agree the environmental information Hornsea Three needs to supply to PINS, as part of a Development Consent Order (DCO) application for Hornsea Three. The Evidence Plan seeks to ensure compliance with the EIA and Habitat Regulations Assessment (HRA) requirements.

2.2.1.2 As part of the Evidence Plan process, the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology Expert Working Group (EWG) was established with representatives from the key regulatory bodies and their advisors, including statutory nature conservation bodies; MMO, Cefas and Natural England. Between June 2016 and publication of this Preliminary Environmental Impact Report (PEIR), a number of EWG meetings were held to discuss key issues with regard to the benthic ecology elements of the Hornsea Three project, including characterisation of the baseline environment and the impacts to be considered within the impact assessment; see the summary of key points raised during consultation in section 1.5 of volume 2, chapter 2: Benthic Ecology.

2.2.1.3 The approach proposed by Hornsea Three for the purposes of characterising the subtidal and intertidal benthic communities within the Hornsea Three benthic ecology study area was an evidence based approach to the EIA, which involved utilising existing data and information from sufficiently similar or analogous studies to inform baseline understanding and/or impact assessments for a new proposed development. In this way, the evidence based approach does not necessarily require new data to be collected, or new modelling studies to be undertaken, in order to characterise the potential impact with sufficient confidence for the purposes of EIA (see volume 1, chapter 5: Environmental Impact Assessment Methodology).

2.2.1.4 The scope of the issues for assessment for benthic ecology is very similar (although not identical) to that previously considered for Hornsea Project One and Hornsea Project Two. The range of issues assessed within volume 2, chapter 2: Benthic Ecology, are briefly summarised below. The spatial extent of the impacts assessed will vary depending on the impact, although the extents are expected to be similar to those identified for Hornsea Project One and Hornsea Project Two. Impacts considered within volume 2, chapter 2: Benthic Ecology include (but are not limited to):

- Construction related activities leading to short term and localised changes (i.e. primarily within the Hornsea Three array offshore and Hornsea Three offshore cable corridor and temporary working areas) in benthic habitats and species including temporary habitat loss, increases in suspended sediments and subsequent deposition;
- Operation phase impacts related to the presence of offshore infrastructure, leading to relatively localised effects on benthic ecology (i.e. primarily within the Hornsea Three array offshore and Hornsea Three offshore cable corridor and temporary working areas). These include presence of subsea infrastructure leading to long term habitat loss and localised changes in community assemblages; and
- Decommissioning phase impacts including localised changes in benthic habitats and species including temporary habitat loss and permanent habitat loss, temporary increases in suspended sediments and accidental release of pollutants.

2.2.1.5 As detailed above, the scale of these impacts are expected to be similar for Hornsea Three as for Hornsea Project One and Hornsea Project Two and therefore the background information, data and statistical analyses used to inform these projects is highly relevant to the Hornsea Three baseline characterisation. It is important to note that there are key differences in Hornsea Three compared to Hornsea Project One and Hornsea Project Two, including the Hornsea Three offshore cable corridor. Where these differences are evident, further information has been sought, including site-specific surveys in these areas, to ensure a robust characterisation of the benthic ecology of these parts of the Hornsea Three benthic ecology study area, as agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG.

2.2.1.6 Hornsea Three is located within the former Hornsea Zone, for which extensive data and knowledge regarding the benthic ecology baseline is already available. This data/knowledge has been acquired through zonal studies and from the surveys and characterisations undertaken for Hornsea Project One and Hornsea Project Two. It was therefore proposed that the Hornsea Three benthic ecology characterisation be completed using a combination of desktop data and information sources, and site specific survey data collected as part of the characterisations of the Hornsea Project One and Hornsea Project Two offshore wind farms and the former Hornsea Zone. Over a series of EWG meetings conducted between June 2016 and publication of this PEIR, it was agreed that in general this approach was appropriate and sufficient for the purposes of characterising the benthic ecology of the Hornsea Three benthic ecology study area, although noting an agreement to supplement this existing data with some site specific additions, described briefly in section 2.2.1.7 and 2.2.1.8 below and in further detail in section 2.4.

2.2.1.7 Within the Hornsea Three array area and along the Hornsea Three offshore cable corridor, additional benthic sampling was undertaken as part of the geophysical survey campaign commissioned by Hornsea Three in 2016. As agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG, these site specific survey data have been incorporated into the Hornsea Three benthic ecology baseline characterisation described in this PEIR (see Figure 2.6 and section 4).

2.2.1.8 The Hornsea Three offshore cable corridor is unique to Hornsea Three. As such, the existing data and knowledge of the baseline environment along the offshore cable corridor for Hornsea Project One and Hornsea Project Two is relevant only in part to the Hornsea Three offshore cable corridor and the evidence-based approach described above cannot be applied. Therefore the baseline characterisation of the Hornsea Three offshore cable corridor within this PEIR has primarily drawn upon the site-specific survey completed in 2016 and desktop information from third-party surveys, including surveys targeting areas within and in close proximity to areas designated for nature conservation. A further site-specific survey of the Hornsea Three offshore cable corridor is planned for Quarter 2 of 2017. Together with the existing data, this survey will be used to establish a robust and up-to-date characterisation of the baseline environment in the Hornsea Three offshore cable corridor. This site-specific Hornsea Three offshore cable corridor survey has been discussed and agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG. The results will be used to update the Hornsea Three benthic ecology baseline characterisation in the Environmental Statement.

2.3 Desktop review

2.3.1.1 There have been a number of broadscale benthic studies in the North Sea which, wholly or in part, spatially overlap with Hornsea Three. A primary source of data that coincides spatially with the Hornsea Three benthic ecology study area was provided by the Humber Regional Environmental Characterisation (REC). This data provides benthic biotope mapping coverage of an area of 11,000 km^2 off the east coast of England and was funded by the Marine Aggregate Levy Sustainability Fund (MALSF; Tappin *et al*., 2011). The Humber Aggregate Dredging Association (HADA) has also collated data from 1,013 benthic grab samples in the Humber and Outer Wash Region in support of the Marine Aggregate Regional Environmental Assessment (MAREA; ERM, 2012). The extent of the resulting biotope map coincides with the nearshore approach to the Hornsea Three offshore cable corridor and this information has been used to support this benthic ecology characterisation. One of the main objectives of the MAREA was to describe the regional benthic characteristics in an area with several marine aggregate licence areas.

2.3.1.2 Other data coinciding with the Hornsea Three benthic ecology study area, and providing coverage across much of the southern North Sea study area, were drawn from the following sources (see Figure 2.1 for those data available in a Geographical Information System (GIS)):

- EMODnet broad scale map of sea bed habitats, including data from the Mapping European Seabed Habitats (MESH) mapping programme (EUSeaMap2016, 2016);
- UK Benthos Application accessed via Oil and Gas UK (http://oilandgasuk.co.uk/product/ukbenthos/). Department for Transport, Local Government and the Regions (DTLR, 2002);
- Benthic sampling programmes coordinated under the North Sea Benthos Project (NSBP, 2010);
- Technical reports for Strategic Environmental Assessment (SEA) Areas 2 and 3 (DTI, 2001a; DTI, 2001b);
- Baseline characterisations from other developments, including offshore wind farms, in the region (e.g. Dudgeon (Royal Haskoning, 2009; Warwick Energy, 2009) and Sheringham Shoal (Scira Offshore Energy, 2006));
- Data from the surveys undertaken in support of the designation of the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) (Defra, 2016);
- Data from benthic surveys undertaken within the North Norfolk Sandbanks and Saturn Reef candidate Special Area of Conservation (cSAC)/Site of Community Importance (SCI) and Haisborough, Hammond and Winterton cSAC/SCI (e.g. Barrio Froján *et al*., 2013) undertaken in support of site designation and the development of appropriate management advice for the site (e.g. Jenkins *et al*., 2015); and

- Other large scale benthic infauna and epifauna surveys undertaken in the southern North Sea including classic infaunal surveys (Petersen, 1914; 1918) and wide scale trawl, grab and video surveys (Dyer *et al*., 1982 and 1983; Jennings *et al*., 1999; Rees *et al*., 1999; Callaway *et al*., 2002).

2.3.2 Nature conservation designations

2.3.2.1 Information on the nature conservation designations relevant to subtidal and intertidal benthic ecology were identified using a number of sources. The JNCC's website and the Natura 2000 European Nature Information Systems (EUNIS) database were used to identify international designations. National designations such as MCZs and rMCZs were identified using the Final Recommendations Report of the Net Gain and Balanced Seas projects, which represented the North Sea (Net Gain, 2011a) and southeast England (Balanced Seas, 2011), respectively. National Nature Reserves (NNRs), Sites of Special Scientific Interest (SSSIs) and Local Nature Reserves (LNRs) were identified using the Department for Environment, Food and Rural Affairs (Defra) MAGIC interactive map application (http://magic.Defra.gov.uk/). Nature conservation designations with benthic features are shown on Figure 2.1.

2.4 Field surveys

2.4.1.1 As discussed in section 2.2.1.6, data acquired for Hornsea Project One and Hornsea Project Two provide a substantial contribution to the characterisation of the benthic habitats and species present within the Hornsea Three benthic ecology study area. These survey data, and the coverage provided by these data is described below in section 2.4.2. As agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG, these data have been used to provide the baseline for the subtidal benthic ecology characterisation of the Hornsea Three array area. These data have, however, also been supplemented with site specific benthic sampling undertaken within the Hornsea Three array area in 2016. This survey is described in section 2.4.3 below.

2.4.1.2 The 2016 site-specific survey is described in section 2.4.3 below and, as discussed in paragraph 2.2.1.8, this will be supplemented by a further ecological survey scheduled for Quarter 2 of 2017.

2.4.2 Historic survey data within the Hornsea Three benthic ecology study area

2.4.2.1 Information is available for the Hornsea Three array area through historic benthic ecology surveys undertaken across the former Hornsea Zone. Detailed benthic subtidal surveys across the former Hornsea Zone were undertaken in 2010 for the Hornsea zone characterisiation (ZoC) study (Figure 2.2). Further benthic subtidal surveys across the Hornsea Project One array area were completed in 2010, 2011 and infill surveys of the Hornsea Project Two array area were completed in 2012 (Figure 2.2). The Hornsea ZoC subtidal benthic sampling array was based on a regular grid pattern (of approximately 5 km spacing), to optimise coverage of the former Hornsea Zone and to increase the likelihood of encountering as many different habitats as possible. For Hornsea Project One and Hornsea Project Two surveys, sampling locations were selected on a stratified random basis to ensure adequate coverage of the different habitats present within the respective benthic ecology study areas. The data acquisition strategies, including the sampling arrays and methodologies, were discussed and agreed with the MMO and their advisors (i.e. the Cefas, JNCC and Natural England).

2.4.2.2 Subtidal benthic habitats were sampled through a combined benthic grab and drop down video (DDV) survey, as well as an epibenthic beam trawl survey. Samples for contaminant analysis were also taken at a number of stations across Hornsea Project One and Hornsea Project Two.

2.4.2.3 Data were available for the Hornsea Three benthic subtidal characterisation from a total of 334 single 0.1 m^2 benthic grabs/DDV deployments undertaken across the Hornsea Three benthic ecology study area and collected between 2010 and 2012 (Table 2.1; Figure 2.2). As outlined in Table 2.1, 27 of the combined benthic grab/DDV locations coincide with the Hornsea Three array area. Data from a total of 102 epibenthic beam trawls undertaken across the Hornsea Three benthic ecology study area between 2010 and 2012 were also available to inform the Hornsea Three subtidal characterisation; none of these locations coincided with the Hornsea Three array area (Table 2.1; Figure 2.2).

2.4.2.4 A survey was carried out at Markham's Triangle rMCZ by Defra in 2012 to acquire data as part of the proposed designation of the site. This survey, which partially overlapped the Hornsea Three array, comprised Hamon grab sampling for infauna and particle size analysis (PSA) and DDV sampling (Table 2.1). The data has been made available to Hornsea Three so that it may contribute to the characterisation of the Hornsea Three array area, as agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG. The PSA data has been incorporated into the dataset for the Hornsea Three benthic ecology study area to establish the sediment type in that region. The Markham's Triangle dataset has been analysed to determine the similarity of the communities in the site with those within the Hornsea Three array; this analysis is further discussed in section 2.6.2.2 and the results are presented in section 4.1.4.22 *et seq*. This infaunal data, together with data to be collected in 2017, will be analysed and biotopes assigned for the Benthic Ecology Technical Report which will inform the Environmental Statement.

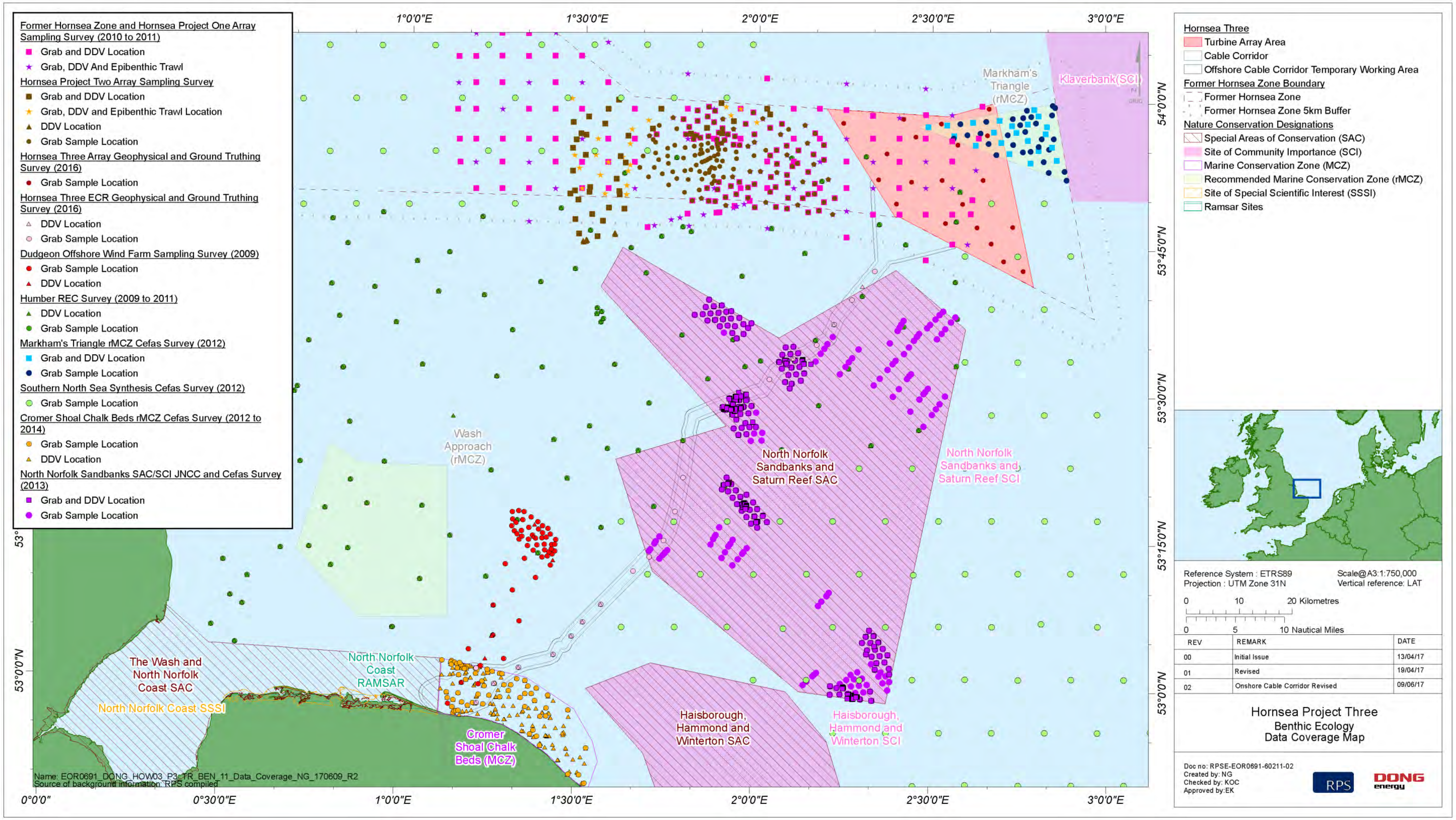

Figure 2.1: Location of Hornsea Three and the former Hornsea Zone with existing desktop data together with historic benthic ecology survey data and site-specific survey data, and nature conservation designations with benthic features.

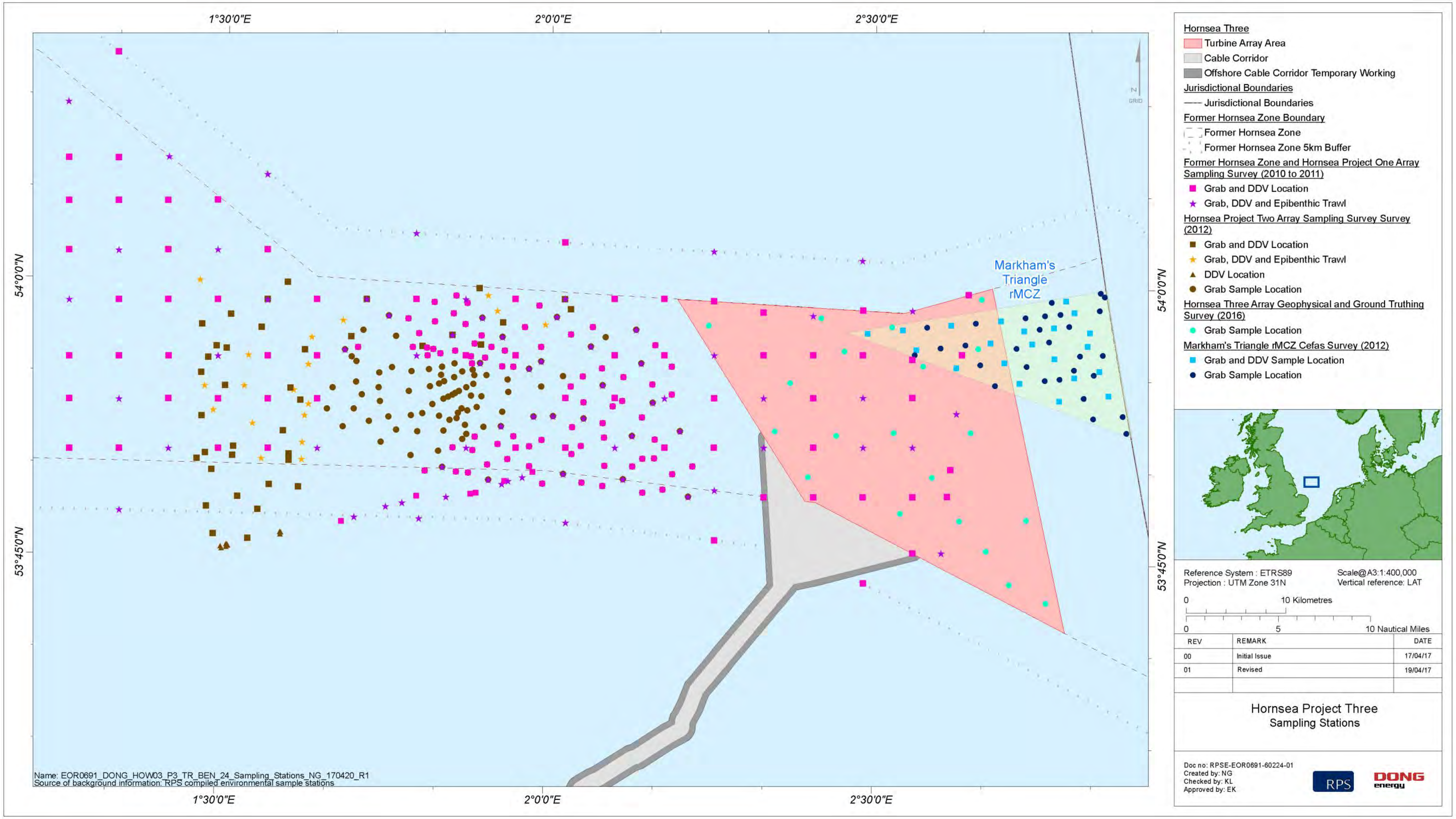

Figure 2.2: The Hornsea Project Three array area with existing (2010-2012) and Hornsea Three site specific (2016) benthic ecology sampling locations (benthic grabs/DDV and trawls). Also shown are sampling sites within Markham's Triangle rMCZ (Defra, 2012 (note: third party survey data).

Table 2.1: Summary of the benthic subtidal and intertidal surveys undertaken and proposed within the Hornsea Project Three study area.

Survey	Date of survey	Combined benthic grab sampling and DDV stations	Epibenthic beam trawls	Sampling stations within the Hornsea Three array area
Existing site specific survey data within the Hornsea Three benthic ecology study area (collected 2010 to 2012)				
ZoC benthic sampling survey	November 2010	122 stations	40 stations	27 grab/DDV stations and 9 epibenthic trawls
Hornsea Project One benthic sampling survey	July, September, November 2010 and June, October 2011	161 stations (40 sampled for sediment chemistry)	41 stations	-
Hornsea Project Two benthic infill survey	July 2012	51 stations (8 sampled for sediment chemistry)	21 stations	-
Markham's Triangle rMCZ survey [a]	April and May 2012 (published in 2014)	21 stations and 29 stations for grab sampling only	-	14 grab stations
Site specific surveys within the Hornsea Three benthic ecology study area (collected 2016)				
Hornsea Three array area geophysical survey ground-truthing campaign	May and June 2016	20 stations (sampled for PSA and infauna); geophysical data (side scan sonar and bathymetry)	-	20 grab stations; coverage of geophysical data
Hornsea Three offshore cable corridor geophysical and benthic sampling survey	September and October 2016	20 stations, 10 of which comprised 50 m DDV transects (19 sampled for PSA and for infauna); geophysical data (side scan sonar and bathymetry)	-	19 grab stations; coverage of geophysical data
Hornsea Three intertidal survey of the landfall	August 2016	-	-	No sampling undertaken; walkover.
Proposed site specific survey within the Hornsea Three benthic ecology study area (to be collected 2017)				
Hornsea Three benthic sampling survey	Proposed for Quarter 2 of 2017	16 stations, plus 5 stations for Day grab sampling only, and 15 stations for DDV transects only	5 stations	36 grab and/or DDV stations and 5 epibenthic trawls

[a] PSA data from the Markham's Triangle rMCZ designation survey has been obtained for the purposes of characterising the Hornsea Three array area. This 2012 survey was undertaken by Cefas (Defra, 2014) and has no connection with the Hornsea Three development.

2.4.3 Site specific surveys of the Hornsea Three benthic ecology study area

2.4.3.1 In addition to the existing benthic datasets for the former Hornsea Zone described in section 5.2 below, a number of site specific surveys were undertaken across the Hornsea Three benthic ecology study area in 2016 (see Figure 2.2 and Figure 2.3; Table 2.1):

- Hornsea Three array area geophysical survey ground-truthing campaign: 20 sample locations (see section 4.1.2 for the results);
- Hornsea Three offshore cable corridor benthic grab/DDV survey: 20 sample locations (see section 4.1.2 for the results and specifically 4.1.4.29 for interpretation of the 50 m transects); and
- Intertidal walkover survey of the landfall site (see paragraphs 4.1.4.75 to 4.1.4.82 for the results).

Hornsea Three array area benthic grab survey

2.4.3.2 A total of 20 benthic grab samples were collected within the Hornsea Three array area as part of the Hornsea Three array area geophysical survey in June 2016. The locations of the grab samples were selected in order to target (for ground-truthing) the range of sediment types recorded across the Hornsea Three array area (see Figure 2.2). At each of the 20 locations, a single 0.1 m^2 grab sample was collected using a mini-Hamon grab for macrofaunal analysis (identification, enumeration and biomass) and a sub sample of the sediment retained for PSA according to the methodologies described in sections 2.5.1.2 and 2.5.1.3.

2.4.3.3 Sediment samples were analysed for particle size distribution at the Institute of Estuarine and Coastal Studies (IECS) laboratory in accordance with the National Marine Biological Analytical Quality Control (NMBAQC) Best Practice Guidelines (Mason, 2016). A combination of laser particle size analysis and dry sieving was used for the fraction <1mm and fraction >1mm, respectively, using IECS' Malvern Mastersizer 2000 for the <1mm fraction and manual sieve shaker with sieve stack for >1mm material.

2.4.3.4 Sediment samples for benthic infauna analysis were processed through a 1 mm sieve, consistent with the approach used for all of the existing data for the Hornsea Three benthic ecology study area (see section 2.5.1.4) and the retained material transferred to an appropriate container and preserved immediately in 4% buffered saline formalin solution. The infaunal samples were analysed at IECS' benthic laboratory (which participates in the NMBAQC scheme) for identification (to species level), enumeration and biomass determination. Consistent with the approach adopted previously for Hornsea Project One, Hornsea Project Two and the ZoC surveys, biomass of the infaunal component was recorded in grams (g) AFDW derived from the blotted wet weights using published conversion factors (Eleftheriou and Basford, 1989). The retained infauna was separated into the following phyla: Polychaeta; Crustacea; Echinodermata; Mollusca; and others.

Hornsea Three offshore cable corridor benthic grab/DDV survey

2.4.3.5 The survey comprised camera ground-truthing and benthic sampling at 20 stations along the Hornsea Three offshore cable corridor. The sample locations were chosen to ground-truth geophysical data acquired during a site-specific geophysical survey which had recently been undertaken in the Hornsea Three offshore cable corridor for the Hornsea Three project.

2.4.3.6 A minimum of 10 seconds of live seabed grab camera footage was taken at each station to ensure that no potential Annex I habitats (such as *S. spinulosa* reefs) were present prior to seabed contact by the grab sampler. If a potential Annex I habitat was identified in the feed from the grab mounted camera, no grab sample was to be taken. Grab sampling was not undertaken at one station as potential *S. spinulosa* reef was observed in the grab-mounted live camera footage (for the results see paragraphs 4.1.4.83 to 4.1.4.85). DDV transects comprised at least 20 high resolution digital photographs, accompanied by at least ten minutes of video footage. At each of the 19 successfully grabbed locations, a single 0.1 m^2 grab sample was collected using a mini-Hamon grab for macrofaunal analysis at the IECS laboratory as described in section 2.4.3.4. A sub sample of the sediment was retained for PSA according to the methodologies described previously in sections 2.5.1.2 and 2.5.1.3, which were subsequently analysed for particle size distribution at the IECS laboratory, as described in sections 2.4.3.3.

Intertidal survey

2.4.3.7 To inform the intertidal benthic characterisation, a Phase 1 intertidal walkover survey was conducted at the proposed landfall area (see Figure 2.3) on 20 August 2016, following guidance set out in the JNCC Marine Monitoring Handbook (Davies *et al*., 2001; i.e. Procedural Guideline No. 3-1 In situ intertidal biotope recording) and in the Handbook for Marine Intertidal Phase I Biotope Mapping Survey (Wyn *et al*., 2006). The survey was undertaken by an experienced marine ecologist from RPS and timed to coincide with spring tides and was undertaken two hours either side of low water to ensure that as much of the intertidal zone as possible was surveyed (see paragraphs 4.1.4.75 to 4.1.4.82).

2.4.3.8 During the intertidal survey, notes were made on the shore type, wave exposure, sediments/substrates present, descriptions of species/biotopes present and the spatial relationships between these. All biotopes present were identified and their extents mapped with the aid of aerial photography and using a hand held Geographical Positioning System (GPS) recorder. Biotopes extending over an area of less than 25 m^2 were not mapped but instead were labelled on the biotope map as target notes. Additional pre-survey determined waypoints were designated as dig-over sites at which two 0.1 m^2 samples were taken to a depth of approximately 15 cm, and the sediment sieved on site using a 1 mm mesh. The sediment type and dominant infauna visible to the naked eye were recorded. Additional dig-over sites were added during the survey, where appropriate, to further characterise a biotope.

2.4.4 Proposed site specific survey within the Hornsea Three benthic ecology study area

2.4.4.1 As noted in section 2.2.1.8, a site specific survey of the Hornsea Three offshore cable corridor and array is scheduled for Quarter 2 of 2017, the results of which will be reported in the Environmental Statement. The scope of this survey has been discussed and agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG. The reader is referred to Figure 2.3 which shows the additional site specific survey locations that are proposed to inform the characterisation of the Hornsea Three offshore cable corridor and Hornsea Three array area..

2.4.4.2 The sampling strategy has been informed by a data gap analysis and detailed interpretation of the geophysical data acquired along the Hornsea Three offshore cable corridor in 2016. The sampling strategy comprises:

- 16 combined DDV/Hamon grab sampling locations to ensure adequate data coverage for both infaunal and epifaunal communities (including three stations within the Hornsea Three array area);
- An additional 15 DDV only transects targeting habitats of conservation importance;
- A minimum of five Day grab samples to be sampled for sediment chemistry; and
- Five epibenthic beam trawl sampling locations distributed across the representative sediment types within the Hornsea Three offshore cable corridor to characterise epifaunal communities.

2.4.4.3 Combined grab/DDV sampling has primarily been focussed on areas of low data confidence, including within the export cable fan at the offshore section of the Hornsea Three offshore cable corridor, the area to the northwest of the North Norfolk Sandbanks and Saturn Reef SAC boundary and the inshore section of the Hornsea Three offshore cable corridor to the west of the Cromer Shoal Chalk Beds MCZ. The 2016 Hornsea Three offshore cable corridor geophysical survey data were also used to ensure that all of the broad scale sediment types will be adequately characterised. Seabed imagery sampling alone has been proposed in areas of higher sensitivity (e.g. potential Annex I habitats, including potential *S. spinulosa* reef habitat) as identified from the geophysical survey data.

2.4.4.4 A limited amount of grab sampling is proposed within the Cromer Shoal Chalk Beds MCZ and the North Norfolk Sandbanks and Saturn Reef SAC, including combined DDV and grab sampling, to provide a more detailed characterisation of the benthic ecology in these areas, together with single Day grab sample in order to collect sediment chemistry data. As clarified during the EWG meeting, these grab sample locations do not target potential *S. spinulosa* reef features within or outside the SAC or chalk reef features within the MCZ. DDV will be performed prior to grab sampling in areas of potentially sensitive habitats. This practice will be adopted as a standard operating procedure during the survey to ensure potential damage to previously unidentified reef habitats, which could be sensitive to grab sampling, are avoided.

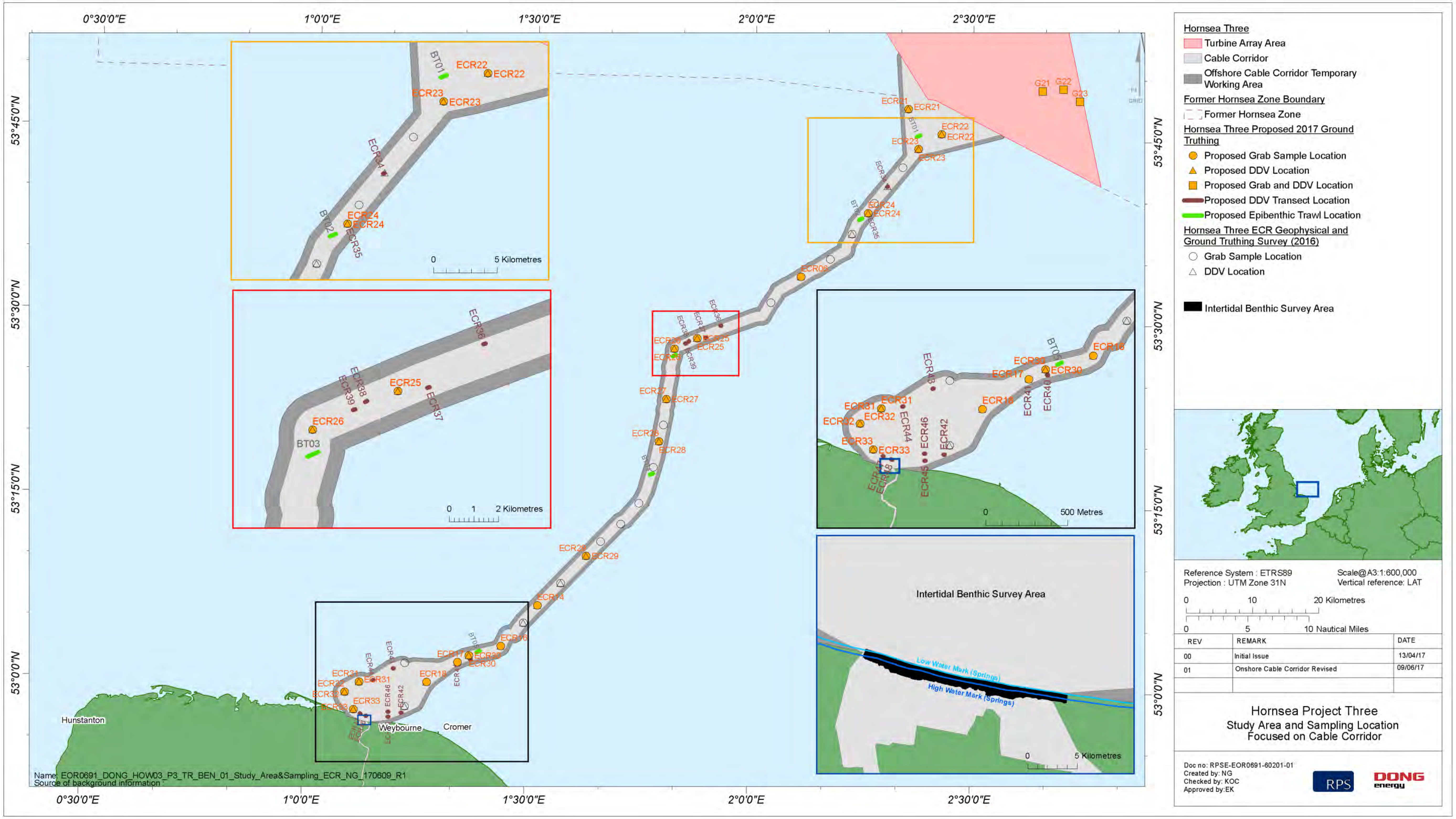

Figure 2.3: The Hornsea Three offshore cable corridor with site specific sampling collected in 2016 and proposed site specific sampling planned for 2017 (combined benthic grab/DDV and epibenthic beam trawl locations.

2.4.4.5 During the site-specific survey scheduled for Quarter 2 of 2017, three of the sampling locations will be located within Markham's Hole (within the Hornsea Three array area), to characterise the muddy sediments in the southeastern part of the Hornsea Three array area. The proposed sampling locations are marked as G21, G22 and G23 in Figure 2.3.

2.4.4.6 At each of the grabbed locations, a single 0.1 m^2 grab sample will collected using a mini-Hamon grab for macrofaunal analysis at the IECS laboratory as described in section 2.5.1.4. A sub sample of the sediment will be retained for PSA according to the methodologies described in section 2.5.1.3. Sample collection and processing will be consistent with that undertaken for all previous surveys within the former Hornsea Zone; as described below in section 2.4.4.5.

2.5 Sample collection and analysis

2.5.1.1 The following section describes the methods of sample collection and analysis for the historic benthic ecology surveys and the site-specific surveys.

Benthic grab sampling

2.5.1.2 The benthic grab surveys were designed based upon guidance provided by 'Procedural Guideline No, 3-9 – Quantitative sampling of sublittoral sediment biotopes and species using remote operated grabs' included in the JNCC Marine Monitoring Handbook (Davies *et al*., 2001) and by the Cefas 'Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites' (Ware and Kenny, 2011). In locations where grab sampling was undertaken, a single 0.1 m^2 grab sample was collected using a mini-Hamon grab for macrofaunal analysis and a sub sample of the sediment removed for characterisation of the physical nature of the substrate (particle size analysis (PSA)). Upon retrieval of the grab sample on board the vessel, the sediment within the grab bucket was viewed in order to assess whether the sample was acceptable (i.e. had not been subject to partial washout during retrieval, had sealed correctly against the sealing plate, and was of sufficient volume relating to depth of bite). After collection, the samples were appropriately preserved and analysed using laboratory facilities for physical and biological properties. The parameters measured included:

- PSA (analysed in ZoC, Project One, Project Two (342 samples combined), Hornsea Three array (20 samples) and Hornsea Three offshore cable corridor surveys (19 samples to date), plus PSA data from the third party Markham's Triangle MCZ survey (50 samples));
- Benthic infauna and epifauna analysis including identification, enumeration and biomass (analysed in ZoC, Project One, Project Two (342 samples combined), Hornsea Three array (20 samples) and Hornsea Three offshore cable corridor surveys (19 samples to date), plus fauna data from the third party Markham'sTriangle MCZ survey (50 samples)); and
- Sediment chemical analysis (ZoC, Project One and Project Two surveys (48 samples combined)).

<u>Particle size analysis</u>

2.5.1.3 Sediment samples were analysed for particle size distribution at a United Kingdom Accreditation Service (UKAS) accredited laboratory. Representative sub-samples of each sediment sample were oven dried to a constant weight and sieved through a series of mesh apertures over the range 64 mm to 63 µm (0.063 mm) on the Wentworth scale. The weight of the sediment fraction retained on each mesh was measured and recorded. This method was in accordance with BS 1377 (Part 2: 9.2/9.4) and Cefas guidance (Ware and Kenny, 2011). Laser diffraction techniques were also used for samples where sediments of less than 63 µm accounted for more than 5% by weight of the sample.

<u>Benthic infauna analysis</u>

2.5.1.4 Sediment samples for benthic infauna analysis were processed through a 1 mm sieve and the retained material transferred to an appropriate container and preserved immediately in 4% buffered saline formalin solution. The samples were analysed at a benthic laboratory which participates in the NMBAQC scheme for identification (to species level), enumeration and biomass determination. Biomass of the infaunal component was recorded in grams (g) ash free dry weight (AFDW) (weight to 0.0001 g) derived from the blotted wet weights using published conversion factors (Eleftheriou and Basford, 1989). The retained infauna was separated into the following phyla: Polychaeta; Crustacea; Echinodermata; Mollusca; and others.

2.5.1.5 The epifaunal component of each sample was analysed separately with identification to species level. Where possible each component was enumerated and presented as discrete counts or in the case of colonies, recorded as present and given a P (present) value.

<u>Sediment chemistry analysis</u>

2.5.1.6 Additional samples for sediment chemistry analysis were collected using a stainless steel Shipek or Day grab. A total of 48 locations within the Hornsea Three benthic ecology study area have previously been sampled for sediment chemistry (Table 2.1). These samples were frozen following collection and transferred to a specialist UKAS accredited chemistry laboratory for testing. The samples were analysed for the following determinands:

- Metals: arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc;
- Hydrocarbons (total petroleum hydrocarbons (TPH));
- Polyaromatic hydrocarbons (PAHs) (Environmental Protection Agency (EPA) 16 and 2-6 ring analysis); and
- Organotins (dibutyltin (DBT), tributyltin (TBT) and triphenyltin (TPT)).

2.5.1.7 Hornsea Project Two samples taken in the Hornsea Three array area during historic benthic surveys were also analysed for total organic carbon (TOC) and those sample during Hornsea Project One and Hornsea ZoC surveys were analysed for organochlorine pesticides.

Drop down video (DDV) survey

2.5.1.8 DDV deployments were undertaken during the ZoC, Project One, Project Two and Hornsea Three offshore corridor surveys.

2.5.1.9 The DDV surveys were undertaken using a new generation digital stills colour camera and video camera mounted to a DDV frame. At each sampling location a minimum of five minutes of video footage and a minimum of five seabed still images were obtained. Video images were digitally overlaid with dGPS positions and recorded in a digital format to 5 Mega Bytes (MB) or better. The DDV footage was reviewed in real time during the surveys by a suitably qualified marine ecologist fully trained and experienced in Annex I reef assessment and following the appropriate JNCC guidance notes (Gubbay, 2007; Irving, 2009; Limpenny *et al.*, 2010). If following on-board review of the DDV footage, an Annex I habitat was confirmed at a location, sampling was limited to DDV only, rather than a combination of benthic grab sampling and DDV. A log of each DDV sample position, time, sample type, water depth, habitat features and species observed was made to assist with the data analysis (appendix available on request).

2.5.1.10 Following the surveys the video records were reviewed and analysed in more detail by marine ecologists. Initially, using image manipulation software (which allows the use of grid overlays for area estimates), static images were analysed in order to identify conspicuous fauna within the images from each transect. The second stage of the analysis was carried out by reviewing video footage from each transect, identifying conspicuous species. The video footage provided a more complete and detailed description of the communities observed, as the less frequently occurring species would have been under-represented from static image analysis alone. The resulting data (from video footage and static image analysis) were merged. The quality control (QC) procedure was carried out on 10% of the still images; in addition, problematic issues/species identification where discussed between senior ecologists experienced in this type of analysis. Both analysis and data QC checks were carried out by ecologists experienced in this type of analysis.

2.5.1.11 Species were identified and their abundance or percentage cover quantified estimated using the Superabundant, Abundant, Common, Frequent, Occasional or Rare (SACFOR) scale. This scale is based on that devised by the JNCC (Connor and Hiscock, 1996) and uses the average species size to classify the population. Sample pictures of species recorded during the DDV analysis are presented in Figure 2.3 (appendix showing digital stills indicative of each sampling location is available on request).

Figure 2.4: Species recorded during previous DDV surveys across the Hornsea Three benthic ecology study area included the echinoderm *Asterias rubens* (left) and dead man's fingers *Alcyonium digitatum* (right).

Epibenthic beam trawl survey

2.5.1.12 Epibenthic sampling was undertaken during the ZoC, Project One and Project Two surveys. A standard 2 m scientific beam trawl (Lowestoft design) fitted with a knotless 5 mm cod end liner was used to collect information on epibenthic invertebrate species, as well as small demersal and juvenile fish to supplement the data collected by grab (predominantly infaunal species focused) and DDV sampling. Data from a total of 102 trawls across the Hornsea Three benthic ecology study area were available and have been drawn upon for the benthic subtidal characterisation of the Hornsea Three array area.

2.5.1.13 The length of the tow was established at approximately 500 m (five to ten minutes duration), although the exact actual length of the tow was determined by ground conditions, with a tolerance of plus or minus 300 m being accepted. The trawl tow speed was approximately 1.5 knots. Proposed trawl locations were selected to provide a representative sample of each of the previously identified broadscale sediment types identified from the geophysical data in order to characterise the epifaunal communities. As with benthic sampling, trawl sites were informed by the outputs of the geophysical survey, to reduce the likelihood of damaging any Annex I habitats. Full epibenthic beam trawl logs, including timings, trawl depths and locations are available as an appendix on request.

2.5.1.14 Once recovered to the deck, the catch was sorted over a 5 mm mesh and all species from each trawl were identified using appropriate keys. The entire catch was then enumerated and measured on a species-by-species basis. Colonial species were recorded as present and, for the most abundant species which included the soft coral *Alcyonium digitatum* and the bryozoans *Flustra foliacea* and *Alcyonidium diaphanum*, the total weight of each species for the trawl recorded in grams.

2.6 Data handling and analysis

2.6.1 Sediment chemistry analysis

2.6.1.1 There are currently no UK Environmental Quality Standards (EQSs) for in situ sediments. In the absence of any standards an initial assessment of whether organisms are at risk from concentrations of toxic contaminants can be undertaken by comparing data with the Cefas Guideline Action Levels for the disposal of dredged material and, where appropriate, with the Canadian Sediment Quality Guidelines (CSQG).

2.6.1.2 The Cefas Guideline Action Levels for the disposal of dredged material are not statutory contaminant standards for dredged material but are used as part of a weight of evidence approach to decision-making on the disposal of dredged material to sea. Although these guidelines relate to the disposal of dredged material, their primary purpose is to ascertain whether contaminated sediments will result in adverse impacts on the marine environment. Sediments with contamination levels below Cefas Action Level 1 (AL1) would be unlikely to be refused a sea disposal licence on the grounds of contamination. Materials with contamination levels above Cefas Action Level 2 (AL2) are likely to be deemed unacceptable for sea disposal. The Cefas ALs are also used as a screening trigger for the assessment of marine dredging activities under the Water Framework Directive (see Annex 2.2: Water Framework Directive Assessment).

2.6.1.3 The CSQG were developed by the Canadian Council of Ministers of the Environment as broadly protective tools to support the functioning of healthy aquatic ecosystems (CCME, 2001). They are based on field research programmes that have demonstrated associations between chemicals and biological effects by establishing cause and effect relationships in particular organisms. The CSQG consist of Threshold Effect Levels (TELs) and Probable Effect Levels (PELs): values below the TEL are within the minimal effect range within which adverse effects rarely occur; values above the PEL are within the probable effect range within which adverse effects frequently occur; and values between the TEL and PEL fall within the possible effect range where adverse effects occasionally occur.

2.6.1.4 Observed PAHs were also compared to the ‘effect range – low’ (ERL) values (where available), as determined by the US National Oceanographic and Atmospheric Administration (NOAA). The ERL for each contaminant represents the lower tenth percentile of a dataset on a continuum of concentrations in sediment, broadly reflecting sediment toxicity (O’Conner, 2004).

2.6.1.5 The results of the sediment chemistry sampling undertaken for Hornsea Project One and Hornsea Project Two, including comparison against relevant thresholds and guidelines, have been represented within this Technical Report (see section 2.6.1).

2.6.2 Benthic infaunal and epifaunal biotope mapping

2.6.2.1 To characterise the Hornsea Three benthic ecology study area, as defined in section 2.1, the data collected during the site-specific Hornsea Three benthic surveys (i.e. the infaunal data from the 20 grab samples at the Hornsea Three array area and 19 grab samples along the Hornsea Three offshore cable corridor; see section 2.4.3), were combined with all existing benthic data for the Hornsea Three benthic ecology study area (i.e. Hornsea ZoC, Hornsea Project One and Hornsea Project Two surveys) and treated as a single dataset, to update the benthic subtidal biotope map for the Hornsea Three array area. No DDV data were acquired during the site-specific survey at the Hornsea Three array area, while only limited DDV data were available at the time of writing for the Hornsea Three offshore cable corridor, therefore the epibenthic biotope map draws on the qualitative DDV data of the Hornsea Three offshore cable corridor (i.e. visual determination of biotopes in DDV footage by judgement only; Bibby Hydromap, 2016) together with results of the Hornsea ZoC, Hornsea Project One and Hornsea Project Two surveys. As discussed in section 2.4.4 a site-specific benthic survey will be undertaken in Quarter 2 of 2017 along the Hornsea Three offshore cable corridor which will provide suitable data to inform the infaunal, epibenthic and epibenthic beam trawl biotope maps in the Environment Statement.

2.6.2.2 As discussed in section 2.4.2.4, the infaunal dataset from Markham’s Triangle has been incorporated into the main dataset for the Hornsea Three benthic ecology study area discussed above. However, this data has not been included in multivariate analyses for the Hornsea Three benthic ecology study area and therefore has not directly informed the infauna biotope map. A basic analysis has been undertaken on Markham’s Triangle data, together with all infaunal data within the Hornsea Three array area, to establish how the datasets compare and ultimately determine whether the Markham’s Triangle dataset supports the current characterisation of the array area, in the context of the assigned biotopes. This analysis has been reported as a discrete section within the results; see section 4.1.4.22 *et seq*.

2.6.2.3 In order to assign biotopes to the benthic infauna (from grab sampling) and epibenthic (from DDV sampling) datasets the results of the combined PSA data were initially simplified, using a simplified Folk Classification, into one of four sediment categories (see Figure 2.5) according to published guidelines (Long, 2006). The approach used is consistent with those used during the UKSeaMap and MESH projects (Long, 2006) and follows advice previously provided by the Marine and Fisheries Agency (now MMO) on biotope mapping for other offshore wind farm projects.

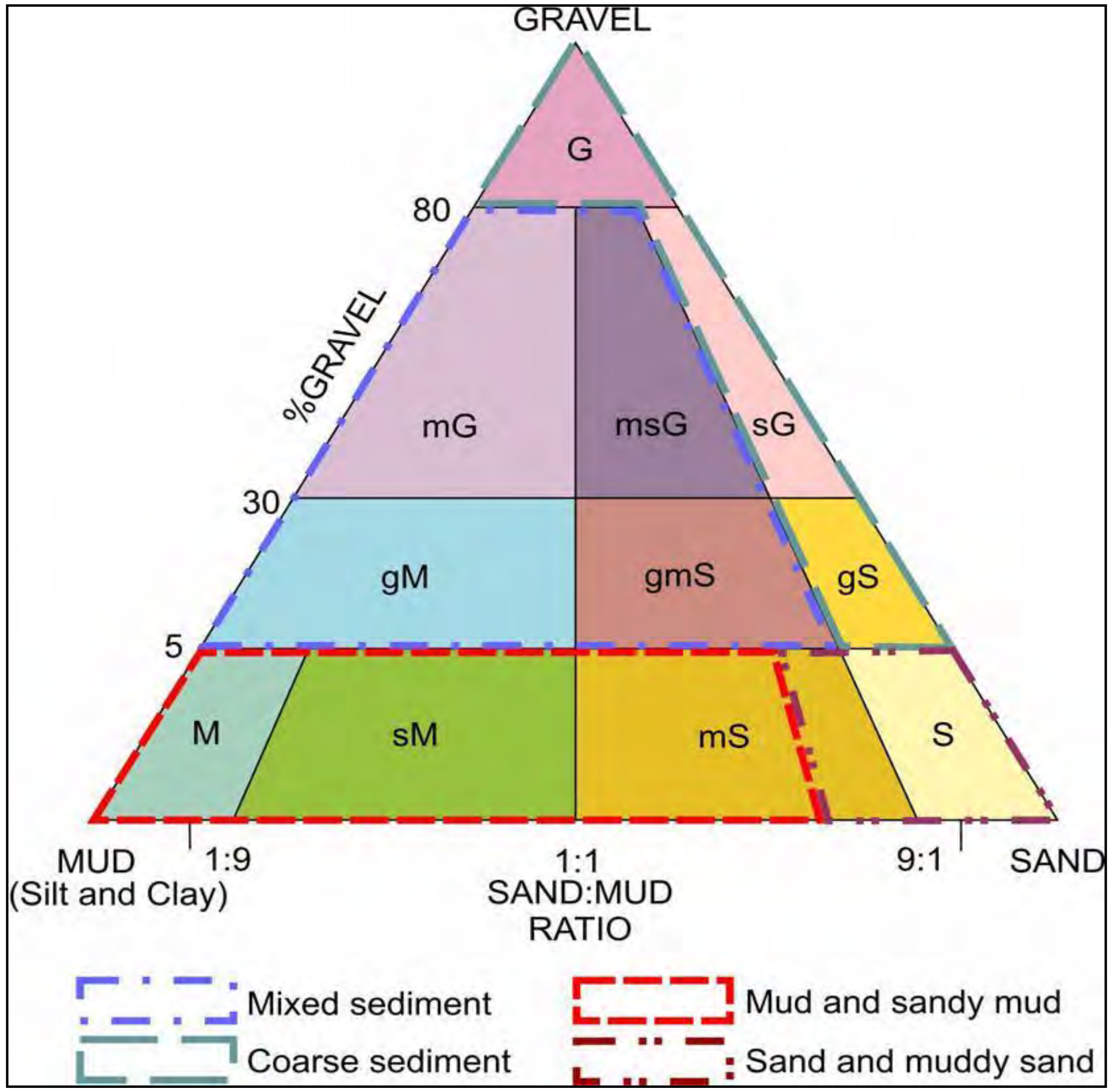

Figure 2.5: Simplified Folk Sediment classifications (from Long, 2006).

2.6.2.4 These sediment/substrate classifications were then assigned as factors to both infaunal and epifaunal datasets and used as a basis for the statistical analyses (i.e. separate cluster analyses were conducted on each simplified folk classification (see below)). This also assisted in reducing the size of the dataset in each analysis as many of the statistical tests outlined below could not readily be performed on the single combined dataset due to its size (381 sites). The benthic infaunal dataset was square root transformed in order to down-weight the species with the highest abundances for multivariate community analysis using the PRIMER v6 software (Clark and Gorley, 2008).

2.6.2.5 The epifaunal data from the DDV analysis and the epifaunal data from the grab samples were combined into a single epifaunal dataset. The epibenthic beam trawl dataset was analysed separately (see section 2.6.2.11) from the DDV and grab epifaunal data, but the results were used to inform the final epibenthic biotope classifications (see section 2.6.2.13). Since the species abundances from DDV footage (i.e. the epifauna dataset) were estimated using the SACFOR scale, these abundances were converted to a 1 to 6 scale, so that rare abundances scored 1, occasional scored 2, frequent scored 3, etc. The epifaunal species recorded in the grab samples were typically recorded in very low abundances and as such were classified as present and assigned a nominal abundance of 0.1 for the purposes of the multivariate analyses.

2.6.2.6 Newly settled juveniles of benthic species may at times dominate the macrofauna, but due to heavy natural post-settlement mortality, they should be considered an ephemeral component and not representative of prevailing bottom conditions (OSPAR Commission, 2004). Subsequent analysis was, therefore, undertaken on epifaunal data that excluded juveniles.

2.6.2.7 The benthic infaunal and epifaunal datasets were each analysed separately, although the statistical analyses conducted on each dataset were identical. The next step in assigning benthic infaunal and epifaunal biotopes was to analyse the macroinvertebrate community structure to determine the relative similarities between sites. Benthic infaunal and epifaunal community structure was investigated through the use of CLUSTER analysis (hierarchical agglomerative clustering) using the PRIMER 6 statistical analysis program (Clarke and Gorley, 2003). This uses the Bray Curtis similarity coefficient to assess the similarity of sites based on the faunal components. The procedure produces a dendrogram indicating the relationships between sites based on the similarity matrix and uses a Similarity Profile (SIMPROF) test (at a 5% significance level) to test whether the differences between the clusters are significant. For the infaunal community cluster analysis, 27 clusters were identified for coarse sediments, 14 clusters for mixed sediments and 34 clusters were identified for sand and muddy sand sediments. For the epifaunal analysis (DDV data and epifaunal component of grab samples), 10 clusters were identified for coarse sediment, 9 for sand and muddy sand sediments and 5 for mixed sediments.

2.6.2.8 Similarity Percentages (SIMPER) analyses were subsequently undertaken on these datasets to identify which species best explained the similarity within groups and the dissimilarity between groups identified in the cluster analysis. The similarity matrix was also used to produce a multi-dimensional scaling (MDS) ordination plot which shows, on a two or three dimensional representation, the relatedness of the communities (at each site) to one another. Full methods for the application of both the hierarchical clustering and the MDS analysis are given in Clarke and Warwick (2001).

2.6.2.9 The results of the cluster analyses and associated SIMPER were reviewed alongside the raw, untransformed data in order to assign preliminary biotopes (Connor *et al*., 2004). Using the clusters identified, a number of sites within a particular cluster were assigned to a single biotope based on relatedness and presence/absence of key indicator species for a particular biotope. The preliminary biotopes were plotted using GIS and the biotopes assigned to each site then reviewed while referring to the geophysical data collected for the Hornsea Three benthic ecology study area. Biotope codes were also reviewed according to those biotopes surrounding each sampling location and where necessary biotopes at certain sites were reassigned. Following this review, biotopes were re-plotted to produce biotope maps.

2.6.2.10 The benthic infaunal and epifaunal biotope extents and boundaries were mapped using the outputs of the geophysical surveys for the Hornsea Three, Hornsea Project One and Hornsea Project Two benthic ecology study areas (i.e. seabed topography and sediment types identified by multibeam bathymetry and side scan sonar; see Figure 2.6)). Where two biotopes were present on the same sediment type, without a clear boundary from the aforementioned data sources, either a mosaic biotope was described or buffer zones were created between sites to create boundaries between the biotopes. It is therefore important to recognise that there is a degree of interpolation between sampling point data and the resulting biotopes mapped. Note that Figure 2.6 shows data from different survey contractors, therefore the interpretation of sediment types is slightly diffierent beteween datasets. While the different datasets are not exactly aligned, the combined geophysical dataset (together with benthic sampling data) is considered suitable for mapping of biotopes.

2.6.2.11 Epibenthic trawl data were also analysed using hierarchical agglomerative clustering to identify similarities and dissimilarities between trawl sites. Prior to analysis, the data, which was a matrix of discrete counts and weights of encrusting/colonial species was modified such that those species recorded as weights were classified as present and given a nominal score of 0.1 for the purposes of the analyses. In addition, the fish species recorded during the epibenthic trawls were removed from the dataset as it was deemed that these species were present in such high numbers that they would dominate the dataset and obscure the patterns in the benthic epifauna. It is important to note however, that the results of the cluster analysis were not reviewed in isolation when assigning the final biotope codes, the biomass data associated with the encrusting/colonial species, and also the complete raw dataset, including fish species present were taken into account.

2.6.2.12 The data were then standardised by total abundance per sample across all variables (species). This was necessary to ensure that the samples were comparable as it was not possible to ensure the sampling effort was consistent across all samples. Prior to generating a Bray Curtis similarity matrix, the data were fourth root transformed, in order to down weight the contributions of quantitatively dominant species (e.g. over 1,000 individuals of certain species such as common brittlestar *Ophiothrix fragilis*) and to allow the assessment of similarity to incorporate less abundant species (i.e. focus on species assembly rather than the key dominating species). The matrix was used to conduct a cluster analysis using the SIMPROF test, to test whether the dissimilarities between groups were significant. As with the infaunal (grab) and epifaunal (DDV) datasets, a SIMPER analysis was conducted to identify which species best explained the similarity within and dissimilarity between the groups. The results of these analyses were also used to assign preliminary biotopes to each of the epibenthic trawls.

2.6.2.13 Following assignment of biotope codes to benthic grab, DDV and epibenthic trawl sample sites and associated mapping (using the methods outlined above in section 2.6.2.12), the infaunal and epifaunal datasets were combined to produce a final, holistic biotope map of the Hornsea Three benthic ecology study area. This was achieved by identifying the characteristic species in each of the draft biotopes and, where (infaunal/epifaunal) datasets overlap, these characteristic species were compared to identify possible overlap between the communities. Where possible, the datasets were consolidated into one biotope code or a biotope mosaic which appropriately describes the infaunal and epifaunal communities present at each site, while also taking into account other environmental variables (e.g. depth, sediment type etc.). These biotope mosaics were usually in the form of an infaunal biotope with an overlaying epifaunal biotope.

2.6.2.14 As the most standardised dataset with the most quantitative data, the grab data was the starting point for this process, (i.e. grab data was prioritised and DDV/trawl data used to identify the subtle differences between the epifaunal communities). Where two distinct epibenthic biotopes overlap a single infaunal biotope, this difference in the epifaunal communities was appropriately represented in the final biotope code and resultant biotope map.

2.6.2.15 The biotope coding has used the Marine Habitat Classification for Britain and Ireland (Connor *et al*., 2004). These biotope classifications are directly comparable to those described by the EUNIS classification, which has been used to describe some of the desktop data (e.g. the Humber REC data). To ensure the historical and characterisation biotopes can be compared, both codes are presented in the biotope summary tables (Table 4.2, Table 4.3 and Table 4.4) within Section 3.

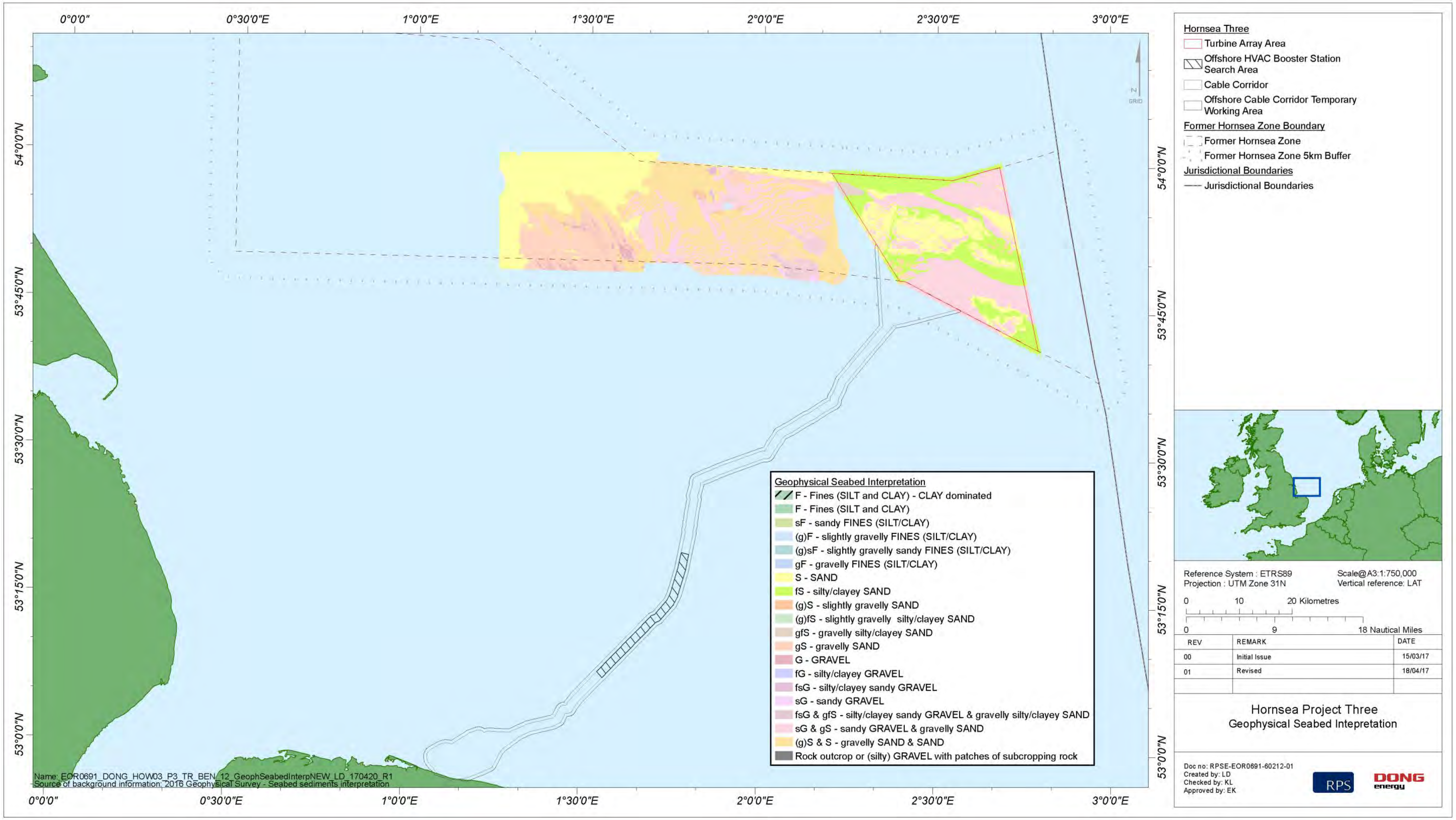

Figure 2.6: Geophysical survey seabed interpretation for the Hornsea Three benthic ecology study area.

2.6.3 Univariate statistical analysis

2.6.3.1 As well as utilising the raw species data to characterise the benthic communities present within the Hornsea Three benthic ecology study area, a number of indices were also calculated. These included: Margalef's Index of Richness (d); Pielou's Evenness index (J'); the Shannon-Wiener Diversity index (H'); and Simpson's index of Dominance (lambda) (Clarke and Warwick, 2001). Such indices are useful in reducing large faunal datasets to a single figure, which may be used in comparison to other sites in assessing community structure. These indices were calculated for each biotope in order to allow for comparisons to be made between the biotopes identified. This was done by calculating the diversity indices for each site, then calculating the mean (± standard deviation) for each biotope. The epibenthic trawl data were standardised by total abundance per sample across all variables (species) prior to calculating the univariate indices. Since Margalef's Index of Richness (d) is dependent on the total number of individuals (which was standardised) this index was not calculated for the epibenthic trawl dataset. As discussed previously in section 2.6.2.11, weights of colonial/encrusting species were assigned a nominal score for the purposes of the analyses.

2.6.3.2 Comparisons were also made between numbers of species (S), total abundance (N) and biomass (B) for the main faunal groups. For the benthic infaunal dataset these were divided into Annelida, Crustacea, Echinodermata, Mollusca and others (includes all other faunal groups (e.g. Tunicata, Cnidaria, Bryozoa) while for the epibenthic trawl dataset the main faunal groups were Crustacea, Echinodermata, Mollusca, Pisces and others (e.g. Cnidaria, Annelida and Bryozoa). This univariate analysis provides further detail on the composition of the benthic infaunal and epifaunal biotopes present in the Hornsea Three benthic ecology study area.

2.6.4 Annex I habitat assessment

2.6.4.1 An Annex I habitat assessment was undertaken on any sampling locations where potential Annex I habitats were identified within the Hornsea Three array and Hornsea Three offshore cable corridor boundaries. These habitats were identified firstly from the geophysical data and then from other data sources including video records, seabed stills and (data available on request). An Annex I *S. spinulosa* reef assessment was required at two sites (ECR02 and ECR04) during the Hornsea Three offshore cable corridor site-specific survey. The Annex I reef assessment at these sites was undertaken with reference to the relevant guidance with details of the assessment criteria outlined below.

***Sabellaria spinulosa* reefs**

2.6.4.2 Where *S. spinulosa* was observed in the DDV footage of the historic surveys and Hornsea Three offshore cable corridor site-specific survey, a comprehensive analysis, with reference to all relevant guidance documents (i.e. Hendrick and Foster-Smith, 2006; Gubbay, 2007; Limpenny *et al*., 2010), was undertaken. The analysis covered all aspects of these proposed methodologies, to determine whether or not an Annex I *Sabellaria* reef was present. To ensure that the assessment was comprehensive and transparent it comprised three stages with each stage drawing on different aspects of the guidance documents outlined above for assessing characteristics of Annex I *S. spinulosa* reefs, so that when the outcomes of each stage were drawn together they provided a full assessment of 'reefiness' as follows:

- Stage One: the initial stage involved a review of the video footage and stills to classify the presence of S. spinulosa into the following categories, where possible: absent, moribund loose tubes; crusts; clumps; and potential reef;
- Stage Two: following the guidance proposed by Hendrick and Foster-Smith (2006), this stage of the assessment was designed to give an overview of the various characteristics considered important to the 'reefiness' of S. spinulosa aggregations. Hendrick and Foster Smith (2006) suggested (Hendrick and 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. 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 the survey, where areas of reef were identified, the characteristics specified in Table 2.2 were scored as also described in Table 2.2, where possible. In addition, notes were be made on other conspicuous species recorded by the images and video footage; and
- This included an assessment of elevation, patchiness and a brief description of the reef (including the nature of the *S. spinulosa* present and other conspicuous species present). Additional characteristics proposed for assessment in the Hendrick and Foster-Smith (2006) guidance (e.g. density, consolidation and extent) were fully covered in the subsequent stage; and Stage Three: whilst the previous stages identified above provided a starting point for evaluating reefiness, the scoring system proposed by Gubbay (2007) was used to draw all the information to interpret the 'reefiness' of *Sabellaria* aggregations (Table 2.3). Recent discussions have suggested that a reef should be elevated above the sea floor by at least 2 cm, have an area of at least 25 m^2 and have a patchiness of no less than 10% (Gubbay, 2007). The parameters summarised in Table 2.3 were measured, where possible, using the broad (i.e. geophysical survey data) and fine scale (DDV and grab) survey data collated during the surveys. Each of the characteristics shown in Table 2.3 was scored as Low, Medium or High. This assessment was further supplemented by an assessment of the associated biodiversity and characterising species from the DDV footage, in line with the methodologies proposed by Gubbay (2007) and Limpenny *et al*. (2010).

Table 2.2: Summary of the analysis and scoring of *Sabellaria spinulosa* reef characteristics.

Characteristic	Analysis of characteristics
Elevation	A rough estimate of the height of the reef from the video footage, and placement within the following size categories of >10 cm, 5 to 10 cm, 2 to 5 cm and <2 cm high.
Patchiness	Estimated from the video footage as a continuous video if conditions allow, or as a series of camera drops along a transect. Where the latter technique is employed patchiness determined on a site by site basis from the following calculation: Total percentage of *Sabellaria* cover over the whole site x 100 Total number of video drops for the site (i.e. total area surveyed)
Consolidation	Qualitative description of the nature of consolidation of the reef derived from the video footage and supported by grab sampling where appropriate.
Density	Qualitative description of the nature of the density derived from the video footage and supported by grab sampling[a].

[a] If following on-board review of the DDV footage an Annex I habitat could be confirmed at a location, sampling was limited to DDV only, and a representative benthic grab sample was not taken.

Table 2.3: Range of figures which could be used as a measure of 'reefiness' (based on Gubbay, 2007 and Limpenny *et al*., 2010).

Measure of 'reefiness'	Not a reef	Low	Medium	High
Elevation (average tube height, cm)	<2	2 to 5	5 to 10	>10
Patchiness (% cover)	<10	10 to 20	20 to 30	>30
Consolidation	<5 on Limpenny scale	5 on Limpenny scale. Stones joined by tubes which overlap	Upright *Sabellaria* including concretion of substrata	Intertwined matrix of upright *Sabellaria* tubes
Density (maximum per m^2)	<500	500-1,700	1,700-3,500	>3,500
Area (m^2)	<25	25 to 10,000	10,000 to 1,000,000	>1,000,000

3. Desktop review

3.1.1.1 As discussed in section 2.1, two study areas were defined; the southern North Sea benthic ecology study area and the Hornsea Three benthic ecology study area (Figure 1.1).

3.1.1.2 There has been a long history of broadscale benthic studies in the southern North Sea benthic ecology study area, and the relationships between sea temperature, primary productivity, hydrographic and sediment conditions with the benthic faunal communities are well understood. Broadscale predictive mapping of seabed habitats undertaken by the EUSeaMap 2016 project also covers the southern North Sea benthic ecology study area; this dataset draws on a variety of benthic and water column environmental datasets, including sediment types, depth, turbidity and tidal current flow to classify and map the dominant seabed and water column features. Existing desktop data for the Hornsea Three benthic ecology study area is generally limited to the Humber REC and HADA MAREA data and biotope maps. Data sources are available for the Natura 2000 sites present within the southern North Sea benthic ecology study area; while they outline broad habitat types the detail on the biotopes present is generally limited, plus the data cover relatively discrete locations compared to the Humber REC and HADA MAREA biotope maps.

3.1.2 Southern North Sea benthic ecology study area

Intertidal benthic ecology

3.1.2.1 The chalk and flint shores of north Norfolk represent one of the few coastal outcrops of bedrock in eastern England and are considered a rare habitat in northwest Europe (Covey, 1998). Chalk shores also occur at Flamborough Head in Yorkshire and on the Thanet coast in Kent, though the reef at North Norfolk is thought to be the longest, with a length of approximately 30 km (Spray and Watson, 2011).

3.1.2.2 The coast between Hunstanton and Weybourne, in North Norfolk, includes sand dunes, mobile shingle beaches, spits, intertidal mud and saltmarsh habitats (DTI, 2002), while the coastline immediately east of Weybourne comprises unstable, eroding cliffs of glacial till over a chalk base (Warwick Energy, 2009). While areas of exposed chalk are present in the subtidal zone between Cley and Overstrand (Spray and Watson, 2011a and 2011b; Watson, 2012), the only areas of chalk bedrock within the intertidal zone are present between Sheringham and West Runton, in the form of isolated stretches which extend into the subtidal zone. These intertidal chalk features represent the only areas of natural rocky substrate above the Mean Low Water Spring (MLWS) in the region (Covey, 1998).

Subtidal benthic ecology

3.1.2.3 The SeaZone HydroSpatial data indicated a broadly homogeneous area of sand in the westernmost half of the former Hornsea Zone grading into slightly gravelly sand and gravelly sand in the southern and north eastern parts of Hornsea Project Two array area, respectively (Figure 3.1). The eastern area of the former Hornsea Zone, including the Hornsea Three array area, generally comprised coarser sandy sediment compared to the western half, with extensive areas of gravelly sand and sandy gravel. Small sections of slightly gravelly sand were also present in the eastern end of the former Hornsea Zone. Distribution of muddy sand was limited to two relatively small areas; a narrow section along the northern margin of the Hornsea Three array area and a central ribbon in the very eastern part of the former Hornsea Zone, including the Hornsea Three array area. In the deeper water, immediately to the north of the former Hornsea Zone, was an area of sediment dominated by muddy sand. In comparison, a large swathe of sediment in the west was dominated by much coarser sediments (i.e. gravels and sandy gravels), particularly towards the westernmost and landward extents of the southern North Sea benthic ecology study area.

3.1.2.4 Similar patterns of substrate were evident in the broad scale habitat showing EUSeaMap data (JNCC, 2016). This data drew on a variety of benthic and water column environmental datasets, including sediment types, depth, turbidity and tidal current flow to classify and map the dominant seabed and water column features. As shown in Figure 3.2 this data indicates that the wider southern North Sea benthic ecology study area to the west of the former Hornsea Zone and just to the west of Hornsea Three array area comprised predominantly circalittoral fine sand or circalittoral muddy sand. The south eastern and northern parts of the Hornsea Three array area and a swathe west of the Hornsea Three array area exhibited coarser sediments, consisting of circalittoral or infralittoral coarse sediment. The greater part of the western southern North Sea benthic ecology study area was shown to mainly comprise infralittoral coarse sediment, reflecting the sediment distributions in the SeaZone HydroSpatial data.

3.1.2.5 The habitats along the Hornsea Three offshore cable corridor were broadly determined to be similar to those within the former Hornsea Zone. The EUSeaMap data indicated that circalittoral/infralittoral fine sands and in particular infralittoral/circalittoral coarse sediments dominated much of the Hornsea Three offshore cable corridor. An area of bedrock, primarily moderate energy infralittoral rock with small regions of high energy infralittoral rock and moderate energy circalittoral rock, was evident just offshore of North Norfolk, within the Hornsea Three offshore cable corridor, in the EUSeaMap data. This characterisation broadly corresponded with subtidal chalk beds which are a qualifying habitat for the Cromer Shoal Chalk Beds MCZ; see paragraph 3.1.3.47.

3.1.2.6 The community assemblages of the southern North Sea benthic ecology study area correspond with the shallow water, southern North Sea ‘infralittoral étage’ as described by Glémarec (1973), which extends from the inflows of the English Channel to the northern flanks of the Dogger Bank. The shallow, well-mixed waters of the southern North Sea benthic ecology study area, allow for the majority of the products of primary (phytoplankton) production to reach the sea floor for consumption by benthic assemblages, leading to comparatively high benthic biomass (Künitzer *et al.*, 1992). Künitzer *et al.* (1992) described the northern part of the southern North Sea benthic ecology study area (i.e. the surrounds of the Hornsea Three benthic ecology study area) as a transitory area between two distinctive infaunal community assemblages corresponding to the southern and central North Sea. The shallow (<30 m), coarse sediments of the southern North Sea assemblage (coinciding with the southern part of the Hornsea Three benthic ecology study area) were found to be characterised by white catworm *Nephtys cirrosa*, the sea potato *Echinocardium cordatum* and the amphipod *Urothoe poseidonis*. The other principle assemblage of infauna, which was found to be associated with deep water (50 to 70 m; coinciding with the northern part of the Hornsea Three benthic ecology study area) and fine sand substrates, supported communities of the polychaetes *Ophelia borealis* and *Nephtys longosetosa* (Rees *et al.*, 1999).

3.1.2.7 The epibenthic components of the southern North Sea benthic assemblage have been historically sampled by trawl and camera surveys (Dyer *et al*., 1982; Jennings *et al*., 1999; Rees *et al*., 1999; Callaway *et al*., 2002). Detailed analyses of NSBP data (Rees *et al*., 2007) identified that the northern part of the southern North Sea benthic ecology study area (i.e. the area encompassing the Hornsea Three benthic ecology study area) corresponds with a transitional area encompassing three or four different mobile epibenthic groupings which are typical of southern North Sea assemblages. Common species included brown shrimp *Crangon crangon* and *C. allmani*, hermit crab *Pagurus bernhardus*, flying crab *Liocarcinus holsatus*, masked crab *Corytes cassivelaunus*, common starfish *Asterias rubens*, burrowing starfish *Astropecten irregularis*, brittlestars *Ophiura ophiura* and *O. albida*, and the green urchin *Psammechinus miliaris*; together with non-commercial fish species such as solenette *Buglossidium luteum*, dab *Limanda limanda* and dragonet *Callionymus* spp.

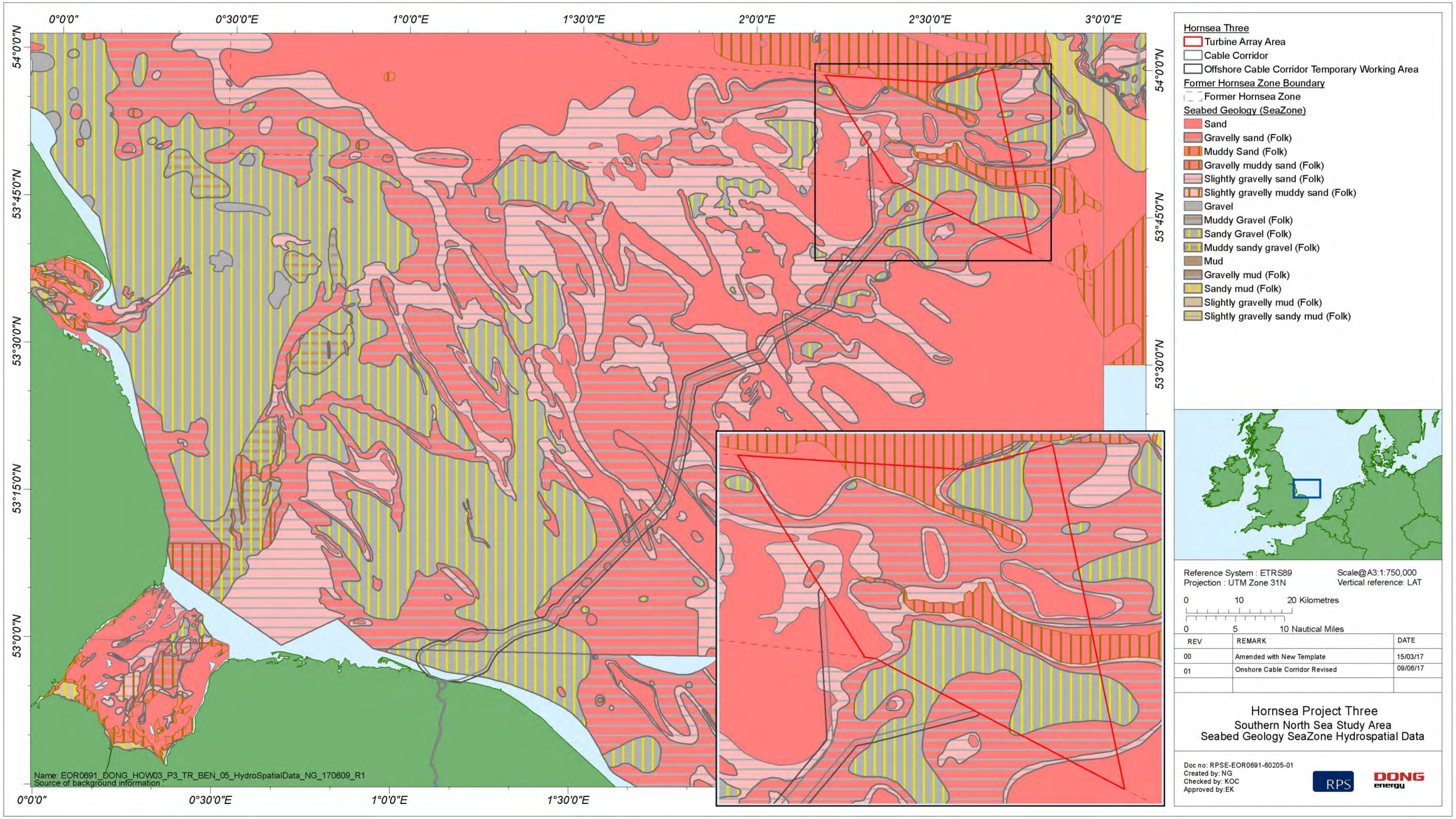

Figure 3.1: Hornsea Three subtidal benthic survey locations and SeaZone HydroSpatial sediment data for the southern North Sea benthic ecology study area.

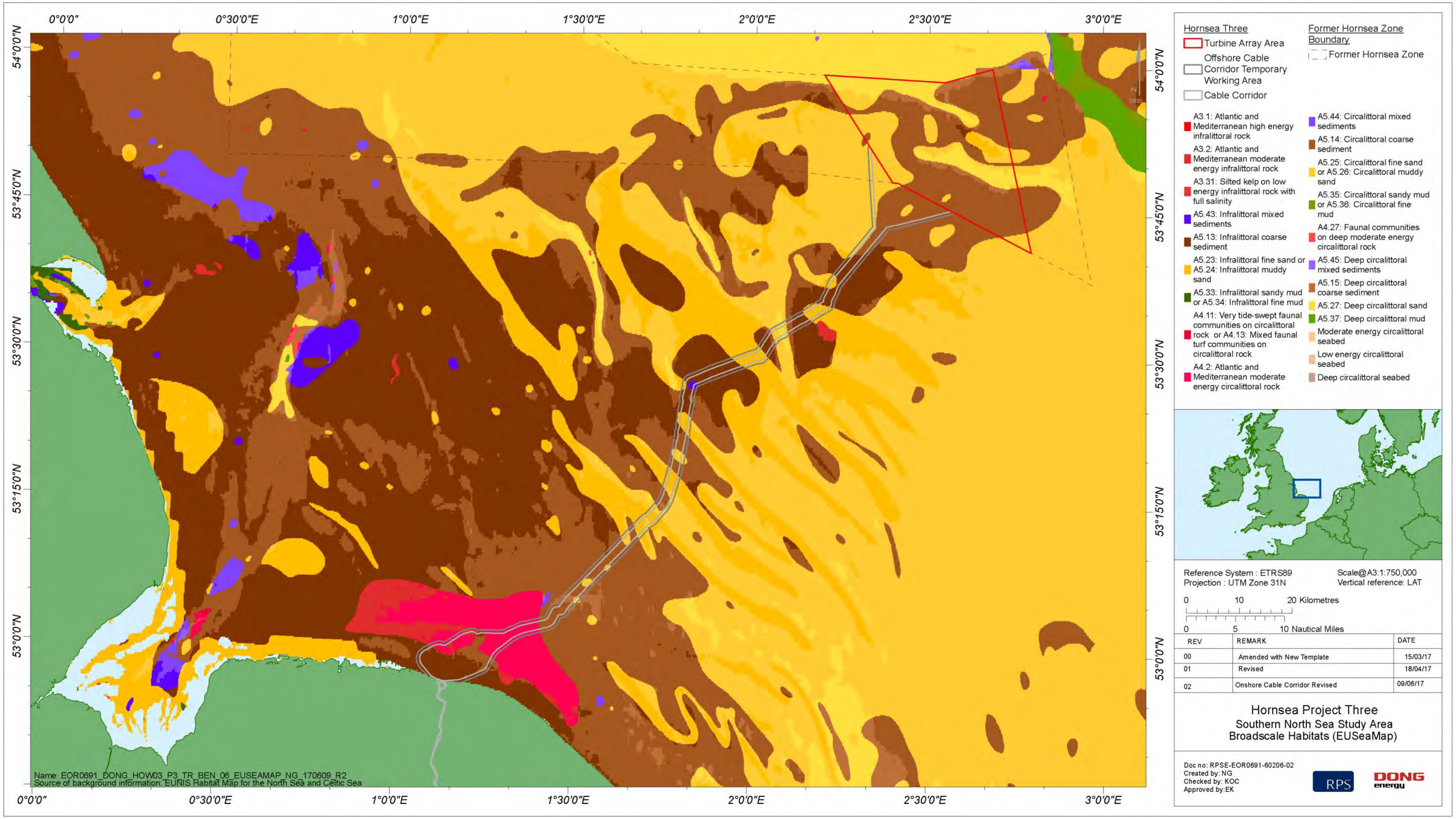

Figure 3.2: Hornsea Three subtidal benthic survey locations and EUSeaMap (2016) predicted EUNIS habitats for the southern North Sea benthic ecology study area.

3.1.2.8 Sessile colonial fauna have been found to play only a minor role in the southern North Sea benthic ecology study area. Both Rees *et al*. (1999) and Jennings *et al*. (1999) distinguished a 'southern' group of relatively sparse sessile epifauna characteristic of sandy substrata, with limited scope for the establishment of attaching and encrusting species. Sessile epifauna characterising the 'southern' North Sea (benthic ecology study area) included the hydroids *Hydractinia echinata*, *Hydrallmania falcata* and *Sertularia argentea*, the bryozoans *F. foliacea* and *Electra pilosa* and the soft coral *A. digitatum* (Jennings *et al*., 1999). Within inshore areas the diversity of epifauna is similarly low with the area characterised by very few species of echinoderms, which together with crustaceans, were found to account for 39% and 40%, respectively, of the overall abundance of epibenthic species (from epibenthic beam trawls) in the REC area (Tappin *et al*., 2011). The biomass of fauna from the REC epibenthic trawls was also dominated by echinoderms and miscellaneous taxa (mostly the bryozoans *A. diaphanum* and *F. foliacea* and the soft coral *A. digitatum*).

3.1.2.9 The UK Benthos Database provides data from benthic studies of the North Sea oil/gas fields within the southern North Sea benthic ecology study area (to the north of the Hornsea Three benthic ecology study area). Analysis of these data and the allocation of biotope codes, based on the UK Marine Habitat Classification (Connor *et al*., 2004), gives an overview of biotopes occurring in the sediments characteristic of the area to the north of the Hornsea Three benthic ecology study area (EMU, 2012a). The main habitats identified and associated assigned biotopes are presented in Table 3.1.

3.1.2.10 Data from benthic sampling programmes coordinated under the NSBP and the site assessments for the North Norfolk Sandbanks and Saturn Reef SCI and the UK Dogger Bank SCI confirm the widespread nature of the habitat types presented in Table 3.1 in the southern North Sea benthic ecology study area (EMU, 2012a). Similar biotopes have also been previously found in the region during benthic studies at aggregate production Area 408 located approximately 10 km to the south of Hornsea Three (Newell *et al*., 2002) (Figure 1.1). This study identified an assemblage of species generally conforming to shallow water mobile sand biotopes although some species were more typical of circalittoral mixed sediments. Conspicuous taxa included the polychaetes *O. borealis*, *Lagis koreni*, *S. bombyx*, *Exogone hebes*, *Pisione remota*, *Phyllodoce maculata*, *Eteone longa*, *Notomastus* spp., *Pholoe inornata* and S. *armiger* together with the amphipods *Bathyporeia* spp. and the brittlestar *Ophiura affinis*. The acorn barnacle *Balanus crenatus* was found attached to gravel and larger stones.

3.1.2.11 Other benthic surveys to the south of the former Hornsea Zone for the North Sea SEA surveys (DTI 2001a; 2001b) found well-sorted medium or fine sands with a variety of ripple features, with quantities of eroded shell in some areas. Mobile epibenthic fauna were sparse and included hermit crabs (Paguridae) and brittlestars together with dab and gobies.

Table 3.1: Principle EUNIS habitats and the corresponding UK Marine Habitat Classification biotopes in the southern North Sea study area (Figure 1.1).

Principal EUNIS Habitat Type EUSeaMap (2016)	UK Benthos Database Biotope code derived from Connor *et al*. (2004)
A5.27: Deep Circalittoral Sand	SS.SSa.CFiSa.EpusOborApri (*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand). SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand). SS.SSa.IMuSa.EcorEns (*Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand).
A5.25: Circalittoral fine sand or A5.26: Circalittoral muddy sand	SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand). SS.SSa.CFiSa.EpusOborApri (*Echinocyamus pusillus*, *Ophelia borealis* and Abra *prismatica* in circalittoral fine sand). SS.SSa.CMuSa (Circalittoral muddy sand).
A5.14: Circalittoral coarse sediment	SS.SCS.ICS (Infralittoral coarse sediment). SS.SCS.ICS.MoeVen (*Moerella* spp. with venerid bivalves in infralittoral gravelly sand). SS.SCS.ICS.CumCset (Cumaceans and *Chaetozone setosa* in infralittoral gravelly sand). SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand).
A5.15: Deep circalittoral coarse sediment	SS.SMx.OMx.PoVen (Polychaete-rich deep *Venus* community in offshore mixed sediments).

Annex I habitats

3.1.2.12 *Sabellaria spinulosa* biotopes have been found across a broad area within the southern North Sea benthic ecology study area, as shown by the Humber REC data (Tappin *et al*., 2011; Figure 3.4). The Humber REC data, which is discussed further in section 3.1.3, indicated that areas of *S. spinulosa* was distributed extensively to the south west of the area characterised by the data, particularly offshore of the Wash (Tappin *et al*., 2011; see Figure 3.4). Surveys undertaken for other offshore wind farms in the vicinity of Hornsea Three, namely the Triton Knoll, Dudgeon East, Sheringham Shoal and Race Bank offshore wind farms (Figure 1.1), also identified aggregations of *S. spinulosa* at numerous locations, although generally these were not identified as having potential for Annex I *S. spinulosa* reefs.

3.1.3 Hornsea Three Benthic Ecology Study Area

Intertidal benthic ecology

3.1.3.1 Desktop information relating to habitats present at the Hornsea Three landfall site at Weybourne and Salthouse is sparse and generally limited to information in Environmental Statements for the Dudgeon and Sheringham Shoal offshore wind farms. The landfall site for the Sheringham Shoal offshore wind farm is located at Weybourne, within the proposed Hornsea Three offshore cable corridor at the landfall site. The survey for the Sheringham Shoal offshore wind farm landfall showed that the intertidal zone comprised a shingle beach backed by a steep shingle bank. The ecology of the intertidal zone was described as being barren or highly impoverished, on account of the high energy substrate being unsuitable for inhabitation by both infauna and epifauna (Scira Offshore Energy Ltd, 2006). No intertidal survey was undertaken at the Dudgeon offshore wind farm landfall site at Weybourne, on account of the barren nature of the shore and limited potential for significant impacts in the area resulting from the Dudgeon offshore wind farm development (Warwick Energy, 2009).

Subtidal benthic ecology

Nearshore section of the Hornsea Three benthic ecology study area

3.1.3.2 The following description (paragraphs 3.1.3.3 to 3.1.3.6) of the inshore area of the Hornsea Three offshore cable corridor and surrounding seabed within the Cromer Shoal Chalk Beds MCZ is based solely on diver surveys. It should be noted that the information represents very limited areas of seabed (based on 111 dives from 2009 to 2010, Spray and Watson (2011a); and 53 dives in 2012, Watson (2012)), and that the diver surveys may have focused on the more prominent features of the benthic environment. At time of preparation of the PEIR, no project-specific data has been collected to supplement this data, however a site-specific survey is scheduled for Quarter 2 of 2017 which will further characterise this area and subsequently inform the environmental statement.

3.1.3.3 Diving surveys have been conducted by Seasearch East on several occasions to investigate the chalk habitat off the North Norfolk coast (Spray and Watson, 2011a and 2011b; Watson, 2012). A diving survey campaign was undertaken in 2012 to specifically investigate the area encompassed by the Cromer Shoal Chalk beds MCZ on behalf of the Marine Conservation Society (MCS). Recorded taxa include sponges; hydroids; anemones; worms and tubeworms; barnacles, crabs; shrimp; lobsters; cephalopods; sea slugs, mussels; whelks; bryozoans; starfish; urchins; brittlestars; sea squirts; seaweed; and a variety of fishes (Watson, 2012).The area within the MCZ is subjected to high energy marine processes responsible for the complex chalk features which include gullies, overhangs and arches. The chalk features are present amongst exposed clay outcroppings at the eastern and western extents of the MCZ, while areas of sands, gravels, cobbles and boulders occur with variable extents around and within the areas of chalk and clay (Spray and Watson, 2011a and 2011b).

3.1.3.4 Dive surveys off the coast of Cley, just west of the Hornsea Three offshore cable corridor, revealed nearshore sediments to comprise a continuation of shingle from the beach out to approximately 50 m, with consistent sandy seabed beyond this, out to 300 m from shore, where substantial clay ridges were found. These features, which were inhabited by piddock bivalves Pholadidae, common lobster *Homarus gammarus* and edible crab *Cancer pagurus*, gave way to flatter chalk grounds to the east (Spray and Watson, 2011a). Coinciding with the Hornsea Three offshore cable corridor, between Salthouse and Weybourne, areas of muddy very fine sand were present, with populations of lugworm *Arenicola marina* and the sand mason worm *Lanice conchilega*. Low-lying chalk was observed in the form of outcrops separated by mobile sediments; these hard surfaces were densely covered in hydroids which supported a community of nudibranch sea slugs. Clay was present in this area as large slabs with little associated biodiversity (Watson, 2012).

3.1.3.5 Dive surveys east of the Hornsea Three offshore cable corridor and over the central part of the MCZ, between Sheringham and East Runton, revealed the most prominent chalk features of the MCZ dive surveys. Chalk was found to be relatively flat in inshore waters, while occurrences of gullies and walls increased offshore, with some features as high as 3 m compared to the surrounding seabed between 200 and 400 m offshore. The horizontal hard surfaces were covered in mixed red and brown macroalgae communities while the vertical surfaces comprised Porifera sponges and ascidian sea squirts. Inverted horizontal surfaces were present in overhangs and arches which supported fish and common lobster (Watson, 2012). Approximately 400 to 500 m from shore, where the topography is particularly rugged and the chalk ridges and gullies are largest, a step in the chalk seabed bed drops by approximately 2 m, to a lower plateau of chalk covered with flint and chalk boulders (Spray and Watson, 2011a).

3.1.3.6 Further east, between Sheringham and West Runton the seabed comprises moderately rugged terrain, with regular gullies of approximately 1 m in height amongst flatter areas of chalk substrate, with frequent occurrences of boulders encrusted by sponges. The flatter plateau of chalk continues east to Cromer, along with surficial distributions of coarse sediments, largely comprising cobbles and boulders encrusted with sponges and hydroids. The exposed chalk varied little in height and was absent of the more prominent features which were prevalent in the west (Spray and Watson, 2011a). In the southeast of the MCZ area, adjacent to Overstrand, small chalk gullies were evident amongst areas of sand, where small cuttlefish, shore crabs and brown shrimp were observed. The plain of exposed clay was also recorded here, with associated communities of hydroids and piddock bivalves (Watson, 2012). Waters off the coast of Trimingham showed similar seabed conditions, with areas of mobile sand, raised clay beds and isolated chalk exposures comprising with narrow gullies and maximum heights of approximately 1 m. The area of chalk at Trimingham was considered by Spray and Watson (2011a) to be the south eastern boundary of the regular chalk habitat.

3.1.3.7 The Cromer Shoal Chalk Beds MCZ, which came into force on 29 January 2016 (Defra, 2016), lies approximately 200 m from the low water mark of the north Norfolk coast and extends 10 km out to sea in waters of up to 25 m depth (Defra, 2015). The chalk and flint shores of north Norfolk represent one of the few coastal outcrops of bedrock in eastern England and are considered a rare habitat in northwest Europe (Covey, 1998).Off the east coast of England, notable areas of chalk shores occur at Flamborough Head in Yorkshire and on the Thanet coast in Kent, though the reef at North Norfolk is thought to be the longest, with a length of approximately 30 km (Spray and Watson, 2011).

3.1.3.8 A dedicated vessel-based seabed survey was undertaken by Cefas between 2012 and 2014 at the Cromer Shoal Chalk Beds MCZ to provide direct evidence of the presence and extent of the broadscale habitats and habitat FOCI (Features of Conservation Importance) that had been detailed in the original Cromer Shoal Chalk Beds rMCZ Site Assessment Document (SAD; Net Gain, 2011). The geophysical survey covered 78% of the MCZ and the environmental sampling survey comprised 196 DDV locations and 70 grab sample locations (Figure 3.3). A total of 358 infaunal taxa and 146 epifaunal taxa were recorded during the environmental sampling campaign. An unrelated survey (George *et al*., 1995), previously recorded 380 species of macroinvertebrates from 14 locations in the nearshore waters off the coast of north Norfolk, where infaunal and epifaunal community assemblages were found to change substantially on an annual basis.

3.1.3.9 The Cefas survey undertaken in 2012 to 2014 determined that the FOCI habitat subtidal chalk covered 12% of the area surveyed which was present in the shallowest reaches of the MCZ, adjacent to the coastline, while the EUNIS habitat ‘A5.1 Subtidal coarse sediment’ was the most prevalent habitat and accounted for 60% of the mapped area; this was generally found further offshore (Table 3.2). The FOCI habitat ‘Subtidal Sands and Gravels’ which was described in the SAD (Net Gain, 2011) was confirmed present (Defra, 2015) with an extent of 167 km^2 and covered a total of 67% of the mapped area; however this habitat was not recommended for designation or included in the designation. The protected habitat features of the Cromer Shoal Chalk Beds MCZ are discussed in section 3.1.3.47 and listed in Table 3.2. The full results and methodology of the Cefas and JNCC survey are detailed in Defra (2015).

<u>Offhsore section of the Hornsea Three benthic ecology study area</u>

3.1.3.10 As discussed in section 2.3, the Humber REC and the HADA MAREA are key studies which provide data on the Hornsea Three benthic ecology study area. The data and associated biotope maps coincide with the Hornsea Three offshore cable corridor (the offshore half of the Hornsea Three offshore cable corridor in the Humber REC; inshore section of the Hornsea Three offshore cable corridor in the HADA MAREA data) and, in the case of the Humber REC, the southwestern corner of the Hornsea Three array area and the southern edge of the former Hornsea Zone (see Figure 3.2). It should be noted that there was no overlap in data between the HADA MAREA dataset and the REC dataset on the Hornsea Three offshore cable corridor, and therefore direct comparisons could not be made between these two datasets within the Hornsea Three benthic ecology study area.

3.1.3.11 Four main functional groups within the REC study area were identified (Tappin *et al*., 2011): ‘Barnacles, ascidians, and tubiculous polychaetes’; ‘Infaunal polychaetes with burrowing bivalves and amphipods’; ‘*Sabellaria spinulosa* reefs’; and ‘Sparse fauna’. The biotope map produced for the REC, as shown in Figure 3.3, recorded the EUNIS habitat A5.25(4) SS.SSa.CFiSa.PoBivAmp ‘Infaunal polychaetes with burrowing bivalves and amphipods in circalittoral fine sand’ (hereafter referred to as PoBivAmp) across much of the east of the REC study area, coinciding with the area encompassing the southern section of the central former Hornsea Zone and the offshore half of the Hornsea Three offshore cable corridor. A similar biotope, A5.27(4) SS.SSa.OSaPoBivAmp ‘Infaunal polychaetes with burrowing bivalves and amphipods in deep circalittoral sand’ was recorded in the Hornsea Three array area, together with a mixed sediment variant of the biotope, A5.44(7) SS.SMx.CMx.PoBivAmp ‘Infaunal polychaetes with burrowing bivalves and amphipods in circalittoral mixed sediments’. The REC data also recorded A5.55 SS.SMx.CMx ‘Circalittoral mixed sediment’, while the biotope A5.611 SS.SBR.Sabspin ‘*Sabellaria spinulosa* on stable circalittoral mixed sediment’ was assigned to the very north-eastern extent of the REC area, coinciding with the centre of the Hornsea Three array area. (Figure 3.4).

3.1.3.12 The HADA MAREA data shows that sediments in the vicinity of the very western end of the Hornsea Three offshore cable corridor are dominated by gravels and small amounts of sand (ERM, 2012). SS.SCS.CCS.PomB ‘*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles’ was recorded in the inshore waters in the very south of the HADA MAREA extent out to approximately 20 km offshore, which coincides with the western portion of the Hornsea Three offshore cable corridor. The SS.SCS.CCS.PomB biotope reflects the functional group ‘Barnacles, ascidians, and tubiculous polychaetes’ identified by the REC data interpretation, and was determined to be one of the most widespread biotopes in shallower areas, while SS.SSa.IFiSa.NcirBat ‘*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand’ (hereafter referred to as NcirBat) was recorded as being the most dominant biotope in offshore waters. The sandy biotope SS.SSa.IFiSa.IMoSa ‘Infralittoral mobile clean sand with sparse fauna’ was recorded from approximately 15 km to 30 km off the North Norfolk coast and this was synonymous with the ‘Sparse fauna’ functional group identified by the REC data. Another sandy biotope, SS.SSa.IFiSa.TbAmPo ‘Semi-permanent tube-building amphipods and polychaetes in sublittoral sand’ was also recorded from approximately 15 km to 30 km off the North Norfolk coast, which broadly reflected the functional described as ‘Infaunal polychaetes with burrowing bivalves and amphipods’ within the REC report.

3.1.3.13 According to HADA MAREA data, species richness was generally lower off the North Norfolk coast in comparison to the greater region covered by the HADA MAREA dataset. The number of taxa was frequently recorded as high as between 100 and 131 in offshore waters adjacent to the Wash and Humber Estuary, while most sampling stations off north Norfolk recorded between 10 and 25 taxa. However minor spatial patterns were evident, with between 25 and 50 species being recorded in the very inshore waters off the coast of north Norfolk, and between 50 and 80 taxa being recorded at a small number of sampling stations approximately 30 km out to sea.

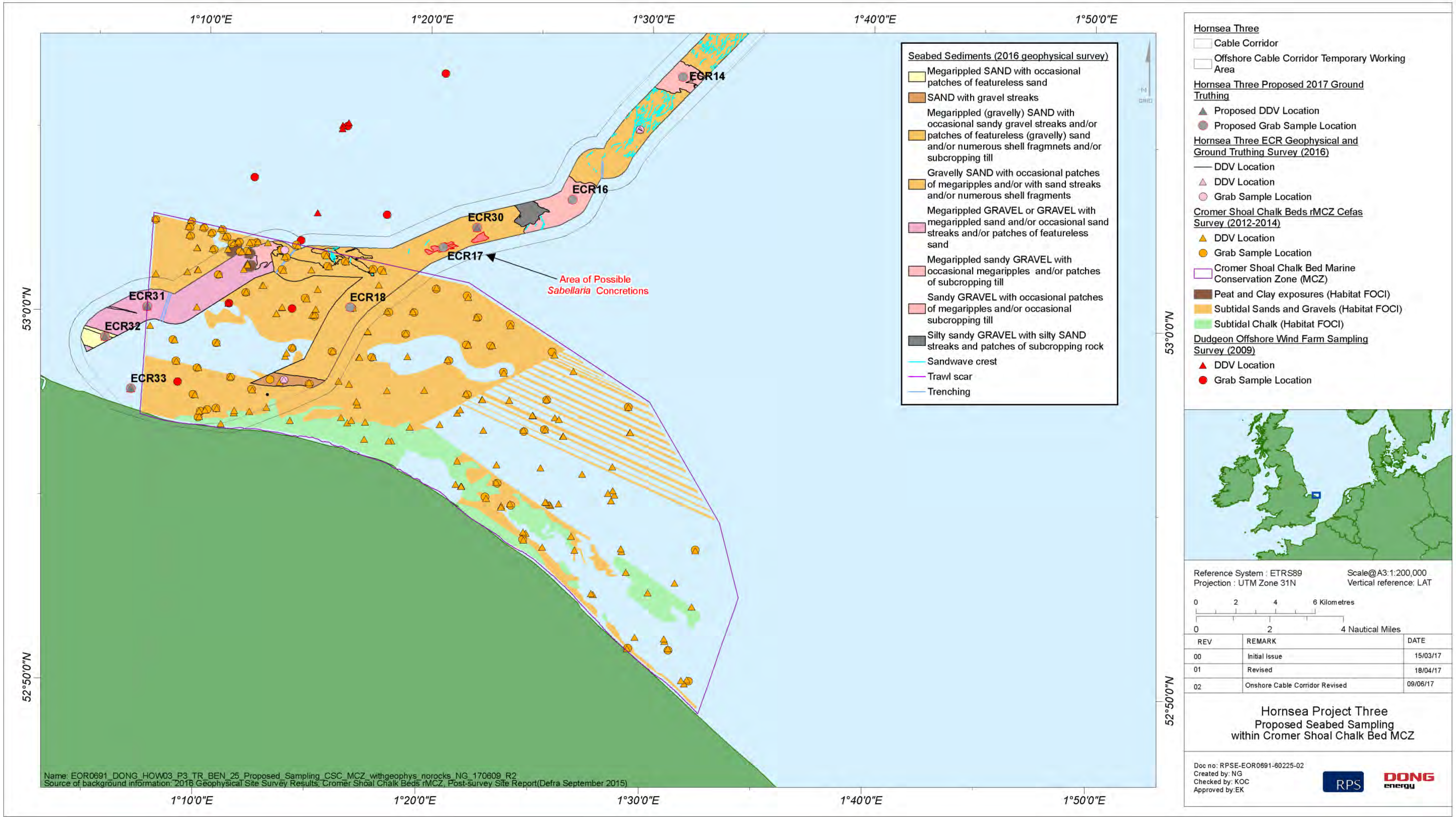

Figure 3.3: Cromer Shoal Chalk Bed MCZ with Cefas geophysical survey data, and site-specific benthic ecology sample locations surveyed in 2016 and proposed for 2017.

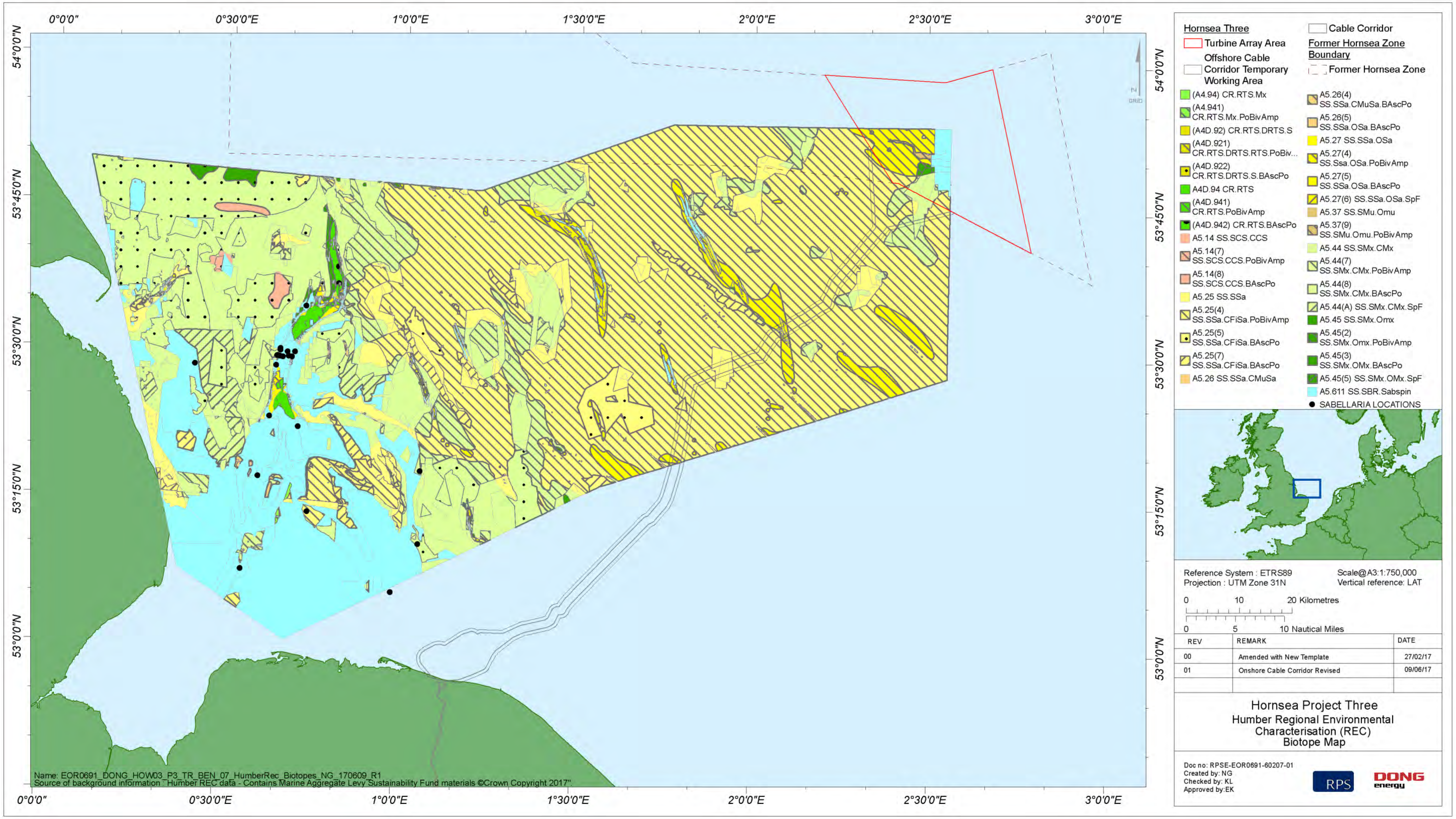

Figure 3.4: Hornsea Three and the Humber Regional Environmental Characterisation (REC) recorded EUNIS biotopes and locations where *Sabellaria* was noted during REC survey.

3.1.3.14 The Humber REC surveys recorded two species classified as nationally rare, the colonial hydroid *Obelia bidentata* and the polychaete *Ophelia bicornis*, and two nationally scarce species of amphipod *Apherusa ovalipes* and *Harpinia laevis*. The only invertebrate listed as 'under threat or decline' by the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) found within the REC study area was the ocean quahog *Arctica islandica*. Four established alien species were identified, the most abundant of these being the American slipper limpet *Crepidula fornicata*. The bivalve *Mya arenaria*, the acorn barnacle *Elminius modestus* and the amphipod *Monocorophium sextonae* were also observed but were not particularly widespread or abundant (Tappin *et al.,* 2011).

3.1.3.15 Natural England and JNCC, in partnership with Cefas, conducted field surveys to investigate the condition of Annex I habitat features within the Haisborough, Hammond and Winterton SCI to assess the present condition of Annex I features and to contribute to the development of a baseline for future long-term monitoring of Annex I feature conditions within the site (Barrio Froján *et al.*, 2013). The presence and broad-scale extent of sandbanks in the SCI was found to coincide with that presented in the Site Assessment Document (JNCC, 2010) with some potential evidence of sandbank mobility (up to 200 m); although overall the sandbanks were concluded to be in a stable condition. Biogenic reef clusters built by *S. spinulosa* were observed, sampled and characterised during the survey. It is likely, however, that their low elevation and high degree of patchiness against a backdrop of unconsolidated mixed sediments prevented the detection of reef at a broad spatial scale on the acquired acoustic side scan data, thus preventing the delineation of any reef feature and the calculation of reef extent.

3.1.3.16 The North Norfolk Sandbanks and Saturn Reef SAC/SCI, which extends from approximately 40 km off the north Norfolk coast out to approximately 110 km offshore, encompasses what is considered to be the most extensive area of offshore linear ridge sandbanks in the UK (JNCC, 2010a), and also coincides with approximately two thirds of the Hornsea Three offshore cable corridor. The sandy sediments support sparse infaunal communities of polychaete worms, isopods, crabs and starfish which are typical of the biotope 'infralittoral mobile clean sand with sparse fauna' (Connor *et al.*, 2004). The site is also designated for *S. spinulosa* reefs, which, along with sandbanks, area primary qualifying feature of the SAC/SCI site.

3.1.3.17 A joint survey by JNCC and Cefas was undertaken in 2013 to develop appropriate management advice given the dynamic nature of both features, and the ephemeral nature of *S. spinulosa* structures (Jenkins *et al*., 2015). Geophysical acquisition, DDV and grab sampling was performed throughout the North Norfolk Sandbanks and Saturn Reef SAC/SCI with two specific objectives: to further investigate the sediments, morphology and faunal communities at the sandbanks; and to identify presence of biogenic reef features, map their extents and characterise the associated faunal communities.

3.1.3.18 Overall six sandbanks were investigated, three of the most inner sandbanks (Leman Bank, Inner Bank and Wells bank), adjacent to central section of Hornsea Three offshore cable corridor, and three of the most offshore sandbanks of the Indefatigables, adjacent to the furthest offshore section of the Hornsea Three offshore cable corridor (see Figure 3.5). Despite the range in distance between the southern and northern extents of the site, the area within the North Norfolk Sandbanks and Saturn Reef SAC/SCI largely comprises sandy sediments and this sediment type is generally consistent throughout the site according to SeaZone HydroSpatial data, EUSeaMap data and the REC data.

3.1.3.19 Sampling on the sandbanks during the Cefas/JNCC survey revealed very subtle differences in the particle size across the profiles of the sandbanks. Sediment comprised medium sand throughout the profiles of both nearshore and offshore sandbank features with no statistically significant differences in mean particle size between the trough, flank or crest of the offshore sandbanks. Only minor, statistically significant differences were observed in particle size between the troughs, flanks and crest in the nearshore sandbanks (Jenkins *et al*., 2015). However the troughs of both nearshore and offshore sandbanks were determined to comprise slightly higher coarse and mud content compared to the flanks and crests.

3.1.3.20 An analysis of the infaunal communities revealed that numbers of taxa and abundances increased with depth throughout the SAC/SCI site, and that species richness was highest in the troughs of the sand banks and lowest on the crests. ANOSIM tests showed significant differences between the infaunal communities of the nearshore (adjacent to central section of the Hornsea Three offshore cable corridor) and offshore sandbanks (adjacent to the furthest offshore section of the Hornsea Three offshore cable corridor), however the difference was small (Global R: 0.2), indicating a substantial overlap in faunal composition between nearshore and offshore communities (Jenkins *et al*., 2015). The apparently small differences in faunal community supports the broad patterns concluded from HADA MAREA and REC datasets for this region, in that biotopes did not vary considerably with distance from the shore (see sections 3.1.3.11 to 3.1.3.14). Statistically significant, but very small (Global R: 0.14), differences were identified in community assemblage between the crest, flank and trough features of the offshore sandbanks, while no such differences were observed for the inner sandbanks (Jenkins *et al*., 2015).

3.1.3.21 The presence of the Saturn *S. spinulosa* biogenic reef within the North Norfolk Sandbanks and Saturn Reef SAC/SCI was first recorded in 2002 (JNCC, 2008), within 100 m of the edge of the Hornsea Three offshore cable corridor. In 2003 the Saturn reef covered an area of approximately 750 m by 500 m and was located between Swarte and Broken Banks on the edge of a small sandbank (BMT Cordah, 2003). Subsequent surveys failed to locate the same reef structure at this location, with bottom trawling or the natural ephemeral nature of the *S. spinulosa* reef proposed as possible factors associated with its apparent disappearance (JNCC, 2010a).

3.1.3.22 However, in 2013, Cefas undertook another survey of the SCI which identified a potential westward migration of the Saturn Reef (originially recorded in the 2003 survey) or, more likely, the loss of the original reef feature and the development of new reef structures, consistent with the ephemeral nature of *S. spinulosa* biogenic structures. The 2013 data show the latest structures to overlap with the proposed Hornsea Three offshore cable corridor (See Figure 3.5).

3.1.3.23 For the investigation into biogenic reef features within the North Norfolk Sandbanks and Saturn Reef SAC/SCI, six survey areas were identified where reefs had previously been recorded. These areas were investigated with high resolution multibeam echosounder, side scan sonar, DDV and Hamon grab sampling. Two of the survey areas were located within the SAC/SCI site, which coincided with the central section of the Hornsea Three offshore cable corridor. Six patches of *S. spinulosa*, with generally 'low reef' quality (according to Gubbay, 2007), were identified and delineated, with areas ranging between 0.004 km^2 and 1.5 km^2 (Jenkins *et al*., 2015); these areas are shown in Figure 3.5, together with the previously known position and extent of the Saturn Reef (indicated by the dark green area adjacent to the proposed DDV survey transect ECR36). This data has revealed a potential westward migration of the Saturn reef (identified in the 2003, as described in paragraph 3.1.3.21) or, more likely, the loss of the original reef feature and the development of a new reef structure, demonstrating to the ephemeral nature of *Sabellaria* aggregations.

3.1.3.24 Areas of known and potential reef were mapped with a precautionary approach to ensure that potential reef areas were captured; as such the delineated boundaries shown in Figure 3.5 should be interpreted as being coarsely indicative and potentially over-representative of *S. spinulosa* extent. These *S. spinulosa* aggregations were considered to be highest quality biogenic features that had been recorded during the 2013 survey (Jenkins *et al*., 2015).

3.1.3.25 Markham's Triangle rMCZ, which coincides with the northeast section of the Hornsea Three array area, is being considered for inclusion in a network of Marine Protected Areas (MPAs) in UK waters to address conservation objectives under the Marine and Coastal Access Act 2009. Markham's Triangle is proposed for two broadscale habitats: subtidal coarse sediment and subtidal sand. Defra undertook surveys to collect evidence in support of the designation of this site in 2012. Grab samples were collected from 50 stations to characterise sediment type and infaunal communities. Video footage and still photographs were also acquired at 21 stations (Defra, 2014).

3.1.3.26 'A5.1 Subtidal coarse sediment' was dominant throughout the Markham's Triangle rMCZ, covering approximately three quarters of the site (Defra, 2014). 'A5.2 Subtidal sand' and 'A5.4 Subtidal mixed sediments' habitats were less prevalent. Mixed sediments were mostly confined to a swathe spanning the northern boundary of the rMCZ area, while bands of sand were found across the central section of the site. See section 4.1.2 for further information on the sediment composition of samples acquired from this survey. See sections 4.1.4.22 to 4.1.4.27 for a high-level multivariate analysis of the benthic communities recorded at Markham's Triangle, in the context of the communities and biotopes recorded in the historic benthic ecology and site-specific surveys in the Hornsea Three benthic ecology study area.

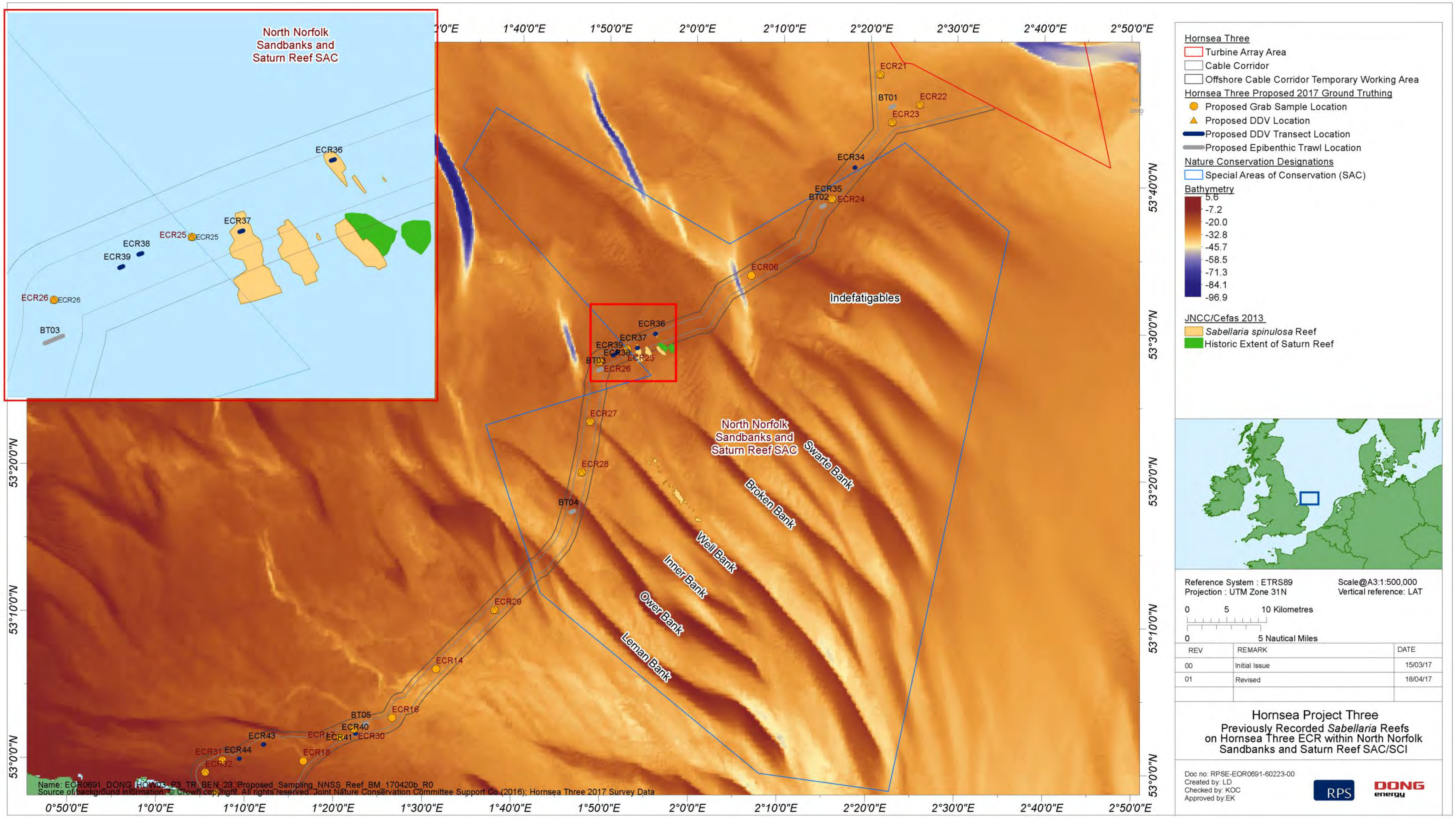

Figure 3.5: The Hornsea Three offshore cable corridor and *Sabellaria* reefs recorded during a survey undertaken by Cefas in 2013. Hornsea Three plan to undertake a benthic ecology survey in 2017 (proposed sampling sites marked on drawing), including sites in proximity to these previously recorded *Sabellaria* reefs.

Nature conservation designations

3.1.3.27 The marine nature conservation designations which fall within the southern North Sea benthic ecology study area, as defined in section 2.1, comprise:

- International designations - Natura 2000 designations (i.e. SACs and SCIs; see Figure 3.6) and Ramsar Sites;
- National designations – MCZs, SSSIs and NNRs;
- National proposed designations – rMCZs; and
- Local designations – LNRs.

3.1.3.28 Designated sites that coincide with the Hornsea Three potential Zone of Influence (ZoI) are described in the context of the baseline characterisation of the southern North Sea benthic ecology area. Designated sites that are considered to fall within the potential ZoI of Hornsea Three comprise the following:

- Sites with relevant benthic ecology features which overlap with Hornsea Three;
- Sites with relevant benthic ecology features which are located within one tidal excursion (approximately 12 km) of the Hornsea Three array area and /or offshore cable corridor.

3.1.3.29 This broad screening of designated sites will be taken forward to the EIA report (see volume 2, chapter 2: Benthic Ecology) where they will be further screened, based on the results of the marine processes assessment (volume 2, chapter 1: Marine Processes), or fully assessed for the effects of Hornsea Three on the relevant benthic ecology receptors that are protected/recommended for each site.

3.1.3.30 All designation sites which fall within the Hornsea Three ZoI are shown in Figure 3.6.

International designations

Natura 2000 sites

3.1.3.31 Of the 12 Natura 2000 sites and associated benthic habitats which are within the southern North Sea benthic ecology study area, four SACs/SCIs are located partly within the ZoI of Hornsea Three. A fifth site, Klaverbank SCI, is also partly within the ZoI of Hornsea Three, but is located within Dutch juristictional waters. These sites are listed and described in detail below:

- The Wash and North Norfolk Coast SAC;
- North Norfolk Coast SAC;
- Haisborough, Hammond and Winterton SCI;
- North Norfolk Sandbanks and Saturn Reef SAC/SCI; and
- Klaverbank SCI.

The Wash and North Norfolk Coast SAC

3.1.3.32 The nearshore end of the Hornsea Three offshore cable corridor coincides with the very eastern extent of the Wash and North Norfolk Coast SAC (Figure 3.6). This site is designated for Annex I habitats 'sandbanks which are slightly covered by seawater all the time', 'mudflats and sandflats not covered by seawater at low tide', 'large shallow inlets and bays', 'reefs' and '*Salicornia* and other annuals colonizing mud and sand' which are the primary reasons for the designation of the site.

Norfolk Coast SAC

3.1.3.33 The nearshore end of the Hornsea Three offshore cable corridor crosses the Norfolk Coast SAC (Figure 3.6), which is designated for Annex I habitats 'coastal lagoons', 'perennial vegetation of stony banks', 'Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*)', embryonic shifting dunes', 'shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes')', fixed coastal dunes with herbaceous vegetation ('grey dunes')' and 'humid dune slacks' which are the primary reasons for the designation of the site. The site is important for the 'coastal lagoons' habitat, which is a priority feature of the site, as it is relatively uncommon in the UK. The North Norfolk SAC was specifically designated for percolation lagoons, which are above the MLWS mark and separated from the sea by shingle banks, but are maintained by percolation of seawater through the banks and by over-topping during weather events.

Haisborough, Hammond and Winterton SCI

3.1.3.34 A proportion of the nearshore subtidal part of the Hornsea Three offshore cable corridor is located within 12 km of this SCI (Figure 3.6). This is designated for Annex I habitats 'sandbanks which are slightly covered by seawater all the time' and 'reefs', which are the primary reasons for the designation of the site.

North Norfolk Sandbanks and Saturn Reef SAC/SCI

3.1.3.35 The North Norfolk Sandbanks and Saturn Reef SCI coincides with part of the central and seaward end of the Hornsea Three offshore cable corridor (Figure 3.4) and has been proposed for designation for the Annex I habitats 'sandbanks which are slightly covered by sea water all the time' and 'reefs', which are primary reasons for the designation of the site.

Klaverbank SCI

3.1.3.36 The Klaverbank SCI is 11 km from the Hornsea Three array area, within the Dutch jurisdiction. This site is designated for Annex I 'reefs', which is the primary reason for the designation of the site. It also protects the grey seal *Halichoerus grypus*, common seal *Phoca vitulina* and harbour porpoise *Phocoena phocoena*. The macrobenthic communities of Klaverbank are considered to be highly diverse and it is reported that 44% of the species in the Dutch EEZ are endemic to this area (Net gain, 2011).

Ramsar Sites

3.1.3.37 Ramsar sites are designated under the Ramsar Convention (The Convention on Wetlands of International Importance) and UK Government policy is to afford Ramsar sites the same level of protection as that provided for Natura 2000 sites. In the UK, many Ramsar sites have statutory underpinning as SSSIs.

3.1.3.38 Within the southern North Sea benthic ecology study area a total of 18 Ramsar sites have been identified, however, of these only North Norfolk Coast Ramsar site is within the Hornsea Three benthic ecology study area. See the description of the North Norfolk Coast SSSI in paragraph 3.1.3.39 for further information.

National designations

SSSIs

3.1.3.39 Under the Wildlife and Countryside Act 1981 (amended 1985) the UK government has a duty to notify as an SSSI any land which in its opinion is of special interest by reason of any of its flora, fauna, geological or physiographical features. Natural England has responsibility for identifying and protecting the SSSIs in England.

3.1.3.40 A total of 58 SSSIs are located within the southern North Sea benthic ecology study area, however, only 23 have marine components seaward of MHWS listed in their citations). The remainder are either important for habitats such as sand dunes and saltmarsh located landward of MHWS or are important in geological terms and are therefore not considered within this benthic ecology characterisation. Of the SSSIs with marine components, only one is in close proximity to Hornsea Three benthic ecology study area (Figure 3.6); the North Norfolk Coast SSSI.

North Norfolk Coast SSSI

3.1.3.41 The Hornsea Three offshore cable corridor landfall is 54 m east of this site, which consists primarily of intertidal sands and muds, saltmarshes, shingle banks and sand dunes throughout 40 km of coastline. There are also extensive areas of brackish lagoons, reedbeds and grazing marshes. The SSSI is a composite site comprising two NNRs at Scolt Head and Holkham, plus the former separate SSSIs at Holme Dunes, Thornham Marshes, Titchwell Marshes, Brancaster Manor, Stiffkey Saltmarshes, Morston Saltmarshes, Blakeney Point, Cley and Salthouse Marshes and several substantial additions. Scolt Head, Holkham, Blakeney Point, Cley and Salthouse Marshes are recognised as Ramsar wetland sites and are included in the United Nations Educational, Scientific and Cultural Organization (UNESCO) list of Biosphere Reserves. This designation legally underpins the North Norfolk Coast SAC and Ramsar designations.

NNRs

3.1.3.42 A total of 21 NNRs with benthic components (predominantly intertidal features) are located within the southern North Sea benthic ecology study area. However, only three of these are considered to potentially be within the Hornsea Three ZoI (in particular the landfall of the Hornsea Three offshore cable corridor). These NNRs are presented below:

- Scolt Head Island;
- Holkam; and
- Blakeney.

3.1.3.43 All of these NNRs are coastal reserves which are important for a variety of intertidal and terrestrial habitats including sand and mud flats and dunes. These are grouped within the North Norfolk Coast SSSI, which is adjacent to the Hornsea Three landfall (Figure 3.6).

3.1.3.44 Increased SSC is considered to be the only impact that may result from Hornsea Three that may affect the above NNRs, SSSI and Ramsar site. The benthic ecology receptors (i.e. intertidal sands and muds, shingle vegetation, saltmarsh and sand dunes) flats are not considered to to be susceptible to increased SSC. Furthermore, any increased SSC is likely to be limited due to the largely high-energy environment in the intertidal and nearshore section of the Hornsea Three offshore cable corridor, which generally comprises shingle, sand and mixed substrate. Therefore North Norfolk Coast Ramsar site, North Norfolk Coast SSSI and he associated NNRs have been screened out of the EIA and will not be considered further in the assessment in volume 2, chapter 2: Benthic Subtidal and Intertidal Ecology.

MCZs

3.1.3.45 The Net Gain project which represented the North Sea, and the Balanced Seas project which represented the waters of the southeast of England, submitted their final recommendations for MCZs to JNCC and Natural England in September 2011. Subsequently a total of 33 sites from around the coast of England were designated in the first tranche of designations in 2013. Four sites from within the southern North Sea benthic ecology study area were designated in this first tranche but none are located near Hornsea Three array area.

3.1.3.46 One Net Gain MCZ, Cromer Shoal Chalk Beds MCZ, coincides with Hornsea Three, specifically the nearshore section of Hornsea Three offshore cable corridor (see Figure 3.6). This MCZ was considered and formally designated under the second tranche of MCZ designations (Defra, 2016).

Cromer Shoal Chalk Beds MCZ

3.1.3.47 The nearshore end of the Hornsea Three offshore cable corridor coincides with the Cromer Shoal Chalk Beds MCZ (Figure 3.6) which is designated for several seafloor features including subtidal chalk and peat and clay exposures (note these also constitute UK BAP priority habitats); see Table 3.2 for a full list of protected features. The Cromer Shoal Chalk Beds MCZ) lies approximately 200 m from the low water mark of the north Norfolk coast and extends 10 km out to sea in waters of up to 25 m depth (Defra, 2015).

Table 3.2: Protected habitats at Cromer Shoal Chalk Beds MCZ and recorded extents.

Protected feature (Defra, 2016)	Spatial extents within MCZ (Defra, 2015)
High energy circalittoral rock	30 km^{2a}
Moderate energy circalittoral rock	
High energy infralittoral rock	Not confirmed present
Moderate energy infralittoral rock	Not confirmed present
Subtidal coarse sediments	148 km^2
Subtidal mixed sediments	49 km^2
Subtidal sand	18 km^2
Peat and clay exposures	Several point records in northwest of MCZ
Subtidal chalk	30 km^{2b}

[a]: Insufficient evidence (Defra, 2015) to refine the classification of the EUNIS biotope ‘A4 Circalittoral rock’.

[b]: While this extent is based on 78% survey coverage, this is 159 km^2 less than reported in the Site Assessment Document (SAD; Net Gain, 2011).

Proposed national designations

3.1.3.48 The rMCZ sites which have not been formally designated to date remain recommended sites. Therefore, habitats and species which are listed as conservation priorities for the following rMCZs have been considered in this characterisation:

- Markham’s Triangle rMCZ (overlapping the Hornsea Three array area); and
- Wash Approach rMCZ (10.5 km from the Hornsea Three offshore cable corridor).

Markham’s Triangle rMCZ

3.1.3.49 Markham’s Triangle rMCZ coincides with the northeast section of the Hornsea Three array area (Figure 3.6). This site is proposed for two broadscale habitats: subtidal coarse sediment and subtidal sand. Shallow sandy sediments are considered to be a suitable habitat for sandeels (*Ammodytes* spp., species of conservation importance) which are an important food source for marine mammals (see volume 5 annex 3.1: Fish and Shellfish Technical Report). Markham’s Triangle is located next to the Klaverbank SAC which is designated for the protection of reefs, harbour porpoise, grey seal and common seal. Therefore it is possible that these features will be present within Markham’s Triangle given the similarities of coarse sediment habitats (Net Gain, 2011).

Wash Approach rMCZ

3.1.3.50 The Wash Approach rMCZ is 10 km from the Hornsea Three offshore cable corridor (Figure 3.6). This site is proposed for two broadscale habitats: subtidal mixed sediment and subtidal sand. The site is also proposed for a habitat feature of conservation importance: Subtidal sands and gravels. The seabed largely comprises circalittoral mixed sediments with subtidal sandbank features and *S. spinulosa* reefs, though these habitats are not proposed for designation (Net Gain, 2011).

Local designations

3.1.3.51 The majority of LNRs are onshore and encompass solely terrestrial habitats. However, of those with coastal features, no sites are located within the southern North Sea benthic ecology study area.

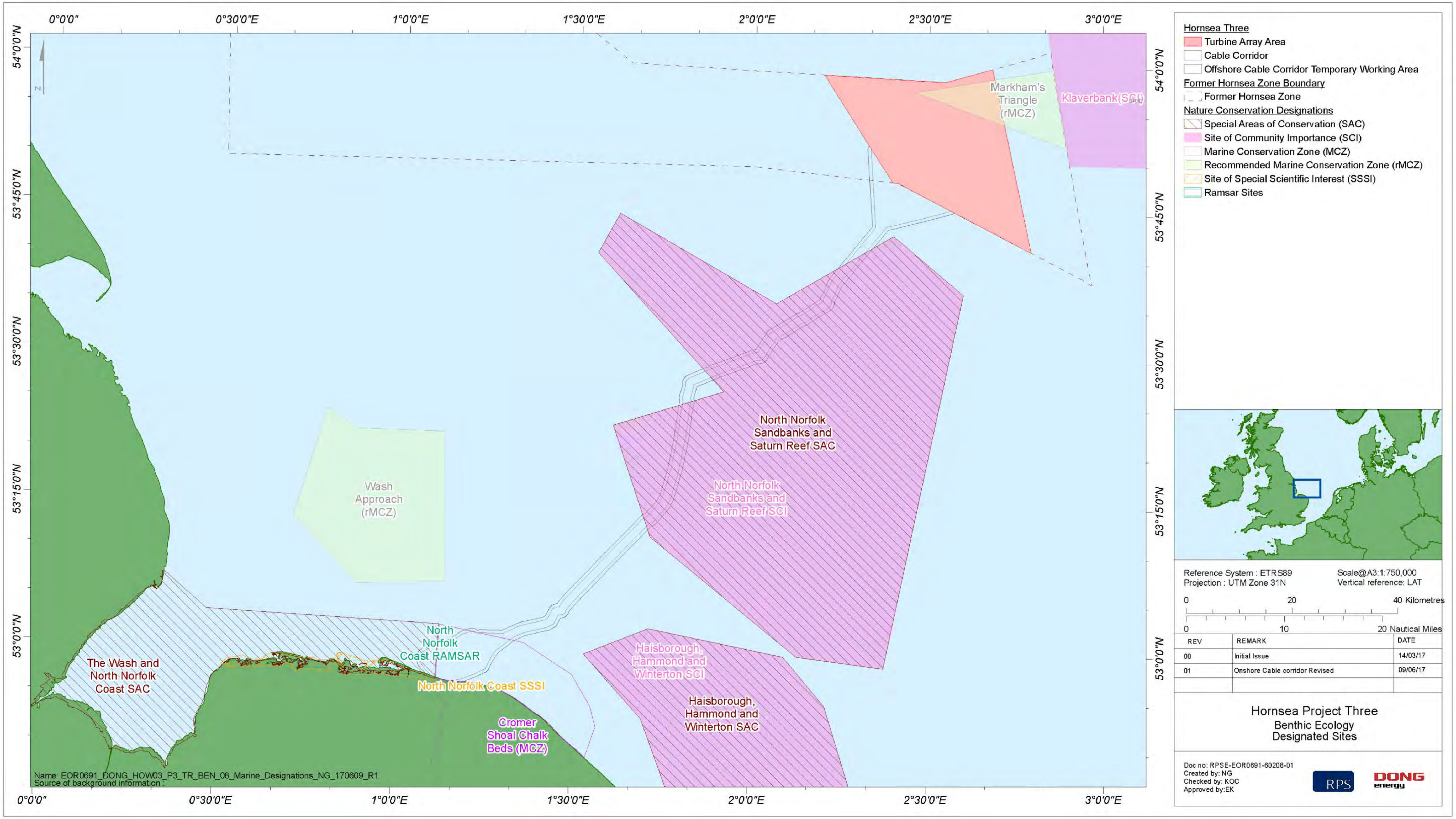

Figure 3.6: The southern North Sea benthic ecology study area and Hornsea Three, with nature conservation designations that have benthic habitat features.

4. Results

4.1 Historic and site specific surveys

4.1.1.1 As noted in section 2.2.1.8, a site specific survey of the Hornsea Three offshore cable corridor will be undertaken in 2017 and will be reported in the Environmental Statement. This section on site specific surveys, therefore, considers the existing data available from the Hornsea ZoC, Hornsea Project One and Hornsea Project Two surveys for the Hornsea Three benthic ecology study area together with the 20 site specific grab samples collected within the Hornsea Three array area and 19 site specific grab samples collected along the Hornsea Three offshore cable corridor.

4.1.2 Physical sediment characteristics

Subtidal Hornsea Three benthic ecology study area

4.1.2.1 The subtidal benthic sediments across the Hornsea Three benthic ecology study area were classified into three main sediment types according to the Simplified Folk Classification as described in section 2.6.2.3: sand and muddy sand (SS.SSA: Sublittoral Sands and Muddy Sands), coarse sediments (SS.SCS: Sublittoral Coarse Sediment) and mixed sediments (SS.SMX: Sublittoral Mixed Sediment). As only a few sites were classified in the mud and sandy mud category these sites were included within the sand and muddy sand category.

4.1.2.2 The percentage sediment composition at each grab location is presented in Figure 4.1 (mud ≤0.63 mm; sand <2 mm; gravel ≥2 mm; the full PSA results and the sediment category assigned to each site are available within an appendix on request) and the simplified sediment types are geographically represented in Figure 4.2. The distribution of sediments throughout the Hornsea Three benthic ecology study area was as follows:

- Sand and muddy sand sediments were found throughout the Hornsea Three benthic ecology study area. These sediments dominated much of the central swathe of the Hornsea Three array area, the central section of the Hornsea Three offshore cable corridor and the majority of the wider Hornsea Three benthic ecology study area, particularly the area in the west of the former Hornsea Zone;
- Coarse sediments were distributed throughout the southern and northern sections of the Hornsea Three array area, particularly the area corresponding with the western edge of Markham's Triangle rMCZ. The areas of coarse material within the Hornsea Three array area were separated by the sand and muddy sand sediments in the centre of the Hornsea Three array area. Patches of coarse material were present in the central former Hornsea Zone, while a large area of coarse sediment dominated the southwestern region of the former Hornsea Zone; and
- Isolated patches of mixed sediments were recorded primarily in the centre and in the northeast of the Hornsea Three array area, again where the array and Markham's Triangle rMCZ overlap. Mixed sediments were also found in the area coinciding with the central area of the former Hornsea Zone and to the southeast of this; towards the Hornsea Three array area.

4.1.2.3 The mean percentage gravel, sand and mud in each of the three sediment categories are presented in Table 4.1. The sand and muddy sand sediments comprised mainly slightly gravelly sands (0.71 ± 1.13% gravel; Table 4.1) with varying degrees of sorting depending on location within the Hornsea Three benthic ecology study area. The sediments near the northern boundary of the Hornsea Three array area were typically poorly sorted, with sorting increasing with increased distance south through the Hornsea Three array area. Conversely, sediments were moderately well sorted along the Hornsea Three offshore cable corridor. The coarse sediments within the Hornsea Three array area, and those present in the wider Hornsea Three benthic ecology study area including the Hornsea Three offshore cable corridor, were typically poorly to very poorly sorted gravelly sands and sandy gravels (31.44 ± 17.54% gravel; Table 4.1). The mixed sediments recorded in the Hornsea Three array area, as well as other discrete areas of the Hornsea Three benthic ecology study area, notably the northeast corner of the Hornsea Project Two array area and several isolated areas along the Hornsea Three offshore cable corridor, comprised typically very poorly sorted muddy sandy gravel and gravelly muddy sand with a mud component of just over 10% (10.06 ± 4.02; Table 4.1).

Table 4.1: Mean (± standard deviation) percentage gravel, sand and mud in each of the broad sediment types identified across the Hornsea Three benthic ecology study area.

Broad sediment type	% gravel (± standard deviation)	% sand (± standard deviation)	% mud (± standard deviation)
Sand and muddy sand	0.71 ± 1.13	95.51 ± 7.02	3.77 ± 7.14
Coarse sediment	31.44 ± 17.54	66.59 ± 17.67	1.93 ± 1.81
Mixed sediment	36.63 ± 15.22	53.32 ± 13.59	10.06 ± 4.02

4.1.2.4 The full PSA results together with the Folk Classifications and Simplified Folk Classifications assigned to each site are available within an appendix on request.

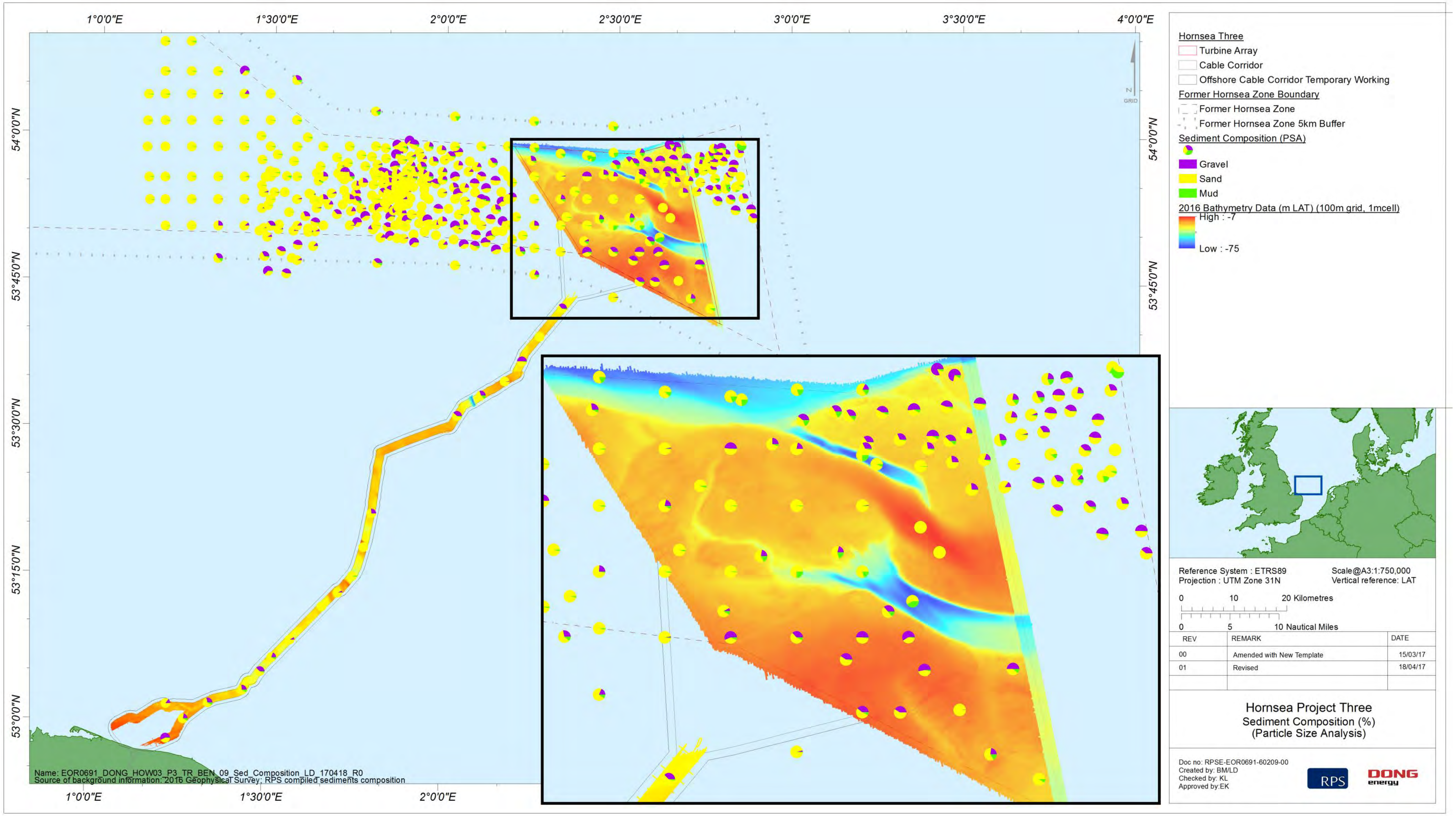

Figure 4.1: Sediment compositions (from particle size analysis) at each benthic grab sampling location within the Hornsea Three benthic ecology study area.

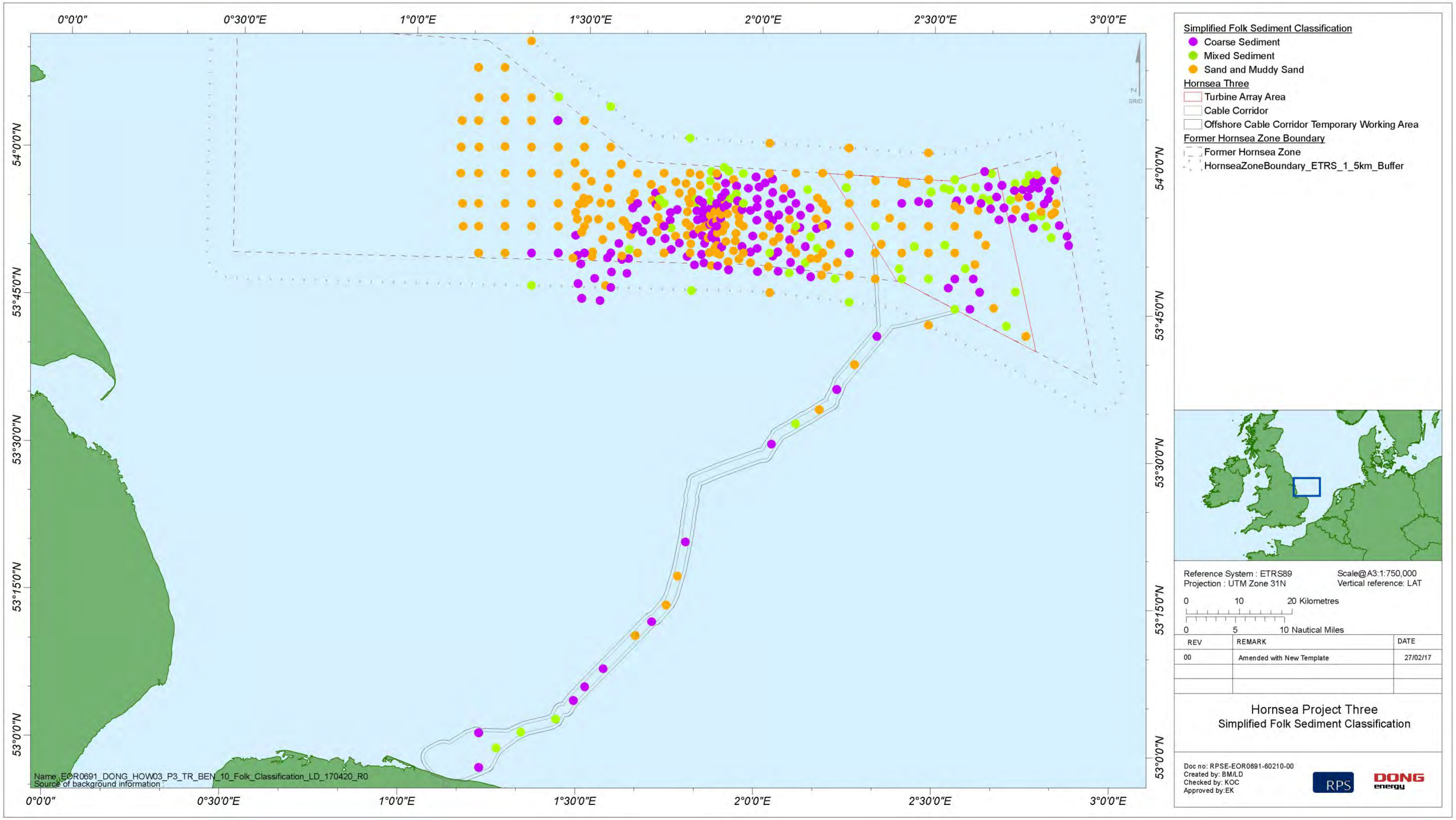

Figure 4.2: Simplified Folk Sediment Classifications for each benthic grab sample location within the Hornsea Three benthic ecology study area.

4.1.3 Sediment Contamination

Subtidal Hornsea Three benthic ecology study area

4.1.3.1 As discussed in section 2.5.1.6, the results of sediment chemistry data are available from a total of 48 sampling locations within the Hornsea Three benthic ecology study area, one of which coincides with the Hornsea Three array area. The sediment chemistry sites were characterised by predominantly sandy sediments with varying amounts of gravel and mud, although, on the whole the proportion of mud was small.

Metals analysis

4.1.3.2 The results of the metals analyses showed that, with the exception of arsenic, cadmium, chromium and nickel, all metals recorded in sediments sampled within the Hornsea Three benthic ecology study area were present at concentrations below the Cefas AL1 and the more stringent Canadian TEL, and were therefore at levels below which biological effects in benthic organisms would be expected.

4.1.3.3 Arsenic exceeded the Canadian TEL at all but five sites (T028, T036 and T040 within the Hornsea Project Two array area and S027 and S158 within Hornsea Project One array area) within the Hornsea Three benthic ecology study area, including sampling location Z62 within the Hornsea Three array area (Figure 4.5). Of the sites with elevated levels of arsenic, five recorded concentrations above the Canadian PEL, the level at which toxicity effects would be evident (sites T022, Z064, S013, S030 and S065; see Figure 4.3 and Figure 4.5 for sample locations). The levels of arsenic in sediments exceeded the Cefas AL1 of 20 mg/kg at 21 sites, however all sites were well within the Cefas AL2 of 100 mg/kg (see Figure 4.3).

4.1.3.4 Historical samples collected during various surveys in the North Sea between 1991 and 1995 have demonstrated several areas of high raw arsenic concentrations in areas off north Yorkshire and the Humber (Whalley *et al.*, 1999). The levels of arsenic present in the historical samples from the Humber and west North Sea were in the range of approximately 14 to 70 mg/kg which are comparable to those reported for the Hornsea Three benthic ecology study area. Arsenic is known to have a high affinity with iron (oxy-) hydroxide coatings on sediment particles and this was confirmed in the sediments of the Humber and the west North Sea where arsenic was demonstrated to have a strong association with iron. Whalley *et al.* (1999) demonstrated that after normalisation against iron, the levels of arsenic in the historical samples including those offshore in the west North Sea were much reduced in significance. The low residual values observed in the Humber and its plume area was of particular interest as the Humber Estuary has been assumed to be a significant source of arsenic to the North Sea. Whalley *et al.* (1999) suggested that these surprising low residual values might be explained by dilution into the Humber Estuary's high suspension load, or by particulate transport away from the region (Whalley *et al.*, 1999). The Humber Estuary also receives a large amount of iron waste (Millward and Glegg, 1997) providing a considerable pool of material to which arsenic may sorb (Cefas, 2000).

4.1.3.5 The level of cadmium marginally exceeded the Cefas AL1 at two sites within the Hornsea Three benthic ecology study area (S136 and T8; see Figure 4.4 for the station locations) but was well within the Cefas AL2 and the Canadian TEL/PEL. The concentration of nickel marginally exceeded the Canadian TEL (15.9 mg/kg) at a single site (S140; see Figure 4.4 for the station location). The full results of the metals analyses are available within an appendix on request.

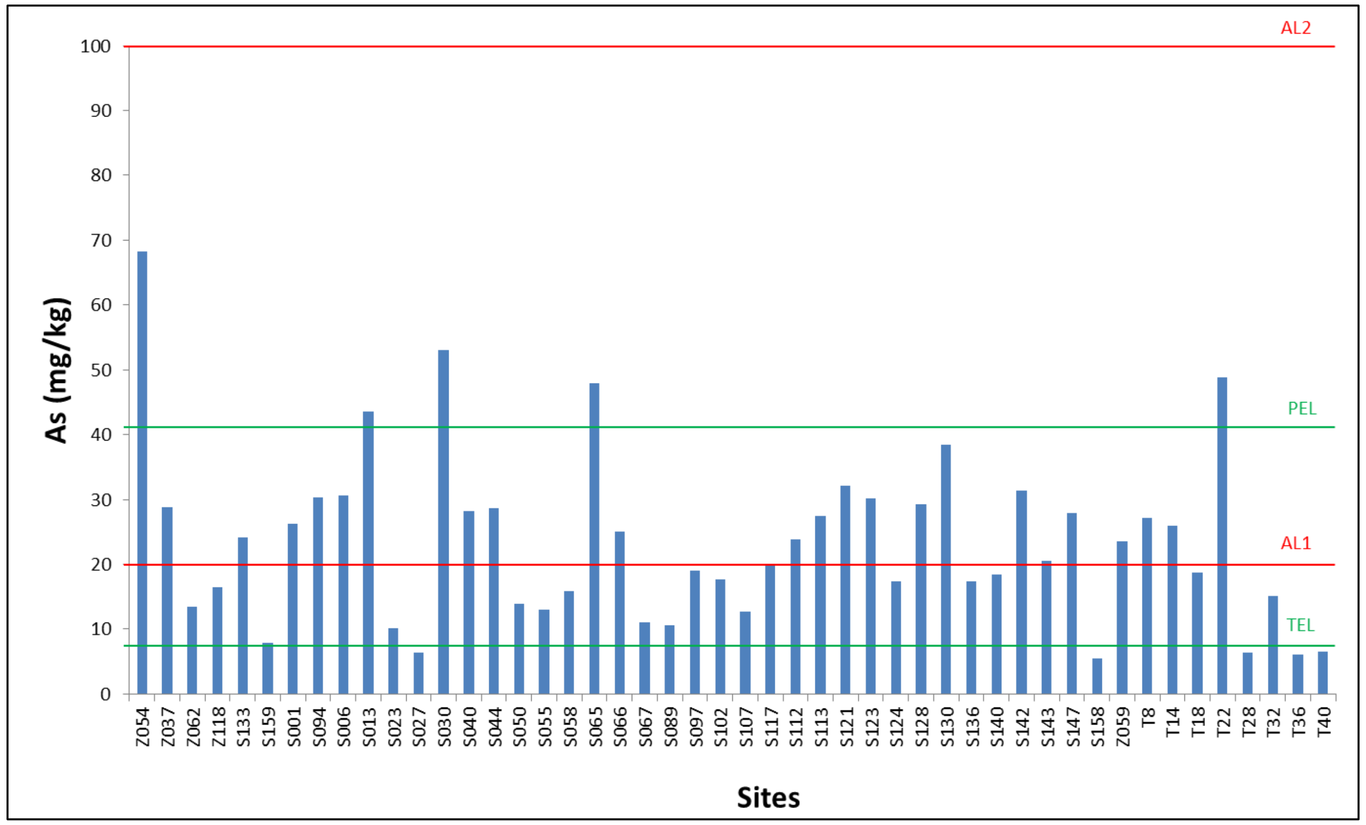

Figure 4.3: Concentrations of arsenic (As) from 48 samples within the Hornsea Three benthic ecology study area with CEFAS Action Levels (AL1 and AL2 in red) and Canadian Threshold Effect Levels (TEL and PEL in green) indicated.

Organotins

4.1.3.6 Levels of TBT and TPT in the Hornsea Three benthic ecology study area subtidal sediments were below the limits of detection of the analysis used at all sites (i.e. <5 µg/kg for TBT and <50 µg/kg for TPT). Although for the majority of the Hornsea Three benthic ecology study area the levels of DBT were also below the limit of detection of the analysis used (i.e. <5 µg/kg), where recorded above this (locations within the Hornsea Project Two array area), the recorded concentrations were all well within the Cefas AL1 for DBT of 0.1 mg/kg.

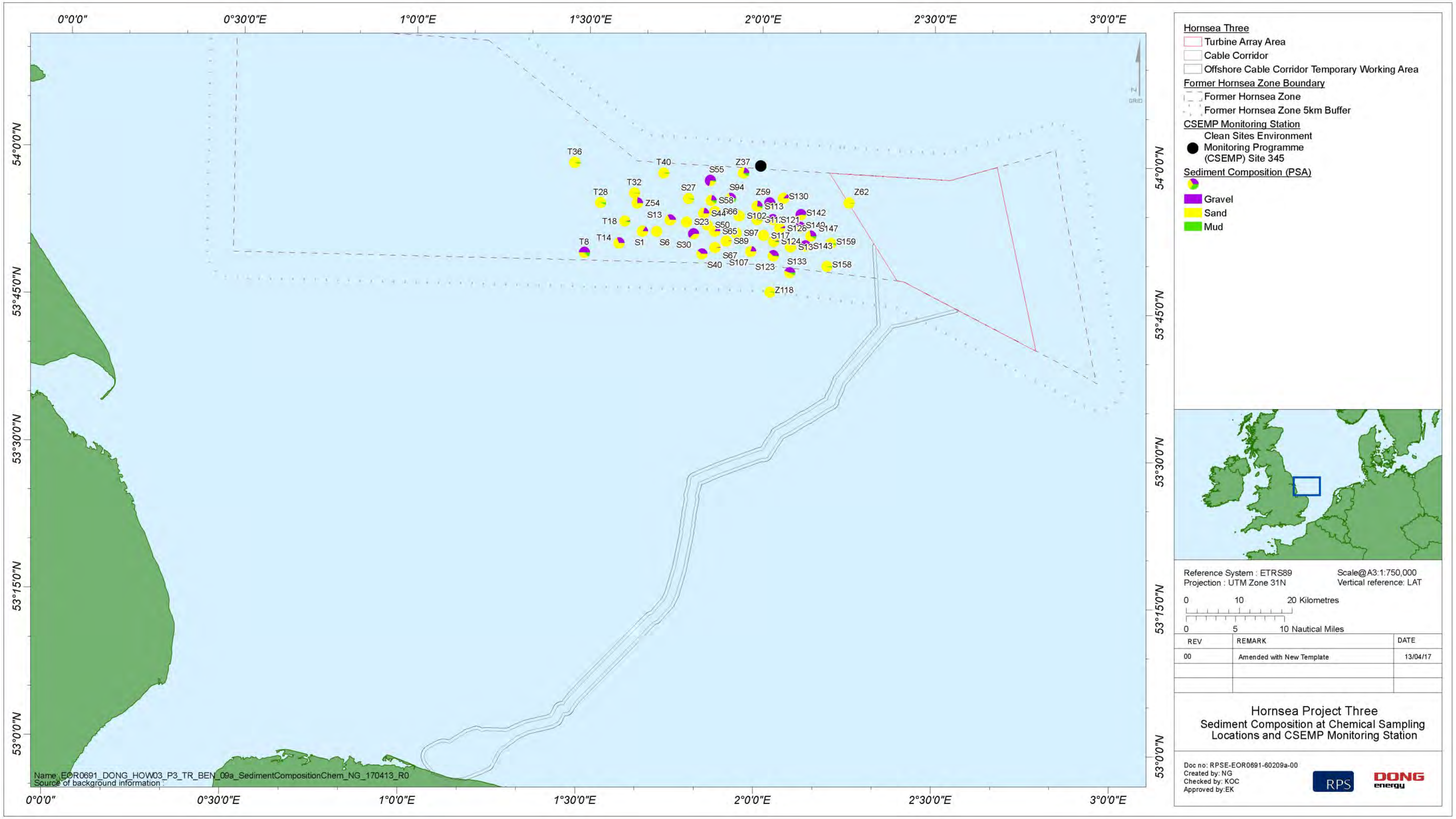

Figure 4.4: Sediment chemistry sample locations within the Hornsea Three benthic ecology study area and associated sediment composition (particle size analysis).

Hydrocarbon analysis

4.1.3.7 The results for total petroleum hydrocarbons (TPH) within the Hornsea Three benthic ecology study area ranged from 0.76 mg/kg to 18.52 mg/kg at a site (T018) within Hornsea Project Two array area (see Figure 4.5). All recorded TPH values from the Hornsea Three benthic ecology study area were well below the Cefas AL1 of 100 mg/kg. The typical range for Total Hydrocarbon Content in offshore North Sea sediments is 17 to 120 mg/kg (Cefas, 2001). The values recorded in the Hornsea Three benthic ecology study area are towards the lower end of this range, supporting the conclusion that hydrocarbon concentrations within the Hornsea Three benthic ecology study area are very low. The full TPH results for each sampling locations are available within an appendix on request.

Polycyclic aromatic hydrocarbons (PAHs)

4.1.3.8 Offshore, the most common types of PAHs are naphthalene, phenanthrene, chrysene and benzo[a]pyrene with total PAH concentrations that generally vary between 0.028 and 0.200 mg/kg (OSPAR Commission, 2000, as cited in Cefas, 2001a). The typical range of values recorded for surface sediments from the North Sea offshore area for total PAH is 0.7 to 2.7 mg/kg (Cefas, 2001b). The results for total PAH (i.e. the summed total of the EPA 16 including dibenzothiophene) ranged between <0.001 and 0.303 mg/kg, although the majority of sites were below 0.030 mg/kg and so within the range of typical sediments for the North Sea. The results can also be compared to data from the Clean Seas Environmental Monitoring Programme (CSEMP), previously known as the National Marine Monitoring Programme (NMMP). Station 345 (offshore of the Humber/Wash) from that programme is within the Hornsea Three benthic ecology study area approximately 8.5 km north-northeast of sample site Z037 (Figure 4.1). Cefas (2001b) report total PAH results for that station ranged from 0.097 to 0.202 mg/kg (the average result being 0.171 mg/kg).

4.1.3.9 From the DTI results (DTI, 2002) the predominantly low NPD/4-6 ring PAH ratios indicate that these compounds are likely to be from pyrolytic (i.e. from the incomplete combustion of organic material), rather than petrogenic, sources.

4.1.3.10 All values of the United States Environmental Protection Agency (US EPA) 16 listed PAHs were well below the Cefas AL1 concentrations for individual PAHs and also the Canadian TEL levels throughout the Hornsea Three benthic ecology study area. In addition to the EPA 16, dibenzothiophene was also measured and was found to be above the typical background concentration of 0.6 µg/kg but well below the ERL (190 µg/kg) (O'Conner 2004; OSPAR, 2009) and are unlikely to cause significant effects on benthic macrofauna.

Organochlorine pesticides

4.1.3.11 All results for organochlorine pesticide concentrations, recorded from samples in the Hornsea Three benthic ecology study area were below the limits of detection of the analyses used (i.e. <1 µg/kg). No assessment against the available Cefas AL1s and the Canadian TELs was possible (where values are available) as these are also below the limit of detection of the analyses.

Total organic carbon (TOC)

4.1.3.12 As discussed in section 2.5.1.7, TOC was recorded for sediment chemistry samples taken from within the Hornsea Project Two array area during the Hornsea Project Two site specific surveys. At all sampling locations, the levels of TOC were low at less than 0.2%.

4.1.4 Benthic ecological characterisation

Benthic infauna biotope mapping

4.1.4.1 The results of the cluster analyses, SIMPROF tests and SIMPER analyses (see Appendix A and B, available on request) were used, together with the raw untransformed data (available within an appendix on request), to assign preliminary biotopes to each sample location in each of the three simplified sediment types described in sections 4.1.2.1 to 4.1.2.4 (i.e. sandy, coarse and mixed sediments). In several instances, clusters that were identified as significantly different from each other in the SIMPROF tests were assigned the same biotope code. This was because a review of the SIMPER results identified that the differences between the groups could be explained by differences in abundances of characterising species rather than the presence/absence of key species. For example, for one of the clusters identified in the sandy sediment analysis (cluster ae, see Appendix A for sites within this cluster), the SIMPER output identified *Tellina (Fabulina) fabula, Magelona johnstoni, Bathyporeia elegans* and *Bathyporeia tenuipes* as the top four species contributing to the cumulative similarity within the cluster. For a separate cluster within the same sandy sediment (cluster ah, see Appendix A for a list of sites within that cluster), the four species contributing to the cumulative similarity within that cluster were identified from the SIMPER as *C. gibba, Tellina (Fabulina) fabula, Bathyporeia elegans*, and *Magelona johnstoni*. However, the SIMPER analysis of dissimilarity between these two clusters identified that the majority of the dissimilarity could be attributed to differences in abundances of key species rather than the presence/absence of key species and as such both clusters were assigned to the SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand) biotope (hereafter referred to as FfabMag).

4.1.4.2 Due to the patchy nature of the distribution of the sediments and communities and the often similar species present, albeit in differing abundances, across the Hornsea Three benthic ecology study area, in some instances it was necessary to assign a different biotope code to sites within a larger homogenous cluster. This was especially true for several of the coarse sediment sites where distinctions between several of the biotopes were often attributable to subtle differences in the overall diversity of polychaete species as well as the location of the sample site with respect to factors such as water depth.

4.1.4.3 The combined 3-D MDS plot (subset) for all stations and sediment types, with biotope as a factor, is presented in Figure 4.5. The 3-D MDS plots for each of the three sediment type groups, sand and muddy sand, coarse sediments and mixed sediments, with biotopes as factors, are available on request (stations with no fauna recorded were excluded from the analyses and are not represented in the MDS plots). The combined 2-D MDS plots have not been presented due to the high stress values observed (> 0.2 for all except mixed sediments). Such high stress levels are to be expected given the large number of data points being analysed (i.e. 382 separate grab stations) and it should be noted that the stress values given in the 3-D plots are still considered to be relatively high and therefore not an excellent representation of the data. However, it is important to note that the MDS plots have not been used in isolation and have been interpreted together with the results of the cluster and SIMPROF analyses and in light of the raw transformed data. The dendrograms for each of the three sediment type groups, sand and muddy sand, coarse sediments and mixed sediments, with biotopes as factors, are available on request. The cluster analysis for all sites and sediment types combined is presented in Appendix A.

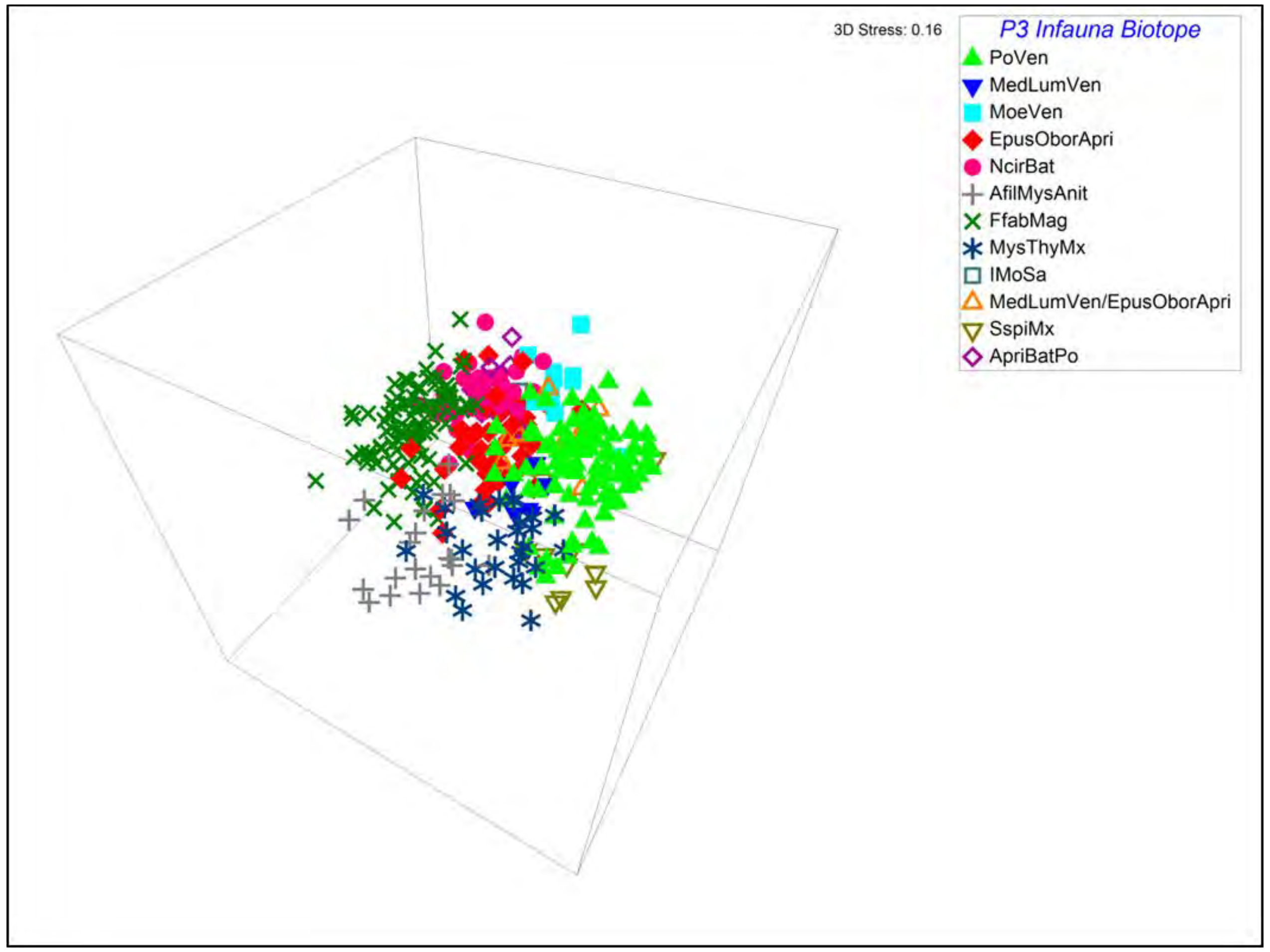

Figure 4.5: Subset 3-D MDS plot for benthic infaunal communities (biotopes) in all sediment types for the Hornsea Three benthic ecology study area.

4.1.4.4 The data presented in Figure 4.5 (and in MDS plots for each of the three sediment type groups; avaialbel on request) show that sites assigned to the same biotope generally clustered together relatively loosely based on infaunal assemblages and a high degree of overlap was observed between groups in all three sediment groups. This was especially true for the sandy sediment sites (MDS plot available on request). This is unsurprising given the relatively homogeneous nature of the seabed, particularly within the sandy sediment areas of the Hornsea Three benthic ecology study area and the fact that generally similar species were observed at all sites with changes in only a few key species accounting for the main differences. For example, cluster analysis showed similar infaunal communities of the NcirBat biotope and the FfabMag biotope. The 3-D MDS plot (available on request) for sand and muddy sand sediments also showed a commonly observed pattern representing the transition from the fine sand communities of the SS.SSa.CFiSa.EpusOborApri (*Echinocyamus pusillus, Ophelia borealis* and *Abra prismata* in circalittoral fine sand) biotope (hereafter referred to as EpusOborApri; red symbols) and the NcirBat biotope (pink symbols) through the muddier sand sediments of the FfabMag biotope (green cross symbols) in areas of lower sediment disturbance where the silt fraction can settle out to the deeper cohesive sandy mud communities of the SS.SMu.AfilMysAnit (*Amphiura filiformis, Mysella bidentata* and *Abra nitida* in circalittoral sandy mud) biotope (hereafter referred to as AfilMysAnit; grey symbols) (Connor *et al.*, 2004).

4.1.4.5 Similarly, the subset MDS for the coarse sediments (available on request) demonstrated a weak grading of the gravelly sand sediment communities of the SS.SMx.OMx.PoVen (Polychaete-rich deep *Venus* community in offshore mixed sediments) biotope (hereafter referred to as PoVen; green triangle symbols) into the mosaic *Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel/*Echinocyamus pusillus, Ophelia borealis* and *Abra prismata* in circalittoral fine sand biotope (hereafter referred to as MedLumVen/EpusOborApri; orange symbols). The MedLumVen/EpusOborApri mosaic biotope, which has a similar but less diverse polychaete and venerid bivalve community and high numbers of the pea urchin *Echinocyamus pusillus* and the polychaete *Ophelia borealis*, grades into the MoeVen biotope (turquoise symbols) in shallower waters with fewer polychaetes but high numbers of venerid bivalves.

4.1.4.6 In comparison, the mixed sediment 3-D MDS (available on request) demonstrates a good degree of separation between the truly mixed sediments of the SS.SMx.CMx.MysThyMx (*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment) (hereafter referred to as MysThyMx) biotope (blue asterisk symbols) and the PoVen biotope. The SspiMx biotope was found at one station to the west of the Hornsea Three array area and along several stations of the Hornsea Three offshore cable corridor. The MysThyMx biotope was found predominantly in the Hornsea Three array area and in the area coinciding with the northeast of Hornsea Project Two array area. Full descriptions of these biotopes, including their distribution across the survey area, are presented below in sections 4.1.4.10 to 4.1.4.18.

4.1.4.7 It is noted from the dendrograms for each of the three sediment types (available on request) that in some cases the same biotopes were assigned across the three broad sediment types identified using the Simplified Folk Classification. Biotopes typically found in sand dominated sediments (e.g. FfabMag) were assigned to sites classified as coarse sediment using the Simplified Folk Classification, based on the infaunal communities present, thus highlighting the importance of revisiting the raw untransformed data when assigning the final biotopes. For example, although sites falling within Group c of the coarse sediment cluster analysis (see Appendix A for a list of sites within this cluster, available on request) were classified according to the Simplified Folk Classification as coarse sediment, SIMPER analysis identified that these sites were characterised, albeit in low numbers, by amphipods *Bathyporeia* spp. the polychaete *Magelona johnstoni* and the venerid bivalve *Tellina (Fabulina) fabula*. As such the sandy sediment FfabMag biotope was deemed more accurate to describe these sites than a coarse sediment biotope.

4.1.4.8 Another example of where the final biotope assigned to the sites did not strictly match the underlying sediment type was the PoVen biotope which was assigned to a large number of sites falling within the coarse sediment class (dendrogram available on request). Although the PoVen biotope is predominantly associated with offshore mixed sediments the classification for this biotope includes gravelly sand sediments (Connor *et al.*, 2004), which matches the Folk sediment classification that was assigned to many of the coarse sediment sites. This, together with the diverse community of polychaetes (i.e. more species and different species than would be expected in other coarse sediment biotopes such as MedLumVen or MoeVen) and venerid bivalves present, suggested that the PoVen biotope best described the data. Full descriptions of these biotopes, including their distribution across the Hornsea Three benthic ecology study area, are presented below in sections 4.1.4.10 to 4.1.4.21.

4.1.4.9 Figure 4.6 shows the geographic extents of the draft benthic infaunal biotopes present throughout the Hornsea Three benthic ecology study area. Twelve infaunal biotopes were identified, one of which was a mosaic biotope where the infaunal data was strongly represented by the characterising species of more than one biotope, and these are presented and described in Table 4.2. The apparent distribution of biotopes is strongly affected by sample density. Areas with very high sample density had high variability of biotopes within small areas. Low sample density areas give an artificial impression of uniformity but broad biotope distributions can be seen. It is also important to remember that the choice of biotope assignment for particular cluster groups can be subjective and the addition of new data to a cluster analysis (such as occurred with the addition of Hornsea Three sample data to the existing Hornsea Project Two, Hornsea Project One and Hornsea ZoC datasets) can result in the reassignment of samples.

<u>The Hornsea Three array area and offshore cable corridor</u>

4.1.4.10 The areas encompassing the south and northeast of the Hornsea Three array area were largely dominated by sandy gravel, according to the site-specific geophysical survey undertaken in the Hornsea Three array area in 2016. The biotope map (Figure 4.6) shows that the distribution of the sandy gravel sediment broadly corresponded with the biotope PoVen, with isolated patches of MysThMx where the gravel sediments transitioned into areas of muddy sediment. The area assigned to the PoVen biotope in the south of the Hornsea Three array area continued south through the tapered section of the Hornsea Three offshore cable corridor. The remainder of the Hornsea Three offshore cable corridor is discussed further in section 4.1.4.12.

4.1.4.11 The biotope AfilMysAnit was assigned to two narrow, linear swathes across the central eastern section of the Hornsea Three array area, which aligned well with the spatial distribution of muddy sand substrate. This sediment type was generally fringed by, or adjacent to, areas of sandy sediment in the Hornsea Three array area, which corresponded with the NcirBat biotope. The central region of the Hornsea Three array area, plus the southeast corner and the central northern fringe, were assigned to the AfilMysAnit and NcirBat biotopes.

4.1.4.12 The majority of the seabed along the Hornsea Three offshore cable corridor comprised the biotope SspiMix, particularly in the most landward and distal sections. The spatial distribution of this biotope was generally consistent with that of the areas of the seabed determined to be sandy gravel and gravelly sand, according to the Hornsea Three offshore cable corridor 2016 geophysical survey. The central section of the Hornsea Three offshore cable corridor was assigned the biotope ApriBatPo which corresponded with coarse sediments. The NcirBat biotope was also assigned in areas limited to the central parts of the Hornsea Three offshore cable corridor and also in the north of the Hornsea offshore cable corridor. The only other biotopes assigned within the Hornsea Three offshore cable corridor were EpusObarApri, which was limited to a small patch in the northern section of the Hornsea Three offshore cable corridor, and MoeVen, in the nearshore extent of the Hornsea Three offshore cable corridor. It is important to note that the faunal community assemblages assigned to the MoeVen biotope on the Hornsea Three offshore cable corridor recorded very few taxa, therefore the biotope was allocated with low confidence. Areas of outcropping chalk and clay are clearly present in the vicinity of the nearshore section of the Hornsea Three offshore cable corridor, according to baseline information (see paragraphs 3.1.3.2 to 3.1.3.9); however the 2016 site specific benthic sampling survey did not explore the most inshore waters, where such habitats are considered to be located. The areas of outcropping chalk and clay, together with other habitat types, will be targeted for further investigation within the site-specific survey at the Hornsea Three offshore cable corridor planned for 2017 (paragraph 2.2.1.8).

Former Hornsea Zone

4.1.4.13 In the deeper waters located across much of the northern part of the former Hornsea Zone, the seabed was characterised by a continuous swathe of the AfilMysAnit biotope in the deeper circalittoral sand, which continued down into the Hornsea Three array area, as described in section 4.1.4.11 above. This biotope was characterised by high abundances of the brittlestar *Amphiura filiformis* and often high numbers of the venerid bivalve mollusc *Kurtiella (Mysella) bidentata* and other taxa, notably the burrowing ghost shrimp *Callianassa subterranea* (Table 4.2).

4.1.4.14 The western section of the Hornsea Three array area largely comprised of communities associated with sand sediments; primarily the EpusOborApri and FfabMag biotopes. These biotopes were limited to this region of the Hornsea Three array area, with the exception of FfabMag, which was also assigned to an isolated pocket in the east of the Hornsea Three array area. The area of FfabMag in the western section of the Hornsea Three array area continued south through the tapered section of the Hornsea Three offshore cable corridor, together with the PoVen biotope, as described in section 4.1.4.11.

4.1.4.15 The majority of the area encompassing the western section of the former Hornsea Zone was dominated by sandy sediments and the biotope FfabMag. Two substantial areas of the former Hornsea Zone were characterised by the EpusOborApri biotope; in the northeast and just southwest of the central former Hornsea. These areas corresponded well with the predicted distribution of circalittoral fine sand or circalittoral muddy sand from the UK SEAMAP data (JNCC, 2010) and MESH predicted EUNIS data (see Table 4.2 for corresponding EUNIS biotopes). The FfabMag biotope was characterised by the polychaete *Magelona johnstoni* and the venerid bivalve *Tellina (Fabulina) fabula* in relatively high abundances together with a number of other polychaetes and sand dwelling amphipods *Bathyporeia* spp. (Table 4.2). The EpusOborApri biotope was characterised by the polychaetes *O. borealis, N. cirrosa, S. bombyx,* the pea urchin *E. pusillus* and the bivalve mollusc *A. prismatica* (Table 4.2).

4.1.4.16 The majority of the remaining areas of sandy sediment in the centre of the former Hornsea Zone supported typically species poor communities represented by the NcirBat biotope. The NcirBat biotope was often found distributed in areas adjacent to the FfabMag biotope. This is consistent with evidence that FfabMag may grade into the sandier biotope NcirBat in areas of increased sediment disturbance, where the finer silt fraction is unable to settle out of the water column (section 4.1.4.4; Connor *et al.*, 2004).

4.1.4.17 Much of the rest of the wider former Hornsea Zone within the Hornsea Three benthic ecology study area was characterised by the relatively diverse PoVen biotope, which corresponded with patches of coarser sediments in the central former Hornsea Zone. This biotope was also associated with a large area of coarse sediments present in the southeastern part of the former Hornsea Zone. The gravelly sand sediments in these areas were characterised by a diverse infaunal community of polychaetes, bivalves, nemerteans and echinoderms (Table 4.2). The infaunal communities assigned to the PoVen biotope closely resembled the MedLumVen, which was recorded in the southeastern part of the former Hornsea Zone. However, the decision to classify these communities as PoVen was made based on the high diversity of polychaetes present and the generally low abundances of key species such as *M. fragilis* and *Lumbrineris* spp. which would be expected in the MedLumVen biotope. A mosaic biotope was however identified consisting of the MedLumVen biotope together with the EpusOborApri biotope). The MedLumVen/EpusOborApri mosaic was generally found in the circalittoral coarse sediments in the central southern part of the former Hornsea Zone. The mosaic was characterised by the polychaete *O. borealis* and the pea urchin *E. pusillus*, typical of the EpusOborApri biotope together with a more diverse array of polychaetes and bivalves typical of the coarser sediment biotope MedLumVen (Table 4.2).

4.1.4.18 Mixed sediments in the central part of the former Hornsea Zone were broadly characterised by the MysThyMx biotope. The MysThyMx biotope comprised the brittlestar *A. filiformis*, the mollusc *Kurtiella (Mysella) bidentata* and an array of polychaetes (Table 4.2).

4.1.4.19 Small areas of the infralittoral coarse sediment biotope MoeVen were located in isolated pockets in the centre and southeast of the former Hornsea Zone. The infaunal community in this biotope was similar to that of the PoVen biotope identified in deeper water, but was characterised by fewer polychaetes and higher abundances of venerid bivalve molluscs including *Goodalia triangularis* and *Spisula eliptica*. One of the main characterising venerid bivalves of this biotope, *Moerella pygmaea*, was also present in low numbers at a few sites within this biotope (Table 4.2).

4.1.4.20 The only benthic species of conservation interest identified in the Hornsea Three benthic ecology study area was the ocean quahog *Arctica islandica*. This species is listed by OSPAR as a threatened and/or declining species for the Greater North Sea (OSPAR Region II) and was recorded from nine locations in the central area of the former Hornsea Zone (from eight sites as single specimens, and one site where two individuals were recorded) and two sites in the wider Hornsea Three benthic ecology study area. Eight of the records were of juvenile *A. islandica*. The single record measured less than 10 mm indicating it was a spat rather than a juvenile of the species (Witbaard and Bergman, 2003). These sites are shown as target notes (TN) on Figure 4.6 . Within the Hornsea Project Two array area, the records were typically from sandy sediment substrates, in particular the EpusOborApri biotope. However, several records were also made from the coarser sediments associated with the PoVen biotope; see Figure 4.6 for locations.

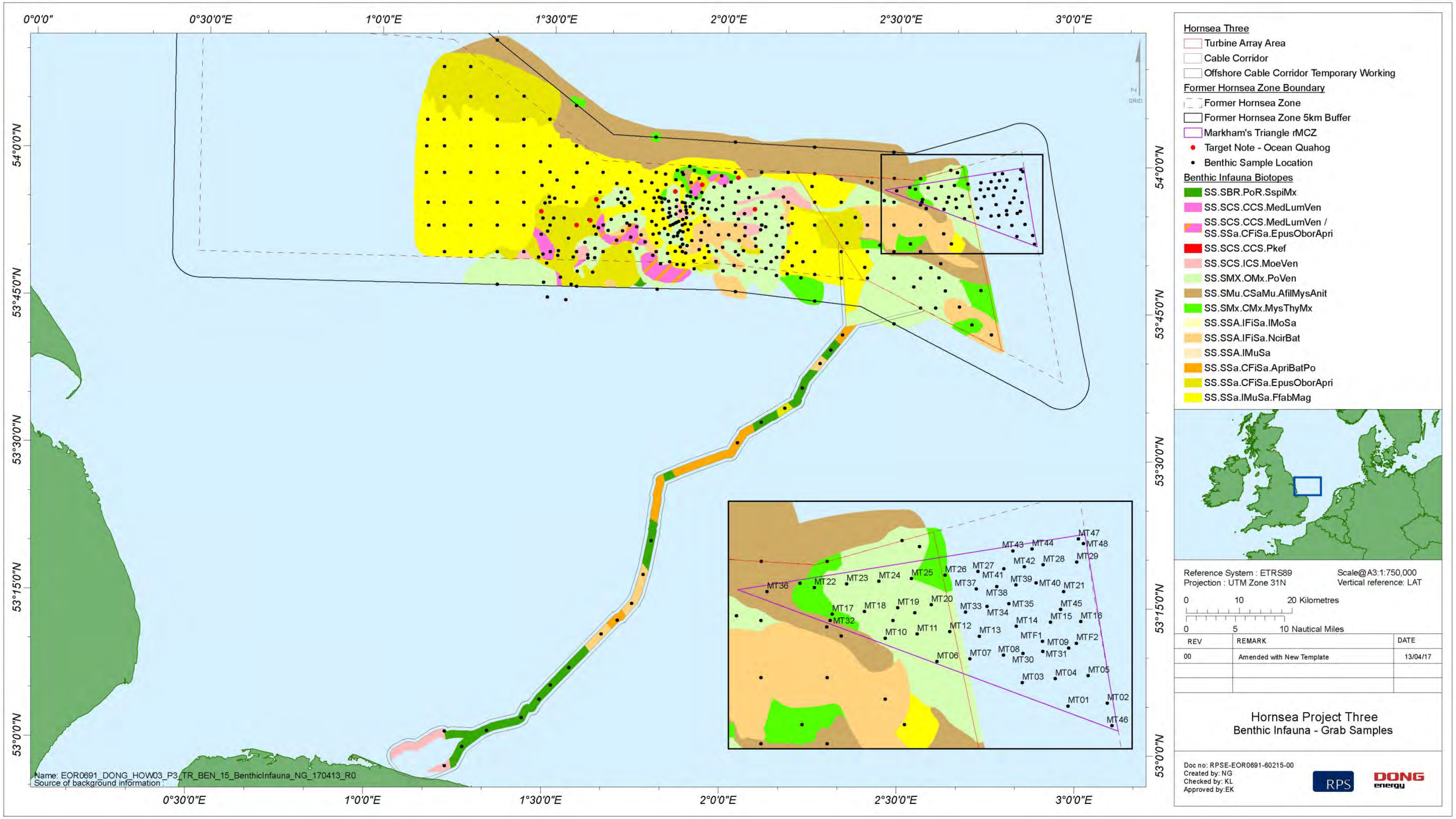

Figure 4.6: Benthic infauna biotopes of the Hornsea Three benthic ecology study area.

Table 4.2: Benthic infauna biotopes identified in the Hornsea Three benthic ecology study area, including a summary of the SIMPER results and geographic locations (see Figure 4.6).

Biotope Code (Conner *et al.*, 2004)	EUNIS code (2007-11)	Simplified Folk Sediment Classification	Biotope Name	Hornsea Three Biotope Description	Characterising species accounting for up to 75% of cumulative similarity (SIMPER)	Geographic Location
SS.SSa.IFiSa.NcirBat (NcirBat)	A5.233	Sand and muddy sand (37 sites).	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand.	This biotope occurred in well sorted medium and fine sands and was characterised by the polychaetes *Nephtys cirrosa* and *Spiophanes bombyx*, the amphipod *Bathyporeia elegans* and the opossum shrimp *Gastrosaccus spinifer*.	*Nephtys cirrosa, Ophelia borealis, Bathyporeia elegans, Corbula gibba, Echinocyamus pusillus, Cochlodesma praetenue, Spiophanes bombyx, Scoloplos armiger, Abra prismatica.*	This biotope was located in the central part of the former Hornsea Zone, the central part of the Hornsea Three array area and three areas along the Hornsea Three offshore cable corridor.
SS.SSa.CFiSa.ApriBatPo (ApriBatPo)	A5.252	Sand and muddy sand (7 sites).	*Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand.	Occurring in circalittoral and offshore medium to fine sands with a community characterised by the bivalve *Abra prismatica*, the amphipod *Bathyporeia elegans* and polychaetes including *Scoloplos armiger, Spiophanes bombyx, Aonides paucibranchiata, Chaetozone setosa, Ophelia borealis* and *Nephtys longosetosa*. The brittlestar *Amphiura filiformis* was also common at some sites.	*Scalibregma inflatum, Corbula gibba, Abra prismatica, Nephtys cirrosa, Mactra stultorum, Paraspio decorata.*	This biotope was located at limited discrete locations in the former Hornsea Zone and the central section of the Hornsea Three offshore cable corridor.
SS.SSa.CFiSa.EpusOborApri (EpusOborApri)	A5.251	Sand and muddy sand (33 sites); coarse sediments (11 sites); mixed sediments (1 site).	*Echinocyamus pusillus, Ophelia borealis* and *Abra prismatica* in circalittoral fine sand.	Offshore sediments dominated by medium to fine sands and characterised by the polychaetes *Ophelia borealis* and *Nephtys cirrosa*, high abundances of the pea urchin *Echinocyamus pusillus* and by the venerid *bivalve Abra prismatica.*	*Ophelia borealis, Spiophanes bombyx, Echinocyamus pusillus, Nephtys cirrosa, Abra prismatica, Nemertea* spp.*, Scoloplos armiger, Dosinia* (juv.)*, Bathyporeia elegans.*	This biotope was recorded in the southwest and northwest of the former Hornsea Zone and in the west of the Hornsea Three array area.
SS.SSa.IMuSa.FfabMag (FfabMag)	A5.252	Sand and muddy sand (91 sites); coarse sediments (7 sites).	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand.	In stable, fine, compacted and slightly muddy sands in the infralittoral and littoral fringe, this community was characterised by venerid bivalves such as *Tellina (Fabulina) fabula, Chamelea striatula* and *Abra prismata*, polychaetes including *Magelona johnstoni* and *Spiophanes bombyx* and the amphipods *Bathyporeia elegans, Bathyporeia tenuipes* and *Bathyporeia guilliamsoniana.*	*Tellina fabula, Magelona johnstoni, Bathyporeia elegans, Corbula gibba, Magelona filiformis, Spiophanes bombyx, Bathyporeia tenuipes, Goniada maculata, Bathyporeia guilliamsoniana. Abra prismatica, Chamelea striatula.*	The biotope was the predominant biotope throughout the west of the former Hornsea Zone and in the west of the Hornsea Three array area. It was also recorded in patches throughout the central section of the former Hornsea Zone.
SS.SMu.CSaMu.AfilMysAnit (AfilMysAnit)	A5.351	Sand and muddy sand (19 sites); coarse sediments (2 sites).	*Amphiura filiformis, Mysella bidentata* and *Abra nitida* in circalittoral sandy mud.	Poorly sorted cohesive muddy sands in moderately deep water with an infaunal community dominated by high abundances of the echinoderm *Amphiura filiformis*, the bivalve *Kurtiella (Mysella) bidentata*, polychaetes and nemerteans.	*Amphiura filiformis, Callianassa subterranea, Kurtiella bidentata, Cylichna cylindracea, Ophiodromus flexuosus, Goniada maculata, Abra alba, Nemertea* spp.*, Sthenelais limicola.*	This biotope was assigned to a swathe of sediment stretching the length of the northern former Hornsea Zone. It was also present in the deeper waters of the central part of the Hornsea Three array area.
SS.SCS.CCS.MedLumVen/ SS.SSa.CFiSa.EpusOborApri (MedLumVen/EpusOborApri)	A5.142/A5.25 1	Coarse sediments (10 sites); mixed sediments (2 sites).	Mosaic of *Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel and *Echinocyamus pusillus, Ophelia borealis* and *Abra prismata* in circalittoral fine sand.	A mosaic biotope with characteristics of both the circalittoral fine sand EpusOborApri biotope and the richer coarser sand MedLumVen biotope dominated by polychaetes and venerid bivalves. This biotope was characterised by the polychaetes Nephtys cirrosa and Ophelia borealis, the echinoderm Echinocyamus pusillus.	*Ophelia borealis, Echinocyamus pusillus,* Nemertea spp.*, Corbula gibba, Aonides paucibranchiata, Scalibregma inflatum, Scoloplos armiger, Glycera lapidum,* Edwardsiidae*, Dosinia exoleta.*	This mosaic biotope was recorded in patches within the central former Hornsea Zone, particularly in the south.
SS.SCS.ICS.MoeVen (MoeVen)	A5.133	Sand and muddy sand (6 sites); coarse sediments (7 sites).	*Moerella* spp. with venerid bivalves in infralittoral gravely sand.	This biotope occurred in infralittoral medium to coarse sand which is subject to moderately strong water movement from tidal streams with communities characterised by high abundances of the venerid bivalve mollusc *Goodallia triangularis* and to a lesser extent *Timoclea ovata* and a relatively diverse assemblage of polychaetes including *Nephtys cirrosa* and *Ophelia borealis.*	*Ophelia borealis*, Nemertea, *Corbula gibba, Echinocyamus pusillus, Nephtys cirrosa, Goodallia triangularis, Glycera lapidum.*	This biotope was found in discrete patches in the central former Hornsea Zone and the shallower water of the nearshore section of the Hornsea Three offshore cable corridor.

Biotope Code (Conner *et al.*, 2004)	EUNIS code (2007-11)	Simplified Folk Sediment Classification	Biotope Name	Hornsea Three Biotope Description	Characterising species accounting for up to 75% of cumulative similarity (SIMPER)	Geographic Location
SS.SCS.CCS.MedLumVen (MedLumVen)	A5.142	Coarse sediments (6 sites); mixed sediments (1 site).	*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel.	Circalittoral gravels, coarse to medium sands, and shell gravels, sometimes with a small amount of silt characterised by polychaetes including *Spiophanes bombyx, Ophelia borealis, Mediomastus fragilis* and *Glycera lapidum* with the pea urchin *Echinocyamus pusillus*. Communities also including Nemertea spp. and venerid bivalves such as *Dosinia* sp. which although in low numbers are likely to have been under-sampled in the grab surveys.	*Spiophanes bombyx, Ophelia borealis,* Nemertea spp., *Lagis koreni, Scoloplos armiger, Mediomastus fragilis, Dosinia* (juv), *Pholoe baltica, Euspira pulchella, Scalibregma inflatum.*	This mosaic biotope was recorded in isolated patches of the central former Hornsea Zone.
SS.SMx.OMx.PoVen (PoVen)	A5.451	Sand and muddy sand (5 sites); coarse sediments (79 sites); mixed sediments (15 site).	Polychaete-rich deep *Venus* community in offshore mixed sediments.	In offshore gravelly sands an infaunal community characterised by a particularly rich community of polychaetes including *Notomastus* spp., *Pista cristata, Scalibregma inflatum* and *Protodorvillea kefersteini*, ribbon worms Nemertea spp., the pea urchin *Echinocyamus pusillus* and low numbers of venerid bivalves including *Timoclea ovata.*	*Spiophanes bombyx, Ophelia borealis,* Nemertea spp., *Lagis koreni, Scoloplos armiger, Mediomastus fragilis, Dosinia* (juv), *Pholoe baltica, Euspira pulchella, Scalibregma inflatum.*	This biotope was distributed extensively throughout the Hornsea Three array area, particularly to the south and northeast of the Hornsea Three array area. It was also found in the southwest and the central section of the former Hornsea Zone.
SS.SMx.CMx.MysThyMx (MysThyMx)	A5.443	Coarse sediments (1 site); Mixed sediments (28 sites).	*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment.	Moderately exposed or sheltered, circalittoral muddy sands and gravels characterised by communities of the bivalve *Mysella bidentata*, polychaetes such as *Glycera alba, Mediomastus fragilis* and *Goniada maculata*. The brittlestar *Amphiura filiformis* was also abundant at some sites.	*Notomastus* spp., Nemertea spp., *Glycera lapidum, Echinocyamus pusillus, Aonides paucibranchiata, Corbula gibba, Scalibregma inflatum, Urothoe marina, Euspira pulchella, Protodorvillea kefersteini, Pholoe baltica, Ophelia borealis, Polycirrus* spp., *Syllis* sp., *Eunereis longissima, Mediomastus fragilis, Pista cristata, Upogebia deltaura, Eulalia mustela.*	This biotope was distributed as isolated patches throughout the central northern and eastern sections of the former Hornsea Zone, particularly within the Hornsea Three array area.
SS.SBR.PoR.SspiMx (SspiMx)	A5.611	Coarse sediments (5); mixed sediments (5 sites).	*Sabellaria spinulosa* on stable circalittoral mixed sediment.	This biotope occurred on mixed sediments and was characterised by high abundances of the tube-building polychaete *Sabellaria spinulosa* and a diverse community of infaunal polychaetes including *Polycirrus* spp., *Scalibregma inflatum, Mediomastus fragilis and Pholoe baltica* together with the bivalve mollusc *Abra alba.*	*Amphiura filiformis, Kurtiella bidentata, Pholoe baltica, Glycera alba, Goniada maculata, Notomastus* spp., Nemertea spp., *Mediomastus fragilis, Lumbrineris gracilis, Upogebia deltaura, Corbula gibba, Phoronis, Magelona alleni, Cylichna cylindracea, Gattyana cirrhosa, Owenia, Atherospio guillei, Callianassa subterranean.*	This biotope was predominantly recorded along the Hornsea Three offshore cable corridor, particularly in the nearshore and most offshore sections.
SS.SSa.IFiSa.IMoSa (IMoSa)	A5.231	Sand and muddy sand (2 sites); coarse sediments (1 site).	Infralittoral mobile clean sand with sparse fauna.	Medium to fine sandy sediment in shallow water, often formed into dunes, on tide swept coasts containing very little fauna due to the mobility of the substratum. Characterised by low numbers of amphipods such as *Bathyporeia* spp., the mysid *Gastrosaccus spinifer* and the venerid bivalve *Ensis siliqua*.	N/A: Less than 2 sites in the group. Species recorded at the site assigned this biotope included: *Sabellaria spinulosa*, Nemertea spp., *Pisidia longicornis, Notomastus* spp., *Scalibregma inflatum, Ampharete lindstroemi.*	This biotope was found in isolated areas in the central former Hornsea Zone.

4.1.4.21 A full species list, including abundances and biomass, as recorded from the benthic grab samples is available within an appendix on request. This full list of infaunal biotopes assigned to each sampling site and the groups identified during the cluster analyses (and tested using SIMPROF) is presented in Appendix A (available on request). The full list of SIMPER outputs, with the draft infaunal biotopes as factors is presented in Appendix B (available on request).

Benthic infauna biotope mapping – Markham's Triangle

4.1.4.22 The infaunal dataset for the 50 samples from Markham's Triangle have not been included in the multivariate analyses described in sections 4.1.4.1 to 4.1.4.21. However, as discussed in section 2.4.2.4, the data have been examined using multivariate analysis in conjunction with the infaunal dataset of the Hornsea Three benthic ecology study area (according to the methods described in section 2.6.2.2), in order to ascertain whether the assemblages, and therefore biotopes, are likely to be comparable to those described for the Hornsea Three benthic ecology study area. The purpose of this broad comparison is to determine whether the data from Markham's Triangle are comparable to the survey data used to characterise the Hornsea Three array area, and to ultimately ascertain whether the historic benthic ecology survey and site-specific survey datasets are sufficient to characterise the baseline benthic ecology of the Hornsea Three array area.

4.1.4.23 The MDS plot presented in Figure 4.7 shows data from all 431 benthic infaunal samples (except two outliers; S073 and S092; including 50 sites within Markham's Triangle) in the Hornsea Three benthic ecology study area, with symbols denoting the area of the Hornsea Three benthic ecology study area that each datum pertains to. Figure 4.7 shows that faunal assemblages from Markham's Triangle (green symbols) generally clustered well with the stations in the Hornsea Three benthic ecology study area. The Markham's Triangle dataset shows a relatively close aggregation with the Hornsea Three array area data (dark blue symbols) and more broadly with the former Hornsea Zone (light blue symbols). The Hornsea Three offshore cable corridor dataset (red symbols) showed least similarity with Markham's triangle dataset and generally only loosely aggregated with the former Hornsea Zone and Hornsea Three array area. This is unsurprising as the Hornsea Three offshore cable corridor comprised biotopes (largely SspiMx) that were generally not representative of the habitats across the rest of the Hornsea Three benthic ecology study area.

4.1.4.24 Figure 4.8, Figure 4.9 and Figure 4.10 show dendrograms of the Hornsea Three array area and Markham's Triangle infaunal datasets for the sandy, coarse and mixed sediment groups, respectively. The biotopes assigned to the sampling stations within the Hornsea Three array area are also shown; as described above, biotopes have not yet been assigned to the Markham's Triangle data, hence the absence of symbols for those data points. The purpose of these plots is to determine how the Markham's Triangle data relates to the Hornsea Three data, in the context of assigned biotopes, and will help, in part, to assign biotopes to the Markham's triangle sampling stations.

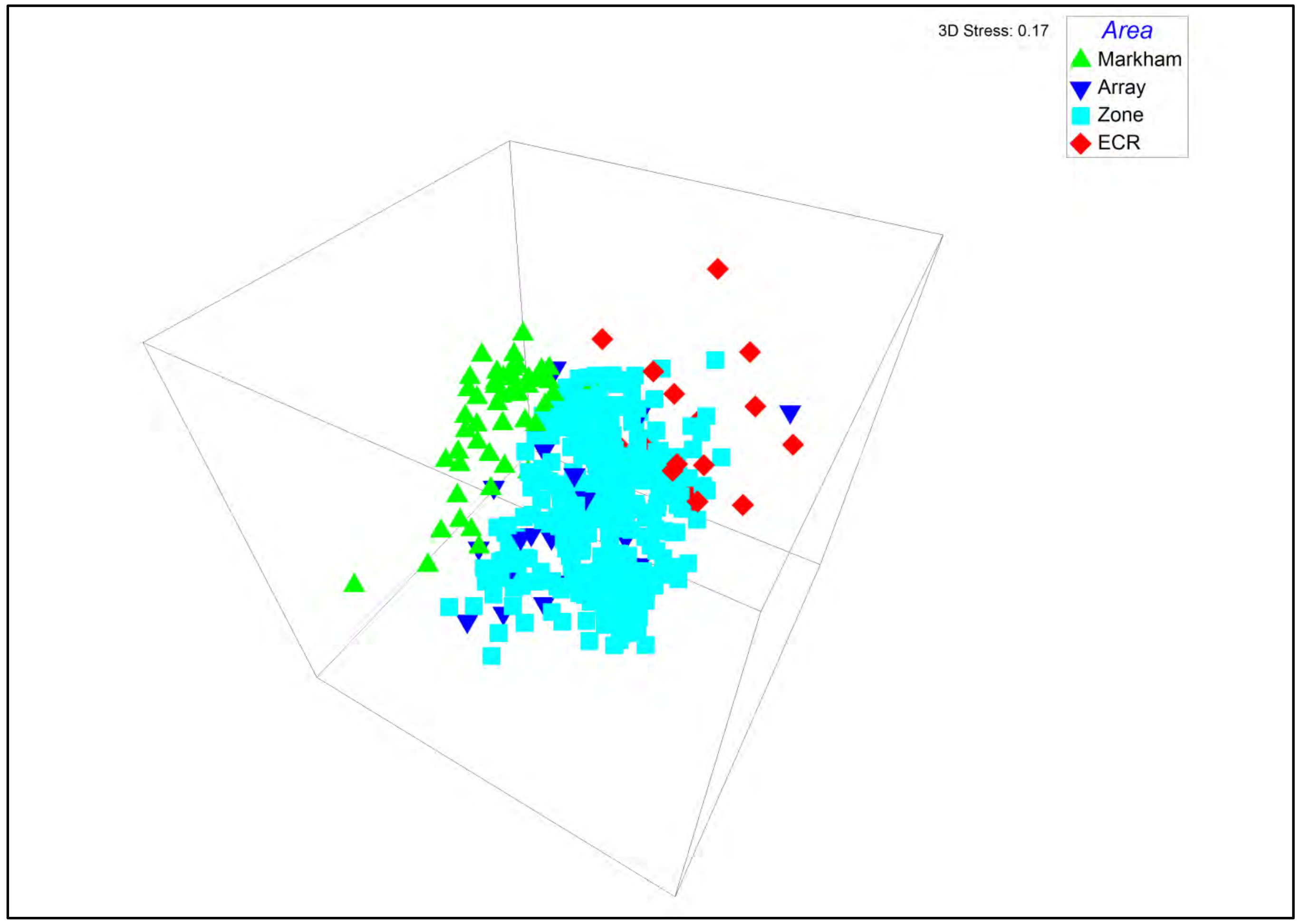

Figure 4.7: Subset 3-D MDS plot for benthic infaunal communities in all sediments within the Hornsea Three benthic ecology study area, including Markham's Triangle (green triangles). ECR (red diamonds) are samples from the Hornsea Three offshore cable corridor.

4.1.4.25 Figure 4.8 shows that ten of Markham's Triangle data points cluster well with the Hornsea Three array area data within the sandy and muddy sand sediment type. Four of the Markham's Triangle stations are likely to be assigned either the NcirBat or FfabMag biotope, while between two and six stations may be assigned the AfilMysAnit biotope, though two of these stations may be assigned another biotope not currently present within the Hornsea Three array area.

4.1.4.26 Figure 4.9 shows that 26 of Markham's Triangle data points cluster well with the Hornsea Three array area data within the coarse sediment type, all of which are likely to be assigned the PoVen biotope. As described in section 4.1.4.25, biotope allocation will not be confirmed prior to an analysis of the SIMPER data together with a review of the untransformed species abundances.

4.1.4.27 Figure 4.10 shows 14 of Markham's Triangle data points alongside the Hornsea Three array area data within the coarse sediment type. Unlike the plots for sandy sediment and coarse sediment, Figure 4.10 does not give an indication of which biotopes are likely to be assigned to the Markham's Triangle data points. The Markham's Triangle stations may be assigned one of four biotopes, including PoVen, MysThyMx, EpusOborApri and MedLumVen/EpusOborAPri, though it is possible the Markham's Triangle stations may be assigned at least one other biotope not listed above. Again (as per section 4.1.4.25), allocation will not be confirmed prior to an analysis of the SIMPER data together with a review of the untransformed species abundances and a spatial review of adjacent biotopes in similar sediment types.

4.1.4.28 The multivariate analysis on the Markham's Triangle dataset, together with the historic benthic survey data and site-specific data from within the Hornsea Three array area, indicates that the infaunal communities are generally comparable, especially for communities in the sandy and coarse sediment types. As such, the the historic benthic survey data and site-specific data are considered to provide sufficient coverage of the Hornsea Three array area to characterise the benthic infaunal biotopes.

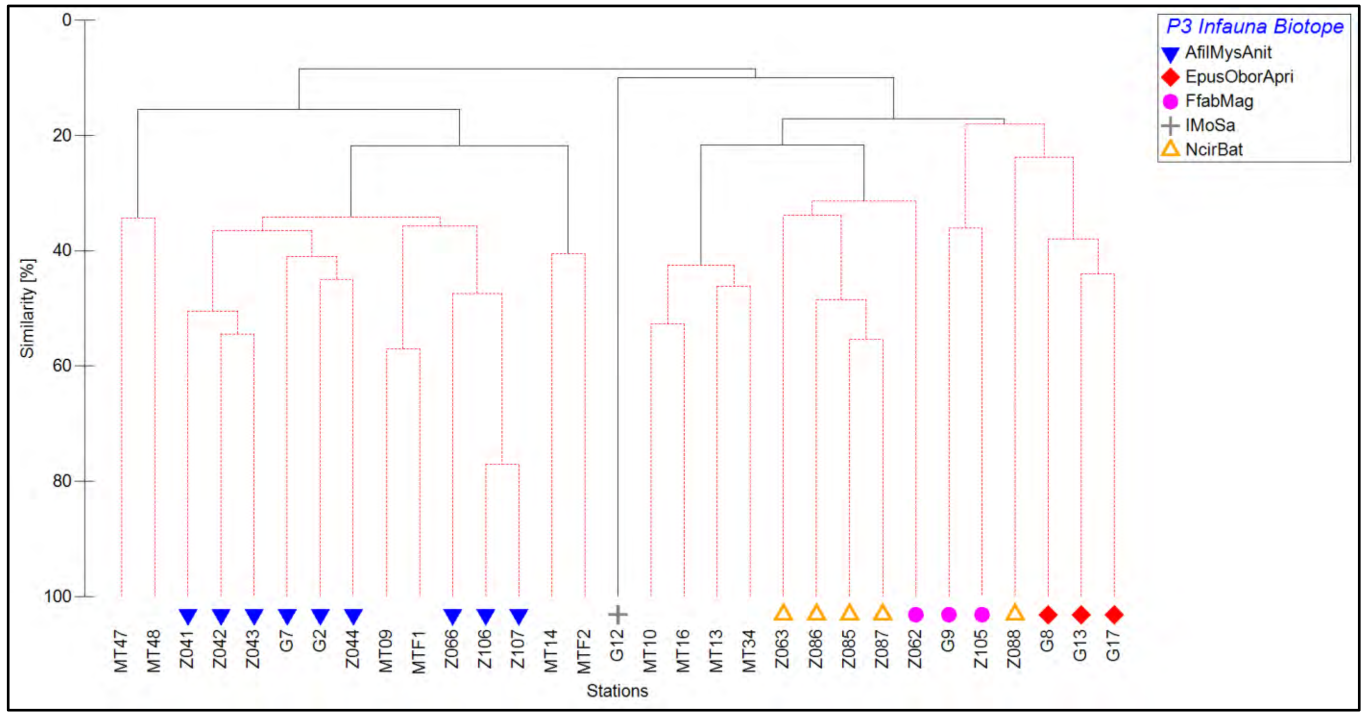

Figure 4.8: Dendrogram of infaunal communities in sandy sediments in the Hornsea Three array area and Markham's Triangle.

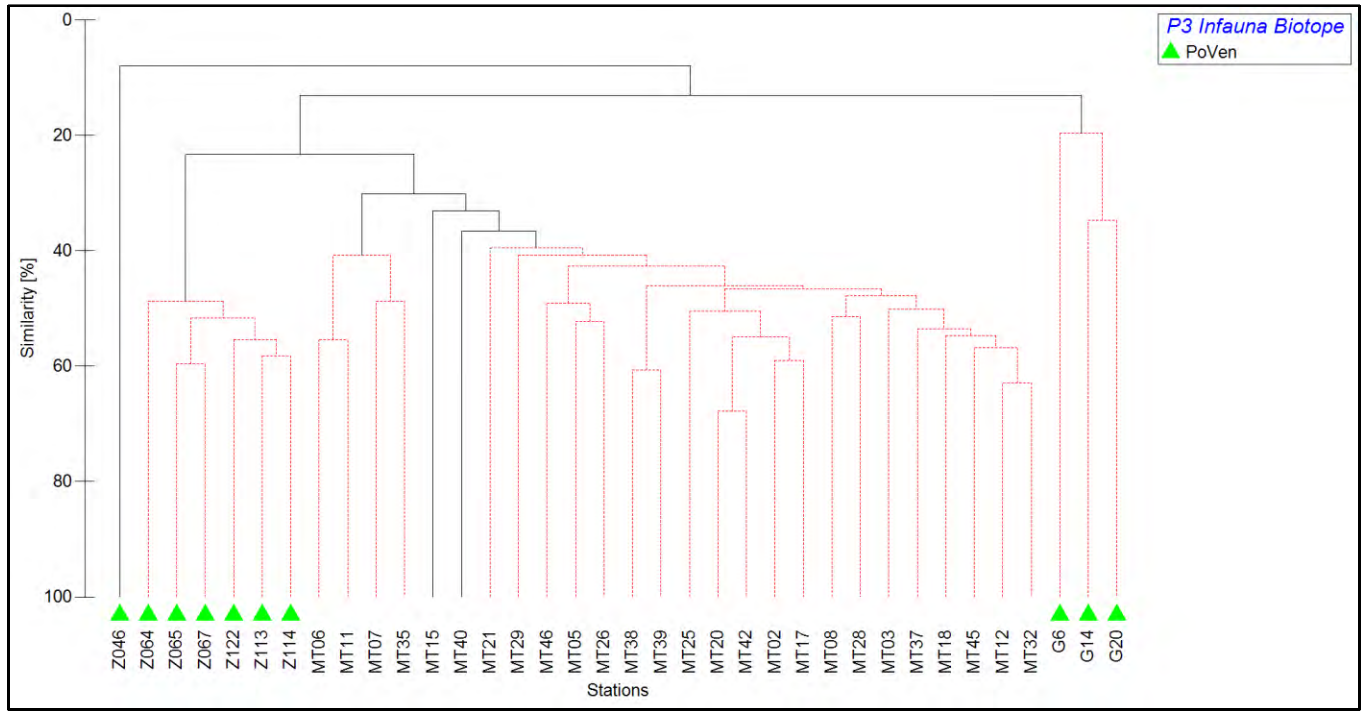

Figure 4.9: Dendrogram of infaunal communities in coarse sediments in the Hornsea Three array area and Markham's Triangle.

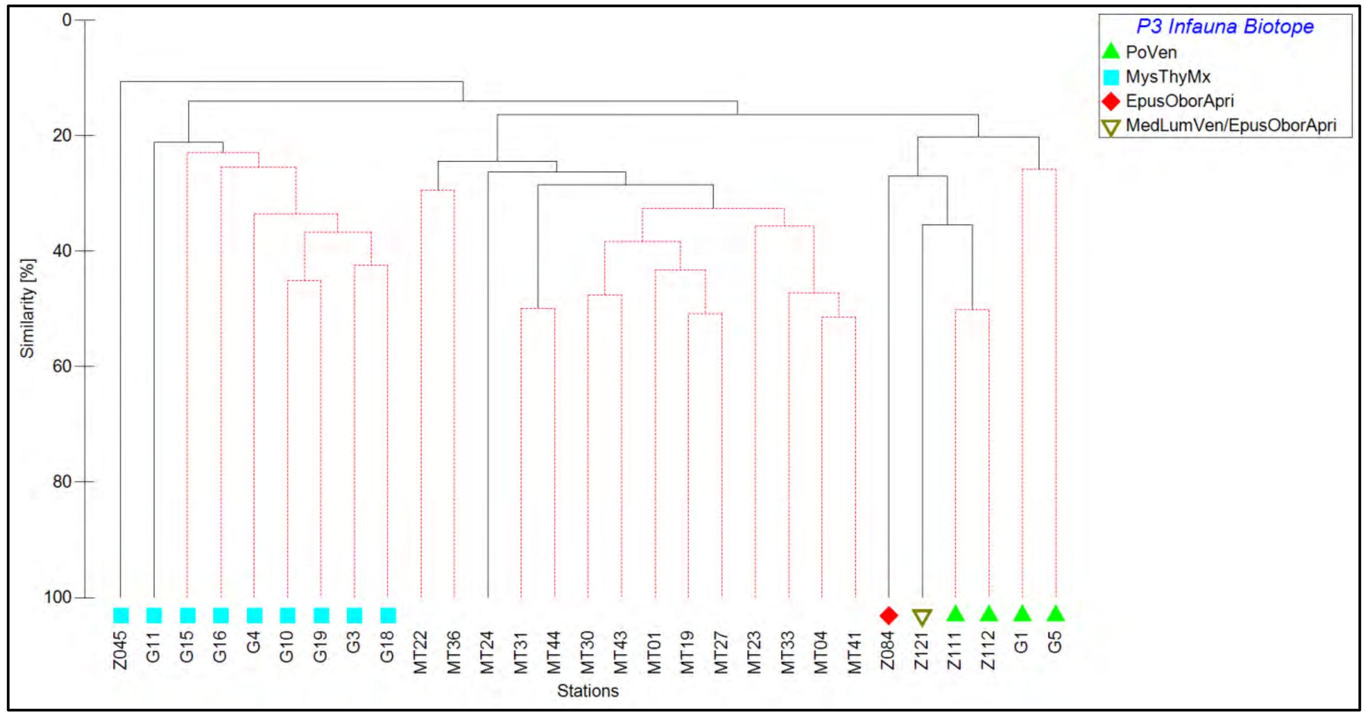

Figure 4.10: Dendrogram of infaunal communities in mixed sediments in the Hornsea Three array area and Markham's Triangle.

Epibenthic biotope mapping

4.1.4.29 As discussed in section 2.6.2.1, the epifaunal and epifloral data collected from the DDV analysis and also from the laboratory analysis of the epibenthic component of the grab samples were combined for the Hornsea ZoC, Hornsea Project One and Hornsea Project Two surveys, and analysed using cluster analysis to group sites with a similar epibenthic composition. No DDV data were acquired during the site-specific survey at the Hornsea Three array area in 2016 and only limited DDV data were available for the Hornsea Three offshore cable corridor survey undertaken in 2016. As such, the epibenthic biotope map draws on the qualitative DDV data for the Hornsea Three offshore cable corridor (i.e. visual determination of biotopes in DDV footage; Bibby Hydromap, 2016), while the existing epibenthic biotopes determined for the majority of sediments in the Hornsea Three array area have been extrapolated to the eastern extent of the Hornsea Three array area using the interpreted geophysical data from the site-specific survey. The resulting biotopes for the eastern section of the Hornsea Three array area and the Hornsea Three offshore cable corridor have been mapped together with results of the Hornsea ZoC, Hornsea Project One and Hornsea Project Two surveys. A site-specific benthic survey will be undertaken in Quarter 2 of 2017 along the Hornsea Three offshore cable corridor which will be used to further inform the infaunal, epibenthic and epibenthic beam trawl biotope maps in the Environment Statement.

4.1.4.30 As with the infaunal analysis, the cluster analyses were undertaken following prior grouping of the dataset according to the Simplified Folk Classification sediment classes (i.e. sand and muddy sediment, coarse sediments and mixed sediment); SIMPROF was used to test whether these groupings were significantly different. The results of the cluster analyses and the combined dendrogram plot for all the sediment groupings are presented in Appendix C, while the full results of the DDV analysis are available within an appendix on request.

4.1.4.31 Preliminary biotopes were then assigned to the data using the results of the cluster analyses and the associated SIMPER outputs. These initial classifications were reviewed alongside the raw untransformed benthic epifauna data before final biotopes were assigned (Connor *et al.,* 2004).

4.1.4.32 In many instances the presence/absence of key species was responsible for the majority of the dissimilarity between the clusters, but due to the nature of the species recorded, the sites were assigned the same biotope. For example, the cluster analysis for sandy sediments identified two clusters (Group h and Group g; see Appendix C for sites within these clusters) one of which (Group h) had the echinoderm *A. rubens* as the only characterising species while the other group (Group g) had *A. rubens* and *A. irregularis* as the only characterising species. The SIMPER showed that approximately 36% of the dissimilarity between groups was due to the almost complete absence of *A. irregularis* from Group h. However, as the community has similarly low abundances of all other species observed, and as the two characterising species were echinoderms with similar habitat preferences, both clusters were assigned to the IMoSa biotope (Table 4.3); populations of brittlestars such as *Amphiura brachiata* were not high enough, and the sediment not considered muddy enough to classify Group g as an alternative biotope such as SS.SSa.CMuSa.Abra.Airr (*Amphiura brachiata* with *Astropecten irregularis* and other echinoderms in circalittoral muddy sand) for example.

4.1.4.33 The combined 2-D MDS plot for all sites and sediment types, with biotopes as factors is presented in Figure 4.11, which shows the stations which were completely devoid of fauna as outliers with all the remaining sites densely clustered together. Figure 4.12 shows a subset of the combined epifauna MDS plot excluding those sites devoid of fauna and shows a high degree of overlap between sites. The high degree of overlap between the IMoSa biotope and SS.SCS.ICS.SSh (Sparse fauna on highly mobile sublittoral shingle (cobbles and pebbles)) biotope (hereafter referred to as SSh) is not surprising given that, although the underlying sediment type differs, these are essentially both characterised by extremely sparse populations with the most conspicuous epifaunal species present being echinoderms. These sites were only assigned different biotope codes due to the nature of the sediments with the IMoSa biotope typical of mobile fine sands and the SSh biotope typical of coarser sediments with a higher proportion of shell and gravel and similarly devoid of epifauna. The MDS plots and dendrograms for each of the three sediment type groups, sand and muddy sand, coarse sediments, and mixed sediments, with biotopes as factors, are avialble on request; the cluster analysis for all sites and sediment types is presented in Appendix C.

4.1.4.34 The majority of the sand and muddy sand sediment sites were assigned the IMoSa biotope and generally exhibited a dense clustering in the MDS plot (available on request), indicating a high degree of similarity between sites. However, it is evident that within the IMoSa cluster there were two main groups of sites which represent the clusters discussed previously in section 4.1.4.32 (Group h and Group g); those sites characterised by *A. rubens* alone and those characterised by both *A. rubens* and *A. irregularis.*

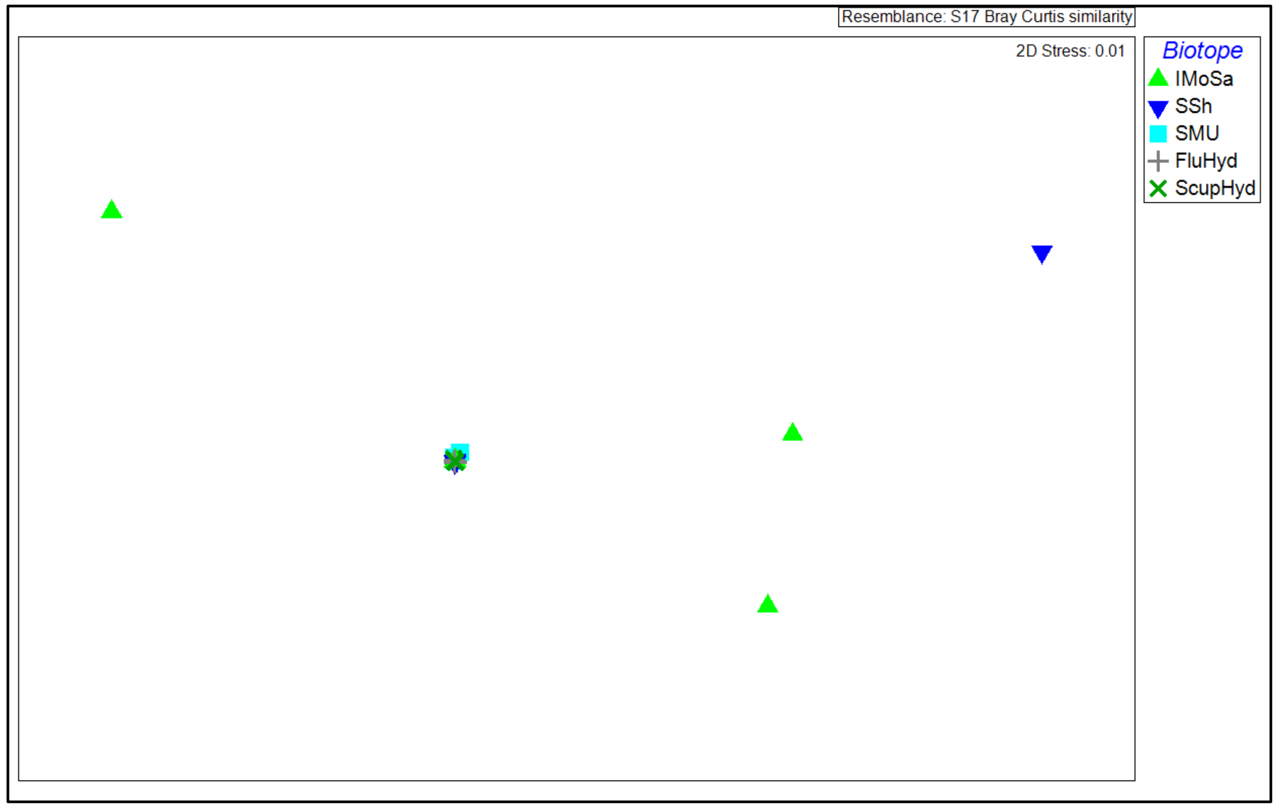

Figure 4.11: 2-D MDS plot for epibenthic communities (biotopes) in all sediment types for the Hornsea Three benthic ecology study area.

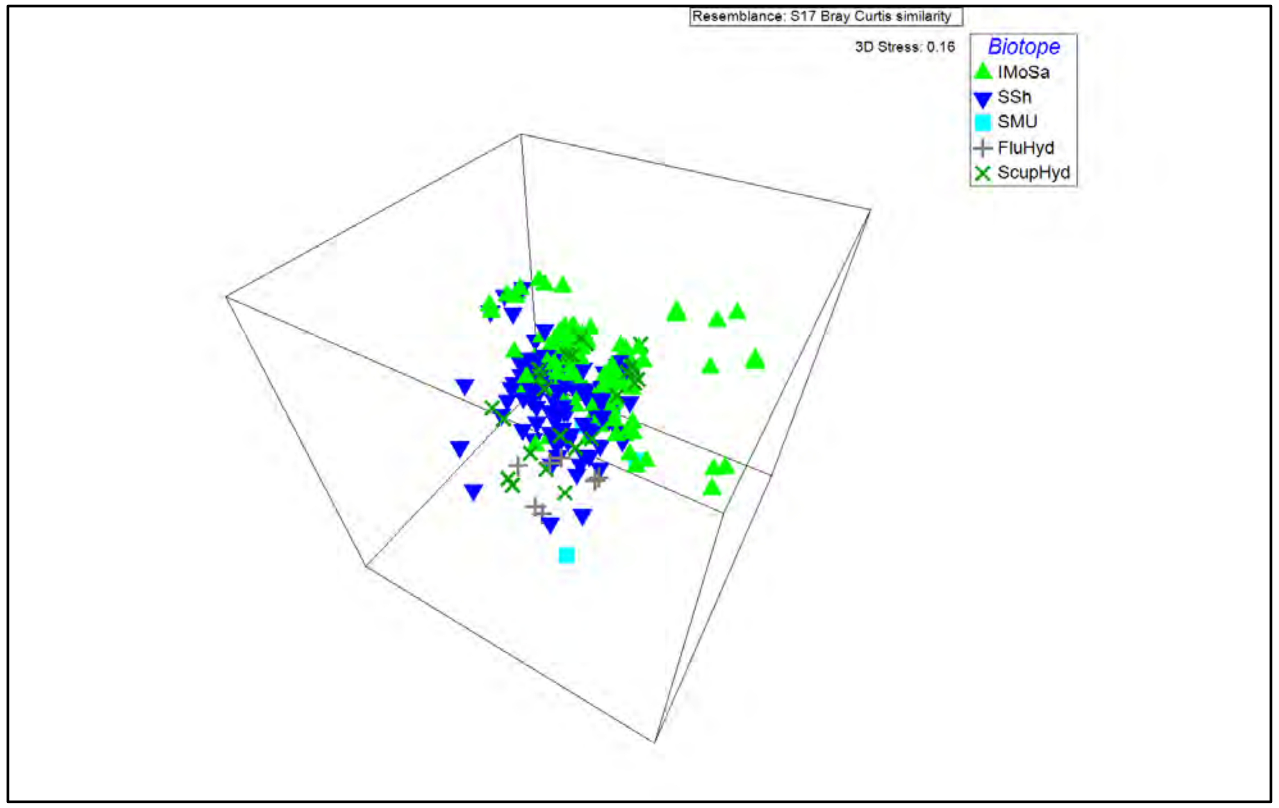

Figure 4.12: Subset of a 3-D MDS plot for the epibenthic communities (biotopes) in all sediment types for the Hornsea Three benthic ecology study area (note subset; 6 outlying sites not shown).

4.1.4.35 Ten sites associated with the sand and muddy sand sediments clustered away from the dominant IMoSa biotope and were assigned the broad SS.SMu (Sublittoral cohesive mud and sandy mud communities) biotope due to the high abundances of Norway lobster *Nephrops norvegicus*. The MDS plot (available on request) shows two anomalous sites, located to the west of the Hornsea Three array area, which were assigned to the SS.SSa.IFiSa.ScupHyd (*Sertularia cupressina* and *Hydrallmania falcata* on tide-swept sublittoral sand with cobbles or pebbles) biotope (hereafter referred to as ScupHyd; green cross symbols) due to the prevalence of cobbles at these sites, with associated epibenthic communities.

4.1.4.36 Similarly, the 3-D MDS plot for coarse sediments (available on request) shows typically dense clustering, indicating little differences in the epibenthic communities observed at these sites. There was some overlap between the SSh biotope (blue triangle symbols) and the ScupHyd biotope (green cross symbols) with the differences between the two being a higher abundance of hydroids in the ScupHyd biotope. The subset MDS also shows a typical pattern of gradation from relatively species poor epibenthic communities associated with the SSh biotope, through the sand sediments dominated by cobbles and pebbles and the ScupHyd biotope, to the FluHyd biotope associated with the deeper more mixed sediments with less sand.

4.1.4.37 The subset 2-D MDS plot for mixed sediments (available on request) showed loose clustering of sites due in part to the fewer number of sites but also to the diverse complement of species in these sites. A general pattern of increasing epibenthic community complexity and diversity was evident in the MDS plot (available on request). The dendrogram for mixed sediments (available on request) shows that the sites assigned the SSh biotope clustered together in the centre of the dendrogram, sharing similarly sparse epifaunal assemblages.

4.1.4.38 Figure 4.13 shows the geographic extents of the epibenthic biotopes present throughout the Hornsea Three benthic ecology study area. Five epifaunal biotopes were identified following the analysis of the DDV data and the epibenthic component of the grabs and these are presented in Table 4.3.

4.1.4.39 The majority of the sand and muddy sand sediment sites across the central sections of the Hornsea Three array area, the Hornsea Three offshore cable corridor and the wider Hornsea Three benthic ecology study area were assigned the IMoSa biotope code due to the lack of epifaunal species present, as is characteristic of this biotope. The most conspicuous epifaunal species present were the echinoderms *A. rubens* and *A. irregularis* which characterised this biotope. Although, turfs of hydroids were occasionally recorded in association with cobbles and pebbles these were typically restricted in distribution and not considered prevalent enough to justify an epifaunal overlay biotope such as ScupHyd. The majority of the substrate was characterised by sand and, as such, these cobbles were not considered to form part of a more diverse biotope than IMoSa. Several areas along the northern boundary of the Hornsea Three array area, the area immediately to the north of this, plus two areas in the southeast of the Hornsea Three array area, were characterised by *N. norvegicus* which is common at deeper depths and in muddier sediments, as such these sites were assigned the SMU biotope.

4.1.4.40 The majority of the coarse sediment sites within the Hornsea Three array area and the wider Hornsea Three benthic ecology study area supported similarly sparse epifaunal communities characterised by the same echinoderms identified in the IMoSa biotope (i.e. *A. rubens* and *A. irregularis*) and as such were assigned to the coarse sediment equivalent of IMoSa, the SSh biotope. As with the sandy sediment, the majority of the coarse substratum was dominated by gravelly sands with only occasional cobbles or boulder, providing substrate for the attachment of hydroids or bryozoans.

4.1.4.41 Sites assigned to the ScupHyd biotope were dominated primarily by the echinoderm *A. rubens* in the areas of coarse sandy sediment with mixed turfs of hydroids and bryozoans on the cobbles and pebbles found throughout this biotope. The areas of FluHyd were typically found in areas of more mixed sediments, including in the north east of the Hornsea Three array area, and three discrete areas along the Hornsea Three offshore cable corridor. Areas assigned to the FluHyd biotope were typically dominated by hydroids and bryozoans, notably *F. foliacea*, the soft coral *A. digitatum* as well as the echinoderm *A. rubens* which was found throughout the Hornsea Three benthic ecology study area. The FluHyd biotope represents a transition between epifaunally diverse rocky substrates and the epifaunally impoverished sediment dominated biotopes (IMoSa) and is typical of the mixed gravelly sediments recorded (Table 4.3).

4.1.4.42 A full epifaunal species list including SACFOR abundances, as recorded in the DDV footage, seabed photography and in the epifaunal component of the grab samples is available within an appendix on request. The full list of epifaunal biotopes for each sampling location and groups identified during cluster analyses (and tested using SIMPROF) is presented in Appendix D (available on request), and a full list of the SIMPER results, with biotopes as factors, is presented in Appendix E (available on request).

Figure 4.13: Epibenthic biotopes in the Hornsea Three benthic ecology study area.

Table 4.3: Epibenthic biotopes identified from DDV and grab analysis in the Hornsea Three benthic ecology study area, including a summary of the SIMPER results and geographic locations (see Figure 4.13).

Biotope Code (Conner *et al.*, 2004)	EUNIS code (2007-11)	Simplified Folk Sediment Classification	Biotope Name	Hornsea Three Biotope Description	Characterising species accounting for up to 75% of cumulative similarity (SIMPER)	Geographic Location
SS.SSa.IFiSa.IMoSa (IMoSa)	A5.231	Sand and muddy sand (174 sites), coarse sediment (3 sites).	Infralittoral mobile clean sand with sparse fauna.	Medium to fine sandy sediment on exposed coasts that often contains very little epifauna due to the mobility of the substratum. Very few epifaunal species were recorded and, with the exception of the echinoderms including *Asterias rubens* and *Astropecten irregularis,* generally occurred at low abundances including flatfish and sandeels. In areas where localised cobbles and pebbles provided substrate for epifaunal species in an otherwise featureless habitat, hydroid turfs and bryozoan crusts were observed on the pebbles and cobbles.	*Asterias rubens, Astropecten irregularis.*	This biotope was distributed extensively throughout the Hornsea Three benthic ecology study area, particularly the Hornsea Three offshore cable corridor and the central section of the Hornsea Three array area, as well as the area to the west of this.
SS.SSa.IFiSa.ScupHyd (ScupHyd)	A5.232	Sand and muddy sand (2 sites), coarse sediment (16 sites), mixed sediment (6 sites).	*Sertularia cupressina* and *Hydrallmania falcata* on tide-swept sublittoral sand with cobbles.	Sand sediment with cobbles and pebbles, exposed to strong tidal stream, this biotope is characterised by the echinoderm *Asterias rubens,* conspicuous mixed hydroid and bryozoan turfs and the sand mason *Lanice conchilega* in the surrounding sand.	*Asterias rubens,* hydroid/bryozoan mixed turf, *Lanice conchilega, Alcyonium digitatum,* Hydroid/bryozoan (meadow).	This biotope was recorded in the central section of the former Hornsea Zone.
SS.SMu (SMu)	A5.3	Sand and muddy sand (10 sites).	Sublittoral cohesive mud and sandy mud communities.	Sublittoral mud and cohesive sandy mud found in offshore areas of deeper water. This biotope is characterised by epifaunal communities of brittlestars, echinoderms *Asterias rubens* and burrowing megafauna including *Nephrops norvegicus*.	*Nephrops norvegicus.*	This biotope was found in the deeper waters to the north, centre and southeast of the Hornsea Three array area.
SS.SCS.ICS.SSh (SSh)	A5.131	Coarse sediment (97 sites), mixed sediment (29 sites).	Sparse fauna on highly mobile sublittoral shingle (cobbles and pebbles).	Sublittoral clean shingle and pebbles with a lack of conspicuous fauna. Although the majority of the sites assigned to this biotope constituted predominantly coarse gravelly sand, rather than pebbles, the distinct lack of epifauna matched this biotope. This biotope was characterised by a lack of epifauna and the presence of similar epifauna to the IMoSa biotope in sandy sediment including the echinoderms *Asterias rubens*, *Astropecten irregularis*, sandeels and locally abundant hydroid turfs and soft coral *Alcyonium digitatum* on cobbles and pebbles.	*Asterias rubens, Astropecten irregularis.*	This biotope was present in large swathes in the north and south of the Hornsea Three array area as well as the areas of coarser sediments to the west of the Hornsea Three array area.
SS.SMx.CMx.FluHyd (FluHyd)	A5.444	Coarse sediment (4 sites), mixed sediment (3 sites).	*Flustra foliacea* and *Hydrallmania falcata* on tide swept circalittoral mixed sediment.	This biotope is best considered as an epifaunal overlay on a substratum of boulder, cobbles or pebbles with gravel and sand. The epifaunal community was characterised by mixed turfs of hydroids and bryozoans including *Flustra foliacea,* barnacles *Balanus crenatus*, the ascidian *Dendrodoa grossularia*, keelworms *Pomatoceros* sp. and anemones including *Urticina* sp. on scattered pebbles and cobbles.	*Asterias rubens, Actiniaria* spp., *Alcyonium digitatum, Liocarcinus* spp., *Pomatoceros* sp., *Flustra foliacea, hydroid* sp.	This biotope was found in two discrete locations to the northeast of the Hornsea Three array area, several areas along the Hornsea Three offshore cable corridor, and in the southwest of the Hornsea Three benthic ecology study area.

Epibenthic trawl data

4.1.4.43 Data from the epibenthic trawl surveys were also used to inform the benthic epifaunal biotope mapping. These data are available within an appendix on request. Cluster analysis was conducted on the standardised, fourth root transformed data (using SIMPER to test for whether the dissimilarities between groups were significant). Analyses were conducted on the trawl dataset with fish species excluded, due to the high abundance of fish species present in the trawls which, if included, would have obscured the benthic epifaunal data. The 3-D MDS is presented in Figure 4.14 (with biotopes as factors) while the corresponding dendrogram produced as part of the cluster analysis of the epibenthic trawl data is available on request. The cluster analysis identified ten significantly different clusters in the epibenthic trawl dataset, though following review of the SIMPER results together with the raw untransformed data, it was concluded that the communities of many clusters were sufficiently similar such that these sites could be combined, resulting in the identification of five epifaunal biotopes (descriptions based on Connor *et al*., 2004) and these are described in Table 4.4. The results of the cluster analyses groupings, together with the assigned biotopes, are presented in Appendix E.

4.1.4.44 Figure 4.14 and the dendrogram (available on request) show that two biotopes that had been previously epibenthic data were recorded in the epibenthic beam trawls: ScupHyd and FluHyd. Approximately 88% of the trawls were assigned to the ScupHyd biotope which demonstrated good clustering to distinguish them from the other sites (turquoise square symbols; Figure 4.14). The remaining sites were assigned to higher level biotopes as it was not possible to assign a more specific biotope based on the species composition of the trawls. These biotopes were: SS.SCS.ICS (infralittoral coarse sediment) biotope (hereafter referred to as ICS), SS.SMx.CMx (circalittoral mixed sediment) biotope (hereafter referred to as CMx); and the SS.SSa.CMuSa (circalittoral muddy sediment) biotope (hereafter referred to as CMuSa).

4.1.4.45 Figure 4.15 shows the location of the epibenthic trawl locations and the epifaunal biotopes assigned based on the trawl data. The majority of the trawl sites within the Hornsea Three benthic ecology study area were described as the ScupHyd biotope (Table 4.4) and this biotope was recorded throughout both sandy and muddy sand sediments and coarser sediments within these areas. The communities were characterised by mobile epifaunal species typical of sand substrates such as echinoderms *A. rubens* and *A. irregularis* but also conspicuous colonies of scour tolerant hydroids including *H. falcata*, bryozoans such as *F. foliacea* and crabs on cobbles and pebbles. This confirms the findings of the infaunal grab data and the DDV analysis, and suggests that the majority of the sediment across the Hornsea Three benthic ecology study area is gravelly sand and sandy gravel with occasional pebbles and cobble which, where present, provided substrate for the attachment of sessile epifauna.

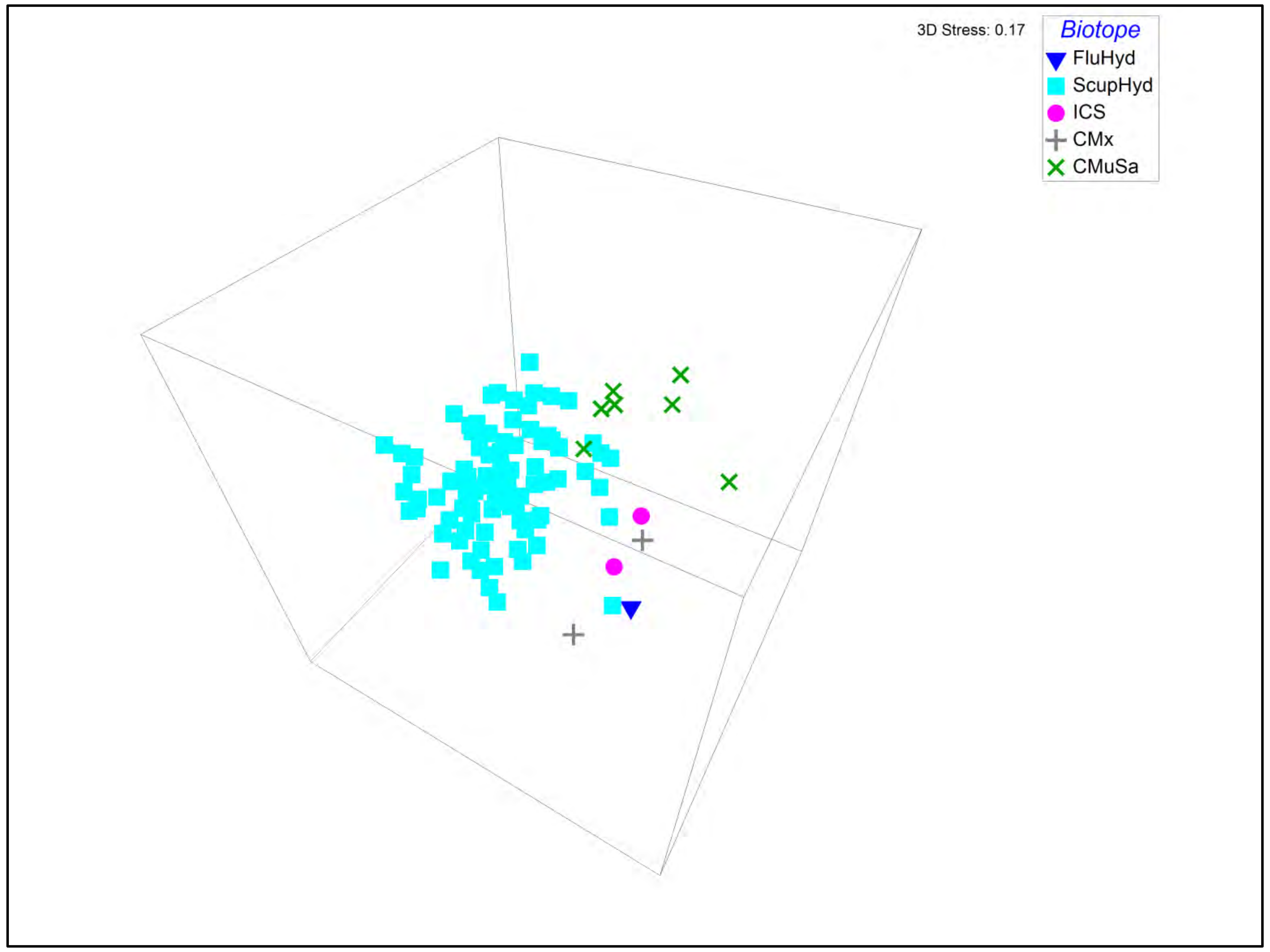

Figure 4.14: 3-D MDS plot of epibenthic beam trawl data for the Hornsea Three benthic ecology study area.

4.1.4.46 Although fish were removed from the epibenthic trawl data prior to analysis, the raw data did show that the trawl sites within the ScupHyd biotope supported significant populations of flatfish typically associated with sandy sediments, including solenette *Buglossidium luteum*, dab *Limanda limanda*, plaice *Pleuronectes platessa* and also sandeels *Ammodytes* spp. Sandeels (both lesser and greater) were generally recorded at the highest abundances along the west and southwestern boundary of the Hornsea Three array area and also in the central part of the former Hornsea Zone. These areas coincide with the sandy areas of the Hornsea Three fish and shellfish study area. The fish assemblage of the Hornsea Three benthic ecology study area is fully assessed in volume 5 annex 3.1: Fish and Shellfish Technical Report.

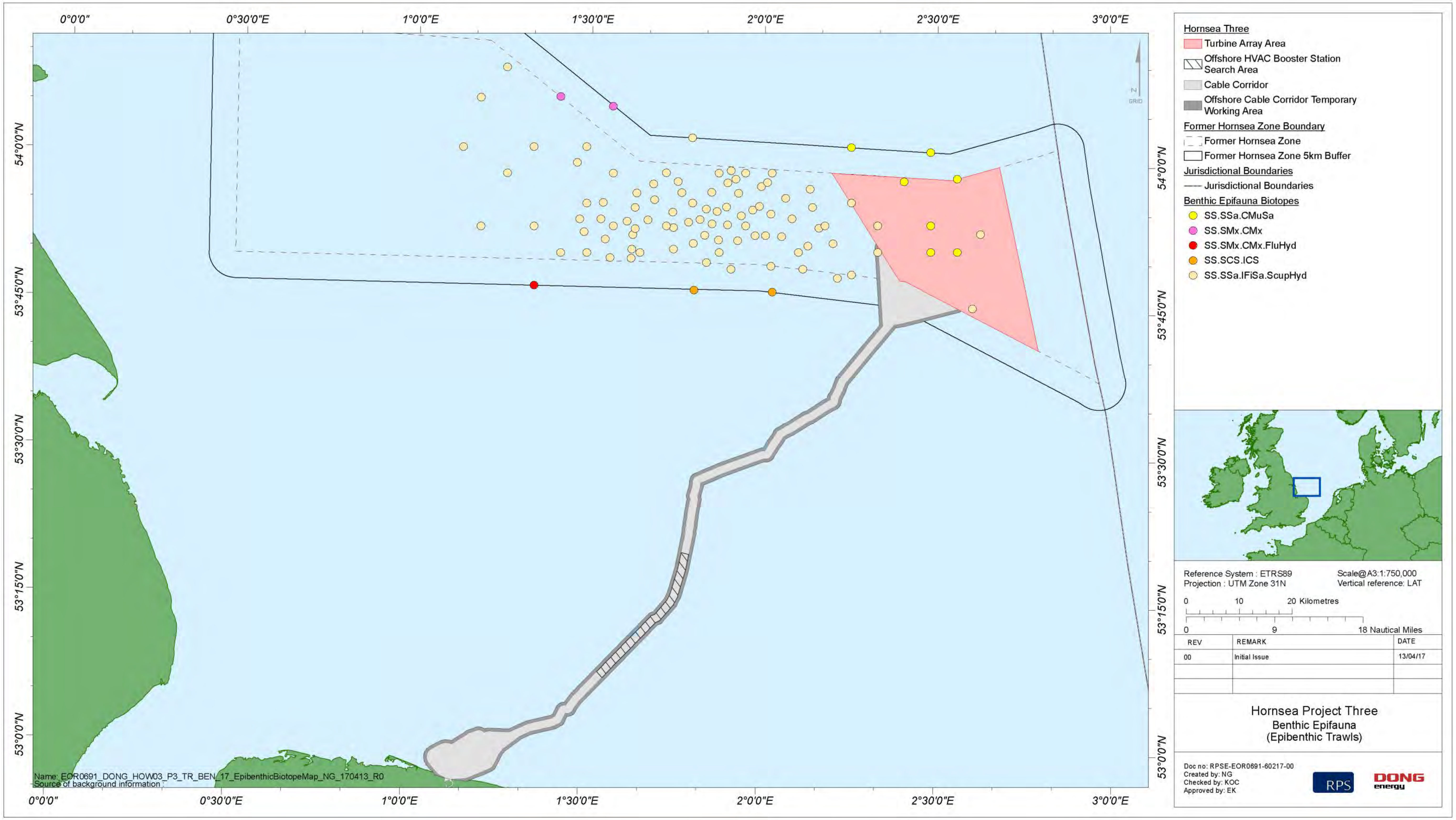

Figure 4.15: Epibenthic biotopes from the epibenthic beam trawl data in the Hornsea Three benthic ecology study area.

Table 4.4: Benthic epifaunal biotopes identified from epibenthic beam trawl data in the Hornsea Three benthic ecology study area, including a summary of the SIMPER results and geographic locations (see Figure 4.15).

Biotope Code (Conner *et al.*, 2004)	EUNIS code (2007-11)	Simplified Folk Sediment Classification	Biotope Name	Hornsea Three Biotope Description	Characterising species accounting for up to 75% of cumulative similarity (SIMPER)	Geographic Location
SS.SSa.IFiSa.ScupHyd (ScupHyd)	A5.232	Sand and muddy sand (49 trawls); coarse sediments (30 trawls) and mixed sediments (11 trawls).	*Sertularia cupressina* and *Hydrallmania falcata* on tide-swept sublittoral sand with cobbles or pebbles.	Occurs in generally shallow sands with cobbles and pebbles, exposed to strong tidal streams. This biotope was characterised by high abundances of mobile epifauna such as the echinoderms *Asterias rubens* and *Astropecten irregularis* and the shrimp *Crangon allmani*, typical of the predominantly sandy sediment substrate. This biotope was also characterised by conspicuous colonies of scour tolerant hydroids including *Hydrallmania falcata* and bryozoans including *Flustra foliacea* and *Alcyonidium parasiticum* on the cobbles and pebbles. Fish communities in this biotope were characterised by high abundances of sand dwelling flatfish species including solenette *Buglossidium luteum*, dab *Limanda limanda*, plaice *Pleuronectes platessa* and sandeels *Ammodytes* spp.	*Asterias rubens, Astropecten irregularis, Flustra foliacea, Alcyonidium parasiticum, Liocarcinus holsatus, Hydrallmania falcata, Alcyonidium diaphanum, Alcyonium digitatum, Pagurus bernhardus*.	This biotope was found across much of the Hornsea Three benthic ecology study area including the area to the west of the Hornsea Three array area.
SS.SSa.CMuSa (CMuSa)	A5.26	Sand and muddy sand (6 trawls) and mixed sediments (1 trawl).	Circalittoral muddy sand.	Circalittoral non-cohesive muddy sands found typically at depths over 15 to 20 m, supporting communities of shrimp *Crangon allmanni*, a variety of crab species including *Liocarcinus holsatus* , *Liocarcinus depurator* and *Pagurus bernhardus* and also low abundances of *Nephrops norvegicus.*	*Crangon allmanni, Asterias rubens, Liocarcinus holsatus, Pagurus bernhardus, Liocarcinus depurator, Processa nouveli holthuisi, Astropecten irregularis, Processa* sp.	This biotope was recorded from seven trawl locations in, and to the north of, the Hornsea Three array area.
SS.SCS.ICS (ICS)	A5.13	Sand and muddy sand (1 trawl); mixed sediments (1 trawl).	Infralittoral coarse sediment.	Occurring on moderately exposed coasts in coarse sand and gravelly sand subject to disturbance by tidal streams and wave action, this biotope was characterised by mobile epifauna including echinoderms and crabs including *Liocarcinus depurator* and *Liocarcinus holsatus* and by lower numbers of hydroids and bryozoans than the ScupHyd biotope. This biotope also had moderately high numbers of shrimp Pandalidae spp. which is typical of gravelly substrate.	Liocarcinus *depurator, Asterias rubens, Pandalina brevirostris, Macropodia parva/rostrata, Crangon allmani, Aequipecten opercularis, Liocarcinus holstatus, Inachus dorsettensis*, Pandalidae, *Hydrallmania falcata, Sertularella polyzonias.*	This biotope was recorded to the south of the southern boundary of the Hornsea Three benthic ecology study area.
SS.SMx.CMx (CMx)	A5.445	Mixed sediment (2 trawls).	Circalittoral mixed sediment.	Occurs on circalittoral mixed sediments with communities dominated by the brittlestar *Ophiothrix fragilis.* This biotope was also characterised by high abundances of the echinoderm *Asterias rubens.*	*Ophiothrix fragilis, Asterias rubens, Simnia patula, Astropecten irregularis, Luidia sarsi, Macropodia tenuirostris, Psammechinus miliaris, Macropodia parva/rostrata, Inachus dorsettensis,* Actinaria, Aequipecten *opercularis.*	This biotope was recorded from two trawl sites in the northwest of the Hornsea Three benthic ecology study area.
SS.SMX.CMx.FluHyd (FluHyd)	A5.444	Mixed sediment (1 trawl).	*Flustra foliacea* and *Hydrallmania falcata* on tideswept circalittoral mixed sediment.	Occurs on circalittoral mixed sediments with communities dominated by high abundances of the soft coral *Alcyonium digitatum* and the hydroid *Flustra foliacea*, crabs including Liocarcinus *depurator*, echinoderms *Asterias rubens* and *Psammechinus miliaris*, the sea squirt *Ascidiella scabra.*	N/A: Less than 2 sites in the group. Species recorded at the site assigned this biotope included: *Alcyonium digitatum, Flustra foliacea, Liocarcinus depurator, Asterias rubens, Psammechinus miliaris, Ascidiella scabra, Crangon crangon.*	This biotope was recorded from a single trawl site located to the southwest of the Hornsea Three benthic ecology study area.

4.1.4.47 Two trawl locations to the northwest of the Hornsea Three benthic ecology study area were classified as the CMx biotope. These trawls were dominated by high abundances of the brittlestar *Ophiothrix fragilis* and the starfish *A. rubens* (Table 4.4). Seven trawls located within, and to the north of, the Hornsea Three array area were characterised by typically muddy sediment species including the shrimp *Crangon allmanni*, a variety of crab species including *L. holsatus, L. depurator* and *P. bernhardus* and also low abundances of *N. norvegicus*; these sites were assigned the CMuSa biotope (see Table 4.4).

4.1.4.48 A full species list, including abundances and biomass, as recorded from the epibenthic trawl data is available within an appendix on request, and a full list of the SIMPER results, with biotopes as factors, is presented in Appendix F.

Univariate statistics

Benthic infauna

4.1.4.49 The following univariate statistics were calculated for each benthic grab site: number of species (S), abundance (N), ash free dry weight (AFDW) biomass (Eleftheriou and Basford, 1989) in grams (g), Margalef's index of Richness (d), Pielou's Evenness index (J'), Shannon-Wiener Diversity index (H') and Simpson's index of Dominance (λ). The mean of each of these indices was then calculated for each of the infaunal biotopes identified in the Hornsea Three benthic ecology study area and these are summarised in Table 4.5 with univariate statistics for individual sites presented in Appendix G. Where a biotope was assigned to a suite of sites, only one of which recorded any taxa (as was the case for the IMoSa biotope), these statistics have not been calculated due to the lack of replicate samples from the same biotope from which to calculate a mean.

4.1.4.50 The univariate statistics shows that the sand sediment biotopes (i.e. NcirBat, FfabMag, EpusOborApri and ApriBatPo) had comparatively lower mean numbers of species than the coarser and mixed sediment biotopes (i.e. PoVen, MedLumVen, MysThyMx and SspiMx). The mean number of species for sites in sandy sediments within the Hornsea Three array area and the extensive areas of sandy sediments to the west was less than 20 taxa (see Figure 4.16), and although abundances were relatively high, typically up to 70 individuals, these were also lower than abundances for the coarser sediment biotopes, which ranged from approximately 50 individuals to over 360 individuals in the MysThyMx biotope (see Figure 4.16). Figure 4.16 shows the number of taxa recorded per infaunal benthic grab sample and highlights that sites with the highest number of taxa were typically found in the east of the Hornsea Three benthic ecology study area and in particular in association with the coarse and mixed sediments located in the southern section of the Hornsea Three offshore cable corridor and in the southwest of the Hornsea Three array area.

4.1.4.51 The NcirBat biotope, assigned to 37 locations, recorded the lowest mean number of species and abundance (16.9 ± 4.2 species and 39.5 ± 14.1 individuals, respectively) of the sandy biotopes, reflecting the relatively species-poor nature of this community. The diversity indices were therefore also lower for this sandy sediment biotope (Table 4.5). This is characteristic of these biotopes, which are typically species poor due to the physical disturbance and mobility of the sandy sediment.

4.1.4.52 The sandy mud sediments associated with the AfilMysAnit biotope had a higher mean number of species (21.1 ± 7.8; see Figure 4.16) and mean abundance (96.9 ± 80.9) than the other sandy sediment biotopes, although still lower than the coarser sediment biotopes. This may have been due to increased sediment stability in these sites which were located in the north of the Hornsea Three array area and immediately to the north of this (Figure 4.6) in deeper water and lower energy environments, as demonstrated by the poorly sorted nature of the sediments.

4.1.4.53 Of the coarse sediment biotopes, SspiMx recorded the highest mean number of species (46.7 ± 31.1; Figure 4.16), and diversity Table 4.5; Figure 4.19). Mean abundance (620.4 ± 10.43.6) was particularly high; typical of this community which comprises high numbers of *S. spinulosa*. The baked bean sea squirt *Dendrodoa grossularia* was also one of the highest contributors to the number of individuals, though numbers were generally high among other taxa in the biotope. The other key coarse sediment biotopes, MoeVen and MedLumVen recorded lower mean number of species (15.5 ± 5.3 and 29.9 ± 10.2, respectively) and mean abundance scores (34.4 ± 16.0 and 156.4 ± 111.7, respectively). The univariate statistics for the MoeVen biotope were comparable to those recorded in the sand sediment biotopes (see section 4.1.4.51). This may have been due to the shallower nature of the areas where this biotope was recorded (Figure 4.6) and the potentially less stable sediments due to stronger water movement in these areas.

4.1.4.54 The mosaic MedLumVen/EpusOborApri biotope recorded values for mean number of species and abundance intermediate between those for the individual EpusOborApri and MedLumVen biotopes (22.8 ± 4.3 species and 47.3 ± 11.7 individuals). This was a transition biotope between the coarser sediment biotopes such as PoVen and the sandy sediment biotopes such as NcirBat.

4.1.4.55 The mixed sediment biotope, MysThyMx, recorded a mean number of species and mean abundances that were higher than the coarse sediment biotopes discussed above in section 4.1.4.53 (32.8 ± 9.4 species and 139.4 ± 70.6 individuals; Table 4.5). These high numbers are to be expected from a biotope which is characteristically rich, due to increased habitat complexity resulting from the mixed sediment substrate. Together these provide a range of microhabitats for a diverse array of mobile and sessile species (Connor *et al.,* 2004).

4.1.4.56 The differing patterns observed between the sandy, coarse and mixed sediment communities are reflected in the diversity indices (Margalef's index of Richness and the Shannon Wiener Diversity index) presented in Table 4.5 and Figure 4.19. Figure 4.19 shows that the number of species was highly variable across the Hornsea Three benthic ecology study and even on relatively small scales within the Hornsea Three array area and along the Hornsea Three offshore cable corridor. Number of species was generally lowest in areas coinciding with sandy sediments within the Hornsea Three array area and in the west of the Hornsea Three benthic ecology study area and highest in the mixed sediments present within the Hornsea Three array area. Both of these diversity indices were smallest for the species poor MoeVen (d = 4.1 ± 1.1; H' = 2.3 ± 0.3) and largest for the infaunally rich PoVen community (d = 6.8 ± 1.5; H' = 2.9 ± 0.3) and MysThyMx community (d = 6.4 ± 1.5; H' = 2.6 ± 0.4). In between, the other sand sediment biotopes recorded intermediate values of diversity, including AfilMysAnit EpusOborApri; FfabMag; NcirBat, which were generally lower than the coarser biotopes and mosaic biotopes: SspiMx; MoeVen; MedLumVenMedLumVen/EpusOborApri.

4.1.4.57 Pielou's Evenness (J') and Simpson's Dominance (λ) scores were generally high (J' >0.7) and low (Lambda < 0.24), respectively, for all biotopes, indicating that the communities were not dominated by a small number of species (Table 4.5).

4.1.4.58 Table 4.5 also shows that the mean biomass was lowest in the sandy sediment biotopes such as NcirBat and ApriBatPo and higher in the coarse and mixed sediments of the PoVen, MedLumVen, MysThyMx and SspiMx biotopes. This is also reflected in Figure 4.18 which shows the total biomass per infaunal benthic grab sample across the Hornsea Three benthic ecology study area. Sites with the highest total biomass were clustered in the centre of the Hornsea Three benthic ecology study area associated with the coarse and mixed sediments in this area (Figure 4.21). Biomass was notably low in the westernmost extent of the Hornsea Three benthic ecology study area, in association with the sandier areas through the central sections of the Hornsea Three array area and the majority of the Hornsea Three offshore cable corridor, with the exception of the nearshore section of the Hornsea Three offshore cable corridor.

4.1.4.59 Figure 4.19, Figure 4.20 and Figure 4.21 show the mean number of species, abundance and biomass (respectively) for each of the major faunal groups for each of the infaunal biotopes (and mosaic biotopes) identified across the Hornsea Three benthic ecology study area from the infaunal grab sample data. As discussed in sections 4.1.4.49 to 4.1.4.58, the coarse and mixed sediment biotopes (SspiMx, MysThyMx, MedLumVen and PoVen) showed the highest mean number of species across the Hornsea Three benthic ecology study area and were dominated by annelid species (Figure 4.19). The SspiMx biotope in particular showed a relatively high diversity in annelids, crustaceans and species encompassed in the 'other' category and these groups exhibited substantially higher abundances of individuals compared to all other biotopes in the Hornsea Three benthic ecology study area. The MedLumVen, PoVen and MysThyMx biotopes also showed relatively high mean numbers of species, though only MedLumVen, together with SspiMx, exhibited high biomasses, which were largely attributable to the mollusc group (Figure 4.21). In comparison, mean abundances in the sandy sediment biotopes were somewhat lower (Figure 4.20). Molluscs, echinoderms and crustaceans were present in similar numbers and abundances to those of the coarse sediment biotopes, though the numbers of annelid species in sandy biotopes were lower compared to the coarse and mixed biotopes. Although these species were present in low numbers, these species were found to dominate the biomass at these sites, with the numerically abundant annelids contributing relatively little however to the overall biomass (Figure 4.21).

4.1.4.60 The MoeVen biotope, characteristic of coarse sediments, showed considerably fewer taxa, individuals and lower biomass compared to the other coarse and mixed sediment biotopes, the reason for this being the assignment of this biotope to two sampling stations on the Hornsea Three offshore cable corridor close to shore, where very few species were recorded. Figure 4.21 shows that crustaceans dominated the biomass for the PoVen and MysThyMx biotopes. This was due to the high abundances of amphipods *Urothoe* spp. and decapod crustaceans such as *Upogebia deltaura* in these biotopes.

4.1.4.61 Figure 4.19 demonstrates the lower total number of species present in the sand biotopes (i.e. IMoSa, FfabMag, NcirBat, EpusOborApri and ApriBatPo) and the lower mean abundances in these biotope areas discussed in section 4.1.4.50 are illustrated in Figure 4.20. These sand biotopes show comparable mean numbers of crustacean and mollusc species, with fewer annelid and echinoderm species. Despite this difference between the sandy and coarse and mixed biotope, the mean numbers of taxa in the majority of the sandy biotopes were dominated by annelids. With respect to biomass, however, molluscs contributed to a large proportion of the total biomass in sandy sediments, which is unsurprising given that each of these biotopes is characterised by one or more species of bivalve mollusc. Figure 4.21 shows that although present in relatively small numbers, echinoderms contributed to the majority of the biomass recorded in sandy biotopes due to the presence of a few large sandy substrate species such as brittlestars and the pea urchin *E. pusillus*. This was also true of the muddier sediment biotope AfilMysAnit, where echinoderms accounted for a considerable proportion of the total biomass due to dominance by brittlestars *Amphiura* spp.

Table 4.5: Mean (± standard deviation) univariate statistics for benthic infaunal biotopes within the Hornsea Three benthic ecology study area. S = number of species; N = abundance; d = Margalef's index of Richness; J' = Pielou's Evenness index; H' = Shannon-Wiener Diversity index; λ = Simpson's index of Dominance; Biomass = Ash Free Dry Weight (AFDW) in grams (g).

Biotope	Simplified Folk Sediment Classification	No. of sites	S	N	d	J'	H' (loge)	Λ	Biomass (g AFDW)
SS.SSa.IFiSa.NcirBat (NcirBat)	Sand and muddy sand (37 sites).	37	16.9 ± 4.2	39.5 ± 14.1	4.4 ± 0.9	0.9 ± 0.1	2.5 ± 0.3	0.1 ± 0.1	0.4 ± 0.4
SS.SSa.CFiSa.ApriBatPo (ApriBatPo)	Sand and muddy sand (7 sites).	7	18.1 ± 4.3	47.6± 13.1	4.5 ± 1.1	0.8 ± 0.1	2.4 ± 0.4	0.1 ± 0.1	0.8 ± 0.9
SS.SSa.CFiSa.EpusOborApri (EpusOborApri)	Sand and muddy sand (33 sites); coarse sediments (11 sites); mixed sediments (1 site).	45	2110 ± 8.3	69.4 ± 48.6	4.5 ± 1.1	0.8 ± 0.1	2.4 ± 0.4	0.2 ± 0.1	0.8 ± 1.7
SS.SSa.IMuSa.FfabMag (FfabMag)	Sand and muddy sand (91 sites); coarse sediments (7 sites).	98	19.4 ± 5.2	60.7 ± 39.1	4.6 ± 0.9	0.8 ± 0.1	2.4 ± 0.3	0.1 ± 0.1	0.7 ± 1.8
SS.SMu.CSaMu.AfilMysAnit (AfilMysAnit)	Sand and muddy sand (19 sites); coarse sediments (2 sites).	21	21.1 ± 7.8	96.9 ± 80.9	4.6 ± 1.2	0.7 ± 0.1	2.2 ± 0.4	0.2 ± 0.1	2.5 ± 5.9
SS.SCS.CCS.MedLumVen/ SS.SSa.CFiSa.EpusOborApri (MedLumVen/EpusOborApri)	Coarse sediments (10 sites); mixed sediments (2 sites).	12	22.8 ± 4.3	47.3 ± 11.7	5.7 ± 1.0	0.9 ± 0.0	2.8 ± 0.2	0.1 ± 0.0	0.3 ± 0.3
SS.SCS.ICS.MoeVen (MoeVen)	Sand and muddy sand (6 sites); coarse sediments (7 site).	13	15.5 ± 5.3	34.4± 16.0	4.1 ± 1.1	0.9 ± 0.1	2.3 ± 0.3	0.1 ± 0.0	0.3 ± 0.5
SS.SCS.CCS.MedLumVen (MedLumVen)	Coarse sediments (6 sites); mixed sediments (1 site).	7	29.9 ± 10.2	156.4 ± 111.7	5.8 ± 1.2	0.7 ± 0.1	2.2 ± 0.3	0.2 ± 0.1	4.1 ± 2.6
SS.SMx.OMx.PoVen (PoVen)	Sand and muddy sand (5 sites); coarse sediments (79 sites); mixed sediments (15 sites).	99	32.7 ± 10.1	111.7 ± 60.3	6.8 ± 1.5	0.8 ± 0.1	2.9 ± 0.3	0.1 ± 0.0	1.4 ± 3.4
SS.SMx.CMx.MysThyMx (MysThyMx)	Coarse sediments (1 site); Mixed sediments (28 sites).	29	32.3 ± 9.3	139.3 ± 70.6	6.4 ± 1.5	0.7 ± 0.1	2.6 ± 0.4	0.2 ± 0.1	2.0 ± 3.3
SS.SBR.PoR.SspiMx (SspiMx)	Coarse sediments (5); mixed sediments (5 sites).	10	46.7 ± 31.1	620.4 ± 1043.6	7.8 ± 4.4	07 ± 0.2	2.4 ± 1.0	0.2 ± 0.2	4.9 ± 7.2

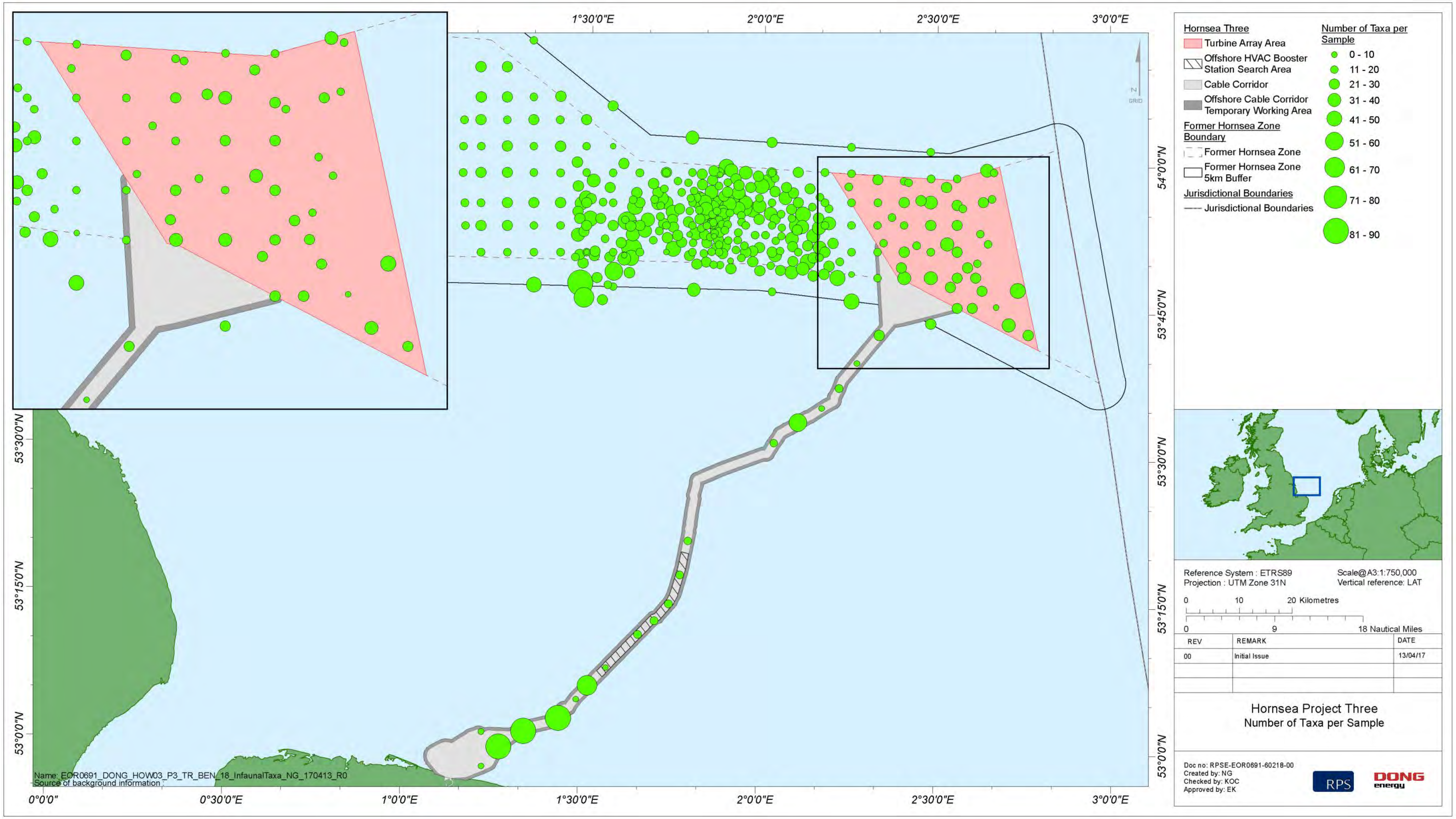

Figure 4.16: Number of taxa recorded for each benthic infaunal sample in the Hornsea Three benthic ecology study area.

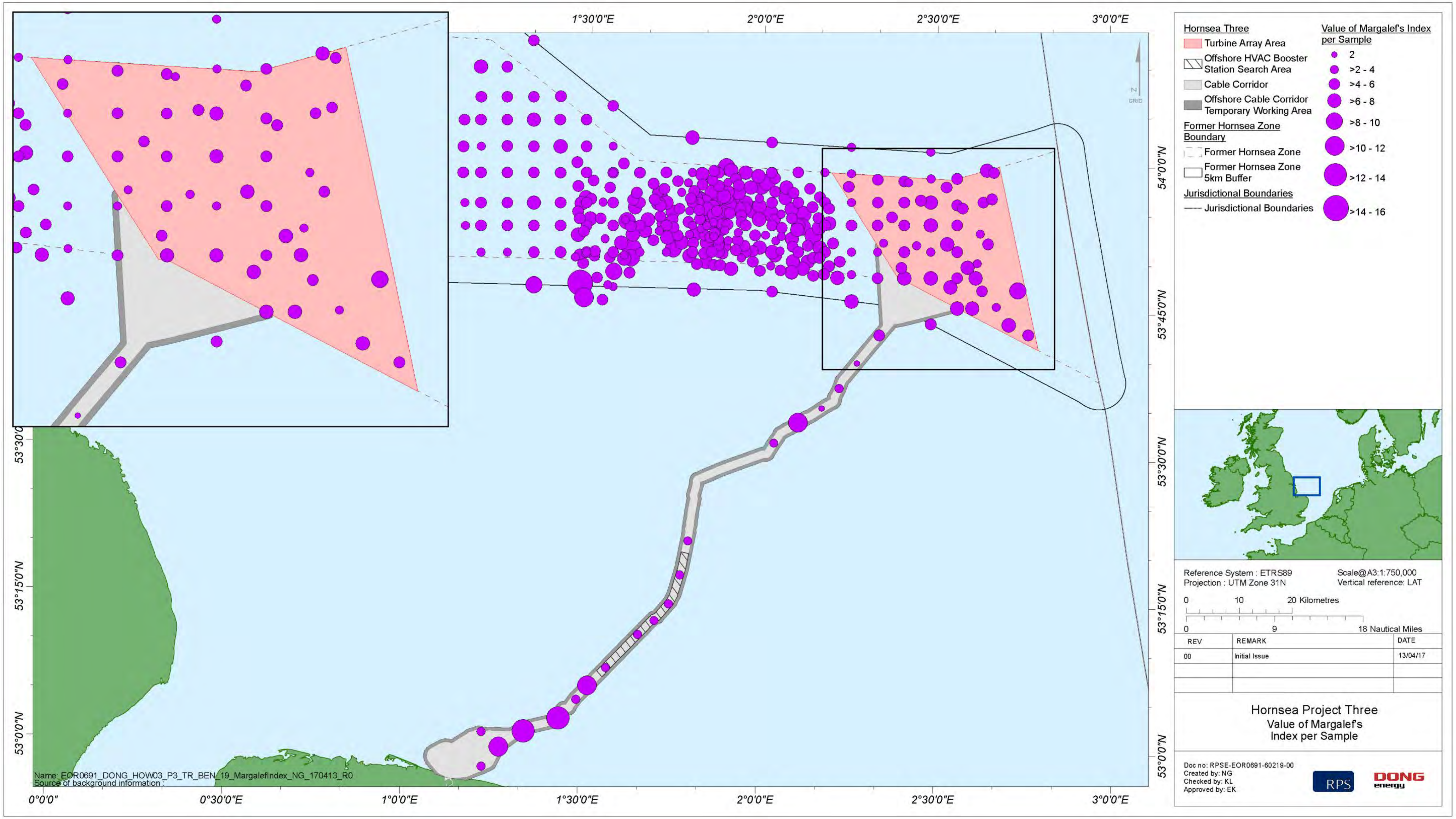

Figure 4.17: Values of Margalef's index (d: species richness) for each benthic infaunal sample within the Hornsea Three benthic ecology study area.

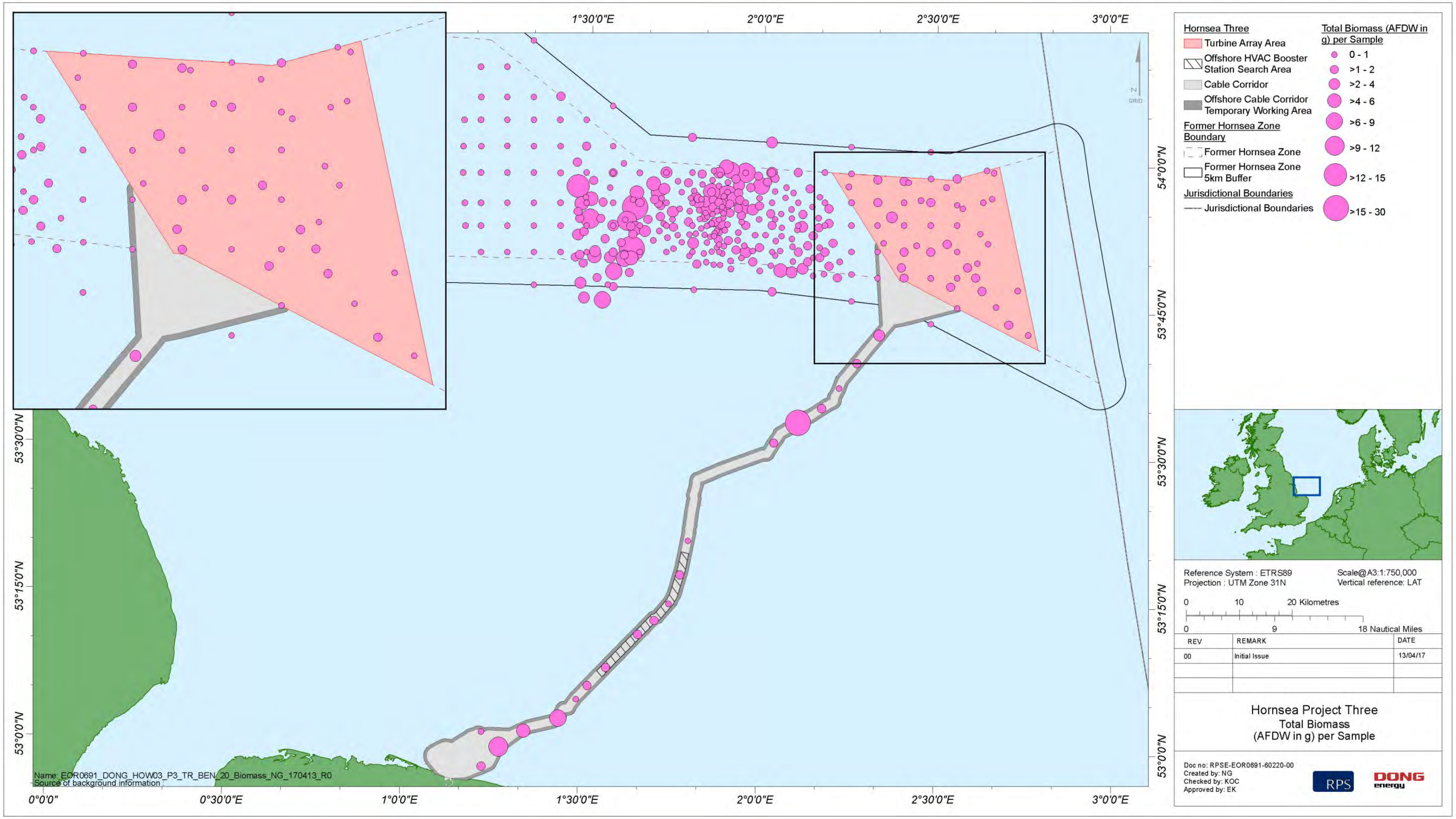

Figure 4.18: Biomass (ash free dry weight in grams) for each benthic infaunal sample in the Hornsea Three benthic ecology study area.

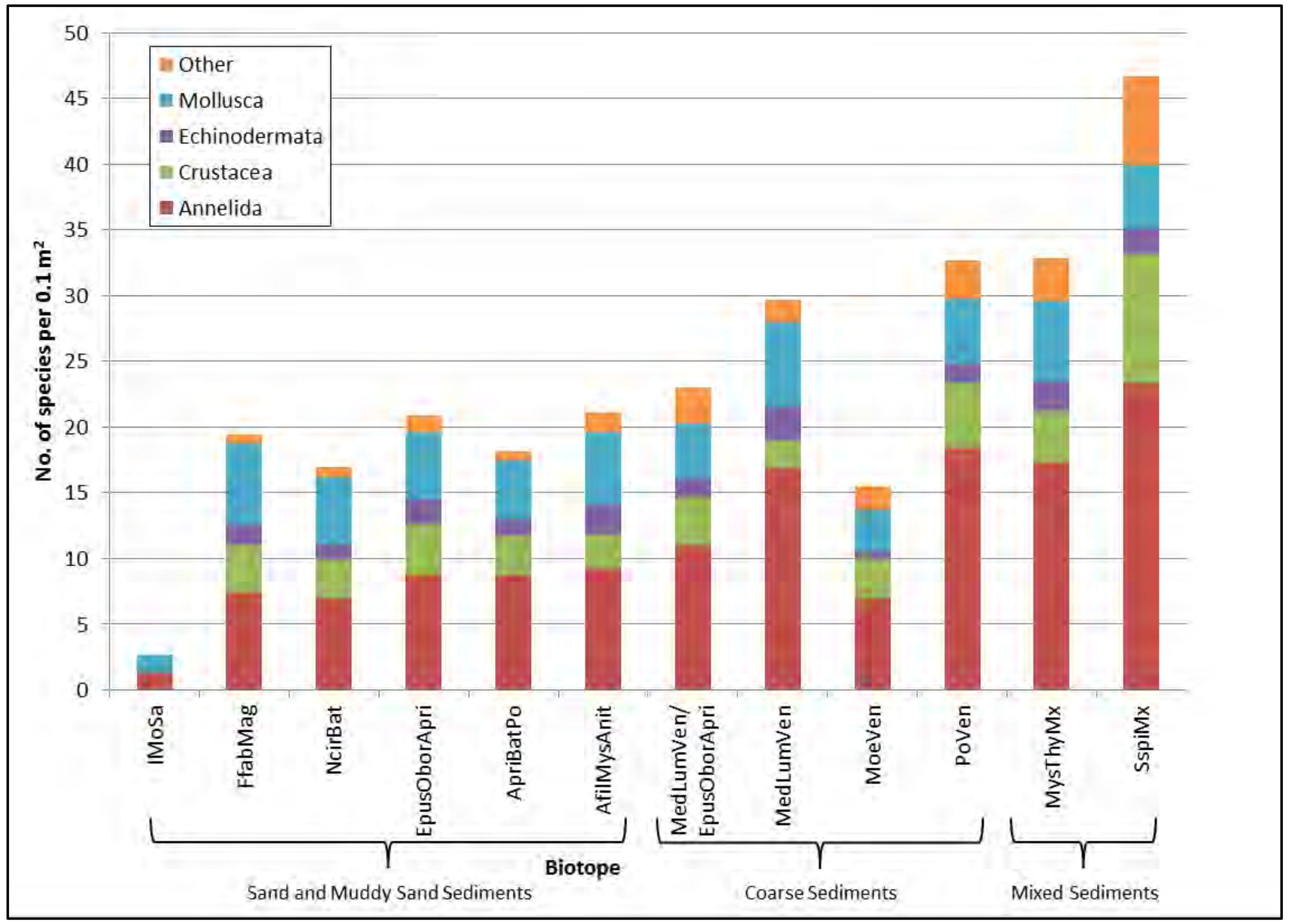

Figure 4.19: Mean number of species (number of species per 0.1 m² grab) per infaunal biotope for each major faunal group in the Hornsea Three benthic ecology study area.

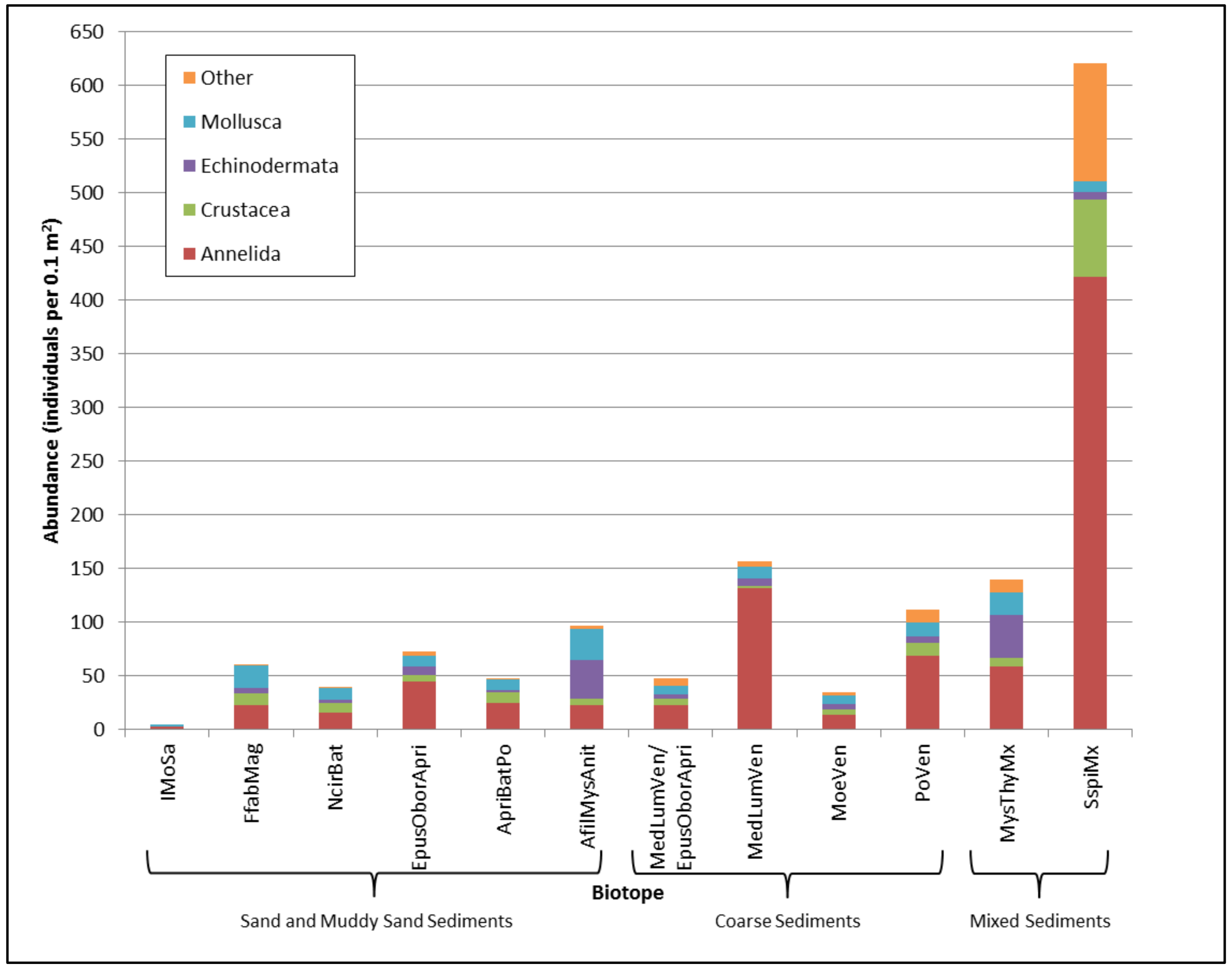

Figure 4.20: Mean abundance (total individuals per 0.1 m² grab) per infaunal biotope for each major faunal group in the Hornsea Three benthic ecology study area.

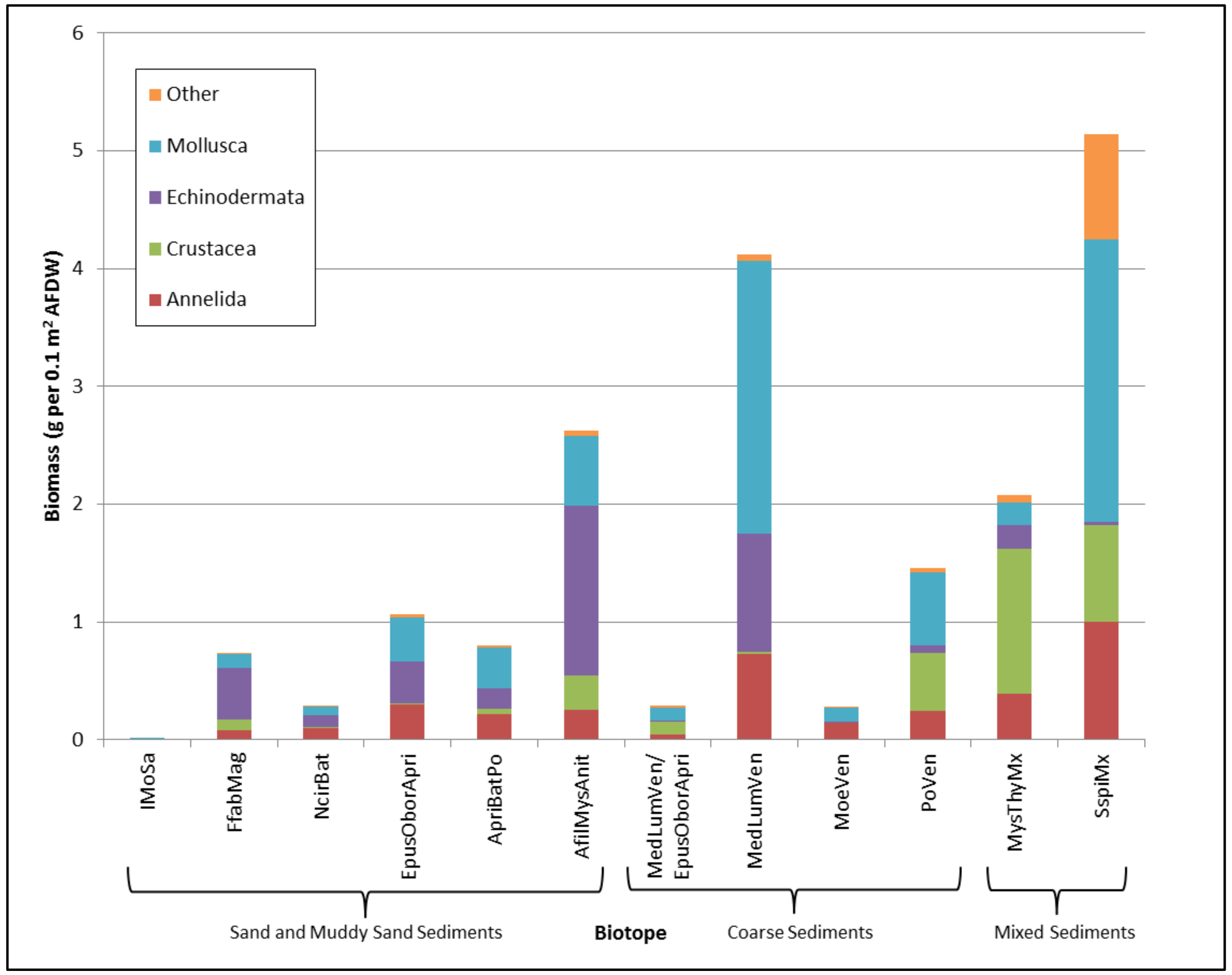

Figure 4.21: Mean biomass (g per 0.1 m² AFDW) per infaunal biotope for each major faunal group in the Hornsea Three benthic ecology study area.

Benthic epifauna

4.1.4.62 Abundances of epifaunal species at each sampling location were estimated from the DDV footage using the semi-quantitative SACFOR scale. As such, quantitative abundances, such as those available for infaunal species, were not available and the full range of univariate statistics, including diversity indices, could not be calculated for this dataset. The mean number of species recorded in each of the benthic epifaunal biotopes identified across Hornsea Three benthic ecology study area is presented in Table 4.6.

Table 4.6: Mean (± standard deviation) number of species (S) for benthic epifaunal biotopes in the Hornsea Three benthic ecology study area identified from DDV and seabed photography analysis.

Biotope	Simplified Folk Sediment Classification	No. of DDV transects	S[a]
SS.SSa.IFiSa.IMoSa	Sand and muddy sand (179 sites), coarse sediment (10 sites).	189	3.9 ± 2.1
SS.SSa.IFiSa.ScupHyd	Sand and muddy sand (2 sites), coarse sediment (16 sites), mixed sediment (6 sites).	24	10.5 ± 5.6
SS.SMu	Sand and muddy sand (10 sites).	10	4.0 ± 1.8
SS.SCS.ICS.SSh	Coarse sediment (97 sites), mixed sediment (29 sites).	126	5.2 ± 1.8
SS.SMx.CMx.FluHyd	Coarse sediment (7 sites), mixed sediment (7 sites).	14	15.3 ± 7.9

[a] Number of species not available for the biotopes assigned to the Hornsea Three offshore cable corridor sampling stations.

4.1.4.63 The sand and muddy sand sediment biotopes IMoSa and SMu had low mean numbers of species (3.9 ± 2.1 and 4.0 ± 1.8, respectively) and these were predominantly echinoderms including *A. rubens* and *A. irregularis.* The sediments in these areas were dominated by large expanses of sand substrate with limited hard substrate for other epifaunal species to become established on. The epifaunal biotope that dominated in the coarse sediment areas, SSh, was similarly species poor (5.2 ± 1.8). As with the IMoSa biotope, other than the occasional pebble or cobble, there was limited stable substrate onto which epifaunal species could be established.

4.1.4.64 The areas of ScupHyd, in the coarser sand sediments with greater occurrence of cobbles and pebbles, had a mean number of species of 10.5 ± 5.6, higher than the species poor sandy biotopes but less than the more diverse communities of the FluHyd biotope. FluHyd in the coarser and more mixed sediments had a high mean number of species (15.3 ± 7.9) due to the greater opportunity for attachment of sessile epifauna such as the *F. foliacea* and other bryozoans and hydroids.

Epibenthic trawl data

4.1.4.65 The univariate statistics for the epibenthic trawl data have been averaged across each of the epifaunal biotopes identified across the Hornsea Three benthic ecology study area and these are presented in Table 4.7. The univariate statistics calculated for each trawl location are presented in Appendix H. The mean number of species was low for the ScupHyd biotope (17.8 ± 5.1 species). Mean abundance, standardised over 500 m, was also low for the ScupHyd biotope (179.8± 109.7 individuals) but was considerably higher for the CMuSa biotope (2,995.2 ± 6,499.4 individuals). This was due to very high abundances of the brittlestar *Ophiura albida* in two of the CMuSa trawls in the north of Hornsea Three benthic ecology study area. Mean total abundances were higher in the coarse sediment biotope ICS (991.5 ± 309.2 individuals) compared to the sand sediment biotopes. However, the highest mean number of species was recorded in the mixed sediment biotopes CMx (32.5 ± 2.1 species) and FluHyd (49 species and 949.7 individuals). For analysis of colonial species which were not enumerated see section 4.1.4.69 below.

Table 4.7: Mean (± standard deviation) univariate statistics for biotopes identified from epibenthic trawl data from the Hornsea Three benthic ecology study area. S = number of species; N = abundance per 500 m; J' = Pielou's Evenness index; H' = Shannon-Wiener Diversity index; λ = Simpson's index of Dominance.

Biotope	Simplified Folk Sediment Classification	No. of trawls	S	N (per 500 m)	J'	H'	λ
SS.SSa.IFiSa. ScupHyd	Sand and muddy sand, coarse sediments and mixed sediments.	90	17.8 ± 5.1	179.8 ± 109.7	0.5 ± 0.1	1.4 ± 0.4	0.4 ± 0.1
SS.SSa.CMuSa	Sand and muddy sand and mixed sediment.	7	20 ± 3.5	2995.2 ± 6499.4	0.5 ± 0.3	1.4 ± 0.7	0.5 ± 0.3
SS.SCS.ICS	Sand and muddy sand and coarse sediments.	2	15.7 ± 3.5	991.5 ± 309.2	0.8 ± 0.02	0.8 ± 0.02	0.4 ± 0.01
SS.SMx.CMx	Mixed sediments.	2	32.5 ± 2.1	776.0 ± 338.3	0.5 ± 0.2	1.8 ± 0.8	0.3 ± 0.2
SS.SMx.CMx. FluHyd	Mixed sediment.	1	49	949.7	0.5	1.8	0.3

4.1.4.66 The diversity indices were typically higher in the coarse and mixed sediment biotopes where greater hard substrate (i.e. cobbles and pebbles) provided opportunity for attachment of sessile epifaunal species. The Simpson's index of Dominance was also low (< 0.5) across all biotopes, indicating that on the whole, the trawl samples were not dominated by a small number of species.

4.1.4.67 Figure 4.22 presents the mean number of species for each of the main faunal groups recorded in each of the biotopes identified from the epibenthic trawl dataset. As discussed in section 4.1.4.65, the mean number of species is higher for the coarse (ICS) and mixed sediment (CMx and FluHyd) biotopes compared to the sand and muddy sand sediment biotopes (ScupHyd and CMuSa). The epibenthic assemblages of the ICS and CMx biotopes were dominated by crustaceans and the 'other' faunal group; comprising hydroids and bryozoans. The FluHyd biotope, which was assigned to a single trawl to the southwest of the Hornsea Three benthic ecology study area, was dominated by similar numbers of crustaceans but more species assigned to the category 'other', namely ascidians, anemones and soft coral. This was also reflected in the biomass of 'other' species recorded in the FluHyd trawl (see Figure 4.22).

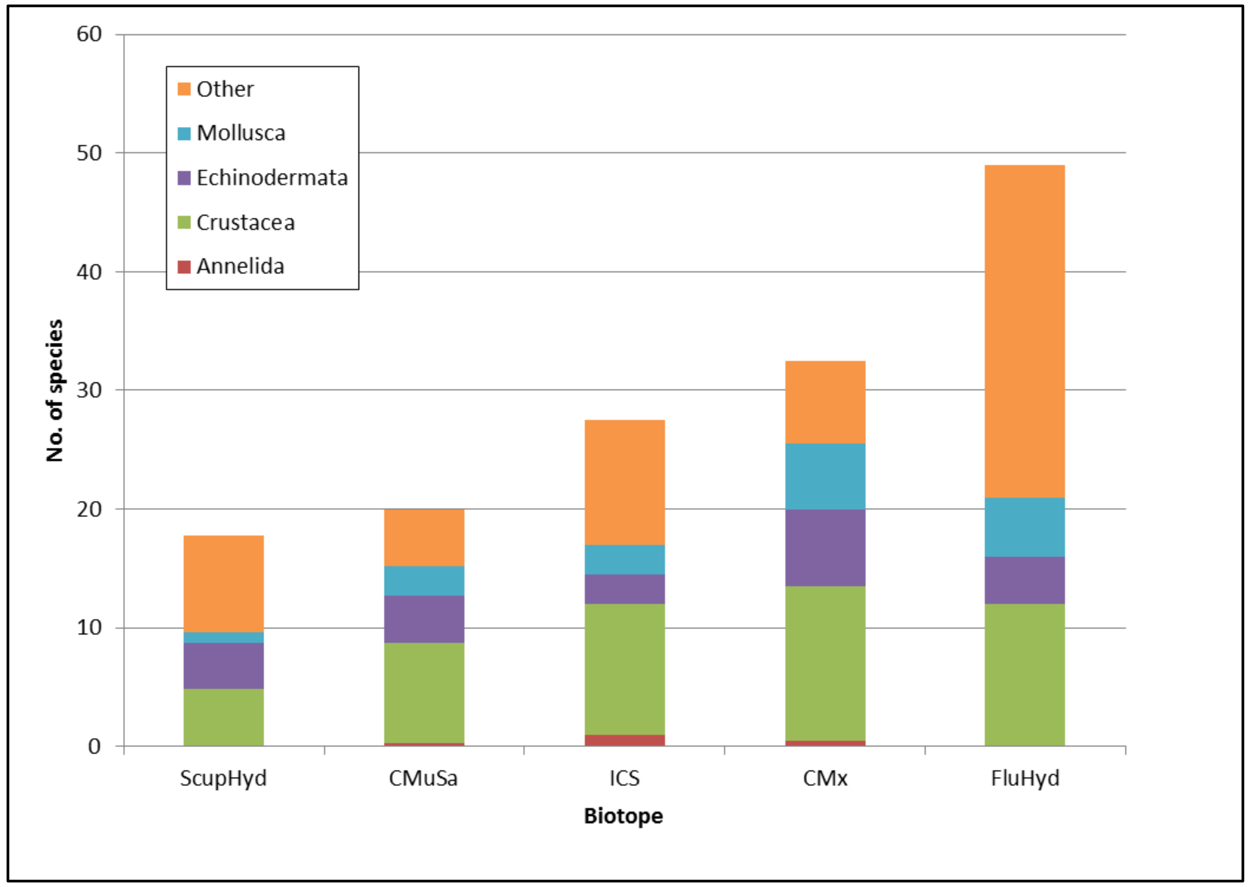

Figure 4.22: Mean number of species for biotopes identified from epibenthic beam trawl data of the Hornsea Three benthic ecology study area.

4.1.4.68 Figure 4.23 shows that the mean abundance was considerably higher for the CMuSa biotope due to the dominance and the super abundance of echinoderms *O. albida* (>16,000 individuals at one site) at two trawl locations in the north of the Hornsea Three benthic ecology study area. Similarly, echinoderms dominated the abundances in the CMx biotope, again due to high numbers of brittlestars, and also the ScupHyd biotope which was dominated by starfish *A. rubens*. The ICS biotope was dominated by crustaceans and molluscs with annelids contributing very little to overall mean abundances across all the biotopes. This is to be expected given that these fauna typically live buried in the sediment and, as such, would not typically be expected to be sampled by epibenthic beam trawl.

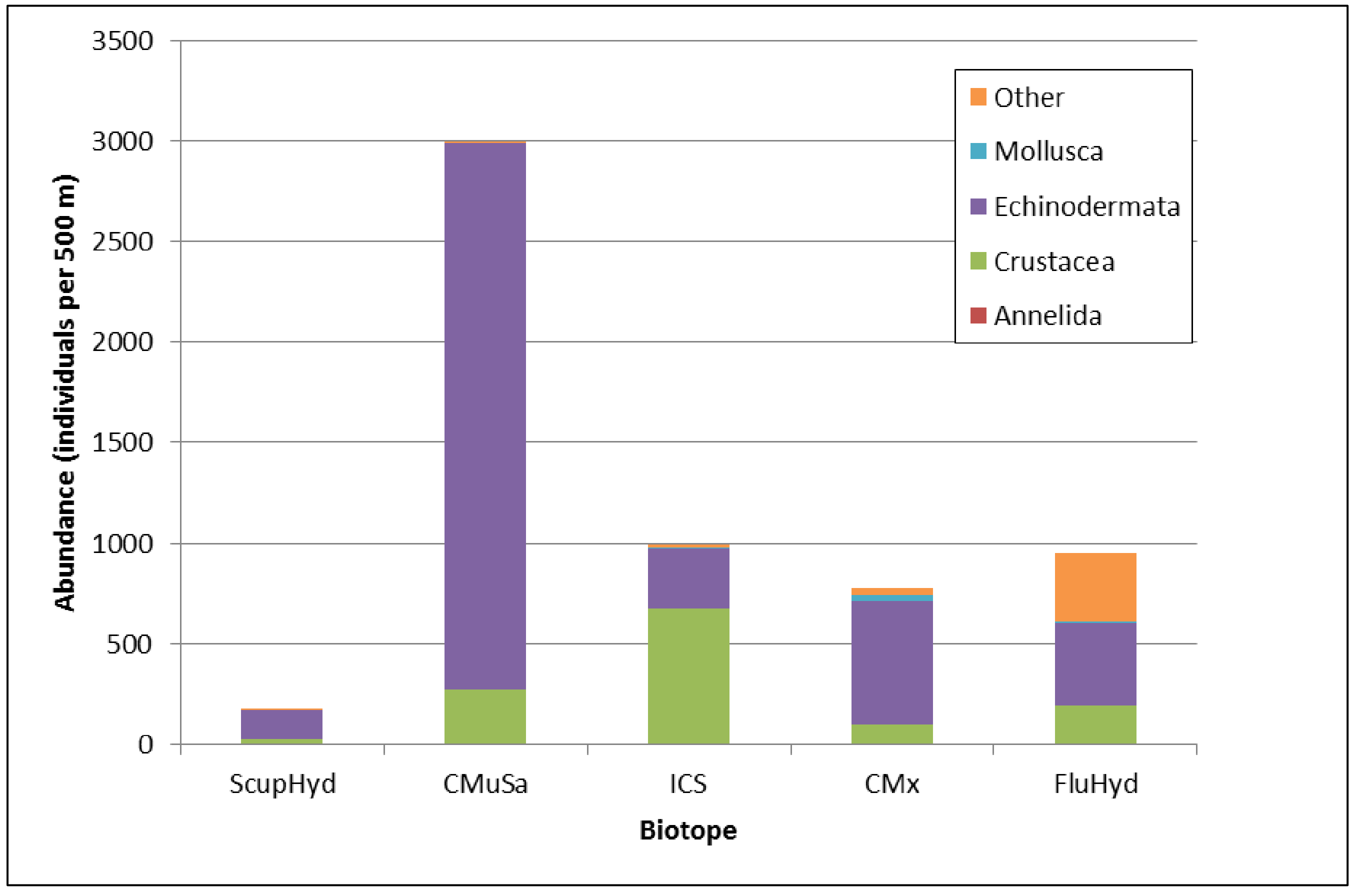

Figure 4.23: Mean abundance (individuals per 500 m) for biotopes identified from epibenthic beam trawl data of the Hornsea Three benthic ecology study area.

4.1.4.69 As discussed in section 4.1.4.65, colonial species were not enumerated in the trawls, rather total weight was recorded (in grams) for the most notable colonial species recorded in the epibenthic beam trawls (i.e. those for which discrete counts could not be made). These species were the bryozoans *F. foliacea* and *A. diaphanum* and the soft coral *A. digitatum*. Figure 4.24 shows that biomass from these species in the CMx biotope was high and solely attributable to *A digitatum*. The FluHyd biotope was the only other biotope to have a higher total biomass of these species, a significant contribution to which also came from *A. digitatum*, and to a lesser extent *F. foliacea*. As would be expected for a site in the FluHyd biotope, one of the largest volumes of *F. foliacea* observed across the Hornsea Three benthic ecology study area was recorded from this site.

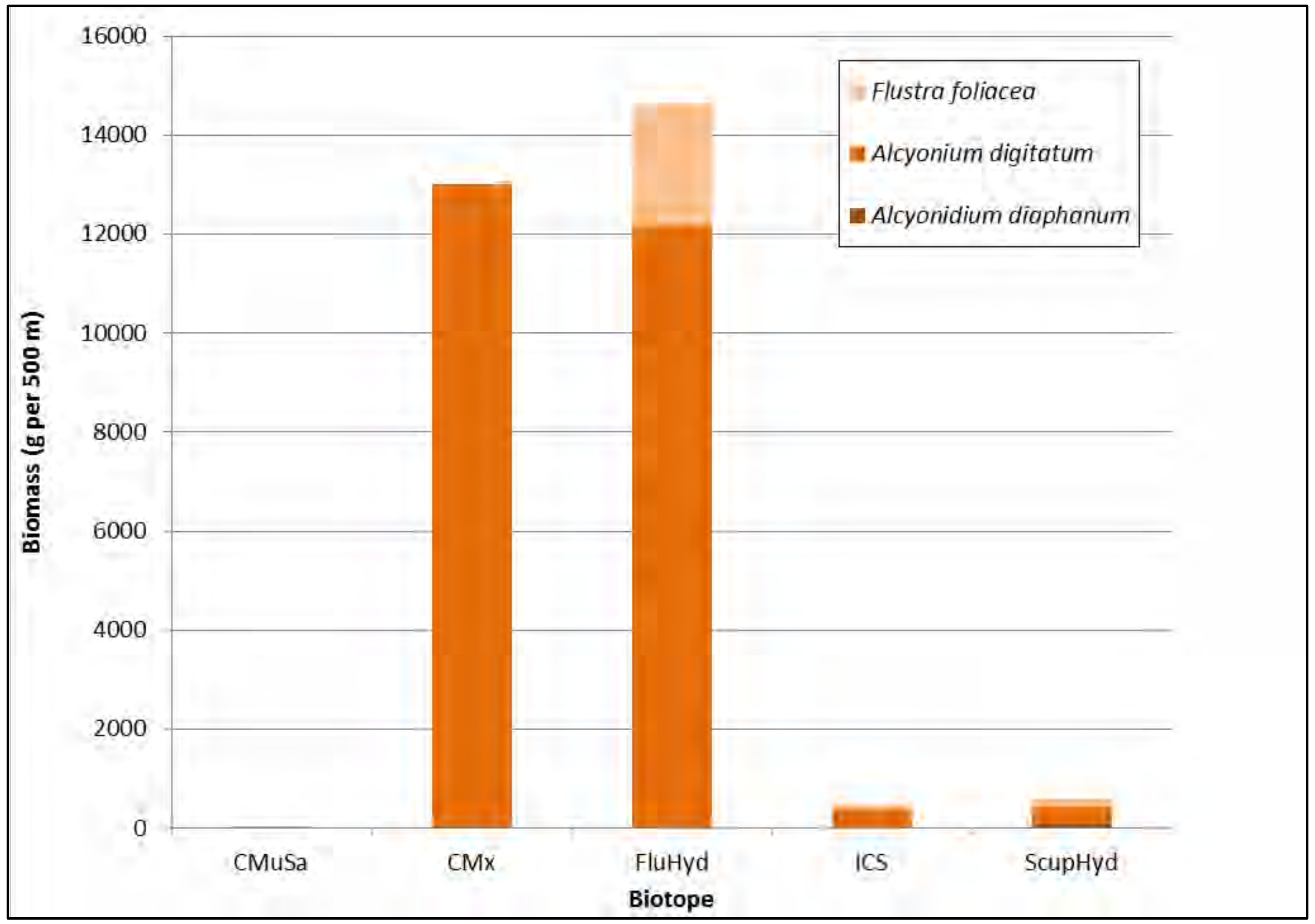

Figure 4.24: Mean biomass (g per 500 m) of key epifaunal species identified from epibenthic beam trawl data of the Hornsea Three benthic ecology study area.

4.1.4.70 As would be expected in the muddy sand biotope CMuSa, with little substrate for the attachment of these species, the biomass of these three species was extremely low. Those trawls assigned the ScupHyd biotope code recorded low biomass of each of the three species, reaffirming the conclusion that the substrate is predominantly sand and coarse gravelly sand with just the occasional cobble and pebble with associated epifauna.

Combined infaunal and epifaunal biotopes

4.1.4.71 Figure 4.25 presents the combined infaunal and epifaunal biotopes identified across the Hornsea Three benthic ecology study area. The method of classifying combined, holistic biotope codes was informed by the draft infaunal and epifaunal biotopes, the characterising species for these biotopes (as highlighted by the SIMPER analysis) and environmental variables (e.g. sediment type and water depth) at each site. The quantitative benthic grab dataset was prioritised when combining the datasets, due to this being the most standardised dataset. The DDV footage, the results of the analysis of the epifaunal component of the grabs and the trawl data were then used to identify subtle differences in epifaunal communities.

4.1.4.72 For many of the sites within the Hornsea benthic ecology study area the infaunal and epifaunal biotopes have been combined to form one single biotope, due mainly to the typically sparse epifaunal communities characterising these areas (i.e. IMoSa, SMu and SSh). Where mosaics of biotopes have been identified, these usually represented infaunal biotopes with an epifaunal overlay. The epifaunal biotopes ScupHyd and FluHyd are usually considered epifaunal overlays of infaunal biotopes and this was especially evident within the Hornsea Three offshore cable corridor and in the central area of the former Hornsea Zone. These epifaunal biotopes were recorded as overlays of infaunal biotopes, particularly those in mixed and coarse sediments, such as PoVen, MoeVen and SspiMx.

4.1.4.73 With respect to the SspiMx biotope, at the locations in the southwest of the former Hornsea Zone where this biotope was assigned to the infaunal sample, the corresponding epifauna data also supported this conclusion, as such these were assigned the SspiMx epifauna biotope. At the sampling stations along the Hornsea Three offshore cable corridor where SspiMx was frequently recorded from the infaunal samples, this was often not reflected in the epibenthic community, which more closely resembled the FluHyd biotope. This is largely due to the moderate representation of the SspiMx biotope by the infaunal communities, where *S. spinulosa* were recorded in the 10's per m^2, while the SspiMx biotope typically comprises over 1000 individuals per m^2.

4.1.4.74 The combined biotope map shown in Figure 4.25 confirms many of the patterns described previously for the subtidal communities present in the Hornsea Three benthic ecology study area:

- Predominantly sandy sediments in the western and central parts of the Hornsea Three benthic ecology study area and much of the Hornsea Three array area were characterised by the FfabMag, NcirBat and EpusOborApri biotopes with typically extremely sparse epibenthic communities. The EpusOborApri biotope was particularly prevalent in the northeast and southwest of the former Hornsea Zone where it was occasionally recorded in association with the ScupHyd epibenthic biotope;
- Muddy sand sediments in the deeper waters to the north of the Hornsea Three benthic ecology study area and in the Hornsea Three array area were characterised by the AfilMysAnit biotope with limited associated epifaunal communities, with the exception of the brittlestars;
- Coarse sediments with diverse infaunal communities characterised by the PoVen biotope in large swathes within the Hornsea Three array area, in the southwest of the former Hornsea Zone and patchily distributed in the central section of the former Hornsea Zone. The majority of these sediments had typically sparse epibenthic communities, however, some in the central former Hornsea Zone were associated with the FluHyd epibenthic overlay; and
- Three areas of mixed sediments along the Hornsea Three offshore cable corridor, characterised by the SspiMx infaunal biotope exhibited the FluHyd epifauna biotope.

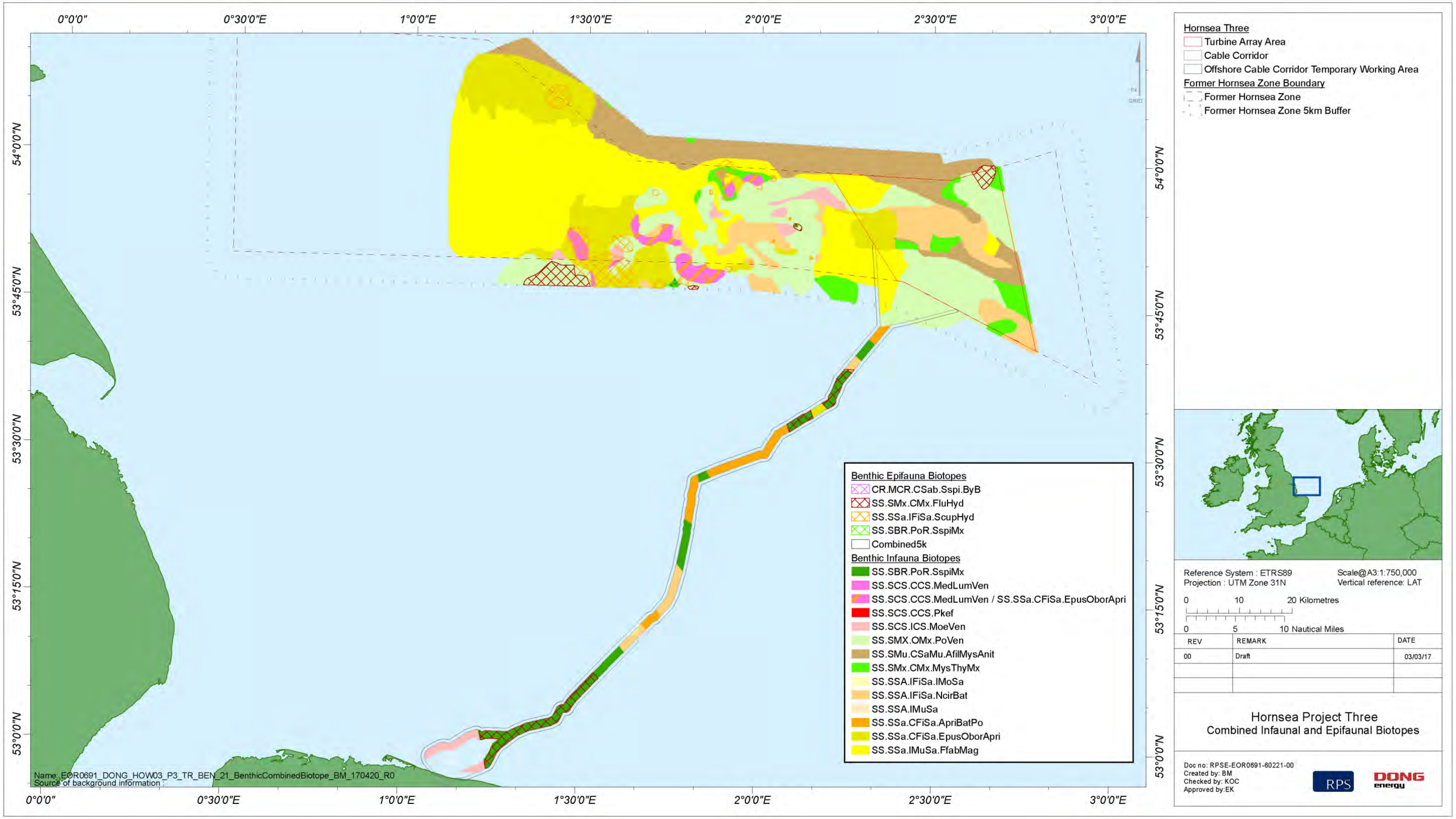

Figure 4.25: Combined infaunal and epifaunal biotope map of the Hornsea Three benthic ecology study area.

Intertidal biotopes

4.1.4.75 The intertidal biotope map for the proposed Hornsea Three offshore cable corridor landfall site extending the breadth of the beach between Weybourne and Salthouse was informed by the results of the Phase 1 walkover survey undertaken in 2016. Figure 4.26 presents the intertidal biotope map for the Hornsea Three offshore cable corridor landfall site, with the biotopes identified during the survey described in Table 4.8. The intertidal zone was surveyed at both the Weybourne beach and the Salthouse beach, including the beach between these locations (approximately 800 m).

4.1.4.76 The intertidal zone between Weybourne and Salthouse and the wider intertidal area comprised a steep shingle beach dominated by barren pebbles and cobbles. This beach profile and sediment type was consistent across the landfall area. The landfall site was, on the whole, characterised by naturally species-poor intertidal benthic communities which are typical of dynamic shingle and sandy shore environments. Habitats located landward of MHWS (i.e. lagoons and reedbeds) are described in volume 3, chapter 3: Terrestrial Ecology). Four intertidal biotopes were recorded at the landfall site in the Hornsea Three benthic ecology study area.

4.1.4.77 Part of the beach at Weybourne, in the east of the landfall area, backed onto vertical clay cliffs, while the western section at Weybourne backed onto the public carpark and a brackish reed bed *Phragmites australis* within a shallow pool of water (Norfolk Wildlife Trust, 2004). The upper shore of the beach at Salthouse, in the west of the landfall area, was backed by a continuous cliff of relatively soft, clayey material, similar to the eastern section of the Weybourne survey site.

4.1.4.78 Sediment at the Weybourne section of the landfall site consisted of shingle from the MHWS mark down to the MLWS and was classified as the LS.LCS.Sh.BarSh: barren littoral shingle biotope (see Table 4.8 for a full description). No fauna were recorded during dig-overs within this biotope. The substrate on the upper and mid shore generally comprised large pebbles (4 to 64 mm) and small cobbles (64 to 256 mm), in accordance with the Wentworth grain size classification system. The beach profile was steep, as expected for a shingle shore, with distinct ridges or berms at four heights up the shore; this profile pattern was generally evident for the full length of the landfall. A sparse driftline of the LS.LSa.St: strandline biotope was present, between 3 to 30 m from the back of the beach, comprising decomposing brown seaweed (*Fucus* spp.), bryozoan colonies, reed stems and twigs.

4.1.4.79 The upper shore at Salthouse comprised a slightly finer, gravelly substrate in comparison to the mid and lower shores. The colour of this material was notably different, with a warmer, browner hue compared to the grey-blue colouration of the shingle lower down the shore. Incidentally, a driftline was present where the finer, gravelly shingle met the coarser shingle. This arrangement continued for the length of the beach at Salthouse. The driftline (LS.LSa.St) was similar to that at Weybourne, consisting of decomposing brown seaweed (*Fucus* spp.), bryozoan colonies, reed stems and twigs. The shingle sediments throughout the landfall area were considered representative of the biotope LS.LCS.Sh.BarSh. Again, no fauna were recorded on, or within, the shingle material. The steep, stepped profile with well-defined berms was observed across the breadth of the landfall area.

4.1.4.80 The substrate on the main slope of the lower shore at Weybourne was slightly coarser compared to that of the upper and mid shore, comprising a greater cobble fraction. This was considered to be a continuation of the LS.LCS.Sh.BarSh biotope from the upper and mid shore. At Salthouse the lower shore was dominated by shingle substrate and was also considered to be a continuation of the biotope LS.LCS.Sh.BarSh recorded in the upper and mid shore. Areas of fine sand with reduced shingle content were observed on the lower shore at Salthouse in the west of the landfall area, similar to that observed at the lower shore at Weybourne in the east of the landfall area, with a gravel fraction apparent around the perimeter of each area of sand. These sandy depressions, which were more prevalent in the western end of the landfall, were thought to be beach cusps caused by wave action and are typical features of shingle beaches. Dig-over samples at both Weybourne and Salthouse indicated that that this biotope was dominated by gammarid amphipods, with between 25 and 50 individuals per m^2, characteristic of the LS.LSa.FiSa biotope.

4.1.4.81 Near the MLWS mark throughout the landfall site, small areas of fine sand were exposed where shingle was absent, with a gravel fraction apparent around each area of sand. The small sandy areas were regularly distributed throughout the shingle biotope of lower shore in several sections of the beach, as such these areas were considered a matrix of the LS.LCS.Sh.BarSh and LS.LSa.FiSa biotopes.

4.1.4.82 A 20 m long outfall pipe was present on the lower shore at Weybourne, exposed from the shingle approximately 60 m from the back of the beach. The distal end of the pipe was approximately 2.5 m high above the lower shore; while the associated structure was estimated to be approximately 6.0 m in height. No growth was present on the structure from the shore up to 1.0 m. Green algae, *Ulva* spp., was present above 1.5 m, as was a barnacle community, up to 3.0 m from the lower shore. Red algae, possibly purple laver (*Porphyra umbilicalis*) and sea lettuce, *Ulva lactuca*, were observed growing on the structure approximately 3.0 m from ground level. Communities on this outfall were classified as the LR.HLR.MusB: mussel and/or barnacle communities' biotope.

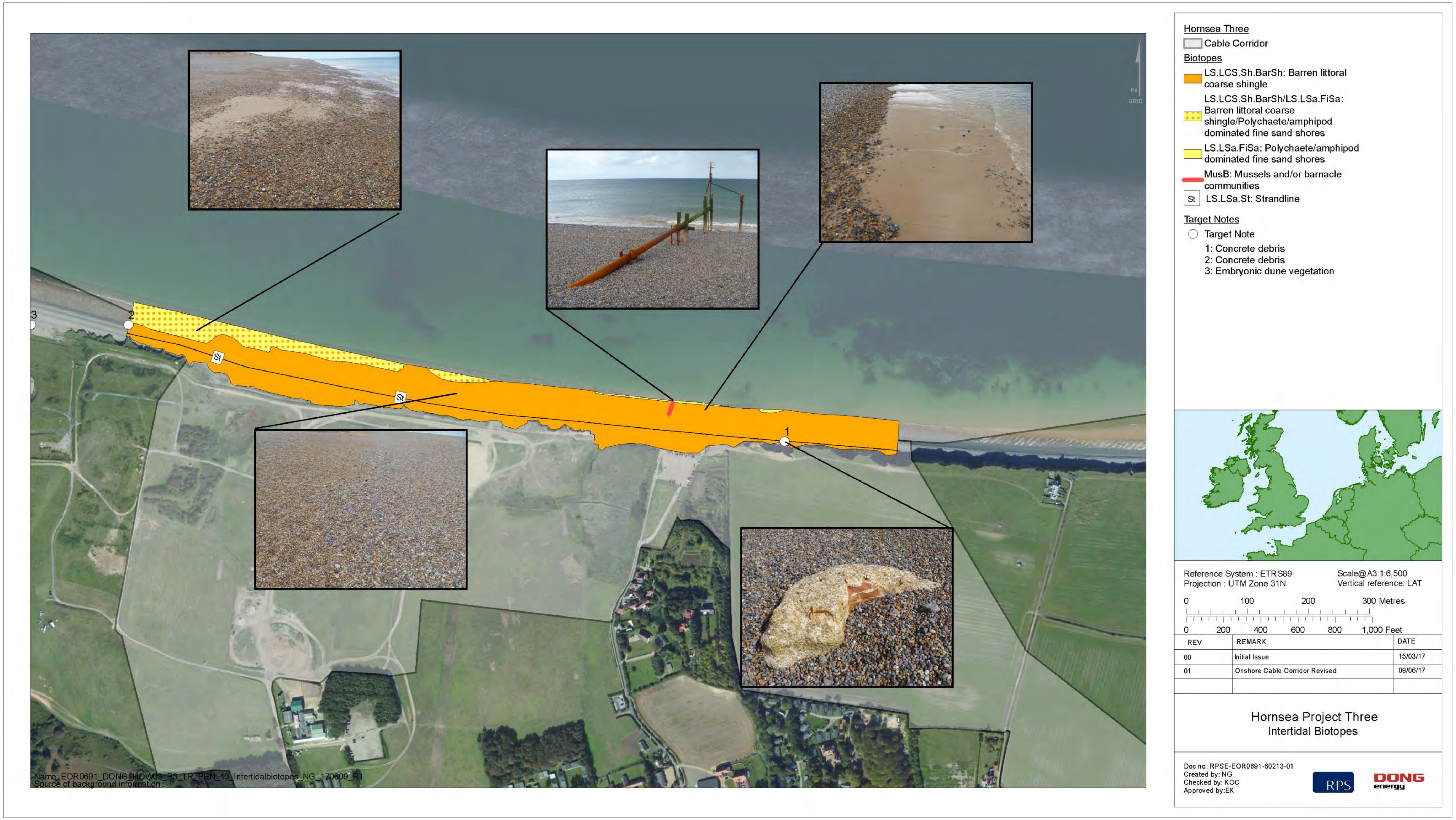

Figure 4.26: Intertidal biotopes at the proposed Hornsea Three offshore cable corridor landfall area at Weybourne and Salthouse, within the Hornsea Three benthic ecology study area.

Table 4.8: Intertidal biotopes identified during the intertidal walkover survey and from dig-over samples taken from the Hornsea Three offshore cable corridor landfall site (see Figure 4.23).

Shore Position	Biotope Code (Conner *et al.*, 2004)	EUNIS code (2007-11)	Biotope Name	Hornsea Three Biotope Description
Upper shore	LS.LSa.St (St)	A2.21	Strandline	The driftline consisted of decomposing bryozoan colonies, brown seaweed (*Fucus* spp.), reeds, feathers and twigs. A community of sandhoppers (including talitrid amphipods) is often associated with driftline debris as it provides suitable cover and humidity. However sandhoppers were not observed on the shingle substrate at Weybourne and Salthouse.
Upper to lower shore	LS.LCS.Sh.BarSh (BarSh)	A2.111	Barren littoral coarse shingle	This biotope extended over the whole shore at Weybourne, Salthouse and between these locations. Sediment comprised mostly shingle, of pebble or cobble dimension, according to the Wentworth classification system, with some gravel. Gravel was generally limited to the lower shore in association with cusp features and transitions to areas of fine sand. No faunal species were recorded within this biotope.
Lower shore	LS.LSa.FiSa (FiSa)	A2.23	Polychaete / amphipod dominated fine sand shores	This biotope was found on the lower shore at, and between, the Weybourne and Salthouse locations. Sediments comprised clean, fine to medium sand. Fine sand shores usually support a range of species including amphipods and polychaetes; dig-over samples revealed gammarid amphipods with abundances of between 25 and 50 per m^2. No other fauna were recorded.
Mid to lower shore	LH.HLR.MusB (MusB)	A1.11	Mussels and/or barnacle communities	Communities of this classification are typically dominated by mussels and/or barnacles comprising *Chthamalus* spp. and/or *Semibalanus balanoides*. This biotope was observed in association with an iron outfall pipe and support structure at Weybourne, in a 1.5 m high band of encrusting barnacle growth, in conjunction with green algae, *Ulva* spp., 1.5 m above the low water mark. No other faunal species were evident.

Annex I reef potential

<u>*Sabellaria spinulosa* reef assessment</u>

4.1.4.83 Although Annex I *Sabellaria* reefs are associated with the SspiMx biotope, the occurrence of a *Sabellaria* biotope does not automatically indicate that a reef is present and, therefore, further scrutiny of the video imagery was necessary.

4.1.4.84 The *Sabellaria* biotope (SspiMx) was recorded at ten locations long the Hornsea Three offshore cable corridor, a full Annex I reef assessment was undertaken for sites ECR02 and ECR04 where *S. spinulosa* aggregations were visible in the DDV. *Sabellaria* aggregations were generally recorded at station ECR04 in the form of domical mounds, while those at station ECR02 exhibited pavement formations. It was not possible to delineate the extent of *S. spinulosa* at station ECR04 from the geophysical acoustic data due to the patchiness of the aggregations, therefore the area of the aggregations was not determined. As such, all assessed seabed photographs and screenshots were averaged to provide an overall reef structure for this station. Both the elevation and patchiness were assessed as being 'low reef' which therefore gives an overall reef structure of 'low reef'. As the reef structure at station ECR04 was determined to be 'low', this area could only achieve a low reefiness score irrespective of the total area of the aggregations.

4.1.4.85 At station ECR02, it was possible to delineate an approximate boundary of *Sabellaria* aggregations from the acoustic data, which were estimated to cover an area of approximately 0.084 km^2 ('medium reef'). The mean elevation at station ECR02 achieved a 'low reef' score in the assessment, while patchiness was determined to represent 'high reef', resulting in an overall reef structure score of 'low reef'. Both of the surveyed areas of *S. spinulosa* aggregations on the Hornsea Three offshore cable corridor were assigned low overall reefiness; therefore it is unlikely that these would be considered Annex I reef habitats.. The full results (including assessment criteria used) of the reefiness assessments are presented in Appendix I.

5. Discussion

5.1 Sediments

5.1.1.1 The sediments recorded in the Hornsea Three benthic ecology study area were broadly divided into sand and muddy sand sediments, coarse sediments and mixed sediments. Sandy and muddy sand sediment was the dominant broad sediment type found across most of the Hornsea Three benthic ecology study area which was recorded at 53% of sample locations. Sandy and muddy sand sediments were found throughout the Hornsea Three benthic ecology study area, though they were particularly prevalent in the found in the western area of the former Hornsea Zone.

5.1.1.2 Coarse sediments, which were dominated by sandy gravel and gravelly sand, were found predominantly in the central section of the former Hornsea Zone and along the Hornsea Three offshore cable corridor. The mixed sediments (i.e. the gravelly muddy sand and muddy sandy gravel) were also generally found in the central section of the former Hornsea Zone, the southern and northern edges of the Hornsea Three array area and the nearshore section of the Hornsea Three offshore cable corridor. These patterns generally support the SeaZone and EUSeaMap (JNCC, 2016) predicted seabed types, although the the historic benthic survey data and site-specific data together with the geophysical interpretation have revealed more complex patterns in the substrate distribution than that predicted by either of these historical datasets. The intertidal sediments at the landfall site were dominated by a steep shingle beach dominated by barren pebbles and cobbles.

5.1.1.3 Subtidal sediments within the Hornsea Three benthic ecology study area were found to have low contaminant loads with most heavy metals and organotins at levels below the Cefas AL1 and the Canadian TEL. Arsenic was the main exception to this and exceeded the Cefas AL1 at most sites and the Canadian PEL (the level at which toxicity would be evident) at five sites, although was within the Cefas AL2 for arsenic at all sites. However, it has been demonstrated that after normalisation against iron, levels of arsenic in North Sea sediments may be much reduced in significance (Whalley *et al.*, 1999). The levels of TPH were below the Cefas AL1, and the levels of total PAHs were within the range typically observed in North Sea sediments. Furthermore, all individual PAHs across the Hornsea Three benthic ecology study area were at levels below the Cefas AL1 and, in most cases, were also below the Canadian TEL. It is therefore concluded that the offshore subtidal sediments present in the Hornsea Three benthic ecology study area are not contaminated with heavy metals or hydrocarbons at levels at which biological effects in benthic organisms would be expected. The levels of total PAHs were however, high in the inshore regions of the Hornsea Three offshore cable corridor, which is typical of this area of the North Sea. The concentrations of all organochlorines were below the limits of detection of the analyses used.

5.2 Benthic Ecology

5.2.1 Subtidal ecology

5.2.1.1 The benthic ecology of the Hornsea Three benthic ecology study area can broadly be described as being characterised by sandy sediment communities, coarse sediment communities with a varying epibenthic component and *S. spinulosa* dominated, species rich, mixed sediments.

5.2.1.2 Sandy sediment communities were present in the central area of the Hornsea Three array, a central section of the Hornsea Three offshore cable corridor and dominated much of the western and central parts of the former Hornsea Zone. The sandy sediments were generally found to have more infaunal communities with lower species diversity than the coarse and mixed sediment communities, with lower abundances and diversity of polychaetes and bivalve molluscs. The habitats identified were typical of exposed or tide swept coasts and the dominance of species such as the bivalve mollusc *C. gibba*, which in large abundances may be indicative of unstable substrates (Crema *et al.*, 1991), suggest that these areas may be subject to seasonal or occasional environmental disturbances (Hrs-Brenko, 2006). Epifaunal communities in these areas were generally absent but, where present, were species poor and characterised by a predominantly mobile species such as echinoderms. The occasional cobble or pebble in these areas were colonised by cnidarians and bryozoans, but these were typically rare in these sediments. The results of the site-specific surveys are supported by the Humber REC which identified the EUNIS habitat A5.25(4) Infaunal polychaetes with burrowing bivalves and amphipods in circalittoral fine sand as the dominant habitat over the areas coinciding with the Hornsea Three benthic ecology study area.

5.2.1.3 The areas of deeper water to the north of the Hornsea Three benthic ecology study area and in the central eastern area of the Hornsea Three array area, although still predominantly sand, comprised a higher proportion of mud and supported communities dominated by infaunal and epifaunal brittlestars and high abundances of burrowing bivalves. The muddy areas within the Hornsea Three array area and north of the Hornsea Three array area also supported high abundances of the Norway lobster *Nephrops*; this is considered in full in volume 5 annex 3.1: Fish and Shellfish Technical Report.

5.2.1.4 The coarse sediments which dominated the central parts of the Hornsea Three benthic ecology study area, including the areas in the south and north of Hornsea Three array area, on the whole, exhibited diverse infaunal communities, similar in many places to those found within mixed sediments, with a range of polychaete species present together with bivalve molluscs, echinoderms and crustaceans. The epifaunal communities were, for the most part, as sparse as those observed in the sandy sediments as described in section 5.2.1.2, characterised by mobile species, including echinoderms with rare occurrences of sessile epifauna in areas where attachment to hard substrate could be made (i.e. on cobbles, pebbles or gravel). The epifaunal communities in some of the coarse sediment habitats along Hornsea Three offshore cable corridor and in the southwest corner of the former Hornsea Zone, however, were more diverse than those typically found in the rest of the Hornsea Three benthic ecology study area, with more frequent occurrences of hydroids and bryozoans due to the greater availability of hard substrate.

5.2.1.5 The mixed sediment substrate communities found in discrete patches throughout the Hornsea Three array area and in the centre of the former Hornsea Zone were largely similar to the coarse sediment communities, and there was a high degree of overlap in the species present. The communities were typically characterised by an array of polychaetes, molluscs and also echinoderms, namely brittlestars. The mixed sediment communities on the Hornsea Three offshore cable corridor differed by being dominated by non-reef forming *S. spinulosa.* The infaunal communities associated with this tube-building polychaete were the most diverse and numerically abundant communities observed throughout the Hornsea Three benthic ecology study area, rich in polychaetes, crustaceans, molluscs and echinoderms. The epifaunal components of these communities were also highly diverse with rich communities of bryozoans, ascidians, anemones, shrimps and crabs.

5.2.1.6 With respect to infaunal species of interest, *A. islandica*, which is listed by OSPAR as a threatened and/or declining species for the Greater North Sea (OSPAR Region II) was noted. Ten individuals (all juveniles or spat) were recorded from nine sites in the Hornsea Three benthic ecology study area, none of which were found in the Hornsea Three array area or the Hornsea Three offshore cable corridor. Given the low occurrence of this species in the grab samples (i.e. ten records from 381 grab samples), it is unlikely that the Hornsea Three benthic ecology study area is of particular importance for this species within the OSPAR Region II.

5.2.2 Intertidal ecology

5.2.2.1 The composition of intertidal substrate was very similar throughout the shore at the Weybourne and Salthouse proposed Hornsea Three offshore cable corridor landfall site. The beach exhibited a steep profile with high exposure to wave energy, as is typical for a shingle shore. Sediments predominantly comprised shingle (pebbles and cobbles, according to the Wentworth classification scheme) with occasional exposures of fine sand. The landfall site demonstrated dynamic high energy conditions with naturally impoverished infaunal communities.

5.2.3 Nature conservation

5.2.3.1 The marine nature conservation designations which fall within the southern North Sea benthic ecology study area comprise international Natura 2000 designations (i.e. SACs, SCIs) and Ramsar sites and national designations (SSSIs, MCZs, rMCZs and NNRs). Those potentially located within the Hornsea Three ZoI have been discussed in full in this report, together with their associated habitats. A summary of these sites is provided in paragraphs 5.2.3.2 to 5.2.3.7.

International Designations

Natura 2000 sites

5.2.3.2 Natura 2000 sites which fall within the southern North Sea benthic ecology study area, and which lie within close proximity to Hornsea Three benthic ecology study area include:

- The Wash and North Norfolk Coast SAC;
- North Norfolk Coast SAC;
- Haisborough, Hammond and Winterton SCI;
- North Norfolk Sandbanks and Saturn Reef SAC/SCI; and
- Klaverbank SCI.

Annex I Habitats

5.2.3.3 *Sabellaria* biotopes (SspiMx and Sspi.ByB) were recorded at the Hornsea Three benthic ecology study area and particularly throughout the Hornsea Three offshore cable corridor. The site-specific survey planned for Quarter 2 of 2017 will target areas of *Sabellaria* reef features found by Cefas in 2013, and other areas of potential *Sabellaria* aggregations, to further characterise the potential for Annex I reefs on the Hornsea Three offshore cable corridor. The data resulting from this survey will be presented in the Environmental Statement.

Ramsar Sites

5.2.3.4 Only the North Norfolk Coast Ramsar site is potentially within the Hornsea Three ZoI, though this has been screened out from further assessment in the EIA report.

National designations

5.2.3.5 Only the North Norfolk Coast SSSI is potentially within the Hornsea Three benthic ecology study area ZoI, which has been screened out from further assessment in the EIA report. Three NNRs potentially lie within the Hornsea Three ZoI (Scolt Head Island, Holkam and Blakeney). These have also been screened out from further assessment in the EIA report.

5.2.3.6 The MCZ and proposed rMCZs and their associated benthic habitats which coinicide with, or are potentially within the Hornsea Three ZoI, include:

- Cromer Shoal Chalk Beds MCZ;
- Markham's Triangle rMCZ; and
- Wash Approach rMCZ.

5.2.3.7 The Hornsea Three offshore cable corridor passes through the Cromer Shoal Chalk Beds MCZ (Figure 3.6) which is designated for subtidal coarse sediments; subtidal mixed sediments; subtidal sand; peat and clay exposures; and subtidal chalk, among others.

5.3 Valued Ecological Receptors

5.3.1.1 The value of ecological features is dependent upon their biodiversity, social, and economic value within a geographic framework of appropriate reference (CIEEM, 2010). The most straightforward context for assessing ecological value is to identify those habitats and species that have a specific biodiversity importance recognised through international or national legislation or through local, regional or national conservation plans (e.g. Annex I habitats under the Habitats Directive, BAP, and southern North Sea MNA).

5.3.1.2 As discussed in paragraph 3.1.3.48, two rMCZs in the vicinity of the Hornsea Three benthic ecology study area, Markham's Triangle MCZ and Wash Approach rMCZ, have not yet been designated (Defra, 2013). However, as these sites remain recommended sites and will be considered within the third tranche, habitats and species which are listed as conservation priorities in the national plans for rMCZs have been considered in the valuation of benthic receptors (see Table 5.1).

5.3.1.3 As only a very small proportion of marine habitats and species are afforded protection under the existing legislative or policy framework, evaluation must also assess value according to the functional role of the habitat or species. For example, some features may not have a specific conservation value in themselves, but may be functionally linked to a feature of high conservation value. The following table shows the criteria applied to determining the ecological value of valued ecological receptors (VERs) within the geographic frame of reference applicable to the Hornsea Three benthic ecology study area (Table 5.1).

Table 5.1: Criteria used to inform the valuation of ecological receptors in the Hornsea Three benthic ecology study area.

Value of VER	Criteria to define value
International	Internationally designated sites (SACs, SCIs and Ramsar sites). Habitats (and species) protected under international law (i.e. Natura 2000 sites (Annex I habitats within an SAC boundary)).
National	Nationally designated sites (SSSIs and NNRs). Species protected under national law. Annex I habitats not within an SAC boundary. UK BAP priority habitats and species that have nationally important populations within the Hornsea Three benthic ecology study area, particularly in the context of species/habitat that may be rare or threatened in the UK[a]. Habitats and species that are listed as conservation priorities in regional plans including MCZs and rMCZs and the southern North Sea MNA.
Regional	UK BAP priority habitats that have regionally important populations within the Hornsea Three benthic ecology study area (i.e. are locally widespread and/or abundant). Habitats or species that provide important prey items for other species of conservation or commercial value.
Local	LNRs. Habitats and species which are not protected under conservation legislation form a key component of the benthic ecology within the Hornsea Three benthic ecology study area.

[a]Measured against criteria such as OSPAR threatened/declining species and IUCN Red List of threatened species.

5.3.1.4 For the purposes of conducting the EIA, the habitats present across the Hornsea Three benthic ecology study area (including biotopes and Annex I habitats) have been grouped into 11 broad habitat/community types. Together with the species of conservation interest, *A. islandica*, which was found within the Hornsea Three benthic ecology study area, these will serve as the12 VERs against which impacts associated with the construction, operation and decommissioning of Hornsea Three can be assessed. Table 5.2 provides a summary of these VERs within the Hornsea Three benthic ecology study area.

5.3.1.5 The biotopes have been grouped into broad habitat/community types according to the results of the statistical analyses described in this report. Habitats with similar physical, biological characteristics (including species complement and richness/diversity) as well as conservation status/interest have been grouped together for the purposes of the EIA. Consideration was also given to the inherent sensitivities of different habitats in assigning the groupings presented in Table 4.2, such that habitats and species with similar vulnerability and recoverability, often as a result of similar broad sediment types and species complements, were grouped together. The overall value of each VER was then assessed using the criteria presented in Table 5.1.

5.3.1.6 Site-specific data on the presence and distribution of subtidal chalk reefs and peat and clay exposures were not available at the time of writing (though such surveys are planned for Quarter 2 of 2017), however, between the Cefas Cromer Shoal Chalk Beds MCZ survey report and the Seasearch data, these habitats have been well documented within the Cromer Shoal Chalk Beds MCZ and are likely to be present in the shallow waters of the nearshore section of the Hornsea Three offshore cable corridor. As such, these habitats have also been considered as VERs against which impacts associated with the construction, operation and decommissioning of Hornsea Three should be assessed (Table 5.2).

5.3.1.7 As discussed previously, the apparent distribution of surveyed biotopes is strongly affected by sample density. Areas with very high sample density showed high variability of biotopes within small areas. Therefore, the use of these broad habitat types to describe the biotopes present will provide a more concise and coherent picture for Ecological Impact Assessment (EcIA), which would otherwise deal with each biotope separately. This is a logical approach for an environment where biotopes tend to grade into one another and for communities which differ in the specific suite of species present but are functionally and compositionally similar (and consequentially have similar sensitivity) as it makes the potential impact of activities similar across the range of similar biotopes present. In addition, it provides a better frame of reference for assessing conservation value. These simplified broad habitat types (VERs) which were recorded within the Hornsea Three benthic ecology study area, have also been presented geographically in Figure 5.1.Note that four of the eight VERs are shown in Figure 5.1. Habitat does not directly occur with the Hornsea Three array, while Habtats F to G, inclusive, will be mapped subsequent to a site-specific survey along the Hornsea Three offshore cable corridor scheduled for Quarter 2 of 2017.

Table 5.2: Summary of valued ecological receptors (VERs) within the Hornsea Three benthic ecology study area and their conservation status (see Figure 5.1 for subtidal VERs).

VER	Representative infaunal and/or epifaunal biotopes	Protection status	Conservation Interest	Distribution within Hornsea Three benthic ecology study area	UK geographic distribution	Importance within Hornsea Three benthic ecology study area and justification
Habitat A: Sandy sediments with low infaunal diversity and sparse epibenthic communities.	IMoSa, IMuSa, NcirBat, FfabMag, EpusOborApri, ApriBatPo and ScupHyd (where present as an epifaunal overlay in small areas of the EpusOborApri biotope).	None	UK BAP priority habitat.	This habitat was recorded throughout much of the western half of the Hornsea Zone, the western and central sections of the Hornsea Three array area and parts of the Hornsea Three offshore cable corridor.	These biotopes have been recorded around much of the coast of the UK including the southern North Sea, particularly the Wash, the English Channel and the Irish Sea.	Regional – UK BAP with nationally important populations close to the Hornsea Three benthic ecology study area.
Habitat B: Brittlestar dominated communities in deep muddy sands.	AfilMysAnit	None	UK BAP priority habitat.	This habitat was recorded within Hornsea Three array area and in a large swathe spanning the northern boundary of the former Hornsea Zone.	Most of the core records are from the Irish Sea but also the northwest coast of Scotland and the southern North Sea coast.	Regional – although this habitat is representative of a nationally important marine habitat, the southern North Sea is not a key geographic area.
Habitat C: Coarse and mixed sediments with moderate to high infaunal diversity and scour tolerant epibenthic communities.	MedLumVen/EpusOborApri, MedLumVen, MoeVen, MysThyMx, PoVen, ScupHyd, FluHyd.	None	UK BAP priority habitat. 'Subtidal sands and gravels' is a habitat FOCI under the Nature Conservation part (Part 5) of the Marine and Coastal Access 2009.	This habitat was recorded throughout much of the Hornsea Three array area and central former Hornsea Zone.	These biotopes have been recorded around the UK coast including principally the Irish Sea and the English Channel.	Regional – although this habitat is representative of a nationally important marine habitat, the southern North Sea is not a key geographic area.
Habitat D: Mixed sediments with high infaunal and epifaunal diversity.	SspiMx, PKef, Sspi.ByB.	None	Protected feature within the Cromer Shoal Chalk Beds MCZ.	This habitat was recorded along much of the Hornsea Three offshore cable corridor as well as discrete sections in the southeast of the former Hornsea Zone.	These habitats have been recorded previously in the southern North Sea, in particular the area between the Humber Estuary and The Wash. More sparse records have been made in the Bristol Channel, the Irish Sea and the English Channel.	Regional - Habitats or species that provide important prey items for other species of conservation or commercial value.
Habitat E: Annex I 'Sandbanks' within an SAC.	n/a	Annex I Habitats Directive	Annex I 'Sandbanks which are slightly covered by seawater all the time' within an SAC. UK BAP priority habitat.	This habitat is a primary reason for the selection of the North Norfolk and Saturn Reef SCI, the Wash and North Norfolk Coast SAC and Haisborough, Hammond and Winterton SCI.	This habitat is found around the coast of the UK both in inshore waters such as those around estuaries and also in offshore waters, predominantly in the North Sea.	International – part of European designated sites (i.e. North Norfolk and Saturn Reef SCI, the Wash and North Norfolk Coast SAC and Haisborough, Hammond and Winterton SCI).
Habitat F: Annex I reefs within an SAC.	SspiMx, Sspi.ByB	Annex I Habitats Directive	Annex I reefs within an SAC. OSPAR habitat: Sabellaria spinulosa reefs. UK BAP priority habitat.	This habitat is a primary reason for the selection of the North Norfolk and Saturn Reef SCI, the Wash and North Norfolk Coast SA, Haisborough, Hammond and Winterton SCI and Klaverbank SCI.	Sabellrai reefs have been found in the Wash, Thames Estuary, along the South Coast, Bristol channel, Northumberland coast, southern North Sea, North and wets of Wales and several locations around Scotland.	International – part of European designated sites (i.e. North Norfolk and Saturn Reef SCI, the Wash and North Norfolk Coast SAC, Haisborough, Hammond and Winterton SCI and Klaverbank SCI).
Habitat G: Subtidal coarse sediments within an MCZ or rMCZ.	MedLumVen/EpusOborApri, MedLumVen, MoeVen, MysThyMx, PoVen, ScupHyd, FluHyd.	MCZ	Protected feature within the Cromer Shoal Chalk Beds MCZ.	This habitat was recorded throughout much of the Hornsea Three array area and central former Hornsea Zone.	These biotopes have been recorded around the UK coast including principally the Irish Sea and the English Channel.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ. Also includes seafloor features for which Markham's Triangle rMCZ has been proposed for designation.

VER	Representative infaunal and/or epifaunal biotopes	Protection status	Conservation Interest	Distribution within Hornsea Three benthic ecology study area	UK geographic distribution	Importance within Hornsea Three benthic ecology study area and justification
Habitat H: Subtidal sandy sediments within an MCZ or rMCZ.	IMoSa, IMuSa, NcirBat, FfabMag, EpusOborApri, ApriBatPo and ScupHyd (where present as an epifaunal overlay in small areas of the EpusOborApri biotope).	MCZ	Protected feature within the Cromer Shoal Chalk Beds MCZ.	This habitat was recorded throughout much of the western half of the Hornsea Zone, the western and central sections of the Hornsea Three array area and parts of the Hornsea Three offshore cable corridor.	These biotopes have been recorded around much of the coast of the UK including the southern North Sea, particularly the Wash, the English Channel and the Irish Sea.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ. Also includes seafloor features for which Markham's Triangle rMCZ has been proposed for designation.
Habitat I: Subtidal mixed sediments within an MCZ or rMCZ.	SspiMx, PKef, Sspi.ByB.	MCZ	Protected feature within the Cromer Shoal Chalk Beds MCZ.	This habitat was recorded throughout much of the Hornsea Three array area and central former Hornsea Zone.	These habitats have been recorded previously in the southern North Sea, in particular the area between the Humber Estuary and The Wash. More sparse records have been made in the Bristol Channel, the Irish Sea and the English Channel.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ.
Habitat J: Subtidal chalk reefs	n/a	Annex I Habitats Directive MCZ	Annex I 'Reefs'. UK BAP priority habitat. Protected feature within the Cromer Shoal Chalk Beds MCZ. 'Subtidal chalk' is a habitat FOCI under the Nature Conservation part (Part 5) of the Marine and Coastal Access 2009.	Desktop data show this habitat has been previously recorded offshore of 200 m seaward of the MLWS mark.	The habitat is present in North Norfolk, Flamborough Head in Yorkshire and on the Thanet coast in Kent, Sussex, Isle of Wight and Studland and County Antrim. Considered rare in northwest Europe.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ.
Habitat K: Peat and clay exposures	n/a	MCZ	UK BAP priority habitat. Protected feature within the Cromer Shoal Chalk Beds MCZ.	Desktop data show this habitat has been previously recorded offshore of 200 m seaward of the MLWS mark.	This is found along the north and south coasts of Wales, the south and east coasts of England and in Cumbria.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ.
Species H: Ocean quahog *Arctica islandica.*	n/a	None	OSPAR List of threatened and/or declining species for the Greater North Sea (OSPAR Region II). FOCI under the Nature Conservation part (Part 5) of the Marine and Coastal Access 2009.	Eight individuals of this species were recorded from seven sites within Hornsea Project Two array area and two sites in the wider Hornsea Three benthic ecology study area. None of the records were from areas within an rMCZ.	Ocean quahogs are found all around and offshore from, British and Irish coasts, particularly the southern North Sea and the English Channel along the Cornwall and Devon coasts.	National – UK BAP with nationally important populations within the southern North Sea benthic ecology study area.

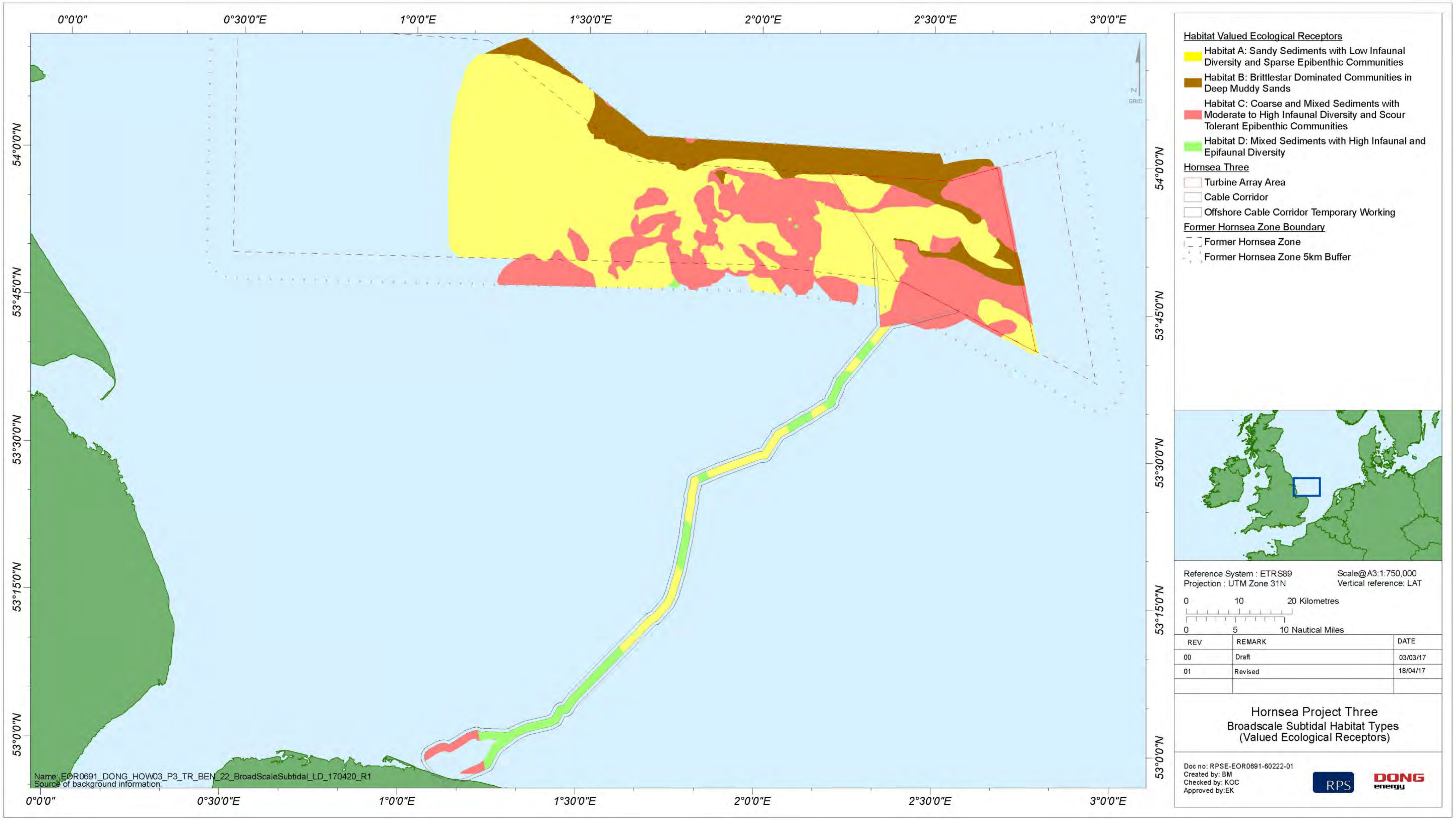

Figure 5.1: Subtidal Valued Ecological Receptors (VERs) in the Hornsea Three benthic ecology study area.

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