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OCEAN ECOLOGY

Marine Surveys, Analysis & Consultancy

Dogger Bank South Offshore Wind Farm SAC Extension Benthic Survey Technical Report

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Details

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Updates

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Abbreviations

AFDW	Ash Free Dry Weight
AOI	Areas of Interest
BMP	Benthic Monitoring Plan
BSH	Broadscale Habitat
Cefas	Centre for Environment, Fisheries and aquaculture Science
CLOC	Clear Liquid Optical Chamber
DBS	Dogger Bank South
DDC	Drop Down Camera
DDV	Drop Down Video
DVV	Dual Van Veen
EUNIS	European Nature Information System
GPS	Global Positioning System
HD	High Definition
HDD	Hard Drive Disks
IDA	Industrial Denatured Alcohol
INNS	Invasive or Non-Native Species
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
MBES	Multibeam Echosounder
MCA	Marine and Coastal Agency
MEDIN	Marine Environmental Data and Information Network
MLWS	Mean Low Water Springs
MPA	Marine Protected Area
MMO	Marine Management Organisation
MP	Megapixel
MU	Management Unit
NMBAQC	Northeast Atlantic Marine Biological Analytical Quality Control Scheme
nMDS	Non-metric Multidimensional Scaling
OEL	Ocean Ecology Limited
OWF	Offshore Wind Farm
PSD	Particle Size Distribution
SAC	Special Area of Conservation
SBAS	Satellite-Based Augmentation System
SCI	Site of Community Importance
SOWF	Sofia Offshore Wind Farm
SSS	Sidescan Sonar
SVP	Sound Velocity Profiler

UPS	Uninterruptable Power Supply
USBL	Ultra-Short Baseline
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
VER	Valued Ecological Receptor
WoRMS	World Register of Marine Species

1. Non-Technical Summary

Ocean Ecology Ltd. (OEL) were contracted to undertake a benthic survey across an area of seabed adjacent to, and overlapping with, the northern boundary of the Dogger Bank Special Area of Conservation (SAC). The key aims of the project were to inform RWE on the character of the benthos within this area by identifying species and habitats of conservation importance, in particular the overlapping Dogger Bank SAC designated features, and identify whether the infaunal communities found in the area of interest are equivalent to those described by (Wieking & Kröncke 2003) and (Diesing et al. 2009).

The benthic survey was undertaken in March 2023 and involved the collection of seabed imagery and grab samples across 58 stations arranged in 12 transects across the Dogger Bank SAC extension survey area. All samples were analysed for macrobenthos and sediment distribution and assessed with univariate and multivariate statistics to test for any significant differences and groupings of macrobenthic communities. This was then used to assign biotopes to macrobenthic groups and identify whether the infaunal communities sampled across the area were equivalent to those described as the North-eastern community (Wieking & Kröncke 2003) and/or communities K and J (Diesing et al. 2009).

Sediments across the survey area were generally homogenous, with all but two stations dominated by sand. Mud and gravel content was low throughout the survey area with the exception of two stations which contained high levels of generally poorly sorted gravel. The majority of samples were comprised of sand (S) and slightly gravelly sand ((g)S) representing EUNIS Broadscale Habitat (BSH) A5.2 'Sand and Muddy Sand'. A small number of stations were classified as Sandy Gravel (sG) or Gravelly Sand (gS) representative of EUNIS BSH 'A5.1 Coarse Sediment'.

A diverse macrobenthic community was identified across the survey area with key taxa including the bristle worms *Scoloplos armiger* and *Protodorvillea kefersteini* as well as the amphipod *Bathyporeia elegans*. Multivariate analysis on macrobenthic data identified 7 macrobenthic groups and two outlier stations across the survey area. The majority of stations fell within macrobenthic Groups F and G suggesting that macrobenthic diversity was evenly distributed across the survey area. Macrobenthic Groups G, A and E exhibited distinction from other macrobenthic groups, with most stations within these groups falling within the boundary of the Dogger Bank SAC and area of known Annex I sandbank in the shallower region of the survey area. Macrobenthic Group A (stations with higher gravel content) were also distinct from other groups with a macrobenthic community similar to those previously described as characteristic of gravelly regions of Dogger Bank. Three notable taxa were identified including two species included in the OSPAR list of threatened species (Ross worm, *Sabellaria spinulosa* and the Ocean quahog, *Arctica islandica*) as well as one taxon of economical importance (clams of the Veneridae family).

Particle Size Distribution (PSD) and macrobenthic data showed that whilst there were significant differences between macrobenthic groupings, the majority of stations closely aligned with the biotope "A5.252 *Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand". The assignment of this biotope to multiple macrobenthic groups highlights the even distribution of macrobenthic diversity across the survey area.

The North-Eastern community as described by (Wieking & Kröncke 2003) is documented as being dominated by *B. elegans* and *S. armiger*, both of which were amongst the most abundant taxa recorded during the Dogger Bank SAC extension survey. Similar macrobenthic communities were observed in Group G of the present study, the Bank community (Wieking & Kröncke 2003) and Group K (Diesing et al. 2009) The two amphipod species *B. elegans* and *Bathyporeia guilliamsoniana* were both present as well as the burrowing bivalve *Fabulina fabula*. Some similarities were also observed between Macrobenthic Group F and the North-Eastern community described in Wieking & Kröncke (2003). *Spiophanes bombyx, B. elegans* and *S. armiger* were present in abundance in both groups along with taxa belonging to the genus of clam *Dosinia* and family of sea anemones Edwardsiidae.

2. Introduction

2.1. Project Overview

The Dogger Bank South (DBS) Offshore Wind Farm (OWF) projects are planned to be located over 100 km off the northeast coast of England on a shallow (<65 m) offshore area of the North Sea known as The Dogger Bank.

DBS will be made up of two separate sites, DBS East, and DBS West, each with a proposed installed capacity of up to 1.5 GW. In January 2023 RWE entered into "Agreements for Lease" for the two projects with The Crown Estate, giving RWE exclusive seabed development rights for the sites. The number of turbines for each site has not yet been determined, however, the design allows for up to 300 wind turbines (a maximum of 150 for each project). The final number will be dependent on the size of turbines eventually installed.

2.2. Background Information

Ocean Ecology Ltd. (OEL) were contracted to undertake a benthic survey across an area of seabed adjacent to, and overlapping with, the northern boundary of the Dogger Bank SAC (Figure 1) to inform RWE on the character of the benthos within this area. The area of study was selected as it is likely that the infaunal communities found in the area may be equivalent to those described as the North-Eastern community (Wieking & Kröncke 2003) and/or communities K and J (Diesing et al. 2009) within previous studies of the Dogger Bank SAC. The distribution of these communities in the vicinity of the Dogger Bank SAC is of interest to DBS for consenting purposes. The results of this survey will therefore be used to assist with the development of consent applications.

2.3. Aims and Objectives

The key aims of the survey were to:

- Identify whether the infaunal communities found in the area of interest are equivalent to those described by (Wieking & Kröncke 2003) and (Diesing et al. 2009).
- Help to identify species and habitats of conservation importance, in particular the overlapping Dogger Bank SAC designated features (Annex I 'Sandbanks which are slightly covered by sea water all the time').

The survey involved the collection of seabed imagery and sediment samples followed by subsequent macrobenthic and PSD analysis.

2.4. Site Information

2.4.1. Site Location

The survey area is situated approximately 36 km northeast of the DBS OWF projects (DBS West and DBS East), 100 km off the northeast coast of England in an area of the southern North Sea called The Dogger Bank.

The Dogger Bank is a significant topographical feature covering an approximate area of 17,600 km^2 within the central North Sea. It is the largest sandbank in UK waters, extending out and into both Dutch and German waters.

It is surrounded by a series of mobile sandbanks, linear ridges, and deep pits. The sediment is typically comprised of sands, muddy sands, coarser gravelly sands, and gravels. The infauna and epifauna of The Dogger Bank has been widely researched (Diesing et al. 2009), the composition of which is diverse and separated into several spatially distinct communities largely determined by sediment characteristics and depth (Diesing et al. 2009). The area is of high importance for fisheries, as The Dogger Bank and surrounding seabed supports abundant sand eel populations, a significant prey source for predators including many commercial fish species (Diesing et al. 2009).

Seabed sediments within the majority of the survey area are thought to be characterised by circalittoral sand, with some areas of circalittoral coarse sediment (Figure 2). Area of seabed that qualify as Annex I sandbank habitat is expected to occur withing the southern region of the survey area that falls within the Dogger Bank SAC (Figure 3, Section 2.4.3).

2.4.2. Designated Sites

The survey area intersects and lies close to a number of Marine Protected Areas (MPAs) as set out below and presented in (Figure 2). These sites form part of a network of UK wide and internationally recognised MPAs.

Dogger Bank SAC

The survey area intersects the northern boundary of the Dogger Bank SAC, a 12,331 km^2 area designated in 2017 to protect sandbank features classified as Annex I Habitat ('1110 - Sandbanks which are slightly covered by seawater all the time') under the EU Habitats Directive. The Dogger Bank SAC overlaps with the north easterly extent of Southern North Sea SAC. Fisheries bylaws were put in place within the SAC from June 2022 by the Marine Management Organisation (MMO), whereby the use of bottom towed fishing gear (demersal, seines and semi-pelagic) throughout the whole SAC was prohibited (Figure 2).

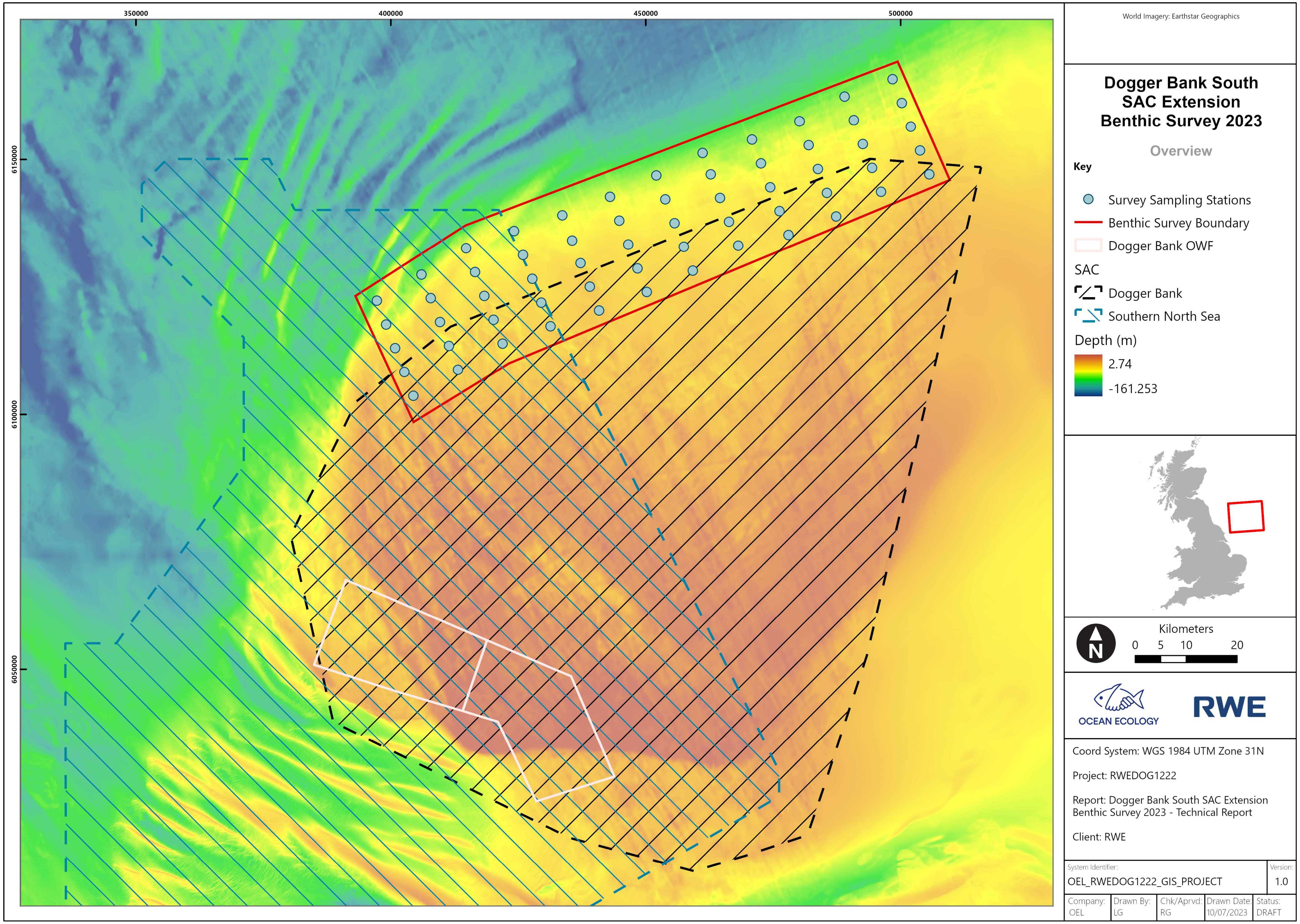

Figure 1 Overview of the Dogger Bank South OWF SAC Extension survey area.

Southern North Sea SAC

The survey area intersects the northern extent of the Southern North Sea SAC. A 36,951 km^2 predominantly offshore area characterised by sandy, coarse sediments. It spans from The Dogger Bank in the north to The Straits of Dover in the south. It was designated in 2019 to protect harbour porpoise (*Phocoena phocoena)*. The SAC is recognised as supporting 17.5% of the UK North Sea Management Unit (MU) population, with the northern extent of particular importance during the summer season (Figure 2).

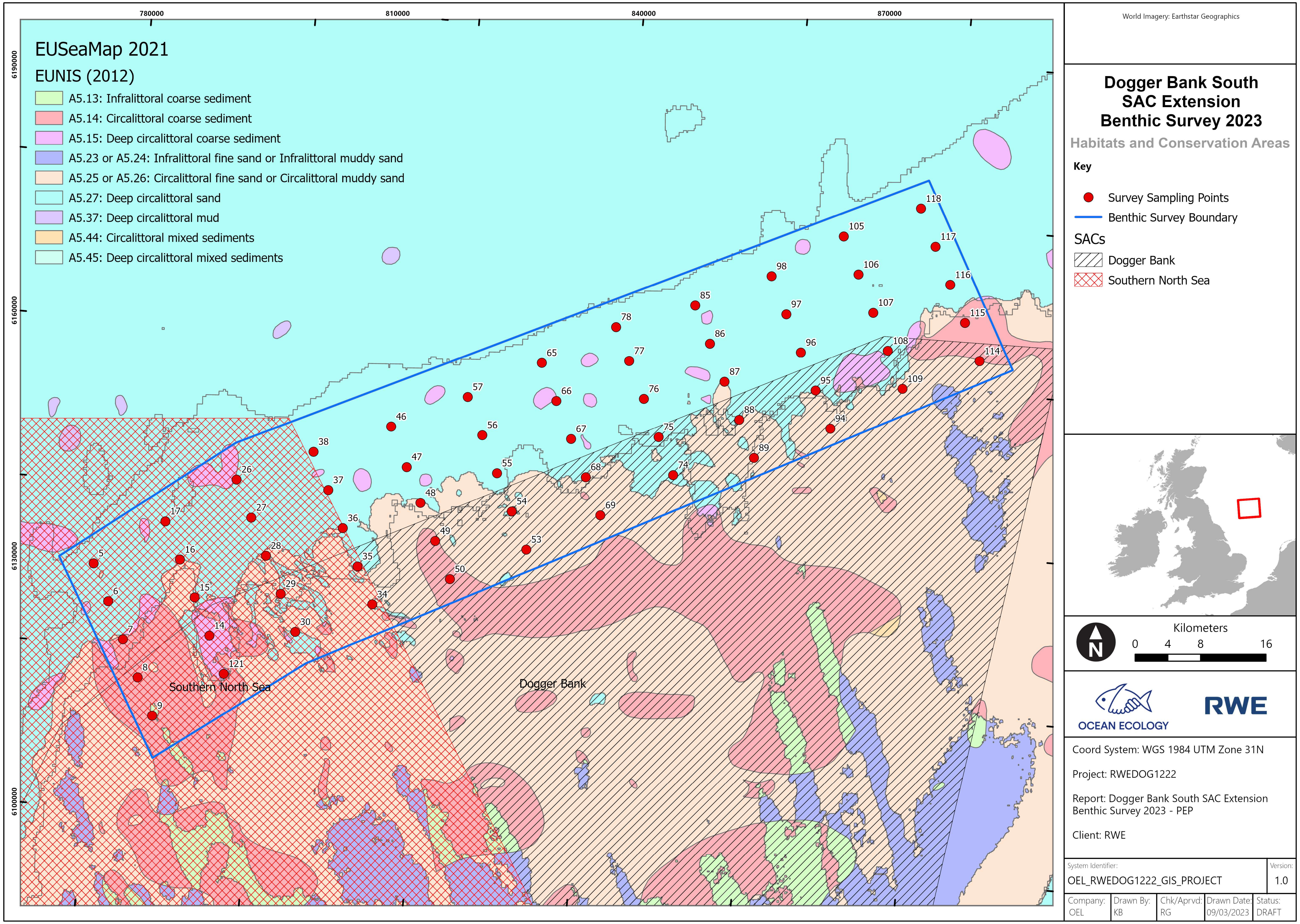

Figure 2 Designated sites and known EUNIS habitats intersecting and within the environs of the survey area.

2.4.3. Benthic Habitats of Conservation, Ecological or Economic Importance

Sandbanks which are slightly covered by seawater all the time

Sandbanks interpreted as Annex I Habitat 1110 'sandbanks which are slightly covered by seawater all the time' are described as sandy, elevated, elongated, rounded, or irregular topographical features permanently submerged and predominantly surrounded by deeper water (CEC, 2013). Sandbanks are of high conservation value, providing feeding and nursery grounds for a wide array of species including those of commercial importance. This is largely due to enhanced levels of primary and secondary productivity that occurs on and around sandbank features (Figure 3).

The sediment type of these habitats is the key driver of the diversity and type of associated communities, as well as physical, chemical, and hydrographic factors (e.g., exposure, temperature, topography, depth, turbidity, and salinity). In UK waters this feature is categorised into four sub-types: gravelly and clean sands, muddy sands, eelgrass *Zostera marina* beds and free-living maerl (Corallinacea) beds. An expansive area of Annex I sandbank habitat extends throughout The Dogger Bank SAC supporting several spatially distinct communities (Wieking & Kröncke 2003, Diesing et al. 2009).

2.4.4. Species of Conservation Interest

Arctica islandica

Arctica islandica or 'Ocean Quahog' is a large, slow growing clam with a thick round/oval shaped shell growing up to 13 cm in length. This species is believed to be one of the longest living molluscs with one individual estimated at 507 years old. They are found in subtidal sandy and muddy sediments around the UK and are sensitive to physical disturbance and habitat destruction from mobile fishing gear. There are known records of this species within the survey area (Figure 3).

Osmerus eperlanus

The European Smelt (*Osmerus eperlanus*) is a species of anadromous fish occurring in coastal and estuarine waters around the UK. They typically grow up to 18 cm long with a long slender appearance. Numbers of this species have severely declined around the UK due to overfishing, habitat destruction and barriers to migration. This species has been recorded as being present to the northwest of the survey area (Figure 3).

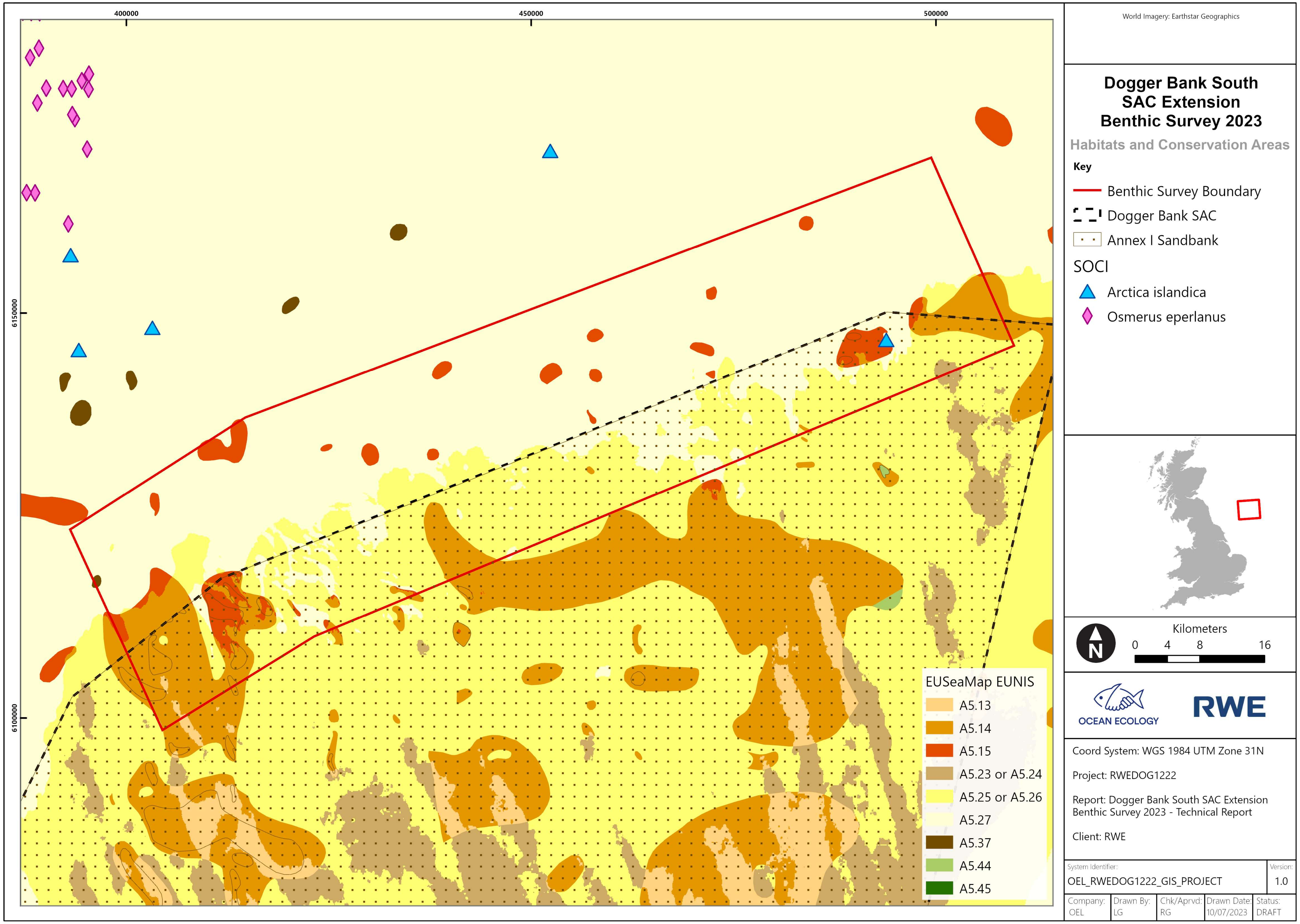

Figure 3 Species of Conservation Interest (SOCI) and Annex I habitats occurring within and in the vicinity of the survey area.

3. Sampling Plan

3.1. Rationale

The predefined sampling plan has been developed to provide adequate spatial coverage throughout the area of interest. Notably to identify whether the infaunal communities found in the area are equivalent to those described as the North-eastern community (Wieking & Kröncke 2003) and/or communities K and J (Diesing et al. 2009).

3.2. Sampling Design

The sampling array consisted of 58 predetermined sampling stations in an area located to the north and northeast of the proposed DBS East and DBS West OWF Projects (Figure 4).

The sampling stations were placed at 5 km intervals along 12 transects each separated by 10 km and orientated in a northwest to southeast arrangement. This captured the depth profile of The Dogger Bank from 50 m below lowest astronomical tide (LAT) up to within the northern aspect of the Dogger Bank SAC boundary. Primary and secondary survey transect lines were proposed as part of the original sampling array but were not sampled in order of priority during the survey due to favourable weather conditions. Stations were sampled in a systematic fashion along all survey lines in turn.

A thorough conflicts check was conducted by OEL for all sampling stations, and in consideration of the requirements detailed in Schedule 2 of the marine license. Ten stations (05, 08, 09, 16, 17, 28, 36, 49, 54, 69) lay between 250 m and 1 nautical mile of a subsea cable and / or pipeline and therefore required prior notification of the asset operator before sampling. Two stations, 14 and 121, were removed from the scope prior to the survey commencing for safety reasons due to their location within a spoil ground with poorly charted features (reducing the original scope of 60 stations to the sampled 58 stations). No other conflicts were noted.

3.3. Sampling Approach

At each sampling station, high-resolution seabed imagery (stills and video) was first collected with a DDC system to allow in situ visual inspection for confirming the absence of protected or sensitive habitats (e.g., potential Annex I Reef) and other ecological, heritage, or safety hazards prior to grab sampling. If during this pre-screening exercise the sampling stations were deemed inappropriate for grab sampling, the sampling station was to be repositioned in a nearby area of sediment and revisited with DDC prior to grab sampling.

Stations were then sampled with a 0.2m^2 Dual Van Veen (DVV) grab sampler, due to the presence of hard compacted sand in the area which was not favourable for a 0.1 m^2 mini-Hamon grab. One sample of approximately 10 L was collected at each station. From the sediments collected, a single sub-sample was taken for PSD analysis, and the remainder was sieved through a 1 mm mesh and retained for macrobenthic analysis. Grab samples were taken within 50 m of the target sampling station.

3.4. Sampling Summary

All scope operations were successfully completed within the allocated survey timeframe.

Digital photographic stills and video footage were successfully obtained at 58 DDC stations and were reviewed *in situ* to assess for the presence of protected or sensitive habitats (e.g., Annex I reef features), and general suitability for grab sampling. This resulted in the collection of 302 still images and 60 videos. No protected or sensitive habitats were noted at any of the DDC stations.

A total of 58 successful macrobenthic samples and 58 PSD samples were collected during the survey.

3.5. Timing

Sampling was undertaken from the 17th to the 20th of March 2023.

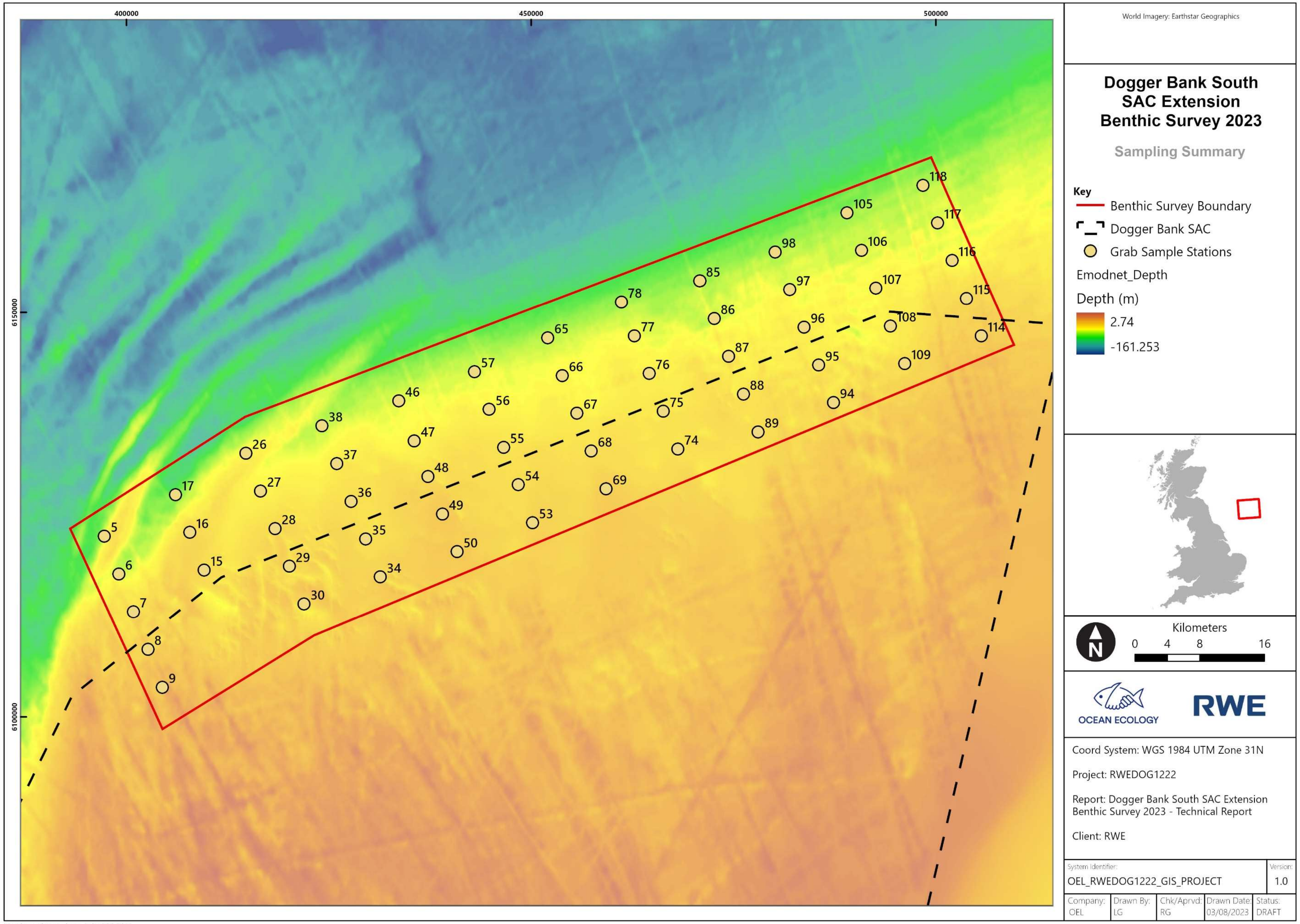

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Figure 4 Grab stations sampled during the survey.

4. Survey Methods

4.1. Project Parameters

4.1.1. Horizontal Datum

All data is referenced to WGS84 UTM Zone 31N, with no datum transformation need.

Table 1 Geodetic parameters.

GPS Satellite System Geodetic Parameters	
Geodetic Datum	WGS_1984
Projection	Universal Transverse Mercator (UTM)
Zone	31 N [EPSG 32631]
Central Meridian (CM)	3.000000
Latitude of Origin	0.00000
False Easting	500000.000000
False Northing	000000
Linear Unit	Metre

4.1.2. Vertical Datum

All altitude and depth data above seabed is referenced to LAT. All depth data below the seabed is referenced to LAT where available.

4.1.3. Unit Format and Conversions

The following units were used throughout this project and have been 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 Marine and Coastal Agency (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, Plate 1).

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 Ultra-Short Baseline (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 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 VRU and gyro.

4.4. 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 was obtained regardless of turbidity (Jones et al. 2020). 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 would be caused should the vessel have lost power or in the event 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).

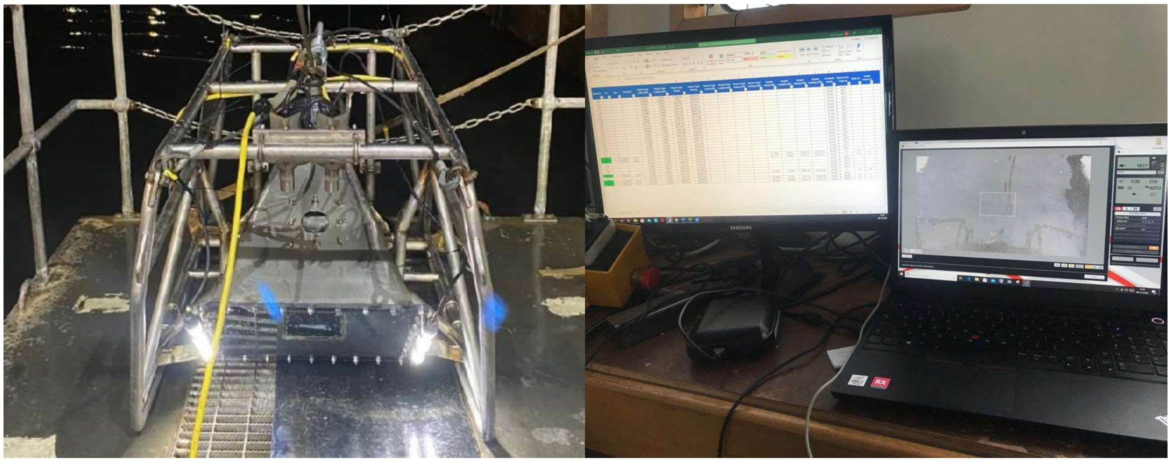

Plate 2 Left: OEL CLOC camera system. Right: The camera system topside setup.

All DDC stations were sampled in consideration of the 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 winch and lowered into the water column. The umbilical was payed out by hand.
- Once the camera system was within 5m 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 were taken. The vessel was manoeuvred within a 50 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 was 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). Detailed notes were taken of visible sediment conditions and seabed features, obvious fauna, and habitat-related features whilst in the field.

4.5. Grab Sampling

4.5.1. Grab Samplers

Sediment samples were collected from within 50 m of the target sampling location using a 0.2 m^2 DVV grab sampler capable of simultaneously collecting two independent 0.1 m^2 samples (Plate 3). A 0.1 m^2 mini-Hamon grab was initially mobilised as the primary grab sampler however, due to the presence of hard compact sands within the survey area, the DVV was mobilised after multiple failed attempts with the mini-Hamon grab.

A single sample of approximately 10 L was retained at each station for macrobenthic and PSD analysis. A sub-sample of the sediment (approx. 0.5 L in volume) from each sample was removed for characterisation of the physical nature of the substrate (via PSD analysis) and the residual sample 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.

4.5.2. Sample Collection

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

- The sample was less than 5 L. i.e., the sample represented less than half 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 50m).

Where three unsuccessful attempts were made within 50 m of the target locations, a fourth attempt was made approximately 100 m from the target. Following a fourth failed attempt the station would have been abandoned, however this did not occur during the survey and all stations were successfully sampled. No pooling of samples took place.

4.5.3. Grab Sample Processing (PSD and Macrobenthic)

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

- An initial visual assessment was made of sample size and acceptability.
- A photograph was taken of the sample with station details and scale bar.
- 10 % of the sample was removed for PSD analysis and transferred to a labelled tray.
- The remaining sample (retained for faunal sorting and identification) was emptied onto a 1.0 mm sieve net laid over a 4.0mm sieve table and washed through using gentle rinsing with a seawater hose.

- This remaining sample was backwashed into a suitably sized sample container and diluted 10 % formalin solution was added to fix the sample prior to laboratory analysis.
- Sample containers were clearly labelled internally and externally with date, sample ID and project name.

Detailed field notes and digital photographs were taken at each station including station number, fix number, number of attempts, and water depth. Visual descriptions of sediment type were made (using the Folk classification categories) at the time of sampling, together with estimates of sample volume. Any notable or conspicuous fauna present were also recorded in the field notes.

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

5. Laboratory Analysis & Interpretation

5.1. Particle Size Distribution (PSD) Analysis

PSD analysis of the sediment samples was undertaken by in-house laboratory technicians at OEL's NE Atlantic Marine Biological Analytical Quality Control (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 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 4**.

Table 4 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 samples were 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 then checked to ensure the components of the sample had been fractioned as far down the sieve stack as their diameter allows. A further 10 minutes of shaking was undertaken if there was evidence that particles are not properly sorted.

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 was syphoned from above the sediment surface until a paste texture is 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.

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 were defined by their size class based on the Wentworth classification system (Wentworth 1922) (Table 5). Statistics such as mean and median grain size, sorting coefficient, skewness, and bulk sediment classes (percentage silt, sand, and gravel) were also derived following the Folk classification (Folk 1954).

Table 5 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

5.2. 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 (Worsfold & Hall 2010). All processing information and macrobenthic records were recorded using OEL's cloud-based data management application ABACUS that employs Marine Environmental Data and Information Network (MEDIN) 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 1 mm mesh sieve in a well-ventilated area. The samples were then re-sieved over a 1 mm mesh sieve to remove all remaining fine sediment and fixative. The low-density fauna was then separated by elutriation with freshwater, poured over a 1 mm mesh sieve, transferred into a Nalgene and preserved in 70 % Industrial Denatured Alcohol (IDA). The remaining sediment from each sample was subsequently separated into 1 mm, 2 mm and 4 mm fractions and sorted under a stereomicroscope to extract any remaining fauna (e.g., high-density bivalves not 'floated' off during elutriation).

All present fauna 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 will utilise the live link within ABACUS to the World Register of Marine Species (WoRMS) web services to ensure the most up to date taxonomic classifications are recorded. Colonial fauna (e.g., hydroids and bryozoans) were identified to species level where possible and recorded as present (P). For subsequent data analysis, taxa recorded as P were given the numerical value of 1. A full reference collection was retained including at least one example specimen of each taxon.

Biomass was measured as blotted wet weight in grams to at least 4 decimal places for all countable taxa (i.e., at species level where possible). As a standard, the conventional conversion factors as defined by (Eleftheriou & Basford 1989) was 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%

5.3. Macrobenthic Data Analysis

5.3.1. 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.

5.3.2. 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 4.3.1 (R Core Team 2022) and PRIMER v7 (Clarke & Gorley 2015) software packages. No replicate samples were available for macrobenthic analysis thus no mean values could be calculated per sampling station.

In accordance with the OSPAR Commission guidelines (OSPAR 2004) records of colonial, meiofaunal, parasitic, egg and pelagic taxa (e.g. epitokes and larvae) were recorded, but were excluded when calculating diversity indices and conducting multivariate analysis of community structure.

Newly settled juveniles of macrobenthic species may at times dominate the macrobenthos, however the (OSPAR 2004) guidelines suggest they should be considered an ephemeral component due to heavy post-settlement mortality and not therefore representative of prevailing bottom conditions (OSPAR 2004). OSPAR (2004) further states that "Should juveniles appear among the ten most dominant organisms in the data set, then statistical analyses should be conducted both with and without these in order to evaluate their importance". As juveniles of Amphiuridae and Tharcioidea appeared in the top ten most dominant taxa across the survey area, a 2STAGE analysis was conducted to compare the two data sets (with and without juveniles) which revealed a 93.8 % of similarity between the two and therefore juveniles were retained in the dataset for all further analyses and discussion. This was based on a p value of 0.1 and therefore if similarity was < 90 %, juveniles would have been excluded.

In accordance with NMBAQC PRP (Worsfold & Hall 2010), Nematoda were recorded during the macrobenthic analysis and included in all datasets for all further analyses and discussion.

5.3.3. Diversity Indices

In order to condense the full macrobenthic community datasets into single metrics that could be compared, a number of univariate metrics, otherwise known as diversity indices, were calculated from the macrobenthic dataset using the DIVERSE routine in PRIMER v7. These included: number of individuals (N); Shannon Wiener diversity (H'), Simpsons dominance (1 – λ'), richness (S) and evenness (J') indices were also calculated.

5.3.4. 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 (transformation) method. Macrobenthic abundance data from grab samples was square root transformed to prevent taxa with intermediate abundances from being discounted from the analysis, whilst allowing the underlying community structure to be assessed.

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 and non-metric multidimensional scaling (nMDS) used to identify groupings of sampling stations that could be grouped together as a habitat type or community. SIMPER (similarities-percentage) analysis was then applied to identify which taxa contributed most to the similarity within that habitat type or community. A detailed description of analytical routines is provided in Appendix I.

5.3.5. Determining EUNIS Classifications

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).

5.3.6. Seabed Imagery Analysis

Seabed imagery was obtained for the purpose of *in situ* screening of stations by completing a visual inspection for protected or sensitive habitats (e.g., potential Annex I Reef) and other ecological, heritage, or safety hazards. Subsequent analysis of the digital stills and video footage was therefore not required, however the stills and imagery obtained during the survey are provided with this report.

6. Results

Sampling at 58 grab stations across the survey area resulted in the acquisition of 58 benthic samples for macrobenthic and sediment PSD analysis. Digital photographic stills and video footage were also obtained for screening purposes at 58 DDC stations resulting in 302 still images and 60 videos. DDC logs are provided in Appendix II, with grab logs in Appendix III and grab sample images in Appendix IV.

6.1. Sediments

In total, 58 sediment samples were analysed for full particle size classification. Example images of all sampled sediment types are presented in Plate 4 with full PSD data provided in Appendix V and summary data provided in Appendix VI.

6.1.1. Sediment Type

Sediment types, as classified using the Folk triangle (Folk 1954), for each station sampled across the survey area are presented in Figure 5. Each Folk classification was converted to BSH type (EUNIS Level 3) using the adapted Folk triangle (Long 2006) (Figure 5). The majority of sediments sampled across the survey area were representative of EUNIS BSH A5.2 – Sand and Muddy Sand (n = 50). The remaining sediment samples were representative of BSH A5.1 - Coarse Sediment (n = 8). Sediments were relatively homogenous with some slight variation from Poorly Sorted Sandy Gravel (sG) to Well Sorted Sands (S). Sand content was high in all samples and mud content was generally low.

The most frequently occurring sediment type was Slightly Gravelly Sand ((g)S) recorded at 32 of the 58 sampling locations. Sand (S) was the second most commonly recorded sediment type (n = 18), followed by Gravelly Sand (gS) (n = 6) then Sandy Gravel (sG) (n = 2)

As a general spatial trend, the majority of the survey area was comprised of sands and sand with varying gravel content distributed relatively evenly throughout. The central and Northeastern region of the survey area was dominated by Slightly Gravelly Sand (g)S whilst the Southwestern region was largely Sand (S) (Figure 6). The survey area consisted largely of sediments representative of EUNIS BSH A5.2 – Sand and Muddy Sand with some stations representative of BSH A5.1 - Coarse Sediment distributed evenly across the survey area (Figure 7).

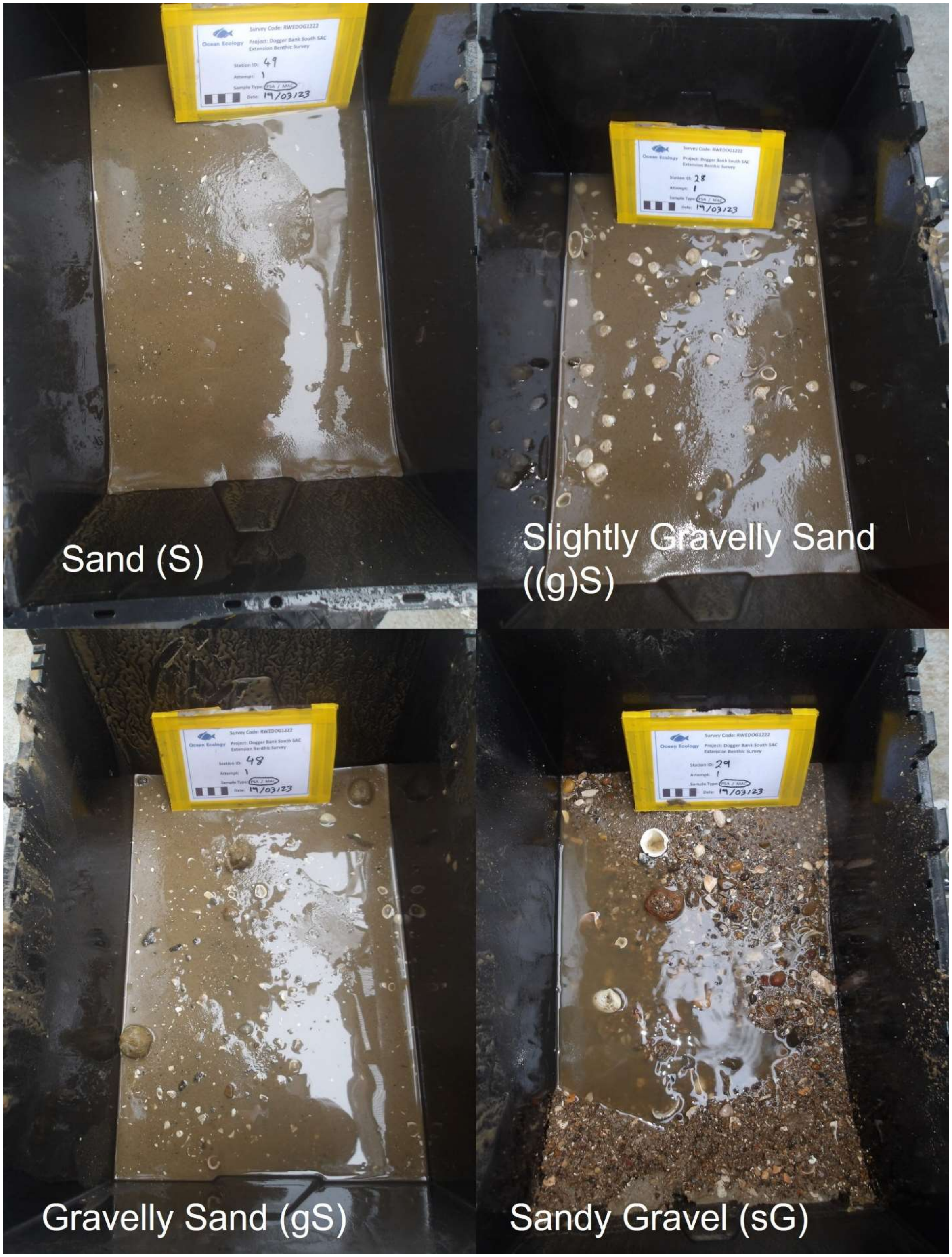

Plate 4 Example of sediments found across the survey area.

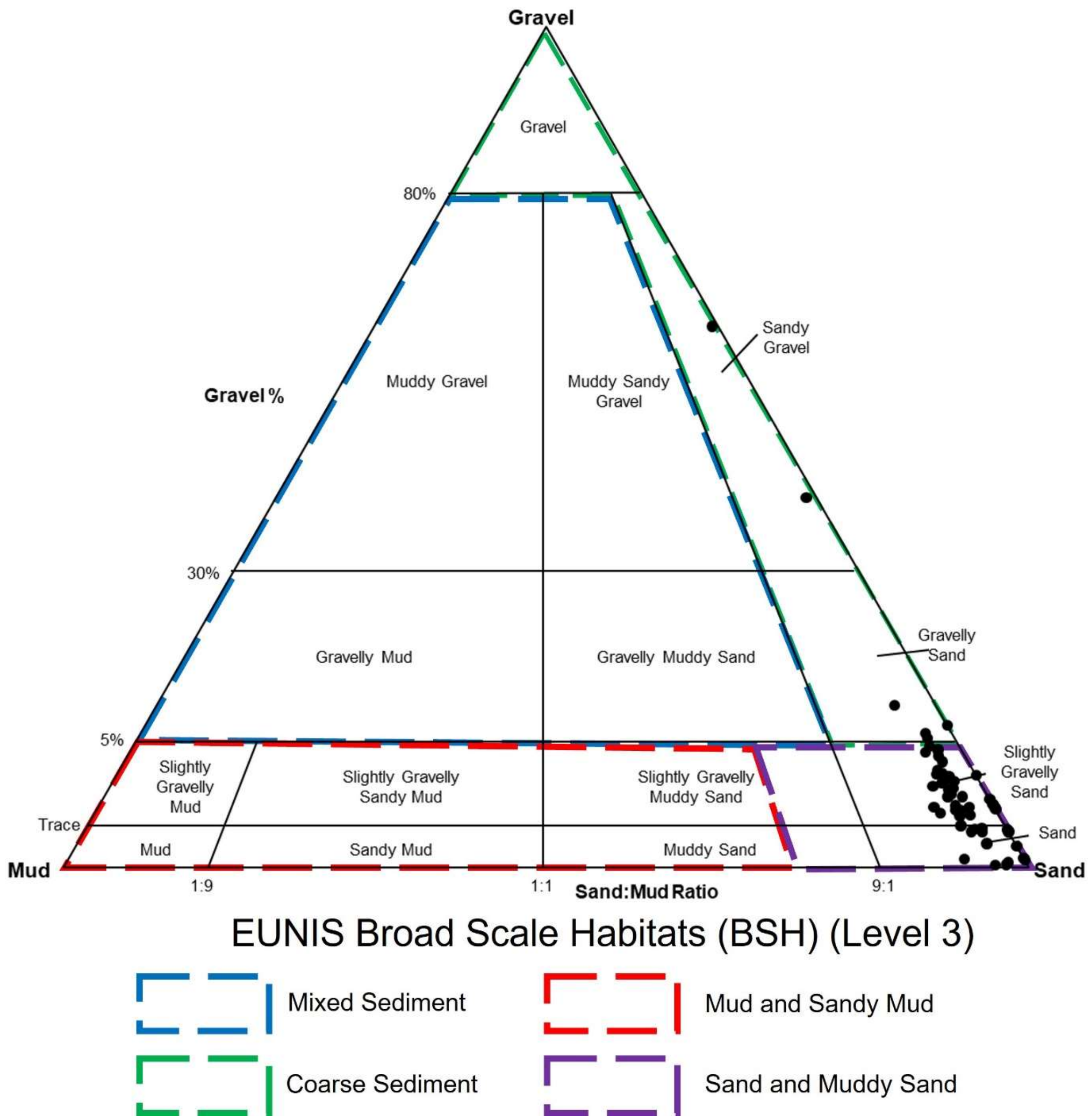

Figure 5 Folk (Folk 1954) triangle classifications of sediment gravel percentage and sand to mud ratio (shown by black dots) overlain by the modified Folk triangle for determination of mobile sediment BSHs under the EUNIS habitat classification system (adapted from (Long 2006)).

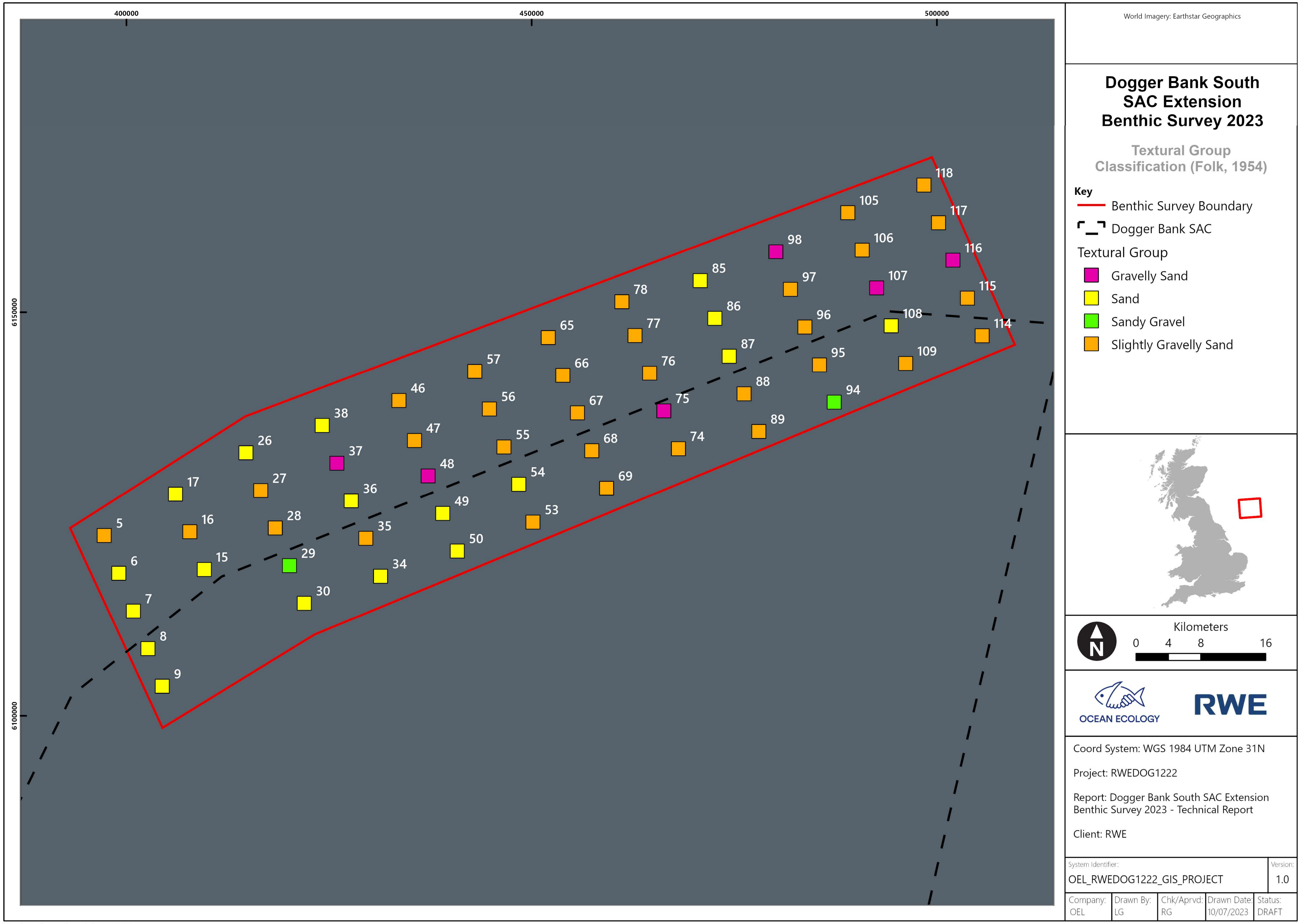

Figure 6 Folk (1954) sediment types as determined from PSD analysis of samples acquired during the survey.

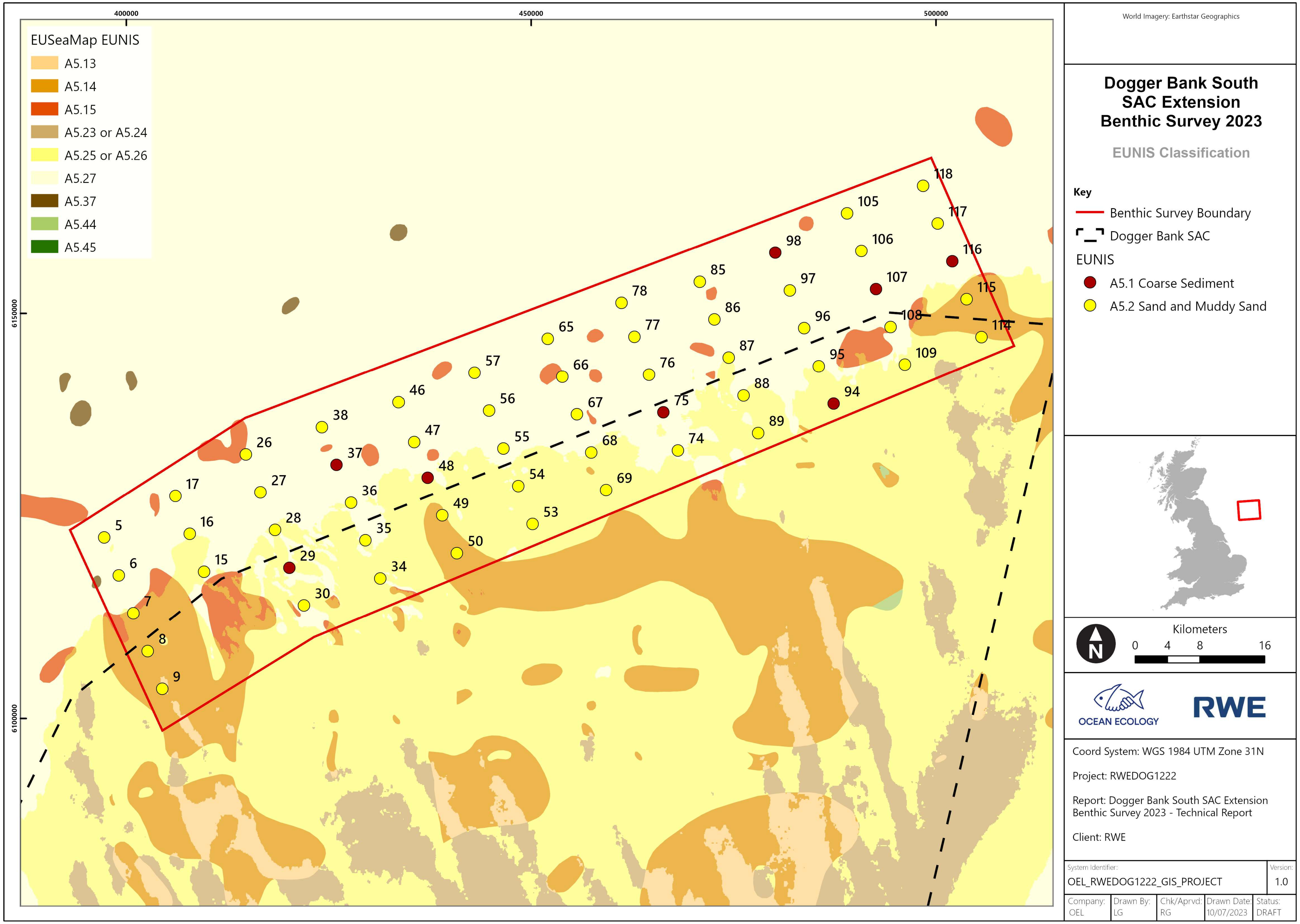

Figure 7 EUNIS habitat classification as determined from utilising the EUNIS sediment descriptions from PSD of samples collected during the survey.

6.1.2. Sediment Composition

Percentage contribution of gravels (>2 mm), sands (0.63 mm to 2 mm) and fines (<63 µm) to overall sediment composition are presented for each grab station in Figure 8 and mapped for each of the sampling stations in Figure 9.

Percentage contribution of sands to the overall sediment composition was by far the greatest across the survey area and was the principal sediment fraction at all stations but Station 94. The mean (± SE) proportion of sands across all stations was 93.9 ± 1.3 %, mean (± SE) gravel content was 4.2 ± 1.3 % and mean (± SE) mud content was 1.8 ± 0.2 %.

Percentage contributions of Gravel and Mud to the overall sediment composition were both very low across all stations except stations 29 and 94 which contained 41.57 % and 64.51 % Gravel respectively. These two stations are located at either end of the survey area and surrounded by stations dominated by Sand (Figure 9).

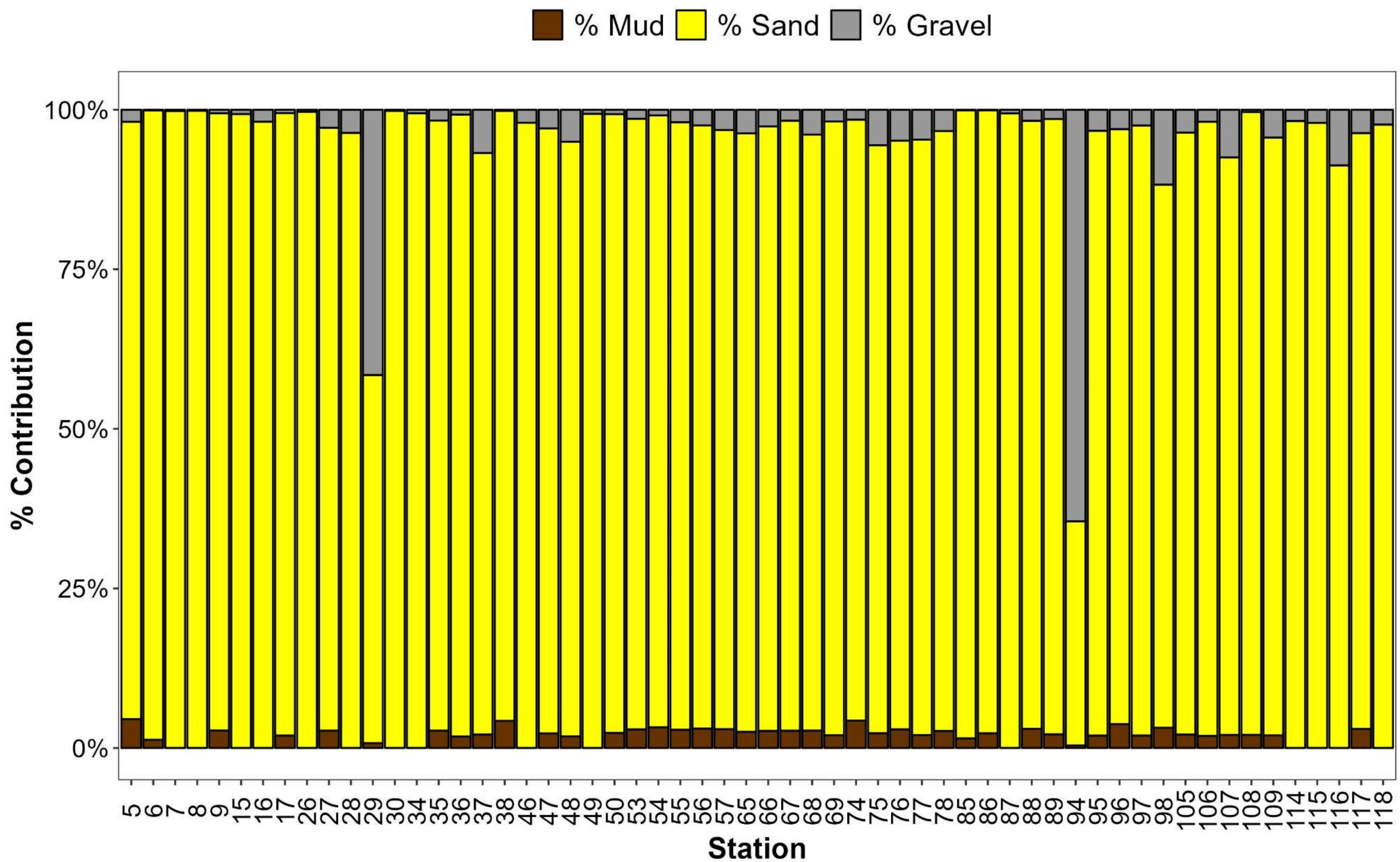

Figure 8 Principal sediment components (gravel, sand, mud) as determined from PSD analysis of samples during the survey.

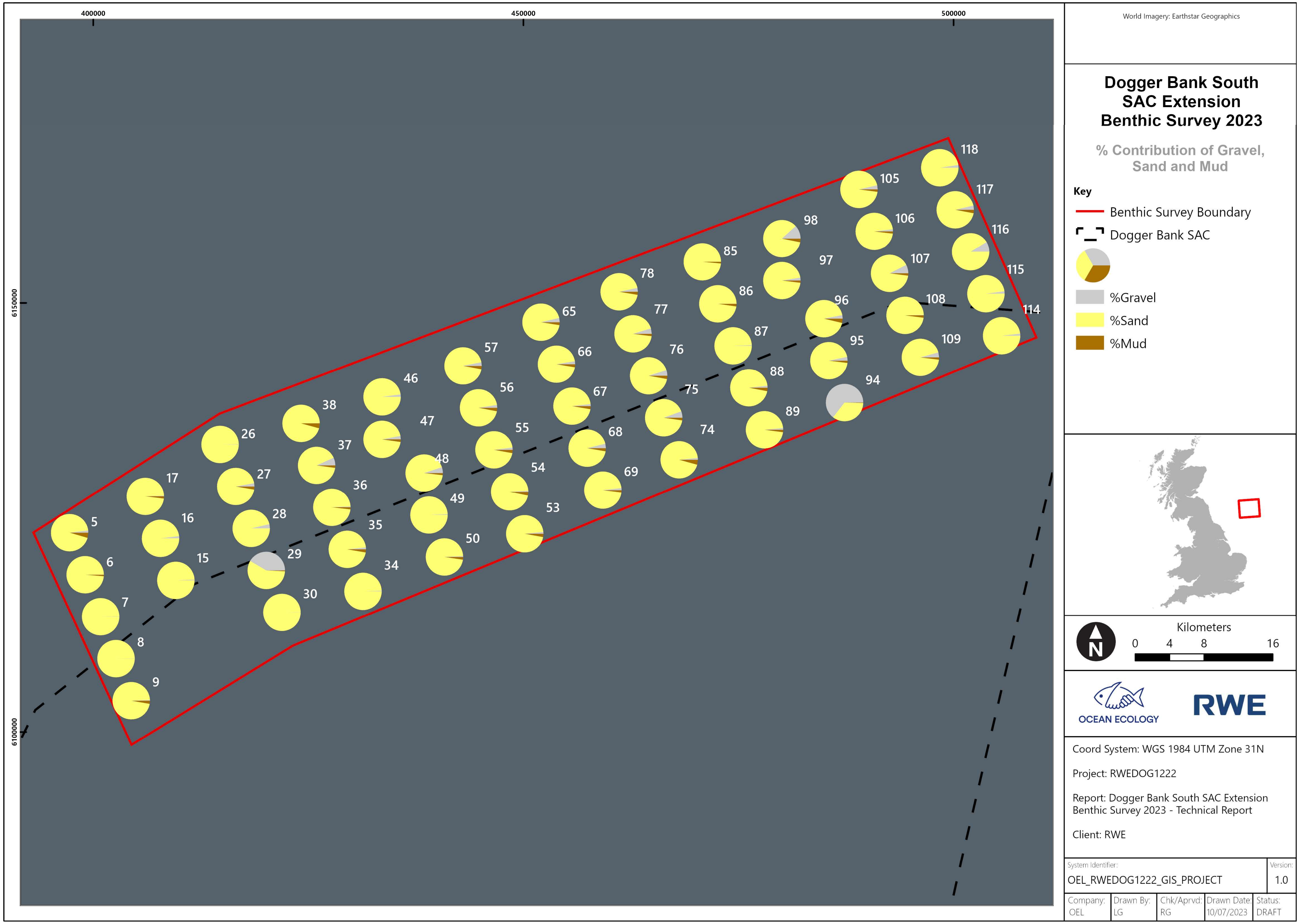

Figure 9 The principal sediment components (gravel, sand, mud) as determined from PSD analysis of samples acquired during the survey.

6.2. Macrobenthic Diversity

Fifty-eight macrobenthic samples were analysed for macrobenthic abundance, diversity and biomass. The macrobenthic assemblages of sediments sampled across the survey area constituted a mean (± SE) of 25 ± 1 taxa per sample. Mean (± SE) abundance was 58 ± 10 individuals per sample and mean (± SE) biomass was 1.3407 ± 0.2906 gAFDW. The full abundance and biomass matrices are provided in Appendix VII and VIII respectively, presenting the abundance of each taxon and biomass per major group (Annelida, Crustacea, Mollusca, Echinodermata and Others) in all samples collected across the survey area.

As shown in Figure 10, the polychaete *S. armiger* was the most abundant taxon sampled accounting for 6.2 % of all individuals recorded. This was closely followed by the amphipod *B. elegans* which accounted for 5.9 % of total abundance. *S. armiger* was also the most frequently occurring species appearing in 82.8 % of all samples as well as having the highest average density of 3.7 individuals per 0.1 m^2. The polychaete *P. kefersteini* was the taxon recorded the maximum number of times in a single sample sample with 123 individuals recorded at station 29.

Figure 11 illustrates the relative contributions to total abundance, diversity, and biomass of the major taxonomic groups in the macrobenthic community sampled across the survey area. Annelida taxa contributed significantly to overall abundance, accounting for approximately 40 % of all individuals recorded whilst Mollusca taxa accounted for approximately 24 %. Annelida and Mollusca taxa also contributed the most to the overall diversity of the macrobenthic assemblages accounting for 32 % and 30 %, respectively. Whilst contributing the least to overall abundance (10 %), Echinodermata taxa contributed the greatest to the total biomass of macrobenthic assemblages accounting for 47 %.

The highest mean abundance was observed at station 29 (n = 565), followed by station 94 (n = 321) (Figure 12). Excluding these two stations, the mean abundance was considerably lower at n = 44. The highest number of taxa was also recorded at station 29 with a total of 61 different taxa identified. Biomass was greatest at station 109 with a total AFDW of 13.4323 g. This was significantly higher than the second highest biomass of 7.7919 gAFDW recorded at station 29 (Figure 12).

Figure 13, Figure 14 and Figure 15 show the distribution of the macrobenthic community abundance (N), diversity (S) and biomass sampled across the survey area. The full complement of univariate diversity indices calculated for each macrobenthic sample are presented in Appendix IX.

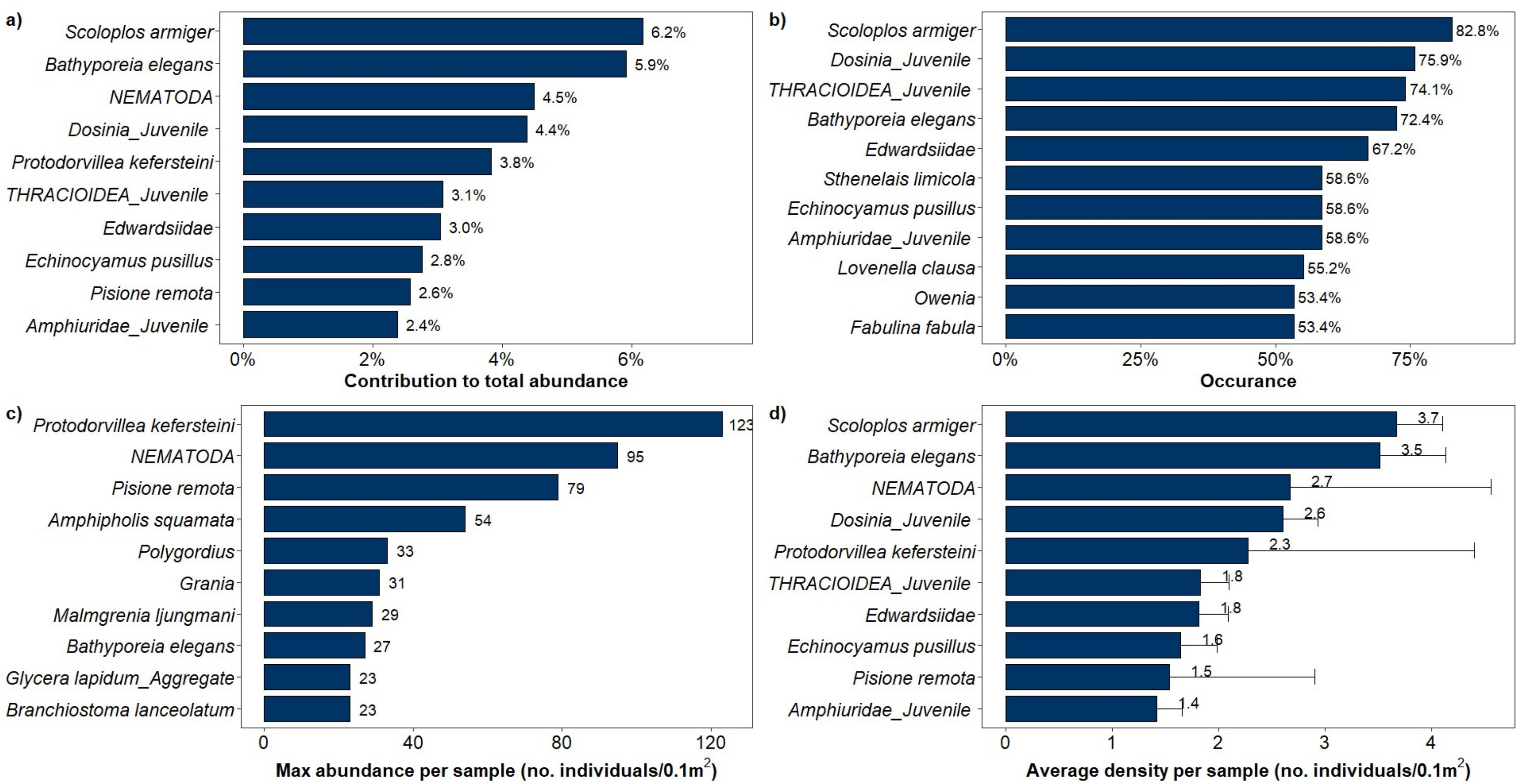

Figure 10 Percentage contributions of the top 10 macrobenthic taxa to total abundance (top left)) and occurrence (top right) from samples collected during the Dogger Bank South OWF SAC Extension Benthic Survey. Also shown are the maximum densities of the top 10 taxa per sample (bottom left) and average densities of the top 10 taxa per sample (bottom right).

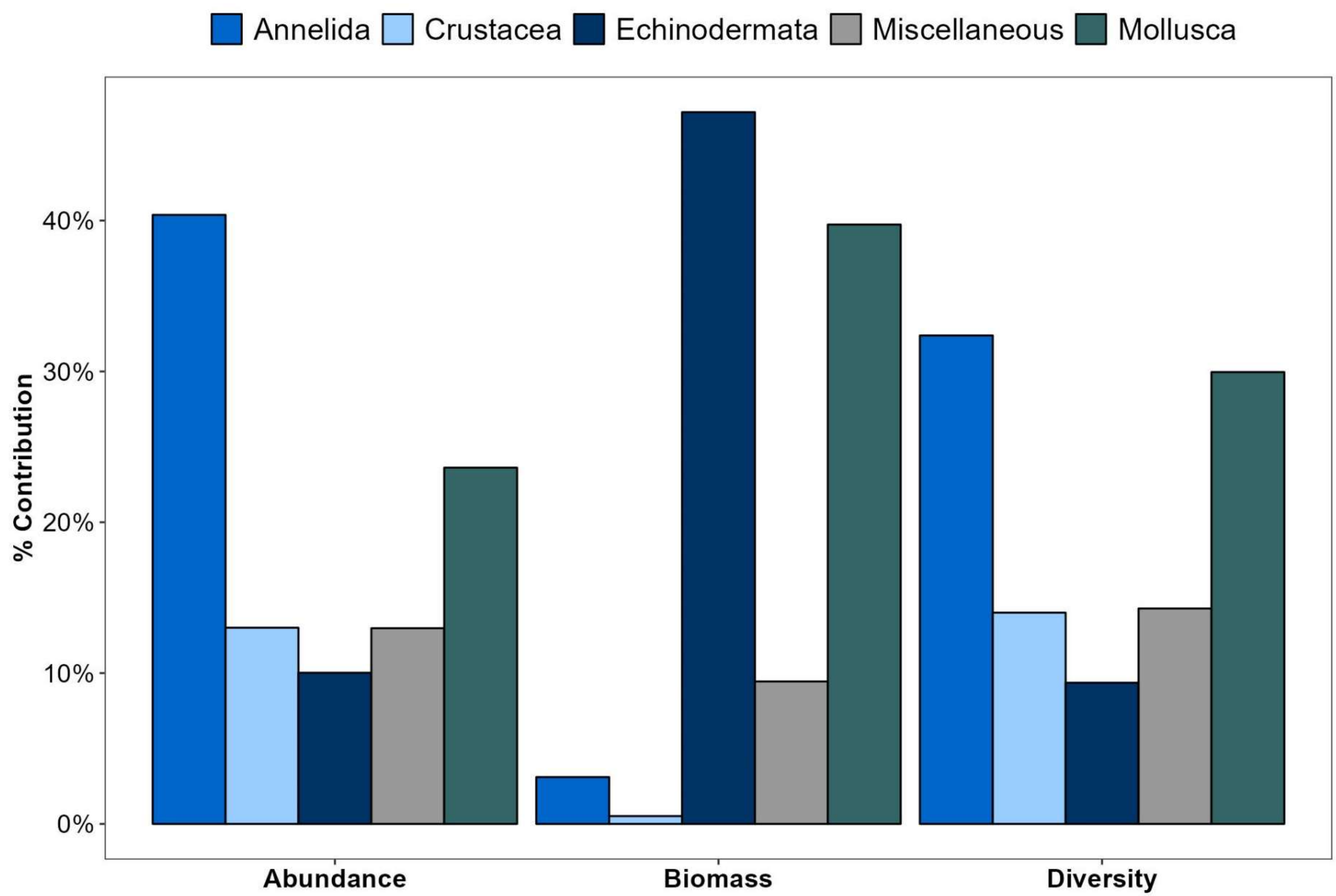

Figure 11 Relative contribution of the major taxonomic groups to the total abundance, diversity, and biomass of the macrobenthos sampled during the survey.

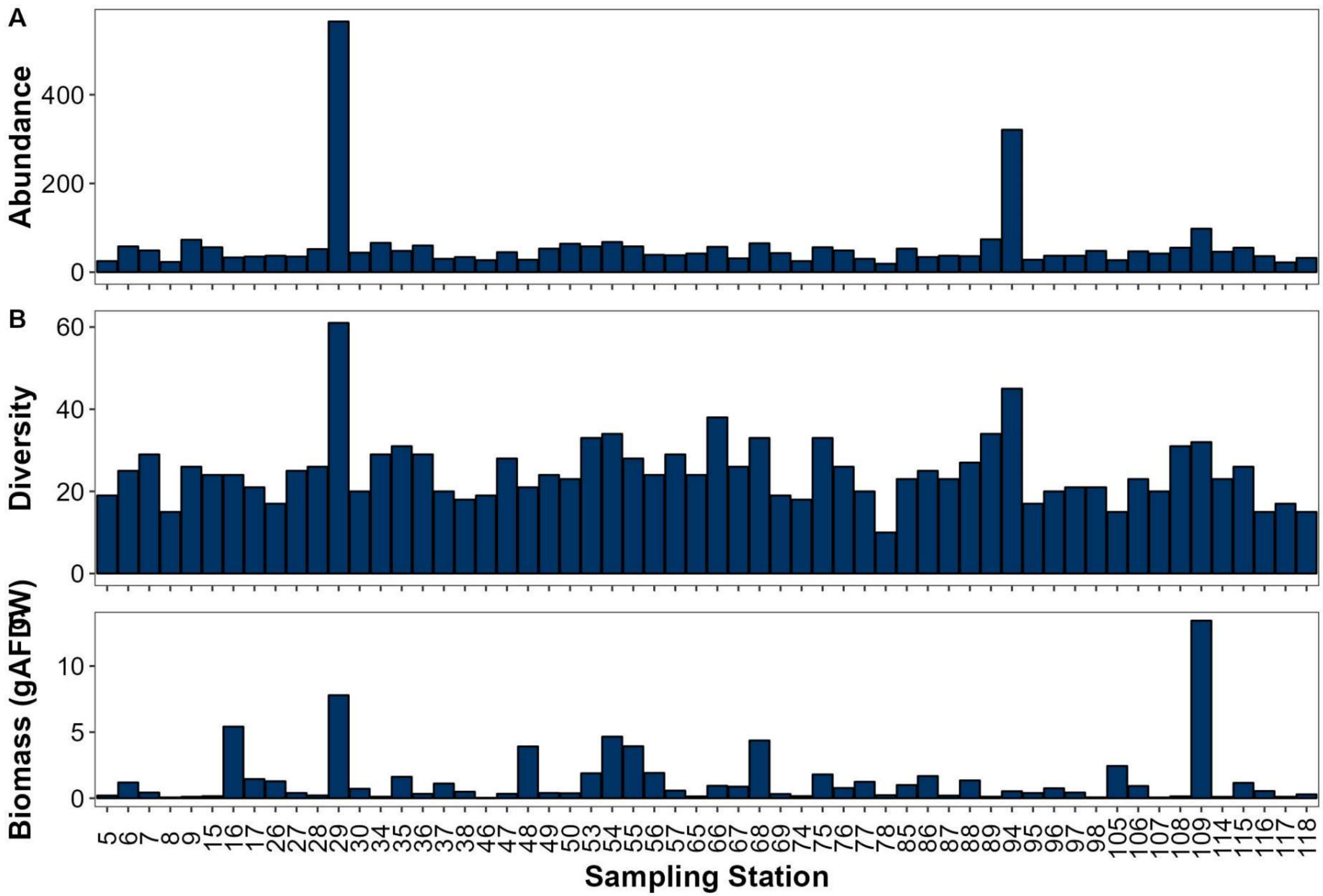

Figure 12 Abundance, diversity, and biomass (gAFDW) per station across the survey area.

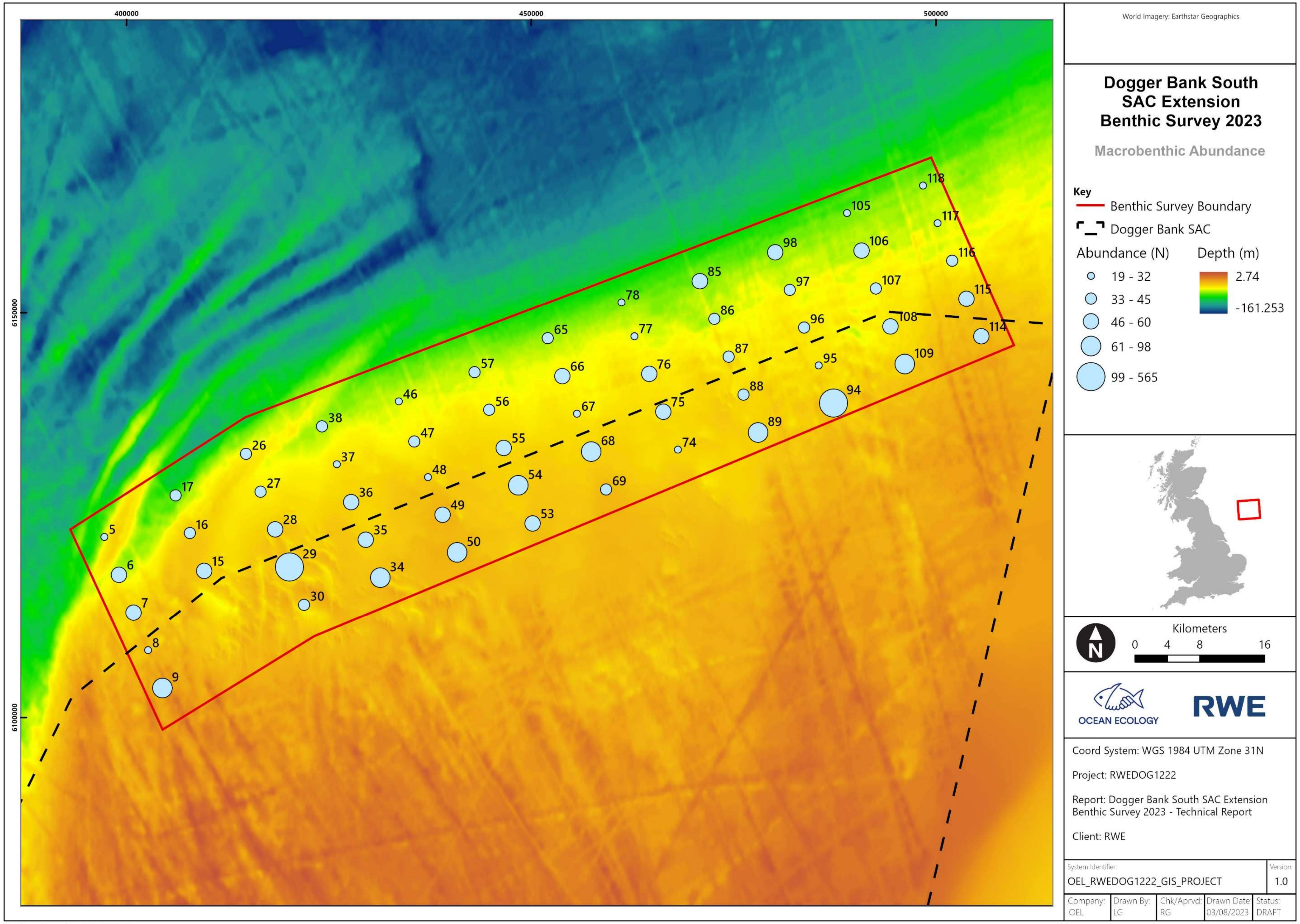

Figure 13 Macrobenthic abundance (N) per grab sampled during the survey.

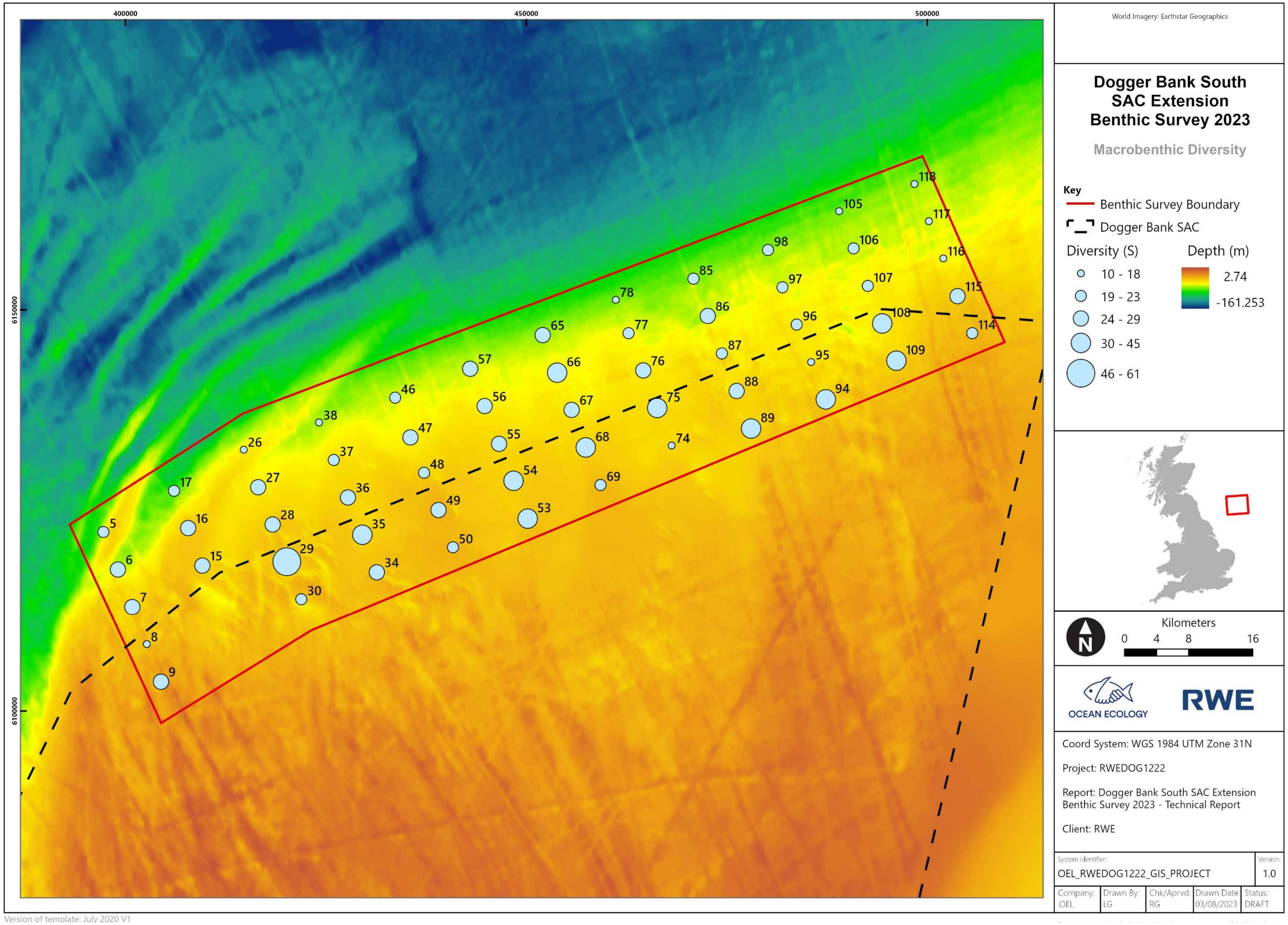

Figure 14 Macrobenthic diversity (S) per grab sampled during the survey.

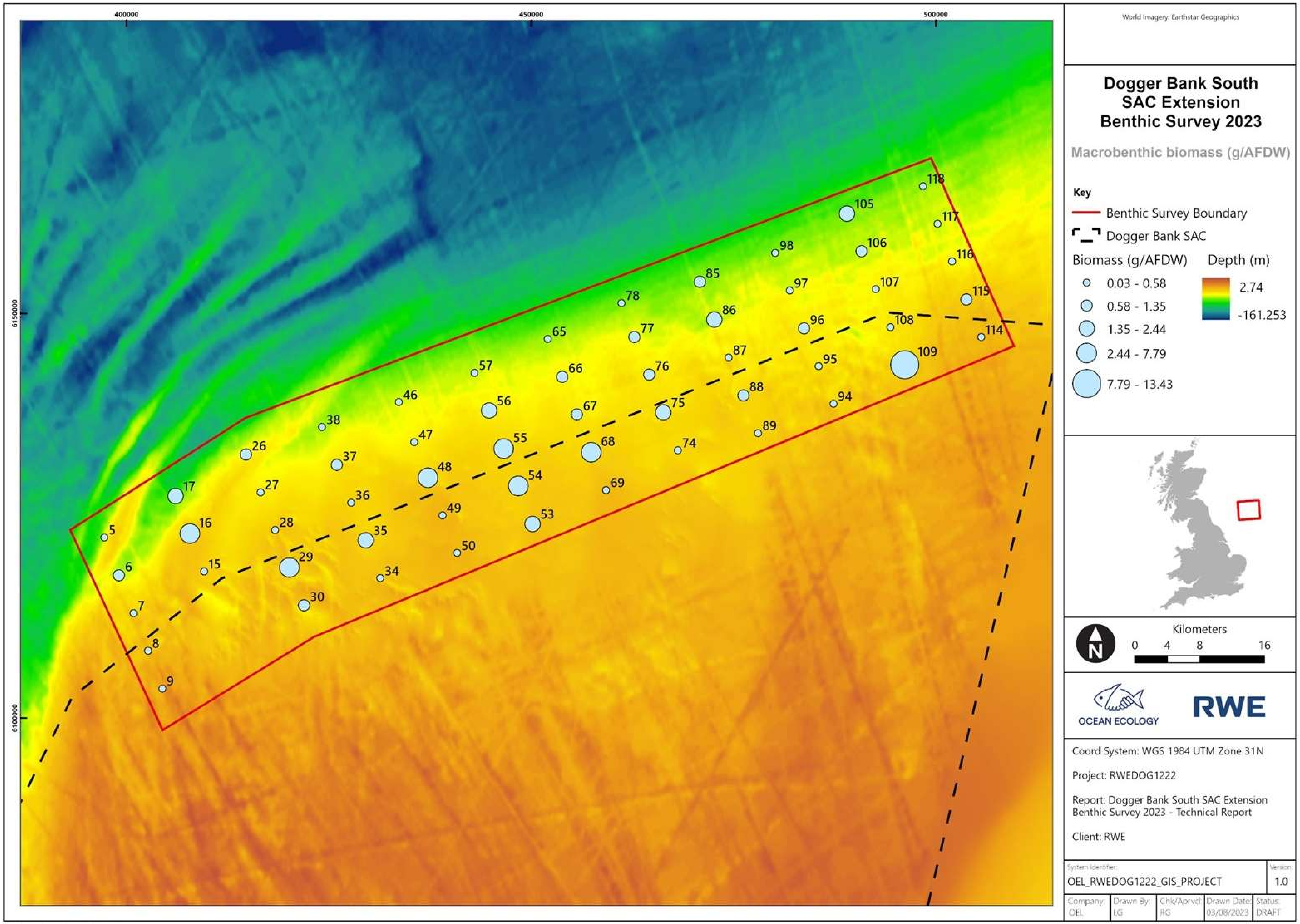

Figure 15 Macrobenthic biomass per grab sampled during the survey.

6.2.1. Macrobenthic Groupings.

Multivariate analysis was undertaken on the square-root transformed macrobenthic grab abundance data, to identify spatial distribution patterns in the macrobenthic assemblages across the survey area and identify 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 7 statistically significantly similar groups ($p > 0.05$) and two outlier stations that did not belong to any group (Figure 16). The majority of samples fell within Groups F (n = 27) and G (n = 14). Groups C and B were made up of 6 and three stations respectively whilst Groups A, D and E consisted of two stations each.

To visualise the relationships between the sampled macrobenthic assemblages, an nMDS plot was generated on the community abundance data (Figure 17). 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 (0.23) indicates that the two-dimensional plot provides a reasonable representation of the similarity between stations, however caution needs to be used when interpreting patterns between and within groups. This relatively high stress value is most likely due to the presence of several groups (clusters) made only of a few stations owing to the high diversity in the macrobenthic community observed across the survey area. In general, the degree of clustering of intra-group sample points demonstrates the level of within group similarity (e.g., points within Macrobenthic Group F show distinct clustering), whilst the degree of overlap of inter-group sample points is indicative of the level of similarity between different Macrobenthic Groups (e.g., Macrobenthic Groups F and G).

Macrobenthic groups are mapped in Figure 18 to further visualise spatial trends.

SIMPER (similarity percentage analysis) was used to identify the key taxa contributing to the within group similarity of each of the 7 macrobenthic groups; the full SIMPER results are provided in Appendix X.

Macrobenthic Group A (2 stations) - Characterising taxa present at the two stations (Stations 29 and 94) in this group were species belonging to the phyla Nematoda, Annelids of the genus G*rania,* as well as the Polychaete *Glycera lapidum* (aggregate). Average similarity of samples within this group was 51.58 %.

Macrobenthic Group B (3 stations) – The taxa contributing most to similarities between the three sampling stations (Stations 8, 15 and 26) within this group (average similarity: 45.49 %) were the bivalve *Cochlodesma praetenue*, the genus of catworm *Nephtys* (juveniles) and the sand-hopper *B. elegans*.

Macrobenthic Group C (6 stations) – Dominant taxa contributing within this group were the armoured bristleworm, *S. armiger,* and the family of sea anemone, Edwardsiidae. The within group average similarity was 37.07%.

Macrobenthic Group D (2 stations) – Characterising taxa present at the two stations (Stations 5 and 46) belonging to this group (average similarity 46.95 %) were the amphipod *Harpinia antennaria* and *S. armiger*.

Macrobenthic Group E (2 stations) – Key taxa contributing to the within group average similarity of 43.78 % were juvenile clams of the genus *Dosinia*, and juveniles belong to the superfamily of bivalves, Thracioidea. Stations 74 and 95 belonged to this group.

Macrobenthic Group F (27 stations) – Characterising taxa present at the stations belonging to this group were *S. armiger*, juvenile bivalves of the genus *Dosinia* and superfamily Thracioidea and *B. elegans*. Average similarity of this group was 40.56 %.

Macrobenthic Group G (14 stations) – The taxa contributing most to similarities between the sampling stations within this group (average similarity: 40.12 %) were *B. elegans*, juvenile clams of the genus *Dosinia*, the amphipod, *B. guilliamsoniana,* and juvenile brittlestars belonging to the family Amphiuridae.

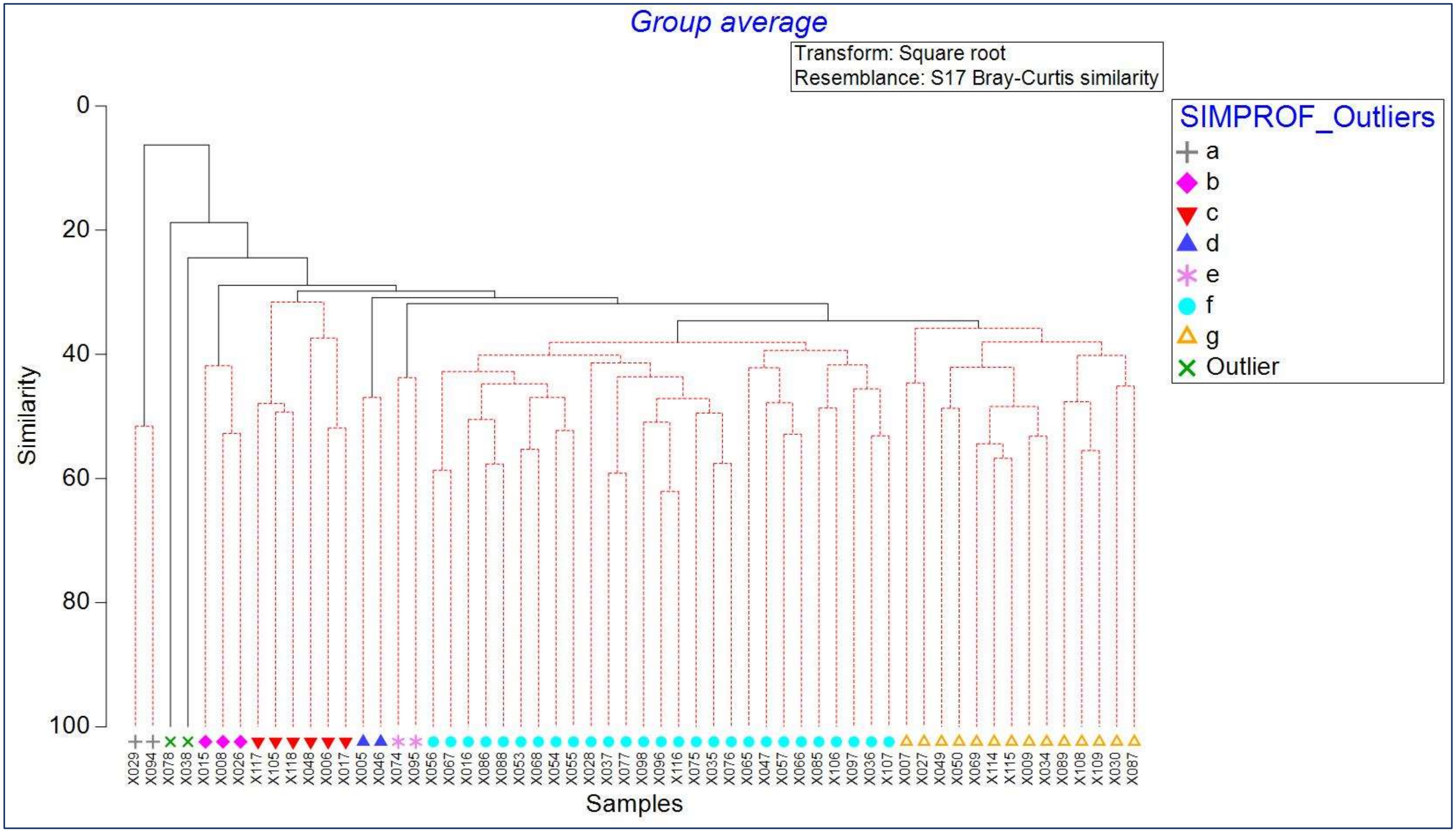

Figure 16 Dendrogram resulting from cluster analysis and associated Type 1 SIMPROF permutation analysis of macrobenthic abundance data.

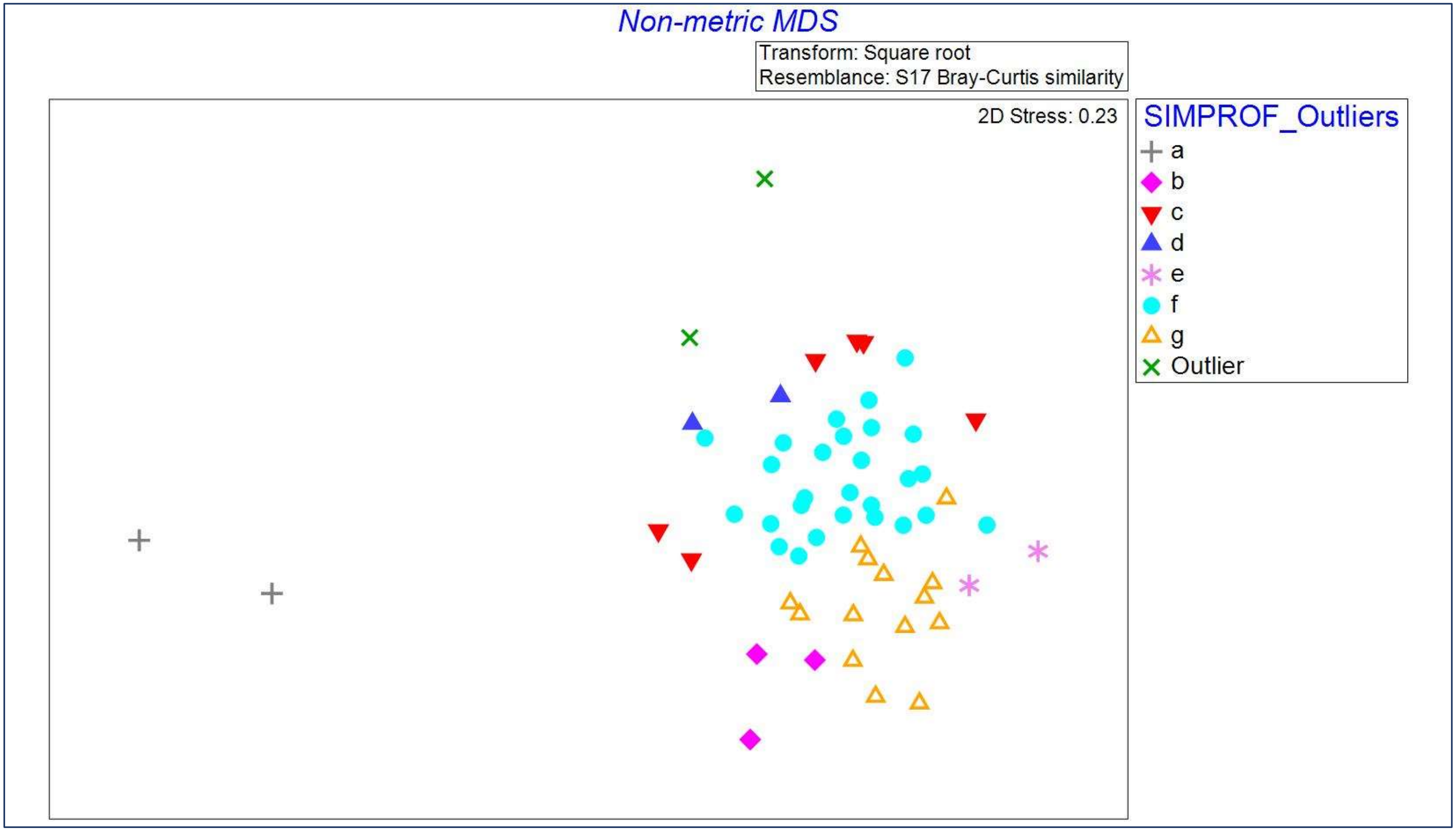

Figure 17 Non-metric MDS ordination plot of square root transformed macrobenthic data based on Bray Curtis similarity of grab samples collected during the survey.

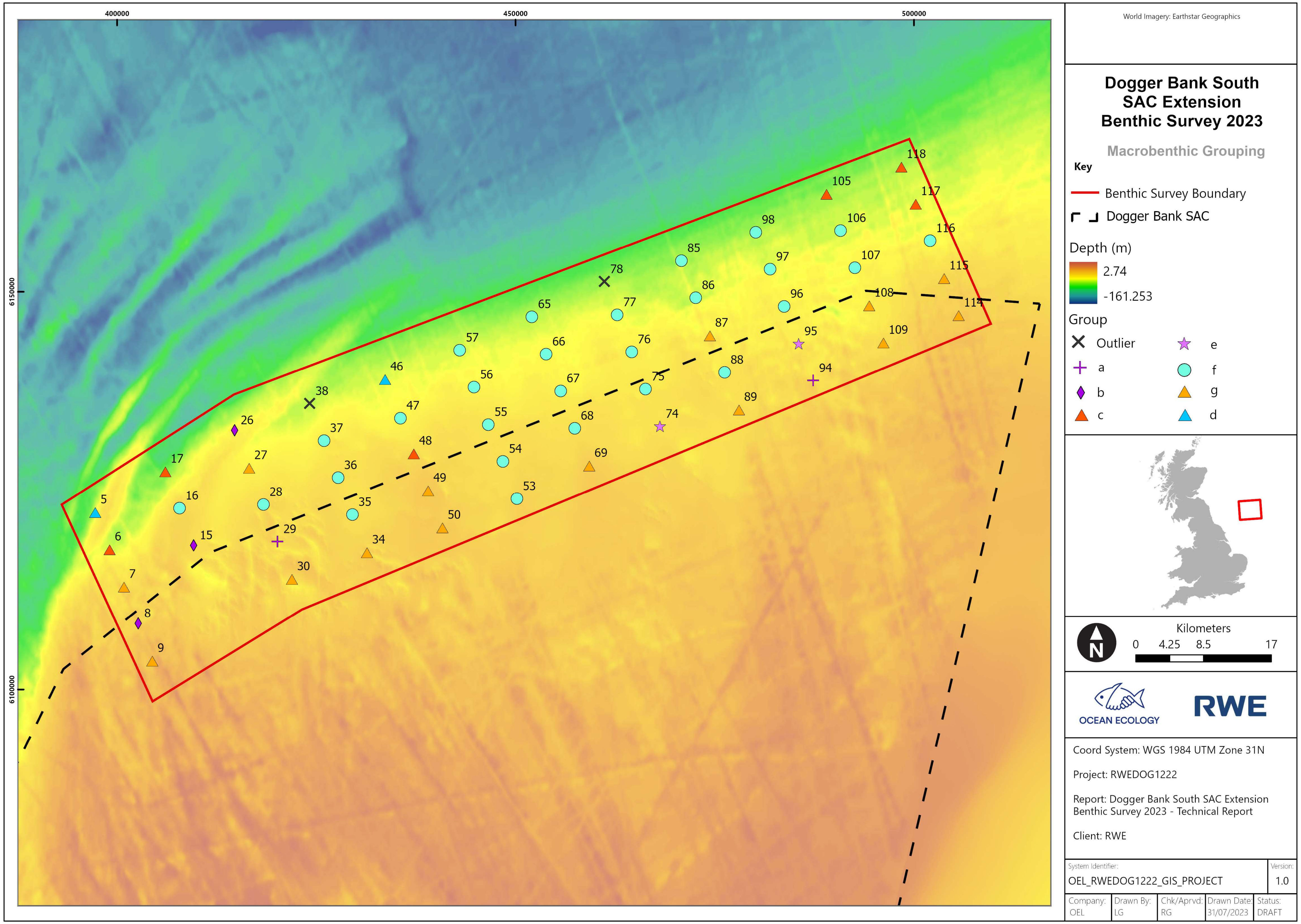

Figure 18 Macrobenthic groupings derived from cluster analysis and associated Type 1 SIMPROF permutation analysis of macrobenthic abundance data.

6.3. Biotope Assignment

For each of the Macrobenthic groups determined using cluster analysis, habitats and biotopes were assigned in considerations with JNCC guidance based upon their faunal and physical characteristics (Parry 2019). The spatial distribution of the habitat and biotopes encountered across the survey area is mapped in Figure 19.

All outlier stations were assigned to their corresponding BSH based on sediment analysis as the macrobenthic multivariate analysis did not show any pattern in the community composition that could be used to assign a biotope. Similarly, macrobenthic Groups C and E were assigned to level 4 EUNIS classifications as their macrobenthic assemblages were not dominated by any key taxa typically associated to any higher resolution biotopes. Therefore, macrobenthic Group C most closely aligned with either EUNIS level 4 habitat "A5.25 Circalittoral fine sand" or "A5.27 Deep circalittoral sand", whilst macrobenthic Group E also best aligned with EUNIS level 4 habitat "A5.27 Deep circalittoral sand".

The biotope "A5.145 *Branchiostoma lanceolatum* in circalittoral coarse sand with shell gravel" most closely aligned with the community observed in Group A. This biotope is described as typical of circalittoral coarse sand with shell gravel, aligning with EUSeaMap predicted habitats, sediment PSD data analysis and seabed imagery which clearly show coarse sand/gravel and shell fragments. Additionally, key characterising taxa of this biotope are a significant population of *B. lanceolatum* as well *as G. lapidum, Polygordius* and *Pisione remota*, all of which were present in samples within macrobenthic Group A.

Macrobenthic Group B most closely aligned with the biotope "A5.252 *Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand". This biotope is described as circalittoral and offshore medium to fine sands between 25 m and 100 m which is consistent with sediment PSD data for this site which describes all stations within this group as "A5.2 Sand and Muddy Sand". The macrobenthic community of this biotope is characterised by the bivalve *A. prismatica* (which was present in this group although not dominant), the amphipod *B. elegans* and polychaetes such as *S. bombyx* and *Nephtys* sp. which were all driving community average similarity within this group.

The biotope most closely aligning with macrobenthic Group D was "A5.252 *Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand" which is typically found in circalittoral and offshore medium to fine sands between 25 m and 100 m. This aligns with sediment PSD data but differs slightly from the predicted habitats derived from EUSea mapping which suggests these stations fall within the level 4 EUNIS classification "A5.27 Deep circalittoral sand". Whilst one of the key defining species of this biotope, *A. prismatica,* was not present in samples, *B. elegans* and *S. armiger* were among the main species driving similarity in this group and are named as key taxa in this biotope.

Macrobenthic Group F is the largest of the 7, consisting of 27 stations. PSA data suggests that the majority of the stations within this group belong to the BSH "A5.2 Sand and Muddy Sand" with 5 stations belong to the BSH "A5.1 Coarse Sediment". The biotope most closely matching this group is "A5.252 *Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand". It is found in circalittoral medium to fine sands between 25 m and 100 m, and whist one of the key characterising taxa, *A. prismatica* was not found in samples, *B. elegans* was one of the main species accounting for similarity within this group. Other taxa characteristic of this biotope were also found in samples collected from this group of stations including *S. bombyx*, *Echinocyamus pusillus, Chaetozone christiei, F. fabula* and *S. armiger*.

Macrobenthic Group G most closely aligns with the infralittoral sand biotope "A5.233 *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand". Whilst EUSea mapping suggests that stations within this group are circalittoral sands, this biotope has been recorded to at least 30 m. All stations in this group were at depths < 40 m. The key characterising taxa of this biotope are *N. cirrosa* and *Bathyporeia* spp of which two species within this genus were recorded (*B. elegans* and *B. guilliamsoniana*). *Magelona johnstoni* and *Magelona filiformis* are also characterising taxa of this biotope, both of which were found to drive similarity within this group.

6.4. Notable Taxa

Three taxa of interest were identified from the 58 grab samples collected across the survey area.

The Ross worm *S. spinulosa* is a protected species when occurring in reef form under the OSPAR list of threatened and/or declining species and habitats (2008) and as an Annex I species under the EU Habitat Directive. The latter directive has been transposed into UK law under the Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended)[1]. Just two individuals were recorded at the two gravel dominated stations (Stations 29 and 94). Seabed imagery analysis showed no sign of reef forming structures at these locations (Section 6.5).

The Ocean quahog, *A. islandica*, is listed as a Species of Principal Importance in England (section 41) and Wales (section 42) under the Natural Environment and Rural Communities Act (2006) and is also protected under the OSPAR List of Threatened and/or Declining Species and Habitats (2008). One individual and 16 juveniles were recorded across the survey area.

One Mollusca taxa belonging to the family of clams Veneridae was identified and is designated as an economically important taxon. Two individuals were recorded.

No invasive or non-native species (INNS) were identified in samples collected from the survey area.

[1] The Conservation of Offshore Marine Habitats and Species Regulations 2017 have been amended by The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 to implement the necessary changes following the UK leaving the EU.

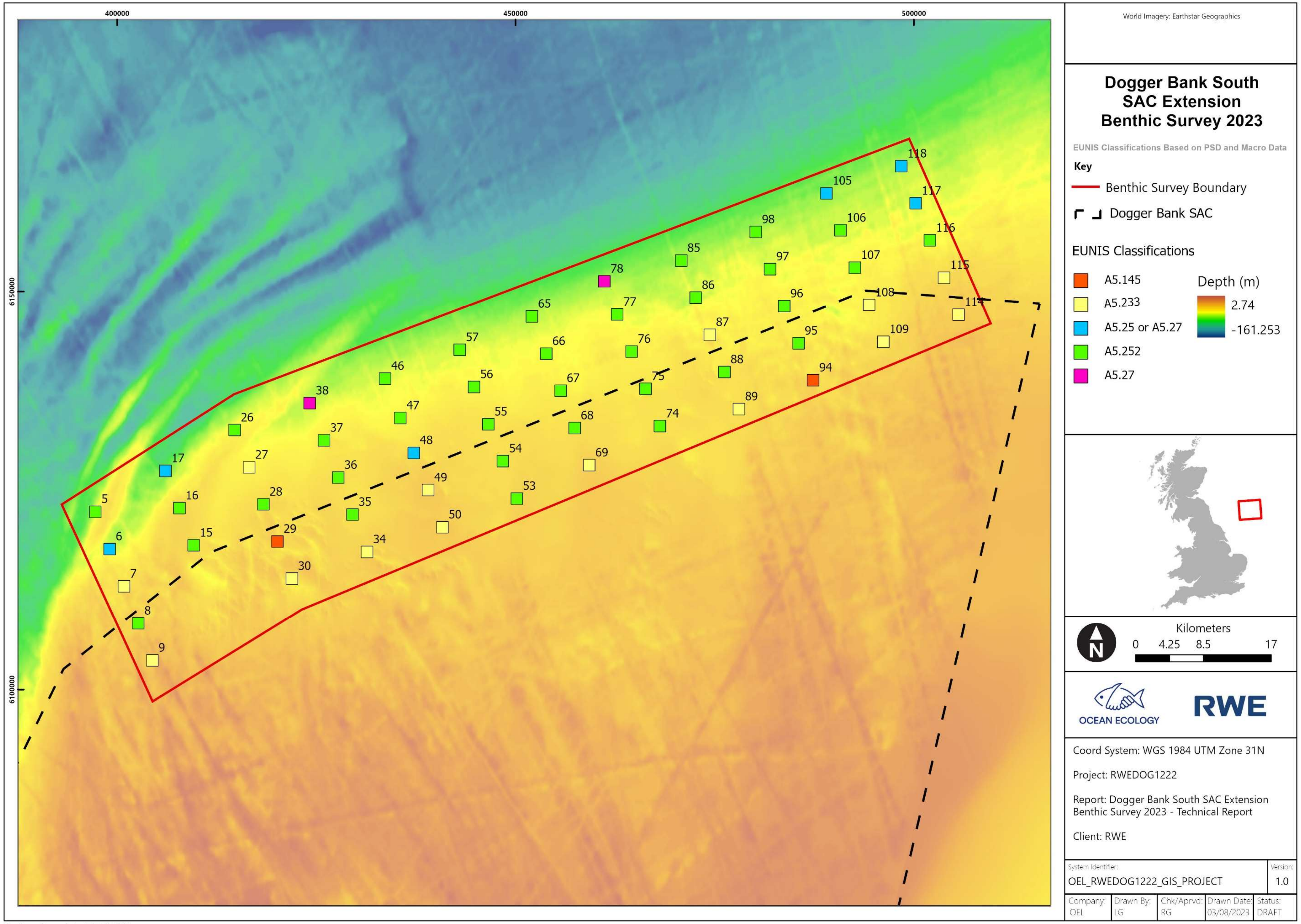

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Figure 19 Spatial distribution of habitat and biotopes identified across the survey area based on macrobenthic and sediment analysis

6.5. Imagery Analysis

Seabed imagery was obtained for the purpose of *in situ* screening of stations by completing a visual inspection for protected or sensitive habitats (e.g., potential Annex I Reef) and other ecological, heritage, or safety hazards. Analysis of the digital stills and video footage was therefore not required. DDC field logs can be found in Appendix II.

7. Discussion

This report presents the interpretation of the macrobenthic and sediment data with the aim of providing information on the character of the benthos across the DBS survey area and assisting with the consenting processes for the project. The results of this study are further interrogated below to assess whether the infaunal communities identified are similar to those described by Wieking & Kröncke (2003) and Diesing et al. (2009).

7.1. Sediments

Despite some subtle variation in sediment types between stations, all but two stations (Stations 29 and 94) were dominated by sand. Mud content was very low across the survey area with no stations exceeding 5 % of the overall sediment composition. Aside from station 94 which was dominated by gravel (64.51 %) and Station 29 which also had high gravel content (41.57 %), gravel content was generally low, with no other stations exceeding 12 %. Both stations with higher gravel content were within the boundary of the Dogger Bank SAC and known area of Annex I Sandbank.

The majority of samples were comprised of sand (S) and slightly gravelly sand ((g)S) representing EUNIS BSH A5.2 Sand and Muddy Sand. Some stations were classified as Sandy Gravel (sG) or Gravelly Sand (gS) representing EUNIS BSH A5.1 (coarse sediment). Stations representative of EUNIS BSH A5.1 were distributed throughout the survey area both within and outside of the Dogger Bank SAC boundary. These sublittoral sediment types may represent 'subtidal sands and gravels' which is listed as a habitat of principal importance under Section 41 of the Natural Environment and Rural Communities Act 2006. To note that this habitat is among the most common habitats found below mean low water springs (MLWS) around the coast of the UK.

All sediments recorded as sand or slightly gravelly sand were classified as well sorted or moderately well sorted, whilst sediments classified as sandy gravel and gravelly sand were mostly all classed as poorly sorted. This is due to large variations in sediment sizes within the mixed sediments, with larger gravels mixed with finer sands (as seen in Plate 4 and Appendix IV).

7.2. Macrobenthos

A diverse macrobenthic assemblage was identified across the survey area from 58 macrobenthic samples collected, with a total of 3,383 individuals and 200 taxa recorded. The most abundant and frequent taxon sampled with the greatest average density per sample was the Bristle worm *S. armiger*. Other key taxa included the amphipod *B. elegans* which contributed to 5.9 % of the total abundance, and the polychaete *P. kefersteini* which was recorded the maximum number of times in one sample. Annelida taxa contributed the most to abundance and overall diversity of the macrobenthic assemblages, whilst Echinodermata and Mollusca taxa dominated the biomass, accounting for approximately 87 % of the total biomass.

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). Multivariate analysis on macrobenthic data identified 7 macrobenthic groups and two outlier stations across the Dogger Bank SAC Extension survey area. The majority of stations fell within macrobenthic Groups F and G accounting for 41 of the 58 macrobenthic sampling stations. This suggests that macrobenthic diversity was evenly distributed across the survey area. Macrobenthic groups G, A and E showed some distinction from other macrobenthic groups, with the majority of stations falling within the boundary of the Dogger Bank SAC and area of known Annex I Sand Bank in the shallower region of the survey area. Grouping of Stations 29 and 94 (macrobenthic Group A) was clearly reflected by the sediment composition of these two stations which both showed significantly higher gravel content than other stations. This difference in sediment type to other stations was also reflected in the macrobenthic community which was characterised by the presence of fauna such as *G. lapidum* which has previously been described as characteristic of gravelly regions of the Dogger Bank (Degraer et al. 2006, Diesing et al. 2009).

Three notable taxa were identified across the survey area. These included the OSPAR threatened and/or declining species Ross worm (*S. spinulosa*) (however there were no sign of reef forming structures observed) as well as the Ocean quahog *A. islandica,* particularly as juveniles. One Economically Important Species was also recorded: clams of Veneridae family.

7.3. EUNIS Habitats/Biotopes

PSD data clearly indicated the dominance of sandy sediments across the survey area with some areas of coarse (A5.1) sediments throughout. This was corroborated by macrobenthic data which suggested that whilst there were significant differences between macrobenthic groupings, the majority of stations closely aligned with the biotope "A5.252 *Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand". The assignment of this biotope to macrobenthic Groups B, D and F further highlights the even distribution of macrobenthic diversity across the survey area. Macrobenthic Group G most closely aligned with the infralittoral sand biotope "A5.233 *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand".

Whilst EUSea mapping suggests that stations within this group belonged to the level 4 EUNIS code circalittoral fine sands, the macrobenthic community was more typical of this infralittoral biotope. This group of stations were mostly located in the shallower region of the survey area, within the boundary of the Dogger Bank SAC and areas of known Annex I Sandbank.

7.4. Comparisons to Weiking and Kroncke (2003) and Diesing et al (2009)

It is thought that macrobenthic communities within the survey area may be similar to those described as the North-Eastern community (Wieking & Kröncke 2003) and/or communities K and J (Diesing et al. 2009) within previous studies of the Dogger Bank SAC.

The North-Eastern community as described by (Wieking & Kröncke 2003) was dominated by *S. bombyx, B. elegans* and *S. armiger*. Both *B. elegans* and *S. armiger* were amongst the most abundant taxa recorded during the Dogger Bank SAC extension survey, accounting for 12.1 % of total abundance and occurring in the highest densities across all samples. Whilst *S. bombyx* was not amongst the most abundant taxa, 40 individuals were recorded within samples.

Similarities can be drawn between macrobenthic Group G, the Bank community as described in Wieking & Kröncke (2003) and Group K observed in Diesing et al. (2009). The two amphipod species *B. elegans* and *B. guilliamsoniana* as well as the burrowing bivalve *F. fabula* were present in all groups as well as taxa belonging to the genus *Magelona*. A key difference between these groups however was that *S. bombyx* dominated the Bank community but was not found to drive similarity within Group G of the present study.

Some similarities were also observed between macrobenthic Group F and the North-Eastern community described in Wieking & Kröncke (2003). *S. bombyx, B. elegans* and *S. armiger* were present in abundance in both groups along with taxa belonging to the genus of clam *Dosinia* and family of sea anemones Edwardsiidae.

No similarities were found between macrobenthic group J described in Diesing et al. (2009) and the present study. Macrobenthic group J is described as being characterised by species more commonly associated with siltier sediments such as *S. armiger, Galathowenia oculate*, *Goniada maculata* and the burrowing bivalves *Thyasira flexuosa* and *Lucinoma borealis*. With the exception of *S. armiger*, none of these taxa were key species in any of the present macrobenthic groups.

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