Hornsea Project Three
Offshore Wind Farm

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Offshore Wind Farm

Environmental Statement:
Volume 5, Annex 2.1 - Benthic Ecology Technical Report

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Hornsea 3
Offshore Wind Farm

Ørsted

Environmental Impact Assessment

Environmental Statement

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
AFDW	Ash-free dry weight
AL1	Cefas Action Level 1
AL2	Cefas Action Level 2
BAC	OSPAR Background Assessment Concentration
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
DBT	Dibutyl tin
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
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EQS	UK Environmental Quality Standards
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

Acronym	Description
JNCC	Joint Nature Conservation Committee
LAT	Lowest astronomical tide
LNR	Local Nature Reserve
MALSF	Marine Aggregate Levy Sustainability Fund
MAREA	Marine Aggregate Regional Environmental Assessment
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
PINS	Planning Inspectorate
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

Acronym	Description
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
SNS	Southern North Sea
SSSI	Site of Special Scientific Interest
TBT	Tributyltin
TEL	Threshold Effect Level
THC	Total hydrocarbon concentrations
TN	Target Note
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
MW	Megawatts
ng/g	Nanograms per gram
nm	Nautical mile

1. Introduction

1.1 Project background

1.1.1.1 Orsted Hornsea Project Three (UK) Ltd., on behalf of Orsted Power (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 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 of 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 and 2017, including within the Hornsea Three array area, the offshore cable corridor and the intertidal area (section 2.4.3).

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 (i.e. Hornsea Three array area, offshore cable corridor and intertidal 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 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.

1.2.1.3 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 characterisation 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.

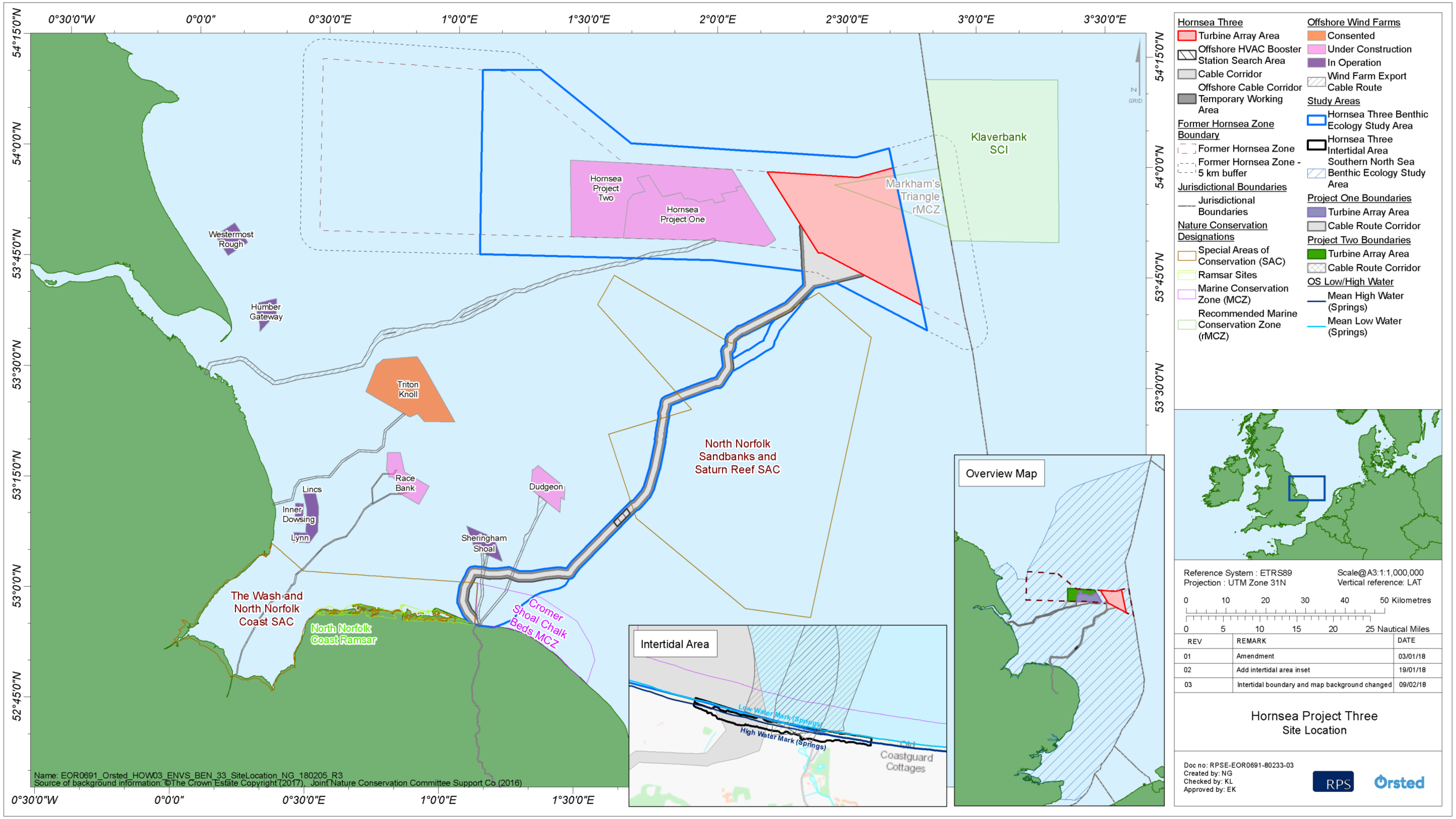

Figure 1.1: Location of Hornsea Three and the former Hornsea Zone, plus other offshore wind farm sites in the southern North Sea benthic ecology study area.

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

2.1.1.2 This area encompasses Hornsea Three, which includes the Hornsea Three array area, Hornsea Three offshore cable corridor (i.e. encompassing subtidal benthic ecology), and intertidal 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. Two offshore cable corridor reroutes were applied to Hornsea Three after publication of the Preliminary Environmental Information Report (PEIR), one at the northern end of the Hornsea Three offshore cable corridor and one in the nearshore section, around the west side of the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ; see Figure 2.1 and volume 1, chapter 3: Project Description). Both the original and reroute sections are included in the Hornsea Three benthic ecology study area, though the majority of the site specific sampling had been undertaken prior to the reroutes. 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 study area.

2.1.1.3 At the intertidal 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).

The southern North Sea benthic ecology study area

2.1.1.4 This is the regional benthic ecology study area and was defined by the boundaries of the southern North Sea Marine Natural Area (MNA) (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 Evidence Plan (document reference number A5.1.1)) 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 Environmental Statement, 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. This involved utilising existing data and information from sufficiently similar or analogous studies to inform baseline understanding and/or impact assessments for Hornsea Three. In this way, the evidence based approach does not necessarily require new data to be collected, or new modelling studies to be undertaken, 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 area 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 area 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 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 Environmental Statement, 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 Hornsea Three site specific additions, described briefly in paragraphs 2.2.1.6 and 2.2.1.7 below and in further detail in section 2.4.

2.2.1.6 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 standalone benthic surveys in 2017; and as part of an inshore geophysical survey campaign in 2017. 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 Environmental Statement (see Figure 2.6 and section 2.4.3).

2.2.1.7 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 Environmental Statement has primarily drawn upon the site specific surveys completed in 2016 and 2017 and desktop information from third-party surveys, including surveys targeting areas within and in close proximity to areas designated for nature conservation. The approach to baseline characterisation, including site specific surveys along the Hornsea Three offshore cable corridor has been discussed and agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG.

2.3 Desktop review

2.3.1.1 There have been several 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 and monitoring surveys from other developments, including offshore wind farms, in the region (e.g. Dudgeon (Warwick Energy, 2009; Fugro EMU Ltd., 2015) and Sheringham Shoal (Scira Offshore Energy, 2006; 2015));
- Data from the surveys undertaken in support of the designation of the Cromer Shoal Chalk Beds MCZ (Defra, 2015);
- Data from benthic surveys undertaken within the North Norfolk Sandbanks and Saturn Reef Special Area of Conservation (SAC) and Haisborough, Hammond and Winterton SAC (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);
- Data acquired in the Southern North Sea Synthesis Benthic Survey, commissioned by Cefas (Allen, 2012);
- Reports from benthic surveys undertaken within the Wash and North Norfolk Coast SAC (e.g. APEM, 2013);
- Data from Marine Recorder, including Seasearch dive surveys within the Cromer Shoal Chalk Beds MCZ and the Wash and North Norfolk Coast SAC; 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 paragraph 2.2.1.5, 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 surveys undertaken in 2016 and 2017 within the Hornsea Three array area, offshore cable corridor and intertidal area. These surveys are described in section 2.4.3 below.

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 characterisation (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 array area 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. 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 several 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 collected across the Hornsea Three benthic ecology study area 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 (Defra, 2014). This survey, which partially overlapped the Hornsea Three array area, 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 can 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 faunal dataset has been broadly analysed to determine the similarity of the communities in the site with those within the Hornsea Three array area; this analysis is further discussed in paragraph 2.6.2.2 and the results are presented in section 4.1.4.26 *et seq*.

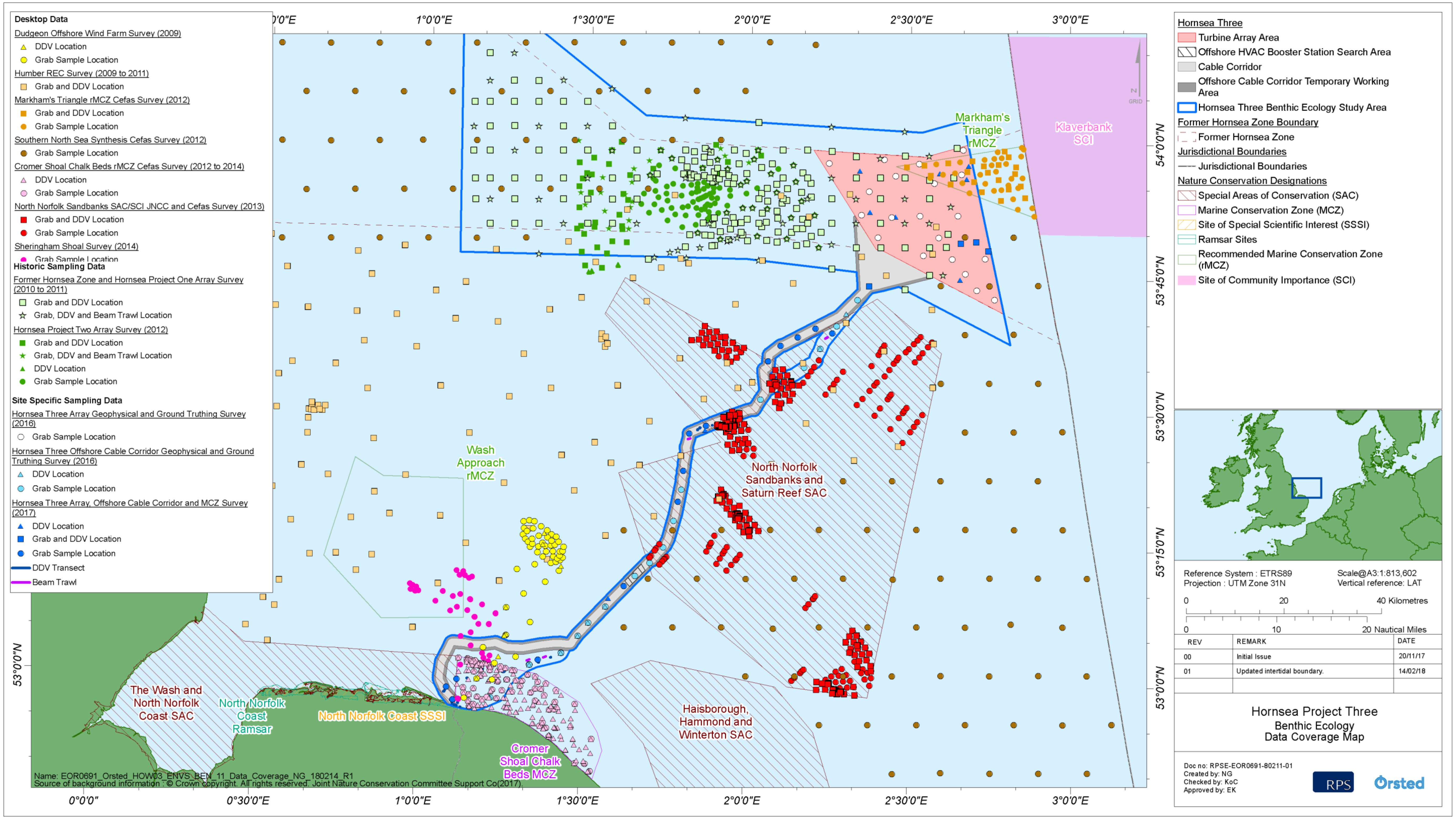

Figure 2.1: The location of Hornsea Three and the former Hornsea Zone with existing desktop data together with historic former Hornsea zone benthic ecology survey data. Hornsea Three site specific survey data and nature conservation designations with benthic features.

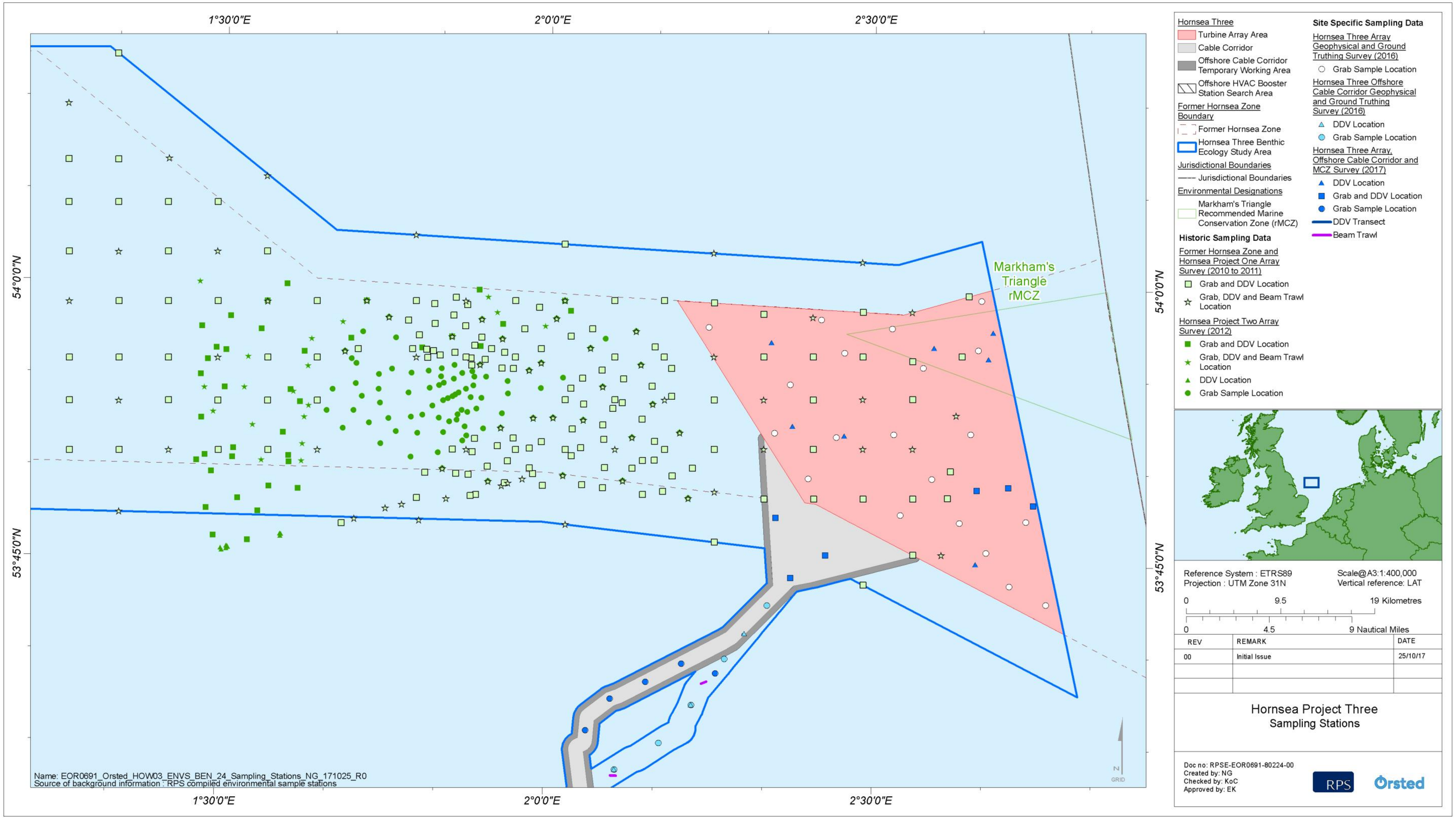

Figure 2.2: The Hornsea Three array area with historic data (2010-2012), Markham's Triangle rMCZ data (Defra, 2012; third-party survey data) and Hornsea Three site specific (2016-2017) data.

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

Survey	Date of survey	Combined benthic grab sampling and DDV stations	Epibenthic beam trawls	Sampling stations within the Hornsea Three benthic ecology study area
Historic 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 of the Hornsea Three benthic ecology study area (collected 2016-2017)				
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	August 2016	-	-	No sampling undertaken; walkover survey
Hornsea Three benthic sampling survey - beyond 60 nm	May 2017	6 stations, 3 of which were also sampled for sediment chemistry, and 10 additional stations for DDV only	-	16 grab and DDV stations
Hornsea Three benthic sampling survey - within 60 nm	August 2017	14 stations plus 15 stations for DDV only, 5 stations for sediment chemistry only, 5 beam trawls	5 stations	29 grab and/or DDV stations, 5 sediment chemistry locations, 5 epibenthic trawls
Inshore geophysical and DDV survey	October 2017	9 DDV transects; geophysical data (side scan sonar, bathymetry and sub-bottom profiler)		9 DDV stations; geophysical data

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 2.4.2, a number of site specific surveys were undertaken across the Hornsea Three benthic ecology study area in 2016 and 2017 (see Figure 2.2, Figure 2.3 and Table 2.1):

- Hornsea Three array area geophysical survey ground-truthing campaign in 2016: 20 sample locations (see section 4.1.4 for the results);
- Hornsea Three offshore cable corridor benthic grab/DDV survey in 2016: 20 sample locations (see section 4.1.2 for the results and specifically paragraph 4.1.4.33 for interpretation of the 50 m transects);
- Intertidal walkover survey in 2016 (see paragraphs 4.1.4.89 to 4.1.4.96 for the results).
- Hornsea Three array area and Hornsea Three offshore cable corridor benthic sampling survey in 2017 beyond 60 nm: 16 sample locations (see paragraphs 2.4.3.12 to 2.4.3.13);
- Hornsea Three offshore cable corridor benthic sampling survey in 2017 within 60 nm: 39 sample locations (see paragraphs 2.4.3.8 to 2.4.3.11); and
- Inshore DDV survey in 2017: 9 sample locations (see paragraphs 2.4.3.14).

Hornsea Three array area benthic grab survey, 2016

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 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 paragraphs 2.5.1.2 and 2.5.1.3.

2.4.3.3 Sediment samples were analysed according to the methods outlined in section 2.5 by the Institute of Estuarine and Coastal Studies (IECS) laboratory, which participates in the National Marine Biological Analytical Quality Control (NMBAQC) scheme.

Hornsea Three offshore cable corridor benthic grab/DDV survey, 2016

2.4.3.4 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.

2.4.3.5 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 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 4.1.4.97 to 4.1.4.105). 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 2.5.1.4. A sub sample of the sediment was retained for PSA according to the methodologies described in paragraphs 2.5.1.2 and 2.5.1.3, which were subsequently analysed for particle size distribution at the IECS laboratory, as described in paragraphs 2.4.3.3.

Hornsea Three intertidal survey, 2016

2.4.3.6 TA Phase 1 intertidal walkover survey was undertaken at the proposed Hornsea Three intertidal area (see Figure 2.3) 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, 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 4.1.4.89 to 4.1.4.96).

2.4.3.7 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.

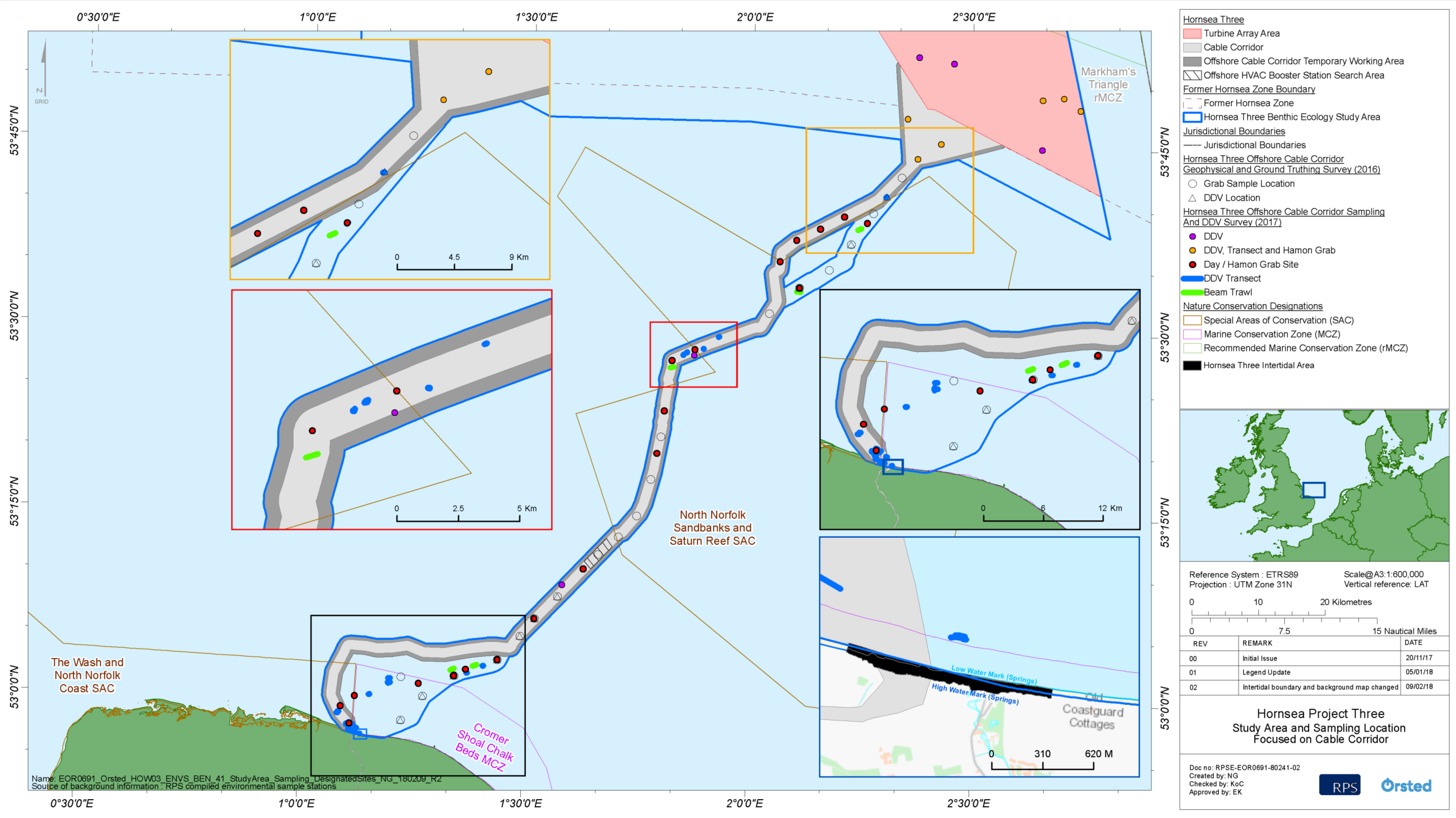

Figure 2.3: The Hornsea Three offshore cable corridor with site specific sampling collected in 2016 and 2017.

Hornsea Three offshore cable corridor benthic sampling survey within 60 nm, 2017

2.4.3.8 The sampling strategy was informed by a data gap analysis and detailed interpretation of the geophysical data acquired along the Hornsea Three offshore cable corridor in 2016. The survey strategy was discussed and agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG.

2.4.3.9 The purpose of this survey was to characterise the Hornsea Three offshore cable corridor, by addressing several objectives, these included the following:

- Provide further data coverage within representative sediment types in areas of the Hornsea Three offshore cable corridor with lower data coverage or certainty, including 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;
- Confirm the presence/absence of historic and potential reef habitats within and outside the boundaries of the North Norfolk Sandbanks and Saturn Reef SAC including rocky reefs and biogenic reefs formed by the Ross worm, *Sabellaria spinulosa*;
- Provide data on sediment chemistry at selected locations;
- Confirm the presence/absence of subtidal chalk and/or clay habitat within the Cromer Shoal Chalk Bed MCZ; and
- Undertake an epibenthic beam trawl survey.

2.4.3.10 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 taken. During the DDV survey, a minimum of five high-quality images were taken at each DDV station along with five minutes of video, where possible. A limited amount of grab sampling was performed within the Cromer Shoal Chalk Beds MCZ and the North Norfolk Sandbanks and Saturn Reef SAC. Along the Hornsea Three offshore cable corridor a 0.1 m^2 mini-Hamon grab was used to sample benthic fauna at 13 stations and a stainless steel 0.1 m^2 Day grab was used to take sediment chemistry samples at five locations where fines content was expected to exceed 5% of the sediment composition.

2.4.3.11 Faunal samples were analysed at the Ocean Ecology laboratory as described in paragraph 2.5.1.4 and a sub sample of the sediment was retained for PSA according to the methodologies described in paragraphs 2.5.1.2 and 2.5.1.3, which were subsequently analysed by Ocean Ecology for particle size distribution. The sediment chemistry samples were analysed for organic carbon, metals, hydrocarbons and organotins, as described in paragraph 2.5.1.6. Beam trawls were performed over distances of approximately 500 m at five locations along the Hornsea Three offshore cable corridor to sample the epibenthic communities, as described in paragraphs 2.5.1.11 to 2.5.1.13.

Hornsea Three array and Hornsea Three offshore cable corridor benthic sampling survey beyond 60 nm, 2017

2.4.3.12 As described in paragraph 2.4.3.8 the scope of this survey was to characterise the Hornsea Three array area and furthest offshore section of the Hornsea Three offshore cable corridor. The strategy was informed by a data gap analysis and detailed interpretation of the geophysical data acquired along the Hornsea Three offshore cable corridor in 2016. The survey strategy was discussed and agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG.

2.4.3.13 Sampling was undertaken with a 0.1 m^2 mini Hamon grab to provide further data coverage within representative sediment types in areas with lower data coverage or certainty, including three locations at Markham's Hole in the Hornsea Three array area and three locations in the cable fan at the northern end of the Hornsea Three offshore cable corridor. Single samples were acquired at each station and subsequently analysed for fauna; a sub sample was also taken from each grab for PSA. A second grab sample was collected at the three stations in the Hornsea Three offshore cable corridor fan which were then analysed for sediment chemistry as described in section 2.6.1. DDV was acquired at 10 geotechnical investigation locations prior to geotechnical operations, to ensure sensitive habitats were not damaged. The DDV data was subsequently analysed for epibenthic fauna and seabed habitats as described in paragraph 2.5.1.8 *et seq*.

Inshore geophysical and DDV survey, 2017

2.4.3.14 High resolution geophysical data were acquired along the section of the Hornsea Three offshore cable corridor that coincides with the inshore section of the offshore cable corridor, including the Wash and North Norfolk Coast SAC and Cromer Shoal Chalk Beds MCZ. Once the geophysical data had been analysed, a DDV survey was undertaken to ground truth different seabed features, including sand ripples and areas of gravel, but with a particular focus on areas where geophysical data was interpreted as being potential subcropping and outcropping bedrock that might represent chalk or clay exposures. A total of 9 DDV transects were performed across these potential outcrops and analysed by Fugro GB Marine Limited.

2.5 Site specific Sample collection and analysis

2.5.1.1 The following section describes the methods of sample collection and analysis common to both the historic and site specific benthic ecology surveys. Note that all raw and derived data and associated analyses are available as appendices on request.

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 (PSA). Upon retrieval of the grab sample on board the vessel, the sediment within the grab bucket was viewed 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, Hornsea Project One, Hornsea Project Two (342 samples combined), Hornsea Three array (23 samples) and Hornsea Three offshore cable corridor surveys (35 samples), 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, Hornsea Project One, Hornsea Project Two (342 samples combined), Hornsea Three array (23 samples) and Hornsea Three offshore cable corridor surveys (35 samples), plus fauna data from the third-party Markham's Triangle MCZ survey (50 samples)); and
- Sediment chemical analysis (ZoC, Hornsea Project One, Hornsea Project Two and Hornsea Three surveys (56 samples combined)).

Particle size analysis

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.

Benthic infauna analysis

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) 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.

Sediment chemistry analysis

2.5.1.6 Samples for sediment chemistry analysis were collected using a stainless steel Shipek or Day grab. A total of 56 locations within the Hornsea Three benthic ecology study area have 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) (United States (US) 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, Hornsea Project One, Hornsea Project Two and Hornsea Three site specific surveys.

2.5.1.9 The DDV surveys were undertaken using a 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, a potential reef 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 each survey the video records and/or photographic stills were reviewed and analysed in more detail by marine ecologists. Static images were analysed 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 where available, identifying conspicuous species. 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. 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 2.4 (an appendix showing digital stills indicative of each sampling location is available on request).

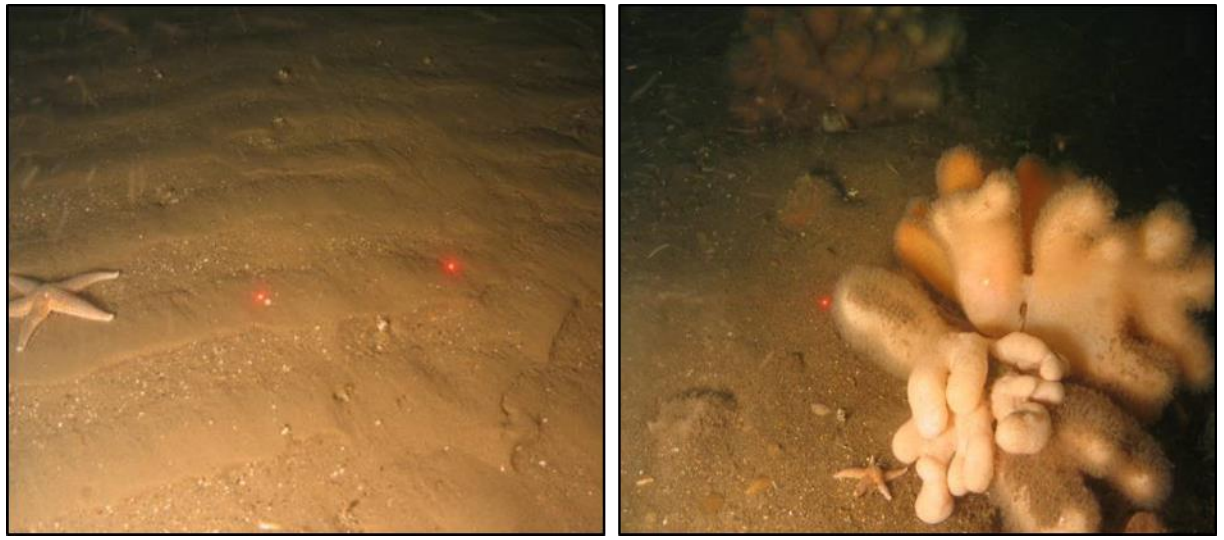

Figure 2.4: Species recorded during previous DDV surveys across the Hornsea Three benthic ecology study area included the echinoderm *Asterias rubens* (left) and dead man's fingers *Alcyonium digitatum* (right).

Epibenthic beam trawl survey

2.5.1.11 Epibenthic sampling was undertaken during the ZoC, Hornsea Project One and Hornsea 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 107 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.

2.5.1.12 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 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 reef habitats. Full epibenthic beam trawl logs, including timings, trawl depths and locations are available as an appendix on request.

2.5.1.13 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, Hornsea Project Two and Hornsea Three, including comparison against relevant thresholds and guidelines, have been presented within this Technical Report (see section 4.1.3).

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 23 grab samples at the Hornsea Three array area and 35 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 benthic ecology study area. DDV data were acquired during 2017 site specific surveys at the Hornsea Three array area and Hornsea Three offshore cable corridor, therefore the epibenthic biotope map draws on quantitative DDV data, supported by qualitative DDV data acquired during the 2016 Hornsea Three site specific survey. Five site specific epibenthic beam trawls were also taken along the Hornsea Three offshore cable corridor and subsequently analysed, from which the data contributed to the epibenthic biotope maps shown in section 4.1.4.

2.6.2.2 As discussed in paragraph 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 site specific infaunal data, to establish how the datasets compare and ultimately determine whether the Markham’s Triangle dataset supports the characterisation of the Hornsea Three array area, in the context of the assigned biotopes. This analysis has been reported as a discrete section within the results; see paragraph 4.1.4.26 *et seq*.

2.6.2.3 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.

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 2.6.2.7)). 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 (450 sites). The benthic infaunal dataset was square root transformed to down-weight the species with the highest abundances for multivariate community analysis using the PRIMER v6 software (Clark and Gorley, 2008).

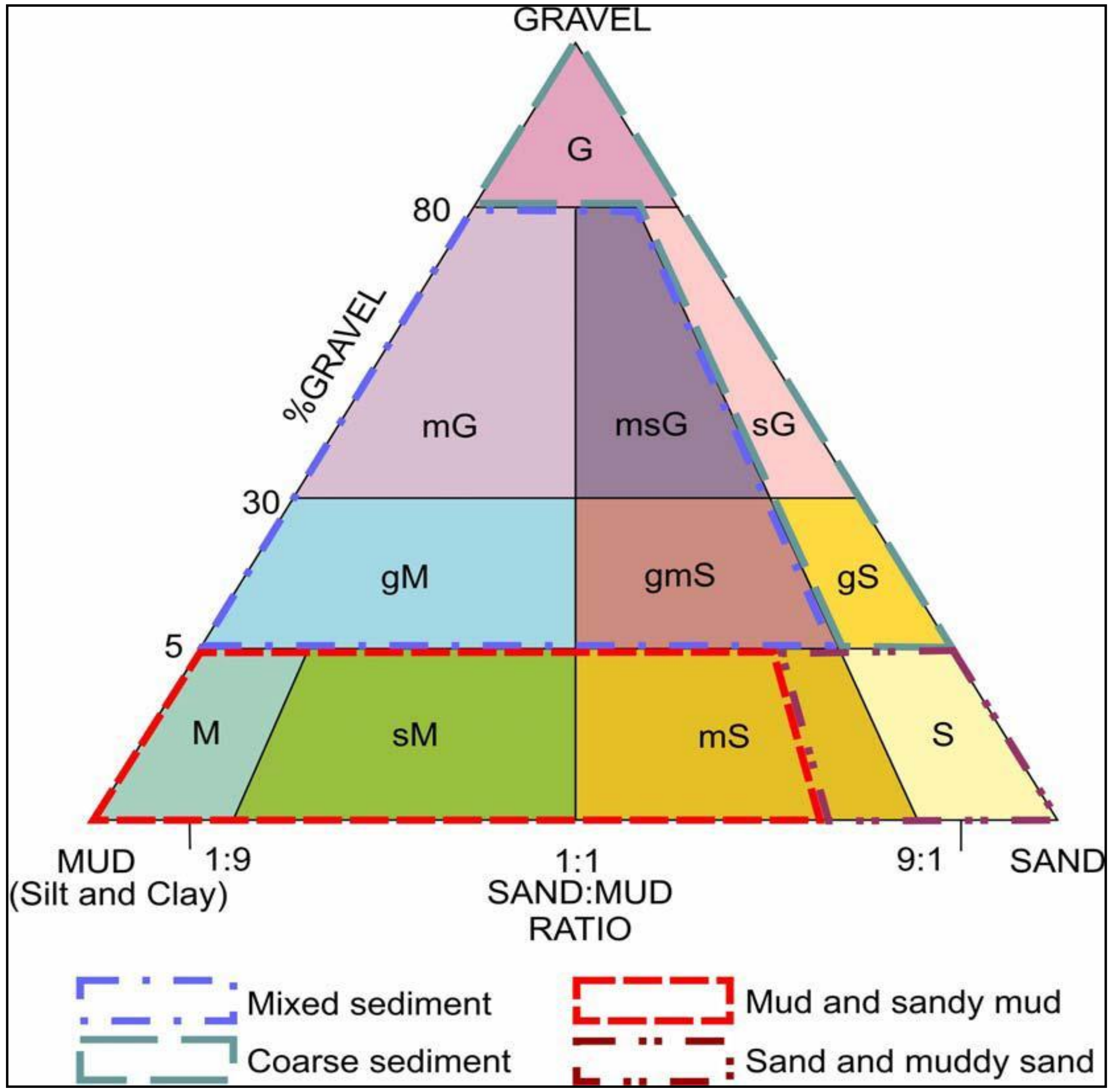

Figure 2.5: Simplified Folk Sediment classifications (from Long, 2006).

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 paragraph 2.6.2.11) from the DDV and grab epifaunal data, but the results were used to inform the final epibenthic biotope classifications (see paragraph 2.6.2.13). Since the species abundances from DDV footage (i.e. the epifauna dataset) were estimated and averaged for each station 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 using CLUSTER analysis (hierarchical agglomerative clustering) in 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, 31 clusters were identified for coarse sediments, 17 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), 20 clusters were identified for coarse sediment, 15 for sand and muddy sand sediments and 9 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 to assign preliminary biotopes (Connor *et al*., 2004). Using the clusters identified, several sites within a 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 different between 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 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, 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 paragraph 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 4.1.4.

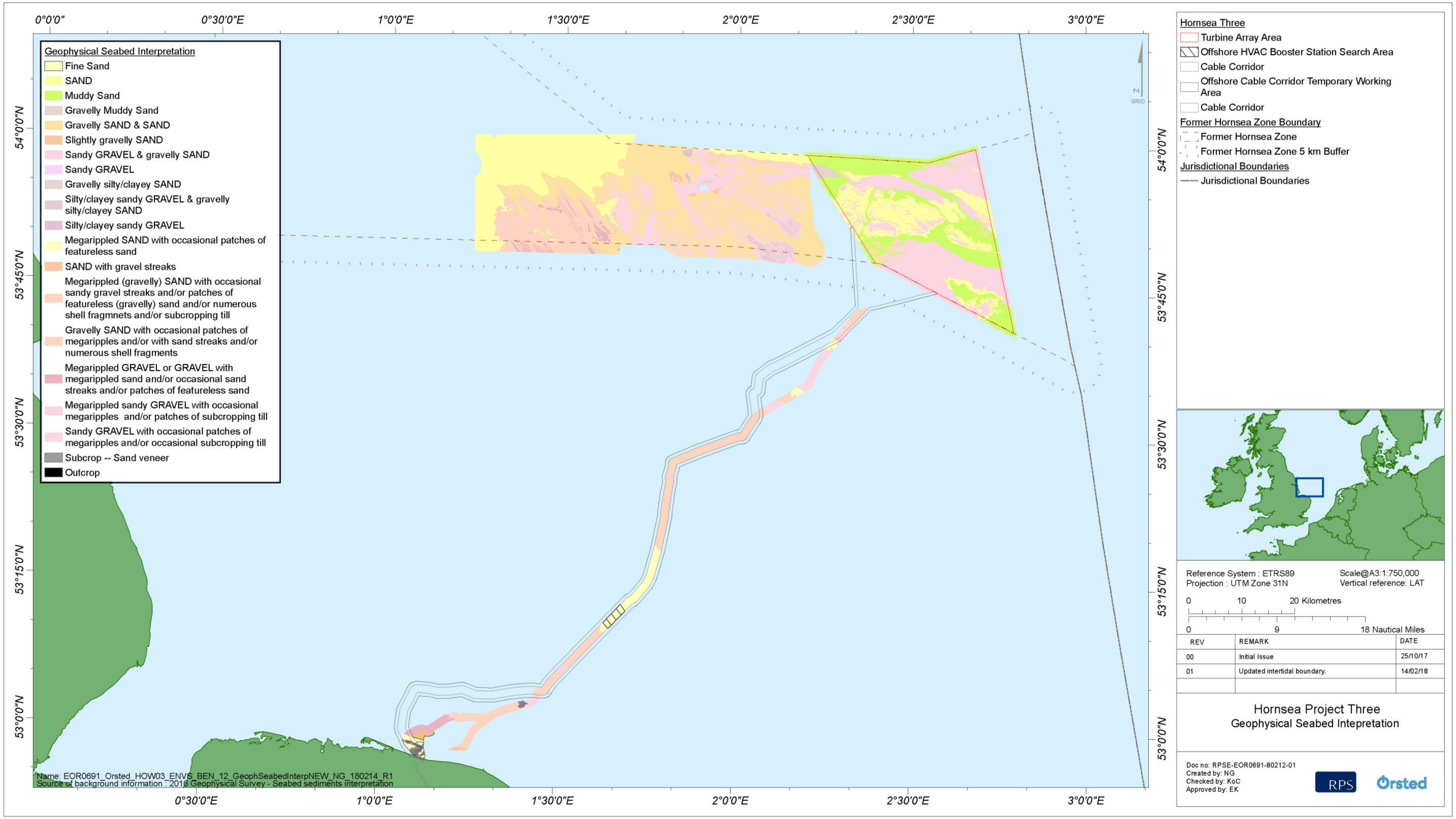

Figure 2.6: Geophysical survey seabed interpretation for the Hornsea Three benthic ecology study area.

Nearshore biotope mapping

2.6.2.16 Biotope mapping in the nearshore part of the Hornsea Three offshore cable corridor was completed using a combination of desktop information and Hornsea Three site-specific survey data to ensure a holistic characterisation of the entire nearshore area. As outlined above, Hornsea Three data (including DDV, benthic grab and geophysical datasets) were analysed and used to identify and map biotopes across the project area, including the nearshore part of the Hornsea Three offshore cable corridor. As detailed in section 2.3 above, a number of desktop data sources from the nearshore area were reviewed to inform the nearshore benthic ecology characterisation. This included information from the Sheringham Shoal and Dudgeon offshore wind farm cable corridors, data from the Cromer Shoal Chalk Beds MCZ and the Wash and North Norfolk Coast SAC, as well as data from Marine Recorder. These sources were reviewed and where grab sample data were analysed to describe sediments and infaunal community composition, including categorisation of communities into biotopes, these biotope classifications were used to inform the nearshore baseline characterisation. Data points from these desktop reports were mapped using GIS software and the Hornsea Three biotope mapping was extended to cover the entire nearshore area, merging adjacent sampling points of the same biotope classification to extend over a wider area. Boundaries between biotopes were drawn using bathymetry and other geophysical data (i.e. site-specific data and desktop sources) and broadscale habitat mapping from the aforementioned data sources (e.g. Defra, 2015 within the Cromer Shoal Chalk Beds MCZ).

2.6.2.17 The results of these desktop data sources, including descriptions of the biotopes identified, are presented in paragraph 3.1.3.2 *et seq*. Detailed description of the Hornsea Three site-specific data, including data analysis and biotope mapping is presented in section 4.1, with a holistic discussion of the nearshore desktop and site-specific datasets, presented in paragraph 4.1.4.83 *et seq*.

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 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 paragraph 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 reef assessment

2.6.4.1 An Annex I habitat assessment was undertaken on any sampling locations where potential biogenic and/or geogenic reef habitats were identified within the Hornsea Three array area and Hornsea Three offshore cable corridor (see Figure 3.5). These habitats were identified firstly from the geophysical data and then from other data sources including video records and seabed stills (data available on request). An *S. spinulosa* reef assessment was required at five sites (sites ECR02, ECR04, 26_CPT_ECR, ECR37 and ECR38; Figure 3.5) and a stony reef assessment was performed at five sites (ECR24, ECR35, ECR36, ECR38 and ECR39) during the Hornsea Three offshore cable corridor 2016 and 2017 site specific surveys. The reef assessments 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 Hornsea Three benthic ecology study area, a reefiness assessment, with reference to relevant guidance documents (i.e. Jenkins *et al*., 2015; Gubbay, 2007; Limpenny *et al*., 2010), was undertaken to determine whether or not a potential *S. spinulosa* reef was present. To ensure that the assessment was transparent it comprised a measure of elevation, patchiness, as outlined in Table 2.2. The scoring system proposed by Gubbay (2007) and the 'reefiness' matrix described in Jenkins *et al*., 2015 was used to draw together all the information to interpret the 'reefiness' of *S. spinulosa* aggregations (Table 2.3). Workshop 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 2.2 were measured, where possible, using the broad (i.e. geophysical) and fine scale (DDV and grab) survey data collated during the surveys.

Table 2.2: Summary of the analysis and scoring of *S. spinulosa* reef characteristics (based on Gubbay, 2007).

Characteristic	Analysis of characteristics
Elevation	A rough estimate of the height of the reef from the video footage or photographic stills, and placement within the following size categories of >10 cm, 5 to 10 cm, 2 to 5 cm and <2 cm high. This was averaged for the total surveyed area, or discrete feature, where possible.
Patchiness	Estimated from the video footage as a continuous video if conditions allow, or as a series of camera drops or photographic stills along a transect. Where the latter technique was employed, patchiness determined on a site by site basis from the following calculation: $\frac{\text{Total percentage of } S. spinulosa \text{ cover over the whole site}}{\text{Total area surveyed}} \times 100$

Table 2.3: *S. spinulosa* reef assessment matrix (based on Gubbay, 2007 and Jenkins *et al.*, 2015).

'Reefiness' matrix			Elevation (cm)			
			<2	2 to 5	5 to 10	>10
			Not a reef	Low	Medium	High
Patchiness (% cover)	<10	Not a reef	NOT A REEF	NOT A REEF	NOT A REEF	NOT A REEF
	10 to 20	Low	NOT A REEF	LOW	LOW	LOW
	20 to 30	Medium	NOT A REEF	LOW	MEDIUM	MEDIUM
	>30	High	NOT A REEF	LOW	MEDIUM	HIGH

Stony reefs

2.6.4.3 Where coarse stony substrate was observed in the DDV footage of the Hornsea Three benthic ecology study area, a stony reef assessment according to the appropriate guidance (Irving, 2009) was undertaken to determine if a potential stony reef was present. The assessment comprised of a measure of elevation and patchiness, and extent where possible, as outlined in Table 2.4. The scoring system proposed by Gubbay (2007) and the 'reefiness' matrix described in Jenkins *et al.*, 2015 was used to draw together all the information to interpret the 'reefiness' of stony features (Table 2.5). The conclusion of the Irving (2009) guidance was that a reef should be elevated above flat sea floor, have an area of at least 25 m^2 and have a composition of no less than 10% coverage of the seabed (Irving, 2009). The parameters summarised in Table 2.5 were measured, where possible, using the broad (i.e. geophysical) and fine scale (DDV) survey data collated during the surveys.

Table 2.4: Summary of the analysis and scoring of stony reef characteristics (based on Irving, 2009).

Characteristic	Analysis of characteristics
Elevation	A rough estimate of the height of the reef from the video footage or photographic stills, and placement within the following size categories of flat seabed, <64 mm, <64 mm to 5 m and >5 m high. This was averaged for the total surveyed area, or discrete feature, where possible.
Composition	Estimated from the video footage as a continuous video if conditions allow, or as a series of camera drops or photographic stills along a transect. Where the latter technique was employed, patchiness determined on a site by site basis from the following calculation: $\frac{\text{Total percentage of stony cover over the whole site}}{\text{Total area surveyed}} \times 100$
Extent	An area of 25 m^2 or greater is considered the minimum extent a reef should cover.

Table 2.5: Stony reef assessment matrix (based on Irving, 2009 and Jenkins *et al.*, 2015).

'Reefiness' matrix			Elevation (cm)			
			Flat seabed	<64 mm	64 mm-5 m	>5 m
			Not a reef	Low	Medium	High
Composition (% cover)	<10%	Not a reef	NOT A REEF	NOT A REEF	NOT A REEF	NOT A REEF
	10 to 40% matrix supported	Low	NOT A REEF	LOW	LOW	LOW
	40 to 95%	Medium	NOT A REEF	LOW	MEDIUM	MEDIUM
	>95% clast supported	High	NOT A REEF	LOW	MEDIUM	HIGH

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 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 these 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 northeastern 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 infralittoral/circalittoral coarse sediments dominated much of the Hornsea Three offshore cable corridor. The EUSeaMap data indicated an area of bedrock, primarily moderate energy infralittoral rock with small regions of high energy infralittoral rock and moderate energy circalittoral rock, was evident within the Hornsea Three offshore cable corridor just offshore the North Norfolk coastline. This characterisation broadly corresponded with subtidal chalk beds which are a qualifying habitat for the Cromer Shoal Chalk Beds MCZ; see paragraph 3.1.3.52.

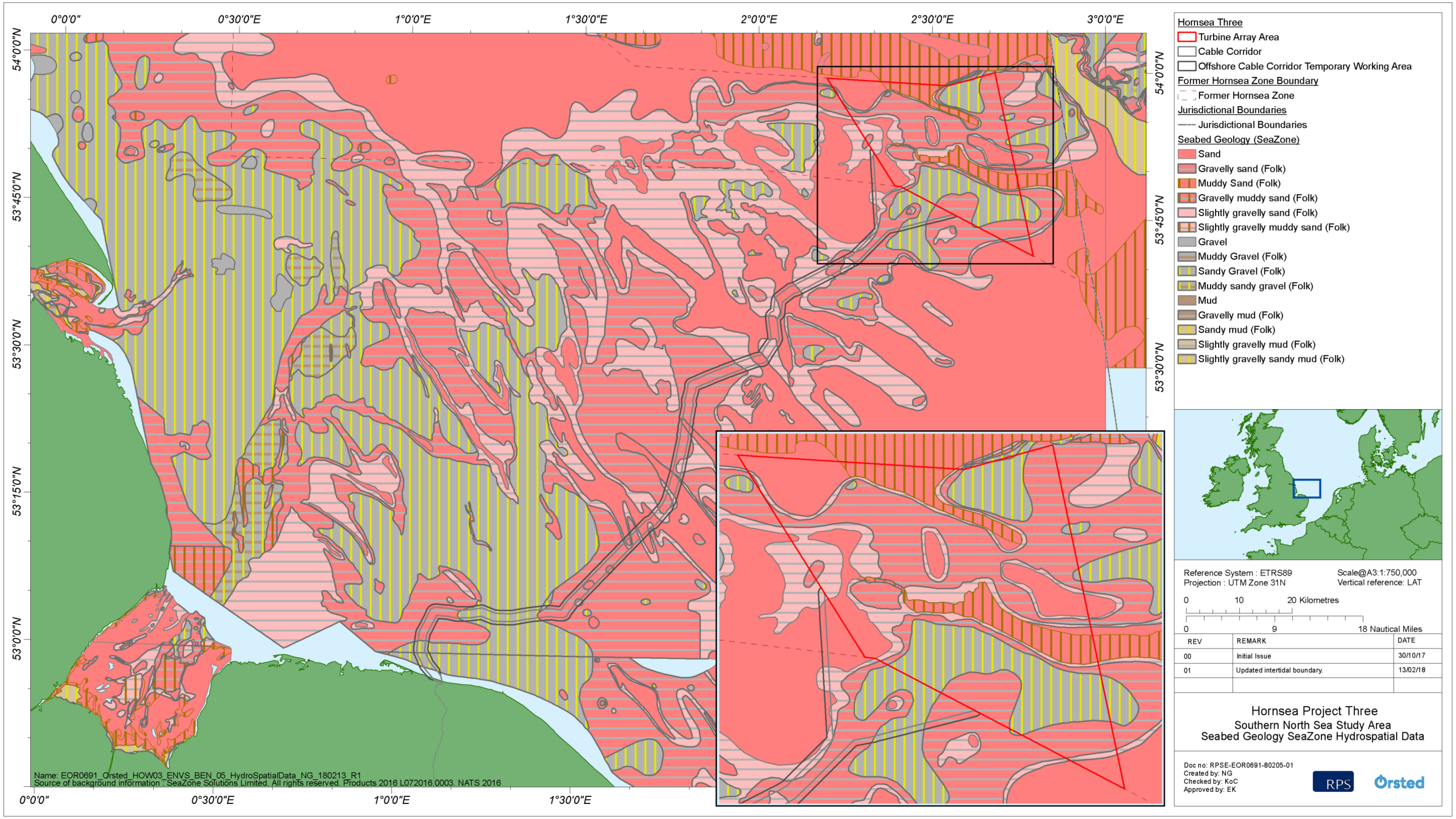

Figure 3.1: Hornsea Three subtidal benthic survey locations and SeaZone HydroSpatial sediment data for the southern North Sea benthic ecology study area.

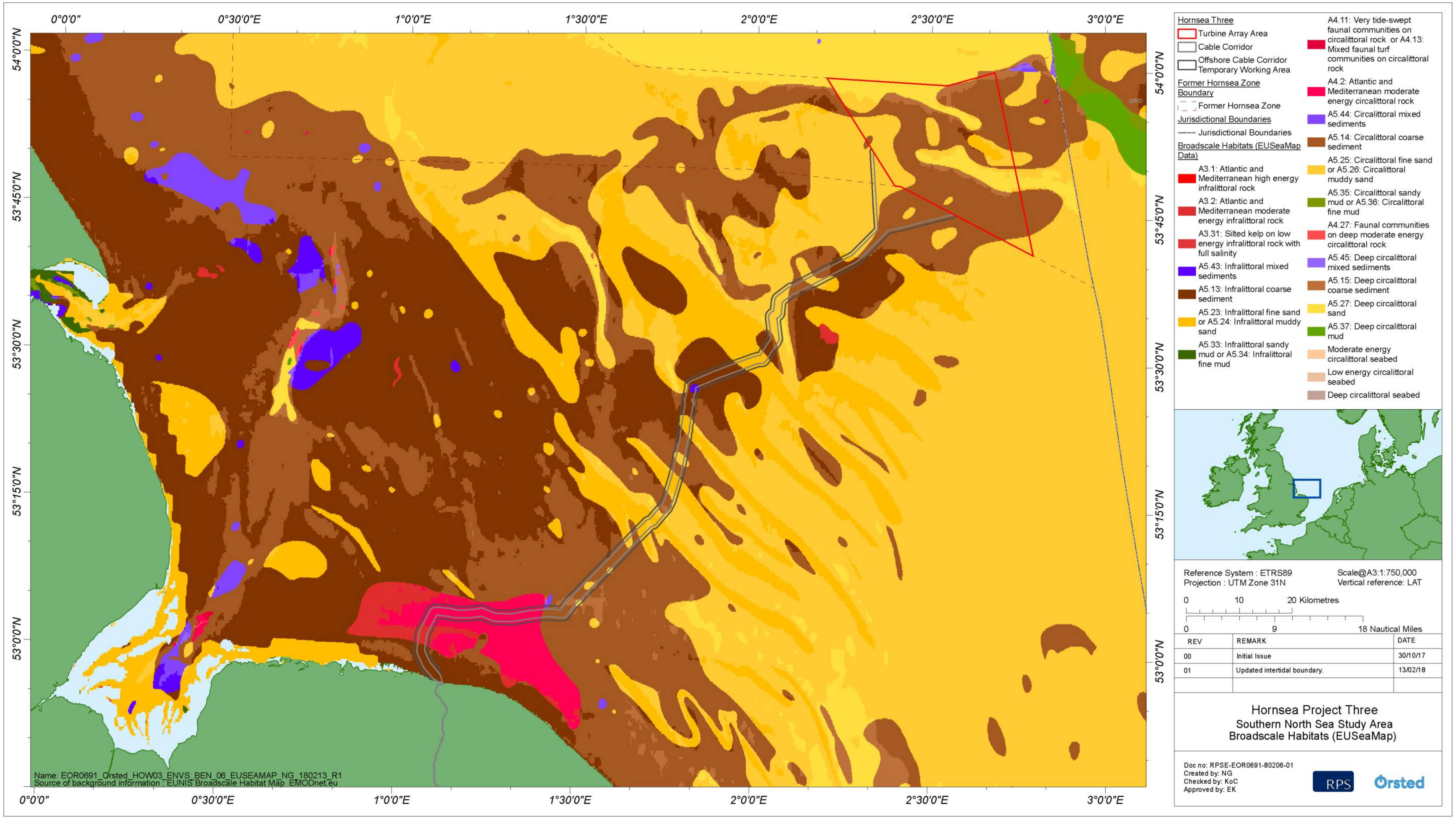

Figure 3.2: Hornsea Three subtidal benthic survey locations and EUSeaMap (2016) predicted EUNIS habitats for the southern North Sea benthic ecology study area.

3.1.2.6 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 *Corystes 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.

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 survey 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.

Table 3.1: Principle EUNIS habitats and the corresponding UK Marine Habitat Classification biotopes in the southern North Sea study area (Figure 3.2; EMU, 2012a).

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).

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 SAC and the UK Dogger Bank SAC 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.

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

3.1.2.12 *S. 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 *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 intertidal 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 intertidal zone. 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 barren or highly impoverished, because 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, due to 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

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

3.1.3.2 As detailed in section 2.3, several data sources have been reviewed to inform the nearshore benthic ecology characterisation, including data from the Sheringham Shoal and Dudgeon offshore wind farm cable corridors, data from the Cromer Shoal Chalk Beds MCZ and the Wash and North Norfolk Coast SAC. These are summarised, with mapping associated with these data sources presented in Figure 3.3. Site-specific benthic survey data (including bathymetry, side scan sonar, grab and DDV data) of the Hornsea Three offshore cable route corridor has been collected during 2016 and 2017, which provides further detail to support the baseline characterisation of the nearshore environment (see Figure 3.3). Detailed description of this site specific data is presented in Section 4.1, with a holistic discussion of the nearshore desktop and site-specific datasets, presented in paragraph 4.1.4.83 *et seq*.

3.1.3.3 Benthic ecology data was collected for the baseline characterisation of the Dudgeon cable corridor in the vicinity of the Hornsea Three offshore cable corridor (Figure 3.3). Sediments along the Dudgeon offshore cable corridor were largely comprised of fine sandy gravel or gravelly sand, with a minimal fine sediment content (i.e. <2.5%). The communities associated with these sediments were characterised by relatively low abundances of polychaetes, including *Leiochone johnstoni*, *Euclymene oerstedii*, *Aonides paucibranchiata*, *Spio filicornis* and *L. conchilega*, crustaceans, including *Ampelisca* spp., *Urothoe* spp., and *Pisidia longicornis* and bivalve molluscs, including *Spisula elliptica*, *Abra* spp. and *Nucula nucleus*. The invasive mollusc *Crepidula fornicata* was also recorded at several stations along the Dudgeon offshore cable corridor. Communities along the Dudgeon offshore cable corridor were relatively consistent with only minor variations in sediment type along the route and consistently low abundances of the characterising species. *S. spinulosa* tubes were recorded in grab samples along the Dudgeon offshore cable corridor, although these were noted to be comprised of dead specimens and no *S. spinulosa* was recorded in the DDV at these locations (Warwick Energy, 2009).

3.1.3.4 Benthic ecology data collected as part of the baseline characterisation (Scira Offshore Energy Ltd., 2006) and the pre and post construction monitoring (Scira Offshore Energy Ltd., 2014) of the Sheringham Shoal offshore wind farm and offshore cable corridor, also coincides with the Hornsea Three offshore cable corridor (see Figure 3.3). These show similar patterns to the Dudgeon offshore cable corridor, with the majority of the Sheringham Shoal offshore cable corridor characterised by either gravelly sand or sandy gravel. The areas close to the Sheringham Shoal sandbank and the most inshore part of the Sheringham Shoal offshore cable corridor were characterised by sand sediments, with minimal fractions of gravel. Fine content was generally low along the route, although to the north of the Sheringham Shoal sandbank, sediments were more mixed, i.e. muddy sandy gravel (Scira Offshore Energy Ltd., 2014).

3.1.3.5 The results of the 2006 baseline characterisation (Scira Offshore Energy Ltd., 2006) indicated that most of the Sheringham Shoal offshore cable corridor was characterised by the SS.SBR.PoR.SspiMx biotope (*S. spinulosa* on stable circalittoral mixed sediment), with abundances of *S. spinulosa* found to be consistently higher to the north of the Sheringham Shoal sandbank than the south. In the most inshore section of the Sheringham Shoal offshore cable corridor, the impoverished sandy biotope SS.SSa.IFiSa.NcirBat (*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand) was dominant while the coarse sediment biotope SS.SCS.CCS.MedLumVen (*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel) biotope was dominant along the southern flank of the Sheringham Shoal sandbank.

3.1.3.6 Post construction monitoring along the Sheringham Shoal offshore cable route found that communities to the north of the sandbank were characterised by a diverse infaunal and epifaunal assemblage on mixed sediments, including the polychaetes *S. spinulosa*, *Spirobranchus lamarcki* and *Scoloplos armiger*, the acorn barnacle *Balanus crenatus*, the invasive mollusc *C. fornicata*, and the tunicate *Dendrodoa grossularia*. By contrast, to the south of the Sheringham Shoal sandbank, the communities were more impoverished and were characterised by the bivalve mollusc *Goodallia triangularis*, the polychaetes *Nephtys* and *Spio goniocephala* together with the bryozoan *Vesicularia spinosa*. This broadly reflects the patterns observed in the 2009 baseline characterisation with the communities south of the sandbank showing lower abundances of *S. spinulosa* than those to the north, although it should be acknowledged that abundances of this species are known to be highly variable temporally and spatially. The most inshore stations were characterised by low abundances of a low number of species, including the polychaetes *Nephtys* spp. and *Travisia forbesii* and the amphipods *Bathyporeia* spp. and *Urothoe* spp., which is consistent with the findings of the 2009 baseline characterisation survey.

3.1.3.7 A pre construction benthic ecology survey of the Dudgeon offshore wind farm and export cable corridor (Fugro EMU Ltd., 2015) showed similar patterns as those discussed above. Areas of subtidal sand in the inshore area and adjacent to the Sheringham Shoal sandbank were characterised by impoverished communities of low abundances of polychaetes (e.g. *Nephtys* spp. and *Lanice conchilega*) and crustaceans (e.g. *Bathyporeia* spp and *Aoridae*). Communities recorded in mixed and coarse sediments along the Dudgeon export cable corridor were characterised by more diverse assemblages, with the richest infaunal communities (e.g. polychaetes, crustaceans and molluscs) associated with those locations with relatively high abundances of *S. spinulosa* (Fugro EMU Ltd., 2015),

3.1.3.8 The nearshore section of the Hornsea Project Three offshore cable corridor also passes through the easternmost section of the Wash and North Norfolk Coast SAC. A range of intertidal and subtidal habitats are present within this SAC, although the majority of these (i.e. mudflats and sandflats, coastal lagoons, saltmarsh habitats; see paragraph 3.1.3.37 below) are located primarily to the west of the Hornsea Three benthic ecology study area, within the Wash, and therefore not expected to be affected by Hornsea Three. The main qualifying features of relevance to Hornsea Three are the Annex I ‘sandbanks slightly covered by seawater all the time’ and ‘reefs’ features which are listed as primary reasons for selection of this designated site, as discussed in paragraph 3.1.3.37 below.

3.1.3.9 Data from MAGIC indicate that the eastern boundary of the SAC is characterised by subtidal mixed sediments. Subtidal mixed sediment communities recorded within the SAC include *Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment (SS.SMx.CMx.FluHyd) and the SS.SBR.PoR.SspiMx biotope (APEM, 2013; Natural England, 2017), consistent with the findings of previous surveys in the area (e.g. those for the Sheringham Shoal offshore cable corridor). Subtidal sand was also mapped by MAGIC near to the Hornsea Three offshore cable corridor. Along the North Norfolk coast part of the SAC, subtidal sand biotopes were primarily characterised by the *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand (NcirBat) and Infralittoral mobile clean sand with sparse fauna (SS.SSa.IFaSa.IMoSa) biotopes (APEM, 2013; Natural England, 2017), consistent with the communities recorded in the inshore sections of the Sheringham Shoal offshore cable corridor as discussed above.

3.1.3.10 Subtidal mud was present (according to MAGIC) in a limited number of discrete areas with communities recorded in the SAC including *Nephtys hombergii* and *Macoma balthica* in infralittoral sandy mud (SS.SMu.ISaMu.NhomMac), although data presented by APEM (2013) did not indicate that these sediments were present in the western part of the SAC (i.e. where the Hornsea Three offshore cable corridor coincides with the SAC). Subtidal coarse sediment communities were reported to be relatively rare along the North Norfolk coast, with most records within The Wash (Natural England, 2017), although MAGIC showed a band of shallow subtidal coarse sediments along the interface with the intertidal. The coarse sediment communities along the North Norfolk coast were reported to be characterised by the biotopes Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand (SS.SCS.ICS.SLan) and *Protodorvillea kefersteini* and other polychaetes in impoverished mixed gravelly sand (SS.SCS.CCS.Pkef) (APEM, 2013; Natural England, 2017).

3.1.3.11 Reef habitats and communities (i.e. both stony reef and biogenic reef) have been recorded throughout the SAC, although these were primarily recorded within The Wash, with fewer occurrences in the east of the SAC (Meadows and Frojan, 2012; McIlwaine *et al.,* 2014; Natural England, 2017). Stony reef is present to the north of the Well and along the western flanks of the Well in the deeper reaches of The Wash. These habitats include mixed and coarse sediment as well as patches of stony reef and as such it was challenging to calculate the extent of stony reef within the SAC accurately. Communities associated with these stony reef habitats were characterised by biotopes including *Flustra foliacea* and *Haliclona oculata* with a rich faunal turf on tide-swept circalittoral mixed substrata (CR.HCR.XFa.FluHocu) (Meadows and Frojan, 2012; McIlwaine *et al.,* 2014; Natural England, 2017).

3.1.3.12 Two discrete areas of circalittoral rock have been mapped in MAGIC in the shallow sublittoral approximately 1.5 km to the west of the Hornsea Three intertidal zone. These were identified and investigated via a number of dive surveys undertaken by SeaSearch between 2009 and 2016, which were primarily focussed on the subtidal chalk reef features within the Cromer Shoal Chalk Beds MCZ (Spray and Watson, 2011a and 2011b; Watson, 2012; discussed further below), although these also extended to the west of the MCZ into the Wash and North Norfolk Coast SAC (see SeaSearch dive locations in Figure 3.3). In these two areas close to the Hornsea Three intertidal zone, these Seasearch surveys recorded clay ridges and low-lying chalk exposures with chalk and flint boulders separated by mobile sediments extending to approximately 300 m from MLWS. These features were inhabited by piddock bivalves Pholadidae, common lobster *Homarus gammarus* and edible crab *Cancer pagurus,* hydroids and a range of other faunal turf species, including bryozoans (e.g. *Bugula*), sea squirts (e.g. *Diplosoma*), polychaetes (e.g. *Sabella and Lanice*) and an associated community of nudibranch sea slugs (Spray and Watson, 2011a; Watson, 2012). Where algal communities were recorded, these were characterised by red foliose seaweeds, including *Dictyota dichotoma* and/or *Dictyopteris membranacea* (Note: site specific DDV survey data in this part of the Hornsea Three benthic ecology study area, targeting potential chalk outcrops are discussed in paragraphs 4.1.4.87 and 4.1.4.88). Biotopes identified in these areas by Seasearch included:

- CR.HCR.XFa: Mixed Faunal turf communities;
- CR.HCR.XFa.FluCoAs *Flustra foliacea* and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock;
- CR.MCR.SfR: Soft rock communities;
- CR.MCR.SfR.Pol: *Polydora* sp. tubes on moderately exposed sublittoral soft rock;
- CR.MCR.SfR.Pid: Piddocks with a sparse associated fauna in sublittoral very soft chalk or clay;
- IR.MIR.KR.XFoR: Dense foliose red seaweeds on silty moderately exposed infralittoral rock; and
- IR.HIR.KFaR.FoR: Foliose red seaweeds on exposed lower infralittoral rock.

3.1.3.13 Subtidal mussel beds have been recorded in areas of The Wash, such as off Seal Sand in the south east of the embayment (APEM, 2013; Natural England, 2017). Similarly, *S. spinulosa* reef has been detected throughout much of the subtidal area of The Wash; however, given its ephemeral nature its presence is highly variable in both space and time. The most consistent records of *S. spinulosa* reef include along the edges of the Well, Roaring Middle, Lynn Deeps and Lynn Knock (Jessop *et al.,* 2010; Eastern IFCA, 2012; Bussell and Saunders, 2010; Jessop and Maxwell, 2011, as presented in Natural England, 2017). However, as discussed in paragraph 3.1.3.9, the mixed sediment communities in the vicinity of the Hornsea Three offshore cable corridor are characterised by the SS.SBR.PoR.SspiMx biotope, which is supported by the findings of the Sheringham Shoal baseline characterisation and monitoring surveys in the same area (paragraph 3.1.3.5), although in this area (i.e. south of the Sheringham Shoal sandbank) no biogenic reef was recorded.

3.1.3.14 The Cromer Shoal Chalk Beds MCZ lies approximately 200 m from the low water mark off the north Norfolk coast and extends out to 10 km in waters of up to 25 m depth (Defra, 2015). Dedicated vessel-based seabed surveys were 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). A total of 358 infaunal taxa and 146 epifaunal taxa were recorded across 70 grab samples and 196 DDV locations with the geophysical survey covering 78% of the MCZ. 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.

3.1.3.15 The Cefas surveys determined that the FOCI habitat 'Subtidal Chalk' occupied 12% of the area surveyed and that this FOCI habitat 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' described in the SAD (Net Gain, 2011) was confirmed as 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. Subtidal chalk was determined to cover an area of 30km^2 within the MCZ, this was based on a modelled extent of moderate energy circalittoral rock. The protected habitat features of the Cromer Shoal Chalk Beds MCZ are discussed in paragraph 3.1.3.52 and listed in Table 3.2.

3.1.3.16 As discussed above, data on the subtidal chalk reefs and other prominent features within the MCZ were acquired through dive surveys (i.e. 111 dives from 2009 to 2010 and 53 dives in 2012; Spray and Watson, 2011a and 2011b; Watson, 2012). As shown in Figure 3.3, these features were located within the MCZ, and to the east and south of the Hornsea Three offshore cable route corridor. These 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). This 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).

3.1.3.17 Dive surveys east of the Hornsea Three offshore cable corridor and over the central part of the MCZ (i.e. to the east of the Hornsea Three offshore cable corridor), 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).

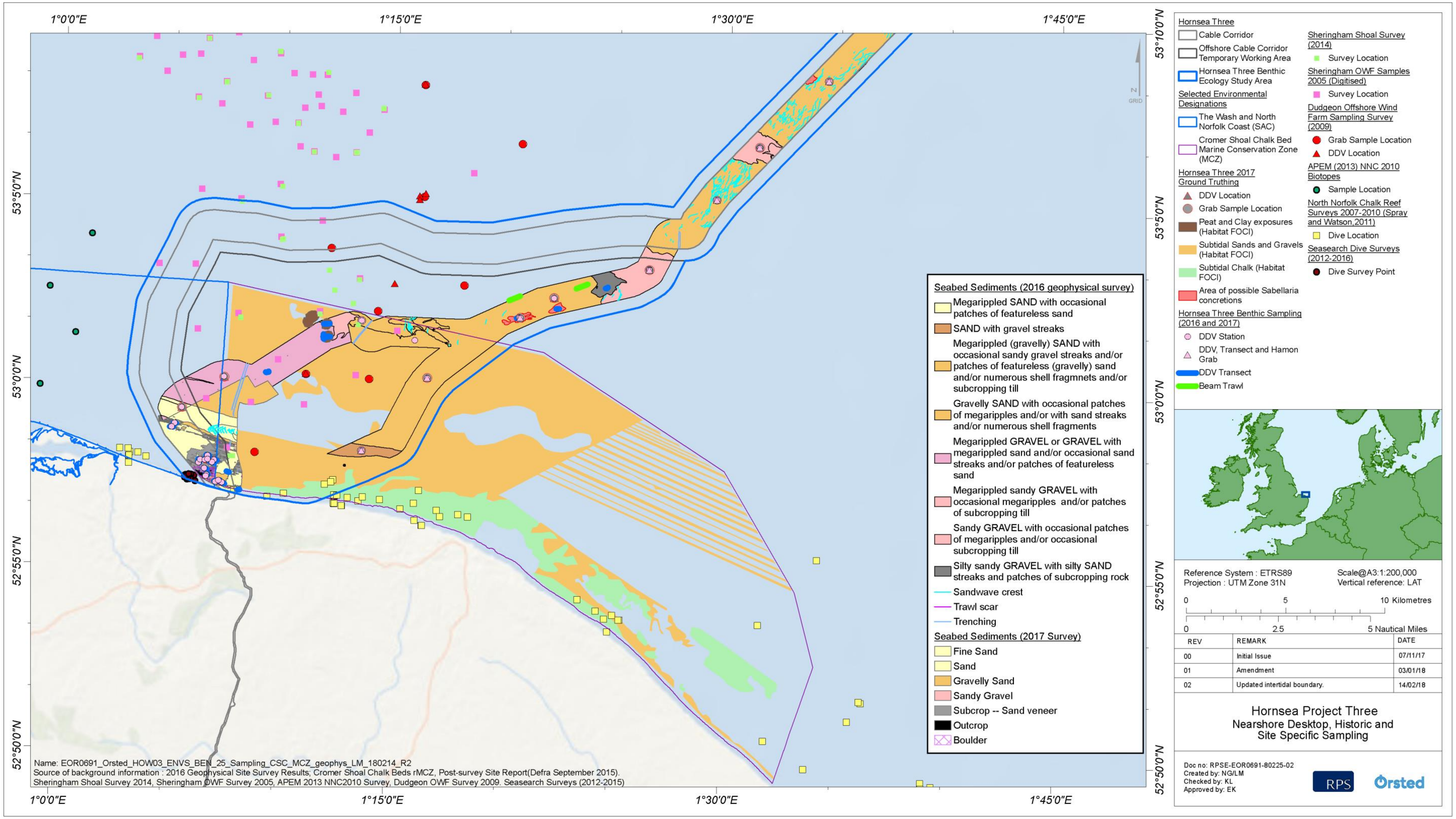

Figure 3.3: Nearshore section of Hornsea Three offshore cable corridor, with Hornsea Three site specific geophysical data and benthic sampling locations (2016 and 2017) and historic datasets (i.e. Sheringham Shoal (2006 and 2014), Dudgeon (2009), Cromer Shoal Chalk Bed MCZ (Defra, 2015) and The Wash and North Norfolk Coast SAC (APEM, 2013; Natural England, 2017)).

Offshore section of the Hornsea Three benthic ecology study area

3.1.3.18 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.

3.1.3.19 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'; '*S. spinulosa* reefs'; and 'Sparse fauna'. The biotope map produced for the REC, as shown in Figure 3.4, 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.OSa.PoBivAmp '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 '*S. 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).

3.1.3.20 The HADA MAREA data shows that sediments near 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 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.

3.1.3.21 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 at 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 recorded in the very inshore waters off the coast of north Norfolk, and between 50 and 80 taxa recorded at a small number of sampling stations approximately 30 km out to sea.

3.1.3.22 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).

3.1.3.23 The North Norfolk Sandbanks and Saturn Reef SAC, which extends from approximately 40 km off the north Norfolk coast out to approximately 110 km offshore, encompasses 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, are primary qualifying feature of the SAC site.

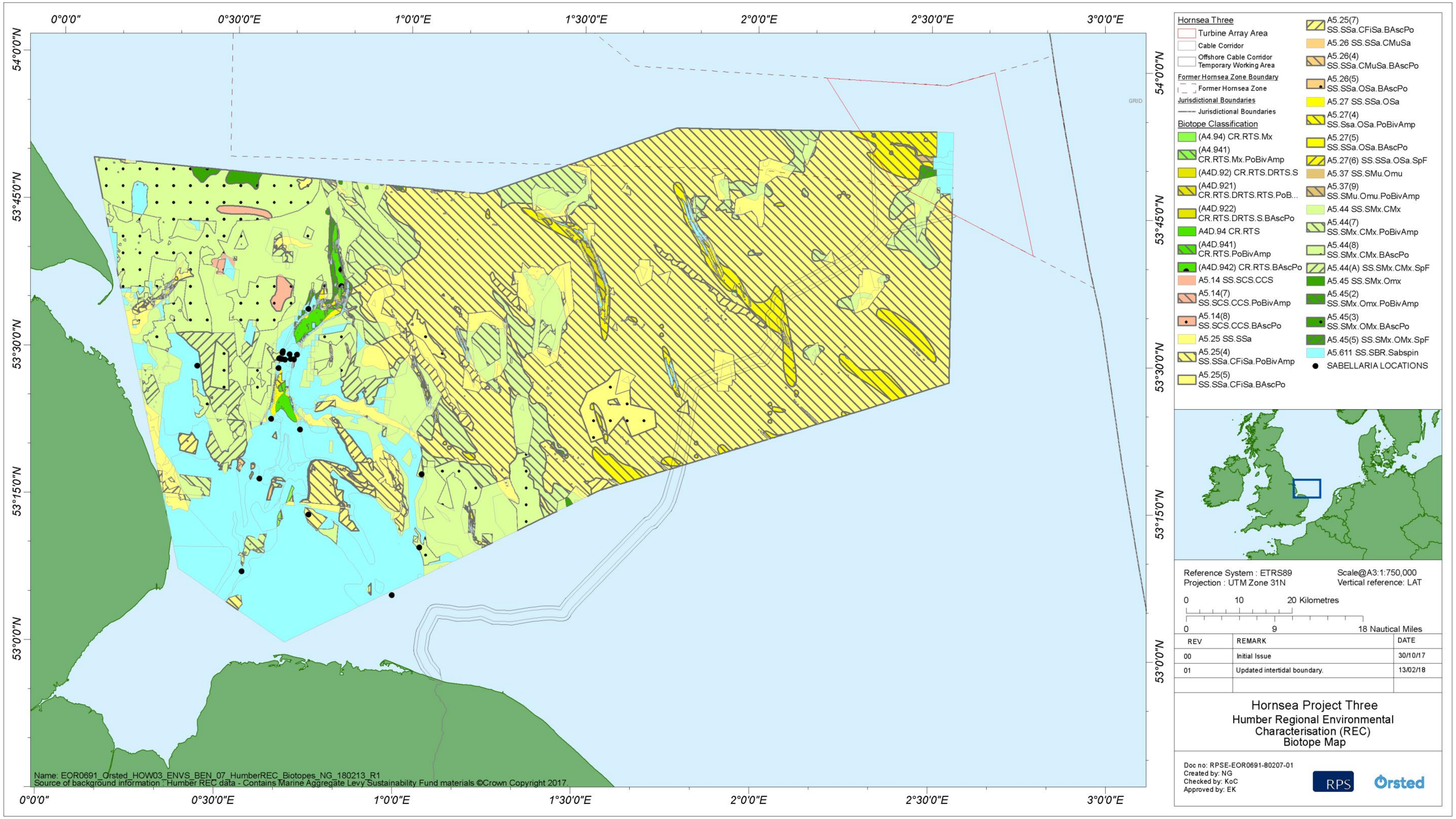

Figure 3.4: Hornsea Three and the Humber Regional Environmental Characterisation (REC) recorded EUNIS biotopes and locations where *S. spinulosa* was noted during REC survey.

3.1.3.24 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 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.

3.1.3.25 Overall six sandbanks were investigated, three of the most inner sandbanks (Leman Bank, Inner Bank and Wells bank), adjacent to the central section of the 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 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.

3.1.3.26 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.

3.1.3.27 An analysis of the infaunal communities revealed that numbers of taxa and abundances increased with depth throughout the SAC site, and that species richness was highest in the troughs of the sandbanks 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 paragraphs 3.1.3.19 to 3.1.3.22). 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). Characterising species within the areas sampled included the polychaetes *Ophelia borealis*, *Polycirrus*, *Lagis koreni*, *Scoloplos armiger* and *Nephtys cirrosa*, and the amphipod *Bathyporeia guilliamsoniana*.

3.1.3.28 The presence of the Saturn *S. spinulosa* biogenic reef within the North Norfolk Sandbanks and Saturn Reef SAC 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).

3.1.3.29 However, in 2013, Cefas undertook another survey of the SCI which identified a potential westward migration of the Saturn Reef (originally 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 Hornsea Three offshore cable corridor (See Figure 3.5).

3.1.3.30 For the investigation into biogenic reef features within the North Norfolk Sandbanks and Saturn Reef SAC, 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 site, which coincided with the central section of the Hornsea Three offshore cable corridor. Seven 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 as tan coloured polygons in Figure 3.5, together with the previously known position and extent of the Saturn Reef (indicated by the dark green area). These data have revealed a potential westward migration of the Saturn reef (identified in the 2003, as described in paragraph 3.1.3.28) or, more likely, the loss of the original reef feature and the development of a new reef structure, demonstrating the ephemeral nature of *S. spinulosa* aggregations.

3.1.3.31 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 the extent of S. spinulosa reef. These *S. spinulosa* aggregations were the highest quality biogenic features recorded during the 2013 survey (Jenkins et al., 2015).

3.1.3.32 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 has been proposed for two broadscale habitats, namely. subtidal coarse sediment and subtidal sand. Recent advice from Natural England through the EWG has indicated that subtidal mud and subtidal mixed sediments are also likely to be features put forward for designation for Markham's Triangle. 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).

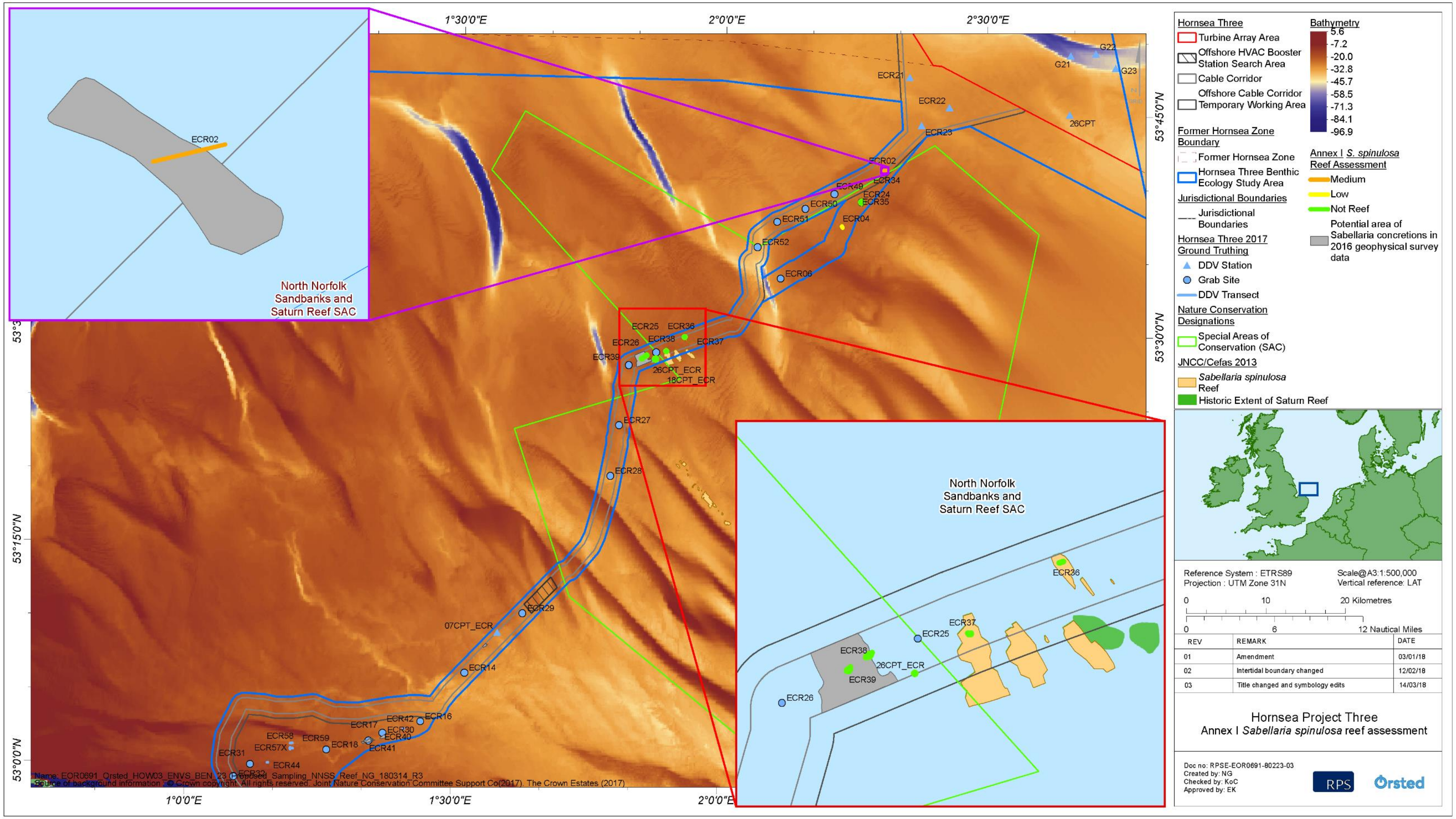

Figure 3.5: The Hornsea Three offshore cable corridor and historic extents of Annex I *S. spinulosa* reefs within the North Norfolk Sandbanks and Saturn Reef SAC together with the results of the Hornsea Three site specific survey *S. spinulosa* reefiness assessments.

3.1.3.33 '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. Subtidal mud was only recorded in the northeast of the rMCZ, outside the boundary of the Hornsea Three array area. See section 4.1.2 for further information on the sediment composition of samples acquired from this survey. See paragraphs 4.1.4.26 to 4.1.4.31 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 and site specific benthic ecology surveys in the Hornsea Three benthic ecology study area.

Nature conservation designations

3.1.3.34 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.

3.1.3.35 All designation sites which fall within the Hornsea Three potential Zone of Influence (ZoI) are shown in Figure 3.6. Sites screened out of the Hornsea Three assessment are discussed further in section 5.2.3.

International designations

Natura 2000 sites

3.1.3.36 Of the 12 Natura 2000 sites and associated benthic habitats which are within the southern North Sea benthic ecology study area, four SACs/SCIs were considered to potentially be in the Hornsea Three ZoI. A fifth site, Klaverbank SCI, located within Dutch jurisdictional waters was also considered. These sites are listed and described in detail below:

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

The Wash and North Norfolk Coast SAC

3.1.3.37 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 the following benthic subtidal features (Note: qualifying marine mammal species are not listed) which are relevant to Hornsea Three project:

- Sandbanks which are slightly covered by sea water all the time (Subtidal sandbanks);
- Mudflats and sandflats not covered by seawater at low tide (Intertidal mudflats and sandflats); and
- Reefs (circalittoral rock, subtidal biogenic reefs (mussel beds and *Sabellaria* spp. reefs) and subtidal stony reef).

3.1.3.38 All other subtidal features and intertidal features of this site (i.e. mudflats and sandflats not covered by seawater at low tide; large shallow inlets and bays; *Salicornia* and other annuals colonising mud and sand; Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*); and Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*) are not considered relevant to the Hornsea Three project as they are either located in the Wash or in the intertidal zone west of Hornsea Three and outside the ZoI.

North Norfolk Sandbanks and Saturn Reef SAC

3.1.3.39 The North Norfolk Sandbanks and Saturn Reef SAC coincides with part of the central and seaward end of the Hornsea Three offshore cable corridor (Figure 3.5) and is designated for the following Annex I habitats, which are discussed in detail in paragraph 3.1.3.23:

- Sandbanks which are slightly covered by sea water all the time; and
- Reefs (including the Saturn *S. spinulosa* biogenic reef).

North Norfolk Coast SAC

3.1.3.40 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.

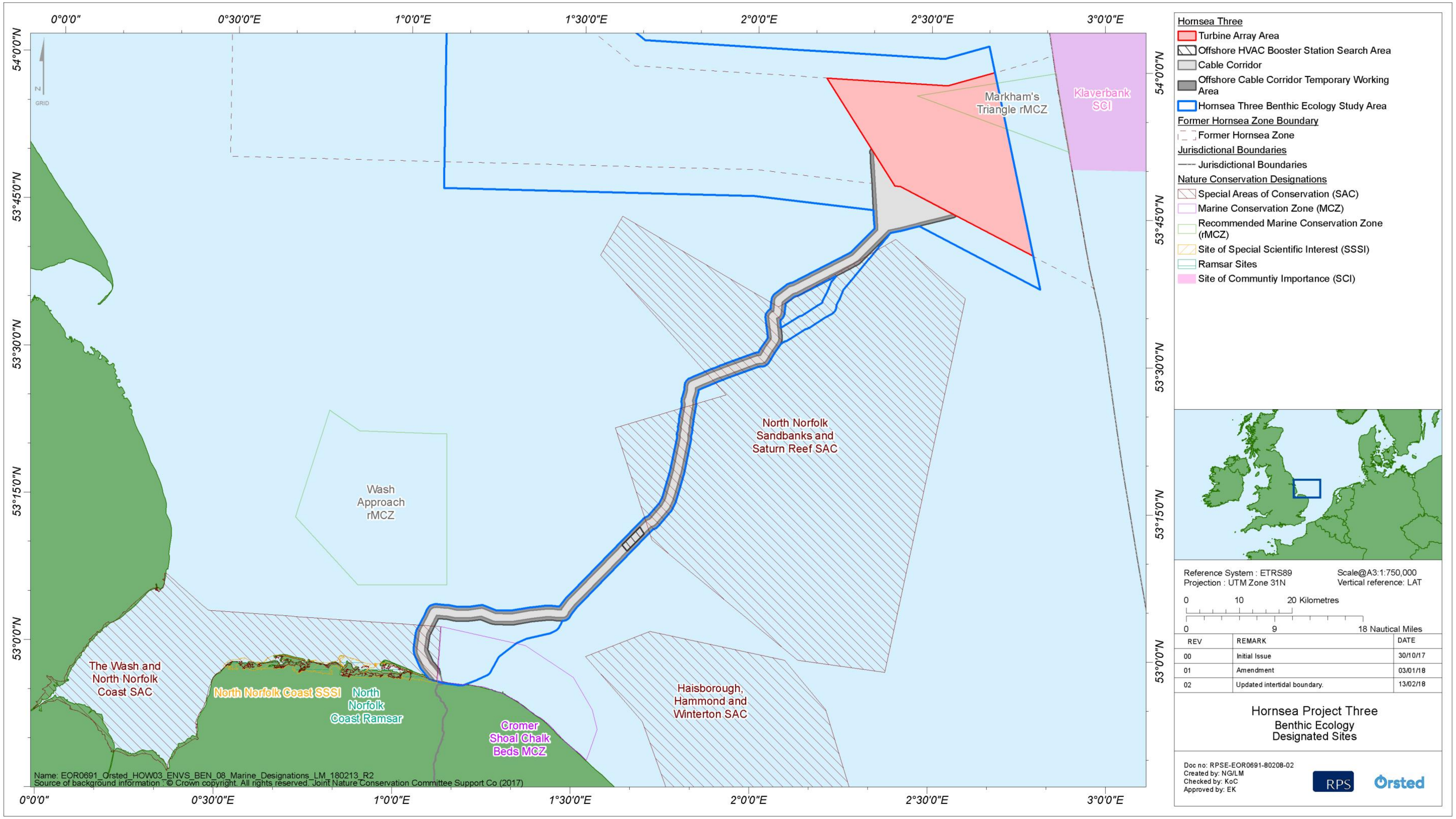

Figure 3.6: The southern North Sea benthic ecology study area and Hornsea Three, with nature conservation designations that have benthic habitat features.

Haisborough, Hammond and Winterton SCI

3.1.3.41 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.

Klaverbank SCI

3.1.3.42 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 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

3.1.3.43 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.

3.1.3.44 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 3.1.3.45 *et seq.* for further information.

<u>National designations</u>

SSSIs

3.1.3.45 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.

3.1.3.46 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 near Hornsea Three benthic ecology study area (Figure 3.6); the North Norfolk Coast SSSI.

North Norfolk Coast SSSI

3.1.3.47 The Hornsea Three intertidal zone 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

3.1.3.48 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 (i.e. the intertidal zone of the Hornsea Three offshore cable corridor). These NNRs are:

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

3.1.3.49 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 intertidal zone (Figure 3.6).

MCZs

3.1.3.50 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.

3.1.3.51 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

3.1.3.52 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). All protected features of the Cromer Shoal Chalk Beds MCZ are presented in Table 3.2. 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^2 [a]
Moderate energy circalittoral rock	
High energy infralittoral rock	Presence not confirmed by SAD
Moderate energy infralittoral rock	Presence not confirmed by SAD
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^2 [b]

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

3.1.3.53 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

3.1.3.54 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, although as noted in paragraph 3.1.3.32, it is likely that the subtidal mixed sediments and subtidal mud features may also be proposed for designation in this rMCZ. Shallow sandy sediments are 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).

Wash Approach rMCZ

3.1.3.55 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

3.1.3.56 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.

4. Results

4.1 Historic and site specific surveys

4.1.1.1 This section considers the existing data available from the Hornsea ZoC, Hornsea Project One and Hornsea Project Two surveys across the Hornsea Three benthic ecology study area together with the 23 sit- specific grab samples collected within the Hornsea Three array area and 35 site-specific grab samples collected along the Hornsea Three offshore cable corridor (see sections 2.4 for a description of the historic and site specific data)

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 paragraph 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 into 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) 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 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 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	0.70 ± 1.13	95.20 ± 7.26	4.09 ± 7.39
Coarse sediment	31.80 ± 17.63	66.19 ± 17.74	1.98 ± 1.84
Mixed sediment	37.61 ± 15.33	52.55 ± 13.59	9.84 ± 4.01

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.

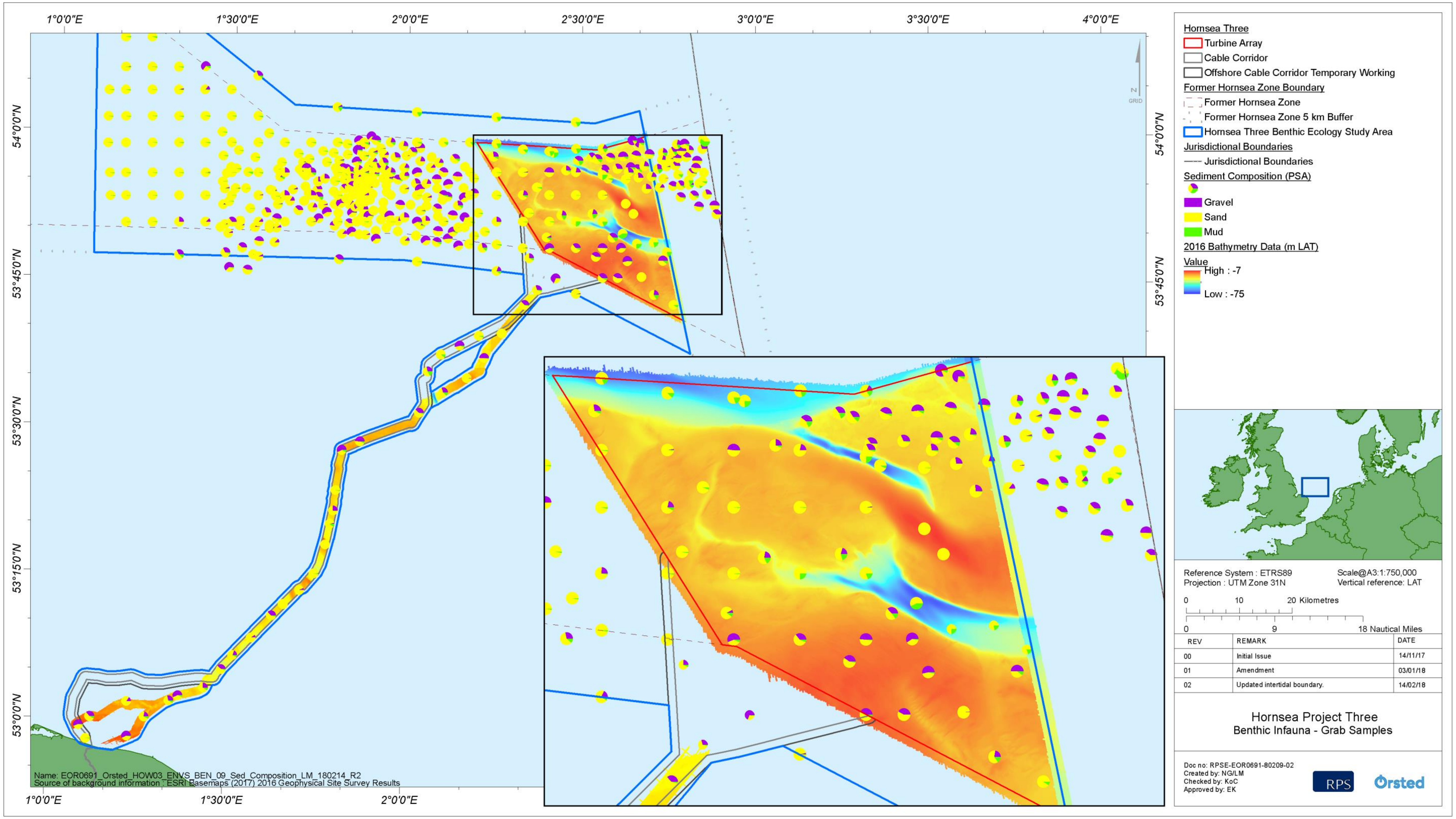

Figure 4.1: **Sediment compositions (from particle size analysis) at each benthic grab sampling location within the Hornsea Three benthic ecology study area.**

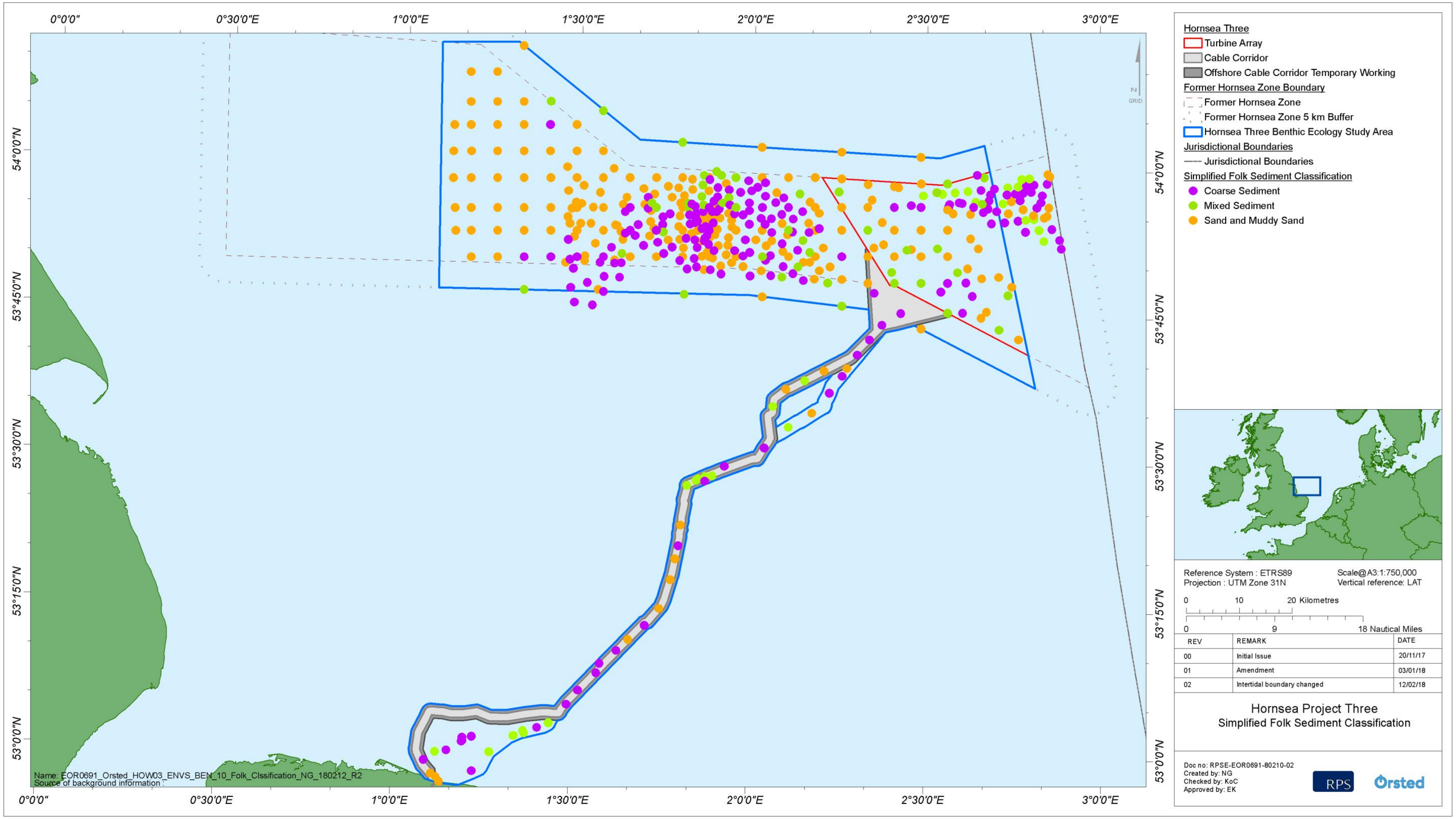

Figure 4.2: Simplified Folk Sediment Classifications for each benthic grab sample location within the Hornsea Three benthic ecology study area.

4.1.3 Sediment Contamination

Subtidal Hornsea Three benthic ecology study area

4.1.3.1 As discussed in paragraph 2.5.1.6, the results of sediment chemistry data are available from a total of 56 sampling locations within the Hornsea Three benthic ecology study area; eight stations coincide with the Hornsea Three offshore cable corridor and one 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, overall the proportion of mud was small.

<u>Metals analysis</u>

4.1.3.2 The results of the metals analyses showed that, except for arsenic, cadmium, mercury and nickel, all metals recorded in sediments sampled at 63 locations within the Hornsea Three benthic ecology study area were present at concentrations below the Cefas Action Level 1 (AL1) and the Canadian Threshold Effect Levels (TEL), and were therefore at levels below which biological effects in benthic organisms would be expected. In general contaminant levels in dredged material below Action level 1 are not considered to be of concern and are unlikely to influence a dredging disposal licencing decision. The TEL is the minimal effect range within which adverse effects rarely occur.

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 all eight sampling locations on the Hornsea Three offshore cable corridor and at station Z62 within the Hornsea Three array area (Figure 4.5). Of the sites with elevated levels of arsenic, five recorded concentrations above the Canadian Probable Effects Level (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). Levels of arsenic exceeded OSPAR Background Assessment Concentration (BAC) of 25 mg/kg in sediments at 20 sites within the wider Hornsea Three benthic ecology study area, although within the Hornsea Three offshore cable corridor arsenic concentrations were within the BAC at all locations. Any direct comparisons between the site specific data and OSPAR BAC should be made with caution as Hornsea Three data were not normalised to 5% aluminium (aluminium was not part of the heavy metal suite analysed). Arsenic exceeded the Cefas AL1 of 20 mg/kg at 24 sites including three on the Hornsea Three offshore cable corridor, however all sites were well within the Cefas AL2 of 100 mg/kg (see Figure 4.3).

4.1.3.4 Several areas of high raw arsenic concentrations were noted in areas off north Yorkshire and the Humber during the early 90's (Whalley *et al.*, 1999). The levels of arsenic present in 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 these samples were much reduced in significance. The low residual values observed in the Humber and its plume area was of interest as the Humber Estuary had been assumed to be a significant source of arsenic to the North Sea. Whalley *et al.* (1999) suggested that these surprisingly 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, the Canadian TEL/PEL and the OSPAR BAC (noting concentrations were not normalised to 5% aluminium in the absence of aluminium results; see paragraph 4.1.3.3). The concentration of nickel marginally exceeded the Canadian TEL (15.9 mg/kg) at a single site (S140) and the concentration of mercury exceeded the Canadian TEL (0.13 mg/kg) at one site along the Hornsea Three offshore cable corridor (ECR23), though both concentrations were below the respective Cefas AL1 thresholds for those metals (see Figure 4.4 for the station locations). The full results of the metals analyses are available as an appendix on request.

4.1.3.6 Levels of mercury were within the OSPAR BAC of 0.07 mg/kg at all sampling locations, with the exception of one (ECR23) at the northern end of the Hornsea Three offshore cable corridor where 0.23 mg/kg was recorded (noting that any direct comparisons with the OSPAR BAR should be made with caution as the site specific sediment chemistry data were not normalised to 5% aluminium; see paragraph 4.1.3.3). However the level of mercury at ECR23 was below the Cefas AL1 threshold and, as outlined in paragraph 4.1.3.2, dredged material with this concentration would typically be considered suitable for disposal at sea.

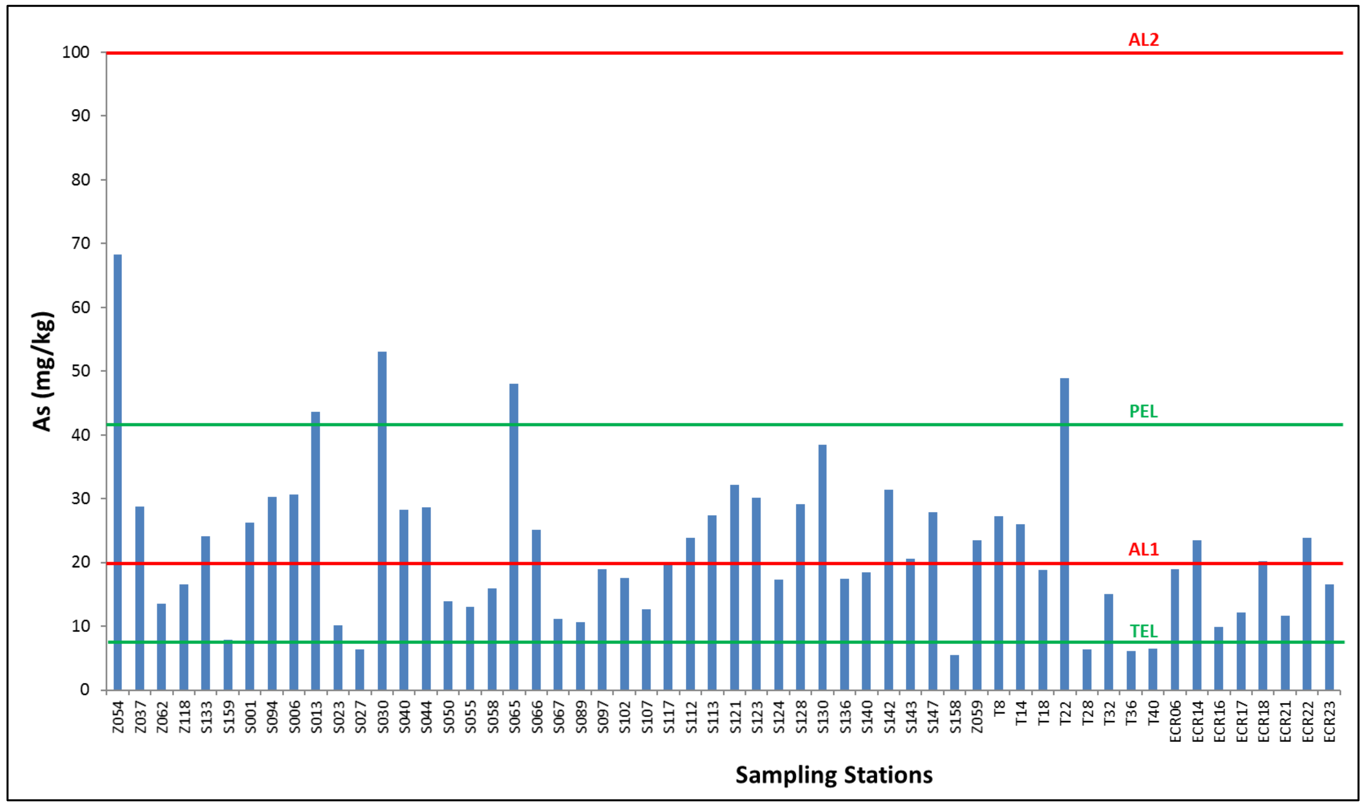

Figure 4.3: Concentrations of arsenic (As) from 56 samples within the Hornsea Three benthic ecology study area with CEFAS Action Levels (AL1 and AL2 in red) and Canadian Threshold Effect Levels (TEL and PEL in green) indicated.

Organotins

4.1.3.7 Levels of TBT and TPT in the Hornsea Three benthic ecology study area 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 (at 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.

Hydrocarbon analysis

4.1.3.8 The results for 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 see Figure 4.4). All recorded TPH values were well below the Cefas AL1 of 100 mg/kg. The typical range for total hydrocarbon content (THC) 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 at the lower end of this range, supporting the conclusion that hydrocarbon concentrations within the Hornsea Three benthic ecology study area are low. The full TPH results for each sampling locations are available as an appendix on request.

Polycyclic aromatic hydrocarbons (PAHs)

4.1.3.9 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 0.360 mg/kg, although most 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 4.4). Cefas (2001b) report total PAH results for that station ranged from 0.097 to 0.202 mg/kg (with an average of 0.171 mg/kg).

4.1.3.10 From the SEA results (DTI, 2002) the predominantly low naphthalene, phenanthrene and dibenzothiophene (including their C1–C3 alkyl homologues; 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.

4.1.3.11 All values of EPA 16 listed PAHs were well below the Cefas AL1 concentrations for individual PAHs (0.1 mg/kg) and the respective Canadian TEL levels throughout the Hornsea Three benthic ecology study area. In addition to the EPA 16, dibenzothiophene was measured and recorded at concentrations up to 0.006 mg/kg and naphthalene was recorded at up to 0.03 mg/kg, which were both well within the Cefas AL1 concentrations for individual PAHs. Therefore, as outlined in paragraph 4.1.3.2, EPA 16 listed PAHs, dibenzothiophene and naphthalene were recorded at levels that would typically be considered suitable for disposal at sea.

Organochlorine pesticides

4.1.3.12 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 (i.e. <1 µg/kg).

Total organic carbon (TOC)

4.1.3.13 As discussed in paragraph 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%.

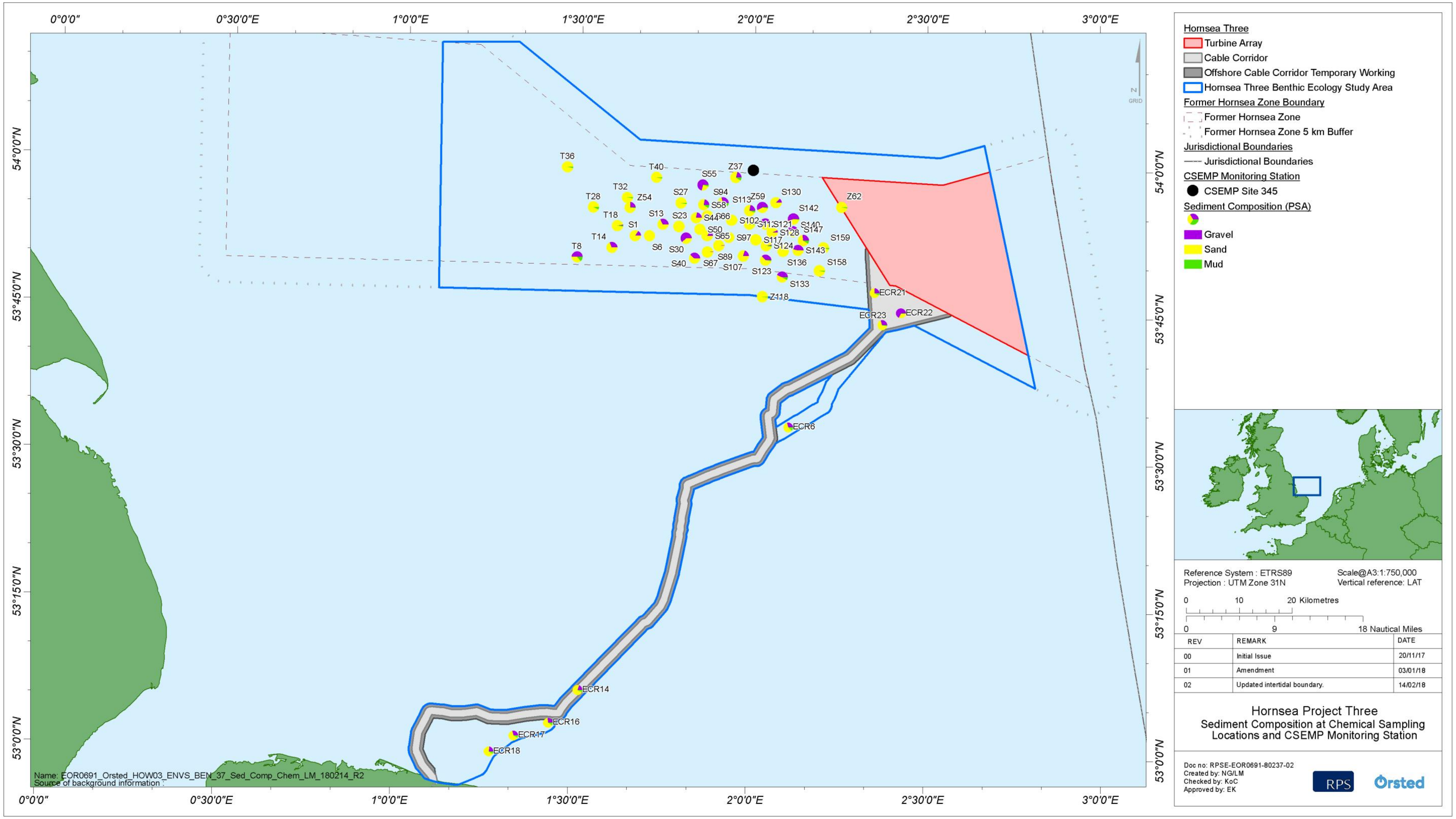

Figure 4.4: Sediment chemistry sample locations within the Hornsea Three benthic ecology study area and associated sediment composition (particle size analysis).

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 were used, together with the raw untransformed data, to assign preliminary biotopes to each sample location in each of the three simplified sediment types described in paragraphs 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, 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, 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 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. Stations with no fauna recorded were excluded from the analyses and are not represented in the MDS plots.

4.1.4.4 The 2-D MDS plots for each sediment type and combined 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. 405 separate grab stations) and the stress value given in the 3-D plot is still considered to be relatively high and therefore not an excellent representation of the data. However, the MDS plots have not been used in isolation and have been interpreted together with the results of the cluster and SIMPROF analyses and considering the raw transformed data.

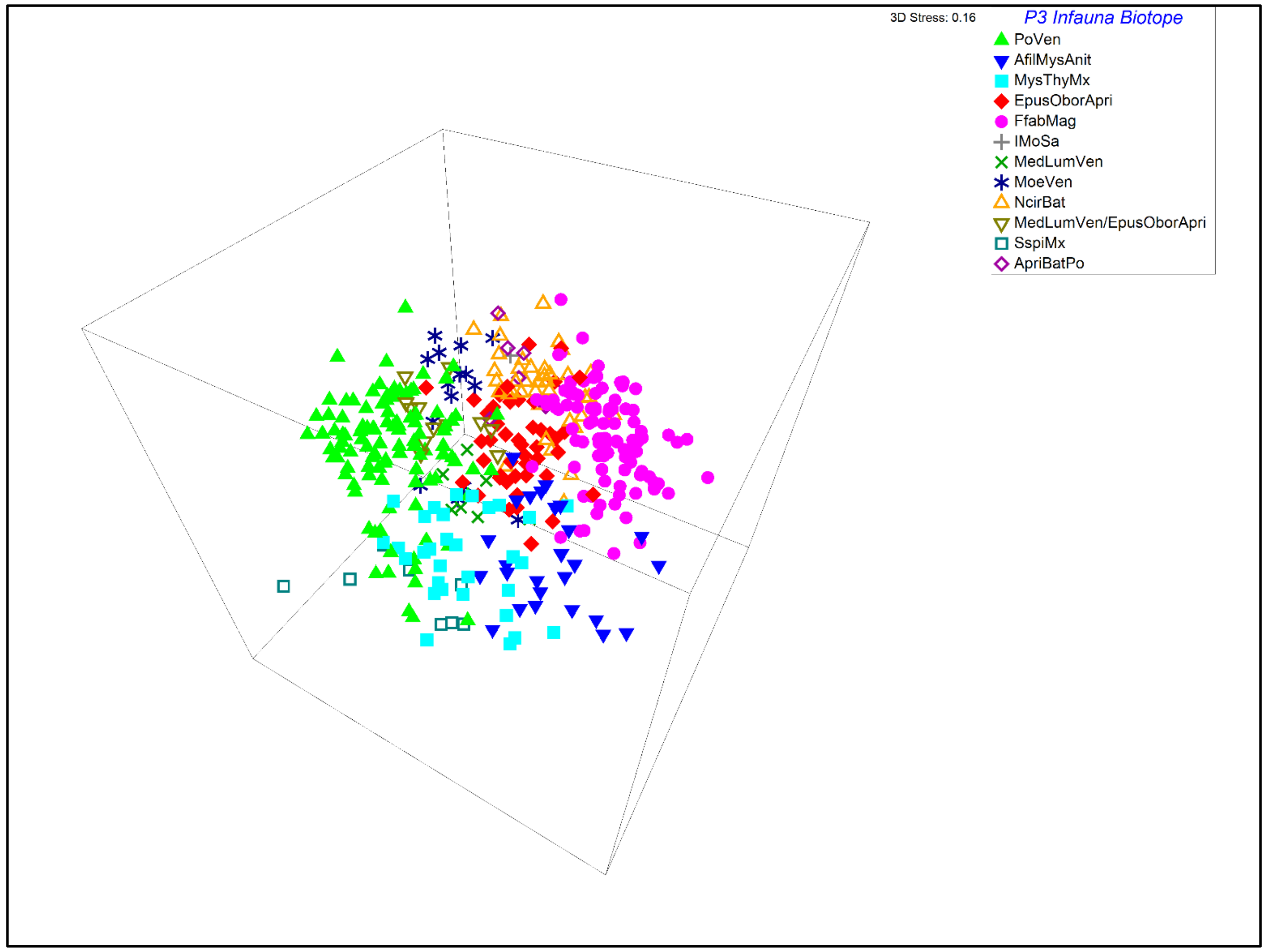

Figure 4.5: Subset 3-D MDS plot for benthic infaunal communities (biotopes) in all sediment types for the Hornsea Three benthic ecology study area.

4.1.4.5 The data presented in Figure 4.5 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 types. This was especially true for the sandy sediment sites. 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 for the NcirBat biotope and the FfabMag biotope. 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 prismatica* in circalittoral fine sand) biotope (hereafter referred to as EpusOborApri; red symbols) and the NcirBat biotope (orange triangles) through the muddier sand sediments of the FfabMag biotope (pink circles) 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; blue triangles) (Connor *et al.*, 2004).

4.1.4.6 Similarly, the coarse sediments 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 triangles) into the mosaic *Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel/*Echinocyamus pusillus, Ophelia borealis* and *Abra prismatica* in circalittoral fine sand biotope (hereafter referred to as MedLumVen/EpusOborApri; light brown triangles). 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 (blue asterisk symbols) in shallower waters with fewer polychaetes but high numbers of venerid bivalves.

4.1.4.7 In comparison, the mixed sediments demonstrate 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 (light blue squares) and the PoVen biotope (green triangles). The SspiMx biotope (dark turquoise squares) 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 (light turquoise squares) 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 each of these biotopes, including their distribution across the Hornsea Three benthic ecology study area, are presented below in paragraphs 4.1.4.12 to 4.1.4.23.

4.1.4.8 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 within one of the clusters in the coarse sediment 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.

4.1.4.9 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 many sites within the coarse sediment class. 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 paragraphs 4.1.4.12 to 4.1.4.24.

4.1.4.10 Figure 4.6 shows the geographic extents of the draft benthic infaunal biotopes present throughout the Hornsea Three benthic ecology study area. As discussed in paragraph 2.6.2.16, the nearshore biotopes are considered holistically in paragraphs 4.1.4.83 to 4.1.4.86 and are presented in Figure 4.28.

4.1.4.11 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.

The Hornsea Three array area and offshore cable corridor

4.1.4.12 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. 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 fan section of the Hornsea Three offshore cable corridor. The remainder of the Hornsea Three offshore cable corridor is discussed further in section 4.1.4.14.

4.1.4.13 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 biotope was also recorded the west of the Hornsea Three offshore cable corridor fan. 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. A sampling station coinciding with Markham's Hole in the Hornsea Three array area, sampled during the Southern North Sea (SNS) Synthesis benthic survey as noted in section 2.3.1.2, supported the classification of AfilMysAnit to the muddy sediments in this area. The survey cruise report (Allen, 2012) concluded that the sediment comprised sandy mud and recorded an infaunal assemblage considered representative of the AfilMysAnit biotope, with characteristic taxa including *Amphiura filiformis*, *Kurtiella (Mysella) bidentata* and *Abra nitida*.

4.1.4.14 The seabed along the Hornsea Three offshore cable corridor comprised a patchy distribution of several biotopes including SspiMx, MysThyMx, ApriBatPo, AfilMysAnit, MoeVen, PoVen and NcirBat. SspiMx was present in isolated sections along the length of Hornsea Three offshore cable corridor and generally corresponded with areas of the seabed determined to be sandy gravel and gravelly sand, according to the Hornsea Three offshore cable corridor geophysical survey. The biotope PoVen was also associated with gravelly sand and sand gravel, often adjacent to areas of SspiMx and located in the landward half of the Hornsea Three offshore cable corridor. A SNS Synthesis sampling station coincided with one area of NcirBat in the southern section of the Hornsea Three offshore cable corridor which corroborated the assignation of this biotope, which included *Nephtys cirrosa* and *Bathyporeia elegans* amongst the top characterising species (Allen, 2012).

4.1.4.15 An area in the central section of the Hornsea Three offshore cable corridor was assigned the biotope ApriBatPo which corresponded with coarse sediments (Figure 4.6). The NcirBat biotope was common to the central part of the Hornsea Three offshore cable corridor and in the north of the Hornsea Three offshore cable corridor. The biotope MoeVen was recorded in isolated pockets, predominantly in the nearshore extent of the Hornsea Three offshore cable corridor, while MysThyMx was limited to a small patch in the northern section of the Hornsea Three offshore cable corridor and AfilMysAnit was found in only one small area in the central section 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 relatively low confidence.

4.1.4.16 The biotope map was compared to, and informed by, other available datasets, including the North Norfolk Sandbanks and Saturn Reef cSAC/SCI Management Investigation Report (Jenkins *et al*., 2015). Two of the six survey boxes (boxes A and C; see Jenkins *et al*., 2015) described in the report coincide with the Hornsea Three offshore cable corridor. The biotopes assigned to sampling stations within these survey boxes matched well with biotopes assigned to the relevant sections of the Hornsea Three offshore cable corridor. Sample stations in survey box A were assigned the same biotope codes (SspiMx and ApriBatPo) as those determined for the relevant central section of the Hornsea Three offshore cable corridor, just south of the fork of the Hornsea Three offshore cable corridor reroute, where the datasets overlapped (Figure 4.6). Sample stations in survey box C were assigned the broad biotope 'circalittoral coarse sediment' which aligns with the Hornsea Three seabed sediment description and shares several characteristic species.

4.1.4.17 Isolated areas of outcropping clay, often with veneers of shelly gravel, were recorded in the very nearshore section of the Hornsea Three offshore cable corridor by DDV and are discussed further in the section on epibenthic biotope mapping (see paragraph 4.1.4.48 and Figure 4.13). site specific

Former Hornsea Zone

4.1.4.18 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 paragraph 4.1.4.13 above. This biotope was characterised by high abundances of the brittlestar *Amphiura filiformis* and often high numbers of the venerid bivalve mollusc *K. bidentata* and other taxa, notably the burrowing ghost shrimp *Callianassa subterranea* (Table 4.2).

4.1.4.19 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, except for 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 fan section of the Hornsea Three offshore cable corridor together with the PoVen biotope, adjoining an area of the AfilMysAnit biotope, as described in paragraph 4.1.4.13.

4.1.4.20 Most 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 several 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).

4.1.4.21 Most 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 NcirBat biotope in areas of increased sediment disturbance, where the finer silt fraction is unable to settle out of the water column (paragraph 4.1.4.5; Connor *et al.*, 2004).

4.1.4.22 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).

4.1.4.23 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).

4.1.4.24 Small areas of the infralittoral coarse sediment biotope MoeVen were 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 *Goodallia triangularis* and *Spisula elliptica*. 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).

4.1.4.25 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.

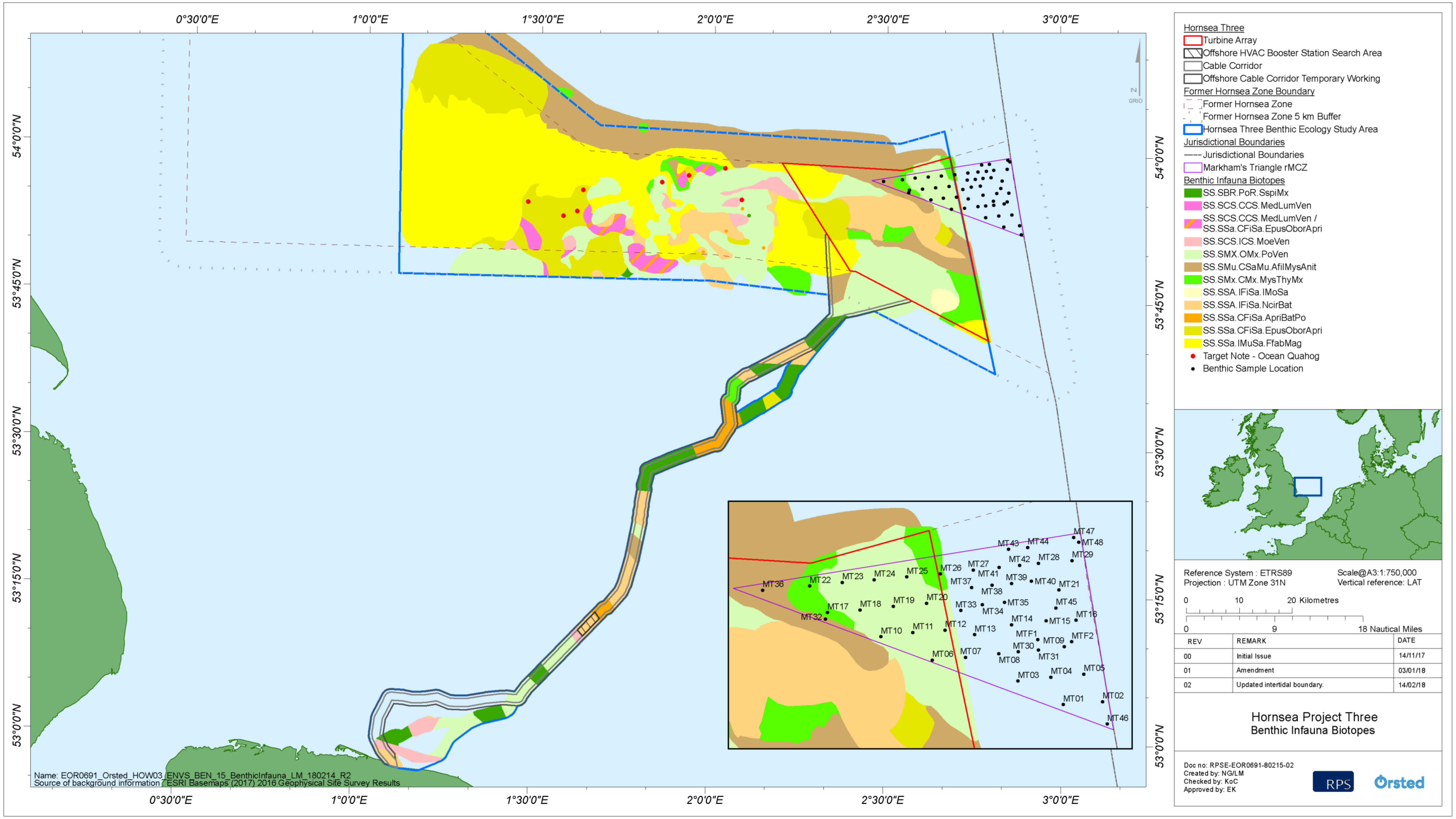

Figure 4.6: Benthic infauna biotopes of the Hornsea Three benthic ecology study area (note the nearshore biotopes are considered holistically in paragraphs 4.1.4.83 to 4.1.4.86 and Figure 4.28).

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 (41 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, Spiophanes bombyx, Corbula gibba, Echinocyamus pusillus, Cochlodesma praetenue, 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 six discrete 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 polychaetes *Scoloplos armiger, Nephtys cirrosa, Ophelia borealis, Spiophanes bombyx* and the amphipods *Bathyporeia elegans* and *Bathyporeia guilliamsoniana*.	*Nephtys cirrosa, Scoloplos armiger, Abra prismatica, Ophelia borealis, Scalibregma inflatum, Corbula gibba, Spiophanes bombyx, Echinocyamus pusillus, Bathyporeia elegans, Bathyporeia guilliamsoniana*.	This biotope was located at small discrete locations in the former Hornsea Zone and at two locations along 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, Spiophanes bombyx* 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, Scoloplos armiger, Nemertea* spp., *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 *Fabulina fabula, Chamelea striatula* and *Abra prismatica*, polychaetes including *Magelona johnstoni* and *Spiophanes bombyx* and the amphipods *Bathyporeia elegans, Bathyporeia tenuipes* and *Bathyporeia guilliamsoniana.*	Fabulina *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. There were no records of this biotope on the Hornsea Three offshore cable corridor.
SS.SMu.CSaMu.AfilMysAnit (AfilMysAnit)	A5.351	Sand and muddy sand (23 sites); coarse sediments (3 sites).	*Amphiura filiformis,* Kurtiella (*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, Notomastus, Corbula gibba, Callianassa subterranea, Glycera lapidum, Nemertea* spp., *Aonides paucibranchiata, Echinocyamus pusillus, Scalibregma inflatum, Kurtiella bidentata*.	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, and at one small area in the centre of the Hornsea Three offshore cable corridor.
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 prismatica* 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 *polychaete Ophelia borealis* and 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.

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.ICS.MoeVen (MoeVen)	A5.133	Sand and muddy sand (6 sites); coarse sediments (9 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, Goodallia triangularis, *Corbula gibba, Echinocyamus pusillus, Nephtys cirrosa, 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.
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 mostly 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 (84 sites); mixed sediments (18 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., *Glycera lapidum Aonides paucibranchiata, Mediomastus fragilis*, *Scalibregma inflatum* and *Protodorvillea kefersteini*, *Polycirrus* spp., ribbon worms *Nemertea* spp. and the pea urchin *Echinocyamus pusillus*.	*Notomastus, Nemertea* spp., *Glycera lapidum, Echinocyamus pusillus, Aonides paucibranchiata, Corbula gibba, Scalibregma inflatum, Urothoe marina, Euspira pulchella, Protodorvillea kefersteini, Pholoe baltica, Ophelia borealis, Polycirrus* spp., *Mediomastus fragilis, Syllis* sp., *Eunereis longissima, Mediomastus fragilis, Pista cristata, Upogebia deltaura, Eulalia mustela, Goniadella gracilis, Glycinde nordmanni.*	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 and along much of the Hornsea Three offshore cable corridor within approximately 40 km from the shore.
SS.SMx.CMx.MysThyMx (MysThyMx)	A5.443	Coarse sediments (1 site); Mixed sediments (29 sites).	*Kurtiella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment.	Moderately exposed or sheltered, circalittoral muddy sands and gravels characterised by communities of the bivalve *Kurtiella bidentata*, polychaetes such as *Glycera alba, Mediomastus fragilis* and *Goniada maculata*. The brittlestar *Amphiura filiformis* was also abundant at some sites.	*Amphiura filiformis, Kurtiella bidentata, Pholoe baltica, Glycera alba, Nemertea, Goniada maculata, Notomastus, Mediomastus fragilis, Lumbrineris gracilis, Upogebia deltaura, Corbula gibba, Phoronis, Magelona alleni, Cylichna cylindracea, Gattyana cirrhosa.*	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. One isolated area was recorded in the northern section of the Hornsea Three offshore cable corridor.
SS.SBR.PoR.SspiMx (SspiMx)	A5.611	Coarse sediments (3); mixed sediments (7 sites).	*S. spinulosa* on stable circalittoral mixed sediment.	This biotope occurred on mixed sediments and was characterised by high abundances of the tube-building polychaete *S. 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.*	*Spirobranchus lamarcki, S. spinulosa, Pholoe inornata*, Nematoda, *Dendrodoa grossularia, Harmothoe impar, Pisidia longicornis, Ampelisca tenuicornis, Eumida sanguinea*, Actiniaria, *Scoloplos armiger*.	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: Three sites in the group with no similarity, due to few taxa. Species recorded at the site assigned this biotope included: *Nephtys cirrosa, Scolelepis, Asbjornsenia pygmaea, Thracia villosiuscula.*	This biotope was found in isolated areas in the central former Hornsea Zone and in the southeast of the Hornsea Three array area.

Benthic infauna biotope mapping – Markham's Triangle

4.1.4.26 The infaunal dataset for the 50 samples from Markham's Triangle have not been included in the multivariate analyses described in paragraphs 4.1.4.1 to 4.1.4.25. However, as discussed in paragraph 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 paragraph 2.6.2.2), to ascertain whether the assemblages, and therefore biotopes, are comparable to those described for the Hornsea Three benthic ecology study area.

4.1.4.27 The MDS plot presented in Figure 4.7 shows data from all 450 benthic infaunal samples (except two outliers); 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.

4.1.4.28 Figure 4.8, Figure 4.9 and Figure 4.10 shows dendrograms for 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; biotopes have not 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 to determine if the communities recorded within Markham's Triangle are comparable to those recorded in the Hornsea Three array area.

4.1.4.29 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. It should be noted that only one of these stations, MT10, occurs within the Hornsea Three array area, and that the others are located east of this area (see inset map in Figure 4.6 for station locations).

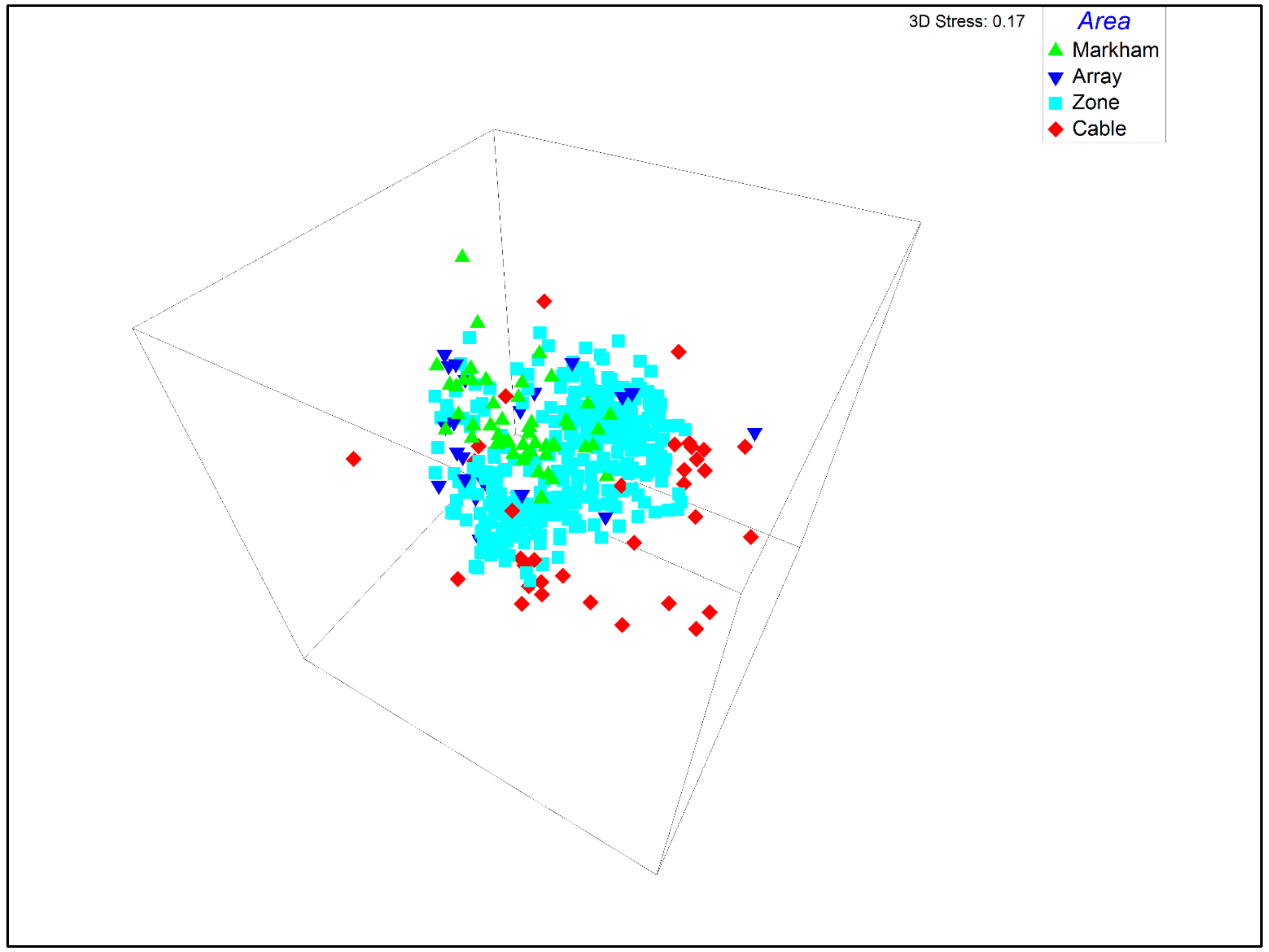

Figure 4.7: Subset 3-D MDS plot for benthic infaunal communities in all sediments within the Hornsea Three benthic ecology study area, including Markham's Triangle (green triangles).

4.1.4.30 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. The prediction that the coarse sediment communities in Markham's Triangle are likely to represent the PoVen biotope is supported by the infauna biotope map (Figure 4.6). Of the 26 Markham's Triangle stations shown in Figure 4.9, 10 coincide with the Hornsea Three array area and are located within or close to the area of seabed classified as PoVen biotope according to the analysis of the Hornsea Three site specific samples.

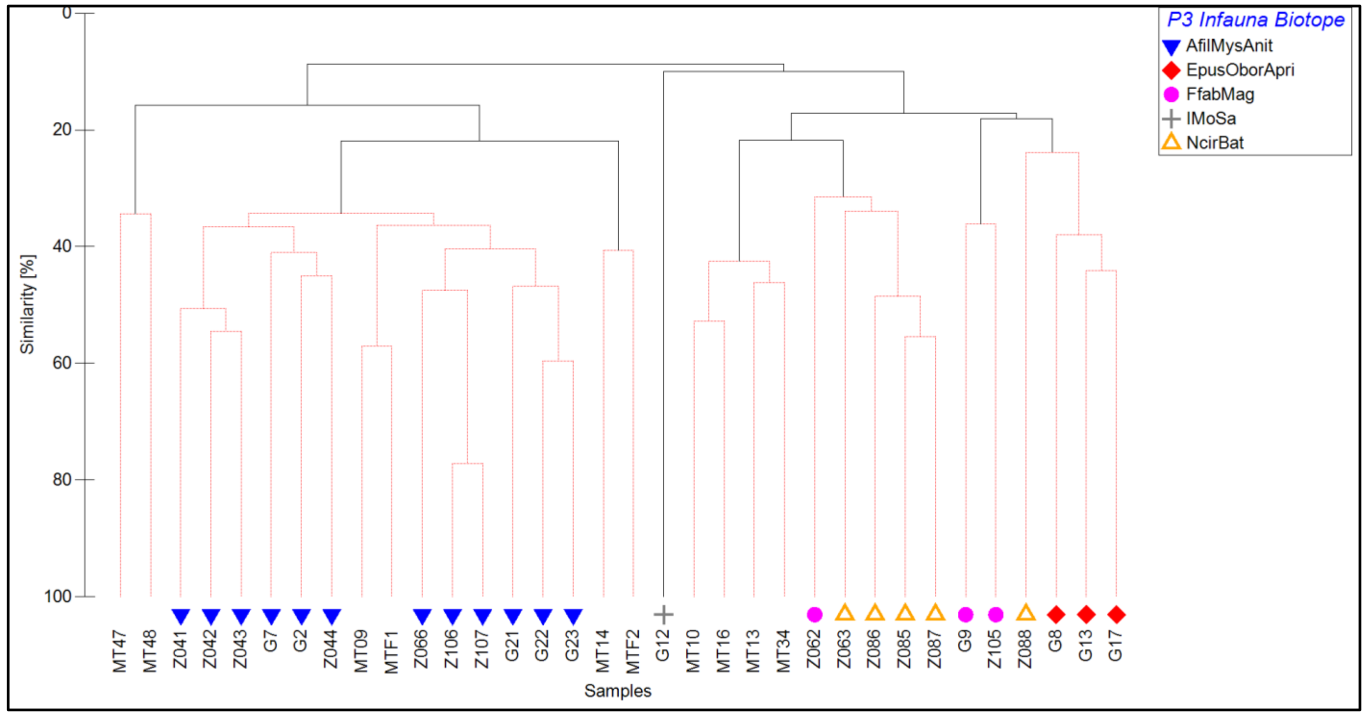

Figure 4.8: Dendrogram of infaunal communities in sandy sediments in the Hornsea Three array area and Markham's Triangle.

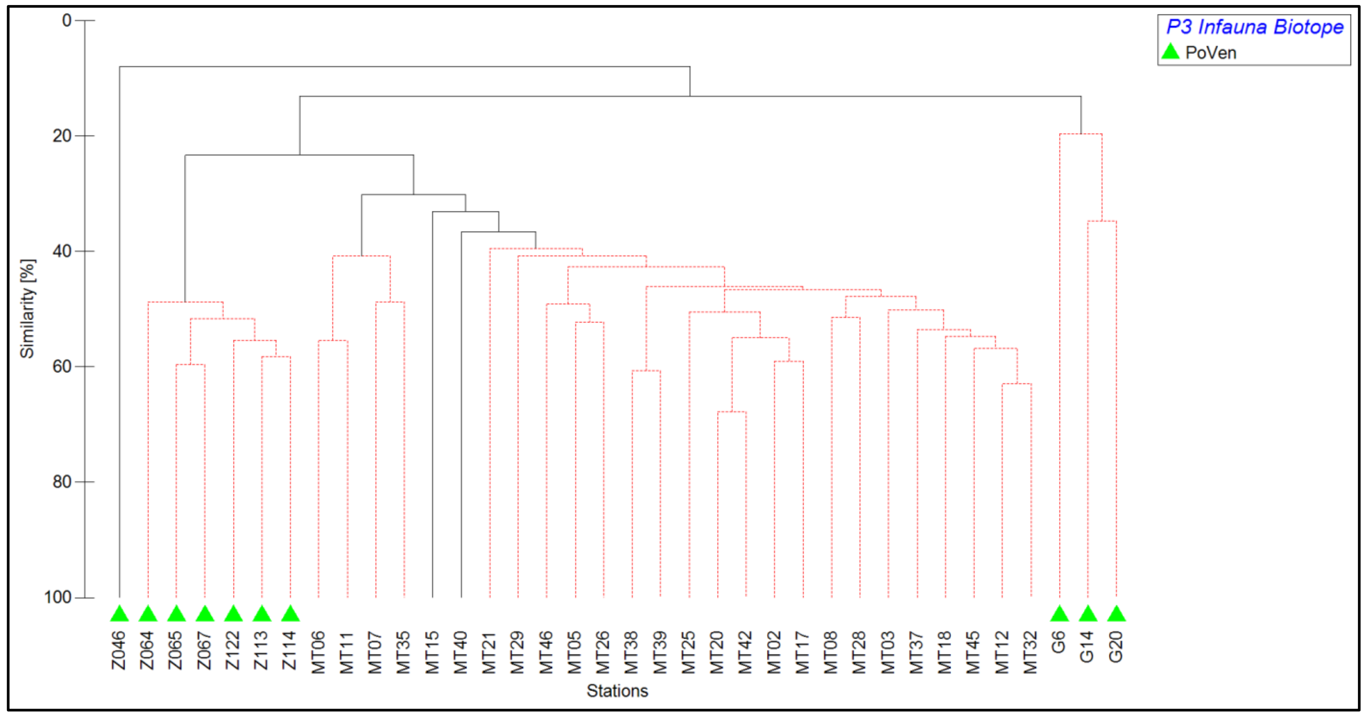

Figure 4.9: Dendrogram of infaunal communities in coarse sediments in the Hornsea Three array area and Markham's Triangle.

4.1.4.31 Figure 4.10 shows 14 of Markham's Triangle data points alongside the Hornsea Three array area data within the mixed sediment type. Unlike the plots for sandy sediment and coarse sediment, Figure 4.10 does not give an obvious indication as to 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. Of the 14 Markham's Triangle stations within mixed sediments, six were located in or close to the Hornsea Three array area and most coincided with the PoVen biotope, according to Figure 4.6.

4.1.4.32 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 historic and site specific benthic ecology data are considered to provide sufficient coverage of the Hornsea Three array area to characterise the benthic infaunal biotopes.

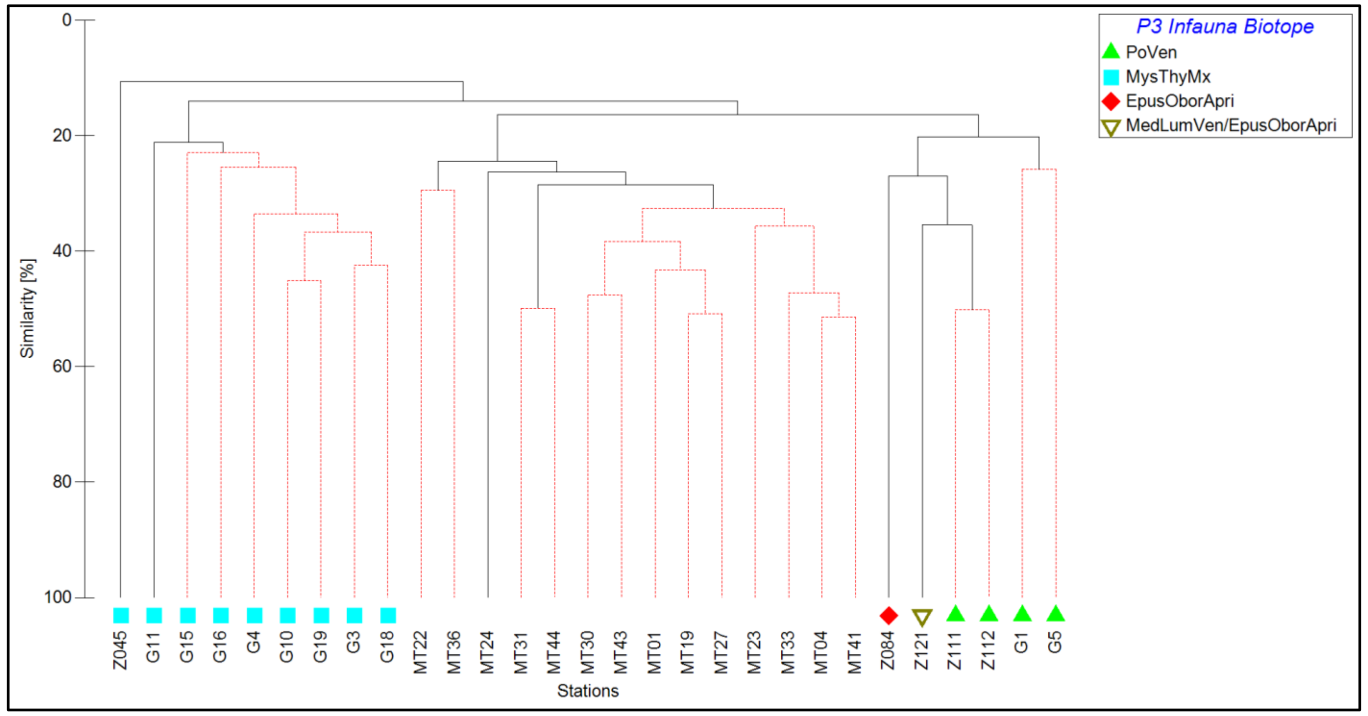

Figure 4.10: Dendrogram of infaunal communities in mixed sediments in the Hornsea Three array area and Markham's Triangle.

Epibenthic biotope mapping

4.1.4.33 As discussed in paragraph 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 historic (Hornsea ZoC, Hornsea Project One, and Hornsea Project Two surveys) and Hornsea Three site specific surveys, and analysed using cluster analysis to group sites with a similar epibenthic composition. DDV data were available for the Hornsea Three offshore cable corridor and from one site specific station in the Hornsea Three array area from site specific surveys undertaken in 2017. As such, the epibenthic biotope map draws on a substantial volume of DDV data and beam trawl data for the Hornsea Three offshore cable corridor. Some minor extrapolation has been undertaken in the very eastern margin of the Hornsea Three array area using the epibenthic biotopes determined for the majority of sediments in the Hornsea Three array area, in conjunction with the interpreted geophysical data from the site-specific survey in 2016. The resulting biotopes for the Hornsea Three offshore cable corridor and the eastern section of the Hornsea Three array area have been mapped together with results of the historic surveys (Hornsea ZoC, Hornsea Project One and Hornsea Project Two surveys).

4.1.4.34 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.

4.1.4.35 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).

4.1.4.36 In many instances the presence/absence of key species was responsible for most 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 one of which had the echinoderm *A. rubens* as the only characterising species while the other group 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 one group. However, as the community has similarly low abundances of all other species observed, and 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 either group 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.

4.1.4.37 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 nine 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 stations devoid of fauna plus another five with very few taxa, and shows a high degree of overlap between stations. 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 stations 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 available on request.

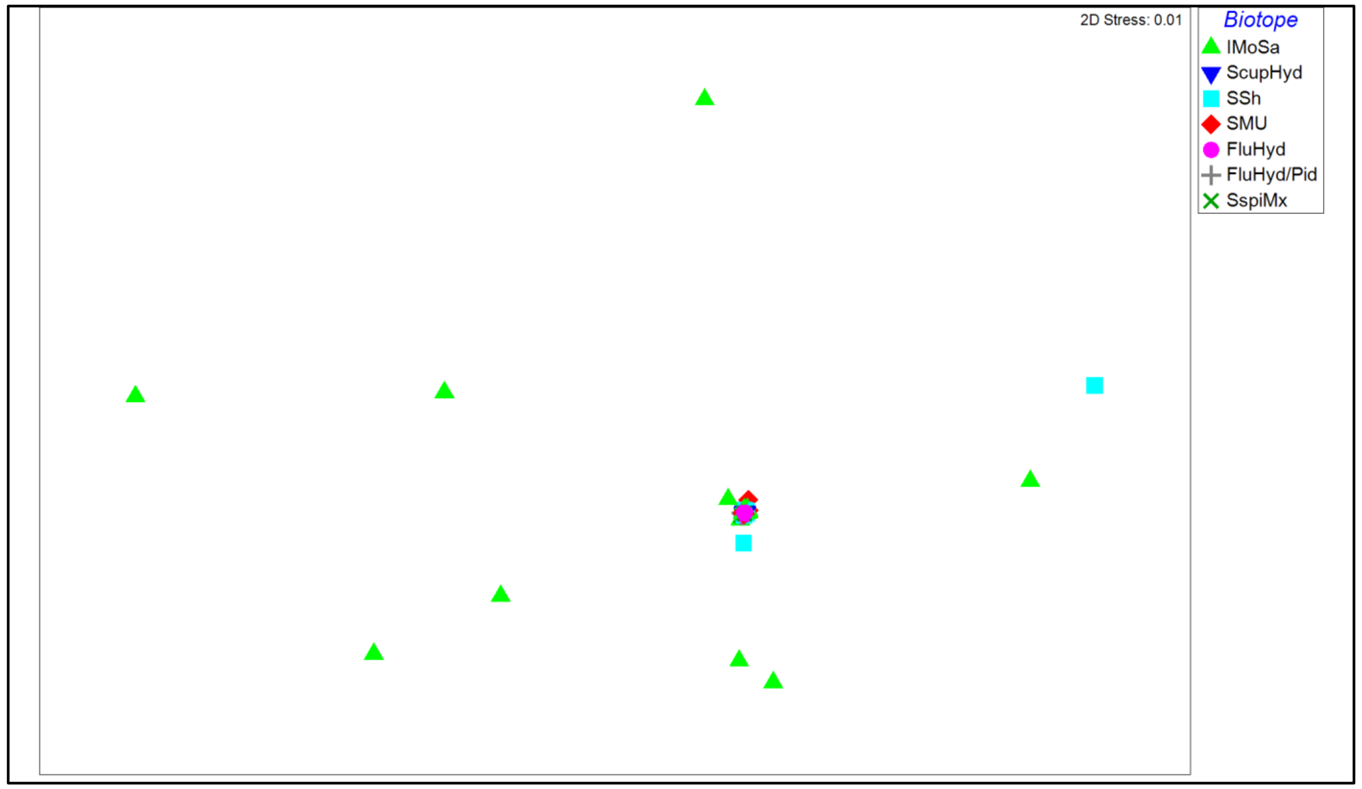

Figure 4.11: 2-D MDS plot for epibenthic communities (biotopes) in all sediment types for the Hornsea Three benthic ecology study area.

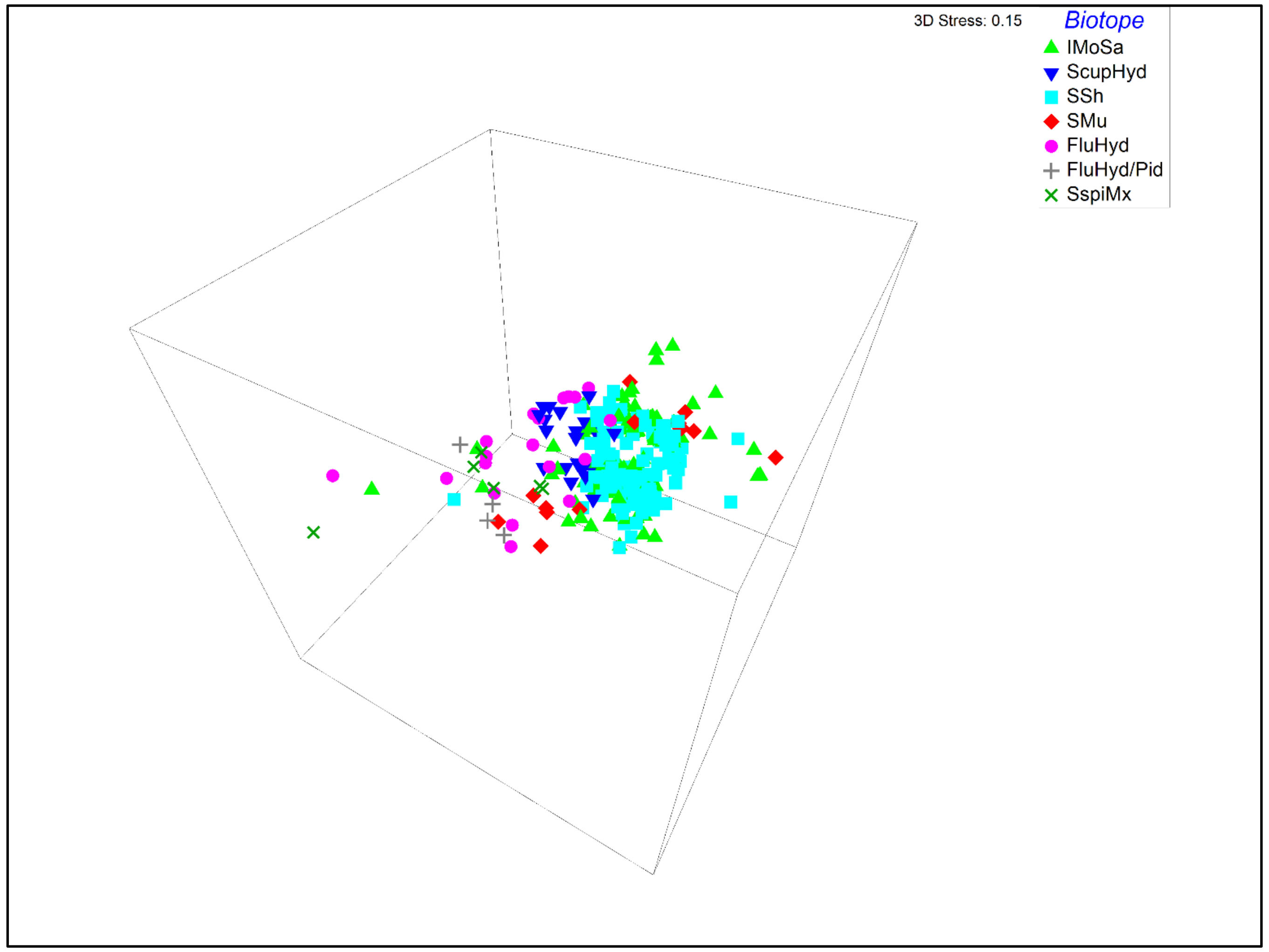

Figure 4.12: Subset of a 3-D MDS plot for the epibenthic communities (biotopes) in all sediment types for the Hornsea Three benthic ecology study area (note subset; 14 outlying stations not shown).

4.1.4.38 Most 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 paragraph 4.1.4.36; those sites characterised by *A. rubens* alone and those characterised by both *A. rubens* and *A. irregularis.*

4.1.4.39 Fifteen stations 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*. Two sites 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; blue inverted triangle symbols, Figure 4.12) due to the prevalence of cobbles at these sites, with associated epibenthic communities.

4.1.4.40 Coarse sediments showed typically dense clustering, indicating little difference in the epibenthic communities observed at these sites. There was some overlap between the SSh biotope (light blue square symbols, Figure 4.12) and the ScupHyd biotope (blue inverted triangle symbols) with the differences between the two being a higher abundance of hydroids in the ScupHyd biotope. Within this sediment type, 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 through to SspiMx, characterised by diverse epifaunal communities amongst the mixed sediments and *S. spinulosa* structures was shown.

4.1.4.41 Four nearshore stations were assigned the mosaic biotope SS.SMx.CMx.FluHyd (*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment)/CR.MCR.SfR.Pid (Piddocks with a sparse associated fauna in sublittoral very soft chalk or clay hereafter referred to as FluHyd/Pid; grey cross symbols). This mosaic biotope reflected a sparse, piddock-dominated community in clay exposures covered for the most part by a thin veneer of coarse sediments associated with the more diverse FluHyd community (pink circles). See paragraph 4.1.4.48 for further discussion on the areas where this mosaic biotope was observed.

4.1.4.42 The mixed sediments had a loose clustering of stations due in part to the lower number of stations but also due to the diverse complement of species in these sites. A general pattern of increasing epibenthic community complexity and diversity was evident in in this sediment group with the majority of stations assigned the SSh biotope (turquoise squares) sharing similarly sparse epifaunal assemblages. Two stations were considered to represent the SspiMx biotope (green crosses), as these were characterised by a strong presence of *S. spinulosa* in the data.

4.1.4.43 Figure 4.14 shows the geographic extents of the epibenthic biotopes present throughout the Hornsea Three benthic ecology study area. Seven 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. As discussed in paragraph 2.6.2.16, the nearshore biotopes are considered holistically in paragraphs 4.1.4.83 to 4.1.4.86 and are presented in Figure 4.28.

4.1.4.44 Most 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. Much 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.

4.1.4.45 Most 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, much of the coarse substratum was dominated by gravelly sands with only occasional cobbles or boulders, providing substrate for the attachment of hydroids or bryozoans. 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.

4.1.4.46 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 six discrete areas along the Hornsea Three offshore cable corridor. Areas assigned to the FluHyd biotope often coincided with the infaunal biotopes PoVen and SspiMx and 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.

4.1.4.47 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). The epifauna biotope SspiMx was recorded in isolated pockets along the Hornsea Three offshore cable corridor and on the southern margin of the central former Hornsea zone; epifaunal communities in this biotope exhibited similar characteristic taxa to the FluHyd biotope, plus a notable presence of *S. spinulosa* tubes.

4.1.4.48 Clay exposures, which are a UK BAP priority habitat and are listed as one of the protected features of the Cromer Shoal Chalk Beds MCZ, were recorded within the MCZ (see Figure 4.13) at locations where this habitat had been previously mapped (Defra, 2015; see sections 3.1.3.52, Table 3.2 and Figure 4.14). An additional area of seabed with clay exposures was also recorded within the MCZ, approximately 1 km southwest of those identified by Defra (2015; see Figure 4.14). The features, at all locations where they were observed, were found to support a relatively low epibiotic diversity dominated by burrowing piddocks (expected to be the common piddock *Pholas dactylus*) in the very limited areas where there was no overlying sediment and was considered representative of the Pid biotope (see Table 4.3 for a description of this biotope). A more diverse epifauna community, considered to be representative of the FluHyd biotope, was recorded where mixed/coarse sediments were present as an overlying veneer over the clay. At all locations, the areas comprising shallow veneers were considerably more extensive than the exposed clay features. As such, the matrix biotope FluHyd/Pid was considered representative of the seabed in these areas. The communities associated with the sediment veneer were dominated by erect bryozoans and hydroids including *Flustra* sp. *Nermetesia* sp. and *Sertularia* sp. together with large crustaceans, including the edible crab *C. pagurus* and the common lobster *Homarus gammarus*.

4.1.4.49 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 as an appendix on request.

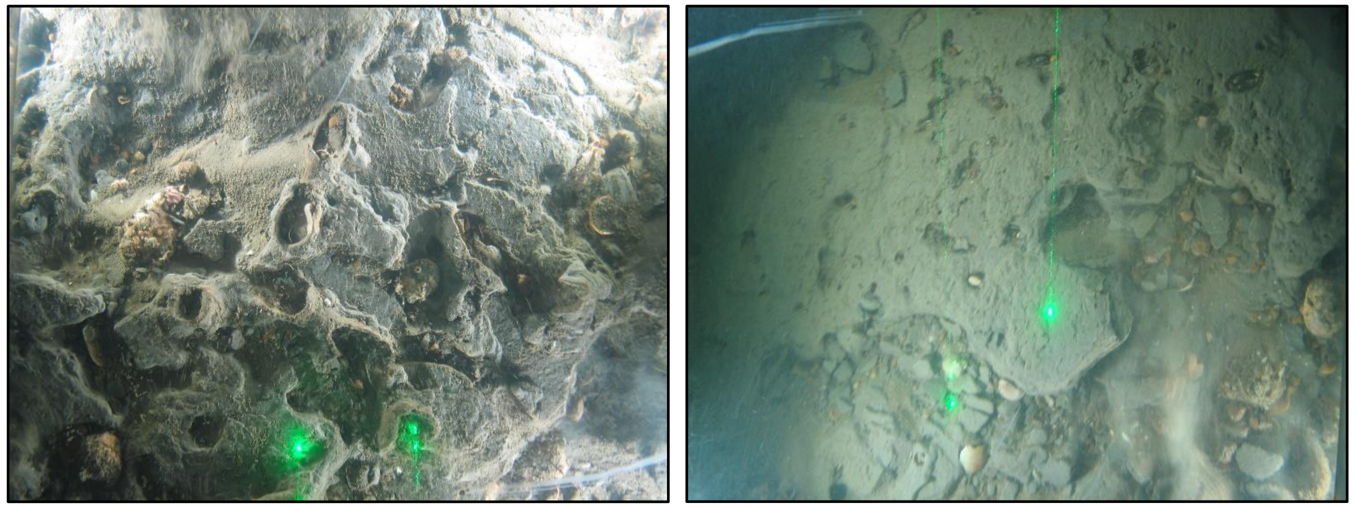

Figure 4.13: Still images of exposed clay features in the Cromer Shoal MCZ recorded at stations ECR57X (left) and ECR59 (right) during the October 2017 DDV Hornsea Three site specific survey. Note the distance between the laser points represents 10 cm.

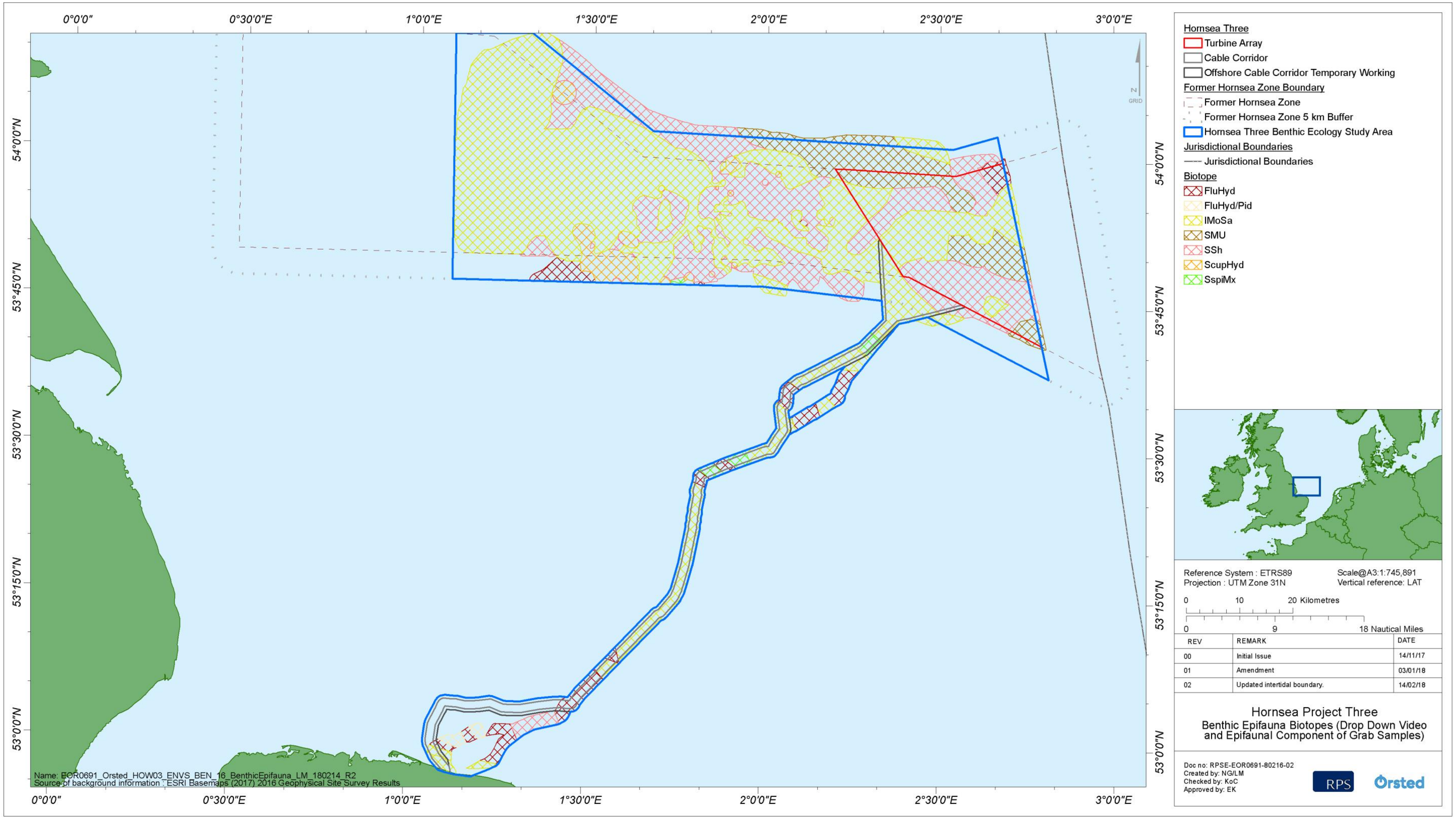

Figure 4.14: Epibenthic biotopes in the Hornsea Three benthic ecology study area (note the nearshore biotopes are considered holistically in paragraphs 4.1.4.83 to 4.1.4.86 and Figure 4.28).

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 4.14).

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 (186 sites), coarse sediment (16 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, except for 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 (16 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 (96 sites), mixed sediment (32 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. One area of this biotopes was recorded along the Hornsea Three offshore cable corridor, just seaward of the MCZ.
SS.SMx.CMx.FluHyd (FluHyd)	A5.444	Coarse sediment (13 sites), mixed sediment (13 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 a discrete location in the northeast of the Hornsea Three array area, in the southwest of the Hornsea Three benthic ecology study area and at several areas along the Hornsea Three offshore cable corridor, particularly the section within approximately 30 km of the shore.
SS.SMx.CMx.FluHyd/ CR.MCR.SfR.Pid (FluHyd/Pid)	A5.444/A4.231	Coarse sediment (4 sites).	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment/Piddocks with a sparse associated fauna in sublittoral very soft chalk or clay.	This mosaic biotope comprises an epifaunal community on a shallow veneer of coarse and mixed sediments over clay which exhibits a sparse community dominated by the piddock bivalve, typically *Pholas dactylus*, where the clay is exposed through the widespread sediment veneer. Clay is generally too soft for sessile taxa to attach to, resulting in an impoverished community where no other substrates are present. Mobile fauna typically includes the crabs *Necora puber* and *Cancer pagurus* and common lobster Homarus gammarus.	Flustra sp., Nemertesia sp., Alcyonidium diaphanum	This biotope was recorded in two discrete areas within 10 km of the shore, inside the Cromer Shoal Chalk Beds MCZ.
SS.SBR.PoR.SspiMx	A5.611	Coarse sediment (4 sites), mixed sediment (2 sites).	*S. spinulosa* on stable circalittoral mixed sediment.	This biotope, also recorded in infaunal sediments, was primarily characterised by high abundances of the tube-building polychaete *S. spinulosa* in the epifaunal datasets, together with A*lcyonium digitatum, Flustra* sp. and Actiniaria.	*Asteroidea, Alcyonidium diaphanum, S. spinulosa,* Hydroid/Bryozoan mixed turf.	This biotope was predominantly recorded along the Hornsea Three offshore cable corridor, particularly in the nearshore and most offshore sections.

Epibenthic trawl data

4.1.4.50 Data from the epibenthic trawl surveys were also used to inform the benthic epifaunal biotope mapping. The 3-D MDS is presented in Figure 4.15 (with biotopes as factors). The cluster analysis identified 17 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 seven epifaunal biotopes (descriptions based on Connor *et al*., 2004) and these are described in Table 4.4.

4.1.4.51 Figure 4.15 shows that two biotopes that had been present in the epibenthic data above were recorded in the epibenthic beam trawls: ScupHyd and FluHyd. Approximately 84% of the trawls were assigned to the ScupHyd biotope which demonstrated good clustering to distinguish them from the other sites (turquoise square symbols; Figure 4.15). Except for two trawl samples determined to represent the FluHyd biotope, 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); the SS.SSa.CMuSa (circalittoral muddy sediment) biotope (hereafter referred to as CMuSa); the CR.HCR.XFa (mixed faunal turf communities) biotope (hereafter referred to as XFa); and the broader SS.SMx (sublittoral mixed sediment) biotope (hereafter referred to as SMx).

4.1.4.52 Figure 4.16 shows the location of the epibenthic trawl locations and the epifaunal biotopes assigned based on the trawl data. Most 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 in both sandy and muddy sand sediments and coarser sediments within these areas. The communities of this biotope 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 much 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.

4.1.4.53 Although fish were removed from the epibenthic trawl data prior to analysis (see paragraph 2.6.2.11), 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.

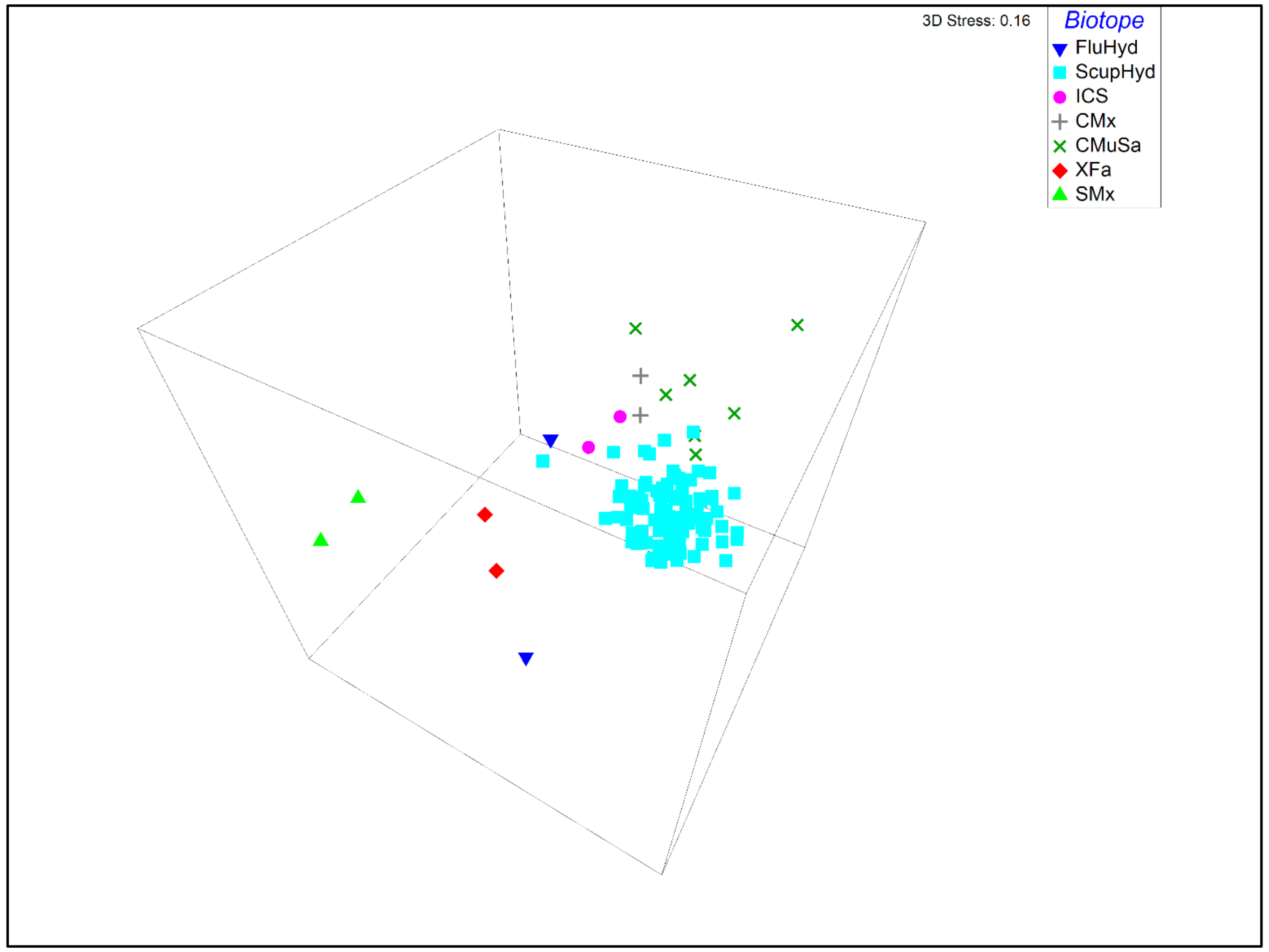

Figure 4.15: 3-D MDS plot of epibenthic beam trawl data for the Hornsea Three benthic ecology study area.

4.1.4.54 Communities recorded within trawl samples at seven locations 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).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).

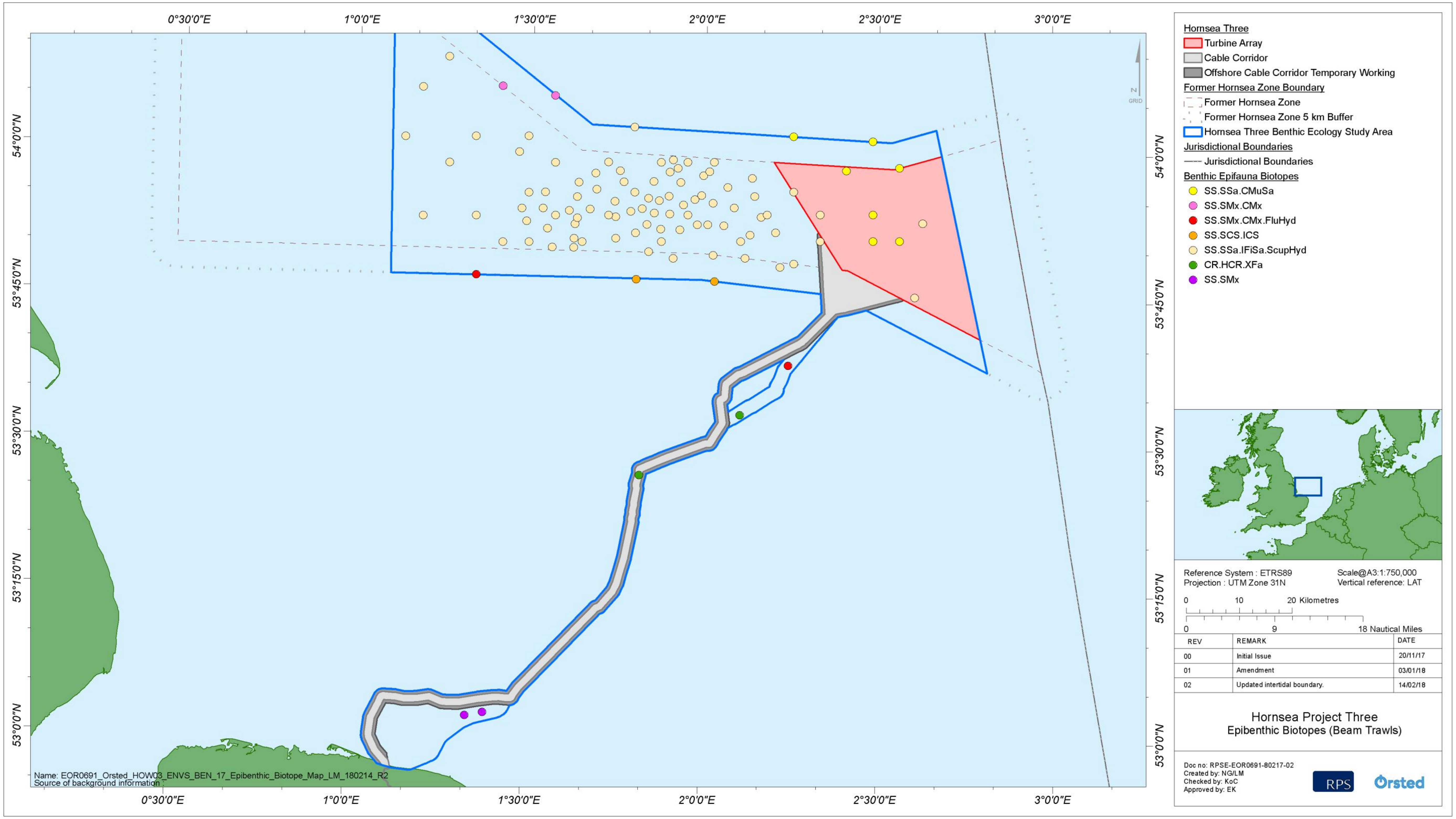

Figure 4.16: Epibenthic biotopes from the epibenthic beam trawl data in the Hornsea Three benthic ecology study area (note the nearshore biotopes are considered holistically in paragraphs 4.1.4.83 to 4.1.4.86 and Figure 4.28).

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 4.16).

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 allmanni, Aequipecten opercularis, Liocarcinus holsatus, 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 (2 trawls).	*Flustra foliacea* and *Hydrallmania falcata* on tide swept 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: The sites did not group significantly. Species recorded at the site assigned this biotope included: *Alcyonium digitatum, Flustra foliacea, Halecium* sp., *Liocarcinus depurator, Asterias rubens, Psammechinus miliaris, Ascidiella scabra, Crangon crangon, Pandalus montagui.*	This biotope was recorded from two trawl sites located to the southwest of the Hornsea Three benthic ecology study area and in the northern section of the Hornsea Three offshore cable corridor.
CR.HCR.XFa (XFa)	A4.13	Coarse sediment (2 trawls).	Mixed faunal turf communities.	This typically occurs on wave-exposed circalittoral bedrock and boulders, characterised by hydroids including *Halecium* species; bryozoans such as *Alcyonidium diaphanum* and *Flustra foliacea*; and sponges. These combine to form a dense mixed faunal turf. Other species include *Alcyonium digitatum, Urticina felina* and *Asterias rubens*. Note the trawl samples assigned to this biotope showed only a loose similarity.	*Asterias rubens*, Macropodia sp., *Inachus* sp., *Aequipecten opercularis, Psammechinus miliaris, Pandalus montagui*, Paguridae.	This biotope was recorded in samples from the northern section of the Hornsea Three offshore cable corridor.
SS.SMx (SMx)	A5.4	Mixed sediment (2 trawls).	Sublittoral mixed sediment.	This broad biotope comprises mixed sediments and supports a wide range of infauna and epibiota including polychaetes, bivalves, echinoderms, anemones, hydroids and Bryozoa.	*Liocarcinus* sp., *Crangon crangon, Macropodia* sp., *Crossaster papposus, Pandalus montagui, Pisidia longicornis, Calliostoma* sp., *Gibbula* sp., *Asterias rubens, Inachus* sp., *Henricia oculata, Ascidiella scabra.*	This biotope was recorded in samples from the nearshore section of the Hornsea Three offshore cable corridor, just outside of the Cromer Shoal Chalk Beds MCZ.

4.1.4.55 Four of the nine beam trawl samples acquired from within the Hornsea Three array area were determined to represent ScupHyd biotope (paragraph 4.1.4.52). The remaining biotopes ascertained for the beam trawl samples acquired along the Hornsea Three offshore cable corridor comprised the broad descriptions of XFa and SMx. The XFa biotope represents a mixed faunal turf community of bryozoans, hydroids and sponges associated with bedrock and boulders. The beam trawl sample stations assigned to this biotope showed only a loose similarity to this biotope and, while the seabed likely comprised coarse sediments, these were not necessarily considered to include bedrock and boulders, however this biotope showed the closest match to the community recorded at these stations. The SMx biotope is very broad and was assigned to two beam trawl sampling stations because no other biotope classification was suitable for the community recorded. Figure 4.15 shows how different the assemblages of the stations assigned to XFa (red diamond symbols) and SMx (green triangle symbols) were compared to those of all other stations.

4.1.4.56 The species list, abundances, biomass and SIMPER results are available within an appendix on request.

Univariate statistics

<u>Benthic infauna</u>

4.1.4.57 The following univariate statistics were calculated for each benthic grab site: number of species (S), abundance (N), 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. Where a biotope was assigned to a suite of sites comprising less than two sites with any taxa (as was the case for the IMoSa biotope), these statistics have not been calculated.

4.1.4.58 The univariate statistics shows that the sand sediment biotopes (i.e. NcirBat, FfabMag, EpusOborApri and ApriBatPo) had generally 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, Hornsea Three offshore cable corridor and the extensive areas of sandy sediments across the former Hornsea zone was less than 21 taxa (see Figure 4.17), and although abundances were relatively high, typically up to 70 individuals, these were also generally lower than abundances for the coarser sediment biotopes, which ranged from approximately 32 individuals to over 537 individuals in the SspiMx biotope (see Figure 4.17). Figure 4.17 shows the number of taxa recorded for each 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.

4.1.4.59 The NcirBat biotope, assigned to 41 locations, recorded the lowest mean number of species and abundance (16.0 ± 5.0 species and 37.0 ± 15.6 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 sandy biotopes, which are typically species poor due to the physical disturbance and mobility of the sandy sediment.

4.1.4.60 The sandy mud sediments associated with the AfilMysAnit biotope had a higher mean number of species (22.1 ± 8.5; see Figure 4.17) and mean abundance (98.2 ± 77.0) 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 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.

4.1.4.61 Of the coarse sediment biotopes, SspiMx recorded the highest mean number of species (39.1 ± 18.3; Figure 4.17, and diversity Table 4.5). Mean abundance (537.2 ± 1087.8) 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 (14.4 ± 5.7 and 29.9 ± 10.2, respectively) and mean abundance scores (31.9 ± 16.2 and 156.5 ± 111.7, respectively). The univariate statistics for the MoeVen biotope were comparable to those recorded in the sand sediment biotopes (see section 4.1.4.59). 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.

4.1.4.62 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.

4.1.4.63 The mixed sediment biotope, MysThyMx, recorded the second highest mean number of species in the coarse sediment biotopes (after SspiMx; 32.6 ± 9.3 species and 138.2± 69.7 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).

4.1.4.64 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 4.18. Figure 4.18 shows that the number of species was highly variable across the Hornsea Three benthic ecology study area 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 diversity indices were smallest for the species poor MoeVen ($d = 3.9 \pm 1.2$; $H' = 2.2 \pm 0.4$) and largest for the infaunally rich PoVen community ($d = 6.8 \pm 1.9$; $H' = 2.9 \pm 0.3$) and MysThyMx community ($d = 6.5 \pm 1.6$; $H' = 2.6 \pm 0.4$). 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; MedLumVen; MedLumVen/EpusOborApri.

4.1.4.65 Pielou's Evenness (J') and Simpson's Dominance (λ) scores were generally high ($J' > 0.7$) and low ($\text{Lambda} < 0.3$), respectively, for all biotopes, indicating that the communities were not dominated by a small number of species (Table 4.5).

4.1.4.66 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 4.19 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 former Hornsea Zone associated with the coarse and mixed sediments in this area (Figure 4.22). 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, except for the nearshore section of the Hornsea Three offshore cable corridor.

4.1.4.67 Figure 4.20, Figure 4.21 and Figure 4.22 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. As discussed in paragraphs 4.1.4.57 to 4.1.4.66, 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 4.20). The SspiMx biotope 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 4.22). In comparison, mean abundances in the sandy sediment biotopes were somewhat lower (Figure 4.21). 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 4.22).

4.1.4.68 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 was 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.

4.1.4.69 Figure 4.20 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 paragraph 4.1.4.58 and illustrated in Figure 4.21. 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 most 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 4.22 shows that although present in relatively small numbers, echinoderms contributed to much 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 (41 sites).	41	16.0 ± 5.0	37.0 ± 15.6	4.2 ± 1.13	0.9 ± 0.1	2.4 ± 0.4	0.1 ± 0.1	0.4 ± 1.0
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	20.9 ± 7.9	72.1 ± 49.6	4.8 ± 1.3	0.8 ± 0.1	2.4 ± 0.4	0.2 ± 0.1	1.1 ± 1.8
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 (23 sites); coarse sediments (3 sites).	26	22.1 ± 8.5	98.2 ± 77.0	4.8 ± 1.5	0.7 ± 0.1	2.22 ± 0.5	0.2 ± 0.1	8.0 ± 14.4
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 (9 site).	15	14.4 ± 5.7	31.9 ± 16.2	3.9 ± 1.2	0.9 ± 0.1	2.2 ± 0.4	0.2 ± 0.1	0.3 ± 0.4
SS.SCS.CCS.MedLumVen (MedLumVen)	Coarse sediments (6 sites); mixed sediments (1 site).	7	29.9 ± 10.2	156.5 ± 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 (84 sites); mixed sediments (18 sites).	107	33.2 ± 13.4	126.2 ± 127.2	6.8 ± 1.9	0.8 ± 0.1	2.9 ± 0.3	0.1 ± 0.1	1.6 ± 3.4
SS.SMx.CMx.MysThyMx (MysThyMx)	Coarse sediments (1 site); Mixed sediments (29 sites).	30	32.6 ± 9.3	138.2 ± 69.7	6.5 ± 1.6	0.7 ± 0.1	2.6 ± 0.4	0.2 ± 0.1	2.3 ± 3.3
SS.SBR.PoR.SspiMx (SspiMx)	Coarse sediments (3); mixed sediments (7 sites).	10	39.1 ± 18.3	537.2 ± 1087.8	7.0 ± 2.9	0.7 ± 0.3	2.3 ± 1.0	0.3 ± 0.3	3.8 ± 7.2

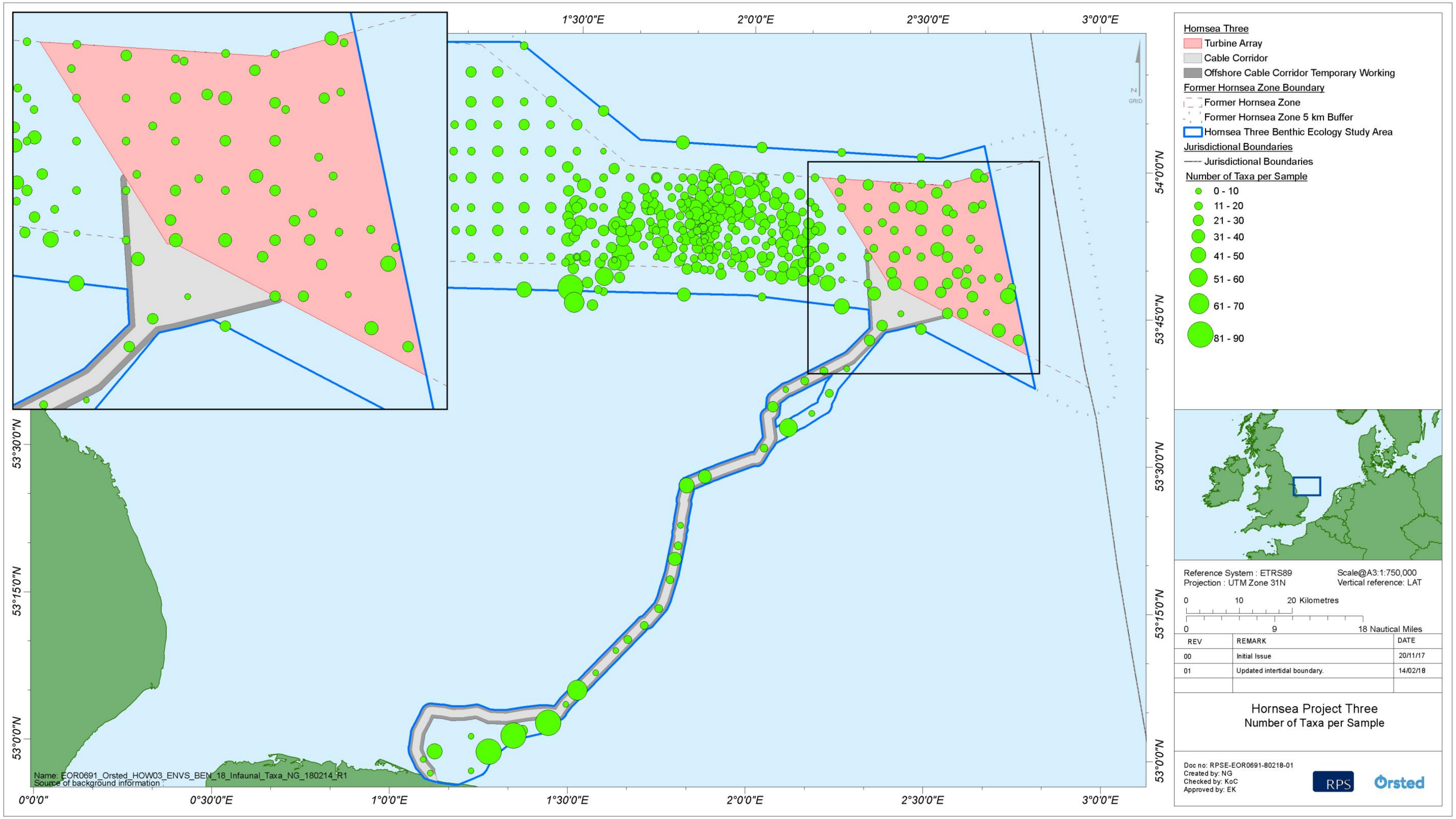

Figure 4.17: Number of taxa recorded for each benthic infaunal sample in the Hornsea Three benthic ecology study area.

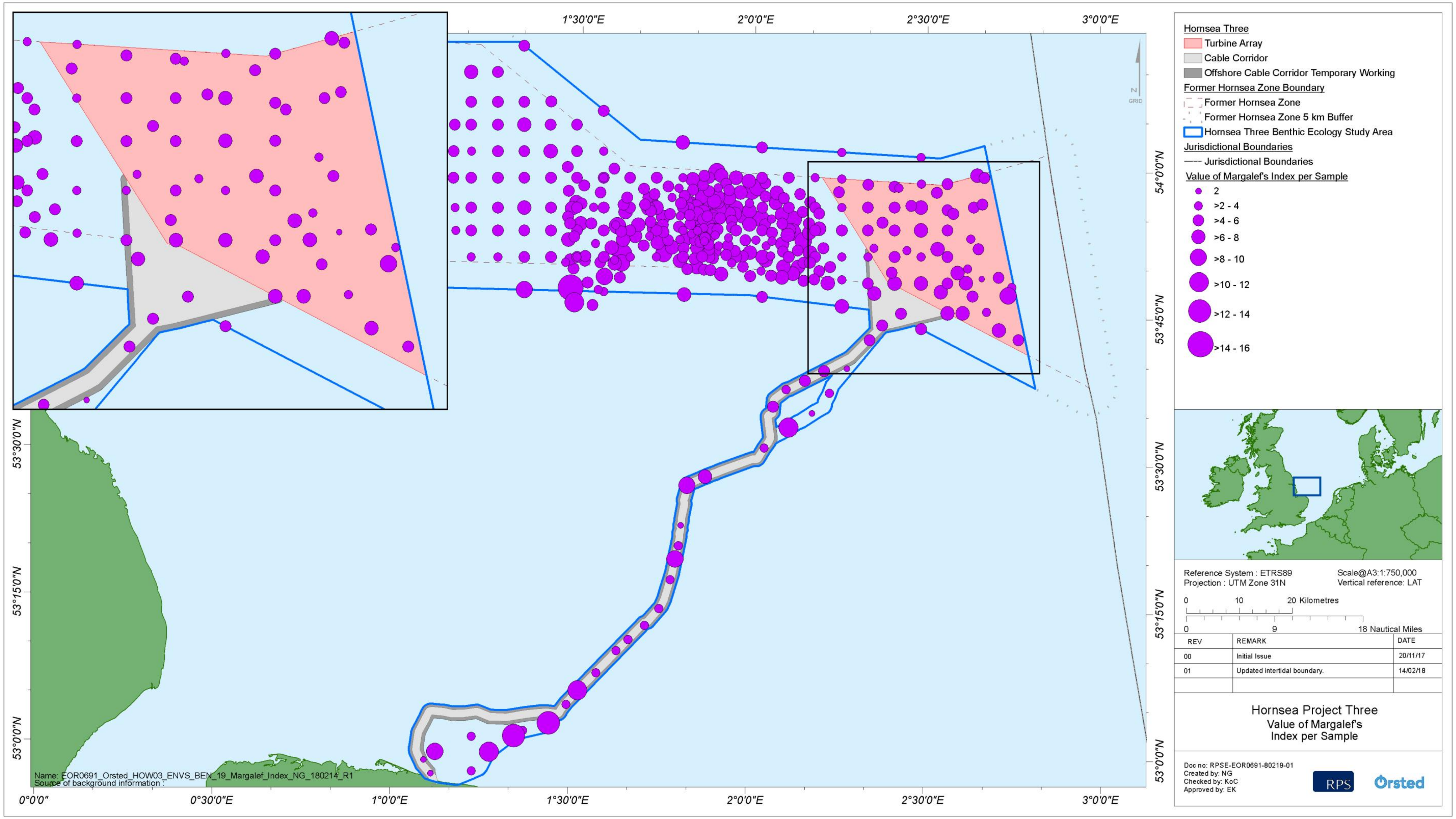

Figure 4.18: Values of Margalef's index (d: species richness) for each benthic infaunal sample within the Hornsea Three benthic ecology study area.

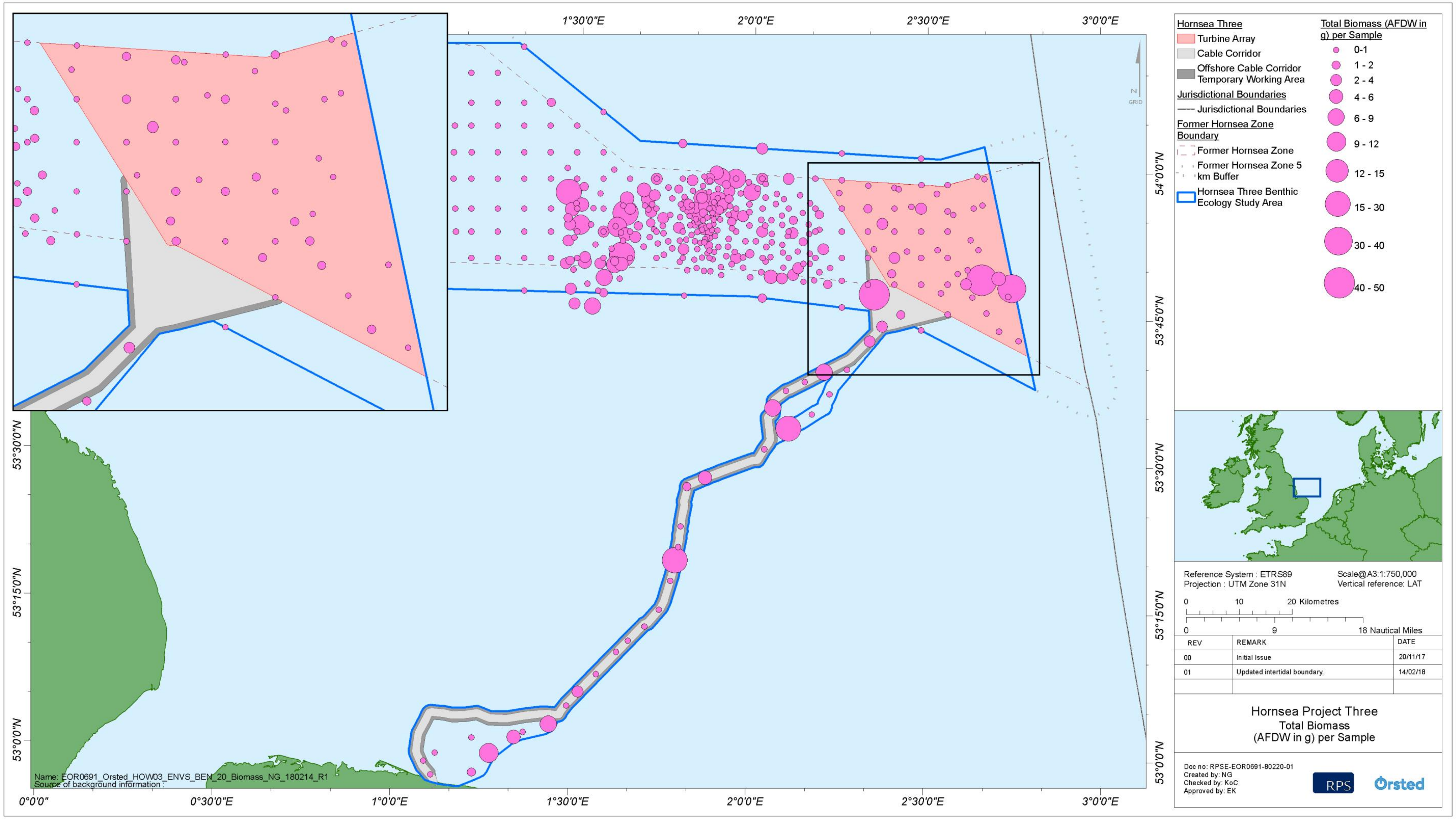

Figure 4.19: Biomass (ash free dry weight in grams) for each benthic infaunal sample in the Hornsea Three benthic ecology study area.

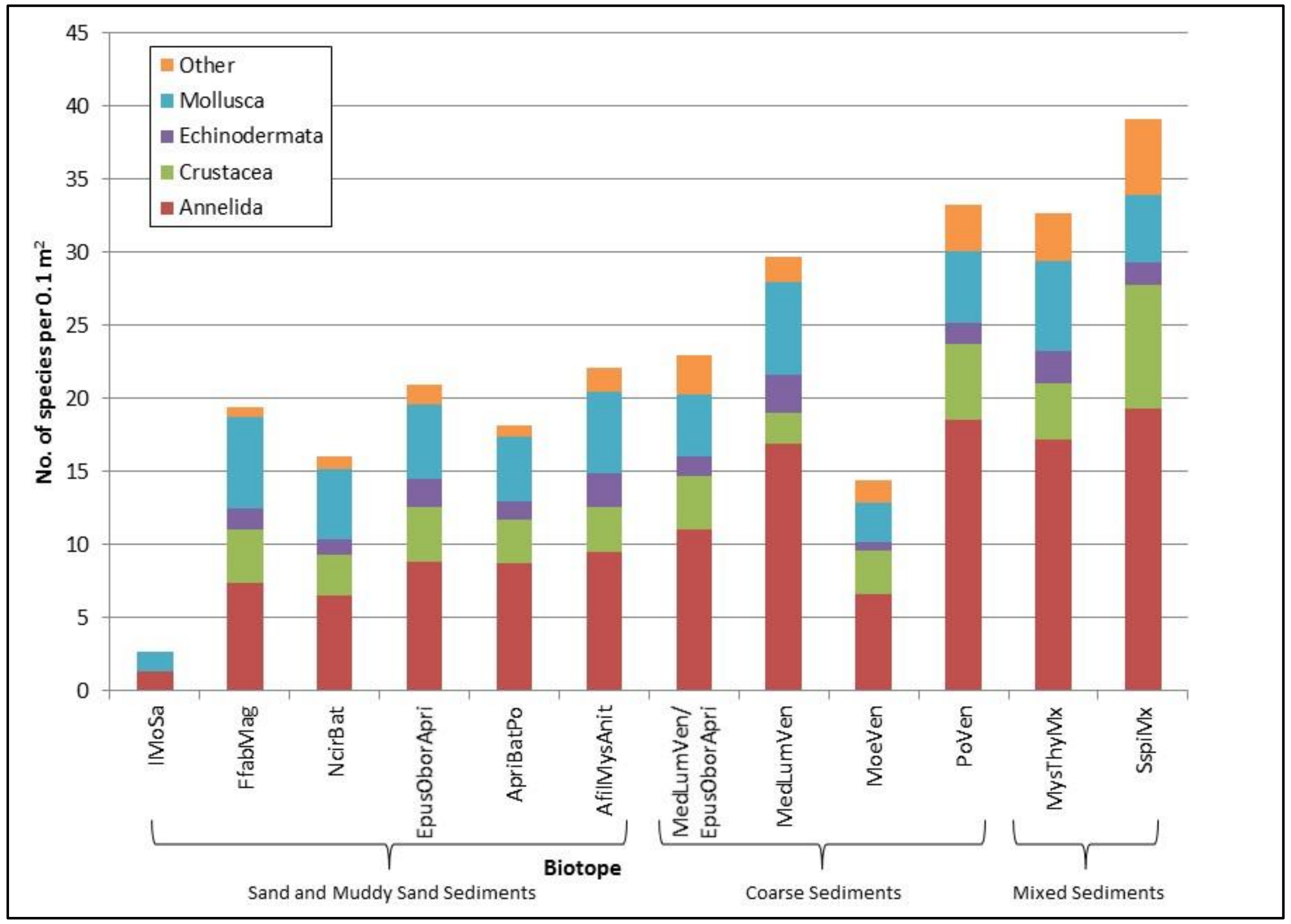

Figure 4.20: Mean number of species (number of species per 0.1 m² grab) per infaunal biotope for each major faunal group in the Hornsea Three benthic ecology study area.

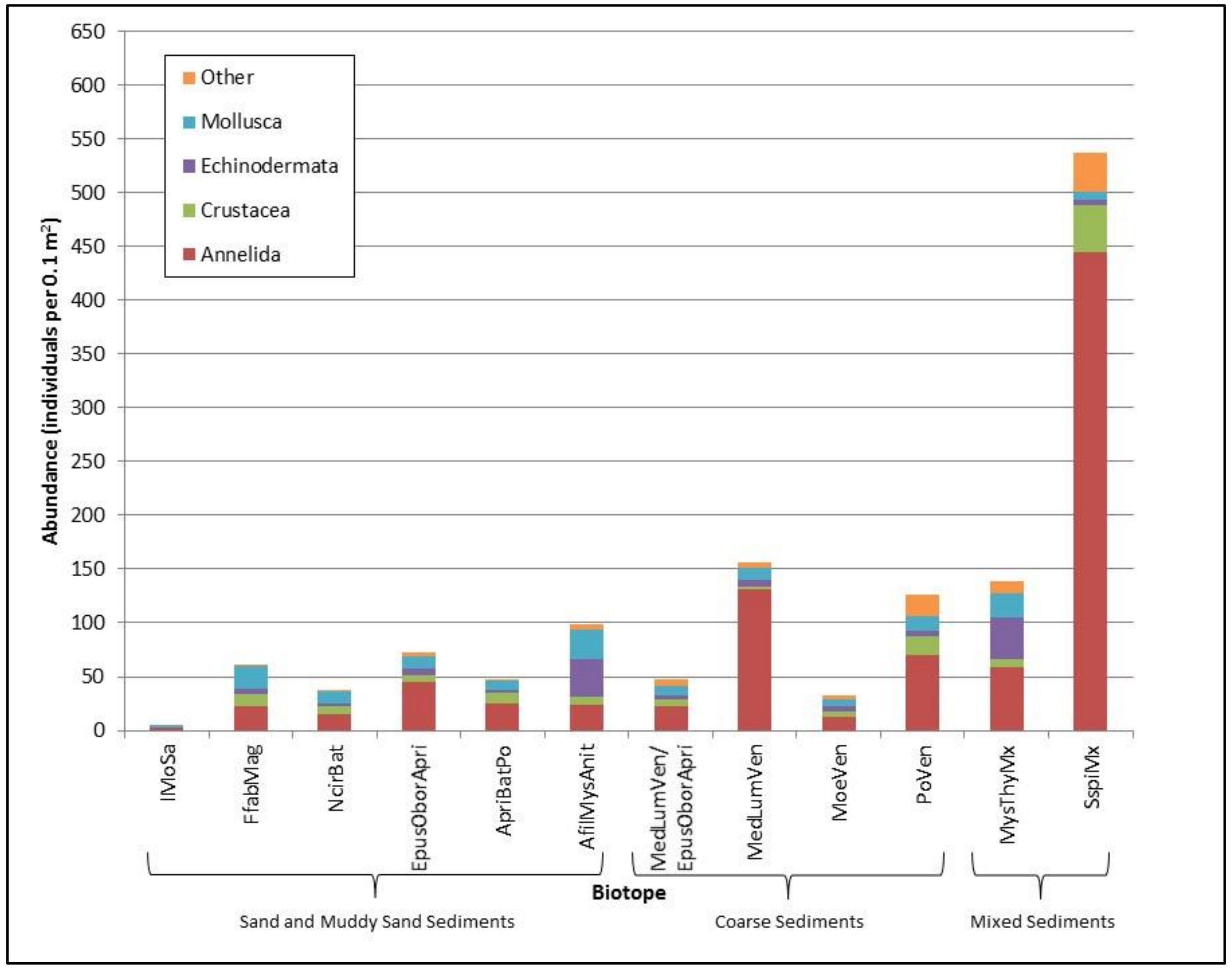

Figure 4.21: Mean abundance (total individuals per 0.1 m² grab) per infaunal biotope for each major faunal group in the Hornsea Three benthic ecology study area.

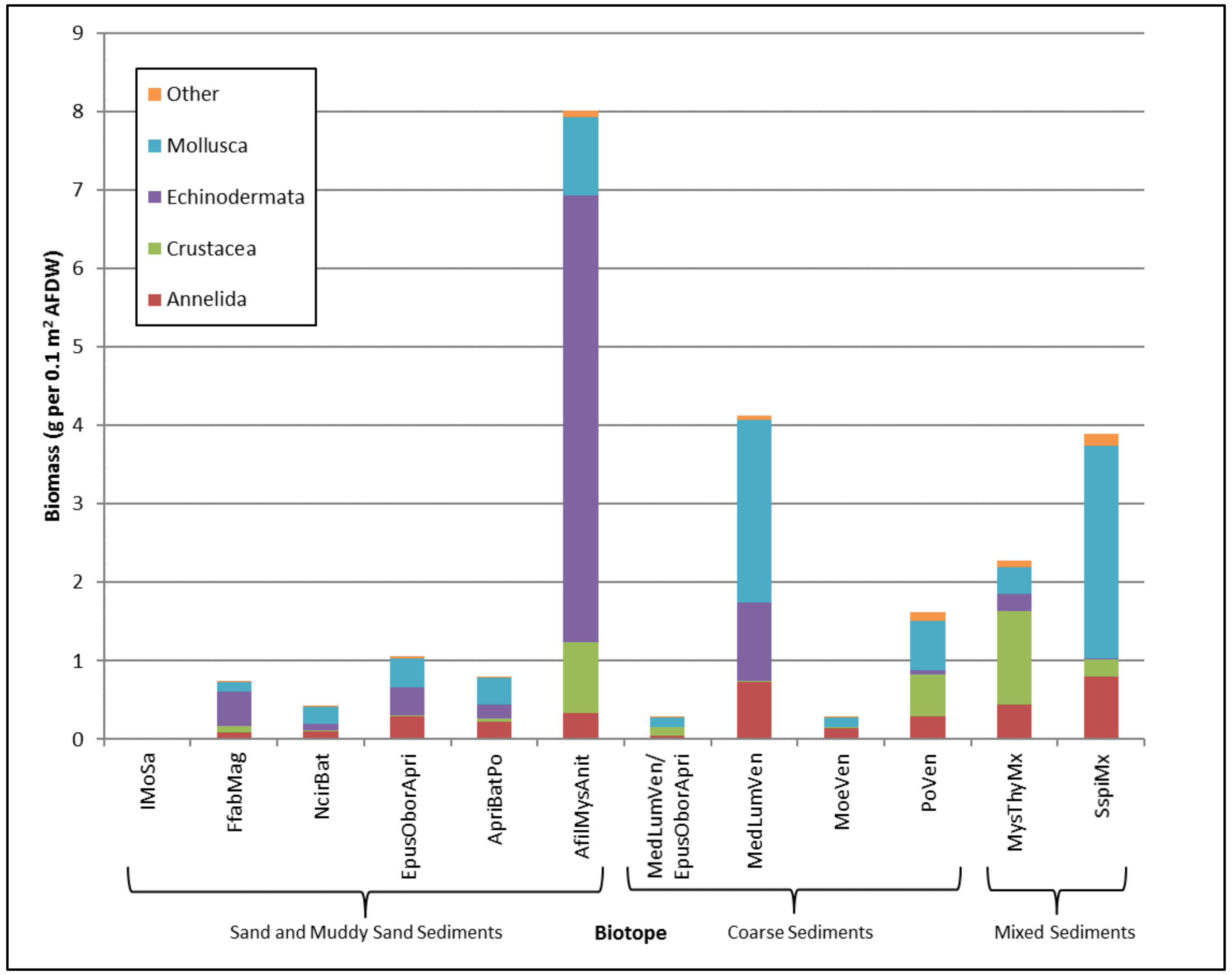

Figure 4.22: Mean biomass (g per 0.1 m² AFDW) per infaunal biotope for each major faunal group in the Hornsea Three benthic ecology study area.

Benthic epifauna

4.1.4.70 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.		

4.1.4.71 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.

4.1.4.72 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

4.1.4.73 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 mean number of species was low for the ScupHyd biotope (17.8 ± 24 species). Mean abundance, standardised over 500 m, was also low for the ScupHyd biotope (179.8 ± 290.8 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 *O. 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). For analysis of colonial species which were not enumerated see paragraph 4.1.4.77 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 ± 24	179.8 ± 290.8	0.5 ± 0.4	1.4 ± 1.3	0.4 ± 0.4
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	0.86 ± 0	0.8 ± 0	0.4 ± 0.0
SS.SMx.CMx	Mixed sediments.	2	32.5 ± 2.1	776 ± 338.3	0.5 ± 0.2	1.8 ± 0.8	0.3 ± 0.2
SS.SMx.CMx. FluHyd	Mixed sediments.	2	16.5 ± 5.78	490.3 ± 684.5	1.2 ± 3.5	1.1 ± 0.2	0.3 ± 0.2
SMx	Mixed sediments.	2	13.6 ± 9.2	448.04 ± 239.6	0.9 ± 0.1	1.05 ± 0	0.9 ± 0.0
XFa	Coarse sediment.	2	19.2 ± 6.4	177.5 ± 0.6	1.7 ± 0	1.8 ± 0.1	0.6 ± 0.0

4.1.4.74 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 except for SMx, indicating that on the whole, the trawl samples were not dominated by a small number of species. The SMx biotope was dominated by the crabs *Liocarcinus* sp. and *Macropodia* sp. and the shrimps *Crangon crangon* and *Pandalus montagui*.

4.1.4.75 Figure 4.23 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 paragraph 4.1.4.73, 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 two trawls 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 4.23). The biotope XFa consisted of the lowest number of taxa and this was reflected in the number of other species, however the number of crustaceans were comparable to those of the other biotopes.

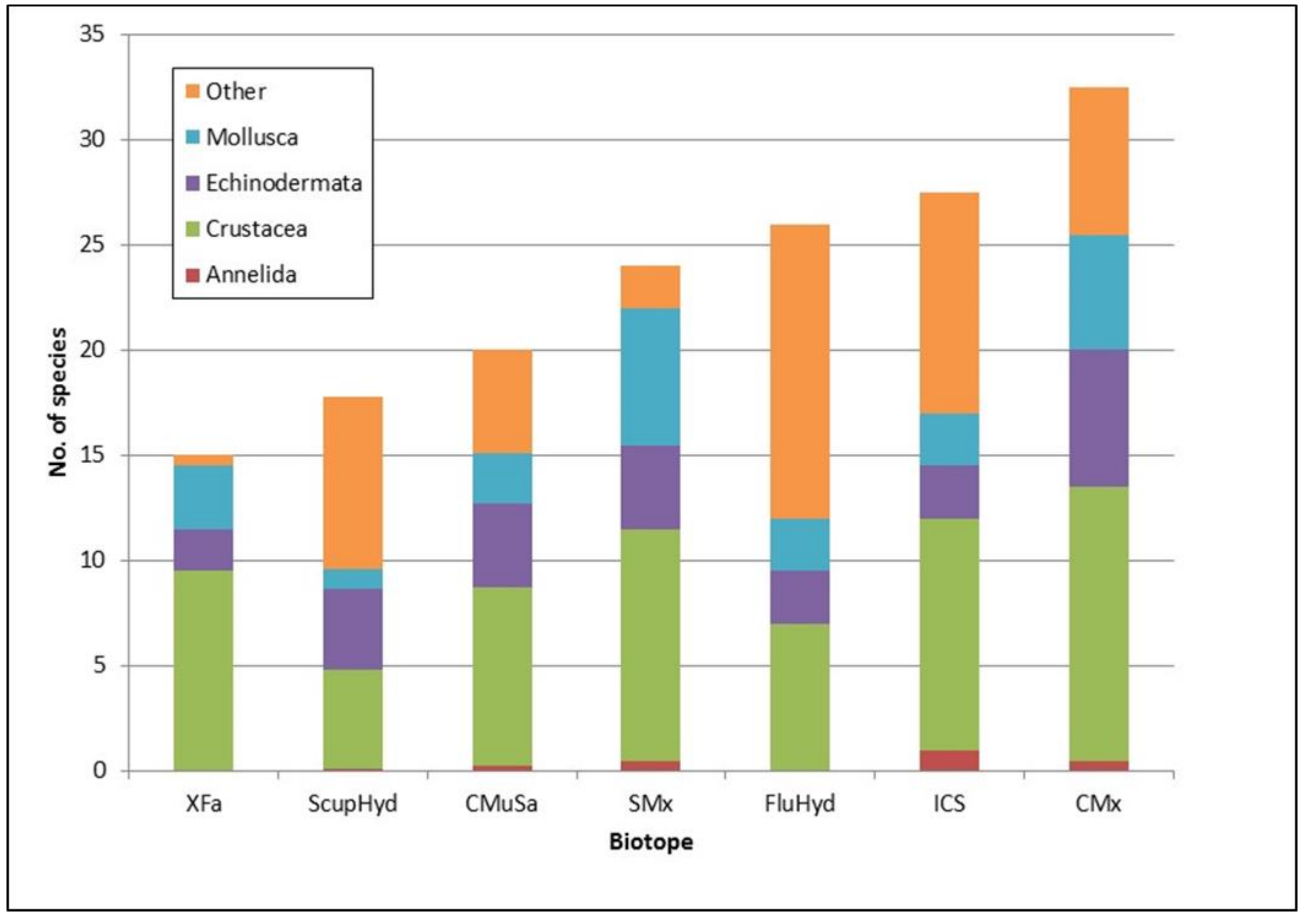

Figure 4.23: Mean number of species for biotopes identified from epibenthic beam trawl data of the Hornsea Three benthic ecology study area.

4.1.4.76 Figure 4.24 shows that the mean abundance was considerably higher for the CMuSa biotope due to the dominance and 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 the ScupHyd and XFa biotopes which were dominated by starfish *A. rubens*. The ICS biotope was dominated by crustaceans 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 be expected to be sampled by epibenthic beam trawl.

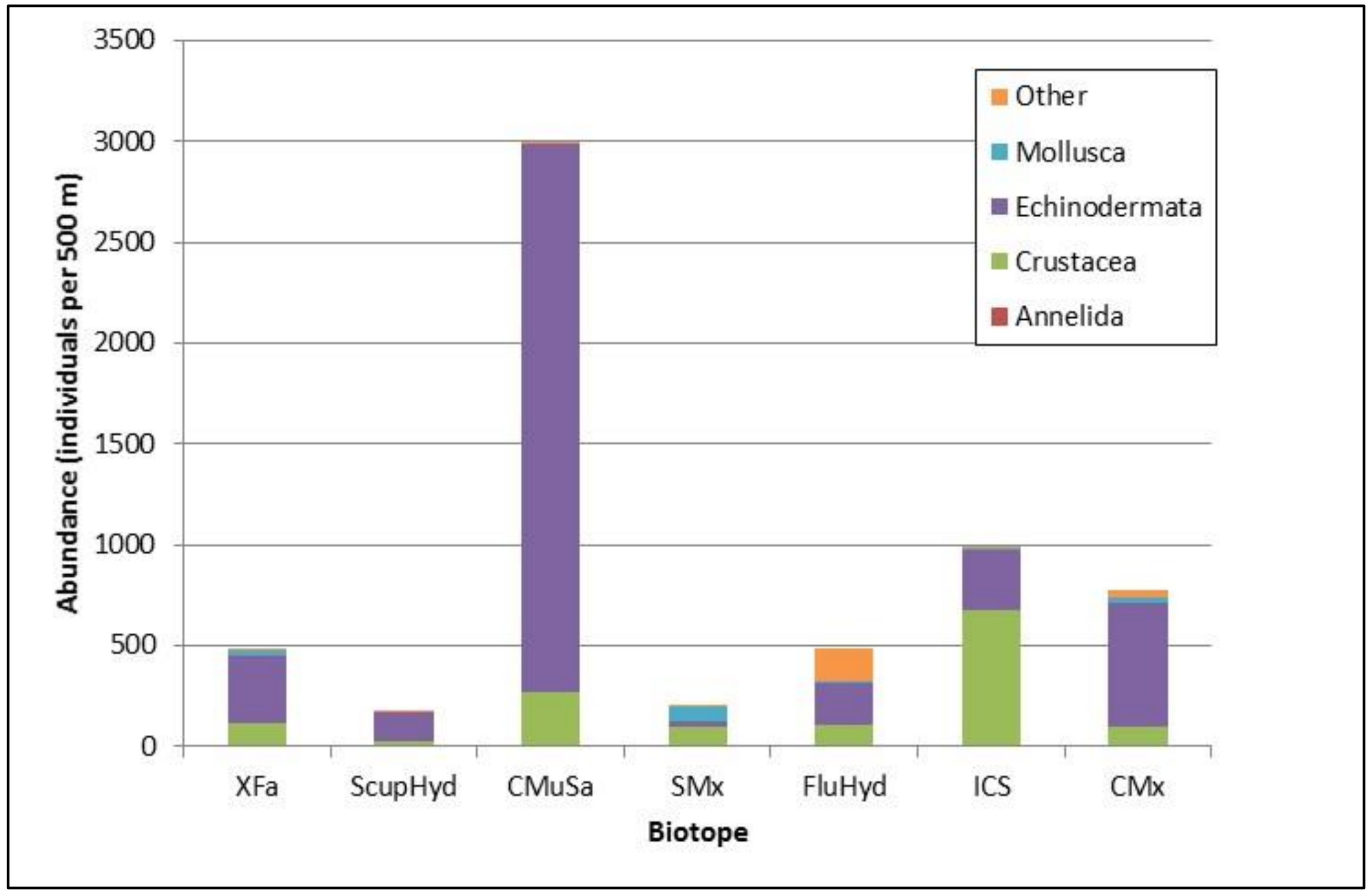

Figure 4.24: Mean abundance (individuals per 500 m) for biotopes identified from epibenthic beam trawl data of the Hornsea Three benthic ecology study area.

4.1.4.77 As discussed in paragraph 4.1.4.73, 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; note that weights were estimated for the five stations on the Hornsea Three offshore cable corridor). These species were the bryozoans *F. foliacea* and *A. diaphanum* and the soft coral *A. digitatum*. Figure 4.25 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, one of the largest volumes of *F. foliacea* observed across the Hornsea Three benthic ecology study area was recorded from a site in the FluHyd biotope. The SMx biotope comprised the highest biomass of *F. foliacea,* with minimal or no records of *A digitatum* or *A. diaphanum*. XFa was the only biotope to include a substantial volume of *A. diaphanum*.

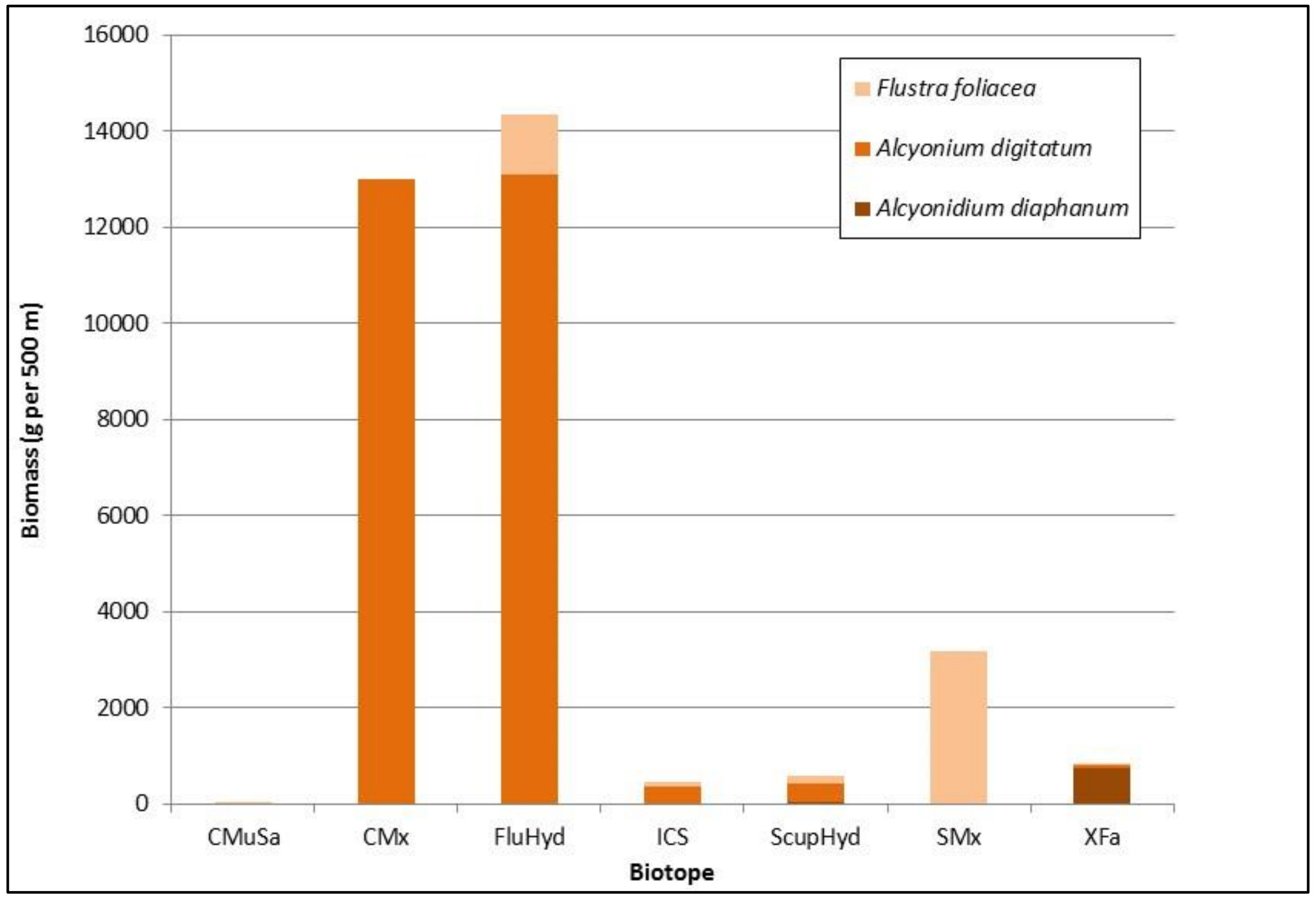

Figure 4.25: Mean biomass (g per 500 m) of key epifaunal species identified from epibenthic beam trawl data of the Hornsea Three benthic ecology study area.

4.1.4.78 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

4.1.4.79 Figure 4.26 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 (Figure 4.6 and Figure 4.14, respectively), 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. As discussed in paragraph 2.6.2.16, the nearshore biotopes are considered holistically in paragraphs 4.1.4.83 to 4.1.4.86 and are presented in Figure 4.28.

4.1.4.80 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, SspiMx and MysThyMx.

4.1.4.81 With respect to the SspiMx biotope, at the locations in the southwest of the former Hornsea Zone where this biotope was assigned to infaunal samples, 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.

4.1.4.82 The combined biotope map shown in Figure 4.26 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 northwest 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, except for 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 and along the Hornsea Three offshore cable corridor. Most of these sediments had typically sparse epibenthic communities, however, some were associated with the FluHyd epibenthic overlay, particularly in the central former Hornsea Zone and along the Hornsea Three offshore cable corridor; and
- Areas of mixed sediments along the Hornsea Three offshore cable corridor, characterised by the SspiMx infaunal biotope, exhibited the FluHyd epifauna biotope.

Nearshore biotopes

4.1.4.83 As described above, the nearshore biotopes identified by the Hornsea Three site specific surveys were found to be characterised primarily by the MoeVen and SspiMx biotopes, with the PoVen biotope characterising the areas further offshore. Within the Cromer Shoal Chalk Beds MCZ and offshore of it, epifaunal communities were characterised by the FluHyd biotope with discrete areas of FluHyd/Pid biotope, particularly in proximity to clay exposures within the MCZ. The most inshore sampling locations were characterised by sandy sediments with relatively impoverished communities, with the NcirBat characterising this area, and a minimal epifaunal component (represented by the IMoSa biotope).

4.1.4.84 These patterns are broadly consistent with the findings of previous surveys in the area (i.e. baseline characterisation and monitoring surveys for Sheringham Shoal and Dudgeon offshore wind farms and surveys within the Wash and North Norfolk coast SAC (see paragraphs 3.1.3.2 *et seq.*)). Biotopes associated with the historic sampling locations in the nearshore section of the Hornsea Three offshore cable route corridor are shown in Figure 4.28. These biotopes classifications have been used to confirm and extend the Hornsea Three biotope map, where site specific survey data were not available within the Hornsea Three cable route corridor.

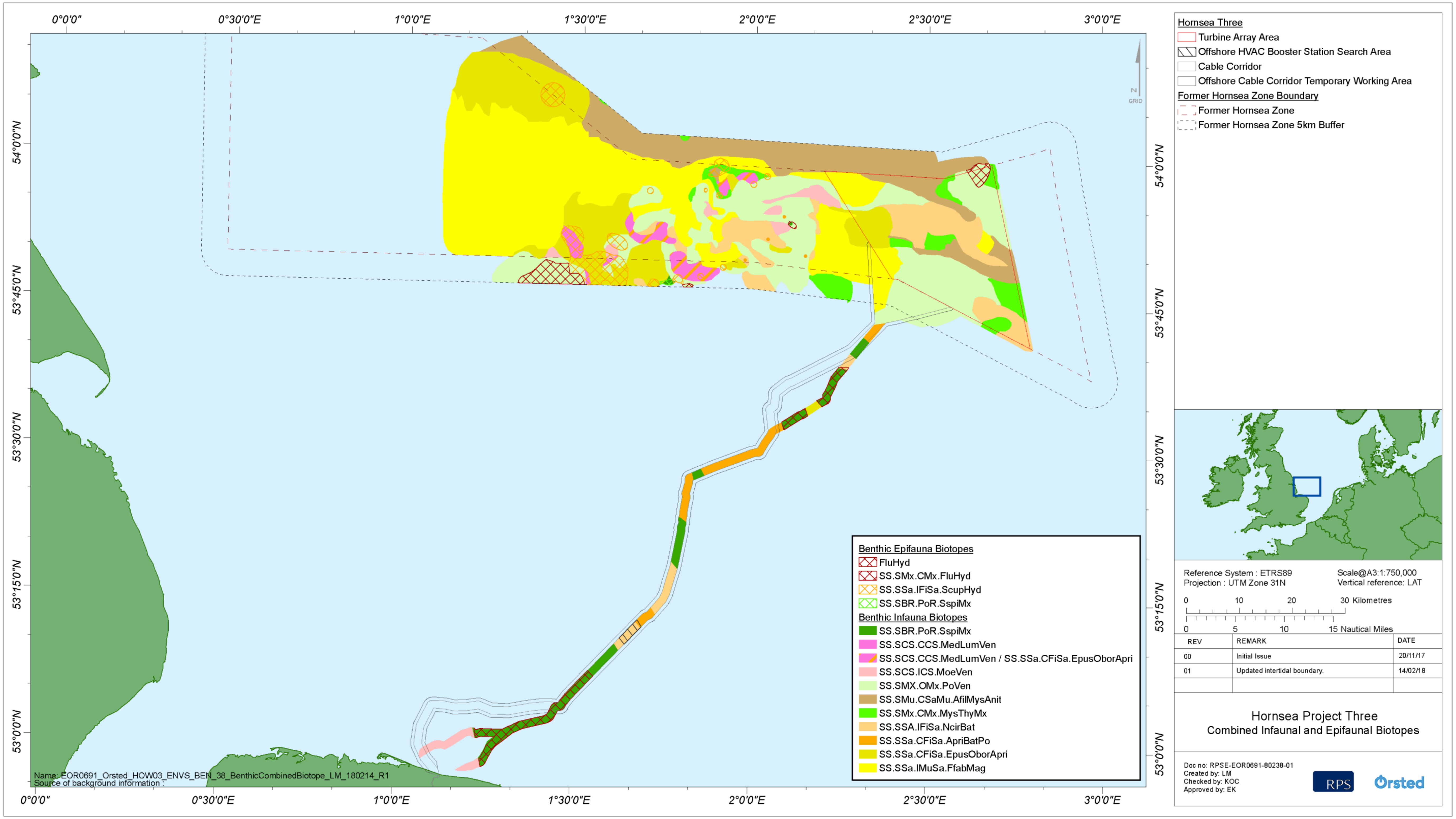

Figure 4.26: Combined infaunal and epifaunal biotope map of the Hornsea Three benthic ecology study area (note the nearshore biotopes are considered holistically in paragraphs 4.1.4.83 to 4.1.4.86 and Figure 4.28).

4.1.4.85 As detailed in paragraph 3.1.3.3, the communities along the Dudgeon offshore cable corridor were characterised by relatively low abundances of polychaetes, crustaceans and bivalve mussels in fine sandy gravel or gravelly sand, with a minimal fine sediment content (Warwick Energy, 2009). These broadly aligned with the MoeVen biotope identified in the Hornsea Three site specific data, along the northern MCZ boundary. Further west of this, the Sheringham Shoal datasets (i.e. Scira Offshore Energy Ltd., 2006; Scira Offshore Energy Ltd., 2014) indicated that the SspiMx biotope dominated the area to the north of the Sheringham Shoal sandbank, with the sandbank itself characterised by the NcirBat biotope and the MoeVen and MedLumVen biotopes characterising the flanks of this. The area to the south of the Sheringham Shoal sandbank was found, in the baseline characterisation (Scira Offshore Energy Ltd., 2006), to be characterised primarily by the SspiMx biotope. This dataset indicated that *S. spinulosa* abundances were considerably lower to the south of the sandbank, with no individuals recorded immediately to the south of the sandbank (consistent with the Hornsea Three site specific data). In the 2014 Sheringham Shoal post construction survey, the communities immediately south of the sandbank were found to be more consistent with the MoeVen biotope, with the bivalve *Goodallia triangularis* and polychaetes characterising this area (Scira Offshore Energy Ltd., 2014), consistent with the Dudgeon and Hornsea Three site specific sampling in this area. The western flank of the sandbank was characterised by the MedLumVen biotope in the Sheringham Shoal baseline characterisation (Scira Offshore Energy Ltd., 2006), which is a more diverse, deeper water variant of the MoeVen biotope (jncc.defra.gov.uk).

4.1.4.86 All surveys indicated that the most inshore part of the Hornsea Three offshore cable corridor was characterised by the NcirBat sandy sediment biotope. These patterns are consistent with the available information on the Wash and North Norfolk Coast SAC, which indicated that this part of the SAC was characterised primarily by communities associated with mixed sediments (e.g. SspiMx and FluHyd) and sandy sediments (e.g. NcirBat; see paragraphs 3.1.3.8 to 3.1.3.10). As discussed above, where data is not available for the Hornsea Three offshore cable corridor, these desktop data sources have been used to extend the biotope maps generated from the Hornsea Three site specific benthic ecology data, to provide a baseline characterisation for the purposes of the EIA.

4.1.4.87 In the most inshore section of the Hornsea Three offshore cable corridor, the Hornsea Three 2017 site specific inshore geophysical survey data identified an area of subcropping rock, to the northwest of the Hornsea Three intertidal zone and within The Wash and North Norfolk Coast SAC. The geophysical data indicated that these areas of subcropping rock were covered by a veneer of sandy sediment of between 0.2 and 3 m depth. Detailed bathymetry data shows that the majority of the seabed surface in this area is characterised by sand ripples of approximately 10 cm elevation and that the subcropping rock comes close to the surface (i.e. sediment veneer of <0.2 cm) in discrete areas. DDV transects were undertaken across this area in October 2017, specifically targeting nine areas where these outcrops were most elevated from the surrounding sediment (see Figure 4.29). The main aim of the survey was to identify areas of potential chalk outcrops which may qualify as chalk reef habitats and/or Annex I stony reef habitats following the criteria identified by Irving (2009; see section 2.6.4).

4.1.4.88 The DDV transects confirmed that the inshore area was characterised primarily by sandy sediments, with rippled sand recorded in both transects and in the geophysical survey interpretation (see Figure 4.29 and Figure 4.27). Where the subcropping rock was interpreted from the geophysical datasets as being close to the surface (i.e. sediment veneer of <0.2 m; i.e. black areas shown in Figure 4.29), increased proportions of mixed coarse sediments, including gravel, cobbles and occasional boulders, were recorded in the DDV footage (see Figure 4.27). The communities associated with these patches of sediments were primarily epifaunal, with faunal turfs comprising hydroids (e.g. *Tubularia indivisa*, *Nemertesia antennina* and *H. falcata*) and bryozoans (e.g. *A. diaphanum* and *F. foliacea*) and other epifauna including barnacles, tubeworms (e.g. *Spirobranchus* sp., low abundances of sponges and the soft coral *A. digitatum*. Sea anemones were also recorded during DDV surveys within these areas of coarser sediments, including, *Sagartia* sp., *Urticina* sp. and *Metridium* sp. and red seaweeds were also recorded, although these were rare. Mobile species recorded in this area included the crustaceans *N. puber* and *C. pagurus* and the sea stars *C. papposus* and *A. rubens*. The communities in these areas were consistent with the FluHyd epifaunal biotope overlay. As indicated in Figure 4.29, DDV transects showed that where these coarse sediments were observed, these were limited in extent and patchy, with areas of rippled sand (e.g. IMoSa) of tens of metres observed in DDV footage separating discrete areas of coarse sediments.

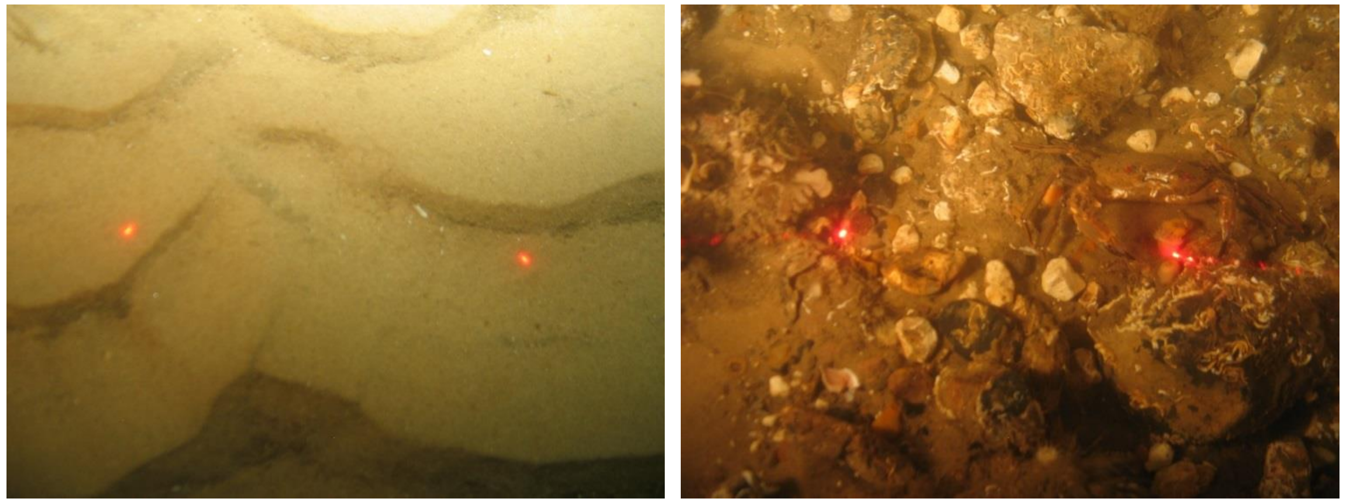

Figure 4.27: Representative images of seabed substrates in inshore areas from DDV transects in areas of subcropping rock (see Figure 4.29). Left image shows rippled sand with no epifaunal communities; right image shows coarse, mixed sediments of shell, gravel and occasional cobbles, with associated epifaunal communities.

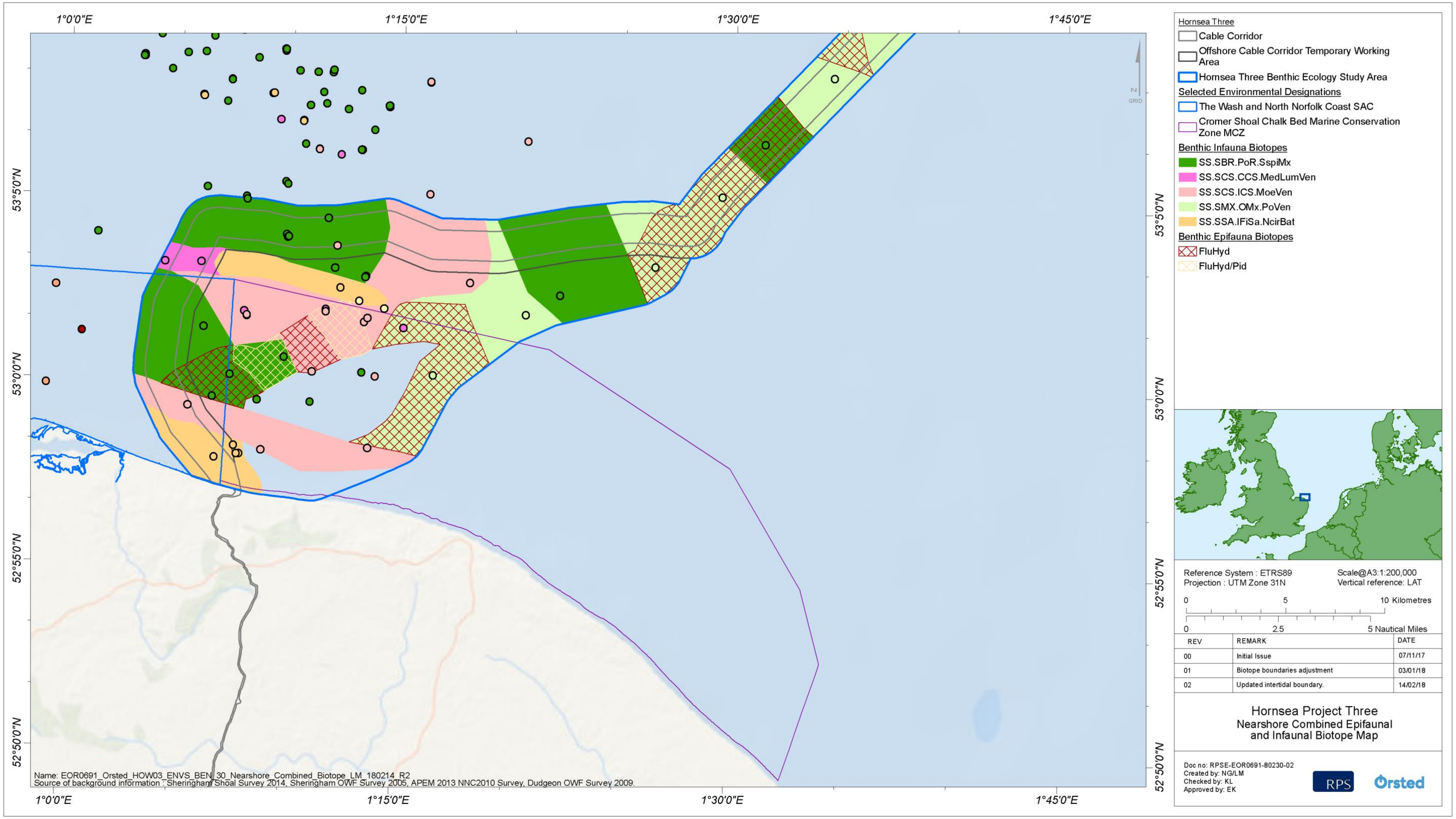

Figure 4.28: Nearshore combined infaunal and epifaunal biotopes in the Hornsea Three benthic ecology study area and infaunal biotopes recorded at nearby desktop data sampling locations.

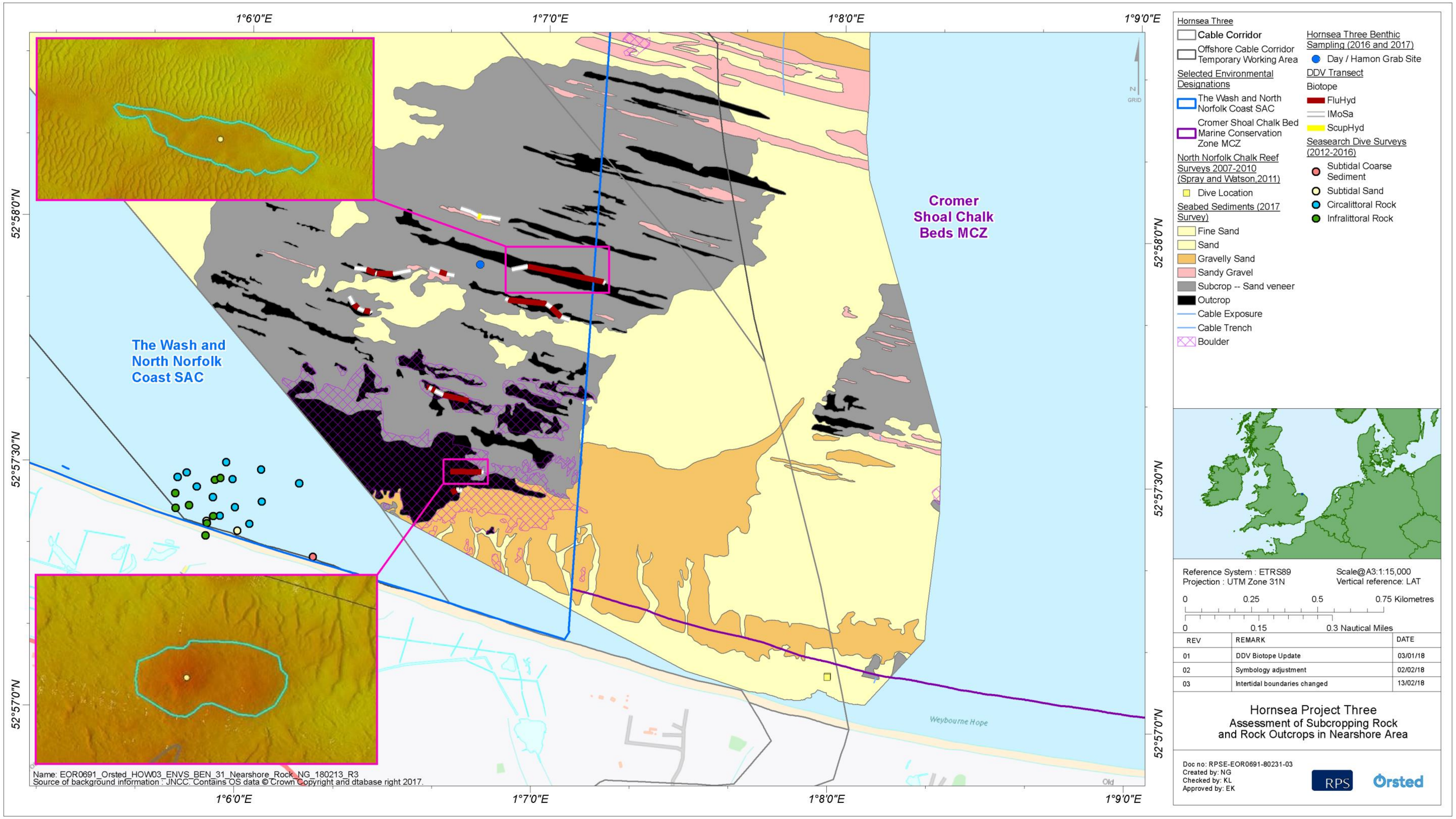

Figure 4.29: Hornsea Three nearshore geophysical seabed interpretation showing subcropping rock (grey) and areas of potential outcrop (black), DDV ground truthing transects with epifaunal biotopes identified and historic records of infralittoral and circalittoral rock in the nearshore area.

Intertidal biotopes

4.1.4.89 The intertidal biotope map for the proposed Hornsea Three offshore cable corridor intertidal zone 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 4.30 presents the intertidal biotope map for the Hornsea Three offshore cable corridor intertidal zone, 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).

4.1.4.90 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 intertidal area. The Hornsea Three intertidal zone was, overall, 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 in the Hornsea Three benthic ecology study area.

4.1.4.91 Part of the beach at Weybourne, in the east of the Hornsea Three intertidal zone, 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.

4.1.4.92 Sediment at the Weybourne section of the Hornsea Three intertidal zone consisted of shingle from MHWS 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 Hornsea Three intertidal zone. 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.

4.1.4.93 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 Hornsea Three intertidal zone 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 Hornsea Three intertidal zone.

4.1.4.94 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 Hornsea Three intertidal zone, like that observed at the lower shore at Weybourne in the east of the intertidal zone, 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 Hornsea Three intertidal zone, 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.

4.1.4.95 Near the MLWS mark throughout the Hornsea Three intertidal zone, 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 mosaic of the LS.LCS.Sh.BarSh and LS.LSa.FiSa biotopes.

4.1.4.96 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.

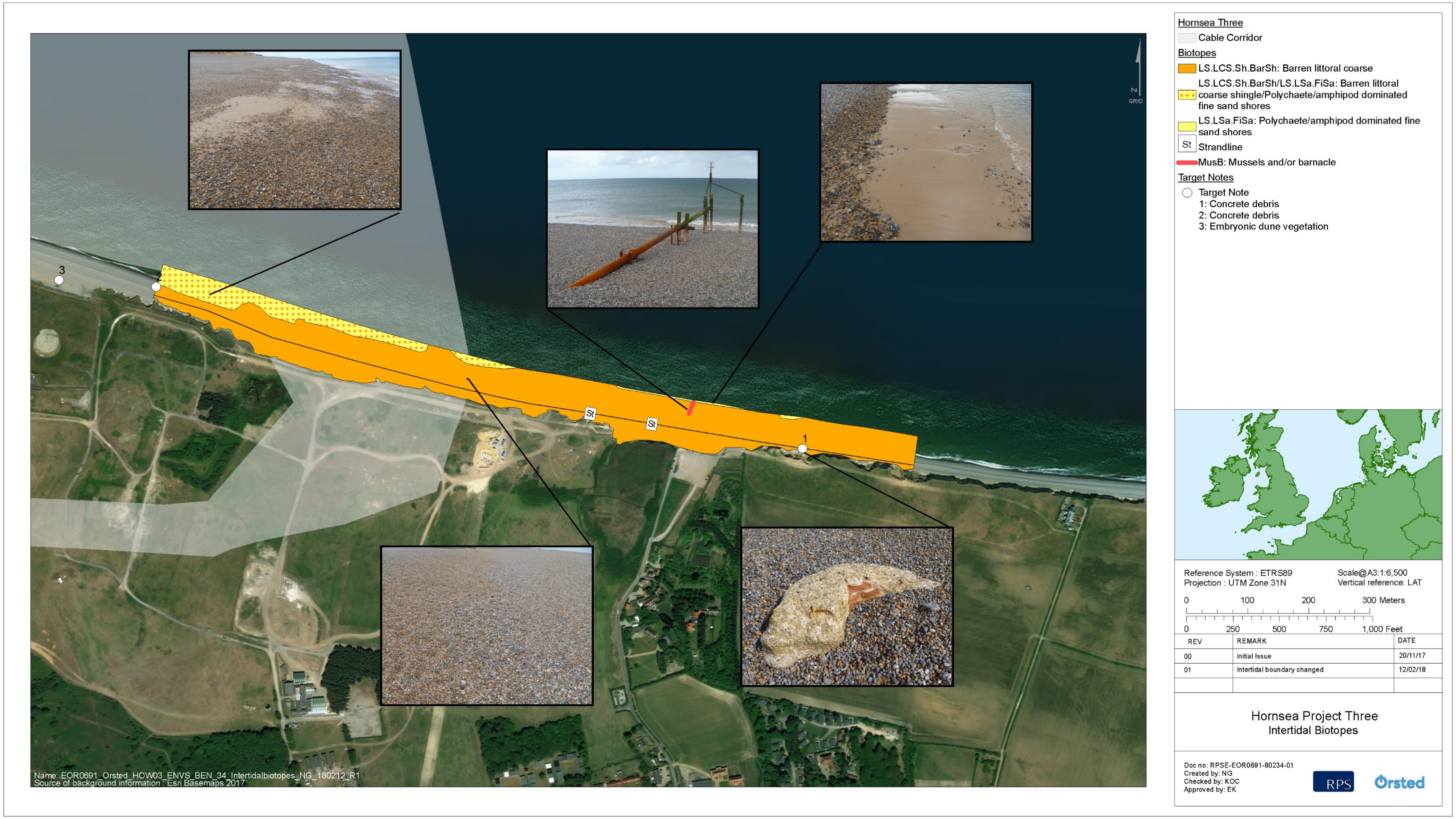

Figure 4.30: Intertidal biotopes at the proposed Hornsea Three offshore intertidal zone at Weybourne and Salthouse, within the Hornsea Three benthic ecology study area.

Table 4.8: Intertidal biotopes identified during the intertidal walkover survey and from dig-over samples taken from the Hornsea Three intertidal zone (see Figure 4.24).

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>

4.1.4.97 Although biogenic *S. spinulosa* reefs are associated with the SspiMx biotope, the occurrence of a *S. spinulosa* biotope does not automatically indicate that a reef is present and, therefore, further scrutiny of the video imagery was necessary.

4.1.4.98 The *S. spinulosa* biotope (SspiMx) was recorded at ten locations along or near the Hornsea Three offshore cable corridor, a full *S. spinulosa* reef assessment was undertaken for sites ECR02, ECR04, 26_CPT_ECR, ECR37 and ECR38 where *S. spinulosa* aggregations were visible in the DDV data (see Figure 3.5). *S. spinulosa* aggregations were generally recorded at station ECR04 in the form of domical mounds, while those at station ECR02 exhibited pavement formations. *S. spinulosa* aggregations at stations 26_CPT_ECR, ECR37 and ECR38 generally comprised a sparse distribution of tubes across the seafloor. It was not possible to delineate the extent of *S. spinulosa* at station ECR04, located within the North Norfolk Sandbanks and Saturn Reef SAC, from the geophysical acoustic data due to the patchiness of the aggregations and the absence of a clear signature in the geophysical (side scan sonar) data, therefore it was not possible to determine the area of the aggregations. 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' for ECR04. 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, therefore it is unlikely that this would be considered Annex I *S. spinulosa* reef habitat.

4.1.4.99 At station ECR02 (approximately 15 km southwest of the Hornsea Three array area boundary and to the north of the northern boundary of the North Norfolk Sandbanks and Saturn Reef SAC; see Figure 3.5), it was possible to delineate an approximate boundary of *S. spinulosa* 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 the patchiness of 70.1% was determined to represent 'high reef', resulting in an overall reef structure score of 'low reef'. However, using expert judgment it was considered appropriate to classify the *S. spinulosa* feature at ECR02 as 'medium reef', given the patchiness far exceeds the threshold of 30% required to achieve high reef for that category. Therefore, it is concluded that there is potential for this aggregation to be considered an *S. spinulosa* reef. Grab sampling was avoided at this station after the notable *S. spinulosa* structure was observed in real-time during DDV operations during the respective benthic survey.

4.1.4.100 No extent was determined for the present distributions of *S. spinulosa* at stations 26_CPT_ECR, ECR37 and ECR38. The *S. spinulosa* aggregations generally comprised areas of thinly distributed tubes. The average elevation at these stations measured under 2 cm and achieved a 'low reef' score in the assessment, while patchiness was described at 4.9% and 8.4% at stations 26_CPT_ECR and ECR38 and determined not to be representative of a reef, while patchiness at ECR37, located within the North Norfolk Sandbanks and Saturn Reef SAC), was measured at 18.3% resulting in low reef. All three areas were concluded to have overall reef structure scores of 'not a reef'.

4.1.4.101 ECR38 was positioned at the edge of an area that was interpreted as being potential *S. spinulosa* aggregation in the geophysical survey data acquired in 2016 (see Figure 3.5). However as discussed above an Annex I reefiness assessment concluded that DDV data from the area represented seabed that was 'not a reef'. Furthermore, a DDV transect (ECR39) performed in the centre of the potential aggregation did not reveal *S. spinulosa* to be present in sufficient densities to warrant a reefiness assessment. Instead, stony habitat was recorded and therefore a stony reef assessment was undertaken, see paragraph 4.1.4.104. The absence of *S. spinulosa* reef structures at this location indicate that the potential reef observed in 2016 geophysical data was either not present at the time, or by 2017 any such structures have since migrated or disappeared, with bottom trawling or the natural ephemeral nature of the *S. spinulosa* reef proposed as possible causes.

4.1.4.102 Similarly, DDV transects performed at the locations of two *S. spinulosa* Annex I reefs previously been mapped by JNCC and Cefas in 2013 showed that these features were no longer present (at least where surveyed by DDV) in 2017 (see Figure 3.5). *S. spinulosa* was present at both locations though an assessment at one concluded 'not a reef' (ECR37) while *S. spinulosa* densities at the other were not visibly sufficient to warrant a reefiness assessment (ECR36). Instead, stony habitat was recorded and a stony reef assessment was undertaken at ECR36, see paragraph 4.1.4.104. The reef structures identified in 2013 were considered to potentially represent the Saturn Reef (originally recorded in 2003) which had migrated west, or, more likely, were new structures and the original Saturn Reef feature had disappeared. The structures identified in 2013 have either disappeared or changed extents such that they were not present at DDV sampling locations 2017. This change was not unexpected and further highlights the ephemeral nature of *S. spinulosa* structures.

4.1.4.103 The full results (including assessment criteria used) of the reefiness assessments are presented in Appendix A, Annex I Reef Assessments.

<u>Stony reef assessment</u>

4.1.4.104 Stony substrate was recorded at five locations along or near the Hornsea Three offshore cable corridor; a full stony reef assessment was undertaken on data from stations ECR24, ECR35, ECR36, ECR38 and ECR39 where stony sediment was visible in the DDV footage (see Figure 4.31). Elevations were observed at between 4.1 cm and 7.6 cm and composition was recorded at between 10.0% and 18.8%. 'Not a reef' was concluded at three locations (ECR24, ECR35 and ECR38), while 'low reef' was determined to be present at the remaining two locations, ECR36 and ECR39, which were located at areas previously found to comprise potential or confirmed Annex I *S. spinulosa* reefs (see Figure 3.5 and Figure 4.31). As discussed in paragraphs 4.1.4.101 and 4.1.4.102, *S. spinulosa* reef structures were not found at these locations in 2017.

4.1.4.105 As detailed in paragraph 4.1.4.87, the Hornsea Three 2017 site specific inshore geophysical survey data identified an area of subcropping rock in the inshore section of the offshore cable corridor, with the subcropping rock interpreted as being close to the surface (i.e. sediment veneer of <0.2 cm) in discrete areas. DDV transects were undertaken across this area in October 2017, specifically targeting nine areas where these outcrops were most elevated from the surrounding sediment (see Figure 4.29). The main aim of these DDV transects were to identify areas of potential chalk outcrops which may qualify as chalk reef habitats and/or Annex I stony reef habitats following the criteria identified by Irving (2009; for stony reefs) and qualitative reefiness descriptions for subtidal chalk reef as provided by Natural England, though the EWG (Note: these broadly aligned with the minimum criteria set out by Irving, 2009). As discussed in 4.1.4.88, these areas were found to be characterised by discrete areas of mixed coarse sediments, surrounding by rippled sand. Elevation of cobbles and/or other rock (including exposed chalk) was found to be less than 64 mm across the entire survey area and the proportion of the seabed comprising either exposed rock or cobbles/boulders was less than 10%. As such, detailed stony reef assessments were not undertaken on the DDV footage, due to the minimum elevation and patchiness criteria for stony reefs and subtidal chalk reefs not being met.

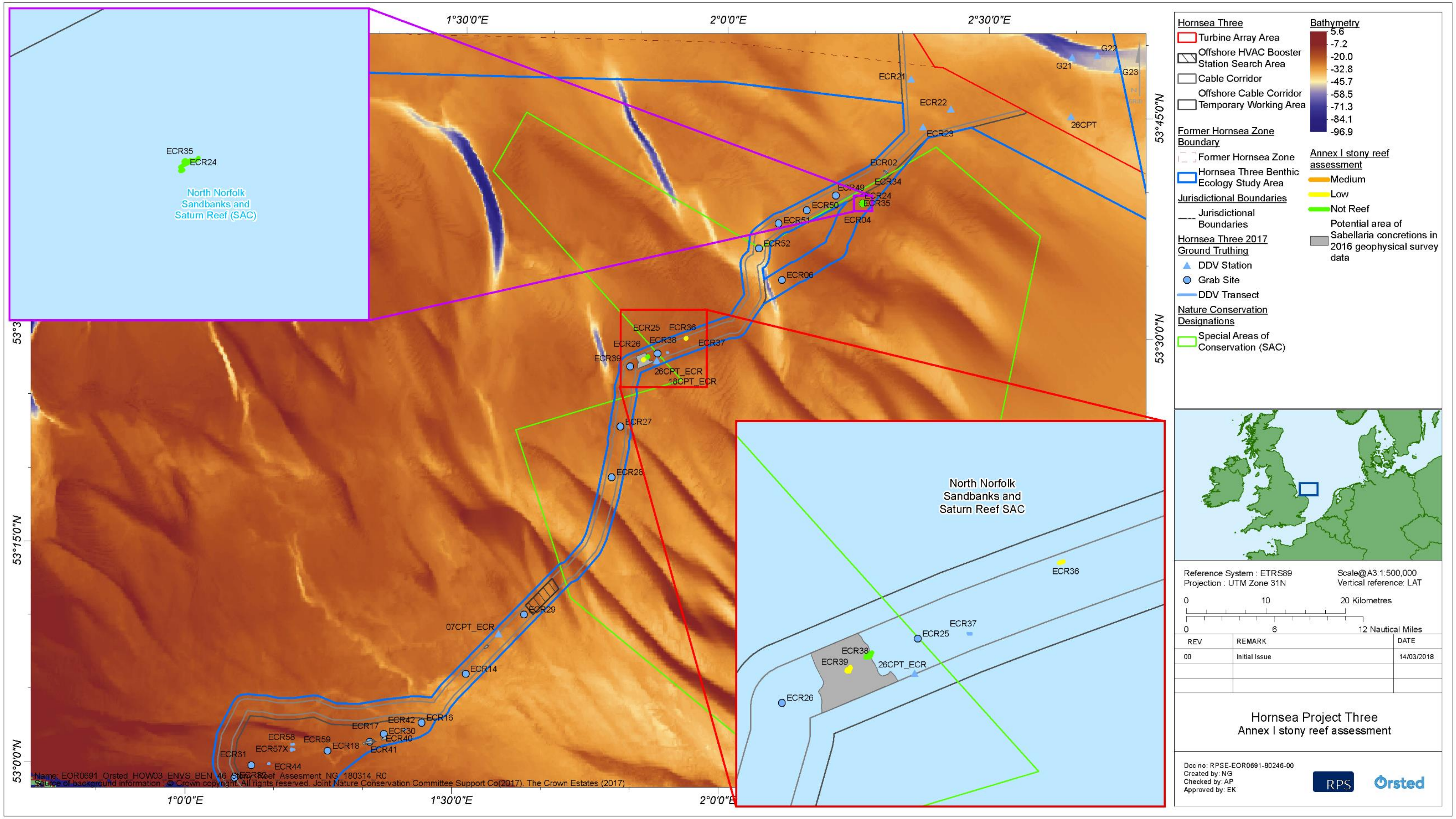

Figure 4.31: The Hornsea Three offshore cable corridor and results of the Hornsea Three site specific survey Annex I stony reef assessments.

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 46% of sample locations. Sandy and muddy sand sediments were found throughout the Hornsea Three benthic ecology study area, though were particularly prevalent 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 historic benthic survey data and Hornsea Three site specific data together with the geophysical interpretation have revealed more complex patterns in the substrate distribution than that predicted by either of these datasets. The intertidal sediments at the Hornsea Three intertidal zone 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 generally 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 the Canadian TEL. It is therefore concluded that the nearshore and 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.

5.2 Benthic Ecology

5.2.1 Subtidal ecology

5.2.1.1 The benthic ecology of the Hornsea Three benthic ecology study area was 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 species is considered further 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, overall, 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 paragraph 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 echinoderms, namely brittlestars. The mixed sediment communities on the Hornsea Three offshore cable corridor differed by being dominated by non-reef forming *S. spinulosa*, though one location in the north of the Hornsea Three offshore cable corridor was found to potentially represent *S. spinulosa* reef. 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 intertidal zone. 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 Hornsea Three intertidal zone 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 3.1.3.36 to 3.1.3.56.

5.2.3.2 Several conservation designations within the Hornsea Three benthic ecology study area ZoI have been screened out from further assessment in the Environmental Statement (chapter 2: Benthic Ecology), based on the findings of the PEIR and chapter 1: Marine Processes, where no impact pathway is considered to exist between Hornsea Three and the benthic ecology receptors of these conservation sites.

5.2.3.3 The following international designations have been screened out:

- North Norfolk Coast SAC;
- Haisborough, Hammond and Winterton SAC;
- Klaverbank SCI; and
- North Norfolk Coast Ramsar

5.2.3.4 The following national designations have been screened out:

- North Norfolk Coast SSSI
- Scolt Head Island; Holkham; and Blakeney. NNRs

5.2.3.5 The proposed national designation, Wash Approach rMCZ, has also been screened out.

International designations included in the assessment

Natura 2000 sites

Natura 2000 sites which fall within the southern North Sea benthic ecology study area, and which have the potential to be affected by Hornsea Three project are:

- The Wash and North Norfolk Coast SAC (sandbanks which are slightly covered by seawater all the time and reefs); and
- North Norfolk Sandbanks and Saturn Reef SAC (sandbanks which are slightly covered by seawater all the time and reefs).

Annex I habitats

5.2.3.6 The Annex I habitat ‘sandbanks which are slightly covered by seawater all the time’ is a feature of both the North Norfolk Sandbanks and Saturn Reef SAC and the Wash and North Norfolk Coast SAC. Effects of Hornsea Three have been assessed against this feature within each of these sites in the Environmental Statement (volume 2, chapter 2: Benthic Ecology).

5.2.3.7 *S. spinulosa* biotopes (SspiMx) were recorded in the Hornsea Three benthic ecology study area and particularly throughout the Hornsea Three offshore cable corridor. The site specific surveys targeted areas of *S. spinulosa* reef found by Cefas in 2013 (Jenkins *et al*., 2015), and areas of *S. spinulosa* aggregations identified in the site specific geophysical data, to further characterise the potential for *S. spinulosa* reefs on the Hornsea Three offshore cable corridor. During the *S. spinulosa* reefiness assessment one discrete area at the northern end of the Hornsea Three offshore cable corridor was determined to comprise 'low reef' owing to the relatively low mean elevation of 3.6 cm, however using expert judgement it was concluded that, given the consistently high coverage of the concretion (70.1%) and the substantial extent (0.084 km^2), that it should be regarded as 'medium reef'. As such, there is potential for this feature to be considered an *S. spinulosa* reef. This *S. spinulosa* reef, which is not located within an SAC, has the potential to be affected by Hornsea Three and is therefore assessed in the Environmental Statement (volume 2, chapter 2: Benthic Ecology).

National designations included in the assessment

5.2.3.8 The MCZ and rMCZ and their associated benthic habitats which coincide with, or have the potential to be affected by Hornsea Three are:

- Cromer Shoal Chalk Beds MCZ (Moderate energy circalittoral rock, high energy circalittoral rock, subtidal chalk, subtidal coarse sediment, subtidal mixed sediments, subtidal sand and peat and clay exposures); and
- Markham's Triangle rMCZ (Subtidal coarse sediment, subtidal sand, subtidal mixed sediments).

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, 2016; IEEM, 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, OSPAR, BAP, and southern North Sea MNA).

5.3.1.2 As discussed in paragraph 3.1.3.53, one MCZ within the vicinity of the Hornsea Three benthic ecology study area, Markham's Triangle rMCZ has not yet been designated (Defra, 2013). However, this site is recommended and will be considered within the third tranche, therefore habitats and species which are listed as conservation priorities in the national plans for this rMCZ 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 and Ramsar sites). Habitats (and species) protected under international law (i.e. Natura 2000 sites (Annex I habitats within an SAC boundary)). OSPAR List of Threatened and/or Declining Species and Habitats.
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. 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.

5.3.1.4 For the purposes of conducting the EIA, the biotopes present across the Hornsea Three benthic ecology study area have been grouped into five broad habitat/community types. The biotopes have been grouped, where appropriate, according to the results of the statistical analyses described in this report. Habitats with similar physical, biological characteristics (including species complement and richness/diversity) 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 because of similar broad sediment types and species complements, were grouped together.

5.3.1.5 Features of nature conservation designations have also been considered as VERs, together with the species of conservation interest, *A. islandica*, which was found within the Hornsea Three benthic ecology study area. The overall value of each VER was determined using the criteria presented in Table 5.1. These VERs will be used to assess impacts associated with the construction, operation and decommissioning of Hornsea Three on benthic ecology within the Hornsea Three and wider southern North Sea benthic ecology study areas. Table 5.2 provides a summary of these VERs within the Hornsea Three benthic ecology study area.

5.3.1.6 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.The VERs that comprise Annex I habitat features of SACs and broad scale habitats features of MCZ/rMCZs (Table 5.2) are not mapped in Figure 5.1, these will be assessed as separate VERs, as appropriate, within the Environmental Statement (volume 2, chapter 2: Benthic Ecology). The biotope representative of peat clay exposures, FluHyd/Pid, is shown in Figure 4.28. the entire area of North Norfolk Sandbanks and Saturn Reef SAC is considered to be representative of ‘sandbanks which are slightly covered by seawater all the time’ (Figure 3.5). While subcropping rock, likely to be chalk, has been identified on the Hornsea Three offshore cable corridor (Figure 4.29), this is not outcrop above the overlying sediments to comprise a subtidal chalk reef.

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	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: *S. spinulosa* reef outside an SAC/SCI with high infaunal and epifaunal diversity	SspiMx	Annex I Habitats Directive	OSPAR habitat: *S. spinulosa* reefs. Qualifying feature of the North Norfolk Sandbanks and Saturn Reef SCI and the Wash and North Norfolk Coast SAC.	One discrete area at the northern area of the Hornsea Three offshore cable corridor.	*S. spinulosa* reefs have been found in the Wash, Thames Estuary, along the South Coast, Bristol channel, Northumberland coast, southern North Sea, North and west of Wales and several locations around Scotland.	National – although it qualifies as *S. spinulosa* reef habitat, it does not form part of a European designated site.
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 within the Hornsea Three project area or within an MCZ/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.
Annex I habitat features of SACs						
'Sandbanks which are slightly covered by seawater all the time'	n/a	Annex I Habitats Directive	UK BAP priority habitat. Qualifying feature of the North Norfolk Sandbanks and Saturn Reef SCI and the Wash and North Norfolk Coast SAC.	Hornsea Three offshore cable corridor coincides with the North Norfolk Sandbanks and Saturn Reef SAC, the entirety of which is considered a representative functioning example of this Annex I feature and is considered and designated as one integrated sandbank system.	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 Sandbanks and Saturn Reef SCI and the Wash and North Norfolk Coast SAC, North Norfolk Sandbanks and Saturn Reef SCI, the Wash and North Norfolk Coast SAC and Haisborough, Hammond and Winterton SCI).

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
Reefs (biogenic reefs, circalittoral rock and stony reefs)	SspiMx	Annex I Habitats Directive	OSPAR habitat: *S. spinulosa* reefs. UK BAP priority habitat. Qualifying feature of the North Norfolk Sandbanks and Saturn Reef SCI and the Wash and North Norfolk Coast SAC.	*S. spinulosa* reef habitats have historically been recorded within the North Norfolk Sandbanks and Saturn Reef SAC near the Hornsea Three offshore cable corridor. Circalittoral rock has been recorded historically in the west of the Hornsea Three intertidal zone within the Wash and North Norfolk Coast SAC.	*S. spinulosa* reefs have been found in the Wash, Thames Estuary, along the South Coast, Bristol channel, Northumberland coast, southern North Sea, North and west of Wales and several locations around Scotland.	International – part of European designated sites (i.e. North Norfolk Sandbanks and Saturn Reef SCI, and the Wash and North Norfolk Coast SAC).
Broad Scale Habitats: Features of MCZ/rMCZs						
Subtidal coarse sediments	MedLumVen/EpusOborApri, MedLumVen, MoeVen, MysThyMx, PoVen, ScupHyd, FluHyd.	MCZ	Protected feature within the Cromer Shoal Chalk Beds MCZ. Feature proposed for designation within the Markham's Triangle rMCZ.	This habitat was recorded throughout the Hornsea Three benthic ecology study area, including within the Markham's Triangle rMCZ, Cromer Shoal Chalk Beds MCZ and Wash and North Norfolk Coast SAC.	These biotopes have been recorded around the UK coast including principally in the Irish Sea and the English Channel.	National - Protected feature of the Cromer Shoal Chalk Beds MCZ and proposed feature for designation of Markham's Triangle rMCZ. .
Subtidal sand	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. Feature proposed for designation within the Markham's Triangle rMCZ.	This habitat was recorded throughout the Hornsea Three benthic ecology study area, including within the Markham's Triangle rMCZ, Cromer Shoal Chalk Beds MCZ and Wash and North Norfolk Coast SAC.	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 – Protected feature of the Cromer Shoal Chalk Beds MCZ and proposed feature for designation of Markham's Triangle rMCZ.
Subtidal mixed sediments	SspiMx	MCZ	Protected feature within the Cromer Shoal Chalk Beds MCZ. Feature proposed for designation within the Markham's Triangle rMCZ.	This habitat was recorded throughout the Hornsea Three benthic ecology study area, including within the Markham's Triangle rMCZ, Cromer Shoal Chalk Beds MCZ and Wash and North Norfolk Coast SAC.	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 – Protected feature of the Cromer Shoal Chalk Beds MCZ and proposed feature for designation of Markham's Triangle rMCZ. .
Subtidal chalk reef	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 showing this habitat located to the south and east of the Hornsea Three offshore cable corridor.	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 – Protected feature of the Cromer Shoal Chalk Beds MCZ.
Peat and clay exposures	FluHyd/Pid	MCZ	UK BAP priority habitat. Protected feature within the Cromer Shoal Chalk Beds MCZ.	Recorded in north of Cromer Shoal Chalk Beds MCZ, as reported in desktop study and Hornsea Three site specific surveys (paragraph 4.1.4.48) . Located to the south and east of the Hornsea Three offshore cable corridor.	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.

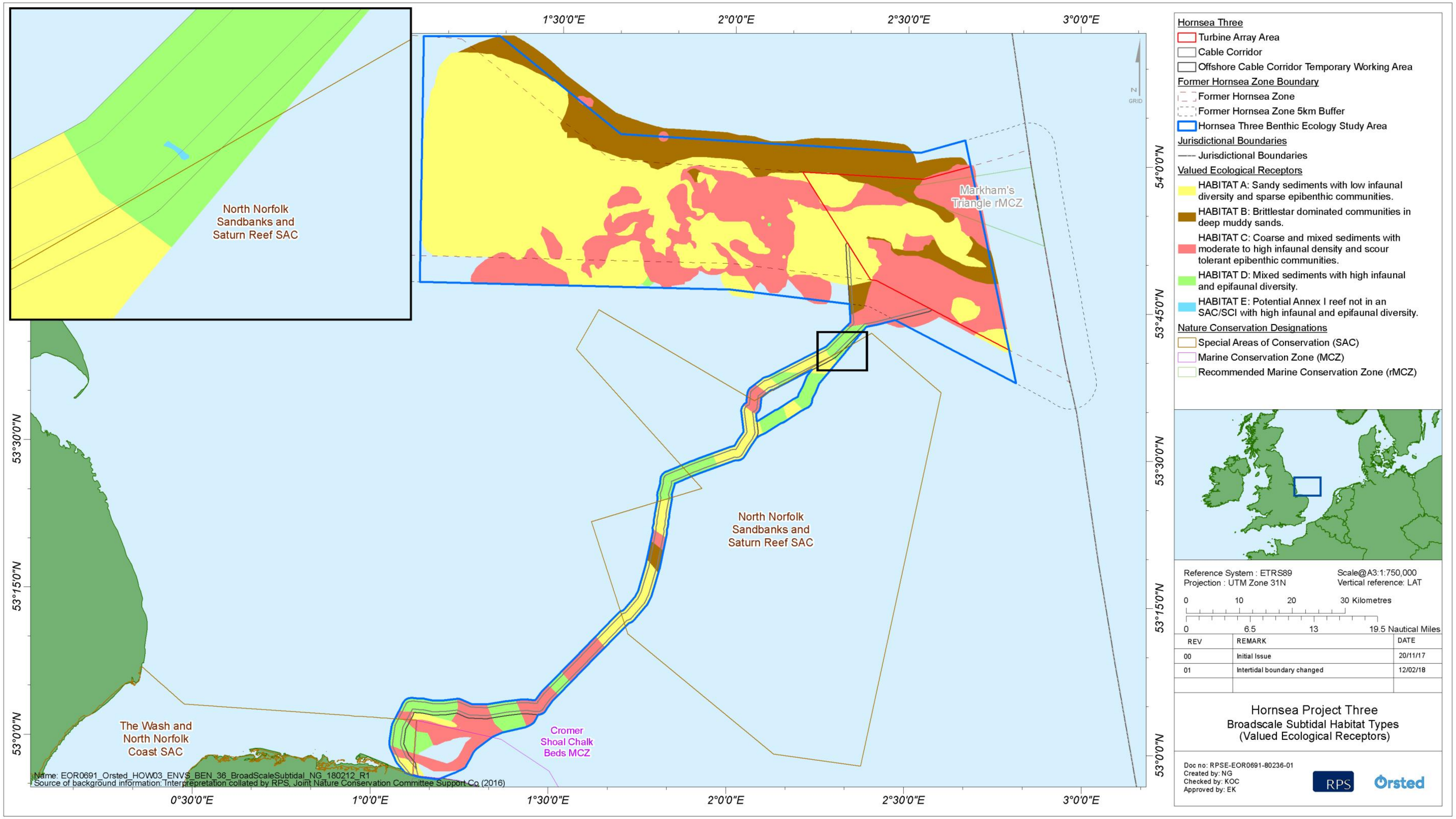

Figure 5.1: Subtidal Valued Ecological Receptors (VERs) in the Hornsea Three benthic ecology study area.

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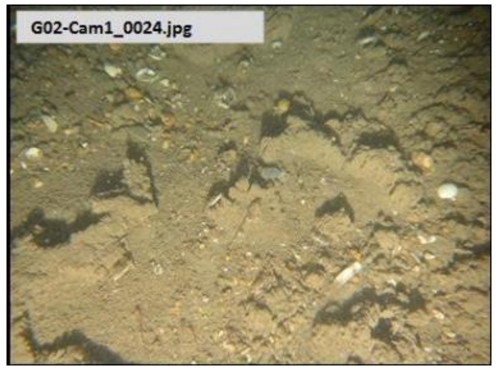
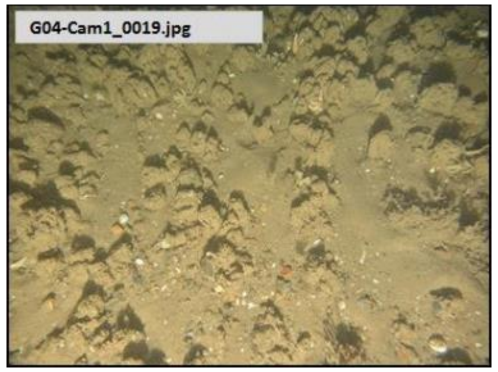
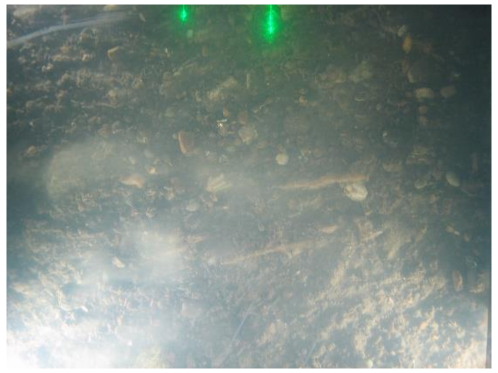
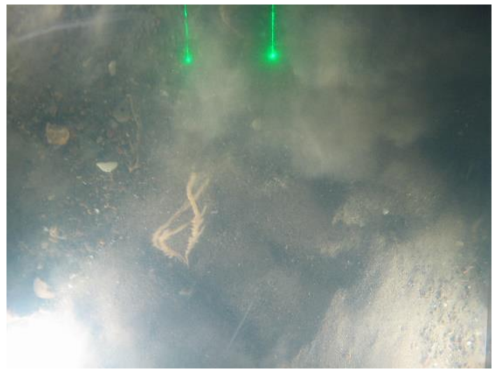
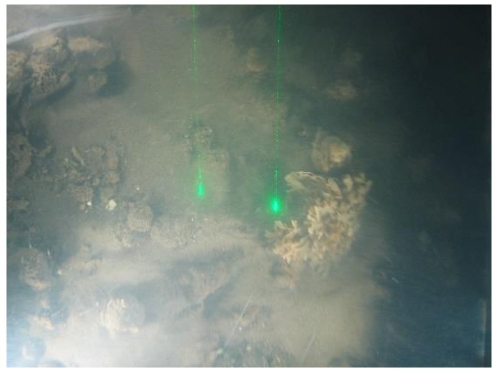
Appendix A Annex I Reef Assessments

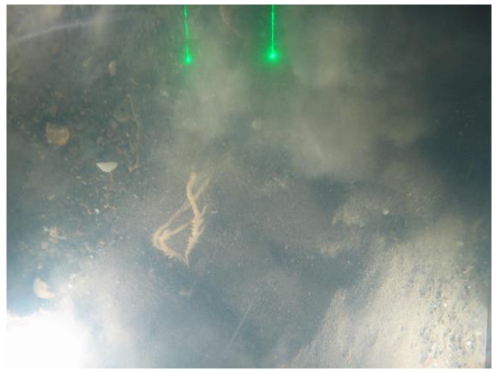
Sabellaria spinulosa reef assessment

Site	Sediment description	*Sabellaria* characteristics			Representative Image	Reef definition		Reefiness
		Elevation	Patchiness	Brief description of reef		Elevation	Patchiness	
ECR02	Rippled sand and occasional boulders.	3.6 cm	70.1%	*Sabellaria* was identified in consistent 'pavement' formations over sediment comprising rippled sand and occasional boulders.		Low reef	High reef	Low reef, however based on expert judgement this aggregation was determined to represent medium reef because of the very high percentage coverage.
ECR04	Rippled sand and occasional boulders.	2.7 cm	17.0%	*Sabellaria* was recorded with a large scale patchy distribution as domical mounds punctuating the rippled sand and occasional boulders. The habitiat boundary was not distinguishable.		Low reef	Low reef	Low reef
26_CPT_ECR	Gravel with sand, occasional shell fragments and biogenic accretions	<2 cm	4.9%	*Sabellaria spinulosa* was observed, classified offshore as areas of thinly distributed tubes		Low reef	Not reef	Not reef

Site	Sediment description	*Sabellaria* characteristics			Representative Image	Reef definition		Reefiness
		Elevation	Patchiness	Brief description of reef		Elevation	Patchiness	
ECR37	Gravelly sand	<2 cm	18.3%	Possible *Sabellaria* tubes and rubble/veneer		Not reef	Low reef	Not reef
ECR38	Gravelly sand	<2 cm	8.4%	Possible *Sabellaria* tubes and rubble/veneer		Not reef	Not reef	Not reef

Annex I stony reef assessment

Site	Sediment Description	Elevation (cm)	Composition (% cover)	Representative Image	Reef definition		Reefiness
					Elevation	Composition	
ECR24	Rippled sand with shell fragments and pebbles and occasional cobbles	5.6	10.0		Not reef	Low	Not reef
ECR35	Gravelly sand with occasional cobbles	4.8	10.9		Not reef	Low	Not reef
ECR36	Gravelly sand	6.4	18.2		Medium reef	Low	Low

Site	Sediment Description	Elevation (cm)	Composition (% cover)	Representative Image	Reef definition		Reefiness
					Elevation	Composition	
ECR38	Gravelly sand	4.1	13.2		Not reef	Low	Not reef
ECR39	Gravelly sand	7.6	18.8		Medium reef	Low	Low