Rampion 2 Wind Farm

Category 6: Environmental Statement

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Section	Description	Page

Contents

List of Figures

List of Tables

List of Plates

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Abbreviations

AIS	Automatic Identification System
AL1	Action Level 1
AL2	Action Level 2
AFDW	Ash Free Dry Weight
AfL	Agreement for Lease
BAC	Background Assessment Concentration
BIIGLE	Bio-Image Indexing and Graphical Labelling Environment
BSH	Broadscale Habitat
CLOC	Clear Liquid Optical Chamber
CPI	Carbon Preference Index
CSQG	Canadian Sediment Quality Guideline
DCO	Development Consent Order
DDV	Drop-Down Video
DTI	Department of Trade and Industry
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ERL	Effect Range Low
ES	Environmental Statement
EUNIS	European Nature Information System
GPS	Global Positioning System
HC	Hydrocarbon
HD	High Definition
HOCI	Habitats of Conservation Interest
HRA	Habitat Regulation Assessment
HM	Heavy Metals
HMW	High Molecular Weight
IDA	Industrial Denatured Alcohol
INNS	Invasive, non-native species
ISQG	International Sediment Quality Guideline
JNCC	Joint Nature Conservation Committee
LED	Light-Emitting Diode
LMW	Low Molecular Weight
LOI	Loss on ignition
MBES	Multibeam Echosounder
MCA	Marine and Coastal Agency
MCZ	Marine Conservation Zone
MEDIN	Marine Environmental Data and Information Network
MLC	Maximum Likelihood Classification
MLWS	Mean Low Water Springs
MP	Megapixel
NMBAQC	NE Atlantic Marine Biological Quality Control
nMDS	Non-Metric Multi-Dimensional Scaling

NERC	Natural Environment Research Council
NTS	Non-Technical Summary
OEL	Ocean Ecology Ltd
OWF	Offshore Wind Farm
PAH	Polycyclic Aromatic Hydrocarbon
PCA	Principal Component Analysis
PEL	Probable Effect Level
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PSD	Particle Size Distribution
QMS	Quality Management System
RED	Rampion Extension Development
RSMP	Regional Seabed Monitoring Programme
SAC	Special Area of Conservation
SD	Standard Deviation
SE	Standard Error
SNCI	Site of Nature Conservation Interest
SOP	Standard Operating Procedures
SSS	Side-Scan Sonar
TCE	The Crown Estate
TEL	Threshold Effect Level
THC	Total Hydrocarbon Content
TOC	Total Organic Carbon
TOM	Total Organic Matter
TOR	Terms of Reference
TRI	Terrain Ruggedness Index
UK BAP	UK Biodiversity Action Plan
UTM	Universal Transverse Mercator

Executive Summary

Rampion Extension Development (RED) has applied for development consent to develop a new offshore wind project, Rampion 2, adjacent to the existing Rampion Offshore Wind Farm (Rampion 1). Rampion was developed following the United Kingdom Round 3 offshore wind development programme run by The Crown Estate (TCE) in 2009. Rampion 2 is located within the English Channel, 14km off the coast of Brighton and Hove and approximately 30km east of the Isle of Wight.

The Rampion 2 offshore export cable route corridor lies to the immediate west of the Kingmere Marine Conservation Zone (MCZ) which protects a range of rocky habitats and subtidal chalk reef systems covered with a thin veneer of mixed sediments. Located to the south of the export cable route and array area is the Offshore Overfalls MCZ. The seabed within this MCZ is predominantly coarse sediment with areas of sand, mixed sediments and exposed bedrock which support a diverse range of fauna such as sponges, hydroids, sea urchins and burrowing worms.

This report presents the full set of results of the seabed imagery, sediment composition and chemistry, macrobenthic analysis and predictive habitat mapping with the aim of setting out the environmental baseline conditions across the proposed Rampion 2 proposed DCO Order Limits As this report was produced prior to further refinements to the offshore proposed DCO order limits, the results are explained in the context of the larger previous ES Assessment Boundary, but still apply to the now smaller proposed DCO order limits as shown in Figure 1. The results will also inform the Environmental Statement (ES) and Non-Technical Summary (NTS) for the Development Consent Order (DCO) and application to the Planning Inspectorate (PINS). Following delays to the subtidal survey as a result of sustained periods of unsuitable weather, a subset of this information including initial predictive habitat mapping was used to inform the Preliminary Environmental Information Report (PEIR) published in July 2021.

The benthic subtidal study area, See **Figure 1** was designed to provide adequate coverage of the Rampion 2 offshore export cable corridor and array areas where previous sampling coverage was deemed to be limited whilst ensuring representative examples of all sediment types and potential features of conservation importance were targeted. The key principles underpinning the survey design were to:

- Provide adequate spatial coverage of the Rampion 2 offshore export cable corridor and array areas;
- Ensure representative sampling of all main sediment types was undertaken; and
- Ensure representative examples of all potential features of conservation interest (including habitats of conservation importance (HOCI) and black seabream nest sites) were adequately ground-truthed.

Seabed imagery was collected using a high-definition optical camera system. Benthic grab sampling was conducted using a 0.1m^2 mini-Hamon grab to obtain macrobenthic

and sediment samples (particle size analysis (PSA) and chemical analysis). A total of 39 camera transects, 23 drop-down Video (DDV), and 39 successful grab locations were sampled throughout the duration of the survey.

A habitat assessment carried out across the identified areas of bedrock reef, stony reef and *Sabellaria* reef across the nearshore export cable corridor and western areas of the . The bedrock reef habitats present were representative of subtidal chalk and peat and clay exposures. Both these features are considered habitats of principle importance in England under Section 41 of the Natural Environment Research Council (NERC) Act (2006). The stony reef habitats across the development site were assessed to be of both low and medium resemblance. These stony reef habitats were considered representative of the habitat of principle importance ‘Fragile sponge and anthozoan communities on subtidal rocky habitats’. Observations of *Sabellaria* reef were deemed to be low resemblance reef across the development site and representative of A5.611 - *Sabellaria spinulosa on stable circalittoral mixed sediment* and A4.221 - *Sabellaria spinulosa encrusted circalittoral rock.*

Some variation in sediment types was observed across the ES Assessment Boundary; however, most stations were dominated by sand. Mud content was highest closer to land and towards the east, while gravel content varied across the survey area. These types of sediment are among the most common habitats found in subtidal settings across the UK coast and fall in the list of habitats of principal importance under Section 41 of the NERC Act (2006) England ‘Subtidal sands and gravels’ and ‘Subtidal mixed muddy sediments’.

Sediment chemistry analysis identified As (Arsenic) as the most abundant metal with Cr (Chromium) the most frequently occurring above OSPAR Background Assessment Concentration (BAC) levels. All other metals were present in concentrations either below detection limits or below reference levels. Among all polycyclic aromatic hydrocarbons (PAHs), only Phenanthrene and Pyrene were found at concentrations above detection limits at two stations. However, reference levels were not exceeded. Total hydrocarbon content (THC) was higher west of the study area compared to the remaining sampled locations. However, when assessing the source origin of hydrocarbons based on the Carbon Preference Index (CPI), it resulted that all but 1 station had hydrocarbons of biogenic origin.

A diverse macrobenthic community was identified across the ES Assessment Boundary with a total of 1,489 individuals and 232 taxa recorded. Most stations were characterised by the presence of Nemertea which occurred in 57.6% of the samples, while the polychaete *Spirobranchus lamarcki* was the most abundant species across the study area. Macrobenthic abundance and richness varied across the study area, with a higher abundance and diversity identified for the stations located furthest inshore and west of the study area. The invasive non-native species *Crepidula fornicata* was recorded forming aggregations at the two grab samples collected closest to land and was also observed in 114 images across the nearshore area of the study area.

The main EUNIS classifications identified across the included both rocky and sediment habitats. Seabed imagery was crucial in the identification of rocky EUNIS habitats and biotopes while grab samples were helpful in assigning biotopes at a finer level where sediments were present. The most common EUNIS biotopes and habitats encountered across the ES Assessment Boundary were A4.13 - Mixed faunal turf communities on circalittoral rock, A4.23 - Communities on soft circalittoral rock, A4.214 - Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock, A5.14 - Circalittoral coarse sediment, A5.261 - *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment, A5.142 - *Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel, A5.131 - Sparse fauna on highly mobile sublittoral shingle (cobbles and pebbles) and A5.233 - *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand.

A predictive habitat mapping exercise was undertaken to provide full coverage mapping for the survey area and to inform **Chapter 9: Benthic Subtidal and Intertidal ecology, Volume 2** of the ES (Document Reference: 6.2.9). This was based on the newly acquired site specific acoustic data and existing ground-truthing data available for the study area. The predictive seabed habitat model was then updated to include the benthic grab samples collected during this survey which resulted in changes to the final predictive mapping output reported previously in the PEIR (Ocean Ecology Limited 2021). Several new biotopes were introduced in these new models and notable increases in correctly classified pixels were observed throughout all maps. A reduction in the % of correct predictions and overall accuracy was also observed and can be explained by the small increase in multiple classifications coupled with the size of the survey area. A good ratio of both training and validation data was required to make a meaningful contribution to the model output.

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1. Introduction

1.1. Project Overview

RED is applying for development consent to develop a new offshore wind project, Rampion 2, adjacent to the existing Rampion 1 Offshore Wind Farm (OWF). Rampion was developed following the United Kingdom Round 3 offshore wind development programme run by TCE in 2009. Rampion 2 is located within the English Channel, 14km off the coast of Brighton and Hove and approximately 30km east of the Isle of Wight. (Figure 1).

RED applied to TCE for an extension to the Rampion Wind Farm in 2018 and following approval under the plan-led Habitats Regulations Assessment (HRA), was awarded development rights for Rampion 2 in 2019 and an Agreement for Lease (AfL) for the extension area with TCE in September 2020. It is one of seven extension proposals that passed TCE's plan led HRA process and is required to connect into the onshore transmission or distribution networks at an existing substation 'node'.

The comprises both the seabed area conditionally awarded under the TCE Round 3 extension process and development within the remainder of the original Round 3 Zone 6 area. The aggregate of these two seabed areas would be optimised to form a single extension development giving rise to a single application for a Development Consent.

As part of this process, a series of onshore and offshore surveys have been undertaken to gather baseline datasets relating to a series of onshore and offshore disciplines ranging from air quality to benthic ecology.

1.2. Site Information

1.2.1. Designated Sites

Kingmere Marine Conservation Zone (MCZ)

The offshore export cable route lies to the immediate west of the Kingmere MCZ (Figure 1) which is located between 5 and 10km off the West Sussex coast to the south of Littlehampton and Worthing and covers an area of ~47km^2. The MCZ contains a range of rocky habitats and subtidal chalk reef systems covered with a thin veneer of mixed sediments, which are important for biodiversity as they support a wide range of marine life. The area is also an important spawning site of the black seabream (*Spondyliosoma cantharus*) within the UK, providing ideal nesting areas.

The MCZ also contains two marine Sites of Nature Conservation Interest (SNCI) known as Kingmere Rocks and Worthing Lumps. Kingmere Rocks is the main reef within the MCZ covering an area of 500m wide by 6km in length of sandstone and mudstone boulders. Worthing Lumps is a chalk outcrop representing some of the best underwater chalk cliffs in Sussex.

Offshore Overfalls Marine Conservation Zone (MCZ)

Located to the south of the offshore export cable corridor and array area, and approximately 18km east of the southern point of the Isle of Wight is the Offshore Overfalls MCZ, an area of 594km^2 (Figure 1). The seabed within the MCZ is predominantly coarse sediment with areas of sand, mixed sediments and exposed bedrock which support a diverse range of fauna such as sponges, hydroids, sea urchins and burrowing worms. The site also protects the geological English Channel Outburst feature, which was formed at the end of the last glaciation by the collapse of ice sheets or glaciers.

1.2.2. Habitats of Conservation Interest (HOCI)

The following HOCI have the potential to be located within the ES Assessment Boundary.

Reefs

Stony Reef

Stony reef habitats occur when stable hard substrata, namely cobbles and boulders >64mm in diameter arise from the surrounding habitat, creating a habitat colonised by a variety of species. Numerous Special Areas of Conservation (SAC) sites have been designated under Annex I of the EC Habitats Directive in UK waters to protect stony reef habitats and associated communities. In some circumstances, these communities can also be representative of the Habitat of Principle Importance ‘Fragile sponge and anthozoan communities on subtidal rocky habitats’ protected under the Section 41 of the NERC Act 2006.

Communities associated with stony reefs can be highly diverse, supporting assemblages of various coral, sponges, ascidians, fish, and crustaceans. These associated communities vary dramatically according to environmental variables and may incorporate species that occupy a range of trophic levels. The complexity of habitat created by stony reefs often supports a higher abundance of mobile fauna such as echinoderms and various crabs, hermit crabs, and squat lobsters, as well as fish species for which these species represent key prey items.

Bedrock Reef

Similar to stony reef, bedrock reef habitat occurs where soft (e.g., clay) or hard bedrock arises from the surrounding seabed, providing a stable habitat for attachment for a diverse range of epibiota. Bedrock reefs and associated biological communities can be highly variable due to the diverse nature of these habitats in terms of topography, structural complexity, and exposure to tidal streams. In the photic zone communities associated with bedrock reefs are often dominated by attached algae, and often support various invertebrate species such as corals, sponges, and sea squirts. These epibiotic communities further increase structural complexity and represent key prey items that in turn attract more mobile and commercially valuable species such as fish and crustaceans. As with stony reefs, numerous SAC sites have been designated under Annex I of the EC Habitats Directive in UK waters and can, in some circumstances, be representative of the Habitat of Principle Importance 'Fragile sponge and anthozoan communities on subtidal rocky habitats' protected under the Section 41 of the NERC Act 2006.

Sabellaria Reef

Sabellaria reefs are biogenic habitats formed by sedentary filter-feeding polychaete worms belonging to the family Sabellariidae habitats and are also protected under Annex I of the EC Habitats Directive in UK waters when occurring in marine protected areas (e.g., SACs). Two species are found in the UK, the honeycomb worm (*Sabellaria 15amose15te*) and the Ross worm (*Sabellaria spinulosa*). Both are gregarious species and can form biogenic reef colonies that can cover hundreds of thousands of square meters of seabed (Jenkins et al. 2018) and similarly large areas of intertidal lower shore (Dubois et al. 2002). Subtidal structures and associated communities can also be representative of the Habitat of Principle Importance '*Sabellaria spinulosa* reefs' protected under the Section 41 of the NERC Act 2006.

Biogenic reefs formed by *Sabellaria* spp. Are thought to benefit wider ecosystem functioning. Their structures are topographically complex, with features such as standing water, crevices and consolidated fine sediments providing microhabitats for other organisms and high levels of biodiversity (Limpenny et al. 2010, Pearce et al. 2011). The associated communities can vary according to local conditions of salinity, water movement, depth, and turbidity.

Fragile Sponge and Anthozoan Communities on Subtidal Rocky Habitats

This habitat is listed as a habitat of principle importance in England under Section 41 of the NERC Act (2006), these communities are found on bedrock which is locally sheltered but close to tide-swept or wave exposed areas. They are dominated by large, slow growing species such as branching sponges and sea fans. The branching sponges include species such as *Axinella dissimilis, Axinella damicornis, Axinella infundibuliformis, Homaxinella subdola* and to a lesser extent *Raspailia* and *Stelligera* species. Other sponge species which may be present include *Dysidea fragilis*, *Pachymatisma johnstonia, Esperiopsis fucorum, Hemimycale columella, Cliona celata, Stelligera rigida, Polymastia boletiformis, Polymastia mamillaris, Stelligera stuposa, Raspailia 15amose* and *Tethya aurantium.*

A silty hydroid/bryozoan turf may develop in the understorey of this rich sponge assemblage, with species such as *Aglaophenia pluma, Cellaria sinuosa, Bugula 15amose15te15, Bugula plumosa* and *Bugula 15amose15te*, and crisiids. Larger species of hydroids such as *Nemertesia antennina* and *Nemertesia 15amose* may be present prominent surfaces together with the bryozoans *Pentapora foliacea* and *Alcyonidium* *diaphanum*. Other fauna includes aggregations of the colonial ascidians *Clavelina lepadiformis* and *Stolonica socialis*, together with the yellow cluster anemone *Parazoanthus axinellae* (UK BAP 2008).

Peat and Clay Exposures

This habitat is listed as a habitat of principle importance in England under Section 41 of the NERC Act (2006). It occurs on circalittoral soft rock, such as soft chalk or clay, most often in moderately exposed tide-swept conditions. As soft chalk and firm clay are often too soft for sessile filter-feeding animals to attach and thrive in large numbers, an extremely impoverished epifauna results on upward-facing surfaces, although vertical faces may be somewhat richer. The rock is sufficiently soft to be bored by bivalves. Species vary with location, but *Pholas dactylus* is the most widespread borer and may be abundant. Other species present may include the sponges *Dysidea fragilis* and *Suberites carnosus* and the polychaete *Bispira volutacornis*. Foliose red algae may be present on the harder, more stable areas of rock. Mobile fauna often include the crabs *necora puber* and *Cancer pagurus* (Connor et al. 2004, UK BAP 2008).

Subtidal Sands and Gravels

Subtidal sands and gravel sediments are listed as a habitat of principle importance in England under Section 41 of the NERC Act (2006) and are considered the most common habitats found below the level of the lowest low tide around the coast of the UK. The sands and gravels found to the west of the UK (English Channel and Irish Sea) are largely shell derived, whereas those from the North Sea are largely formed from rock material.

Sublittoral sand and gravel habitats occur in a wide variety of environments, from sheltered (sea lochs, enclosed bays, and estuaries) to highly exposed conditions (open coast). The particle structure of these habitats ranges from mainly sand, through various combinations of sand and gravel, to mainly gravel. While very large areas of seabed are covered by sand and gravel in various mixes, much of this area is covered by only very thin deposits over bedrock, glacial drift, or mud. The strength of tidal currents and exposure to wave action are important determinants of the topography and stability of sand and gravel habitats (UK BAP 2008).

Subtidal Chalk

Subtidal chalk is listed as a habitat of principle importance in England under Section 41 of the NERC Act (2006). A characteristic of chalk coasts, in contrast to many harder rocky coasts of western and northern Britain is the geomorphological structure in which, because of subaerial and marine erosion, a vertical cliff face abuts an extensive foreshore (a wave eroded platform) often extending several hundreds of metres seawards. This is of significance in the formation of subtidal chalk sea caves and reefs habitats and the occurrence of the associated communities/biotopes (Tittley et al. 1998).

The most extensive areas of sublittoral chalk in Britain occur in Kent and Sussex. In southeast England shallow subtidal (up to 5m) communities are limited or absent due to the unusual friable and easily eroded nature of chalk and the prevailing harsh environment, characterised by extreme water temperatures, high levels of turbidity, siltation and scouring. In these conditions, it is difficult to undertake subtidal surveys and hence the extent of this habitat and its associated communities are not well documented (Tittley et al. 1998). However, less robust species (e.g. large seaweeds) which are more prone to scouring are replaced by more opportunistic species. As a result, the shallow subtidal is dominated by animals and communities that are low in species richness reflecting the hostile environment.

1.1. Report Scope

This report presents the results of the seabed imagery, sediment composition and chemistry, macrobenthic analysis and predictive mapping, with the aim of setting out the environmental baseline conditions across the proposed ES Assessment Boundary to inform the ES which will accompany the DCO application.

The grab sampling data has undergone detailed statistical analysis to provide a comprehensive account of the biological and physio-chemical status of the seabed substrates. Habitats and biotopes have been mapped through interpretation of the seabed imagery analysis which, in combination with analysis of the grab samples, have been used to delineate HOCI occurring within the survey area.

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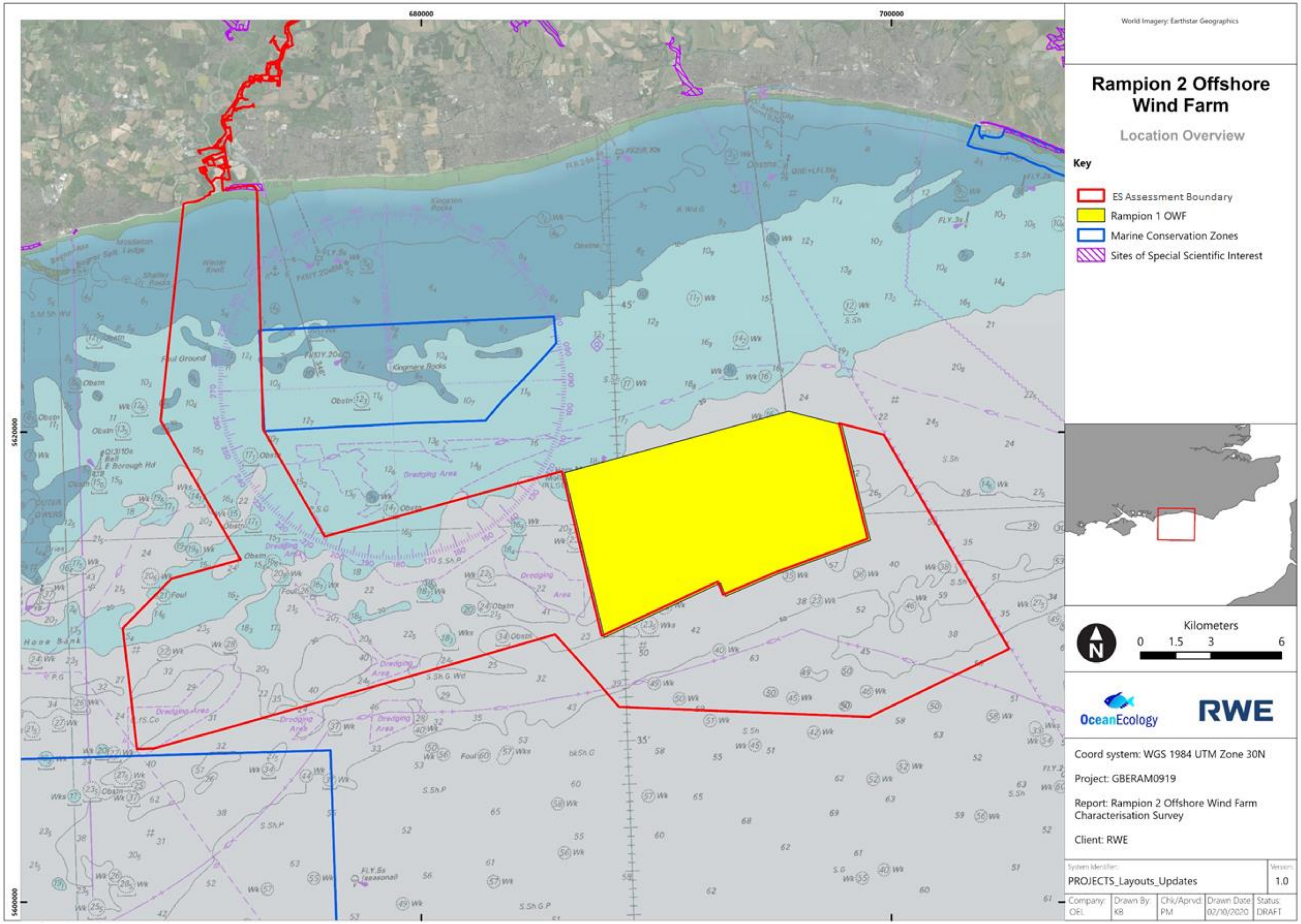

Figure 1 ES Assessment Boundary and designated sites.

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2. Review of Existing Data

2.1. Existing Datasets

The design of the sampling array was informed by a review of existing data for the assessment area and its environs which comprise both broadscale habitat type data, as well as site-specific survey data. Specifically, this included the following data sources:

- Acoustic survey data covering the proposed export cable corridor and array area including high resolution side scan sonar (SSS) and multibeam bathymetry (MBES) collected specifically for the project in Q3 2020;
- Benthic grab data collected during the year 1 post-construction monitoring survey for the existing Rampion 1 OWF undertaken in 2019;
- Targeted black seabream nest mapping from aggregate extraction licence area monitoring conducted in 2017, 2018, 2019 and 2020;
- Predicted European Nature Information System (EUNIS) habitats from the EUSeaMap 2019;
- Data collated for the purposes of the Regional Seabed Monitoring Programme (RSMP; (Cooper & Barry 2017)); and
- The initial Rampion 2 Predictive Habitat Map Methods Report (2021).

2.2. Summary of Existing Datasets

Acoustic Survey Data 2020

This section presents the acoustic data coverage for ES Assessment Boundary. The initial review of this data conducted for the purposes of producing the sampling array identified a number of distinctive features including boulders and boulder fields; areas of ripples; areas of megaripples and sand waves; areas of trawl marks; and wrecks. The review also identified a number of potential HOCI mainly along the offshore export cable corridor including potential reefs (of both geogenic and biogenic origin) and black seabream nests (Figure 2).

The acoustic data also suggests areas of heterogenous sediments across the study area, particularly along the offshore export cable corridor where areas of coarse sediment appear to be interspersed with the habitats of interest described above.

Rampion 1 OWF Data

Sediments sampled during the benthic baseline and year 1 post-construction monitoring survey (Figure 2) for the existing Rampion 1 OWF were homogeneous within triplicate sampling stations (i.e. between replicates) and showed limited variation across the survey area (Ocean Ecology Limited 2020). Sediments mostly consisted of Slightly Gravelly Sand ((g)S) (EUNIS A5.2), Gravelly Muddy Sand (gmS) and Muddy Sandy Gravel (msG) (EUNIS A5.4), Gravelly Sand (gS) and Sandy Gravel (sG) (EUNIS A5.1).

The majority of the sediments recorded were classified as very poorly sorted as a result of the mixed composition of different size fractions of all three principal sediment types (gravel, sand and mud) with some stations classified as extremely poorly sorted. Sediments recorded as moderately, moderately well or well sorted were composed of Slightly Gravelly Sands ((g)S).

Whilst only three of these samples were located within the ES Assessment Boundary, the results largely corroborate the interpretation of the acoustic data and EUSeaMap predictions.

Black Seabream Nest Mapping

A nationally significant black seabream nesting site is located within the Kingmere MCZ due to the combination of mixed energy infralittoral rock and mixed sediments and chalk outcrops. The MCZ provides statutory protection for these features of interest and the aggregates industry operating in the locality is required to monitor black seabream nest densities and nest viability to ensure that there are no significant negative impacts caused by aggregate dredging.

Since 2002, Hanson Aggregates Marine and Tarmac Marine have monitored the black seabream nest distribution within several survey areas using a combination of acoustic survey data and seabed imagery. The mapping of the black seabream nesting areas from the surveys undertaken in 2017/18 and 2019/20 is presented in Figure 2. This shows that black seabream nesting sites are present within parts of the export cable route corridor, outside of the MCZ, which also appears to be evident within the most recent site-specific acoustic data, along with some further potential nesting areas that have been investigated during the Rampion 2 benthic habitat survey.

EMODnet Habitat Mapping

The ES Assessment Boundary comprises of a number of sediment habitats as presented in the EUSeaMap 2019 predicted habitat mapping shown for the survey area in Figure 2.

This map reflects the same broad patterns observed in the acoustic data discussed above with the majority of the export cable corridor and western array area dominated by infralittoral, circalittoral and deep circalittoral coarse sediments (EUNIS A5.13, A5.14 and A5.15) and much of the eastern array area dominated by deep circalittoral sand (EUNIS A5.27). Discrete areas of infralittoral and circalittoral mixed sediments (A5.44 and A5.45) are predicted to the far west of the western array area whilst clusters of rock habitats (EUNIS A3.1 and A4.1) are predicted in the central array and along the export cable corridor.

Cooper and Barry (2017) Data

Cooper & Barry (2017) describe the results of a baseline assessment of the UK's macrobenthic infauna, with a particular focus around sites and regions of marine aggregate dredging as part of the implementation of the RSMP. Although monitoring the impacts of aggregate extraction was the focus of the study, a “big data” approach was taken, collating data from across UK waters, including across and in proximity to Rampion 2, from various industries including OWFs, oil and gas, nuclear and port and harbour sectors.

Data points coinciding with the Rampion 2 export cable corridor were predominantly characterised by cluster groups associated with sediments constituted by high proportions of gravel (Groups C1a and A2b) whereas data points located within the array areas, particularly the eastern area, were constituted by high proportions of sand (Groups D1-D2d). As shown in Figure 2 this is contradictory to some of the predicted EUSeaMap mapping, particularly in the western reaches of the eastern array area where coarse sediment habitats are predicted.

Initial Rampion 2 Predictive Habitat Map Methods Report (2021)

A series of predictive habitat maps at varying levels of EUNIS classification were initially produced for the Rampion 2 study area. In doing so the predictive outputs aimed to identify the presence of habitats of conservation, ecological and economic importance across the study area.

Initial maps identified seven biotopes as occurring throughout the survey area. These included; *Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment (A5.444), *Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles (A5.141), *Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel (A5.142), Infralittoral mobile clean sand with sparse fauna (A5.231), Sponges and anemones on vertical circalittoral bedrock (A4.139), and *Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment (A5.431).

Potential reef habitat from the predictive model was identified as occurring in low density throughout the composite and broad scale maps, particularly in the nearshore and west of the survey area. The series of models did not predict the presence of species of conservation importance. The A5.431 biotope containing a species of prolific, non-native mollusc *Crepidula fornicata* was identified from within the Level 5 model as dominating the nearshore infralittoral.

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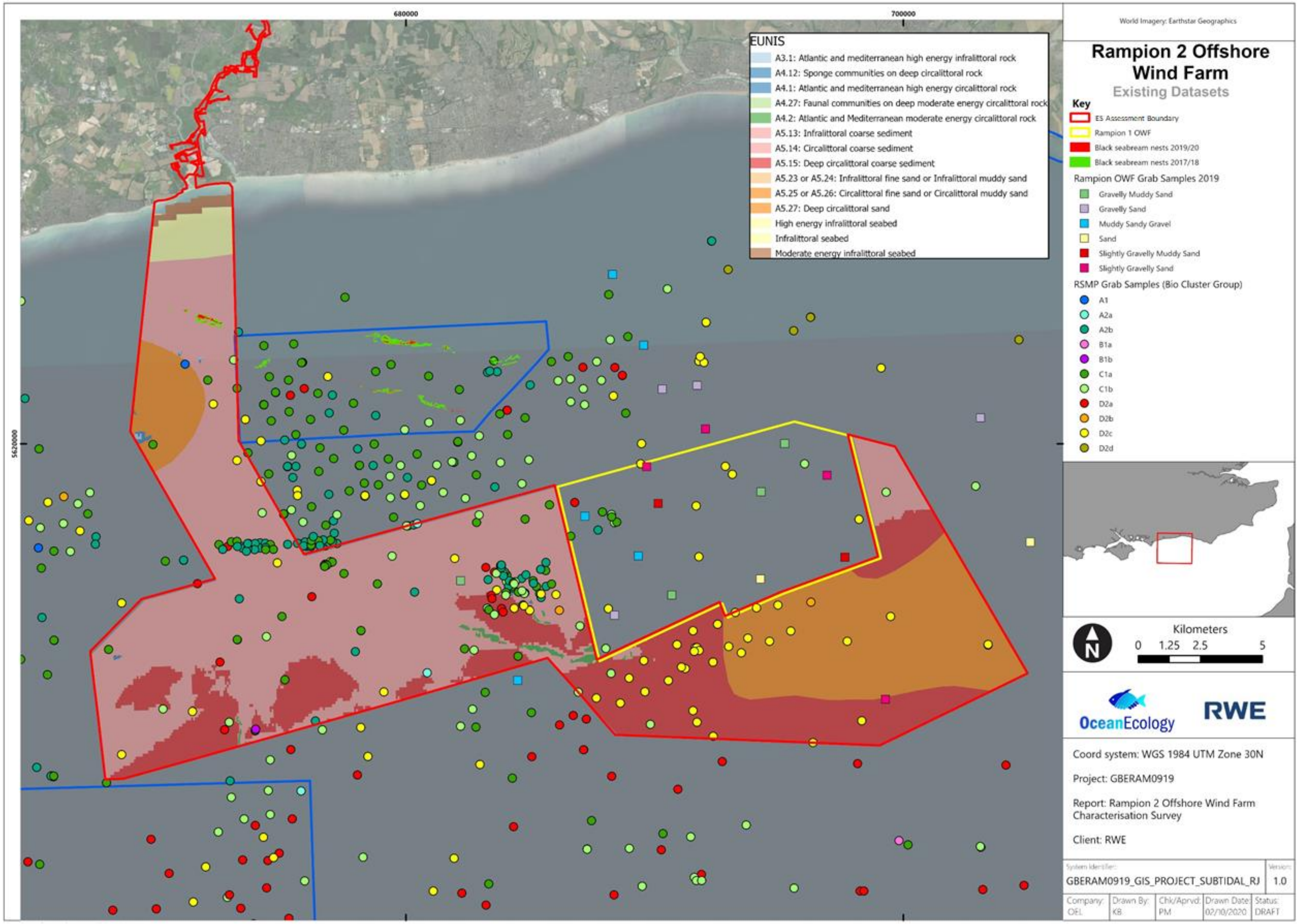

Figure 2 Existing benthic datasets across and within the proximity of the ES Assessment Boundary.

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3. Survey Design

3.1. Sampling Rationale

The benthic subtidal survey array was designed to provide adequate coverage of all areas of the Rampion 2 offshore export cable corridor and array areas where previous sampling coverage was deemed to be limited whilst ensuring representative examples of all sediment types and potential features of conservation importance were targeted. This was set out in a Terms of Reference (ToR) (OEL_GBERAM0919_TOR_SUB) signed off by the Marine Management Organisation (MMO) prior to the survey. The key principles underpinning the survey design were to therefore:

- Provide adequate spatial coverage of the Rampion 2 export cable corridor and array areas;
- Ensure representative sampling of all main sediment types was undertaken; and
- Ensure representative examples of all potential features of conservation interest (including HOCI and black seabream nest sites) were adequately ground-truthed.

3.2. Sampling Strategy

Table 1 sets out the final sample stations signed off by the MMO across the subtidal survey area based on the rationale outlined in Section 3.1 and presented in Figure 3.

Table 1 Final agreed sampling strategy.

DDV Transects	DDV Stations	Hamon Grabs	Day Grab
39	21	45	10

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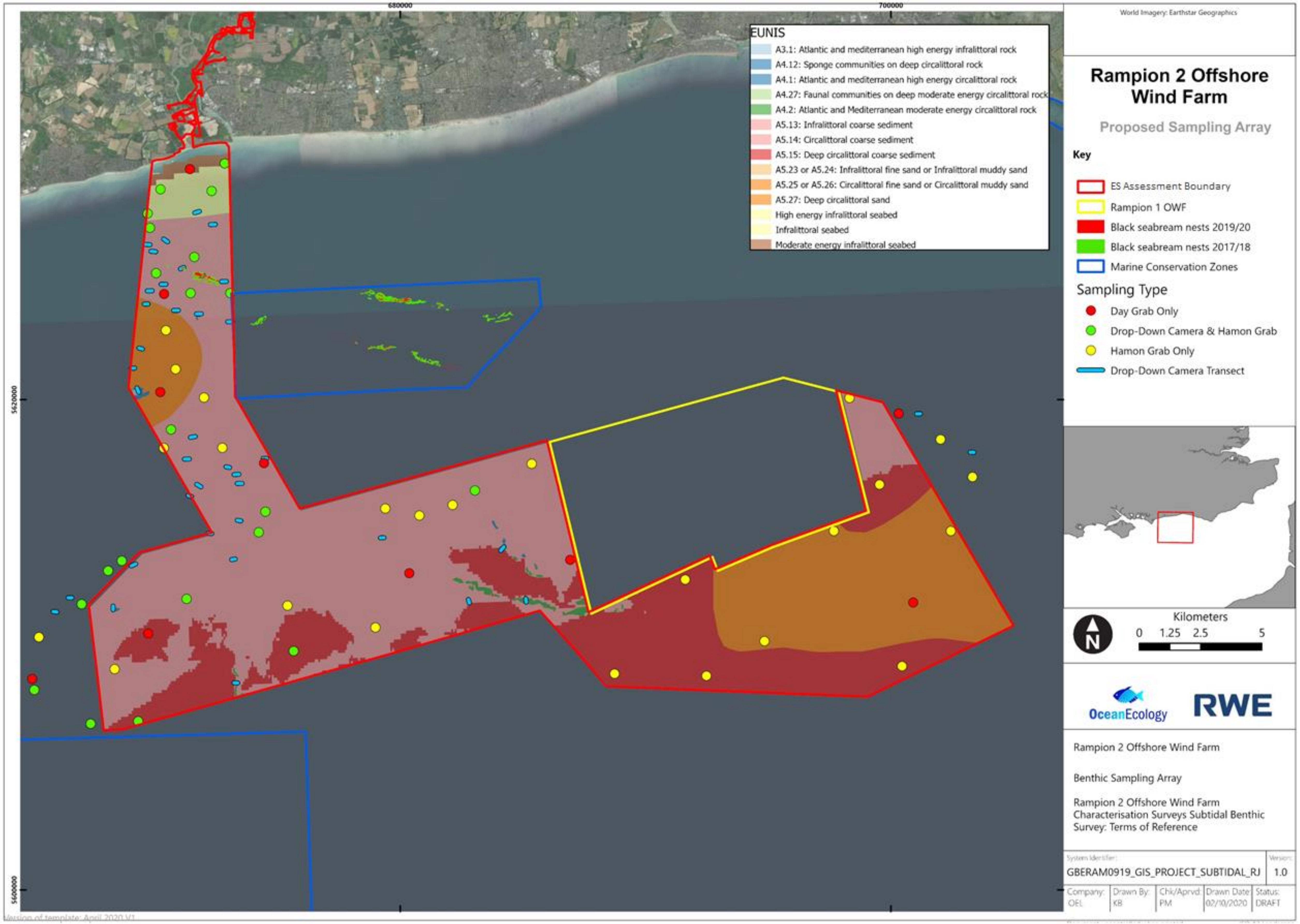

Figure 3 Proposed sampling array for the ES Assessment Boundary characterisation survey (taken from the ToR).

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4. Field Methods

4.1. Survey Vessel

All work was conducted aboard Ocean Ecology's (OEL) dedicated 10.4m Marine and Coastal Agency (MCA) category 2 coded survey vessel '*Seren Las*' (Plate 1) between 7th December 2020 and the 28th February 2021.

The vessel was equipped with a Hemisphere V104s Global Positioning System (GPS) Compass system that provided an accurate offset position of the sampling equipment when deployed from the stern A frame. This provided a GPS feed to a dedicated survey navigation PC operating EIVA NaviPac and TimeZero Navigator v3 marine navigation with routing module and SeaTraceR Class B Automatic Identification System (AIS).

Plate 1 Nearshore survey vessel 'Seren Las'.

4.1.1. Geodetic Parameters

All coordinates were based on World Geodetic System 1984 (WGS 1984) with projected grid coordinates based on Universal Transverse Mercator (UTM) zone 30N with a Central Meridian of 03˚E. A summary of geodetic and projection parameters is provided in Table 2.

Table 2 Geodetic parameters used for the nearshore benthic survey.

Local geodetic Datum Parameters	
Datum	World Geodetic System 1984 (WGS 1984)
Spheroid	WGS 1984
Project Projection Parameters	
Grid Projection	Universal Transverse Mercator, Northern Hemisphere
UTM Zone	30 N
Central Meridian	03˚ 00’ 00” East
Latitude of Origin	00˚ 00’ 00” North
False Easting	500000.0m
False Northing	0m
Scale factor on Central Meridian	0.9996
Units	Metres

4.2. Survey Equipment

4.2.1. Drop-Down Camera Systems

Seabed imagery (simultaneous video and stills) was collected using a high-definition optical camera system (Plate 2). The imagery was collected using OEL’s ROVTech subsea camera system providing 1080p High Definition (HD) video and 20 Megapixel (MP) stills imagery. Due to greater turbidity in the shallower nearshore areas, the camera was mounted in a Clear Liquid Optical Chamber (CLOC) filled with fresh water to ensure imagery of suitable quality was obtained (Jones et al. 2021). Lighting from two LED (Light-Emitting Diode) strip lamps and two lasers separated by 10cm were projected into the field of view for illumination and scaling.

4.2.1. Benthic Grab Samplers

A 0.1m^2 mini-Hamon grab (Plate 3) was used to obtain macrobenthic and sediment samples (particle size analysis (PSA)) at each of the proposed grab sampling locations. Grab sampling was conducted in line with v08 of the RSMP Protocol for Sample Collection and Processing (Cooper & Mason 2019). A 0.1m^2 Day grab was used to collect sediment samples for subsequent chemical contaminant analysis (heavy metals (HM), and Hydrocarbons (HC)). Where coarser sediment was identified during the camera survey, the mini-Hamon grab was used to obtain chemical samples.

4.3. Sampling Approach

4.3.1. Drop Down Camera Sampling

All seabed imagery was collected in consideration of the JNCC epibiota remote monitoring operational guidelines (Hitchin et al. 2015). Along the transects, images were taken every ~10m and more often when features of interest were encountered. At each screening DDV location, a minimum of 60 seconds of video footage and five seabed still images (of between 0.5m^2 to 1m^2 of seabed coverage depending on visibility) were obtained. All video footage was reviewed *in situ* by OEL's environmental scientists.

The camera system was deployed as follows:

- The vessel approached the target location, and the deck personnel were alerted to prepare lifting equipment, camera, and umbilical when on position;
- The camera umbilical was run through a block on the A frame;
- The camera was raised using the A frame winch and lowered into the water column to within 5m of the seabed;
- Video recording was then started, and the camera lowered until gently landing on the seabed;
- The camera was then kept on the seabed to wait for any suspended sediments in the field of view to disperse before a still image was taken;
- The camera was then raised from the seabed and was moved along the transect at a speed of 0.3-0.5 knots. Where possible the seabed was kept in view throughout;
- Following the capture of the final image, the camera was lifted, video recording was stopped, and the camera was retrieved to the surface;
- The winch operator then took the tension on the wire and the deck crew ensured the camera umbilical was free for recovery;
- The vessel skipper then confirmed sea conditions were suitable for retrieval and the camera system was recovered aboard; and
- The camera frame was then lowered onto the deck and the tension released.

Full DDV video and stills sampling logs are presented in Appendices I and II.

Plate 2 Left: OEL's ROVTech camera system equipped with CLOC. Right: OEL's ROVTech camera system topside computer control station.

4.3.2. Benthic Grab Sample Collection

The grab was deployed from the hydraulic 'A' frame on the aft deck of *Seren Las* and lowered to the seabed. Detailed field notes were taken including station number, fix number, number of attempts, sample volume, sediment type, conspicuous fauna, any sign of protected features and water depth.

To ensure consistency in sampling, grab samples were screened by the lead marine ecologist and considered unacceptable if:

- The sample was less than 5L. i.e., the sample represents less than half the 10L capacity of the grab used;
- The jaws failed to close completely or were jammed open by an obstruction, allowing fines to pass through (washout or partial washout);
- The sample was taken at an unacceptable distance from the target location (beyond 20m); and
- There was obvious contamination of the sample from survey equipment, paint chips etc.

Where a suitable sample was not collected after three attempts, the sample location was moved up to 50m away. Where samples of less than 5L were continually achieved, these samples were assessed on-site to establish if the sample volume was acceptable to allow subsequent analysis. No pooling of samples took place.

Full sampling logs for macrobenthic, PSA, and chemical grab samples are presented in Appendices III and IV.


Plate 3 Left: OEL's 0.1m^2 Day Grab. Right: OEL's 0.1m^2 mini-Hamon grab.

4.3.3. Mini-Hamon Grab Sampling Processing

Initial mini-Hamon grab sample processing was undertaken onboard the survey vessel in line with the following methodology:

- Initial visual assessment of sample size and acceptability made;
- Photograph of the sample with station details and scale bar taken;
- 10% of the sample removed for Particle Size Distribution (PSD) analysis and transferred to a labelled tray;
- Remaining sample emptied onto 1.0mm sieve net laid over 4.0mm sieve table and washed through using gentle rinsing with seawater hose;
- Remaining sample for faunal sorting and identification backwashed into a suitable sized sample container and diluted 10% formalin solution added to fix the sample prior to laboratory analysis; and
- Sample containers clearly labelled internally and externally with date, sample ID and project name.

4.3.4. Day Grab Sample Processing

Initial Day grab sample processing was undertaken onboard the survey vessel in line with the following methodology:

- Assessment of sample size and acceptability made; and
- Photograph of drained sample showing undisturbed sediment surface with station details and scale bar taken.

Subsamples were then taken from the surface of the sample while retained in the grab (not decanted) as follows:

Two replicate samples for HC and Organics (i.e., Total Organic Carbon (TOC) and Total Organic Matter (TOM)) analysis were collected using a metal scoop to a nominal depth of 2cm. The samples were preserved in 120ml amber glass jars and stored frozen (<-18°C).

A single replicate sample for HM analysis was collected using a plastic scoop to a nominal depth of 2cm. The samples were preserved in 500ml plastic tubs and stored frozen (<-18°C).

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5. Laboratory and Analytical Methods

On arrival to the laboratory, all samples were logged in and entered into the project database created in OEL's web-based data management application ABACUS[1] in line with in-house Standard Operating Procedures (SOPs) and OEL's Quality Management System (QMS).

5.1. Seabed Imagery Analysis

Following the methods described in Section 4.3.1, digital photographic stills and video footage were successfully obtained along all transects and DDV stations and subsequently analysed to aid in the identification and delineation of EUNIS habitats and HOCI along the study area. Prior to analysis, seabed images were enhanced using the open-source image editing software GNU Image Manipulation Program (www.gimp.org).

All seabed imagery analysis was undertaken using the Bio-Image Indexing and Graphical Labelling Environment (BIIGLE[2]) annotation platform (Langenkämper et al. 2017) and in line with JNCC epibiota remote monitoring interpretation guidelines (Turner et al. 2016) with consideration of the latest NMBAQC/JNCC Epibiota Quality Assurance Framework (QAF) guidance and identification protocols.

A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of Annex I reef habitats as detailed in Table 3 and Table 4. The annotation label tree used during analysis had major headings for each reef type. Under each reef type labels were assigned for each of the categories required to determine whether reef habitat was present.

Analysis of still images was undertaken in two stages. The first stage, "Tier 1", consisted of labels that referred to the whole image being assigned, providing appropriate metadata for the image. The second stage, "Tier 2", was used to assign percentage cover of reef types by drawing polygons.

Table 3 Characteristics of stony reef (Irving 2009).

Characteristic	'Reefiness'			
	Not a Reef	Low	Medium	High
Composition (proportion of boulders/cobbles (>64mm))	<10%	10-40% matrix supported	40-95%	>95% clast-supported
Elevation	Flat seabed	<64mm	64mm - 5m	>5m
Extent	<25m^2	>25m^2		
Biota	Dominated by infaunal species	>80% of species present composed of epibiotal species		

[1] https://abacusprojects.co.uk/
[2] https://www.biigle.de/

Table 4 Characteristics of *Sabellaria spinulosa* reef (Gubbay 2007).

Characteristic	'Reefiness'			
	Not a Reef	Low	Medium	High
Elevation (cm)	<2	2 - 5	5 – 10	>10
Extent (m^2)	<25	25 – 10,000	10,000 – 1,000,000	>1,000,000
Patchiness (% Cover)	<10	10 - 20	20 – 30	>30

5.1.1. Tier 1 Analysis

The first stage, "Tier 1", consisted of assigning labels that referred to the whole image, providing appropriate metadata for the image. Depending on reef type, this included:

- Extent: As it is not possible to fully determine the extent of reef habitats from a single image alone this label was used to identify areas that were highly unlikely to constitute reef habitats. An example being an image that shows a large boulder being preceded and succeeded by images of unconsolidated sandy sediments;
- Biota: Labels assigned to determine whether epifauna dominate the biological community observed; and
- Elevation: Labels assigned depending on reef type. Laser points were used to assist in the assignment of categories.

5.1.2. Tier 2 Analysis

The second stage, "Tier 2", was used to assign percentage cover of reef types. This was achieved by drawing polygons around instances of each reef type within the image.

5.2. Particle Size Distribution Analysis

PSD analysis was undertaken by in-house laboratory technicians at OEL's NE Atlantic Marine Biological Quality Control (NMBAQC) participating laboratory in line with NMBAQC protocols (Mason 2016). The full raw PSD dataset is presented in Appendix V.

5.2.1. Sample Preparation

Frozen sediment samples were first transferred to a drying oven and thawed at 80°C for at least 6 hours prior to visual assessment of sediment type. Before any further processing (e.g. sieving or sub-sample removal), samples were mixed thoroughly with a spatula and all conspicuous fauna (>1mm) which appeared to have been alive at the time of sampling removed from the sample. A representative sub-sample of the whole sample was then removed for laser diffraction analysis before the remaining sample screened over a 1mm sieve to sort coarse and fine fractions.

5.2.2. Dry Sieving

The >1mm fraction was then returned to a drying oven and dried at 80°C for at least 24 hours prior to dry sieving. Once dry, the sediment sample was run through a series of Endecott BS 410 test sieves (nested at 0.5φ intervals) using a Retsch AS200 sieve shaker to fractionate the samples into particle size classes. The dry sieve mesh apertures used are given in Table 5.

Table 5. Sieve series employed for PSD analysis by dry sieving (mesh size in mm).

Sieve aperture (mm)												
63	45	32	22.5	16	11.2	8	5.6	4	2.8	2	1.4	1

The sample was then transferred onto the coarsest sieve at the top of the sieve stack and shaken for a standardised period of 20 minutes. The sieve stack was checked to ensure the components of the sample had been fractioned as far down the sieve stack as their diameter would allow. A further 10 minutes of shaking was undertaken if there was evidence that particles had not been properly sorted.

5.2.3. Laser Diffraction

The fine fraction residue (<1mm sediments) was transferred to a suitable container and allowed to settle for 24 hours before excess water syphoned from above the sediment surface until a paste texture was achieved. The fine fraction was then analysed by laser diffraction using a Beckman Coulter LS13 320. For silty sediments, ultrasound was used to agitate particles and prevent aggregation of fines.

5.2.4. Data Merging

The dry sieve and laser data were then merged for each sample with the results expressed as a percentage of the whole sample. Once data was merged, PSD statistics and sediment classifications were generated from the percentages of the sediment determined for each sediment fraction using Gradistat v8 software.

Sediment were described by their size class based on the Wentworth classification system (Wentworth 1922) (Table 6). Statistics such as mean and median grain size, sorting coefficient, skewness and bulk sediment classes (percentage silt, sand and gravel) were also derived in accordance with the Folk classification (Folk 1954).

Table 6. Classification used for defining sediment type based on the Wentworth Classification System (Wentworth 1922).

Wentworth Scale	Phi Units (φ)	Sediment Types
>64mm	<-6	Cobble and boulders
32 – 64mm	-5 to -6	Pebble
16 – 32mm	-4 to -5	Pebble
8 – 16mm	-3 to -4	Pebble
4 - 8mm	-3 to -2	Pebble
2 - 4mm	-2 to -1	Granule
1 - 2mm	-1 to 0	Very coarse sand
0.5 - 1mm	0 – 1	Coarse sand
250 - 500µm	1 – 2	Medium sand
125 - 250µm	2 – 3	Fine sand
63 - 125µm	3 – 4	Very fine sand
31.25 – 63µm	4 – 5	Very coarse silt
15.63 – 31.25µm	5 – 6	Coarse silt
7.813 – 15.63µm	6 – 7	Medium silt
3.91 – 7.81µm	7 – 8	Fine silt
1.95 – 3.91µm	8 – 9	Very fine silt
<1.95µm	<9	Clay

5.3. Sediment Chemical Analysis

All organic matter, hydrocarbon and metals analysis was undertaken by SOCOTEC UK Limited. A full description of the methods used to test for each chemical determined is provided as Appendix VI.

Indices and ratios were calculated to assess source origin of hydrocarbons in the sediment sampled across the ES Assessment Boundary (Ines et al. 2013, Aly Salem et al. 2014, Al-hejuje et al. 2015). Generally, there are three sources of hydrocarbons depending on their origin: biogenic, petrogenic and pyrogenic. Hydrocarbons of biogenic origin are the produce of biological processes or early diagenesis in marine sediments (e.g., perylene) (Venkatesan 1988, Junttila et al. 2015). Hydrocarbons of petrogenic origin are the compounds present in oil and some oil products following low to moderate temperature diagenesis of organic matter in sediments resulting in fossil fuels. Hydrocarbons of pyrogenic origin are the product of incomplete combustion of organic material (Page et al. 1999, Junttila et al. 2015), such as forest fires and incomplete combustion of fossil fuels.

Based PAH compounds the following ratios were calculated as follows:

The ratio between light (LMW) and heavy molecular weight (HMW) PAHs is typically used as a proxy to determine the origin source of PAH compounds in sediments, ratios above 1 indicate a petrogenic source while ratios below 1 indicate a pyrogenic source. LMW PAHs include compounds with 2-3 rings while HMW PAHs include compounds with more than 4 rings (Edokpayi et al. 2016).

Phenanthrene/Anthracene ratio: values lower than 10 indicate a pyrogenic source origin for the hydrocarbons; while values higher than ten account for hydrocarbons of petrogenic origin (Kafilzadeh et al. 2011).

Fluoranthene/Pyrene ratio: for values higher than one, the hydrocarbons are pyrogenic in origin, for values below one, the hydrocarbons are petrogenic in origin (Kafilzadeh et al. 2011).

Based on aliphatic hydrocarbons and n-alkanes, the following index and ratios were calculated:

Carbon Preference Index (CPI): the ratio between the concentration of odd-numbered and even-numbered carbon chains in n-alkanes. CPI values close to 1 indicate hydrocarbons of petrogenic origin; CPI values below 1 indicate pyrogenic origin (Fagbote 2013), while CPI values higher than 1 indicate a biogenic origin of alkanes (Al-hejuje et al. 2015).

Pristane/Phytane ratio: values close to one indicate hydrocarbons of petrogenic origin, values higher than one indicate biogenic origin of alkanes, while ratios below one indicates pyrogenic origin. Pristane is typically found in marine organisms while Phytane is a component of oil (Guerra-García et al. 2003) hence the use of this ratio to assess source origin of hydrocarbons.

5.3.1. Total Organic Carbon (TOC)

After the removal of any inorganic carbon species, TOC of dry sediment was determined by combustion at 1,600ºC in an oxygen atmosphere; the combustion gases were then measured for carbon concentration. The analysis was undertaken on subsamples from the <1mm fraction of each sample. A full description of the methods used is provided as Appendix VI.

5.3.2. Total Organic Matter (TOM)

TOM of dry sediment was determined using Loss on Ignition (LOI) at 450°C as a surrogate. The analysis was undertaken on subsamples from the <1mm fraction of each sample. A full description of the methods used is provided as Appendix VI.

5.4. Macrobenthic Analysis

All elutriation, extraction, identification and enumeration was undertaken at OEL's NMBAQC scheme participating laboratory in line with the NMBAQC Processing Requirement Protocol (PRP) (Worsfold & Hall 2010). All processing information and macrobenthic records were recorded using OEL's cloud-based data management application 'ABACUS' that employs MEDIN[3] validated controlled vocabularies ensuring all sample information, nomenclature, qualifiers, and metadata are recorded in line with international data standards.

For each macrobenthic sample, the excess formalin was drained off into a labelled container over a 1mm mesh sieve in a well-ventilated area. The samples were then re-sieved over a 1mm mesh sieve to remove all remaining fine sediment and fixative. The low-density fauna was then separated by elutriation with fresh water, poured over a 1mm mesh sieve, transferred into a Nalgene, and preserved in 70% Industrial Denatured Alcohol (IDA). The remaining sediment from each sample was subsequently separated into 1mm, 2mm and 4mm fractions and sorted under a stereomicroscope to extract any remaining fauna (e.g., high-density bivalves not 'floated' off during elutriation). All macrobenthos present was identified to species level, where possible, and enumerated by trained benthic taxonomists using the most up to date taxonomic literature and checks against existing reference collections. Nomenclature utilised the live link within ABACUS to the WoRMS[4] REST webservice, to ensure the most up to date taxonomic classifications were recorded. Colonial fauna (e.g., hydroids and bryozoans) were recorded as present (P). For the purposes of subsequent data analysis, taxa recorded as P were given the numerical value of 1.

5.4.1. Faunal Biomass

Following identification, all specimens from each sample were pooled into 5 major groups (Annelida, Crustacea, Mollusca, Echinodermata, and Miscellaneous taxa) to measure blotted wet weight major group biomass to 0.0001g. As a standard, the conventional conversion factors as defined by Eleftheriou & Basford (1989) were applied to biomass data to provide equivalent dry weight biomass (Ash Free Dry Weight, AFDW). The conversion factors applied are as follows:

- Annelida = 15.5%
- Crustacea = 22.5%
- Mollusca = 8.5%
- Echinodermata = 8.0%
- Miscellaneous = 15.5%

[3] Marine Environmental Data and Information Network
[4] http://www.marinespecies.org

5.5. Data Analysis

5.5.1. Data Truncation and Standardisation

The macrobenthic species list was checked using the R package '*worms*' (Holstein 2018) to check against WoRMS taxon lists and standardise species nomenclature. Once the species nomenclature was standardised in accordance with WoRMS accepted species names, the species list was examined carefully by a senior taxonomist to truncate the data, combining species records where differences in taxonomic resolution were identified.

5.5.2. Pre-Analysis Data Treatment

All data were collated in excel spreadsheets and made suitable for statistical analysis. All data processing and statistical analysis was undertaken using R v 1.2 1335 (Team & R Core Team 2020) and PRIMER v7 (Clarke & Gorley 2015) software packages.

5.5.3. Multivariate Statistics

Prior to multivariate analyses, data were displayed as a shade plot with linear grey-scale intensity proportional to macrobenthic abundance (Clarke et al. 2014) to determine the most efficient pre-treatment method. Macrobenthic abundance data from grab samples was square-root transformed to prevent taxa with intermediate abundances from being discounted from the analysis.

The PRIMER v7 software package (Clarke & Gorley 2015) was utilised to undertake the multivariate statistical analysis on the biotic macrobenthic dataset. To fully investigate the multivariate patterns in the biotic data, macrobenthic assemblages were characterised based on their community composition, with hierarchical clustering used to identify groupings of sampling stations that could be grouped together as a habitat type or community. SIMPER analysis was then applied to identify which taxa contributed most to the similarity within that habitat type or community. A detailed description of the analytical routines employed is provided in Appendix VII.

5.5.4. Determining EUNIS Classification

Macrobenthic assemblages were characterised based on their community composition, with hierarchical clustering used to identify groupings of sampling stations that could be grouped together as a habitat type or community. Setting these groupings as factors within PRIMER, SIMPER analysis was then applied to identify which taxa contributed the most to the similarity within that community. EUNIS classifications were then assigned based on the latest JNCC guidance (Parry 2019).

5.6. Predictive Habitat/Biotope Mapping

All mapping and modelling processes were conducted in ESRI ArcGIS utilising the Spatial Analyst Extension within a combination of ESRI ArcMap version 10.7 and ESRI ArcPro Version 2.7. The predictive mapping presented here is a re-run of the predictive modelling exercise presented in the PEIR (Ocean Ecology Limited 2021) with the additional inclusion of the ground-truthing data collected during the Rampion 2 benthic characterisation survey, as listed in Section 5.6.1.

5.6.1. Ground Truthing

EUNIS classification point data were obtained and collated from various sources:

- Cefas OneBenthic Database[5]
- EMODnet – EUNIS habitat point observations[6]
- Rampion 2 PSD analysis data
- Rampion 2 macrobenthic analysis data
- Rampion 1 OWF benthic ecology baseline characterisation (RSK 2012)
- Rampion 1 OWF pre-construction benthic survey report (Power 2016)

Cefas OneBenthic Database

Using the OneBenthic Database, 203 sediment samples collected from within the Rampion 2 scoping boundary derived from several different survey programs were extracted. To ensure sample data was not truncated prior to analysis, the data was split into 10 subgroups based on the size classification used for the sediment analysis and individually run through Gradistat grain size distribution and statistics package version 9.1 to determine the EUNIS Broadscale Habitat type (BSH).

EMODnet EUNIS habitat point observations

A total of 76 EUNIS classifications were extracted from the EMODnet Seabed Habitats Portal.

ES Assessment Boundary PSD Analysis

Broadscale EUNIS classifications were obtained from 39 grab samples collected by OEL as part of the Rampion 2 benthic characterisation survey. The data was run through Gradistat grain size distribution and statistics package version 9.1 to determine the EUNIS BSH type.

ES Assessment Boundary Macrobenthic Analysis

EUNIS classifications were obtained from 33 grab samples collected by OEL as part of the Rampion 2 benthic characterisation survey. Macrobenthic abundance data were

[5] https://openscience.cefas.co.uk/matool_mhtest/
[6] https://www.emodnet-seabedhabitats.eu

analysed to determine key and characterising taxa at each station and whether stations would group based on their macrobenthic compositions to then use this information to assign EUNIS biotopes and habitats.

Rampion 1 OWF

A total of 197 habitat classifications from two Rampion 1 OWF survey reports (Ocean Ecology Limited 2021). Classifications were first converted from Marine Habitat Classifications for Britain and Ireland (MNCR) format to the EUNIS classification.

5.6.2. Training and Validation

The ground-truth data was divided into 4 datasets containing EUNIS BSH, Level 4 and Level 5 and All EUNIS classifications combined. A random stratified sampling technique was conducted on each EUNIS classification to ensure sampling incorporated all available classes. Seventy percent of the data from each classification was selected for model training whilst 30% was retained for model validation (Table 7). A sense check was conducted on all data, in which data collected from duplicate coordinates were removed.

Table 7 Total data points used to train and validate each predictive map.

EUNIS Level	Training	Validation
All	368	98
BSH	330	137
Level 4	135	53
Level 5	97	54

Confusion Matrix

Confusion matrices are calculated to measure map accuracy by highlighting the percentage of pixels classified correctly. They are produced in ArcMap by combining the outputs of each predictive map with its corresponding validation dataset. The resulting integer values are converted to percentages using the expression = INT(([Values]/[Total]) * 100+0.5.

Cohen's Kappa

Cohen's Kappa is a widely applied discrete multivariate technique for assessing the accuracy of habitat mapping predictions. It measures the degree of agreement between variables above that expected by chance alone (Lucieer et al. 2013). The value is interpreted further to identify the level of agreement and percentage of reliable data (Table 8).

It is calculated from the confusion matrix

$$\kappa = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)}$$

Where Pr(a) represents the actual observed agreement and Pr(e) represents an agreement by chance.

Table 8 Interpretation of Cohen's Kappa adapted from Altman (1991), McHugh (2012) and Lucieer et al. (2013).

Value of Kappa	Level of agreement	Agreement *	% data that are reliable
0-.20	None	Poor	0-4%
.20-39	Minimal	Fair	4-15%
.40-.59	Weak	Moderate	15-35%
.60-.79	Moderate	Good	35-63%
.80-.90	Strong	Very good	64-81%
Above .90	Almost Perfect	Very good	82-100%

Physical Variables

Acoustic data in the form of Multibeam Eco Sounder (MBES) bathymetry and backscatter were obtained from GoBe in a series of xyz formatted data files. These files were transformed and mosaiced into two rasters displayed at 1m resolution. A SSS raster in .tiff format was obtained from GoBe at 0.1m resolution. The backscatter raster was omitted from the final maps due to strong differences in acoustic signatures between the nearshore and offshore areas, which had the potential to significantly influence the final model predictions.

Bathymetric Derivatives

Six derivatives were calculated from the bathymetric raster, these were: Slope, Aspect as Eastness and Northness (in radians), Terrain Ruggedness Index (TRI), Curvature, and Profile Curvature.

Data Transformation

Bathymetry, SSS and bathymetric derivatives were selected for the final predictive mapping process. A "Standardise" and "Stretch" function was applied to each variable using the "Transformation" function within the Geomorphometry and Gradient Metrics toolbox[7] extension in ArcPRO.

Principal Components

Principal Component Analysis (PCA) transforms a number of different, but potentially correlated, variables into a smaller number of uncorrelated principal components (Amiri-Simkooei et al. 2011). In doing so, it condenses all information into the first few bands, removing highly correlated information and thus reducing dimensionality without losing data (Costa & Battista 2013). PCA was conducted on the transformed variables. The resulting outputs produced a series of multiband rasters containing the first three principal

[7] (https://evansmurphy.wixsite.com/evansspatial/arcgis-gradient-metrics-toolbox

components and a statistical text file containing the covariance matrix, correlation matrix, eigenvalues and the percent of accumulated eigenvalues.

Signature Files

Signature files were created in ArcPro from each EUNIS classification dataset and the resulting multiband PCA raster. A signature file is a subset of cells which represent a class or cluster. Signatures incorporate small buffers around sea-truth points, and in doing so assume that the associated habitat within a buffer is the same as the classified data entry (Brown et al. 2005).

Maximum Likelihood Classification

Maximum Likelihood Classification (MLC) is a widely applied pixel based predictive mapping approach (Brown et al. 2005, Ierodiaconou et al. 2011, Calvert et al. 2014, Boswarva et al. 2018) that calculates the probability a given pixel belongs to a specific class, thereby producing a grid of classes in the form of a raster thematic map (Ierodiaconou et al. 2011, Micallef et al. 2012). MLC was conducted here by combining the variables selected within the multi-band PCA rasters with signature files containing EUNIS classification data.

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6. Results

6.1. Seabed Imagery

A total of 39 camera transects and 23 DDV locations were sampled throughout the duration of the survey resulting in the collection of 1,252 still images and approximately 188GB of HD video. Of the 1,252 images collected, 211 were duplicates of the same area of seabed, therefore a total of 1,041 images were analysed for this report.

The main assessment was conducted using the still images captured during the DDV transects and stations due to high turbidity levels, which reduces the resolution of analysis from the video imagery. The main BSH habitats identified are presented in Plate 4. Example imagery from each DDV station/transect, BSH description, and the EUNIS habitat description is presented in Appendix VIII and Appendix IX.

The dominant BSH habitats identified in the seabed imagery across the survey area were A5.1- Subtidal Coarse Sediment, A4.1 – High Energy Circalittoral Rock and A4.2 – Moderate Energy Circalittoral Rock.

EUNIS habitats identified across the ES Assessment Boundary included A4.13 - Mixed faunal turf communities on circalittoral rock, A4.23 - Communities on soft circalittoral rock, A4.131 - Bryozoan turf and erect sponges on tide-swept circalittoral rock, A4.134 - *Flustra foliacea* and colonial ascidians on tide-swept moderately wave exposed circalittoral rock, A4.214 - Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock, A4.221 - *Sabellaria spinulosa* encrusted circalittoral rock, A5.14 - Circalittoral coarse sediment, A5.25 - Circalittoral fine sand, A5.26 - Circalittoral muddy sand, A5.44 - Circalittoral mixed sediments, A5.141 - *Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles, A5.611 - *Sabellaria spinulosa* on stable circalittoral mixed sediment, and A5.431 – *Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment (biotope mis-match with circalittoral coarse sediment) (Plate 4).

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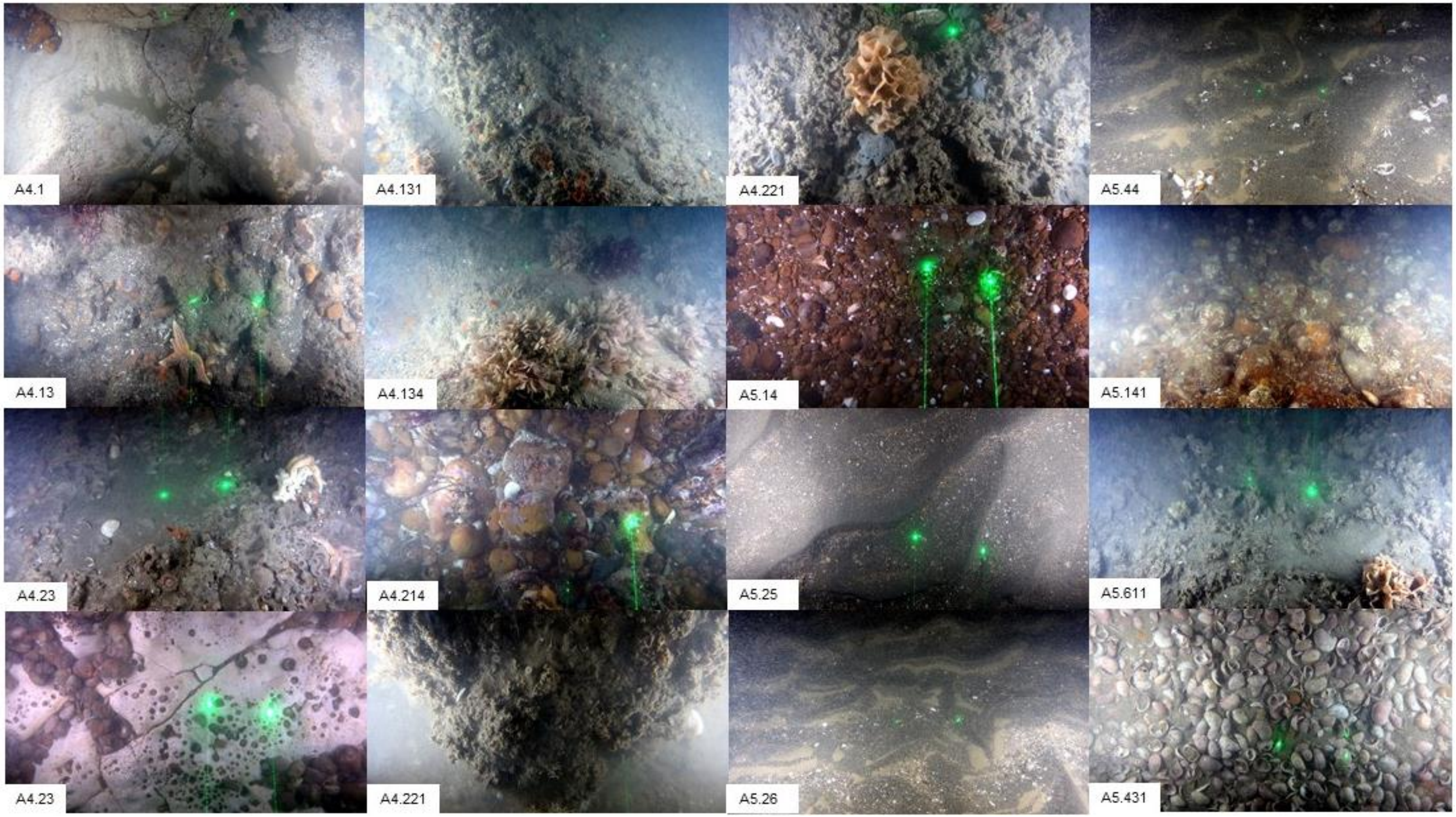

Plate 4 Example seabed imagery of the different EUNIS habitats observed across the ES Assessment Boundary.

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6.1.1. Annex I Reef Assessment

Rocky Reef

A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of reef habitats detailed in Table 3.

Table 9 Summary of Annex I rocky reef assessment for each station/transect along which reef was observed.

Transect/ Station	Stony Reef (Number of Images)			Bedrock
	Not a Reef	Low	Medium	
004	0	6	0	0
006	0	6	0	0
007(2)	3	0	0	3
007	3	0	0	3
021	0	0	0	9
023	1	0	0	6
032	1	0	0	9
036	2	3	0	3
T_001	8	15	0	0
T_002	4	17	1	0
T_003	5	3	0	16
T_004	8	0	0	13
T_005	4	16	1	1
T_006	13	0	0	11
T_007	14	0	0	7
T_008	13	0	0	7
T_009	17	4	0	0
T_010	12	0	0	9
T_012	13	0	0	13
T_013	22	3	0	0
T_014	16	4	1	6
T_015	9	8	2	0
T_016	3	11	0	0
T_017	7	7	8	0
T_018	24	0	0	3
T_021	18	0	0	3
T_022	17	0	0	11
T_025	8	0	0	5
T_027	16	0	0	2
T_028	4	0	0	21
T_029	0	5	0	11
T_030	0	0	0	18
T_031	5	0	0	16
T_033	15	0	0	3

Areas of rocky reef that met the qualifying criteria were present across the western areas of the study area and nearshore areas of the export cable corridor (Figure 4). Bedrock reef was identified at five stations and along 19 transects across the ES Assessment Boundary. Coverage of this habitat type was most extensive in the area covered by transects T_028 and T_30 (Table 9, Figure 4). Stony reef habitat was identified at three stations and along 11 transects all of which were deemed to be representative of low resemblance stony reef. Coverage of this habitat type was most extensive in the area covered by transects T_002 and T_005. Areas deemed to be representative of medium resemblance stony reef were observed along 5 transects with greatest confidence in observations at T_017 (Table 9, Figure 4).

Biogenic Reef

A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of biogenic reef habitats detailed in Table 4.

Discrete areas of biogenic reef that met the qualifying criteria were present across the ES Assessment Boundary. *S. spinulosa* reef was identified in 15 images along transects T_024 and T_027 (Figure 4). Observations at both transects were deemed to be representative of low resemblance reef. This HOCI was deemed representative of A5.611 - *Sabellaria spinulosa* on stable circalittoral mixed sediment and A4.221 - *Sabellaria spinulosa* encrusted circalittoral rock (Plate 5 and Table 10).

Table 10 Summary of biogenic reef assessment for each station/transect along which reef was observed.

Transect/Station	Biogenic Reef (Number of Images)		
	Not a Reef	Low	Medium
T_024	20	10	0
T_027	16	5	0

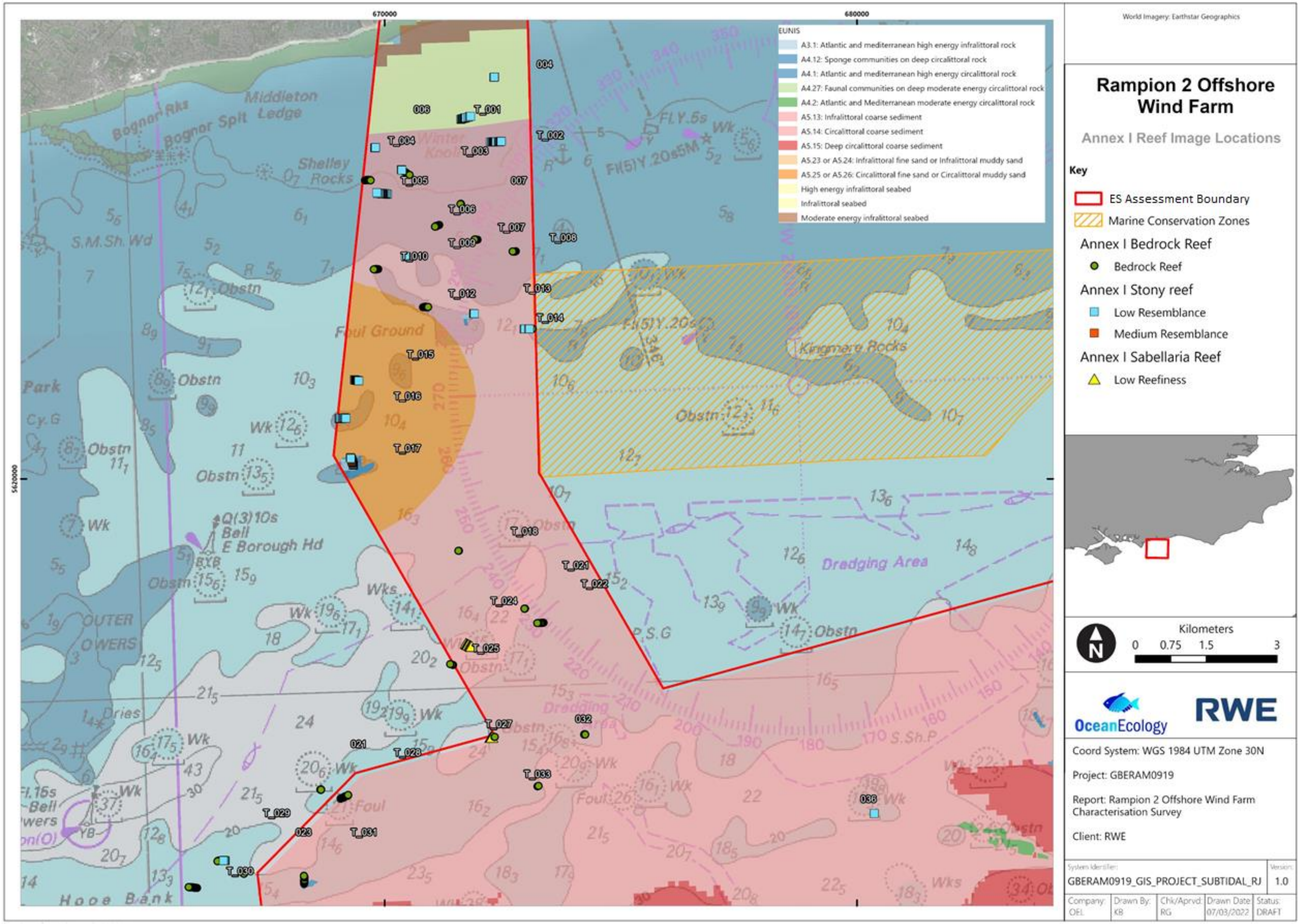

Figure 4 Annex I reef assessment across the ES Assessment Boundary overlain on existing EUNIS (EUSeaMap 2019) habitat mapping.

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6.1.2. Other HOCI Present

Fragile Sponge and Anthozoan Communities on Subtidal Rocky Habitats

Fragile Sponge and Anthozoan Communities on Subtidal Rocky Habitats were observed in 46 images across 12 transects (Figure 5) within the western reaches of the study area and nearshore areas of the export cable corridor (Plate 5). These habitats were characteristic of A4.13 - Mixed faunal turf communities on circalittoral rock and were closely associated with transects deemed to be representative of Annex I rocky reef. Coverage of this HOCI was most extensive at transects T_012, T_014 and T_28.

Peat and Clay Exposures

Peat and clay exposures were observed in 17 images across one station (ST032) and three transects (T_011, T_027 and T_033) (Figure 5) within the western reaches of the study area and nearshore areas of the export cable corridor (Plate 5). These features coincided with moderate energy circalittoral rock and were deemed to be representative of the EUNIS habitat A4.23 - Communities on soft circalittoral rock. Evidence of piddock activity was observed in these images, however determining whether these were recent or historical was not possible.

Subtidal Chalk

Subtidal chalk was observed in 63 images across two stations (ST004 and ST036) and six transects (Figure 5) within the western reaches of the study area and nearshore areas of export cable corridor (Plate 5). These features coincided with moderate energy circalittoral rock and were deemed to be representative of the EUNIS habitat A4.23 - Communities on soft circalittoral rock. Evidence of piddock activity was observed in these images, however determining whether these were recent or historical was not possible.

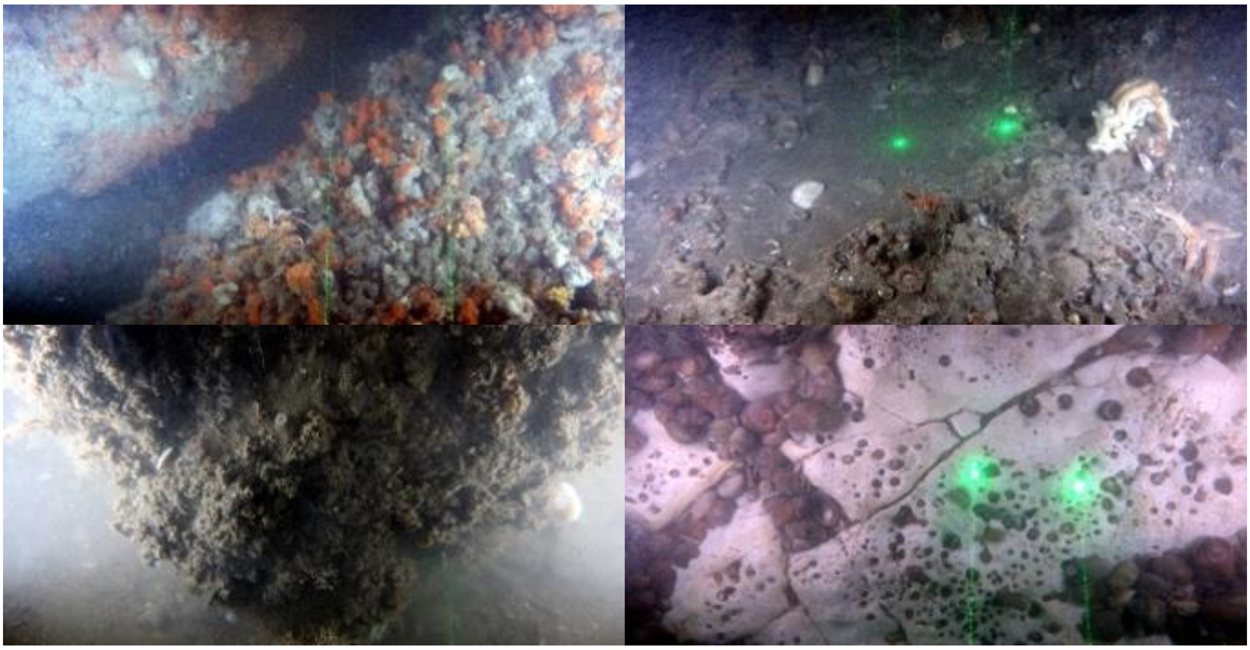

Plate 5 Top left Fragile Sponge and Anthozoan Communities on Subtidal Rocky Habitats; Top right Peat and Clay Exposures; Bottom left *Sabellaria spinulosa* reef; Bottom right Subtidal chalk.

Subtidal Sands and Gravels

Subtidal sands and gravels were common across the survey area and were observed in 590 images across the majority of stations and transects sampled across the ES Assessment Boundary. This feature coincided with A5.14 - Circalittoral coarse sediment, A5.26 - Circalittoral muddy sand, A5.25 - Circalittoral fine sand and A5.44 - Circalittoral mixed sediments. Additionally, 294 images recorded rippled bedforms (<10cm in height) across the ES Assessment Boundary.

6.1.3. Non-Native Species

The invasive non-native slipper limpet *Crepidula fornicata* was observed in 114 images across five stations and 10 transects (Figure 6, Plate 6) across the nearshore area of the offshore export cable corridor. In some areas these slipper limpets formed dense beds on circalittoral coarse sediment. This was assigned as A5.431- *Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment on circalittoral coarse sediment accompanied by the biotope mismatch label.

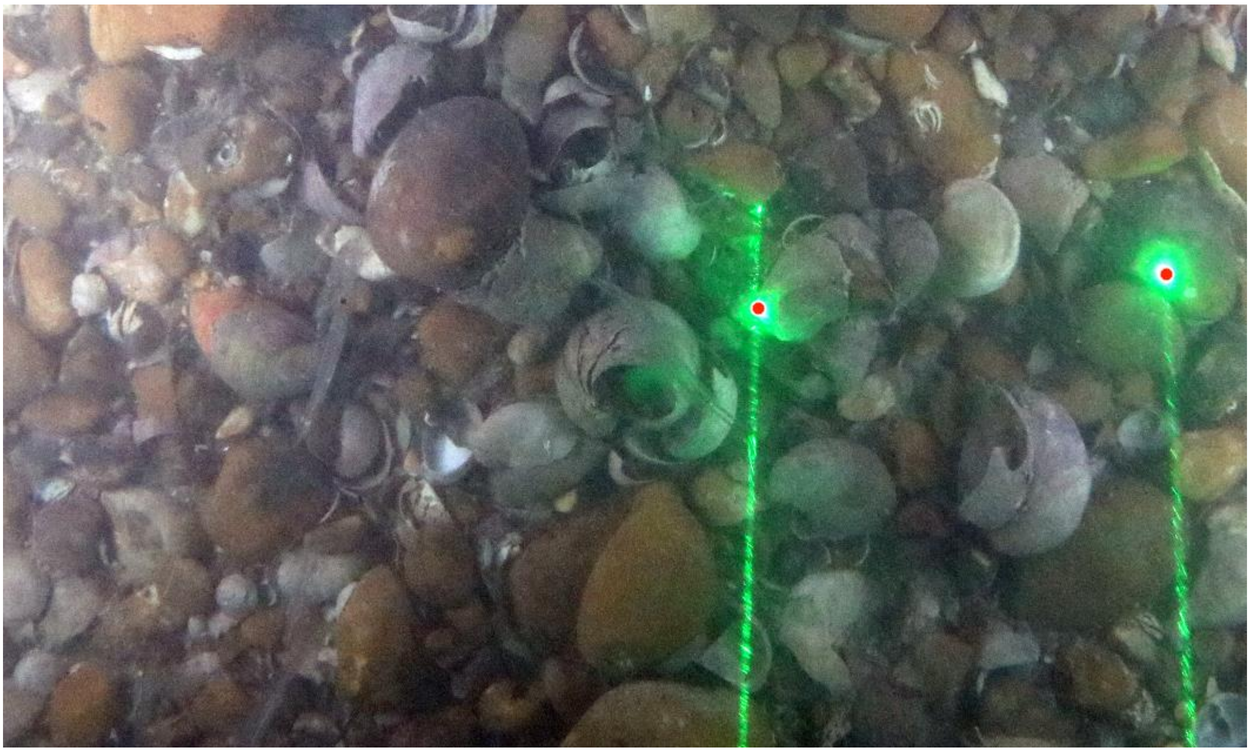

Plate 6 Example imagery of *Crepidula fornicata* stacks taken from the ES Assessment Boundary.

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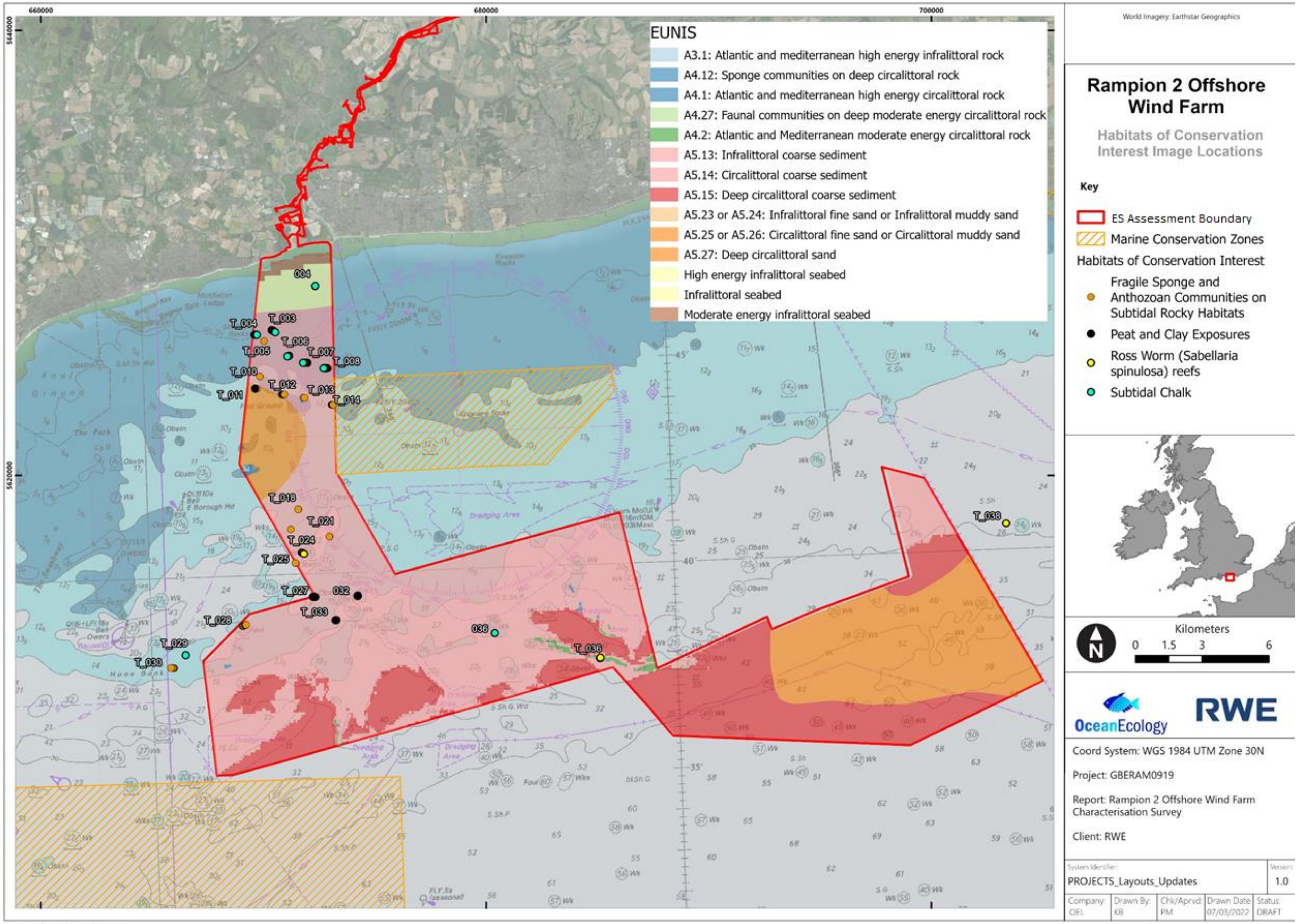

Figure 5 Other HOCI present in seabed imagery across the ES Assessment Boundary overlain on existing EUNIS (EUSeaMap 2019) habitat mapping.

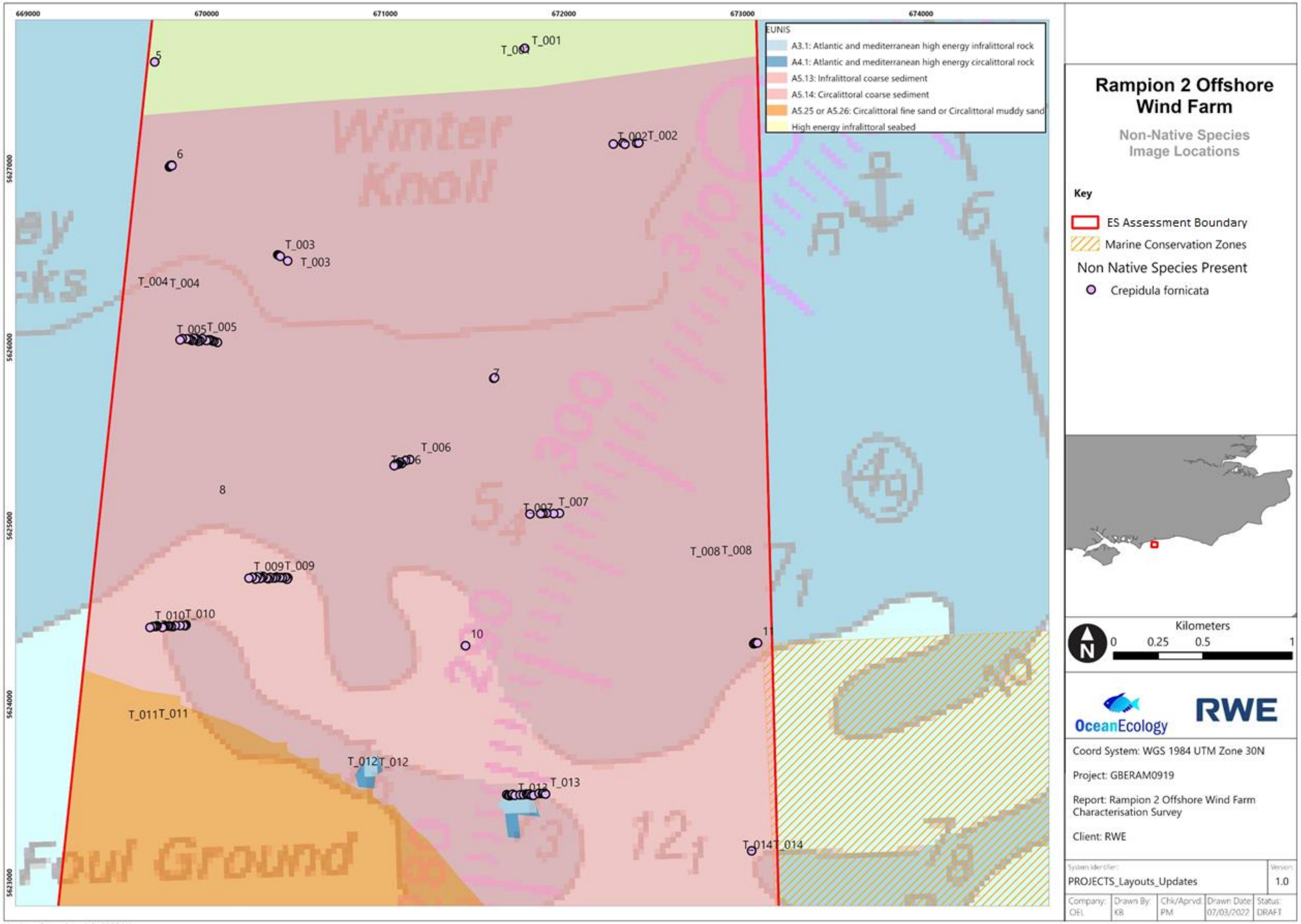

Figure 6 Seabed imagery locations where non-native *Crepidula fornicata* was observed across the ES Assessment Boundary overlain on existing EUNIS (EUSeaMap 2019) habitat mapping.

6.2. Particle Size Distribution

A total of 39 successful grab samples were collected during the survey. Grab samples were unable to be obtained from 12 stations during the survey. These failed samples occurred due to the coarse sediment (pebbles/cobbles/bedrock) present at the target location.

6.2.1. Sediment Type

Sediment types at each sampling station as classified by the Folk (1954) classification are summarised in Appendix X and illustrated in Figure 7. Despite some variation in sediment types between stations, 28 stations out of 39 were dominated by sand. Mud content was highest close to land and towards the east. Gravel content varied across the study area. Specifically, 17 sediment samples consisted of Gravel (G), Sandy Gravel (sG) and Gravelly Sand (gS) representing EUNIS BSH A5.1 (Coarse Sediment), 11 were made of Muddy Sandy Gravel (msG), Muddy Gravel (mG) and Gravelly Muddy Sand (gmS) representing EUNIS BSH A5.4 (Mixed Sediment), eight samples consisted of Slightly Gravelly Sand ((g)S) and Sand (S) representing EUNIS BSH 5.2 (Sand and Muddy Sand) and the remaining three sediment samples were made of Slightly Gravelly Muddy Sand ((g)mS) and Sandy Mud (sM) representing EUNIS BSH 5.3 (Mud and Sandy Mud). Figure 8 maps the distribution of these sediment types across the ES Assessment Boundary.

These sublittoral sediment types represent 'subtidal sands and gravels' and 'subtidal mixed muddy sediments' listed as priority habitats under Section 41 of the NERC Act 2006 (England). To note that these habitats are among the most common habitats found below the mean low water springs (MLWS) around the coast of the UK.

Most of the sediments recorded were classified as extremely poorly to poorly sorted (77% of stations) due to the mixed composition of different size fractions of all three principal sediment types (gravel, sand, and mud). However, seven stations (18%) were classified as moderately to well sorted and comprised almost entirely of sand and two stations were classified as moderately sorted and comprised almost exclusively of gravel.

6.2.2. Sediment Composition

Mean sediment grain size (µm) across the survey area ranged between 6.8µm at Station 12 and 7066.5µm at Station 5 (Figure 9). Percentage contribution of gravel (>2mm), sand (>63µm <2mm), and mud (<63µm) are presented by station in Figure 10. The percentage contribution of sand was greatest across most stations except for the stations furthest inshore and ST055 where a high percentage of gravel was present. Stations 11 and 12 had the highest mud content. The mean (± SE) proportion of sand across all survey Stations was 60.8 ± 4.7%, mean (± SE) gravel content was 29.6 ± 4.6% and mean (± SE) mud content was 9.6 ± 2.5%.

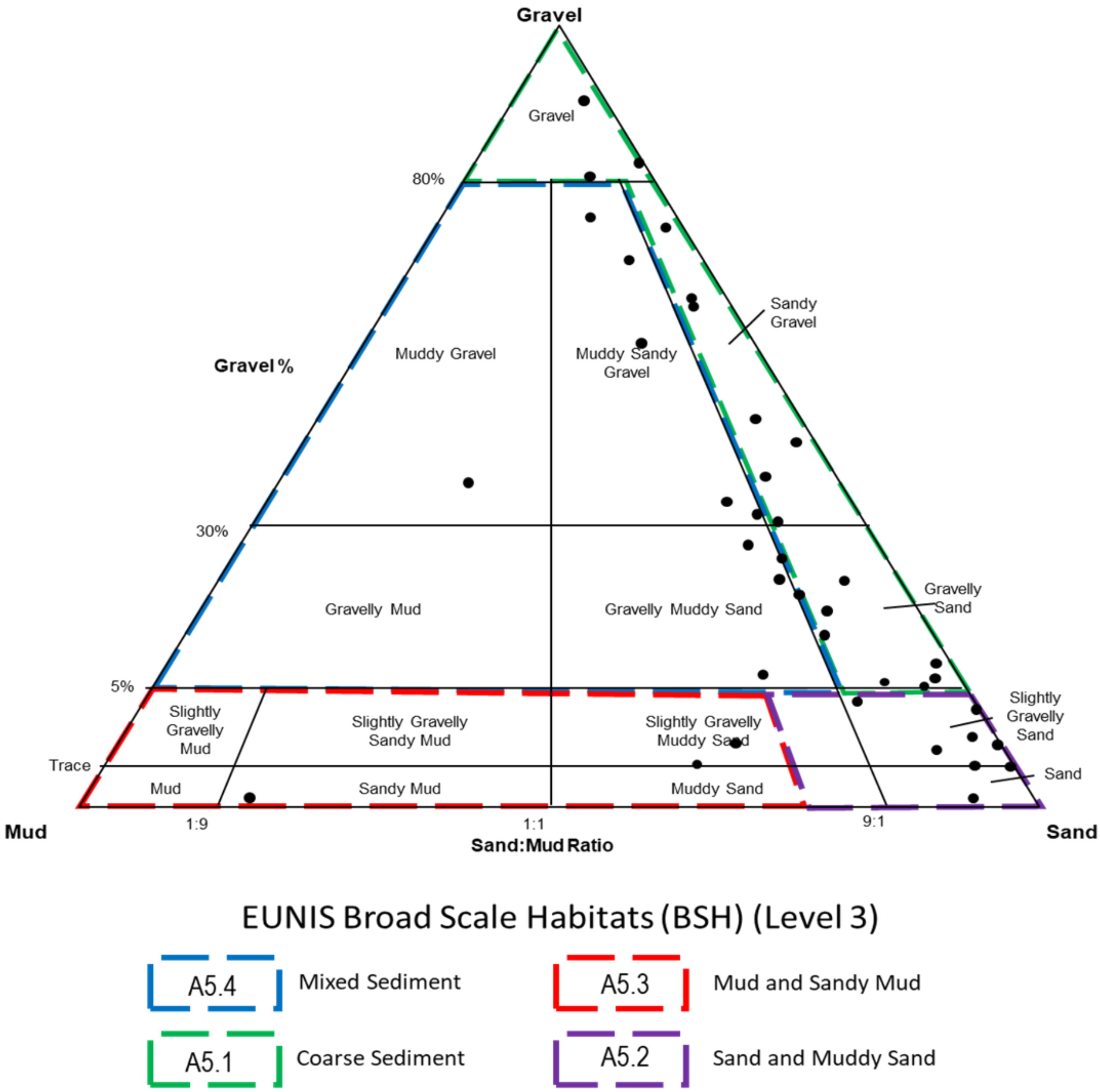

Figure 7 Folk (1954) triangle classifications of sediment gravel percentage and sand to mud ratio of samples collected across the ES Assessment Boundary, overlain by the modified Folk triangle for determination of mobile sediment BSHs under the EUNIS habitat classification system (adapted from (Long 2006)).

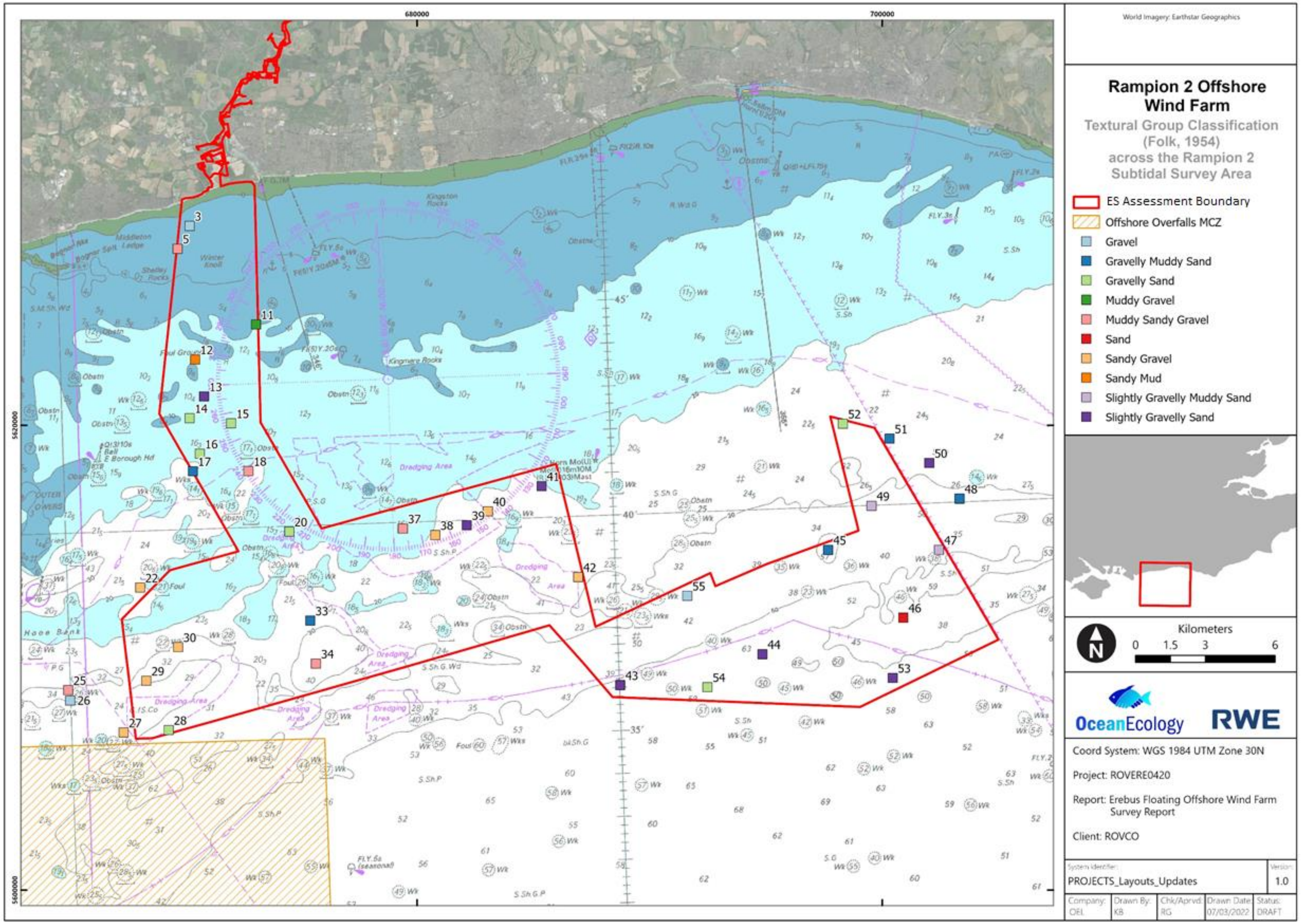

Figure 8 Folk (1954) sediment types as determined from PSD analysis of samples acquired across the ES Assessment Boundary.

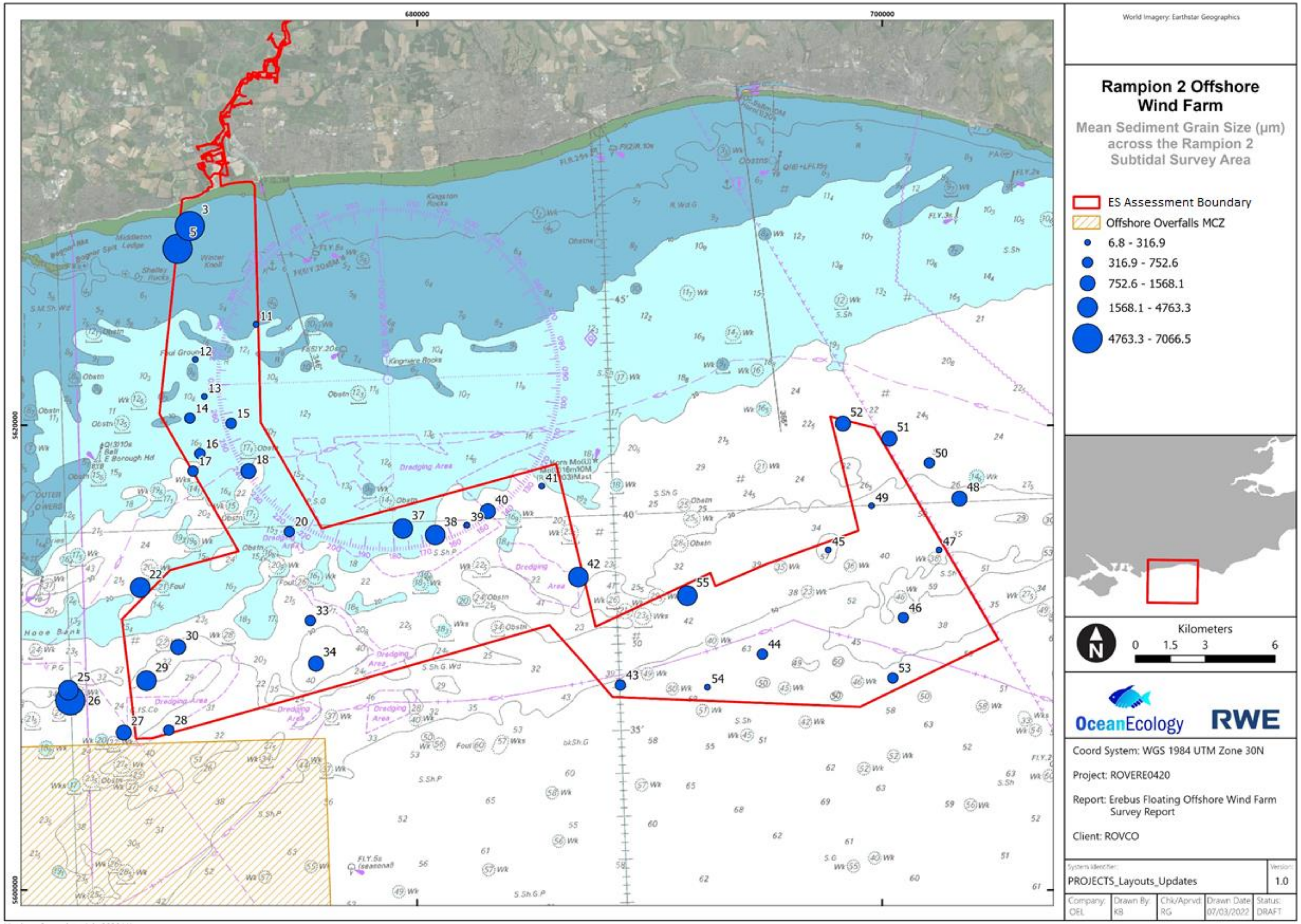

Figure 9 Comparison of mean sediment grain size (µm) of sediment samples collected across the ES Assessment Boundary.

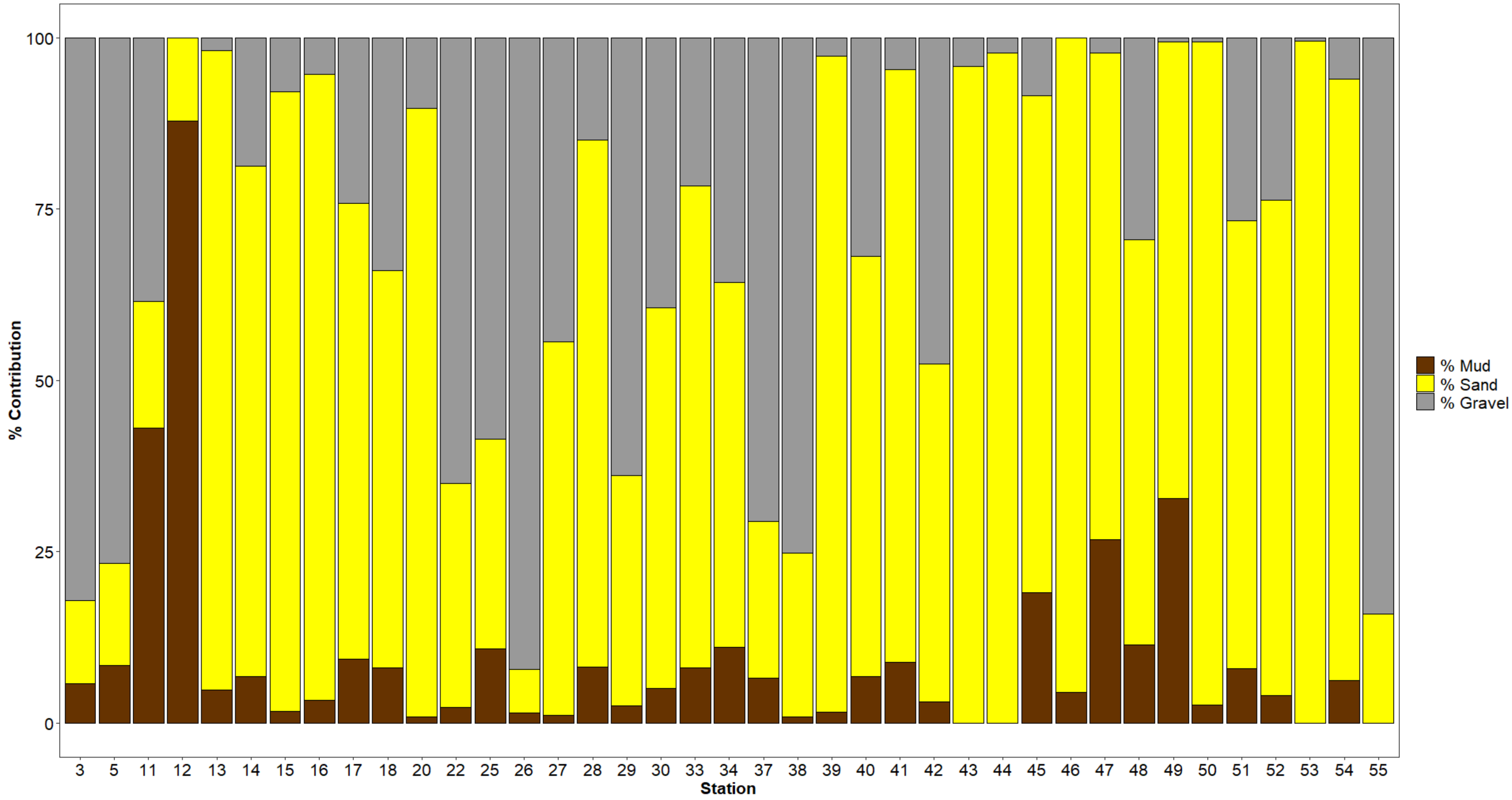

Figure 10 Principal sediment components (Gravel, Sand, Mud) as determined from PSD analysis of stations sampled across ES Assessment Boundary.

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6.3. Sediment Chemistry

A total of seven successful chemical samples (HM and HC) were collected across the ES Assessment Boundary a. Chemical samples were unable to be obtained from 8 stations during the survey due to the coarse sediment (pebbles/cobbles/bedrock) present at the target location. Grab samples taken for chemical analyses were analysed for heavy and trace metals, PAH, THC, TOC, and TOM. Raw sediment chemistry data are provided in Appendix XI.

6.3.1. Total Organic Carbon (TOC) and Total Organic Matter (TOM)

TOC concentrations ranged from 0.07% at Station 046 to 0.31% at Station 014 with an average value (± SD) of 0.18 ± 0.09% across the survey area (Figure 11). Average TOC across the ES Assessment Boundary seems to be slightly lower than the global sediment average TOC content for the deep ocean (0.5%) and eastern margins (2%) (Seiter et al. 2004). TOM concentrations ranged from 1.4% at Station 020 to 3.4% at Station 046 with an average value (± SD) of 2.1% ± 0.7% (Figure 12).

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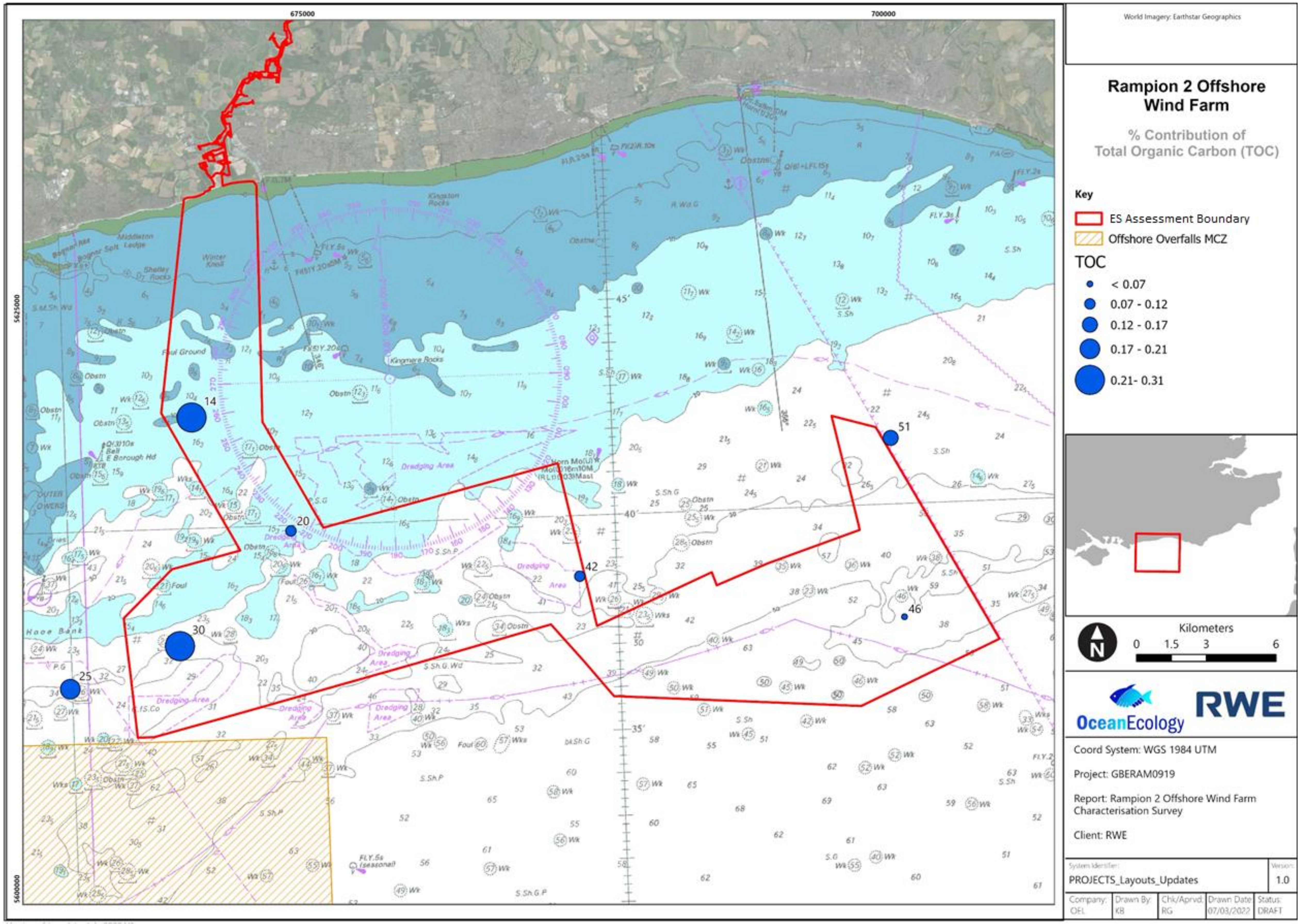

Figure 11 Percentage contribution of TOC at each sampling station sampled across the ES Assessment Boundary.

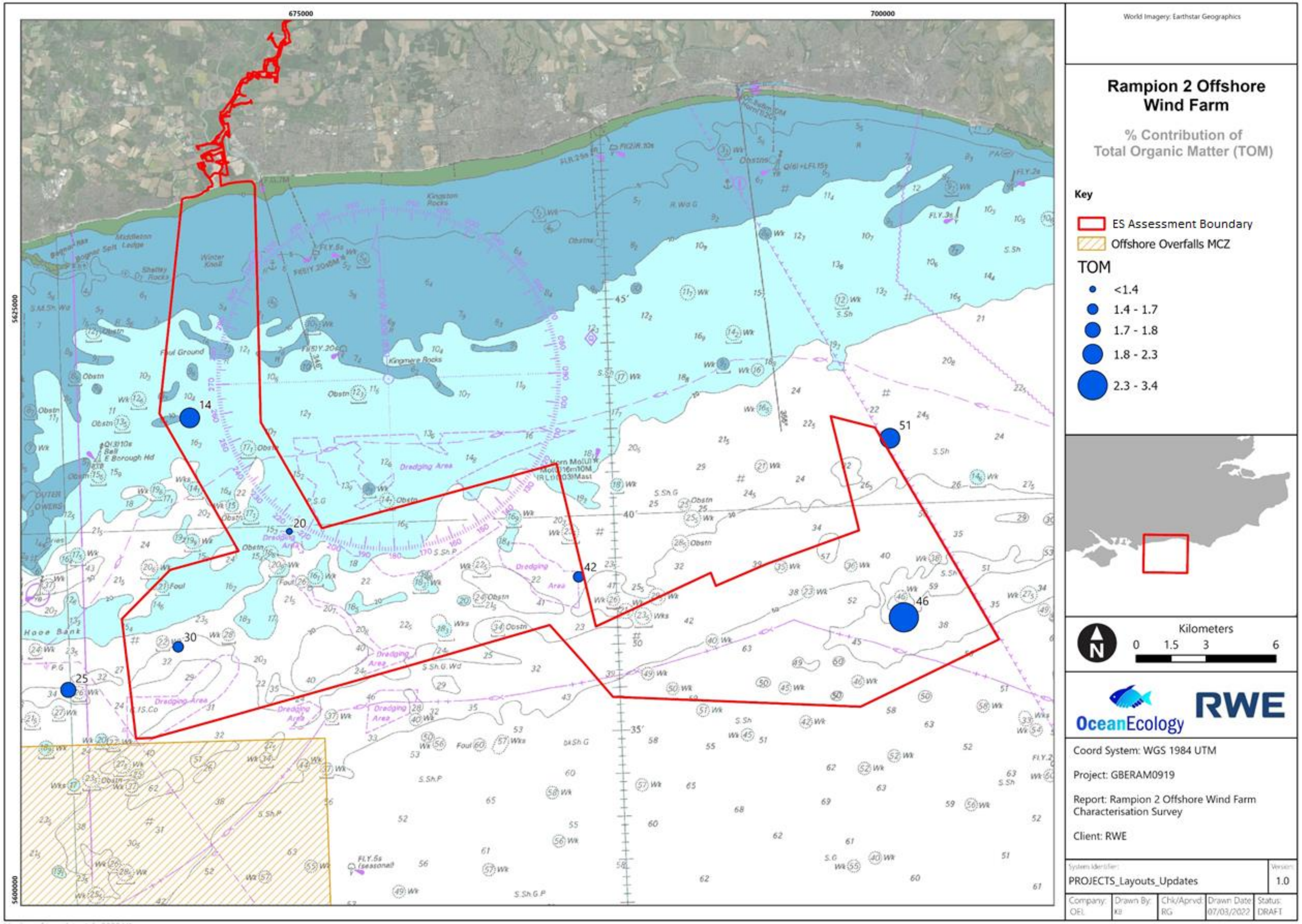

Figure 12 Percentage contribution of TOM at each sampling station sampled across the ES Assessment Boundary.

6.3.2. Heavy and Trace Metals

A total of eight heavy and trace metals were analysed from sediments taken at each of the seven stations. These were Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn).

The raw data (presented as a dry-weight concentration, mg kg^{-1}) are shown in Table 11. Where available, mean metal concentrations were compared to the OSPAR Background Assessment Concentration (BAC) (OSPAR et al. 2009), the USA Environmental Protection Agency (EPA) Effect Range Low (ERL) (NJDEP 2009), Cefas (1995) Action Level (AL) 1 and AL2, and the Canadian sediment quality guideline (CSQG) Threshold Effect Level (TEL) and Probable Effect Level (PEL) (CCME 2001).

BACs were developed to assess the status of metal concentrations in sediment within the OSPAR framework with metal concentrations significantly below the BAC considered to be near background levels. ERLs were developed by the USA EPA for assessing the ecological significance of sediment concentrations. Concentrations below the ERL rarely cause adverse effects in marine organisms. All stations exceeded ERL levels for As. In addition, 6 stations exceeded BAC levels for Cr, but did not exceed ERL levels (Table 11). All remaining metals did not exceed ERL or BAC levels.

Cefas ALs are used as part of a ‘weight of evidence’ approach to assessing dredged material and its suitability for disposal at sea (Cefas 2003). Contaminant levels in dredged material which fall below AL1 are of no concern and are unlikely to influence decision-making, while contaminant levels above AL2 are generally considered unsuitable for sea disposal. Contaminant levels between AL1 and AL2 require further assessment (MMO 2015, Mason et al. 2020). Concentrations of As were recorded at levels that exceeded Cefas (2003) AL1 at five stations, with no metals recording in excess of Cefas (2003) AL2 (Table 11).

CSQG are based on field research programmes that have demonstrated associations between chemicals and biological effects by establishing cause and effect relationships in particular organisms (CCME 2001). At levels above the TEL, adverse effects may occasionally occur, whilst at levels above the PEL, adverse effects may occur frequently. The TEL has been adopted as the International Sediment Quality Guideline (ISQG) (CCME 2001). Concentrations of As above TEL were recorded at all seven stations and above PEL at one station (ST051). All remaining metals fell below TEL and PEL limits (Table 11). All remaining metals did not exceed TEL or PEL limits.

Table 11 Heavy and trace metals (mg kg^{-1}) in sediments. Orange shading indicates values above OSPAR BAC.

Analyte	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
014	20.3	<0.2	31.8	4.9	13.1	<0.08	10.5	31.7
020	16.9	<0.2	9.9	2.9	6.9	<0.08	4.3	14.5
025	21.1	<0.2	18.1	13.3	8.7	<0.08	8.6	27.0
030	30.9	<0.2	20.4	4.6	9.8	<0.08	9.5	25.1
042	24.1	<0.2	19.3	4.3	8.4	<0.08	10.8	24.0
046	10.2	<0.2	6.6	3.2	6.3	<0.08	4.9	11.6
051	59.2	<0.2	32.3	6.1	15.1	<0.08	14.9	34.7
Min	**10.2**	**-**	**6.6**	**2.9**	**6.3**	**-**	**4.3**	**11.6**
Max	**59.2**	**-**	**32.3**	**13.3**	**15.1**	**-**	**14.9**	**34.7**
Mean	**26.10**	**-**	**19.77**	**5.61**	**9.76**	**-**	**9.07**	**24.09**
StDev	**15.91**	**-**	**9.80**	**3.55**	**3.24**	**-**	**3.64**	**8.45**
OSPAR BAC	25	0.31	8	27	38	0.07	36	122
ERL	8.2*	1.2	81	34	47	0.15	21*	150
CEFAS AL1	20	0.4	40	40	50	0.3	20	130
CEFAS AL2	100	5	400	400	500	3	200	800
ISQG/TEL	7.24	0.7	52.3	18.7	30.2	0.13	-	124
PEL	41.6	4.2	160	108	112	0.7	-	271

*The ERLs for As and Ni are below the BACs therefore As and Ni concentrations are usually assessed only against the BAC.

The most abundant metal was As which ranged from 10.2mg kg^{-1} at ST046 to 59.2mg kg^{-1} at ST051 with an average value (± SD) of 26.10 ± 15.91mg kg^{-1}. Cr and Zn were also recorded in high concentrations ranging between 6.6mg kg^{-1} at ST046 to 32.3mg kg^{-1} at ST051 with an average value (±.SD) of 19.77 ± 9.80mg kg^{-1} for Cr and ranging between 11.6mg kg^{-1} at ST046 to 34.7mg kg^{-1} at ST051 with and average value of 24.09 ± 8.45mg kg^{-1} for Zn (Figure 13). Concentrations of Zn did not however exceed guidance levels unlike Cr which exceeded BAC levels at 6 stations. Concentrations of Cu, Pb, and Ni did not exceed guidance levels across any of the seven stations sampled with concentrations of Cd and Hg all below limits of detection.

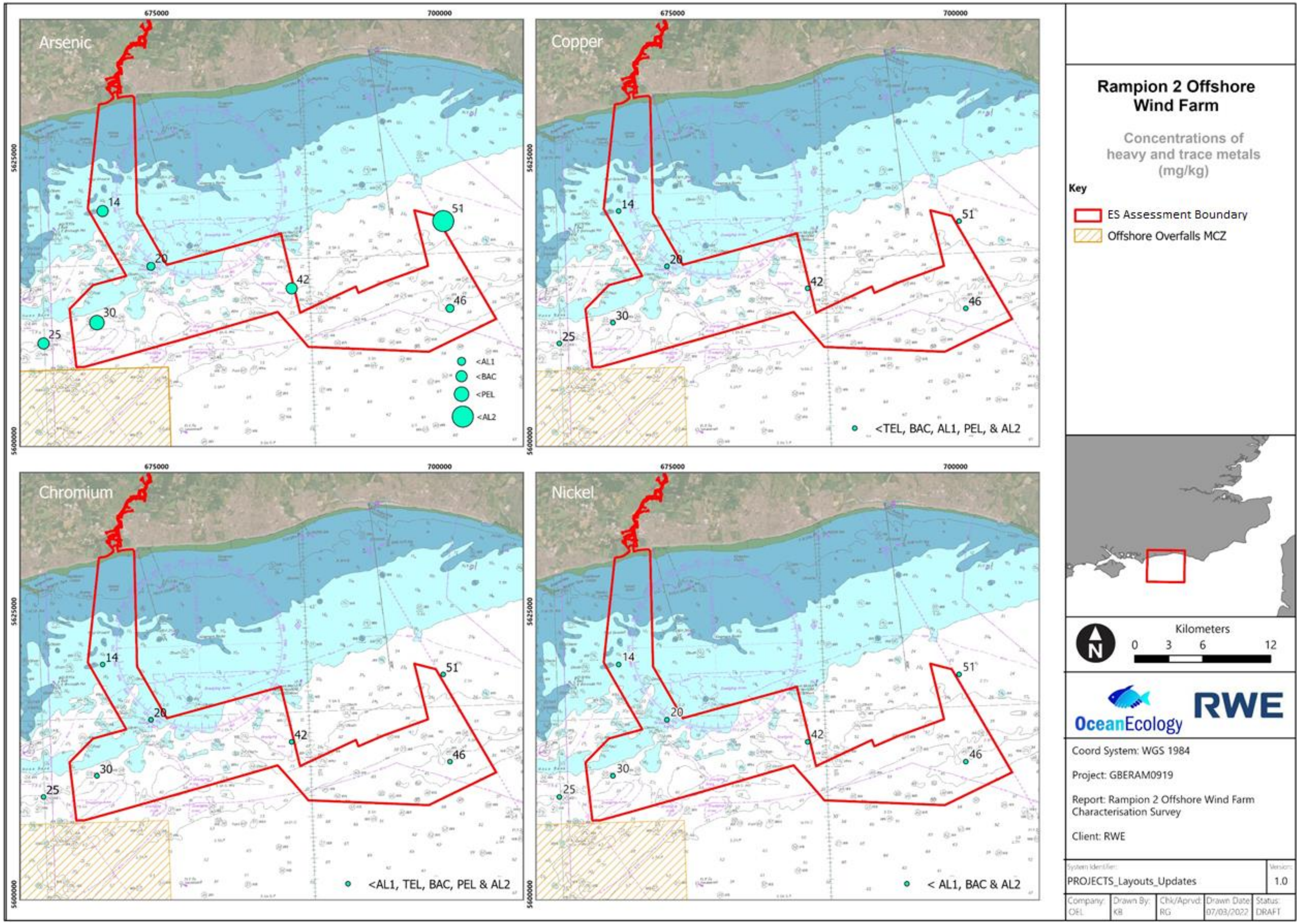

Figure 13 Concentration of the main heavy and trace metals sampled at each station across the ES Assessment Boundary.

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6.3.1. Polycyclic Aromatic Hydrocarbons (PAH)

The full range of PAHs as specified in the Department of Trade and Industry (DTI) regulations (DTI 1993) as well as by the EPA was tested for all seven samples collected.

The results of the PAH analyses undertaken are summarised in Table 12 with full results reported in Appendix XI. Mean PAH concentrations were compared to OSPAR BAC levels and ERLs, and ISQG TEL and PEL. There are no Cefas Action Levels for PAHs, however there is a proposed revised AL1 for PAHs following the DEFRA (2003) review, so for the purpose of this work the AL1 was reported against for reference.

With the exception of Phenanthrene (1.39µg kg^{-1} at ST020) and Pyrene (1.09µg kg^{-1} at ST030), all PAHs were recorded below limits of detection across all 7 sampling stations (Table 12). At the two stations where PAHs were detected, reference levels were not exceeded (Table 12). It was not possible to calculate the ratio between LMW and HMW due to the majority of PAH concentrations recording below detection limits (Figure 14). Furthermore, ratios of Phenanthrene/Anthracene (Ph/Ant) and of Fluoranthene/Pyrene (Fl/Py) could not be calculated due to the number of stations recording PAHs below limits of detection.

6.3.1. Total Hydrocarbons Content (THC) and Saturates

THC in sediment samples ranged from 1,220µg kg^{-1} at ST020 to 4,920µg kg^{-1} at ST025 with an average value (± SD) of 2,267.1 ± 1,370.2µg kg^{-1} (Figure 14).

N-alkanes (saturates) in sediments had carbon chains length ranging between C15 to C37 with the dominant chains being C37 for the odd numbered chains and C30 for the even numbered chains. The highest concentration of total n-alkanes was recorded at ST020 with 184µg kg^{-1} while the lowest concentration of total n-alkanes was recorded at ST046 with <28µg kg^{-1}. Average concentration of n-alkanes (± SD) for the survey area was 84.7 ± 52.2µg kg^{-1}. Pristane was the highest at ST025 with 1.59µg kg^{-1} and lowest at ST020, ST030, ST042, ST046, ST051 with <1µg kg^{-1}. Phytane was recorded at <1µg kg^{-1} across all seven sampled stations.

The Carbon Preference Index (CPI) and the ratio Pristane/Phytane can be used to assess the origin source of n-alkanes in sediments. To note that in most stations the Pristane/Phytane ratio could not be calculated as all samples had undetectable Phytane concentrations. When using the CPI to assess n-alkanes origin sources, it was found that for all stations (except for ST025), their origin was biogenic (CPI >1) (Figure 14).

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Table 12 Summary of average PAH concentration (mg kg^{-1}) against OSPAR and CSQG.

Analyte	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Dibenzothiophene	Anthracene	Fluoranthene
Min	<1	<1	<1	<1	<1	<1	<1	<1
Max	<1	<1	<1	<1	1.39	<1	<1	<1
Mean	-	-	-	-	-	-	-	-
St. Dev	-	-	-	-	-	-	-	-
AL1	100	100	100	100	100	100	-	100
BAC	8	-	-	-	32	-	-	39
ERL	160	-	-	-	240	190	-	600
TEL	34.60	5.87	6.71	21.20	86.70	-	46.9	113.00
PEL	391	128	88.9	144	544	-	245	1494.00

Analyte	Pyrene	Benzo[a]anthracene	Chrysene	Benzo[a]pyrene	Indeno[123,cd]pyrene	Dibenzo[a,h]anthracene	Benzo[ghi]perylene
Min	<1	<1	<1	<1	<1	<1	<1
Max	1.09	<1	<1	<1	<1	<1	<1
Mean	-	-	-	-	-	-	-
St. Dev	-	-	-	-	-	-	-
AL1	100	100	100	100	100	100	100
BAC	24	16	20	30	103	-	80
ERL	665	261	384	430	-	-	-
TEL	153	74.80	108	88.80	-	6.22	-
PEL	1398	693	846	763	-	135	-

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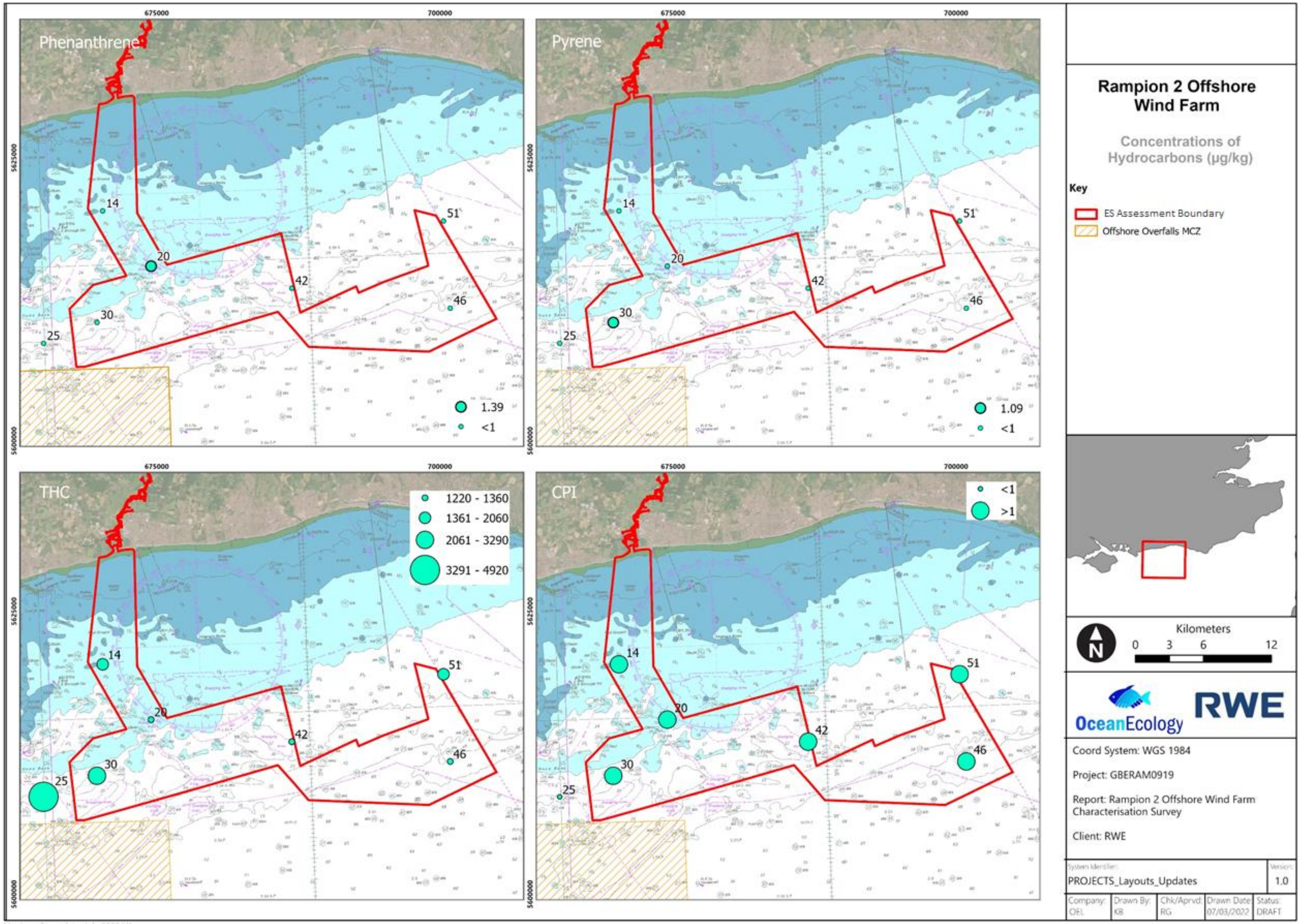

Figure 14 Concentration (µg kg^{-1}) of key hydrocarbons and relative indices and ratios (PAHs top; total hydrocarbons bottom) at each sampling station across the ES Assessment Boundary.

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6.4. Macrobenthos

6.4.1. Macrobenthic Composition

A diverse macrobenthic assemblage was identified across the study area based on grab samples, with a total of 1,489 individuals and 232 taxa recorded. The mean (± SE) number of taxa was 19.1 ± 2.7 per station. Mean (± SE) abundance per station was 45.1 ± 8.2 with a mean (± SE) biomass per station of 0.4 ± 0.1 gAFDW.

The full abundance matrix is provided in Appendix XII. The biomass (gAFDW) of each major taxonomic group (Annelida, Crustacea, Mollusca, Echinodermata and Miscellaneous) in each sample collected is presented in Appendix XIII.

As shown in Figure 15, the polychaete *S. lamarcki* was the most abundant species sampled, accounting for 11.9% of all individuals recorded. It also accounted for the maximum abundance in a single sample and greatest average density per sample (Figure 15c and d). Another key taxon was the phylum Nemertea which was the most frequently occurring taxon recorded in 57.6% of samples (Figure 15b).

The sampling stations with the highest abundance were stations ST011, ST026, ST017 and ST003 (Figure 17), where ST011 was dominated by the polychaete *S. lamarcki*, accounting for over 60% of the total abundance. Sampling stations with the highest diversity (S, number of species/taxa) were stations ST026, ST017 and ST029, with specimens belonging to ST061, ST050 and ST050 different taxa, respectively (Figure 18).

Biomass ranged between 0.0018 and 3.66 gAFDW per sample, with the highest value found at Station ST003 due to high mollusc biomass (Figure 19). Across the entire study area, most of the biomass was accounted for by the group Mollusca, while abundance and diversity were driven by the group Annelida. Figure 16 illustrates the relative contributions to total abundance, diversity, and biomass of the major taxonomic groups in the macrobenthic community sampled across the study area.

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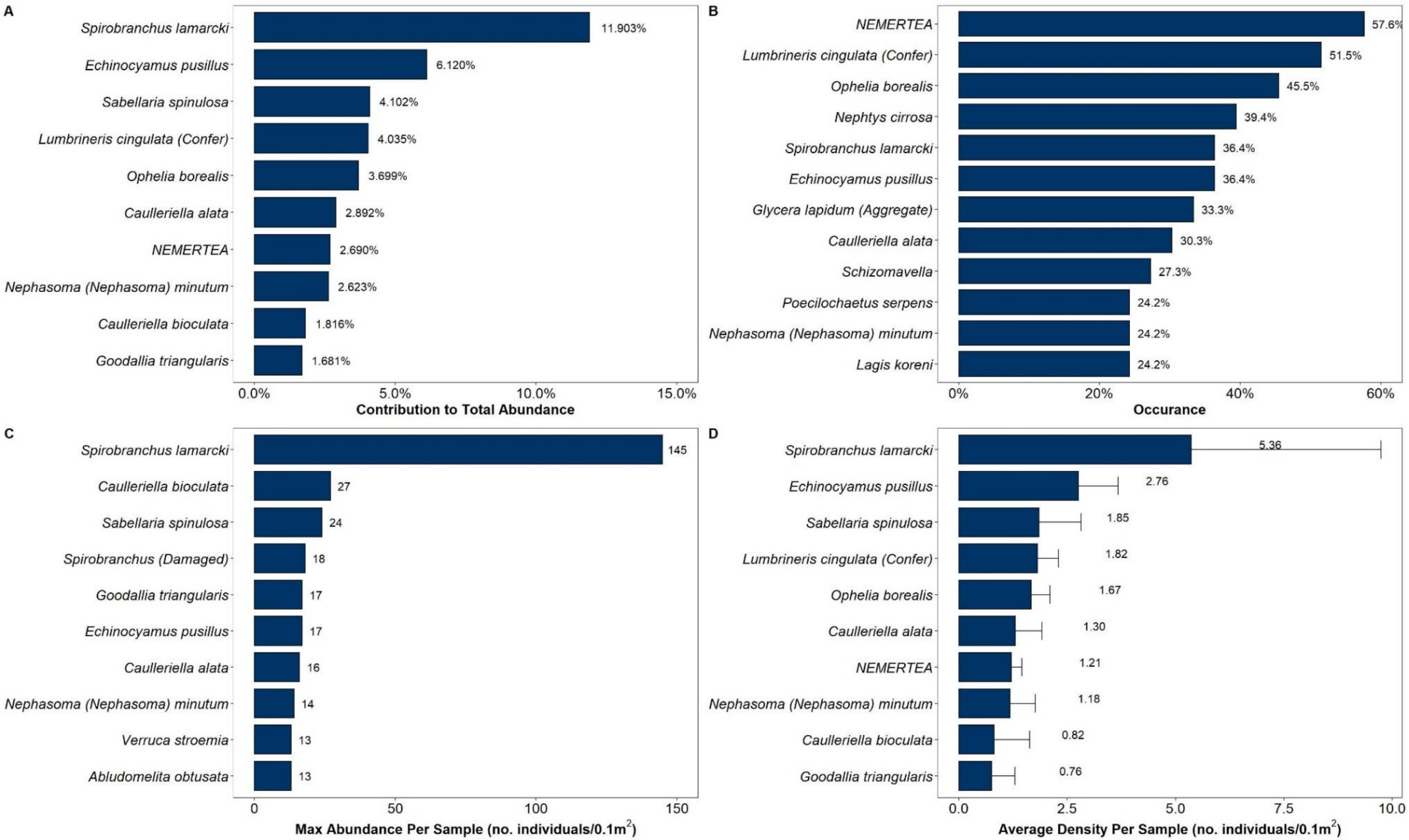

Figure 15 Percentage contributions of the top 10 macrobenthic taxa to total abundance (a) and occurrence (b) from samples collected across the ES Assessment Boundary. Also shown are the maximum densities of the top 10 taxa per sample (c) and average densities of the top 10 taxa per sample (d).

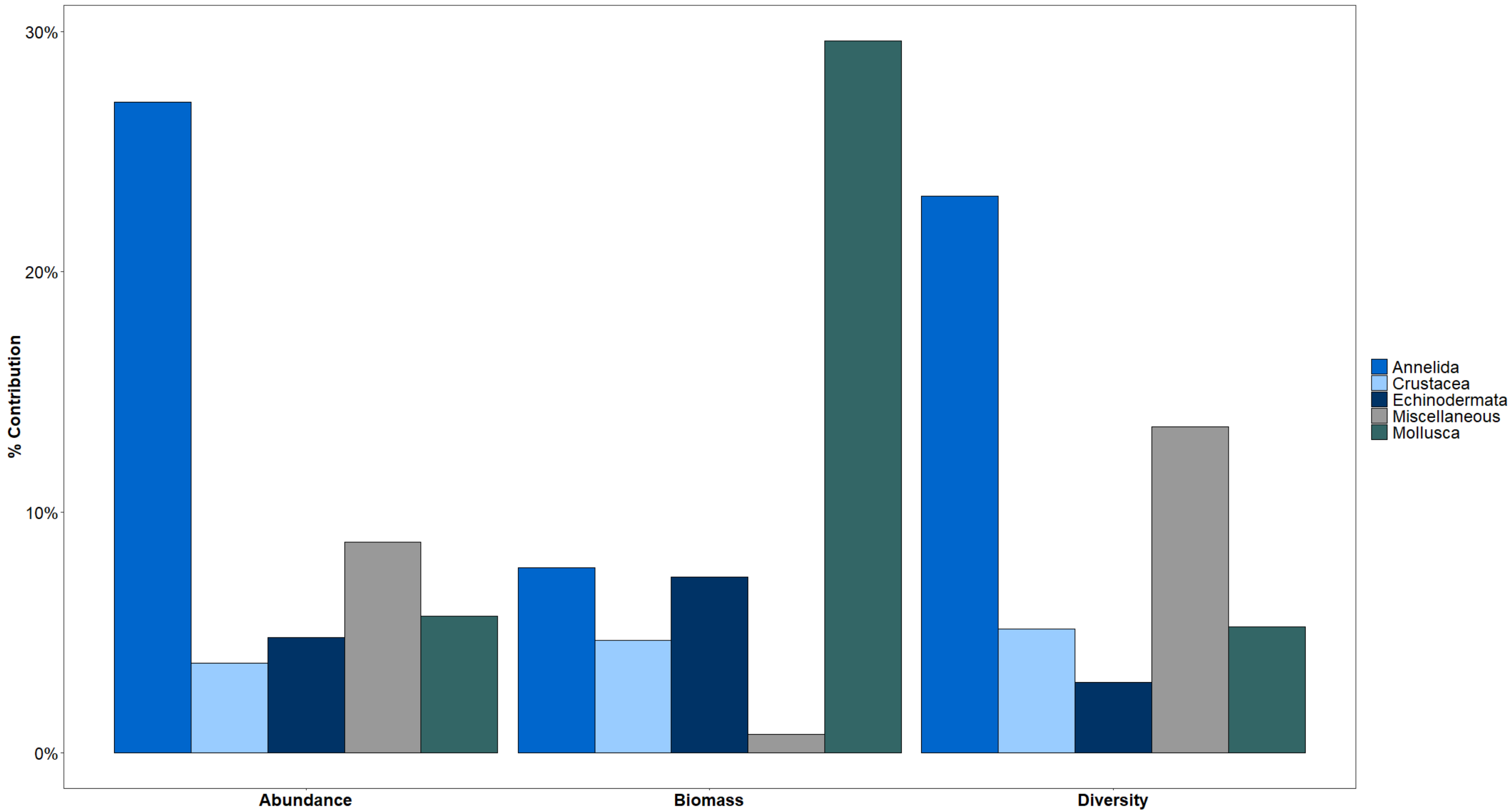

Figure 16 Relative contribution of the major taxonomic groups to the total abundance, diversity and biomass of the macrobenthos sampled across the ES Assessment Boundary.

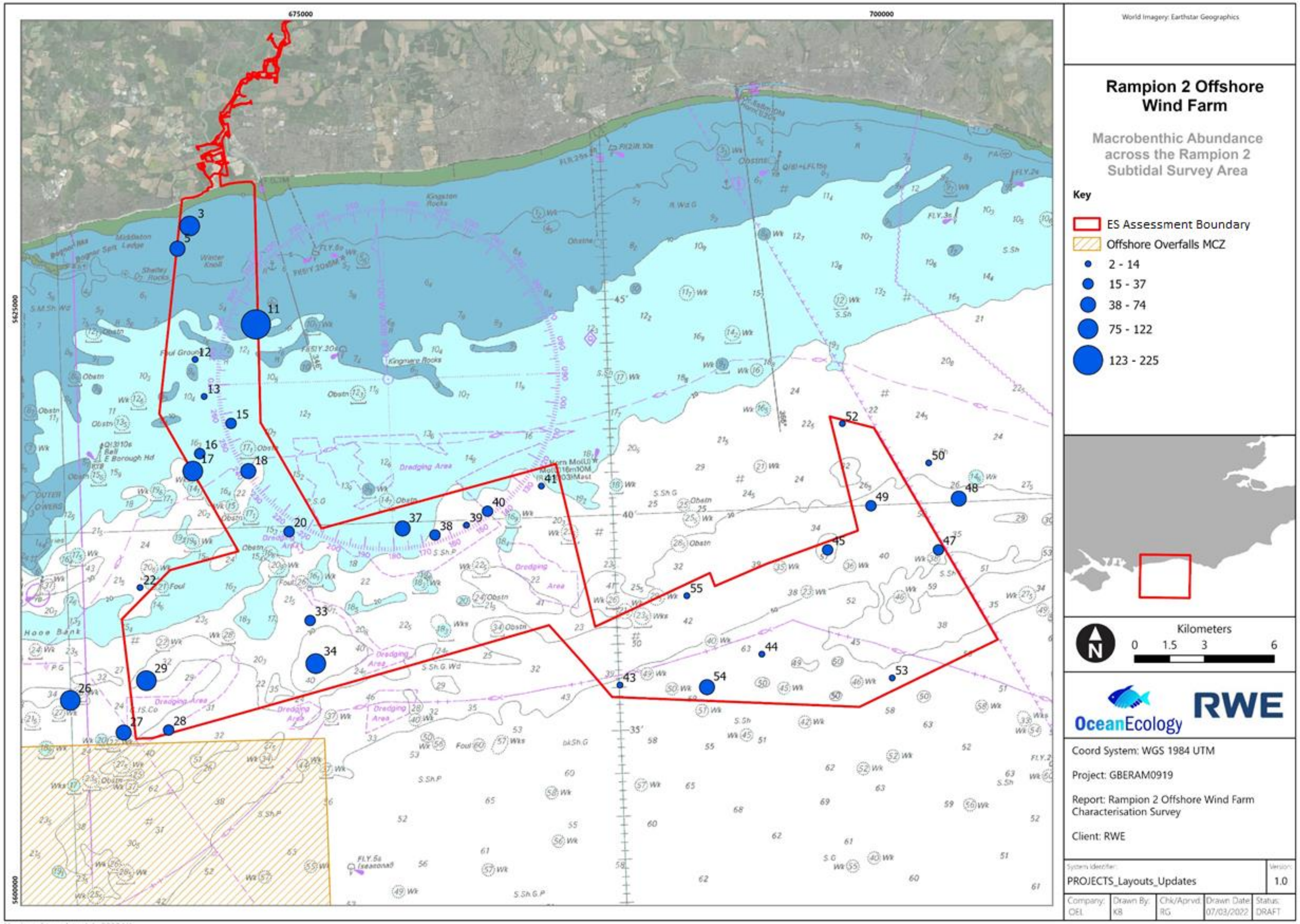

Figure 17 Comparison of macrobenthic abundance per station sampled across the ES Assessment Boundary.

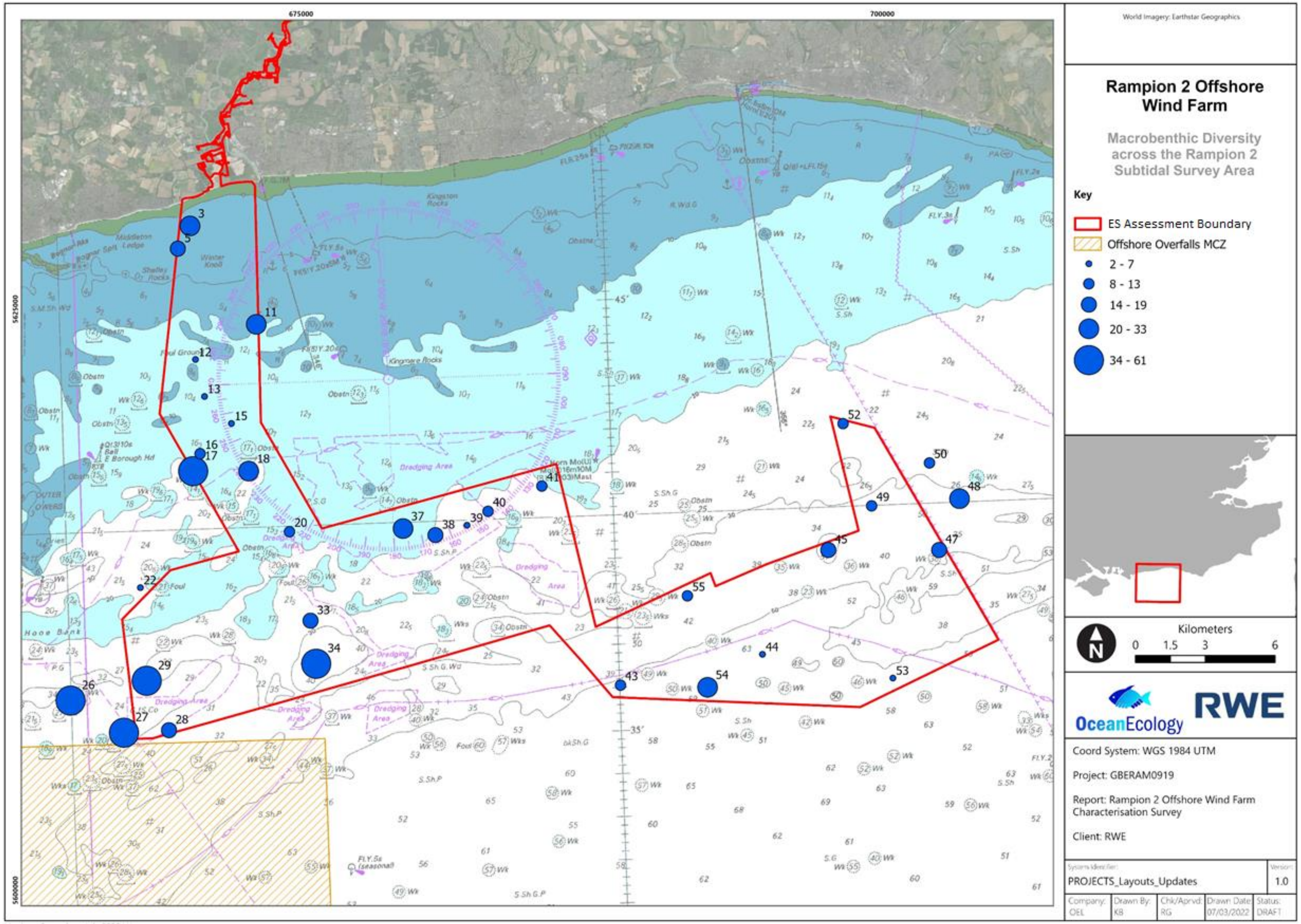

Figure 18 Comparison of macrobenthic diversity per station sampled across the ES Assessment Boundary.

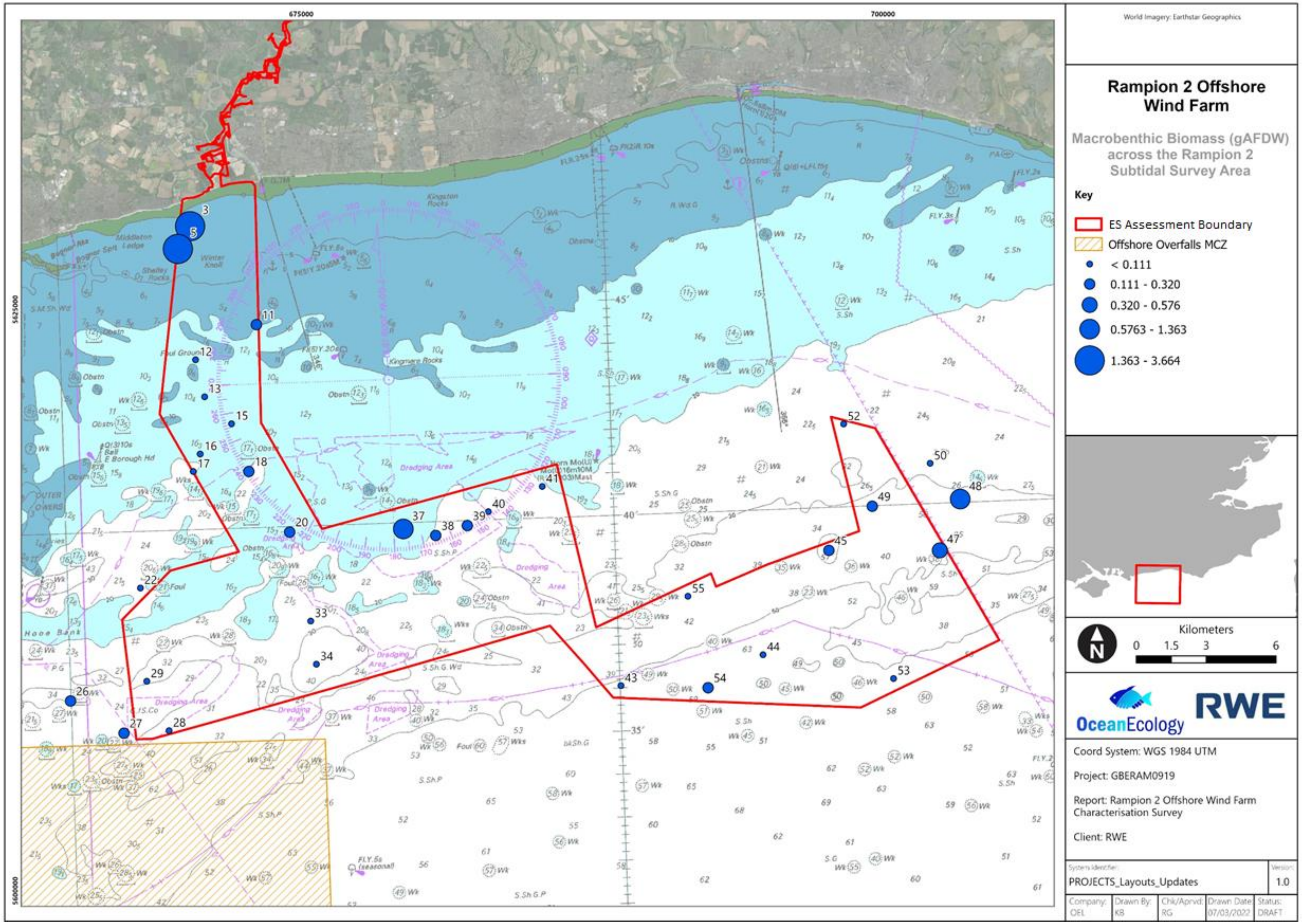

Figure 19 Comparison of macrobenthic biomass (gAFDW) per station sampled across the ES Assessment Boundary.

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6.4.2. Notable Taxa

Two species of interest were identified from the 33 macrobenthic samples analysed: *C. fornicata* and *S. spinulosa* (Table 13).

All individuals of the invasive, non-native species (INNS) *C. fornicata* occurred in the two stations collected closest inshore, Stations ST003 and ST005, each with 11 specimens. The biotope A5.431- *Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment was observed in the nearshore area of the ES Assessment Boundary based on imagery analysis (Figure 6 and Plate 6).

Of the 61 individuals of *S. spinulosa* identified across the survey area, 45 were recorded between Stations ST017 and ST018, while the remaining 16 specimens were recorded at Stations ST011 (n=6), 26 (n=2) and ST054 (n=8). To note that Stations ST017 and ST018 are in proximity of transects T_024 and T_027 along which low 'reefiness' *S. spinulosa* reef were observed (see Paragraph 6.1.1 and Plate 5 for more details).

Table 13 Notable taxa found across the ES Assessment Boundary.

Taxon	Major Group	Designation	No. of individuals
Crepidula fornicata	Mollusca	INNS	22
Sabellaria spinulosa	Annelida	OSPAR listed & Annex I in reef form	61

6.4.3. Macrobenthic Faunal Groupings

Multivariate analysis was undertaken on the square-root transformed macrobenthic abundance data derived from grab samples to identify spatial distribution patterns in faunal assemblages across the ES Assessment Boundary and identify the characterising taxa present.

Cluster analysis of the macrobenthic data was performed on a Bray-Curtis similarity matrix to analyse the spatial similarities in macrobenthic communities recorded across all sampled stations. The dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF (similarity profile routine) permutation test of all nodes within the dendrogram, identified 5 statistically significantly similar groups ($p > 0.05$) and two outlier stations (Stations ST011 and ST028) (Figure 20). Of the outlier stations, station ST011 was the one with the highest abundance across the whole survey area.

To visualise the relationships between the sampled macrobenthic assemblages, a non-metric multi-dimensional scaling (nMDS) ordination plot was generated on the community abundance data (Figure 20). The nMDS represents the relationships between the communities sampled, based on the distance between sample (station) points. The stress value of the nMDS ordination plot (0.17) indicates that the two-dimensional plot provides an adequate representation of the similarity between stations. The degree of clustering of intra-group sample points demonstrates the level of within group similarity, whilst the degree of overlap of inter-group sample points is indicative of the level of similarity between different Macrobenthic Groups.

The spatial distribution of the five Macrobenthic Groups and outliers is mapped in Figure 21. SIMPER (similarity percentage analysis) was used to identify the key taxa contributing to the within group similarity (see Appendix XIV for SIMPER results).

Macrobenthic Group A (15 stations) – This was the largest group identified based on the SIMPROF routine. Taxa contributing the most to the similarity within this group (average similarity 19.26) were the white catworm *Nephtys cirrosa* bristle worm and the *Ophelia borealis* and together accounting for over 60% of the group total average similarity.

Macrobenthic Group B (3 stations) – Stations ST045, ST047 and ST049 fell into this group, all located offshore and to the east of the study area. The taxa characterising these locations were the polychaetes *Poecilochaetus serpens* and *Lagis koreni* together contributing to over 40% of the group total average similarity of 27.81.

Macrobenthic Group C (4 stations) – Taxa contributing the most to the within group average similarity of 25.49 were the polychaetes *Caulleriella alata* and *S. lamarcki*, and the small brittle star *Amphipholis squamata*. Stations ST003 and ST005 located closest to shore belonged to this group together with Stations ST037 and ST038 located further offshore and slightly to the east of the survey area.

Macrobenthic Group D (3 stations) – Stations ST026, ST027 and ST029 fell into this group, all located offshore and to the west of the study area. The taxa characterising these locations were the peanut worm *Nephasoma minutum,* the pea urchin *Echinocyamus pusillus*, and Nemertea together contributing to over 20% of the group total average similarity of 44.93.

Macrobenthic Group E (6 stations) – The taxa contributing most to similarities between the four sampling stations within this group (average similarity: 31.10) were *E. pusillus*, the polychaete *Lumbrineris cingulata* and Nemertea (over 40%).

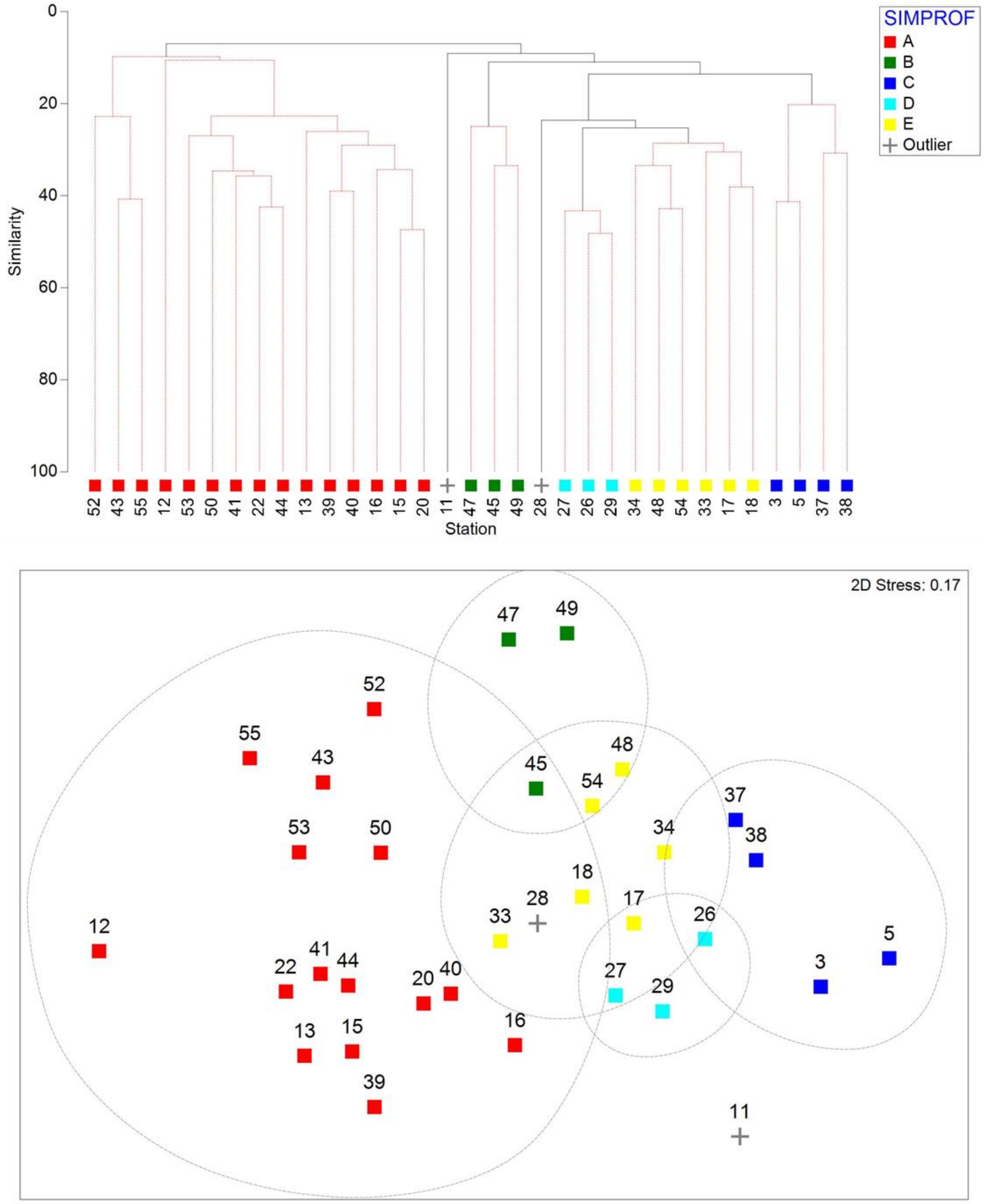

Figure 20 Top: Dendrogram resulting from the cluster analysis and associated SIMPROF test on a Bray-Curtis similarity matrix derived from square-root transformed macrobenthic abundance data. Bottom: Two-dimensional nMDS ordination of macrobenthic communities sampled across the ES Assessment Boundary based on square-root transformed and Bray-Curtis similarity abundance data. Macrobenthic Groups were identified based on the SIMPORF routine.

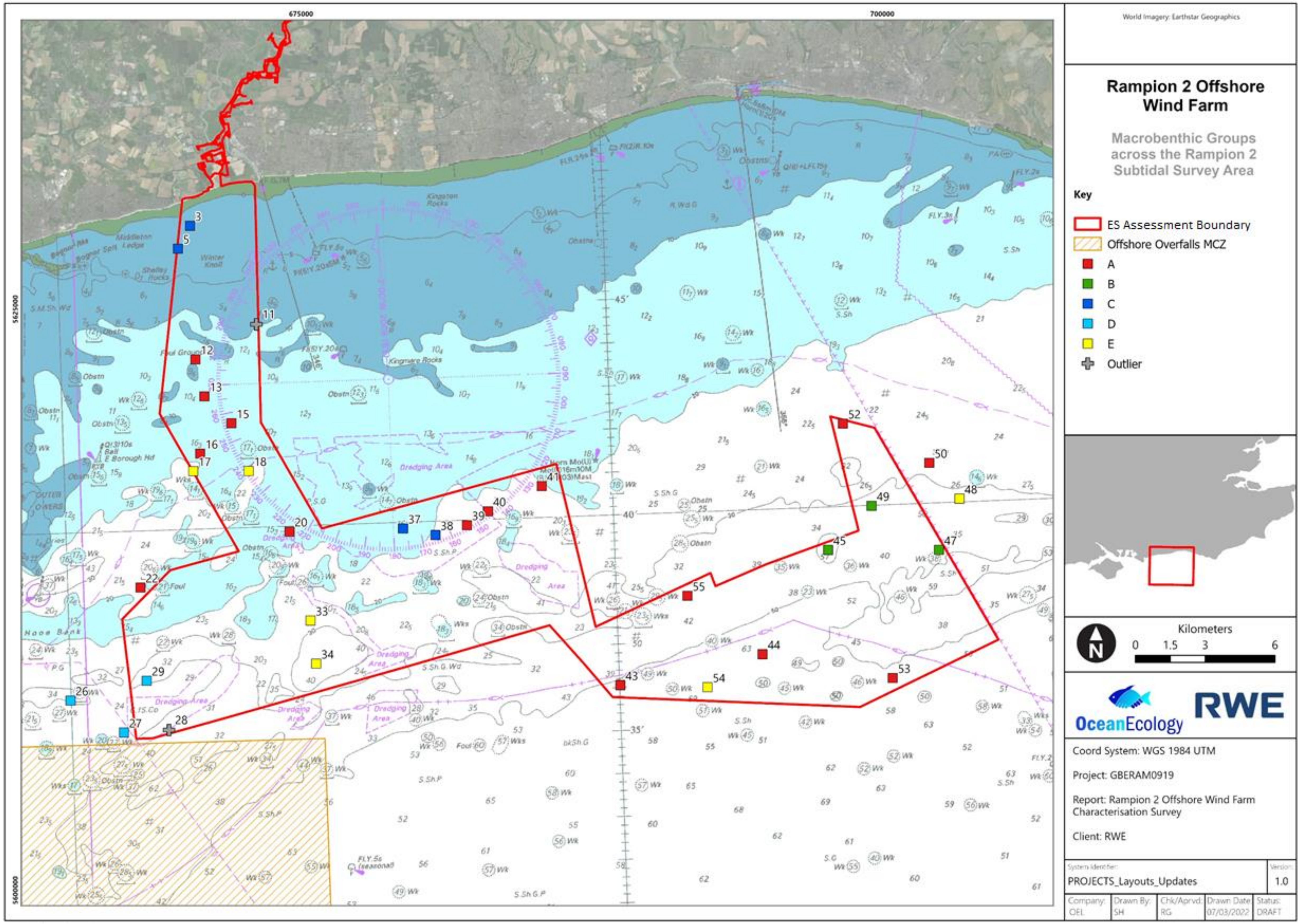

Figure 21 Spatial distribution of Macrobenthic Groups (A-E) and outliers identified for each station across the ES Assessment Boundary.

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6.4.4. Biotope Assignment

For each of the five Macrobenthic Groups determined using cluster analysis and the SIMPROF routine, biotopes were assigned according to the JNCC classification tool (JNCC 2015) based upon their faunal and physical characteristics (Table 14). Correlation of EUNIS/MNCR (Marine Nature Conservation Review) biotopes was undertaken using the JNCC correlation table (JNCC 2018). As Stations 11 and 28 were considered outliers, both were excluded from the biotope assessment.

Macrobenthic Group A (15 stations) - despite the overall low abundance of fauna observed at the stations falling within this group, a total of 175 individuals were counted between the 15 stations making up Macrobenthic Group E. The PSD data (Figure 7 and Figure 10) together with the few taxa that characterised this group, namely *O. borealis, N. cirrosa* and *Bathyporeia guilliamsoniana*, indicated that biotope “A5.233 *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand” was the closest match.

Macrobenthic Group B (3 stations) - included stations characterised by the presence of polychaetes such as *L. koreni, Poecilochaetus serpens* and *Scalibregma inflatum* as well as bivalves like *Kurtiella bidentata* and *Abra alba.* Given the relatively high mud content found at these stations, the biotope that most closely aligned with the observed community was “A5.261 *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment”. To note that this biotope can exhibit some cyclical behaviour with the community switching to “A5.355 *Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud”. Nevertheless, as sediment data indicated (Slightly) Gravelly Muddy Sand as the substrate present at these sampling stations, biotope A5.261 was deemed to be the closest match.

Macrobenthic Group C (4 stations) - included stations characterised by coarse/mixed sediments with cobbles and the occasional boulder and a macrobenthic assemblage characterised by the presence of a number of polychaetes. This aligns with biotope “A5.131 Sparse fauna on highly mobile sublittoral shingle (cobbles and pebbles)”. It should also be noted that Stations 3 and 5 which belonged to this group had considerable numbers of the INNS *C. fornicata* and the imagery analysis reported the presence of biotope “A5.431 *Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment” in proximity of these two stations.

Macrobenthic Group D (3 stations) – the biotope that most closely aligned with the community observed in this group was “A5.142 *Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel”, which is consistent with the presence of coarse sediments at these stations. Similarly, **Macrobenthic Group E** (6 stations) also appeared to align with biotope A5.142. However, two of the stations within **Macrobenthic Group E**, Stations 17 and 18, were also characterised by the presence of *S. spinulosa*. Imagery analysis reported the presence of the biotope “A5.611 *Sabellaria spinulosa* on stable circalittoral mixed sediment” in proximity of these stations, which correlates well with their sediment type and composition identified as BSH A5.4 Mixed Sediment (Figure 7 and Figure 10).

Table 14 Summary of biotopes encountered across the ES Assessment Boundary based on macrobenthic and sediment data.

Fauna Groups	Station	Assigned Biotope	Notes
A	12	A5.233 *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	
	13		
	15		
	16		
	20		
	22		
	39		
	40		
	41		
	43		
	44		
	50		
	52		
	53		
	55		
B	45	A5.261 *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment	
	47		
	49		
C	3	A5.131 Sparse fauna on highly mobile sublittoral shingle (cobbles and pebbles)	Presence of *Crepidula fornicata*
	5		Presence of *Crepidula fornicata*
	37		
	38		
D	26	A5.142 *Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel	
	27		
	29		
E	17		Presence of *Sabellaria spinulosa*
	18		Presence of *Sabellaria spinulosa*
	33		
	34		
	48		
	54		

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6.5. Predictive EUNIS Habitat/Biotope Mapping

The following tables, Table 15 to Table 18, indicate the percentage cover of each EUNIS habitat predicted across the ES Assessment Boundary based on the data listed in Section 5.6. The output predictive maps are displayed in Figure 22 to Figure 25. The EUNIS composite predictive map (Figure 22) comprised predominantly of Atlantic and Mediterranean high energy Circalittoral rock (A4.1), Infralittoral fine sand (A5.23) and *Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel (A5.142). The BSH predictive map (Figure 23) predominantly comprised of Atlantic and Mediterranean high energy Circalittoral rock (A4.1) and Sublittoral sand (A5.2). The Level 4 predictive map (Figure 24) was dominated by Infralittoral fine sand (A5.23) and also Circalittoral coarse sediment (A5.14) whilst the Level 5 predictive map (Figure 25) was dominated by Infralittoral mobile clean sand with sparse fauna (A5.231) and *Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in Circalittoral coarse sand or gravel (A5.142).

Table 15 The number and percentage of pixels classified per EUNIS classification (composite map).

EUNIS	Pixels	Percentage
A3.215	0	0.0
A4.1	10110712	11.3
A4.13	1551234	1.7
A4.2	7890194	8.8
A4.231	17723	0.0
A5.1	2537737	2.8
A5.131	1114896	1.2
A5.14	858699	1.0
A5.141	3469513	3.9
A5.142	10123931	11.3
A5.2	9195081	10.2
A5.23	10566060	11.8
A5.231	4755778	5.3
A5.233	6674887	7.4
A5.25	63219	0.1
A5.261	1562637	1.7
A5.3	445583	0.5
A5.4	7553315	8.4
A5.42	44371	0.0
A5.43	1715420	1.9
A5.431	1108632	1.2
A5.44	557449	0.6
A5.444	6837431	7.6
A5.5	905663	1.0
A5.52	168440	0.2

Table 16 The number and percentage of pixels classified per broad scale habitat EUNIS code.

EUNIS	Pixels	Percentage
A5.4	0	0.0
A5.1	12662431	14.4
A5.2	25948607	29.5
A4.2	10146994	11.5
A3.2	253805	0.3
A5.5	3721232	4.2
A4.1	29173778	33.2
A5.3	6017654	6.8

Table 17 The number and percentage of pixels classified per Level 4 EUNIS code.

EUNIS	Pixels	Percentage
A4.13	0	0
A4.23	22032	0.0
A5.13	3767150	6.2
A5.14	19682131	32.6
A5.23	28957169	47.9
A5.25	72745	0.1
A5.26	7852479	13.0
A5.42	52544	0.1
A5.43	389064	0.6
A5.44	10678591	17.7
A5.52	207362	0.3

Table 18 The number and percentage of pixels classified per Level 5 EUNIS biotope code.

EUNIS	Pixels	Percentage
A3.215	0	0.0
A4.139	48267	0.1
A4.231	194814	0.5
A5.422	159781	0.4
A5.431	2812741	6.6
A5.444	9527442	22.5
A5.141	541339	1.3
A5.142	29035633	68.6
A5.231	20413659	48.2
A5.131	4844479	11.4
A5.233	13566619	32.1
A5.261	3923333	9.3

6.6. Model Validation

Model validation is displayed as a series of confusion matrices (Table 19 to Table 22) indicating the percentage of pixels classified correctly and highlighting the miss-classified EUNIS codes, and a Cohen's Kappa score of agreement per predictive map (Table 23). Overall, the greatest percentage of correctly classified pixels occurred within sublittoral coarse sediment (A5.1) with 77.5% of pixels classified correctly. The greatest percentage of miss-classifications occurred within the map displaying all levels (Figure 22) whilst miss-classification was largely reduced in all single level maps (Figure 23 - Figure 25). The Cohen's Kappa scores ranged from non/poor level of agreement (all EUNIS levels) to moderate/good (Level 4 and level 5).

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6.6.1. Confusion Matrices

Table 19 Confusion matrix for all EUNIS classification levels (composite map).

%	A5.142	A5.1	A5.4	A5.233	A5.444	A5.2	A5.131	A4.13	A5.261	A5.231	A5.141
A5.4	1.5	54.5	39.5	0.5	0.5	0.5	4.5	0.5	0.5	0.5	0.5
A5.142	8.5	69.5	15.5	1.5	0.5	3.5	0.5	0.5	0.5	0.5	0.5
A5.1	6.5	77.5	11.5	1.5	0.5	2.5	0.5	0.5	0.5	0.5	0.5
A5.233	0.5	54.5	3.5	3.5	2.5	24.5	0.5	1.5	0.5	7.5	0.5
A5.25	0.5	0.5	0.5	100.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
A5.2	2.5	76.5	11.5	1.5	0.5	7.5	0.5	0.5	0.5	0.5	0.5
A5.131	0.5	76.5	5.5	5.5	0.5	2.5	7.5	0.5	0.5	3.5	1.5
A5.44	0.5	55.5	0.5	44.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
A5.431	0.5	100.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
A5.2	0.5	47.5	0.5	5.5	0.5	37.5	0.5	0.5	0.5	6.5	0.5
A5.444	1.5	63.5	12.5	5.5	16.5	1.5	0.5	0.5	0.5	0.5	0.5
A4.13	4.5	51.5	12.5	0.5	0.5	4.5	17.5	3.5	0.5	2.5	4.5
A4.1	9.5	62.5	16.5	5.5	0.5	0.5	0.5	3.5	0.5	0.5	0.5
A5.141	0.5	45.5	39.5	0.5	0.5	0.5	0.5	10.5	0.5	0.5	4.5
A5.14	0.5	20.5	18.5	0.5	0.5	0.5	0.5	7.5	0.5	0.5	53.5
A5.231	0.5	31.5	2.5	3.5	0.5	50.5	0.5	0.5	0.5	12.5	0.5
A5.23	0.5	36.5	0.5	12.5	0.5	44.5	0.5	0.5	5.5	0.5	0.5
A5.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	100.5	0.5	0.5
A5.261	0.5	76.5	0.5	2.5	0.5	16.5	0.5	0.5	0.5	0.5	1.5

Table 20 Confusion matrix for the EUNIS BSH predictive map.

%	A5.1	A5.4	A5.2	A4.1	A5.3
A5.4	55.5	27.5	14.5	3.5	0.5
A5.1	75.5	20.5	3.5	0.5	0.5
A5.2	19.5	2.5	74.5	0.5	2.5
A4.2	38.5	34.5	26.5	0.5	0.5
A5.5	39.5	60.5	0.5	0.5	0.5
A4.1	67.5	16.5	6.5	10.5	0.5
A5.3	56.5	0.5	42.5	0.5	0.5

Table 21 Confusion matrix for the EUNIS Level 4 predictive map. Blue indicates the percentage of classifications that have been predicted correctly.

%	A5.44	A5.14	A5.43	A5.23	A4.13	A5.13	A5.26
A4.13	300.5	12700.5	2500.5	1100.5	3300.5	300.5	100.5
A5.13	128.5	1471.5	357.5	14.5	14.5	128.5	500.5
A5.14	271.5	1785.5	471.5	157.5	14.5	14.5	14.5
A5.23	4.5	433.5	376.5	4.5	4.5	4.5	4.5
A5.25	6.5	273.5	246.5	6.5	6.5	6.5	6.5
A5.26	100.5	6300.5	500.5	700.5	100.5	10100.5	100.5
A5.43	100.5	7300.5	100.5	2500.5	100.5	8900.5	100.5
A5.44	100.5	100.5	100.5	100.5	100.5	100.5	100.5

Table 22 Confusion matrix for the EUNIS Level 5 predictive map.

%	A5.142	A5.131	A5.233	A5.444	A4.139	A5.431	A5.141	A5.231	A5.261
A5.422	0.5	0.5	0.5	0.5	100.5	0.5	0.5	0.5	0.5
A5.431	0.5	18.5	0.5	34.5	0.5	46.5	0.5	0.5	0.5
A5.444	0.5	20.5	22.5	52.5	2.5	1.5	0.5	0.5	0.5
A5.141	17.5	0.5	6.5	0.5	0.5	0.5	76.5	0.5	0.5
A5.142	43.5	0.5	13.5	0.5	0.5	0.5	26.5	17.5	0.5
A5.231	6.5	0.5	3.5	0.5	0.5	0.5	0.5	86.5	3.5
A5.131	3.5	4.5	39.5	2.5	25.5	3.5	7.5	13.5	0.5
A5.233	5.5	0.5	24.5	3.5	4.5	0.5	1.5	61.5	0.5
A5.261	11.5	0.5	0.5	0.5	0.5	0.5	4.5	84.5	0.5

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6.6.2. Cohen’s Kappa

Table 23 Results of the Cohen’s Kappa.

Predictive Model Type	Cohen’s Kappa score
All	0.10
Broad scale	0.25
Level 4	0.38
Level 5	0.35

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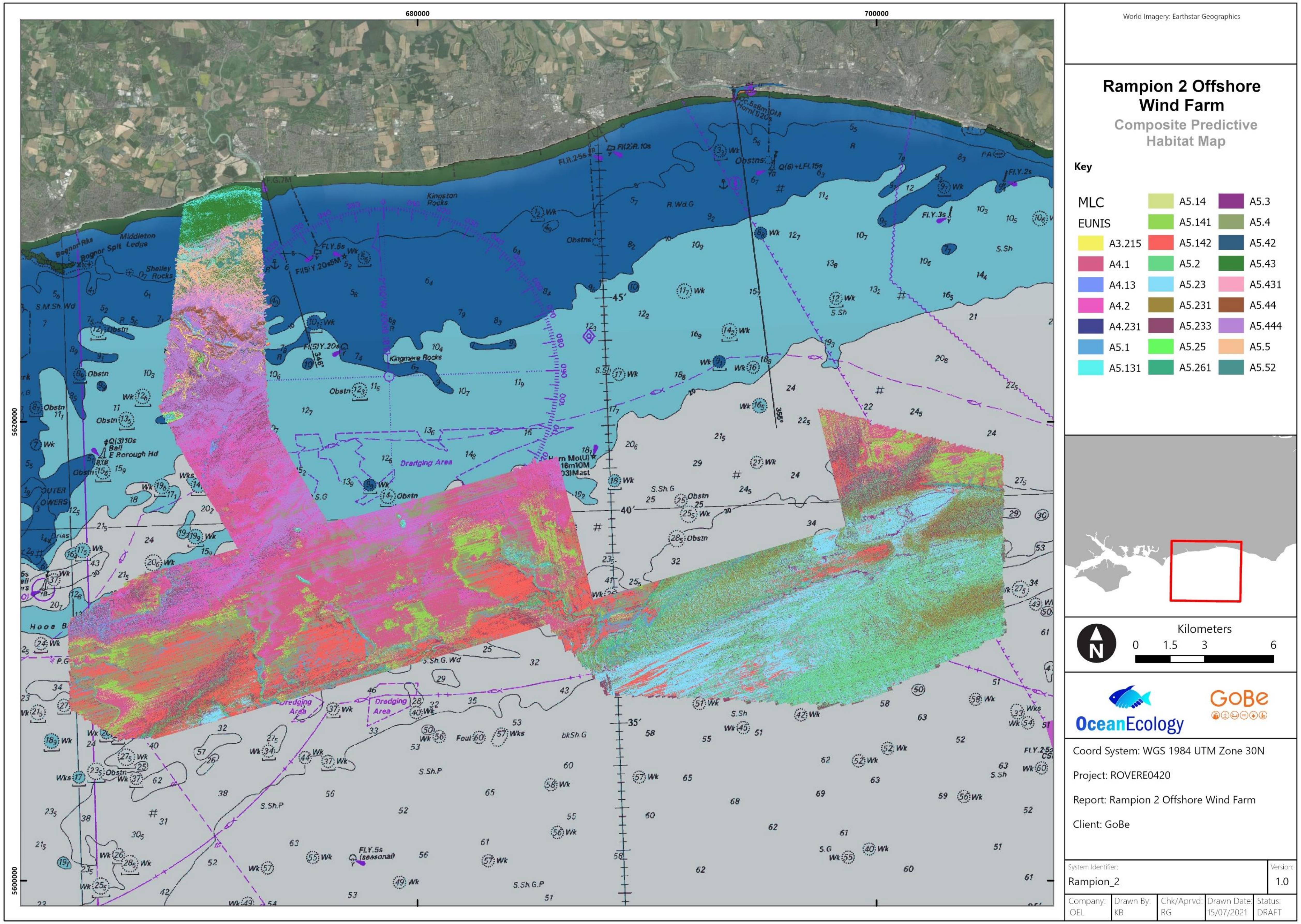

Figure 22 Composite (all EUNIS classification levels) predictive habitat map of the Rampion 2 study area.

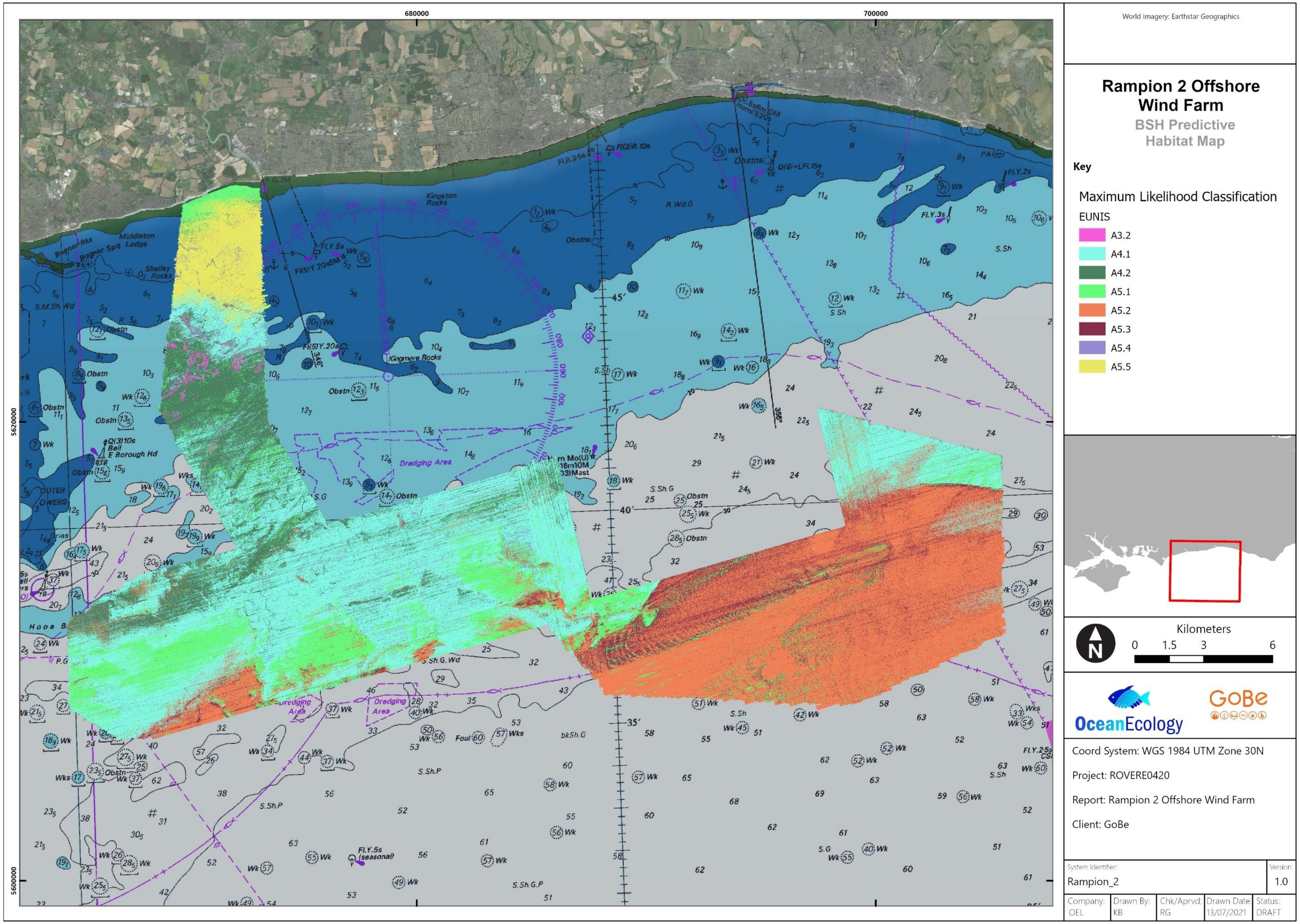

Figure 23 Broadscale predictive habitat map of the Rampion 2 study area.

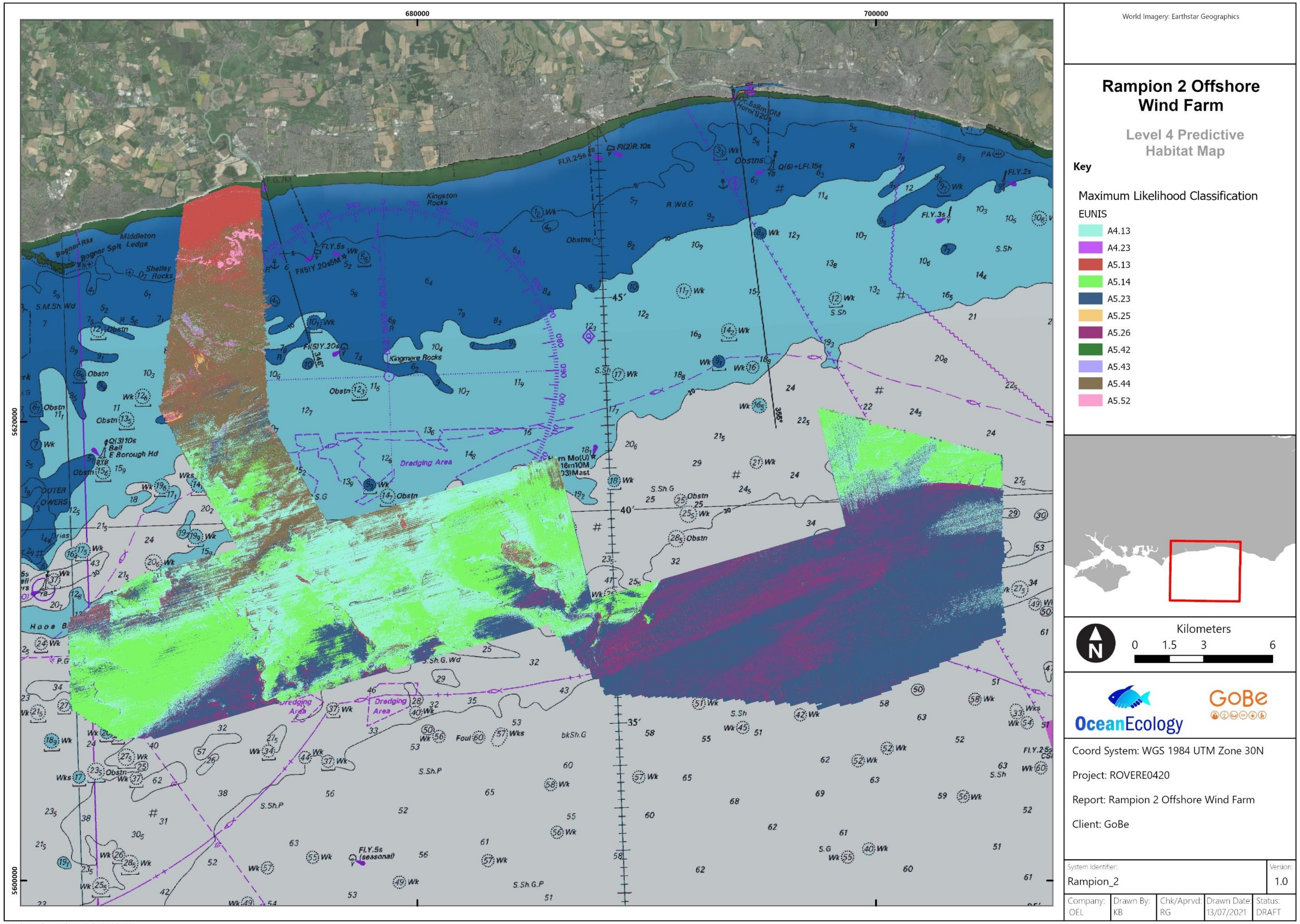

Figure 24 Level 4 predictive habitat map of the Rampion 2 study area.

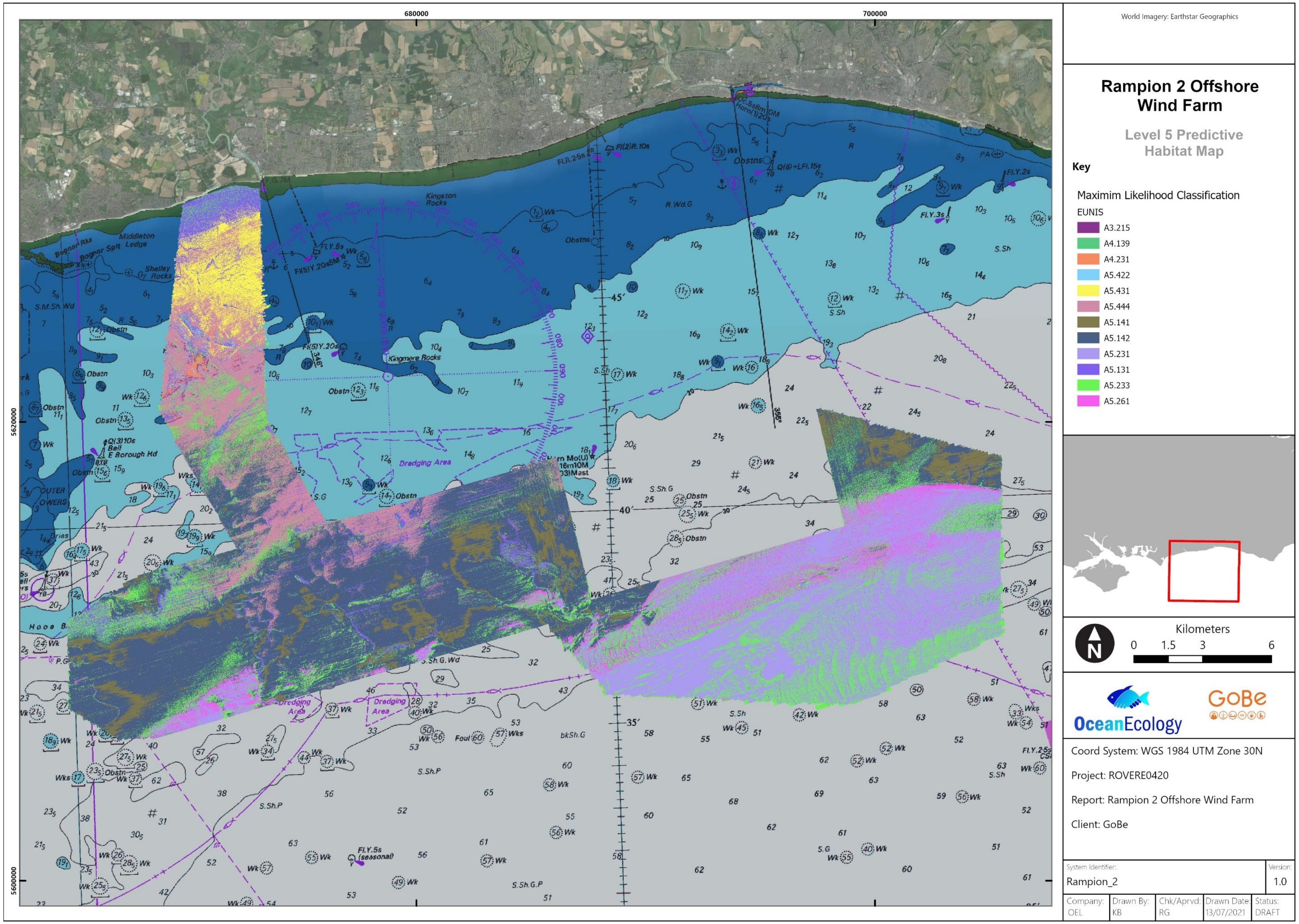

Figure 25 Level 5 predictive habitat map of the Rampion 2 study area.

7. Discussion

The aim of this report was to set out the environmental baseline conditions across the proposed ES Assessment Boundary to inform the ES, NTS and DCO as well as providing a robust dataset for future comparison if required. The report presents the results of the macrobenthic, sediment and seabed imagery analysis conducted following completion of the survey as well as the final predictive habitat mapping produced using all available acoustic and biological data available for the ES Assessment Boundary.

7.1. Habitat Assessment

The dominant BSH habitats identified during the seabed imagery analysis for the survey area were A5.1- Subtidal Coarse Sediment, A4.1 – High Energy Circalittoral Rock and A4.2 – Moderate Energy Circalittoral Rock.

Bedrock, stony reef and *Sabellaria* reef habitats were observed across the western areas of the study area and nearshore areas of the export cable corridor (Figure 4) (Section 6.1.1). These reef habitats were deemed to correlate to those which fall under Annex I of the EC Habitats Directive but not protected under this legislation as they do not represent Annex I habitat designated within an SAC. The bedrock reef habitats present were representative of the HOCI subtidal chalk at two stations (ST004 and ST036) and 6 transects, and peat and clay exposures at one station (ST032) and three transects (T_011, T_027 and T_033) (Section 6.1.2). Both these features are considered habitats of principle importance in England under Section 41 of the NERC Act (2006). The stony reef habitats across the study area were assessed to be of both low and medium resemblance (as per Irving (2009). These stony reef habitats can, in some circumstances, support diverse communities of branching sponges and sea fans. Across the ES Assessment Boundary, these reef habitats were deemed to be representative of the HOCI 'Fragile sponge and anthozoan communities on subtidal rocky habitats', at one station (ST032) and three transects (T_011, T_027 and T_033) (Section 6.1.2). Observations of discrete *Sabellaria* reef habitats were deemed to be of low 'reefiness' across the development site and representative of A5.611 - *Sabellaria spinulosa* on stable circalittoral mixed sediment and A4.221 - *Sabellaria spinulosa* encrusted circalittoral rock.

7.2. Sediments

Some variation in sediment types was observed across the study area; however, most stations were dominated by sand (Figure 10). Mud content was highest closer to land and towards the east, while gravel content varied across the study area. Of the 39 stations analysed, 17 belonged to EUNIS BSH A5.1 Coarse Sediment, 11 to BSH A5.4 Mixed Sediment, 8 to BSH A5.2 Sand and Muddy sand and the remaining three to BSH A5.3 Mud and Sandy Mud (Figure 8). These types of sediment are among the most common habitats found in subtidal settings across the UK coast and fall in the list of habitats of principal importance under Section 41 of the NERC Act ‘Subtidal sands and gravels’ and ‘Subtidal mixed muddy sediments.

Due to the limited number of stations (n=7) that underwent sediment chemical analysis, it was difficult to draw comparisons between sediment type and composition and its chemical characteristics. Several guidelines exist to assess the degree of contamination and likely ecological impacts of contaminants in marine sediments. These regulations defined the levels below which effects are of no concern and/or rarely occur (AL1, BAC, TEL), and the levels above which adverse biological effects are considerable and/or occur frequently (AL2, ERL, PEL). *Ad hoc* decisions need to be made when contaminant concentrations fall between these levels. To note that Cefas ALs1 are typically the most conservative measures to assess sediment contamination and often result in “false positives” meaning that non-toxic sediment samples fail to pass this screening test. Conversely, ALs2 tend to be rather permissive allowing samples with relatively high contaminant concentrations to fall between AL1 and AL2 and thus requiring expert judgment to further assess their potential toxicity (MMO 2015, Mason et al. 2020). Recent studies have been revising these ALs with the goal of reducing the range of concentrations falling between AL1 and AL2 and minimise the number of samples requiring an *ad hoc* treatment; however, no policy has been made yet based on these recommendations and suggestions (MMO 2015, Mason et al. 2020).

Among all metals, As was the most abundant while Cr was the most frequently occurring above BAC levels. All other metals were present in concentrations either below detection limits or below reference levels. Specifically, As was above the TEL at all stations (n=7), but above the BAC at only two stations (ST030 and ST051), and above AL1 at 5 stations; Cr concentration was above the BAC at 6 stations, but below all other reference levels.

To note that the TEL (7.24mg kg^{-1}) for As is about three times lower than the BAC (25mg kg^{-1}) and AL1 (20mg kg^{-1}). This may be due to the TEL being based on North American data and as such it may not be representative of UK conditions (Mason et al. 2020). In comparison, OSPAR BAC and Cefas ALs are based on UK data and therefore are more suitable for the current assessment. No stations had As concentrations above AL2 however Station 51, with an As concentration of 59.2mg kg^{-1}, was above the PEL meaning that adverse biological effects could be present at this location. Elevated metal sediment concentrations do not necessarily imply toxicity to benthic communities (Rees et al. 2007) as the bioavailability of these metals is more important than simply concentration levels. Unfortunately, no macrofauna data was available at this station to further discuss the potential effects of elevated As concentrations on the macrobenthic community.

Among all PAHs, only Phenanthrene and Pyrene were found at concentrations above detection limits, at stations ST020 and ST030, respectively. However, at these two stations reference levels were not exceeded. THC was higher at the three stations to the west of the survey area compared to others. However, when assessing the source origin of hydrocarbons based on the CPI, it resulted that all but one station (ST025) had hydrocarbons of biogenic origin. Stations with high THCs were also rich in TOC which could be related to transportation and deposition of hydrocarbons across the survey area.

7.3. Macrobenthos

A diverse macrobenthic community was identified across the ES Assessment Boundary with a total of 1,489 individuals and 232 taxa recorded. However, most stations were characterised by the presence of Nemertea which occurred in 57.6% of the samples, while the polychaete *S. lamarcki* was the overall most abundant species across the study area (Figure 15).

Macrobenthic communities can be highly heterogenous as they are heavily influenced by ambient environmental conditions such as sediment composition (Cooper et al. 2011), hydrodynamic forces and physical disturbance (Hall 1994), depth (Ellingsen 2002) and salinity (Thorson 1966). Macrobenthic abundance (N) and richness (S) varied across the ES Assessment Boundary (Section 6.4.1), with a higher macrofaunal abundance and diversity at stations located nearshore and west of the study area (Figure 17 and Figure 18). The 5 Macrobenthic Groups identified by the multivariate cluster analysis (Section 6.4.3) reflected the variability of the benthic community across the survey area as well as sediment composition (Figure 21). Macrobenthic Group A was characterised by the white catworm *N. cirrosa* and the amphipod *Bathyporeia* typical of fine to medium sands. Macrobenthic Group B was characterised by taxa with an affinity for muddier substrates like *A. alba* and *L. koreni*. Macrobenthic Group E was typical of coarser substrates dominated by the polychaete *L. cingulata*.

7.1. Other Species of Interest

The INNS slipper limpet (*C. fornicata*) was recorded at the two grab samples collected the closest to land (ST003 and ST005), each counting 11 specimens. In addition to this, *C. fornicata* was also observed in 114 images across five stations and 10 transects across the nearshore area of the export cable corridor. *C. fornicata* is an invasive non-native species (INNS) that originated from the eastern USA and has been present in the UK for over a century. Initially confined to the south and south-east coast of England, it is now common in Europe.

Slipper limpets form stacks usually consisting of up to 12 individuals with the largest at the bottom and increasingly smaller animals on each other's backs. They live on the seabed out beyond the low tide mark to depths of 60m. Populations are particularly well developed in wave protected areas such as bays, estuaries or sheltered sides of wave exposed islands (Blanchard 1997).

7.2. EUNIS Habitats/Biotopes

The main EUNIS classifications identified across the ES Assessment Boundary included both rocky and sediment habitats. Seabed imagery was crucial in the identification of rocky EUNIS habitats and biotopes while grab samples were helpful in assigning biotopes at a finer level where sediments were present. EUNIS classifications therefore included A4.13 - Mixed faunal turf communities on circalittoral rock, A4.23 - Communities on soft circalittoral rock, A4.131 - Bryozoan turf and erect sponges on tide-swept circalittoral rock, A4.134 - *Flustra foliacea* and colonial ascidians on tide-swept moderately wave exposed circalittoral rock, A4.214 - Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock, A4.221 - *Sabellaria spinulosa* encrusted circalittoral rock, A5.141 - *Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles, A5.611 - *Sabellaria spinulosa* on stable circalittoral mixed sediment, A5.431 - *Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed, A5.261 - *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment, A5.142 - *Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel, A5.131 - Sparse fauna on highly mobile sublittoral shingle (cobbles and pebbles) and A5.233 - *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand (Plate 4 and Section 6.4.4).

Overall, the habitat identified across the ES Assessment Boundary, using a combination of geophysical data, seabed imagery, sediment and macrofauna samples for ground truthing, reflect the existing EMODnet broad scale habitat mapping while providing a more refined assessment of the habitats and biotopes present across the survey area, including key features and designated habitats.

The addition of 39 new samples to the modelling process resulted in some changes to the final output maps from what was modelled in the pre-survey predictive maps (Ocean Ecology Limited 2021). Several new biotopes were introduced in these new models and notable increases in correctly classified pixels were observed throughout all maps, in particular, A5.2 in the broadscale map increased from 68.5 to 74.5%, A5.44 in the Level 4 map increased from 60.5 to 65.5%, and finally in the Level 5 map, A5.142 increased from 33.5 to 43.5%. A reduction in the percentage of correct predictions and overall accuracy was also observed and can be explained by the small increase in multiple classifications coupled with the size of the survey area.

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