Bellrock OFFSHORE WIND

Bellrock Offshore Wind Farm

Wind Farm Development Area

Environmental Impact Assessment Report - Volume IV

Appendix 7.3: Bellrock Wind Farm Development Area Benthic Characterisation Survey 2023 Report

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Bellrock Offshore Wind Farm Project

Wind Farm Development Area

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Details

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Updates

Section	Description	Page
Several	Updated Project terminology throughout	Whole document

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Abbreviations

BIIGLE	Bio-Image Indexing and Graphical Labelling Environment
BSH	Broadscale Habitat
DDC	Drop-Down Camera
EUNIS	European Nature Information System
HA	Habitat Assessment
HD	High Definition
HOCI	Habitat of Conservation Importance
JNCC	Joint Nature Conservation Committee
LED	Light-Emitting Diode
MBES	Multibeam Echosounder
MCZ	Marine Conservation Zone
MP	Megapixel
MPF	Marine Protected Feature
MPA	Marine Protected Area
MW	Mega Watt
OEL	Ocean Ecology Ltd
PSD	Particle Size Distribution
SAC	Special Area of Conservation
SOCI	Species of Conservation Interest
SPA	Special Protection Area
SSS	Side-Scan Sonar
UPS	Uninterruptable Power Supply
USBL	Ultra-Short Baseline
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
VRU	Vapor Recovery Units
WFDA	Wind Farm Development Area

Non- Technical Summary

Introduction

Ocean Ecology Limited (OEL) were commissioned by TerraSond to undertake a benthic habitat assessment of the Bellrock Offshore Wind Farm Project Wind Farm Development Area (Bellrock WFDA). The Bellrock WFDA is located in the Central North Sea, approximately 120 km east of Stonehaven. The area is approximately 279 km^2 and is intended to accommodate a 1,800 MW capacity of floating offshore wind. Eight Marine Protected Areas (MPAs) surround but do not overlap the WFDA. The nearest of these is the East of Gannet and Montrose Fields Nature Conservation Marine Protected Area (NCMPA) which lies 45 km to the northeast of the WFDA.

Survey Strategy

A total of 113 combined Drop-Down Camera (DDC) and grab sampling stations were sampled across the Bellrock WFDA (the 'survey area') based on an estimated density of 1 station per 10 km^2. The offshore Habitat Assessment (HA) survey element, as reported here, was undertaken aboard the vessel DSV Curtis Marshall during July 2023.

EUNIS Habitats/Biotopes

An integrated interpretation of particle size distribution (PSD) data, seabed imagery, and acoustic data indicated that the prevalent benthic habitat across the survey area was A5.27 Deep circalittoral sand, with a small area of A5.37 Deep circalittoral mud to the east of the survey area. Acoustic data (Side-Scan Sonar (SSS) and Multibeam Echosounder (MBES)) can be used to define habitat boundaries, however in this case, data showed uniformity with no distinct features. This supports the observation of a relatively homogenous seabed consisting of muddy sands and sandy muds across the survey area.

Other Features of Interest

Occasional records of the burrowed mud Priority Marine Feature (PMF) exist on the east coast of Scotland, with noteworthy occurrences in offshore waters of the northern North Sea. Therefore, a comprehensive burrow assessment was made across the survey area based on seabed imagery analysis. While burrow density increased to the east of the survey area suggesting the presence of the burrowed mud PMF, seabed imagery revealed no spatial relationship between burrow density and the presence of seapens, which were the most commonly occurring epifauna observed in the seabed imagery. This indicates that seapen and burrowing megafauna were not a biotope component of the burrowed mud PMF observed across the WFDA. Macrobenthic data derived from grab samples collected as part of the wider characterisation survey may provide a greater insight into the component species of the burrow mud PMF habitat observed allowing for a more accurate assessment of this habitat. The macrobenthic data will be reported as part of the full characterisation report and will facilitate higher resolution biotope mapping.

1. Introduction

1.1. Project Overview

The proposed Bellrock Offshore Wind Farm Wind Farm Development Area (Bellrock WFDA) is in the north-east corner of the E1 ScotWind Plan Option (PO) in the Central North Sea, approximately 120 km east of Stonehaven (Figure 1). The area is approximately 279 km^2 and is intended to accommodate a 1,800 MW capacity (Figure 1). Water depths across the WFDA range from approximately 110 m below Lowest Astronomical Tide (LAT) to approximately 70 m below LAT. Information available from EMODnet (EMODnet, 2021) suggest the surface and shallow sub-surficial sediments of the Bellrock WFDA comprise deep circalittoral sand and deep circalittoral mud.

1.2. Aims and Objectives

The primary aim of this survey and subsequent analysis and reporting was to support environmental consenting to permit construction activities.

The key objectives of the habitat assessment were to:

- Provide an initial description of the seabed habitats within the Bellrock WFDA (the 'survey area') based on DDC imagery; This was achieved using DDC and sediment grab sampling followed by subsequent laboratory analysis to provide accurate ground–truthing of geophysical data collected by TerraSond; and
- Identify and assess the status of species and habitats of conservation importance, including Priority Marine Features (PMFs), Annex I protected species and habitats, and Annex V species[1] of the Habitats Regulations, species listed under Schedule 5 of the Wildlife & Countryside Act[2], OSPAR species and habitats[3] and designated features of the MPA network (e.g., SAC and Nature Conservation MPA).

[1] https://jncc.gov.uk/our-work/article-17-habitats-directive-report-2019-species/
[2] https://www.legislation.gov.uk/ukpga/1981/69/schedule/5
[3] https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats

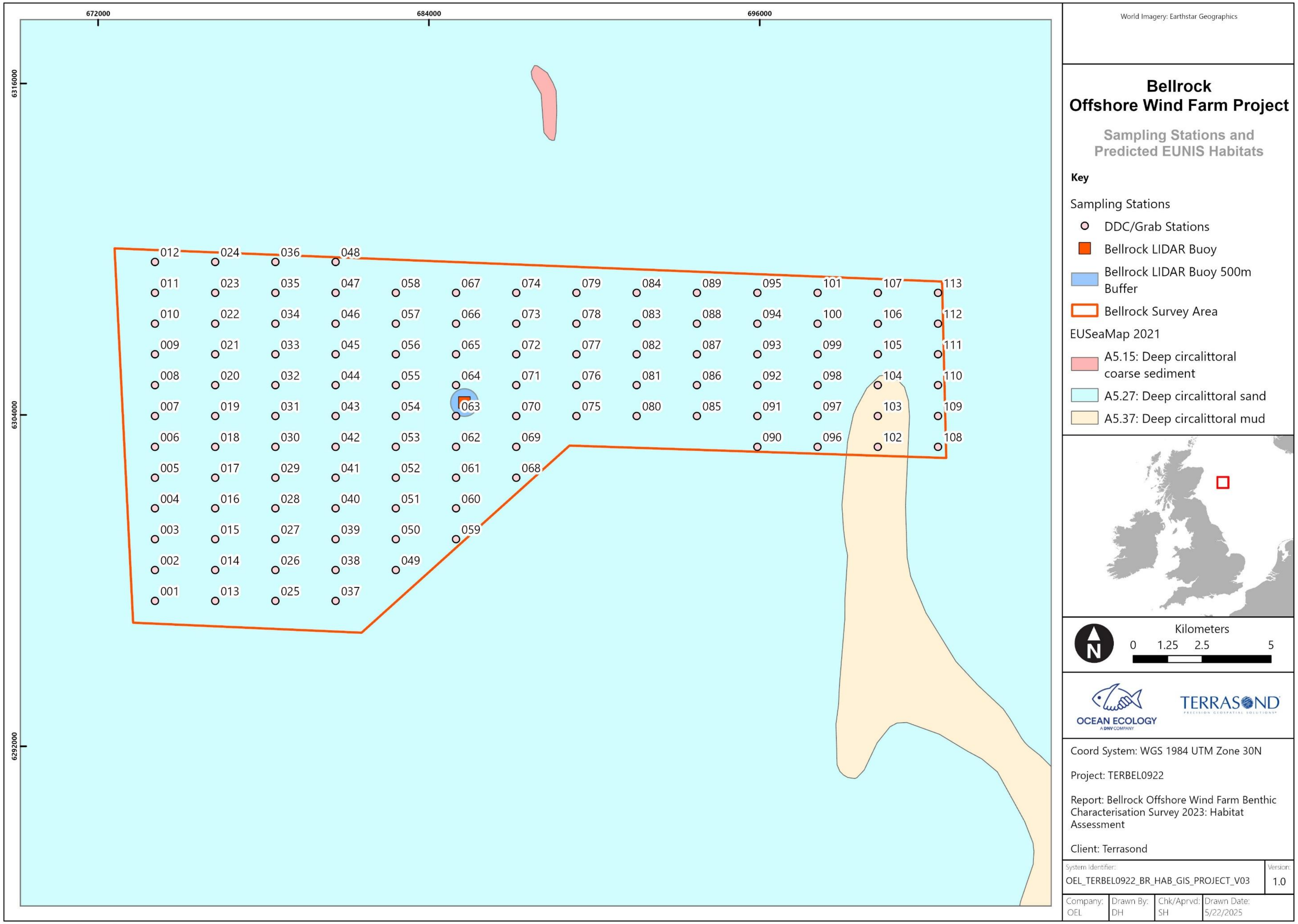

Figure 1 DDC and grab stations sampled during the survey overlain on predicted EUNIS habitat type (EMODnet, 2021).

2. Current Understanding

2.1. Existing Habitat Mapping

The 2021 EUSeaMap broad-scale predictive model classifies and maps intertidal and subtidal habitats according to the European Nature Information Systems (EUNIS) classification criteria. The system is able to identify keystone species that have been evidenced to inhabit areas with certain environmental conditions and can therefore act as an indicator, allowing inferences of overall community composition. The EUSeaMap data indicated that the habitats present across the proposed survey area primarily consisted of Deep circalittoral sand (A5.27) and Deep circalittoral mud (A5.37), as mapped in Figure 1 (EMODnet, 2021).

2.2. Relevant Conservation Legislation

European Commission Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora, commonly known as the 'Habitats Directive' ensures the conservation of a wide range of rare, threatened endemic animal and plant species as well as habitats. The EU Habitats Directive (1992) was transposed into UK law by The Conservation of Habitats and Species Regulations 2017 within 12 nautical miles (nm), and The Conservation of Offshore Marine Habitats and Species Regulations 2017 between 12 nm out to 200 nm or the UK Continental Shelf. Under these regulations, a network of Special Protected Areas (SPA) and Special Areas of Conservation (SAC) have been established to grant protection and conservation to rare and threatened habitats and species.

The Marine (Scotland) Act 2010 provides the legal mechanism to assist in the conservation and enable the recovery of protected wildlife and habitats within nature conservation MPAs.

2.3. Designations

The survey area lies central to, but does not overlap, several designated Marine Protected Areas (MPAs). The nearest of these is the East of Gannet NCMPA which lies 45 km to the northeast of the survey area. **Figure 2** illustrates all designated sites present in the wider region surrounding the Bellrock WFDA while below is a summary of the sites occurring within a 115 km radius from the survey area.

East of Gannet and Montrose Fields NCMPA

This NCMPA lies approximately 45 km northeast of the Bellrock WFDA and is designated for the protection of the ocean quahog (*Arctica islandica*) and the habitat offshore deep-sea muds.

Turbot Bank NCMPA

This NCMPA is situated approximately 60 km northwest of the survey area and is designated for the protection of sand eels as a commercially important species and important prey species for bird species such as Atlantic puffin (*Fratercula arctica*) and black-legged kittiwake (*Rissa tridactyla*).

Firth of Forth Banks Complex NCMPA

The MPA complex is comprised of three MPAs and the Bellrock WFDA is approximately 64 km from the complex, which covers an area of 2130 km^2. This MPA complex is designated for the protection of the ocean quahog (*A. islandica*), offshore subtidal sands and gravels, shelf banks and mounds and moraines.

Fulmar Marine Conservation Zone (MCZ)

This MCZ is situated 95 km southeast of the survey area and is designated for the ocean quahog (*A. islandica*) and the habitats subtidal mixed sediments, subtidal mud and subtidal sand.

Swallow Sand MCZ

This MCZ is located approximately 85 km south of the Bellrock WFDA and is designated for the protection of the habitat's subtidal coarse sediment and subtidal sand, as well as the geological feature North Sea glacial tunnel valleys such as Swallow Hole.

North East of Farnes Deep MCZ

This MCZ is located 100 km southwest of the survey area and is designated for the ocean quahog *(A. islandica*) and the habitats subtidal coarse sediments, subtidal mixed sediments, subtidal mud and subtidal sand.

Farnes East MCZ

This MCZ lies 115 km southwest of the survey area and is designated for the ocean quahog (*A. islandica*) and the habitats moderate energy circalittoral rock, sea-pen and burrowing megafauna communities, subtidal coarse sediments, subtidal mixed sediments, subtidal mud and subtidal sand.

2.3.1. Priority Marine Features

PMFs are habitats and species that are considered to be marine nature conservation priorities in Scottish waters (Tyler-Walters et al., 2016). The following PMF habitats have been recorded within or near to the survey area.

Ocean quahog

The ocean quahog (*A. islandica*) holds the remarkable distinction of being the longest-lived mollusc on record, with the potential to survive for more than four centuries. This species predominantly inhabits the sandy and muddy sediments found at depths ranging from 10 to 280 m. Its primary habitat spans the maritime expanses surrounding Scotland, particularly offshore in the eastern regions and the northern North Sea. Notably, approximately seventy percent of documented British records of the ocean quahog are concentrated in Scottish waters, a testament to its historical prevalence in these marine environments. However, there is a growing concern as this vulnerable species is now experiencing a decline, prompting increased attention to its conservation.

Burrowed muds

Burrowed muds in Scotland are designated as PMF due to being a home to a diverse range of marine species such as worms, clams, and various types of crustaceans. They provide essential ecosystem services playing a crucial role in nutrient cycling and water purification. Burrowed mud habitats can store significant amounts of carbon in the form of organic matter. The burrows created by mud-dwelling organisms create complex physical structures in the seabed, providing shelter and foraging opportunities for a variety of other species, including those that are not directly associated with the mud habitat enhancing the overall resilience and stability of the marine ecosystem. Burrowed mud habitats are sensitive to disturbance from human activities such as bottom trawling, dredging, and pollution. These activities can damage or destroy the habitat and disrupt the communities living within it. Designating burrowed mud as PMFs helps raise awareness of their importance and provides a basis for conservation efforts and regulations to protect them.

Offshore deep sea muds

Offshore deep sea muds in Scotland are designated as PMFs due to their unique and rare status as habitats in the marine environment. These muds possess distinct geological formations and sediment types that are not commonly found elsewhere. Within these offshore deep sea muds, a diverse and abundant array of marine life thrives, including notable species such as polychaete worms, bivalve molluscs, sea cucumbers, and soft corals. These muds are delicate ecosystems that are highly vulnerable to disturbances, including activities like seabed mining and bottom trawling. Such disturbances can have severe consequences for the intricate balance of these ecosystems, underscoring the need for their protection and recognition as PMFs. Furthermore, these offshore deep sea muds serve as crucial nursery and feeding grounds for commercially valuable fish species. They provide essential habitats where these fish can reproduce and find sustenance, supporting the sustainability of fisheries and the long-term health of fish populations.

Offshore subtidal sands and gravels

Offshore subtidal sands and gravels in Scotland are designated as PMFs due to their ecological significance and the valuable habitats they provide. These habitats encompass diverse sandy and gravelly seabed areas that support a wide range of marine organisms. They serve as biodiversity hotspots, providing shelter, food, and breeding grounds for various species including sand eels, flatfish, brittle stars, and burrowing anemones. These habitats are essential as nursery grounds for many fish species, supporting the growth and development of juvenile fish before they move into other habitats.

They also serve as important feeding areas, sustaining bottom-dwelling organisms and filter feeders. The organic matter and nutrients present in these habitats support the survival and growth of many marine organisms. Offshore subtidal sands and gravels play a crucial role in maintaining sediment stability, preventing erosion, and providing a stable substrate for other organisms such as burrowing species. The conservation of these habitats is vital for maintaining the overall health and functioning of the marine ecosystem.

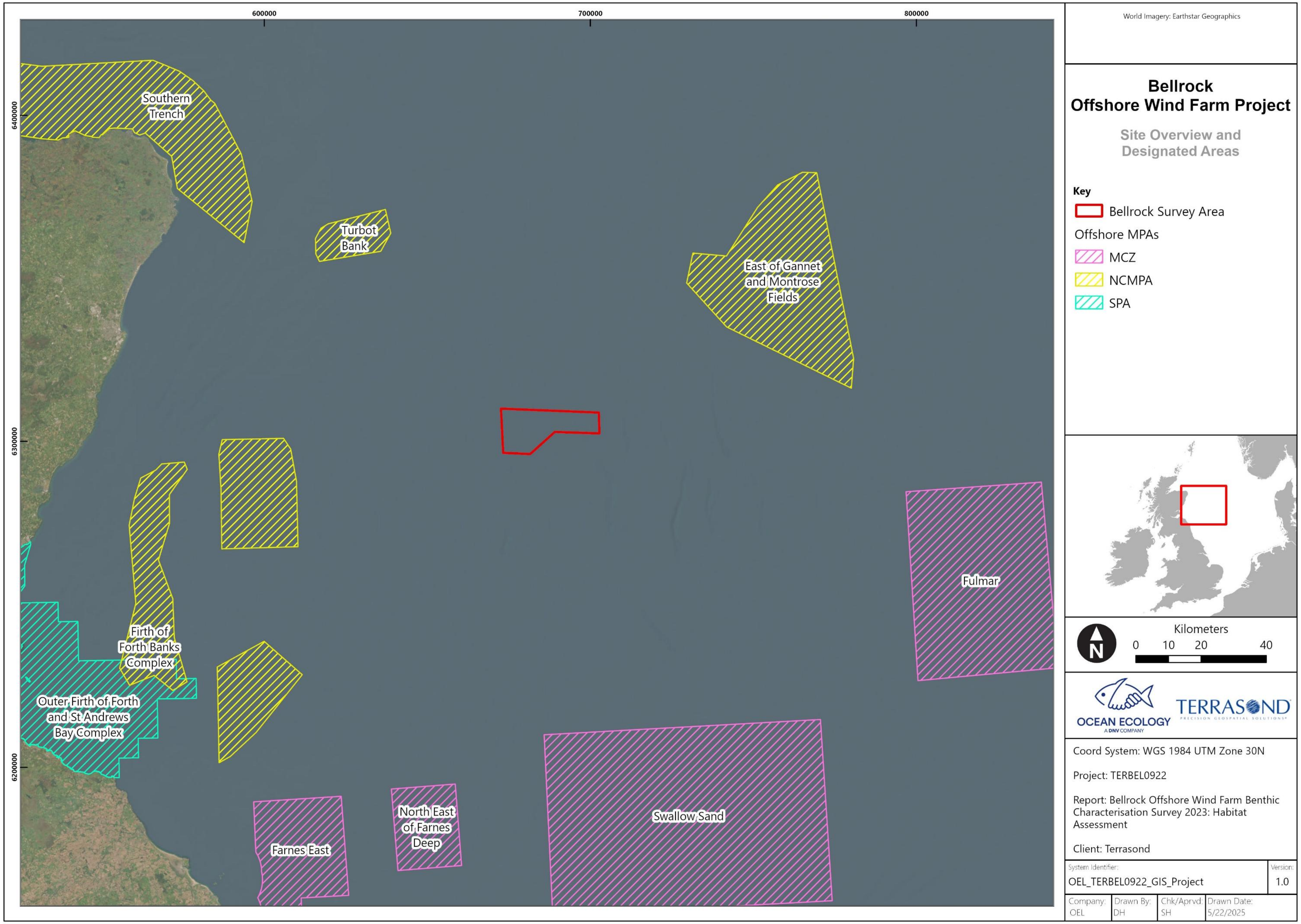

Figure 2 Overview of the Bellrock WFDA Benthic Characterisation survey area in relation to designated MPAs in the North Sea

3. Survey Design

3.1. Rationale

A sampling plan was developed to provide adequate spatial coverage throughout the area of interest. In the absence of geophysical datasets at the sampling design stage, consideration was given to the recommendations of best practice guidance (Saunders et al., 2011 and Natural England, 2021) whilst also accounting for all surface, subsurface, and subsea hazards, and their respective exclusion / buffer zones if / where present. To maximise the likelihood that all sediment (Noble-James et al., 2018 and Saunders et al., 2011) types within the survey area were adequately sampled, the number of sampling stations originally proposed based on the assumption of geophysical data being available (75 stations in total) was increased by 50 % (113 stations in total). Indicative broad scale habitats (BSHs) were inferred from EMODnet datasets (EUSeaMap 2021) to inform micrositing of sampling locations within the grid design.

The sampling array consisted of 113 predetermined sampling stations across the survey area. The sampling stations were placed at 1 km intervals along 14 transects each separated by 2.5 km and orientated in a north to south arrangement. This captured the depth profile of the survey area from 60 m below LAT to 110 m below LAT within the Bellrock WFDA boundary.

3.2. Sampling Approach

At each sampling station, high-resolution seabed imagery (stills and video) was first collected using DDC to i) determine the suitability of the station for grab sampling (i.e., no hazards or sensitive habitat) and ii) provide an indication of the epibiota present at each location. If during this pre-screening exercise the sampling stations were deemed inappropriate for grab sampling (e.g., presence of biogenic reef habitat), the sampling station was repositioned in a nearby area of sediment and revisited with DDC prior to grab sampling. Stations were then sampled with a 0.2 m^2 dual Van Veen (DVV) grab sampler if prior visual inspection deemed the sediment suitable.

2.3. Timing

The sampling was undertaken during periods of favourable weather between the 5th and 28th of July 2023

4. Field Methods

4.1. Project Parameters

4.1.1. Horizontal Datum

Table 1 Geodetic and projection parameters

Parameter	Details
Name	World Geodetic System 1984 (WGS84)
Ellipsoid	WGS 84
Semi-Major Axis (a)	6378137.000 m
Semi-Minor Axis (b)	6356752.314 m
Inverse Flattening	298.257 223 563
Geodetic parameters EPSG Code	4326
Projection	Universal Transverse Mercator (UTM)
Zone	30 North
Central Meridian	3° West
Latitude of Origin	0°
False Easting	500 000.00 m
False Northing	0.00 m
Scale Factor at Central Meridian	0.9996
Projected coordinate system EPSG code	32630
Units	metres

4.1.2. Datum Transformation Parameters

All data was referenced to WGS84, UTM 30N, with no datum transformation required.

4.1.3. Vertical Datum

All altitude and depth data above seabed shall be referenced to LAT. All depth data below the seabed shall be referenced to LAT with depth below seabed included in brackets. LAT shall be derived using a Vertical Offshore Reference Frames (VORF) model.

4.1.4. Unit Format and Conversions

The following have been used throughout this project and are expressed using the following conventions.

Table 2 Project unit format and convention details.

Unit Formats and Conventions	
Geographical Coordinates	Latitude N DD˚MM.mmmmmm' to 6 decimal places. Longitude E/W DD˚MM.mmmmmm' to 6 decimal places.
Grid Coordinates	Meters in the following format: Easting EEE EEE.eee m to 3 decimal places. Northing NNN NNN.nnn m to 3 decimal places.
Linear distances	Meters to 1 decimal places.
Offset measurement sign conventions	Meters in the following format: 'Y' is positive forward. 'X' is positive to starboard. 'Z' values are positives upwards from the waterline.
Time	UTC (GMT).

4.2. Survey Vessel

Sampling was conducted aboard the 26 m MCA Category 1 coded survey vessel 'DSV Curtis Marshall'. The vessel was mobilised from Hartlepool on the east coast of England and operations were performed on a 24-hour basis.

Table 3 Vessel details

Vessel Name	DSV Curtis Marshall
Area of operation	Offshore
Call Sign	2HWN3
MMSI	235107219
Mobilisation Port	Hartlepool
Length	26 m
Beam	7.7 m
Draft	2.8 m

Plate 1 DSV Curtis Marshall.

4.3. Survey Navigation

4.3.1. Surface Positioning

Surface positioning aboard the DSV Curtis Marshall was determined using a Hemisphere V104s Global Positioning System (GPS) compass system. The Hemisphere V104s internal GPS receiver utilises a minimum of 4 GPS satellites, managing the navigation information required to obtain a position within 3 m at 95 % accuracy. The V104s automatically tracks Satellite-Based Augmentation System (SBAS) differential correction to improve position accuracy to > 1 m at 95 % accuracy. The V104s includes an integrated gyro and two tilt sensors to provide an accurate heading for navigation software.

4.3.2. Subsea Positioning

The vessel was equipped with an Easytrak Nexus 2 Lite USBL system and 1329A Omni-directional +/- 90 ° Micro Beacons for subsea positioning of the camera and grab. The Easytrak Nexus 2 Lite is an advanced USBL positioning and tracking system that determines the position of dynamic subsea targets through the transmission and reception of acoustic signals between the submerged transceiver and a target beacon. The USBL was fully calibrated prior to survey operations using a Valeport SWiFT sound velocity profiler (SVP). Readings were obtained daily from both the up-cast and down-cast.

4.3.3. Navigation Software

A vessel-based positioning system was employed utilizing EIVA NaviPac V4.6 software to ensure the accurate positioning of the vessel and subsea positioning of the sampling equipment via the USBL system as well as recording continuous track plots of the sampling equipment and recording sampling fixes. A navigation screen, displaying EIVA Helmsman Display was provided at the helm position of the vessel for the Officer on Watch.

4.3.4. Positional Checks & Calibrations

The GPS has an internal precision calculation which outputs a graphical representation of horizontal accuracy, displaying numerical precision as easting and northing. The accuracy of vessel heading, and reference systems was verified during mobilisation using agreed reference points.

A USBL calibration was undertaken using the inbuilt Easytrak Nexus calibration software package to eliminate any alignment errors of the installation. Offsets were measured dynamically between the Easytrak Nexus Transceiver Head and the external sensors interfaced. This enabled accurate operation of the Easytrak Nexus tracking system when pole-mounted onto a vessel with external Vapor Recovery Units (VRU) and gyro.

4.4. DDC System and Seabed Imagery Collection

Seabed imagery (simultaneous video and stills) was acquired at each station using OEL's SubC Rayfin PLE camera system, set up to obtain 1080p High Definition (HD) video and 20 Megapixel (MP) still images. The camera system (Plate 2) consisted of a SubC Imaging Rayfin PLE camera mounted in a Clear Liquid Optical Chamber (CLOC) (otherwise known as a 'freshwater lens') filled with fresh water to ensure imagery of suitable quality is obtained regardless of turbidity. The frame included LED strip lamps and a 10 cm point laser scaling array that was projected into the field of view, a 300 m umbilical and topside computer. The camera was powered with the use of an Uninterruptable Power Supply (UPS) to ensure no damage was caused should the vessel have lost power or in case of a power surge. A full redundancy SubC Rayfin PLE camera system was stored onboard for use if required.

The CLOC was height and angle adjustable providing a variety of options for view, lighting, and focal length to maximise data quality with respect to prevailing conditions (e.g., high turbidity).

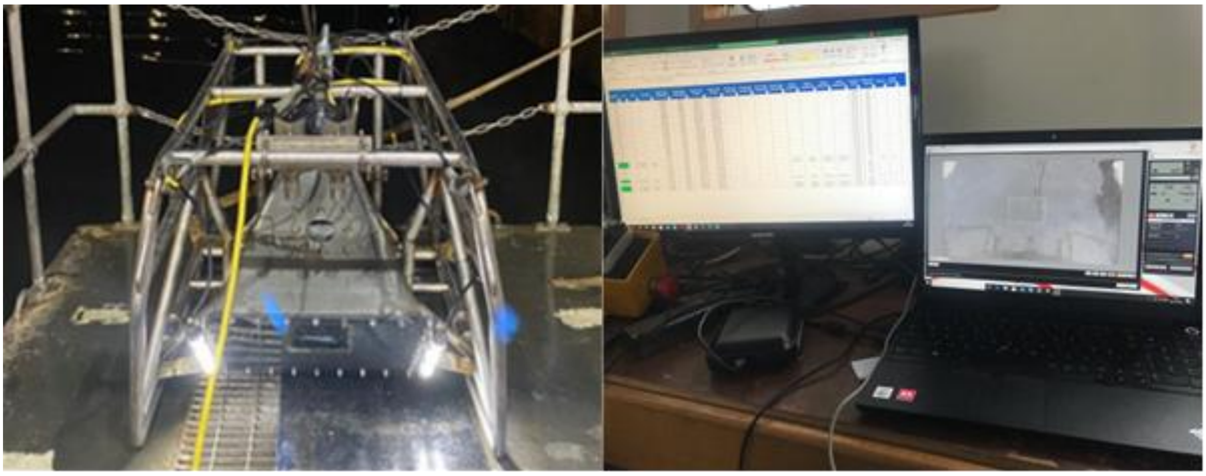

Plate 2 Left: OEL CLOC camera system. Right: The camera system topside setup.

All DDC stations were sampled in consideration of the Joint Nature Conservation Committee (JNCC) epibiota remote monitoring operational guidelines (Hitchin et al., 2015).

The camera system was deployed from the hydraulic 'A' frame on the aft deck of the DSV Curtis Marshall using the following method:

- As the vessel approached the target location, deck personnel began to prepare lifting equipment, camera, and umbilical.
- Deck personnel were alerted by the vessel master once on position, and the camera was raised using the A-frame and deck winch and lowered into the water column. The umbilical was payed out by hand.
- Once the camera system was within 5 m of the seabed, video recording was started, and the camera was gently lowered and landed on the seabed.
- Once any disturbed sediment/ debris had cleared, still images could be taken. Images were taken every 5-10 m using a 'bed-hopping' approach. The vessel was manoeuvred within a 20 m radius of target location, and the camera was raised from the seabed between capturing still images. This ensured broad coverage around the target location.
- Following the capture of the final image, the camera was lifted, video recording was stopped, and the camera could be slowly brought 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 umbilical was reeled in as the camera was lifted.
- Once the vessel master had confirmed sea conditions were suitable, the camera system was recovered aboard and lowered onto the deck.

All footage underwent a preliminary review in situ by OEL's onboard Environmental Scientists. Videos were recorded in a digital format direct to topside hard disk drives (HDDs) and digitally overlaid retrospectively with information including project, date, time, depth, and coordinates. Detailed notes were taken of visible sediment conditions and seabed features, obvious fauna, and habitat-related features whilst in the field.

4.5. Grab Equipment and Sediment Sampling

Sediment samples were collected from within 20 m of the target sampling location using OEL's 0.2 m^2 (2 x 0.1m^2) DVV grab sampler. A 0.1 m^2 mini Hamon grab sampler was kept onboard as back up for sampling coarser sediments, although this was not required, and all samples were collected using the DVV (Plate 3).

A single deployment of the DVV yielded two samples of approximately 5-10 L each at each station for macrobenthic and PSD analysis. A sub-sample of the sediment (approx. 0.5 L in volume) was removed for characterisation of the physical nature of the substrate (via PSD analysis). The second sample, from the other side of the DVV, was elutriated through a 1.0 mm sieve and retained for macrobenthic analysis.

The grab sampler was deployed from the port side of the DSV Curtis Marshall using the main deck crane.

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

- Sample replicates were less than 5 L. i.e., the sample represented less than approx. a half of the 10 L 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 20 m).
- There was obvious contamination of the sample from survey equipment, paint chips etc.

Should a grab have failed, a second and third attempt were conducted at the same site of the first failed attempt. Following three failed attempts, the vessel should move at least 50 m from the initial target station location for a fourth attempt. If the fourth attempt failed, the station may be abandoned. No pooling of samples will take place. However, where samples of less than 5L were continually achieved, these samples were retained and assessed to establish if the sample volume was acceptable to allow subsequent analysis.

Encountering an Unexploded Ordinance (UXO) was considered low risk as per the Bellrock UXO Threat and Risk Assessment document (DOC: 50012_2_UXOTARA_Bellrock OWF_OWC_V1.0). In the unlikely event that a UXO was found in grab samples, the procedures set out in OEL's RAMS were to be followed in full to minimise risk to personnel.

Detailed safe working procedures for deployment and retrieval of the DDC on the DSV Curtis Marshall is provided in the project specific RAMS (OEL_HSE_RAM_TERBEL0922_V02).

Plate 3 Left: OEL’s 0.2 m^2 DVV grab sampler. Right: OEL's 0.1 m^2 mini Hamon grab sampler.

5. Laboratory and Analytical Methods

5.1. Seabed Imagery Analysis

All seabed imagery analysis was undertaken using the Bio-Image Indexing and Graphical Labelling Environment (BIIGLE[4]) annotation platform (Langenkämper et al., 2017) and in line with JNCC epibiota remote monitoring interpretation guidelines (Turner et al., 2016). A full reef habitat assessment was conducted where appropriate to determine whether habitats met the definitions of Annex I reef habitats as detailed in Table 4 and Table 5. The annotation label tree used during analysis had major headings for each of reef type. Under each reef type labels were assigned for each of the categories required to determine whether reef habitat was present. The full label tree used in the project can be found in Appendix III.

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 4 Characteristics of stony reef (Irving, 2009).

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

Table 5 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

[4] https://www.biigle.de/

5.2. Determining Habitat Classifications

Habitats were identified and classified in accordance with the EUNIS habitat classification system (under the 2012 EUNIS classification system), in line with JNCC guidance on assigning benthic biotopes (Parry, 2019). Classifications were assigned based on the combined analysis of seabed imagery and Broad Scale habitat (BSH) data derived from the PSD, alongside existing habitat maps (EMODnet). Seabed features were assigned the highest level of classification possible. All habitat / biotope determination was undertaken through consideration of the following:

- Existing habitat mapping (derived from EMODnet);
- Review and interpretation of geophysical data;
- Seabed imagery;
- PSD

5.3. Habitat Mapping

All habitat mapping was undertaken in ESRI ArcPro Version 3.1.2 by a habitat mapping specialist and reviewed by a secondary senior environmental scientist. This involved overlaying EUNIS classifications and habitat assessment scores assigned to each sampling location on the mosaiced SSS and MBES data allowing for delineation of areas representative of similar acoustic signatures aligned to those at each DDC/grab station. Each sampling location was assigned to a EUNIS habitat / biotope based on the available data (still images and existing EMODnet mapping). Following this, an Annex I habitat assessment was carried out at each sampling location and where the criteria for Annex I habitats were met (as per Table 4 and Table 5), then these locations were additionally assigned as Annex I habitats. Finally, this classification was overlaid on the mosaiced SSS and MBES data to delineate large scale habitats and features of interest.

5.4. Particle Size Distribution Analysis

PSD analysis of the sediment samples was undertaken by in-house laboratory technicians at OEL's NMBAQC participating laboratory in line with NMBAQC best practice guidance (Mason, 2016).

Frozen sediment samples were first transferred to a drying oven and thawed at 80°C for at least 6 hours before 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 (>1 mm) which appeared to have been alive at the time of sampling were 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 1 mm sieve to sort coarse and fine fractions. The >1 mm fraction was then returned to a drying oven and dried at 80°C for at least 24 hours before dry sieving.

Once dry, the sediment sample were run through a series of Endecott BS 410 test sieves (nested at 0.5 φ 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 6.

Table 6 Sieve series employed for PSD analysis by dry sieving.

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.

The sub-sample for laser diffraction was first screened over a 1 mm sieve and the fine fraction residue (<1 mm sediments) 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.

The dry sieve and laser data was 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 v9 software.

Sediment descriptions are defined by their size class based on the Wentworth classification system (Wentworth, 1922) (Table 7). Statistics such as mean and median grain size, sorting coefficient, skewness and bulk sediment classes (percentage silt, sand and gravel) were derived following the Folk classification (Folk, 1954).

Table 7 The classification used for defining sediment type based on the Wentworth Classification System (Wentworth, 1922).

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

In addition to OEL's standard quality control procedures, the PSD sample processing was subject to external quality control checks by an independent, competent benthic laboratory participant in the NMBAQC scheme as per the RSMP protocol (Cooper & Mason, 2019; Ware et al., 2011).

6. Results

6.1. Geophysical Data

The SSS and MBES data collected by TerraSond during the geophysical survey campaign covered the entire survey area. These data were interpreted together with the seabed imagery and PSD data to inform the seabed habitat assessment and mapping process (Figure 3).

The SSS displayed typically uniform reflectivity across the survey area. No features of interest presenting as strong reflectivity signatures in the SSS data were observed that could have been interpreted as potential bedrock and biogenic reefs (Figure 3).

Bathymetry data displayed a largely featureless area with no bedforms such as sand ripples or waves. Water depth gradually increased eastward, moving away from the coast, with three narrow and deep channels presenting as linear north-south features occurring at regular intervals laterally across the Bellrock WFDA (east to west) with the deepest reaching up to 120 m of water depth (Figure 3).

6.2. Seabed Imagery

DDC sampling was successfully conducted at 113 stations, resulting in the collection of 647 still images and 113 videos. Full DDC video logs can be found in Appendix I and stills logs in Appendix II.

Generally, the seabed imagery correlated well with the geophysical data collected at the Bellrock site. The habitat assessment was conducted using the still images captured during the DDC deployments with the main habitat identified based on the seabed imagery. Findings of the image analysis including BSH description and the EUNIS habitat description are presented in Appendix III.

One BSH and one EUNIS Level 4 (biotope complex) were identified in the seabed imagery collected across the survey area (Table 8).

Table 8 EUNIS BSH and biotope complexes identified in seabed imagery across the survey area.

BSH	EUNIS Code	EUNIS Description
A5.3	A5.37	Deep circalittoral mud

The most common fauna observed captured in the still imagery included seapens, hermit crabs, and sea urchins (Plate 4).

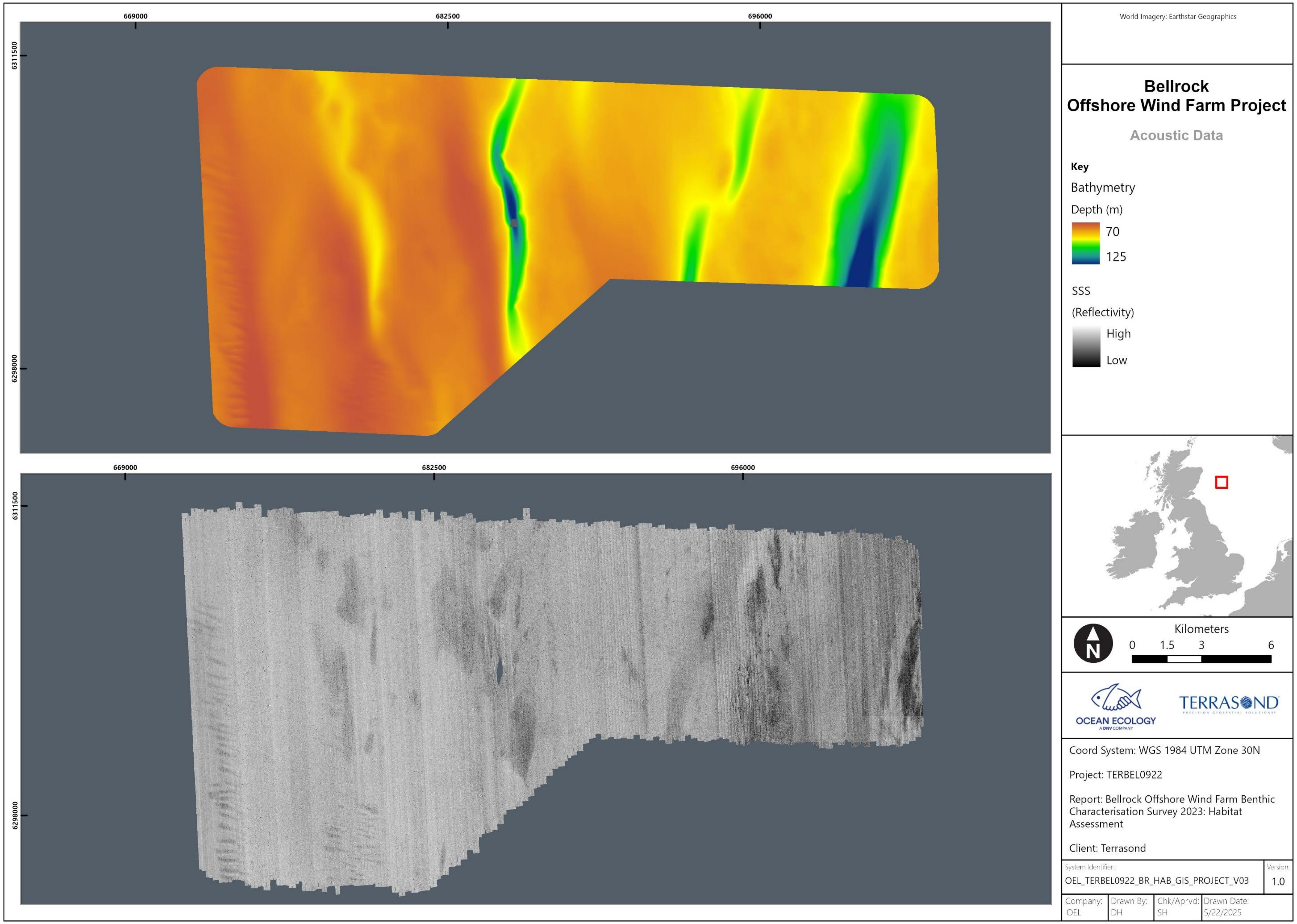

Figure 3 MBES (top) and SSS (bottom) data acquired by TerraSond during the geophysical survey campaign.

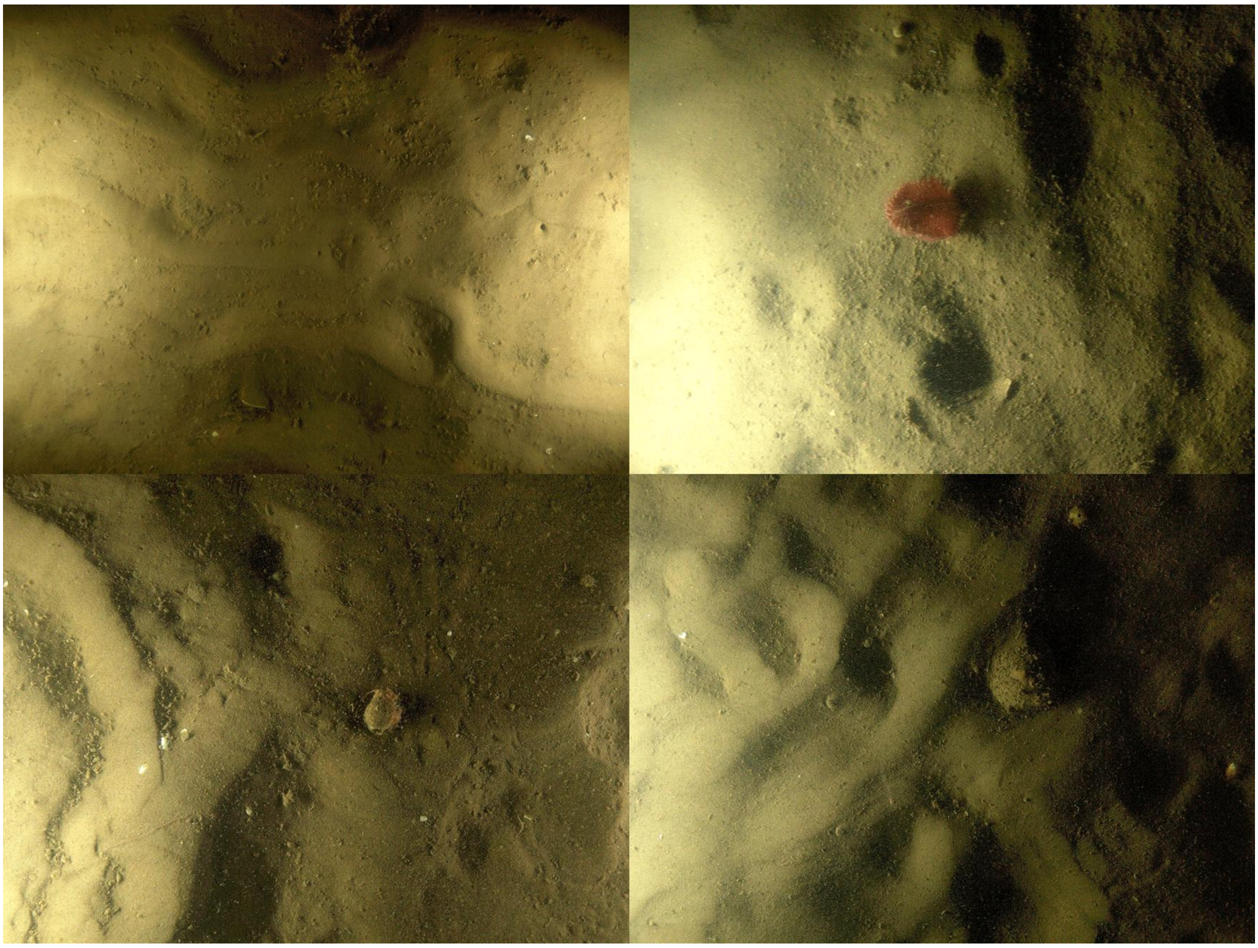

Plate 4 Example seabed imagery collected during the survey. Left to right, top to bottom: Deep circalittoral mud; Seapen (*Pennatula phospohorea)*; Hermit crab (*Paguridae*); Sea urchin (*Spatangoida)*

6.3. Other Features of Note

Areas of the PMF habitat burrowed mud were identified in seabed imagery. An in-depth assessment of this habitat was conducted (Appendix VI), ultimately determining the average density of burrows per station (Figure 4). Burrows were detected in 59 of the 113 surveyed stations. A further assessment on seapen (*Pennatula phosphorea*) density was undertaken (Appendix VII), with seapens observed at 16 stations (Figure 5).

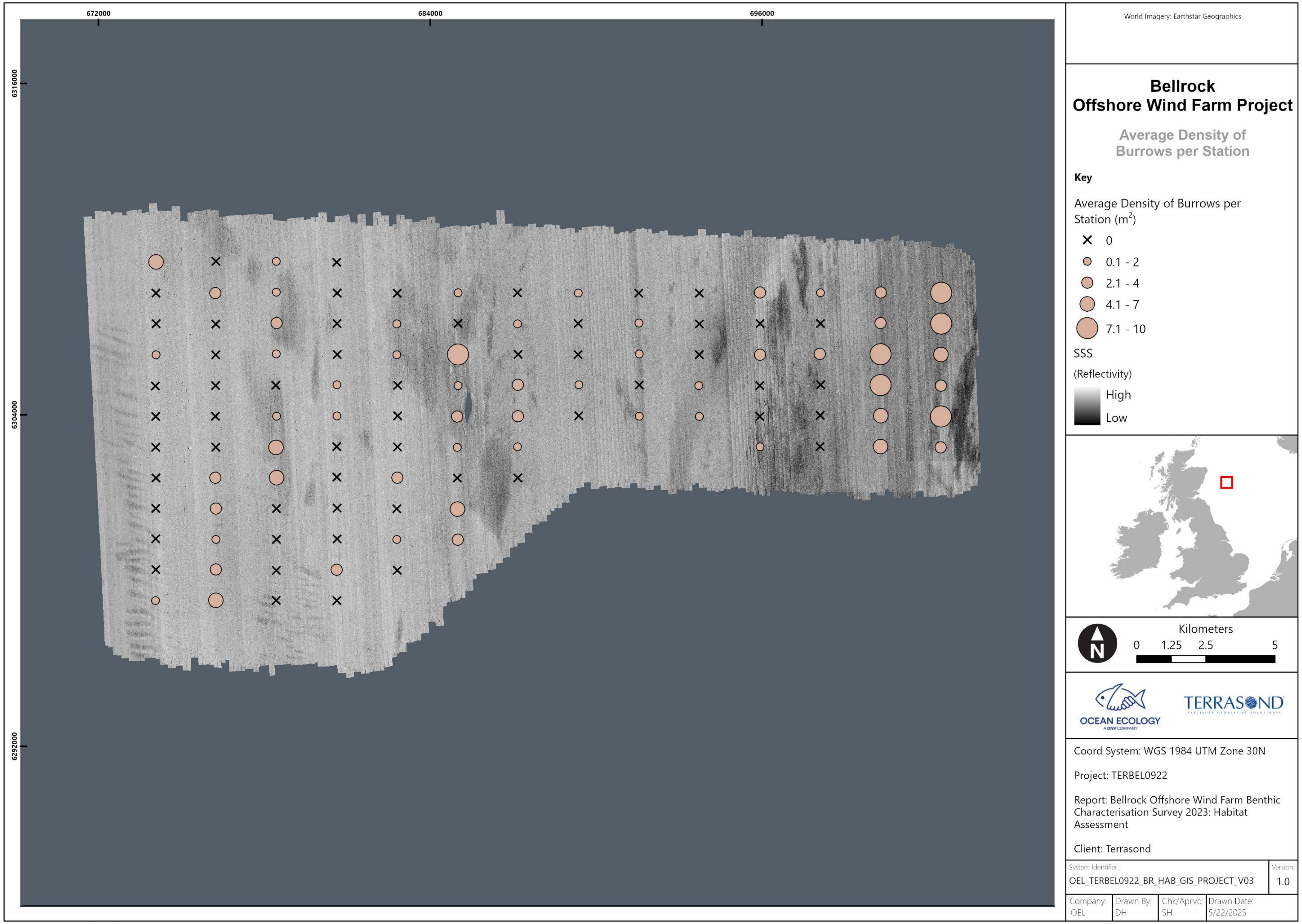

Figure 4 Average density of burrows per station (m^2) across the survey area.

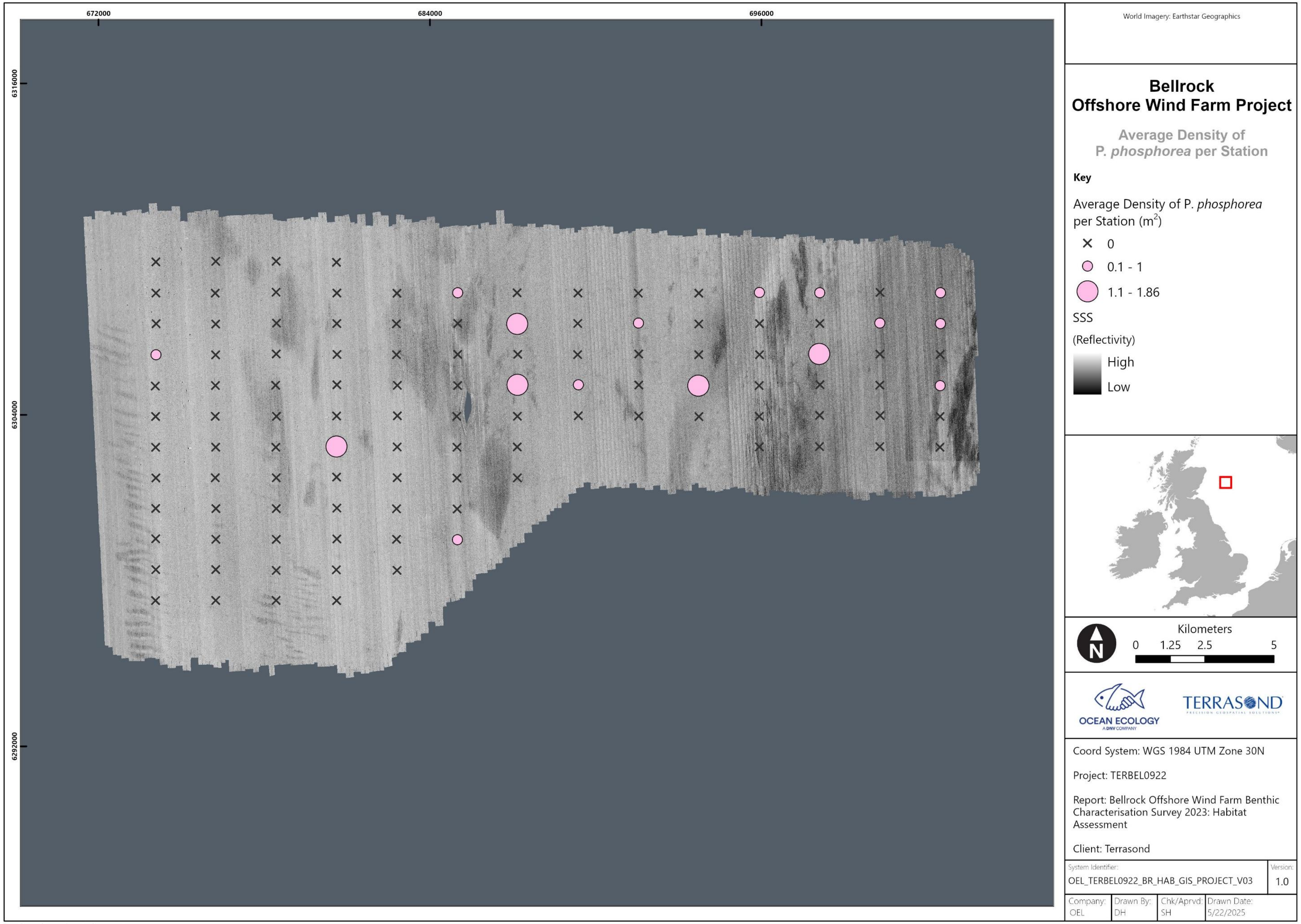

Figure 5 Average density of *P. phosphorea* per station (m^2) across the survey area.

6.4. Sediment

6.4.1. PSD Analysis

In total, 113 sediment samples were analysed for full particle size classification. Example images of all sampled sediment types are presented in Plate 5 with full particle size data provided in Appendix IV and summary data provided in Appendix V.

6.4.2. Sediment Type

Sediment types, as classified using the Folk triangle (Folk, 1954), for each station sampled across the survey area are presented in Figure 6. Each Folk classification was converted to BSH Type (EUNIS Level 3) using the adapted Folk triangle (Long, 2006) (Figure 6). Sediments were heterogeneous across the survey area with sand dominating across all stations and variable contributions of mud and gravel. Sediment textural group and BSH are mapped in Figure 7 and Figure 8.

Of the 113 sampling stations, 103 stations represented EUNIS BSH A5.2 (Sand and Muddy Sand) including Sand (S), Muddy Sand (mS), Slightly Gravelly Muddy Sand ((g)mS), and Slightly Gravelly Sand ((g)S); 6 stations represented EUNIS BSH A5.3 (Mud and Sandy Mud) including Muddy Sand (mS); and 4 stations represented EUNIS BSH A5.4 (Mixed Sediment) including Gravelly Muddy Sandy (gmS).

6.4.3. Sediment Composition

Sediments across the survey area were characterised predominantly by sand, with varying though generally low gravel and mud content. The percentage of gravels (>2 mm), sands (0.63 mm to 2 mm), and fines (< 63 µm) at each station are presented in Figure 9. The mean proportion (± Standard Error, SE) of sands across all stations was 89 % (± 0.5 %), the mean (± SE) gravel and mud content across the survey area was 0.7 % (± 0.2 %) and 11 % (± 0.45 %) respectively. Spatial trends of sediment composition are mapped in Figure 10. Figure 10.

Plate 5 Sediment types sampled. Left to right: ST0001, Slightly Gravelly Sand. ST0002, Slightly Gravelly Sand. ST0003, Sand. ST0036, Slightly Gravelly Muddy Sand. ST0033, Muddy Sand. ST0031, Gravelly Muddy Sand.

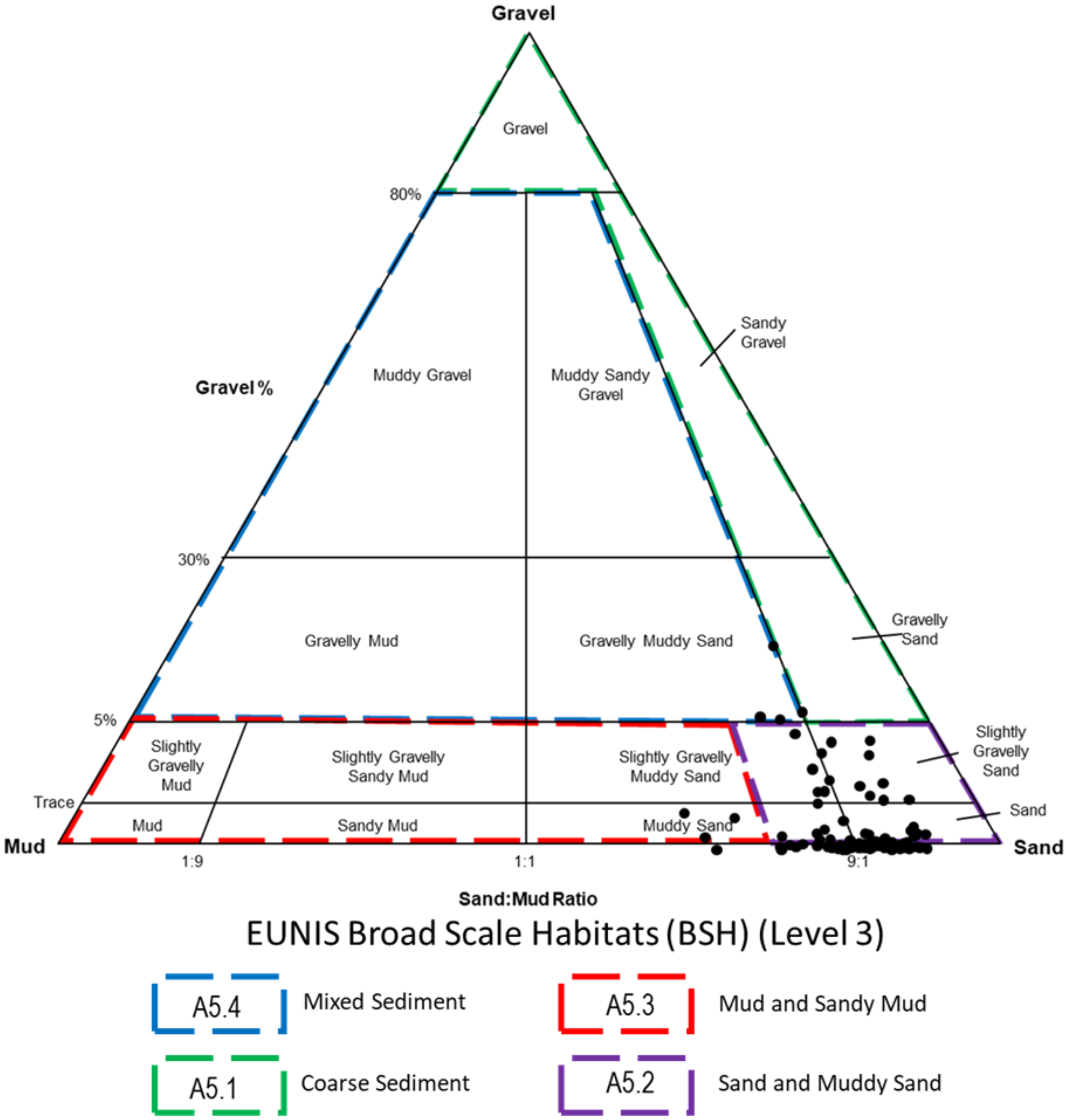

Figure 6 (Folk, 1954) triangle classifications of sediment gravel percentage and the sand-to-mud ratio of samples collected during the survey, overlain by the modified Folk triangle for determination of mobile sediment BSHs under the EUNIS habitat classification system (adapted from (Long, 2006)).

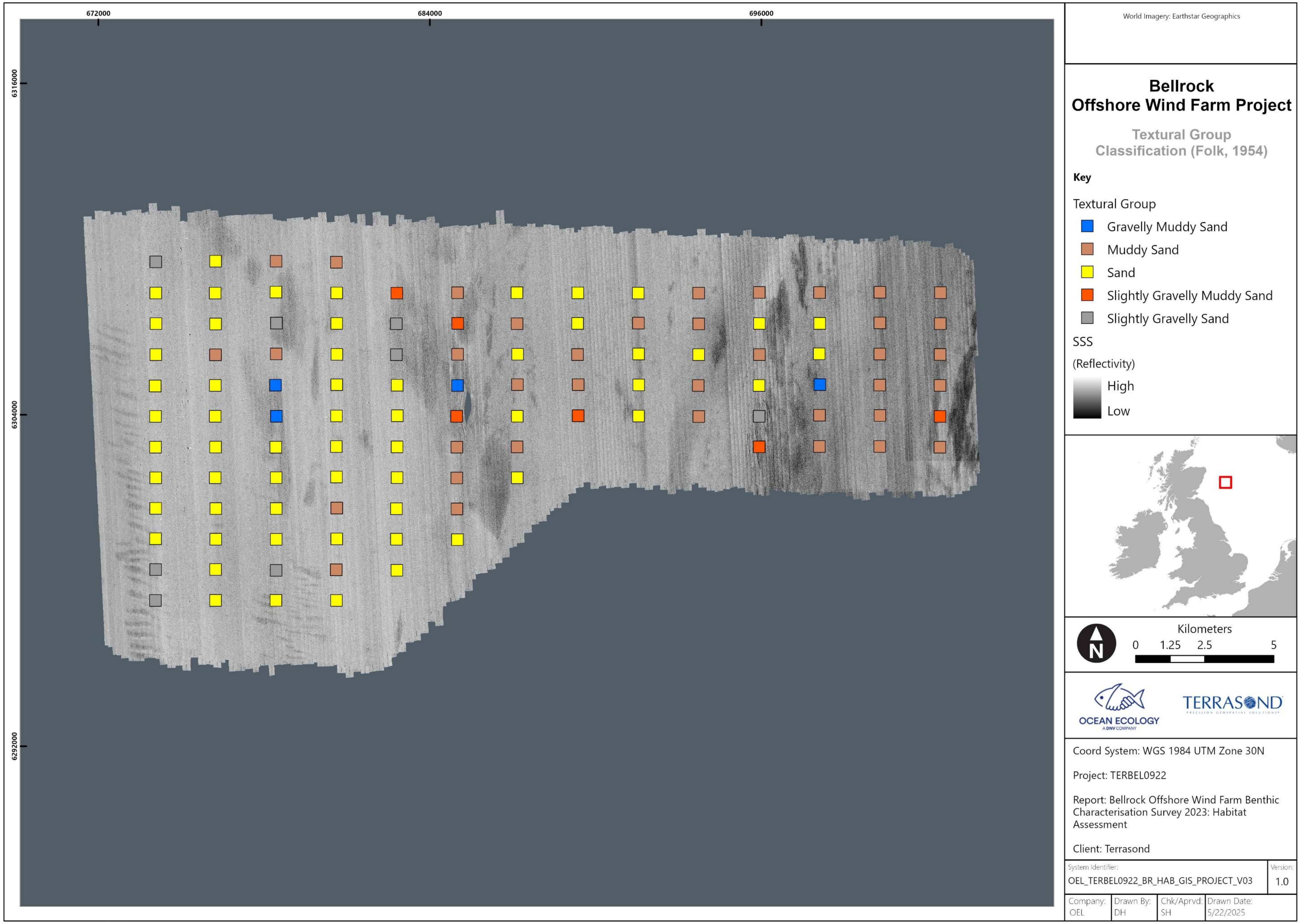

Figure 7 Textural Groups as determined from PSD analysis of samples acquired during the survey.

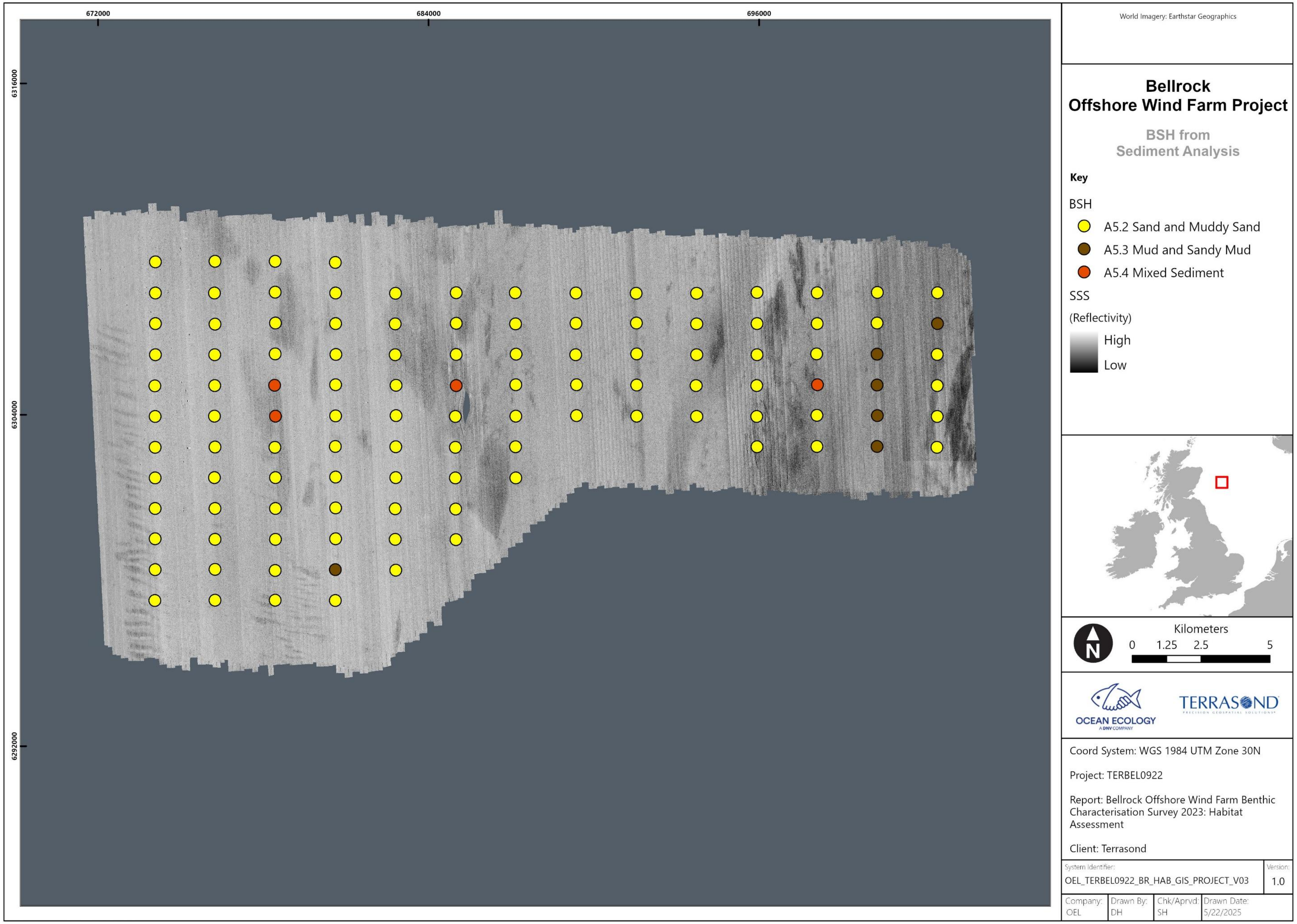

Figure 8 EUNIS BSH classification as determined based on PSD of sampled collected during the survey.

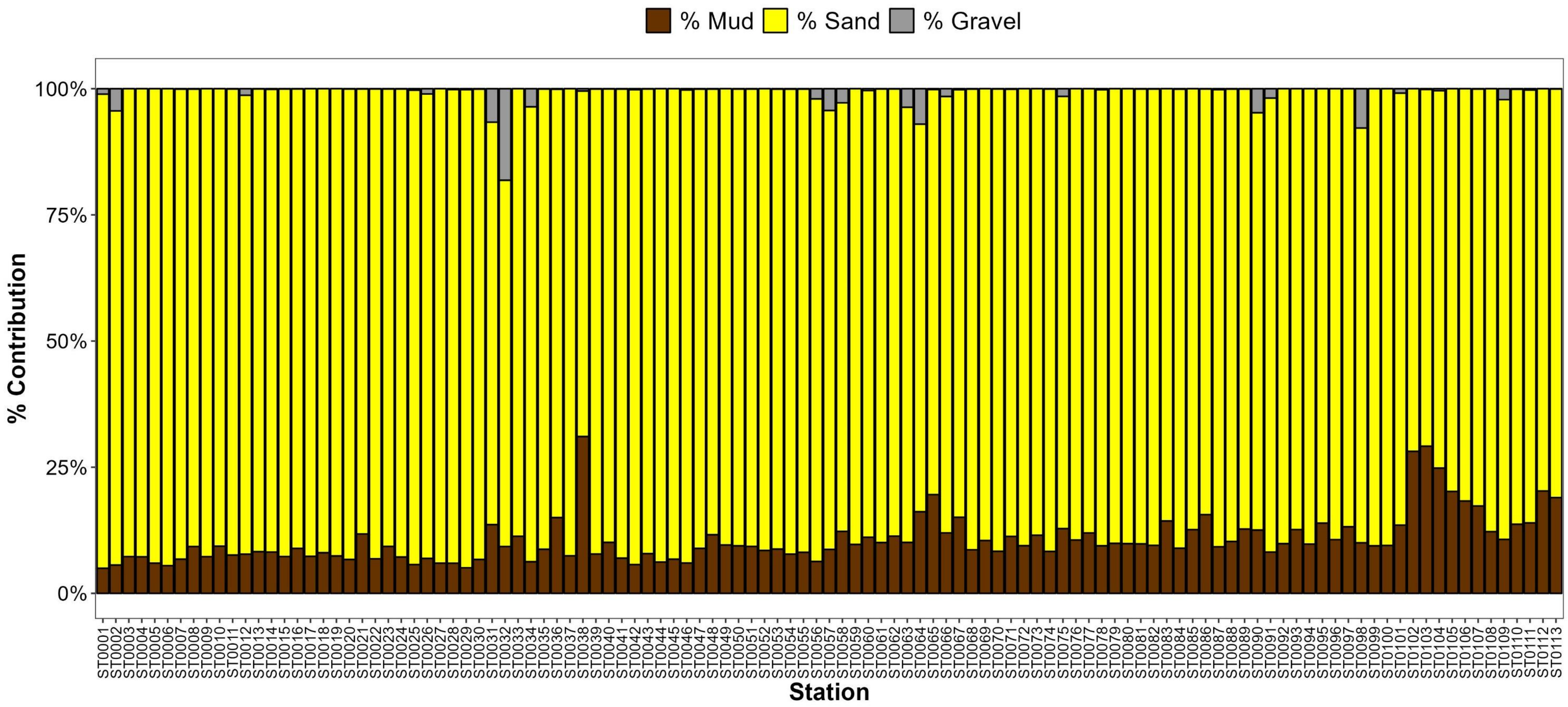

Figure 9 Relative contribution to the volume of sediment at each sampling station across the survey area.

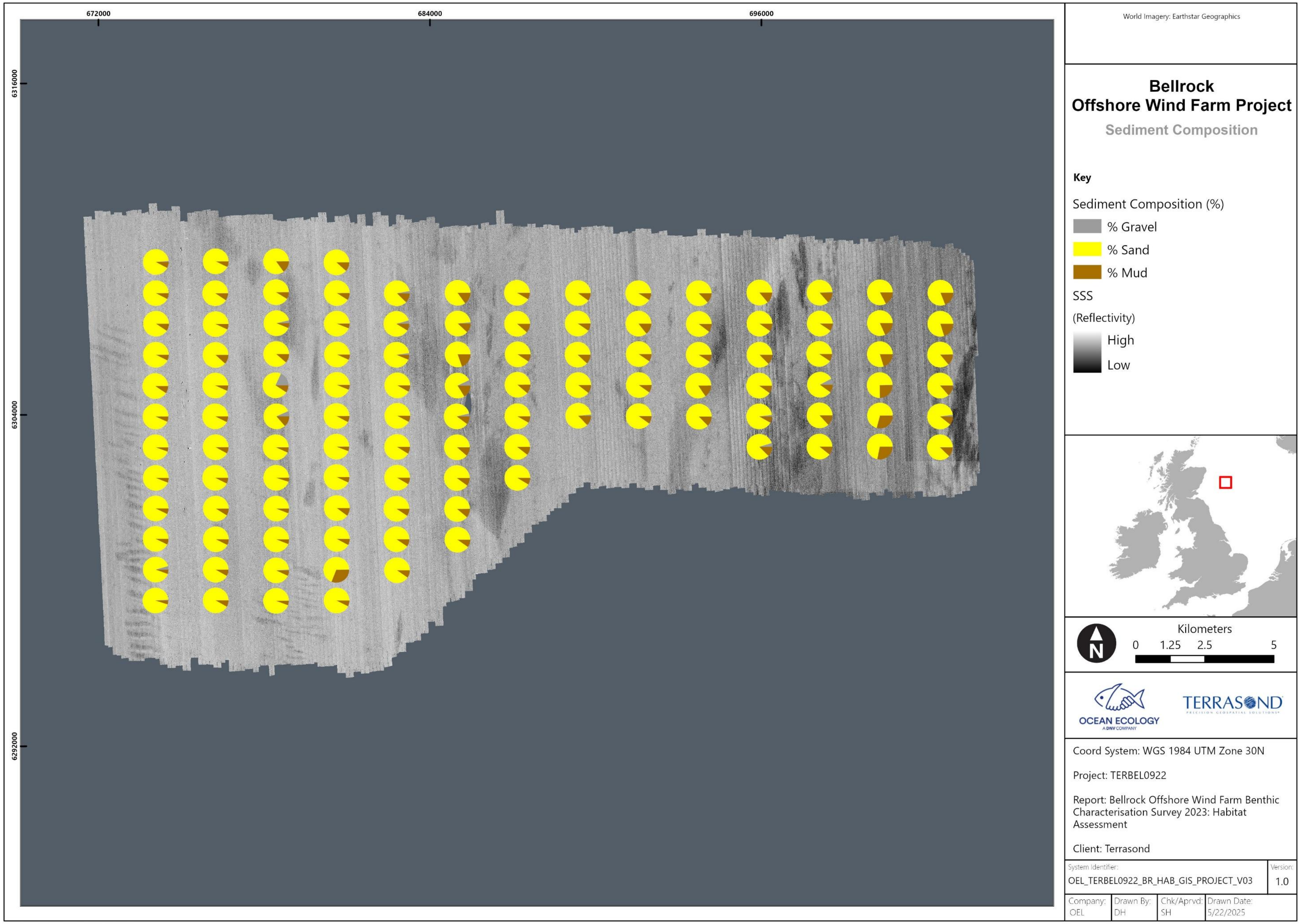

Figure 10 Principal sediment components (gravel, sand, mud) as determined from PSD analysis of samples acquired during the survey.

6.5. Habitat Mapping

Habitat mapping based on the interpretation of the seabed imagery and PSD datasets described the majority of the survey area as representative of EUNIS habitat complex A5.27 Deep Circalittoral Sand representing the offshore subtidal sands and gravels PMF habitat. Small areas of mud occurred in deeper waters representative of A5.37 Deep Circalittoral Mud. In the eastern reaches of the survey area habitat A5.37 overlapped with an area of burrowed mud as observed in the seabed imagery analysis and was identified as the burrowed mud PMF habitat.

Overall, the habitat mapping aligned well with EUSeaMap predicted habitats as shown in Figure 1. Due to the depth of the survey area, the level 4 EUNIS codes A5.27 and A5.37 were assigned; however, no biotope-characterising taxa were identified during seabed imagery analysis meaning that level 5 EUNIS codes could not be derived (Figure 11).

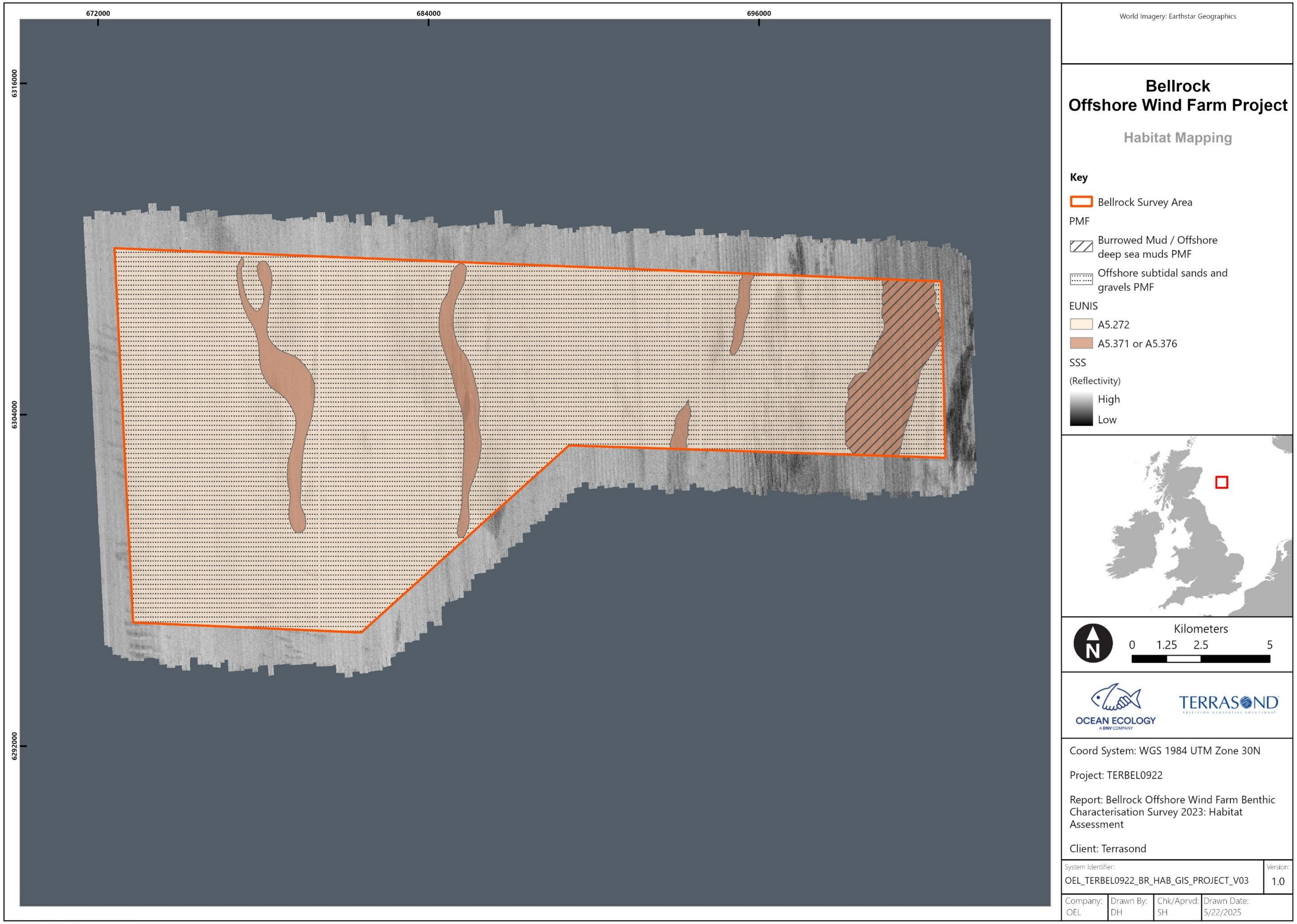

Figure 11 EUNIS habitat/biotope mapping across the survey area.

7. Discussion

An integrated interpretation of PSD data, seabed imagery, and acoustic data suggested that the prevalent benthic habitat across the Bellrock WFDA was A5.27 Deep circalittoral sand, with small areas of A5.37 Deep circalittoral mud occurring in correspondence of deeper waters. Acoustic data (SSS and MBES) can be used to define habitat boundaries, however, in this case, acoustic data was homogenous with no distinct features. Sandy mud and muddy sand can be particularly difficult to distinguish from each other as they exhibit similar reflectivity signatures resulting in homogenous SSS data. Likewise, the challenges associated with differentiating between muddy sand and sandy mud during seabed imagery analysis meant that PSD data was used as the primary information source to delineate areas of sand and mud. Low confidence scores were assigned to the polygons identifying these features and their boundaries as PSD data was collected at discrete sampling locations to ground-truth acoustic and imagery data. Nevertheless, findings from this survey closely aligned with the predicted BSH mapping as shown in Figure 1. The level 4 EUNIS codes A5.27 and A5.37 were assigned given the overall depth of the survey area being more than 70 m.

A general, broad-scale trend was observed across the survey area with sediments becoming increasingly muddier moving to the east where water depth also became increasingly deeper. The area to the east of the survey area which was assigned the EUNIS code A5.37 Deep circalittoral mud (Figure 11) also corresponded to the deepest area surveyed. Mixed sediments (EUNIS BSH A5.4) were confirmed as present at three stations based on the PSD data, however, no polygons were drawn due to the homogenous nature of the acoustic data at these locations and their environs (Figure 8). Analysis of macrobenthic data may allow for the assignment of higher level EUNIS classifications at these locations and therefore the production of more detailed habitat mapping if key taxa characteristic of known biotopes is identified.

A comprehensive burrow assessment was made on all still images collected across the survey area, yielding data on burrow density per station, with the aim of determining whether the burrowed mud PMF was present within the survey area. This habitat is widely distributed in sheltered sea lochs, other open coast muddy habitats along the western coast of Scotland, and even on the continental slope. Occasional records exist on the east coast, with noteworthy occurrences in offshore waters of the northern North Sea. The key identifying characteristics of this PMF are typically found in areas with fine mud, sandy mud, and muddy sand, at water depths ranging from 10 meters to over 500 meters (Tyler-Walters et al., 2016). It is important to note that the Bellrock survey area was situated offshore in the open waters of the northern North Sea and that stations to the east of the survey area assigned to the EUNIS habitat A5.37 were among those with the highest densities of burrows (Figure 4). This indicates the presence of the burrowed mud PMF at these locations. However, seabed imagery data revealed no spatial relationship between burrow mud density and the presence of seapens which were the most commonly occurring epifauna observed in the seabed imagery (Figure 4 and Figure 5). This indicates that seapen and burrowing megafauna were not a biotope component of the burrowed mud PMF observed. Macrobenthic data derived from grab samples collected as part of the wider characterisation survey may provide a greater insight into the component species of the burrow mud PMF habitat observed allowing for a more accurate assessment of this habitat. The macrobenthic data will be reported separately as part of the full characterisation report and will facilitate higher resolution biotope mapping.

The key objectives of this habitat assessment were to provide an initial description of the seabed habitats within the survey area and identify and assess any species and habitats of conservation importance such as PMF habitats and/or species. Whilst this was achieved, it should be noted that the lack of newly acquired geophysical data at the sampling design stage has resulted in the habitat and biotope mapping outputs being of a lower level of resolution and confidence than would otherwise have been achieved if geophysical data would have been available to inform the sampling design.

Upon review of the geophysical data, which was made available only after the survey was completed, it was noted that very few stations were located in areas of predicted muddy sediment as indicated by the lower acoustic reflectivity in the SSS data. It therefore became apparent that the design of the sampling array partially resulted in a systematic underrepresentation of areas of predicted mud due to their linear (north to south) occurrence at regular intervals laterally across the Bellrock WFDA (east to west). The distance between these linear features of muddy sediments was similar to the distance between sampling stations (grid design) meaning they were often missed due to the sampling design.

This finding aptly demonstrates the preference for stratified random sampling designs based on review of existing geophysical datasets as opposed to systematic grids for the purposes of habitat mapping (Noble-James et al., 2018). Due to delays in the prior geophysical survey of the Bellrock WFDA, geophysical data was not available at the point of determining the location of the sampling stations for the benthic characterisation survey meaning a systematic grid, rather than stratified random design had to be employed. Whilst efforts were made to reduce the chances of this approach resulting in bias towards or against regularly spaced features (by increasing sampling density from 75 to 113 across the site) the results indicated that a greater number of sampling stations distributed across a grid with reduced intervals would have allowed for greater resolution of habitat/biotope mapping across the survey area.

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