# APPENDIX 9-1

***BENTHIC CHARACTERISATION SURVEY 2023: TECHNICAL REPORT***

OCEAN ECOLOGY

FUINNEAMH SCEIRDE TEO

# Sceirde Rocks Windfarm Project

## Benthic Characterisation Survey 2023: Technical Report

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Marine Surveys, Analysis & Consultancy

# Sceirde Rocks Offshore Wind Farm Benthic Characterisation Survey 2023: Technical Report

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| Section | Description | Page |
|---|---|---|
| | | |
| | | |
| | | |

# Contents

## List of Tables

## List of Figures

## List of Plates

## Abbreviations

| | |
|---|---|
| **AFDW** | Ash Free Dry Weight |
| **AHRS** | Altitude and Heading Reference System |
| **BAC** | Background Assessment Concentration |
| **BIIGLE** | Bio-Image Indexing and Graphical Labelling Environment |
| **BSH** | Broadscale Habitat |
| **CLOC** | Clear Liquid Optical Chamber |
| **CPSPI** | Carrowmore Point to Spanish Point and Islands |
| **CSQG** | Canadian Sediment Quality Guideline |
| **DBT** | Dibutyltin |
| **DDC** | Drop-Down Camera |
| **DVV** | Dual Van Veen |
| **EC** | European Commission |
| **ECR** | Export Cable Route |
| **eDNA** | Environmental DNA |
| **EPA** | Environmental Protection Agency |
| **ERL** | Effect Range Low |
| **EUNIS** | European Nature Information System |
| **FST** | Fuinneamh Sceirde Teoranta |
| **GPS** | Global Positioning System |
| **HA** | Habitat Assessment |
| **HD** | High Definition |
| **HDD** | High-Definition Drives |
| **INS** | Inertial Navigation System |
| **JNCC** | Joint Nature Conservation Committee |
| **KBI** | Kilkieran Bay and Islands |
| **LAT** | Lowest Astronomical Tide |
| **LED** | Light-Emitting Diode |
| **LoD** | Limit of Detection |
| **LOI** | Loss Of Ignition |

| | |
|---|---|
| **MBES** | Multibeam Echosounder |
| **MP** | Megapixel |
| **MW** | Megawatt |
| **NE** | Natural England |
| **NMBAQC** | Marine Biological Analytical Quality Control |
| **nMDS** | Non-Metric Multidimensional Scaling |
| **IDA** | Industry Denatured Alcohol |
| **INS** | Inertial Navigation System |
| **ISQG** | International Sediment Quality Guideline |
| **OCP** | Organochlorine Pesticides |
| **OEL** | Ocean Ecology Ltd |
| **OWF** | Offshore Wind farm |
| **PAH** | Polycyclic Aromatic Hydrocarbons |
| **PCB** | Polychlorinated biphenyls |
| **PEL** | Probable Effect Level |
| **PSD** | Particle Size Distribution |
| **QAF** | Quality Assurance Framework |
| **SAC** | Special Area of Conservation |
| **SBAS** | Satellite-Based Augmentation System |
| **SE** | Standard Error |
| **SIMPER** | Similarity Percentages |
| **SIMPROF** | Similarity Profile Routine |
| **SoW** | Scope of Work |
| **SPA** | Special Protection Area |
| **SROWF** | Sceirde Rocks Offshore Windfarm |
| **SSS** | Side-Scan Sonar |
| **SVP** | Sound Velocity Profiler |
| **TBT** | Tributylitin |
| **TEL** | Threshold Effect Level |
| **THC** | Total Hydrocarbons |
| **TOC** | Total Organic Carbon |

| | |
|---|---|
| **UPS** | Uninterruptable Power Supply |
| **USBL** | Ultra-Short Baseline |
| **UTC** | Universal Time Coordinated |
| **UTM** | Universal Transverse Mercator |
| **UXO** | Unexploded Ordinance |
| **WoRMS** | World Register of Marine Species |

# 1. Non-Technical Summary

**Introduction**

Ocean Ecology Limited (OEL) were commissioned by Fuinneamh Sceirde Teoranta (FST) to undertake a baseline benthic characterisation survey of the proposed Sceirde Rocks Offshore Windfarm (SROWF). The SROWF site is located off the West coast of Co. Galway, Ireland to the northwest of the Aran Islands, approximately 5 to 11.5 km from the Irish mainland coastline. The array area is approximately 90 km$^2$ and measures approximately 15.7 km in the NW-SE direction and 7.8 km wide in the SW-NE direction. The preferred Export Cable Route (ECR) is approximately 60 km in length. It will be the first commercial-scale offshore windfarm on Ireland's west coast, with an expected nominal capacity of 450 megawatts (MW). Seven marine protected areas surround but do not overlap the site. The nearest of these is Kilkieran Bay and Islands Special Area of Conservation (SAC) which lies 40 m to the east of the site.

**Survey Strategy**

A total of 65 combined Drop-Down Camera (DDC) and grab sampling stations were targeted across the SROWF site: 35 stations within the array area and 30 along the ECR. An additional 36 DDC transects were sampled throughout the SROWF survey area to ground-truth the presence of potential biogenic/ geogenic reef identified in the geophysical data. Of these, 21 transects were positioned in the array and 15 in the ECR. The survey was undertaken aboard the vessels *MV Situla,* and *MV Roman Rebel* during October 2023.

**Sediment**

Of the 35 targeted stations within the array area, 30 were successfully sampled. Most of the sampling stations located within the array area (21 out of 30) were classified as Broad Scale Habitat (BSH) A5.1 'Coarse sediment' with the remaining stations located to the south of the array area where it intersects the ECR mostly corresponding to BSH A5.2 'Sand and muddy sand'. Sediments along the ECR were mostly made up of sand representative of BSH A5.2 interspersed with coarse sediments to the north of the ECR and mud to the middle and south of the ECR.

Total Organic Carbon (TOC) content did exhibit minimal variability across the survey area, with similar TOC content observed in the sediments sampled across both the array area and along the ECR. Trace and heavy metal concentrations were generally low across the proposed SROWF site with none of the measured metals exceeding any of the reference levels except for Arsenic (As) at stations ST001, ST004 and ST041 and Chromium at station ST060. However, despite these elevated values, no anomalies were observed in the macrobenthic community recorded at these stations and no pattern was observed between the concentrations of these metals and that of mud, or any of the other contaminants measured. None of the measured Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), organotins and Organochlorine Pesticides (OCPs) were reported in concentrations above any of the reference levels and in most

cases they were below the limit of detection. Average Total Hydrocarbon Content (THC) in sediments was lower across the array area than along the ECR with values as low as 221 µg $kg^{-1}$ in the array compared to the lowest value of 1,070 µg $kg^{-1}$ along the ECR.

**Water Sampling**

Water samples were collected at 17 stations within the array area and 16 stations along the ECR. TOC levels were generally overall low across the SROWF site with most samples having TOC content below detection limit. Similarly, most of the nutrients measured in the water samples (e.g., Nitrite, Nitrate and Orthophosphate) had concentrations below the limit of detection while Chloride concentration ranged between 8,630 $mgl^{-1}$ and 18,200 $mgl^{-1}$ across the proposed SROWF site with comparable values between the array and the ECR.

**Macrobenthos**

A more diverse macrobenthic community was observed across the array area compared to the ECR with a total of 19,700 individuals and 444 taxa recorded in the array area compared to 6,967 individuals and 313 taxa recorded along the ECR. Dominant taxa across the array area included Nematoda and *Polygordius* spp. while the ECR was dominated by juvenile brittle stars of the family Amphiuridae. To note that the highest diversity was recorded at station ST027 within the array area where a maerl bed was observed.

The composition of macrobenthic community across the proposed SROWF site was heavily influenced by sediment type and composition with coarse sediments typically supporting *Glycera lapidum* and *Protodorvillea kefersteini* while muddy sand and sandy mud supported *Timoclea ovata*, *Harpinia antennaria, Spiophanes bombyx* and *Amphictene auricoma*.

**EUNIS Habitats/Biotopes**

An integrated interpretation of particle size distribution (PSD) and macrobenthic data, seabed imagery, and acoustic data was used to map the habitats and biotopes present across the array area and along the ECR. More specifically, the interpretation of acoustic data (Side-Scan Sonar (SSS) and Multibeam Echosounder (MBES) bathymetry) was used to define habitat boundaries, which were overlapped with ground-truthing data from grab sampling and seabed imagery analyses.

The prevalent benthic habitats across the array area were the rocky biotopes representative of European Nature Information System (EUNIS) A4.121 '*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock', A4.212 '*Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock' and A4.214 'Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock' in deeper waters and A3.116 'Foliose red seaweeds on exposed lower infralittoral rock' in shallower waters flanked by soft substrate habitat complexes A5.15'Deep circalittoral coarse sediment' and A5.14 'Circalittoral coarse sediment'.

The prevalent habitats along the ECR included the rocky biotope A4.121 '*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock' interspersed with sand and mud dominated habitats classified as A5.27 'Deep circalittoral sand' and A5.37 'Deep circalittoral mud' in deep waters and as A5.26 'Circalittoral muddy sand' in shallower waters.

**Annex I Reef**

The rock habitats observed across the array and ECR met the qualifying criteria of Annex I reefs being a complex of bedrock reef and low and medium stony reefs. As neither area fall within the boundaries of a designated site, these features are not afforded protection as designated features under the EU Habitats Directive. Comparable features are known to occur within the SACs located within the vicinity of both areas and are qualifying reasons for their designation, with conservation objectives of maintaining their favourable condition.

**Other Features of Interest**

The pink sea fan *Eunicella verrucosa* is known to occur on the rocky reefs of the Inishmore Island SAC and of the Carrowmore Point to Spanish Point and Islands SAC and it is also a 'Vulnerable' species under the IUCN Red List. Therefore, a comprehensive sea fan assessment was made across the survey area based on seabed imagery analysis. While rocky reefs were present across large sections of the survey area, *E. verrucosa* was only observed in relatively high numbers (two-three individuals per still images) along transects T06 and T01 both located along the ECR with T06 being the closest to the Inishmore Island SAC and T01 to Carrowmore Point to Spanish Point and Islands SAC. This may indicate that this species occurs beyond the boundaries of these two SACs, however more evidence would be required to better understand whether the distribution of this species extends across all of the reefs observed along the ECR and adjacent to the Inishmore Island and Carrowmore Point to Spanish Point and Islands SACs.

Additionally, at station ST027 and along nearby transect T033, the habitat complexes A5.51 'Maerl beds' and A5.511 '*Phymatolithon calcareum* maerl beds in infralittoral clean gravel or coarse sand' were observed consisting of pink encrusting algae, hedgehog maerl, maerl nodules and maerl gravel. Maerl beds are listed as an OSPAR threatened and/or declining habitat. Additionally, Maerl is listed as an Annex V species under the EU Habitats Directive and in Ireland has been assessed to be in a bad status and declining due to deterioration of the environmental conditions supporting the recovery of maerl. The maerl bed observed in the array is located approximately 7 km from the closest known maerl bed occurring within the Kilkieran Bay and Islands SAC whose conservation objectives include maintaining the extent and to conserve the quality of this feature. Further evidence in required to better understand whether maerl is present in other areas of the SROWF site.

**Environmental DNA (eDNA)**

Sediment eDNA was extracted from a total of 30 grab samples collected across the array and 28 along the ECR. Invertebrate and Eukaryotes DNA was analysed from these samples and the main findings included the presence of maerl DNA at stations ST026 and ST027. This corroborated the seabed imagery analysis indicating the presence of a potential maerl bed in proximity of these two stations. In contrast, maerl DNA was also recorded at station ST004 where no other evidence of maerl was observed most likely because this station was located at a water depth of 79 m, too deep for maerl to live. This may point to advection of eDNA material from other locations. None of the notable taxa recorded from the grab samples were recorded in the eDNA samples, instead two invasive non-native species of Japanese seaweeds and one species of deep sea amoeba also originally from Japan were recorded in the eDNA extracted from sediment samples.

Water eDNA indicated the presence of a diverse fish community including Atlantic Salmon (*Salmo salar*) which is an Annexes II and V species under the EU Habitats Directive and listed in the IUCN Red List, and 20 species of commercial importance. Also included in the IUCN Red List and occurring across the survey area were Atlantic Horse Mackerel and Haddock. Marine mammals and birds were also identified as part of the water eDNA analysis. The analysis confirmed the presence of Minke Whale, the Common Dolphin, and seals from the genus *Phocidae*, consistent with observations made during the marine mammal monitoring of the Galway Bay in 2019. In terms of birds, the species identified were common to Ireland and included the Ruddy Turnstone and the Bar-Tailed Godwit and the Common Guillemot.

# 2. Introduction

## 2.1. Project Overview

Ocean Ecology Limited (OEL) was commissioned by Fuinneamh Sceirde Teoranta (FST), a joint venture between Corio Generation and Ontario Teachers' Pension Plan, to undertake a benthic characterisation survey of the seabed across the proposed site of the Sceirde Rocks Offshore Windfarm (SROWF), a proposed offshore windfarm (OWF) located in the Northeast Atlantic Ocean off the west coast of Ireland (Figure 1 and Figure 2). It will be the first commercial-scale offshore windfarm on Ireland's west coast, with an expected nominal capacity of 450 megawatts (MW).

## 2.2. Site Information

The SROWF site is located off the West coast of Co. Galway, Ireland to the northwest of the Aran Islands, approximately 5 to 11.5 km from the Irish mainland coastline. The array area is approximately 90 km$^2$ and measures approximately 15.7 km in the NW-SE direction and 7.80 km wide in the SW-NE direction. The preferred Export Cable Route (ECR) is approximately 60 km in length. The SROWF array and ECR boundaries (Figure 1 and Figure 2) are larger than the actual turbine area and cable corridor boundary in order to obtain a general characterisation of the area. Water depths across the array and ECR range from approximately 0 m with rock pinnacles rising above sea surface at the 'Skerd Rocks' to 86 m below Lowest Astronomical Tide (LAT) at the western extent of the site.

The Sceirde Rocks are an extensive group of rocks and shoals, some of which are always above water and others just awash. The outer rock, on the southwest side of the group, is called Skerdmore and it stands 18 metres high, Doonguddle to the southeast of Skerdmore stands 12 metres high.

## 2.3. Aims and Objectives

The key focus of the benthic characterisation survey was to conduct accurate ground-truthing of the geophysical data available for the array and ECR areas using Drop-Down Camera (DDC) and sediment grab sampling and to provide a comprehensive baseline dataset characterising the habitats and associated biological (infaunal/epifaunal) communities for future monitoring. The survey also aimed to identify and determine the extent and distribution of Annex I habitats as well as establishing a marine sediment and water quality baseline for the survey area.

The key outcomes of the benthic characterisation survey were to:

- Characterise habitats and biological communities and their variability, for instance with depth and lateral distribution, across the site.
- Gather quantitative and semi-quantitative benthic and epibenthic biological community data which can be used to monitor change in the communities over time.

- Identify and determine the extent and distribution of benthic habitats of conservation and ecological importance (e.g. including Annex I habitats) present across the site.
- Produce detailed habitat mapping for the survey area.
- Quantify water quality parameters and their variability, for instance with depth and lateral distribution across the site.

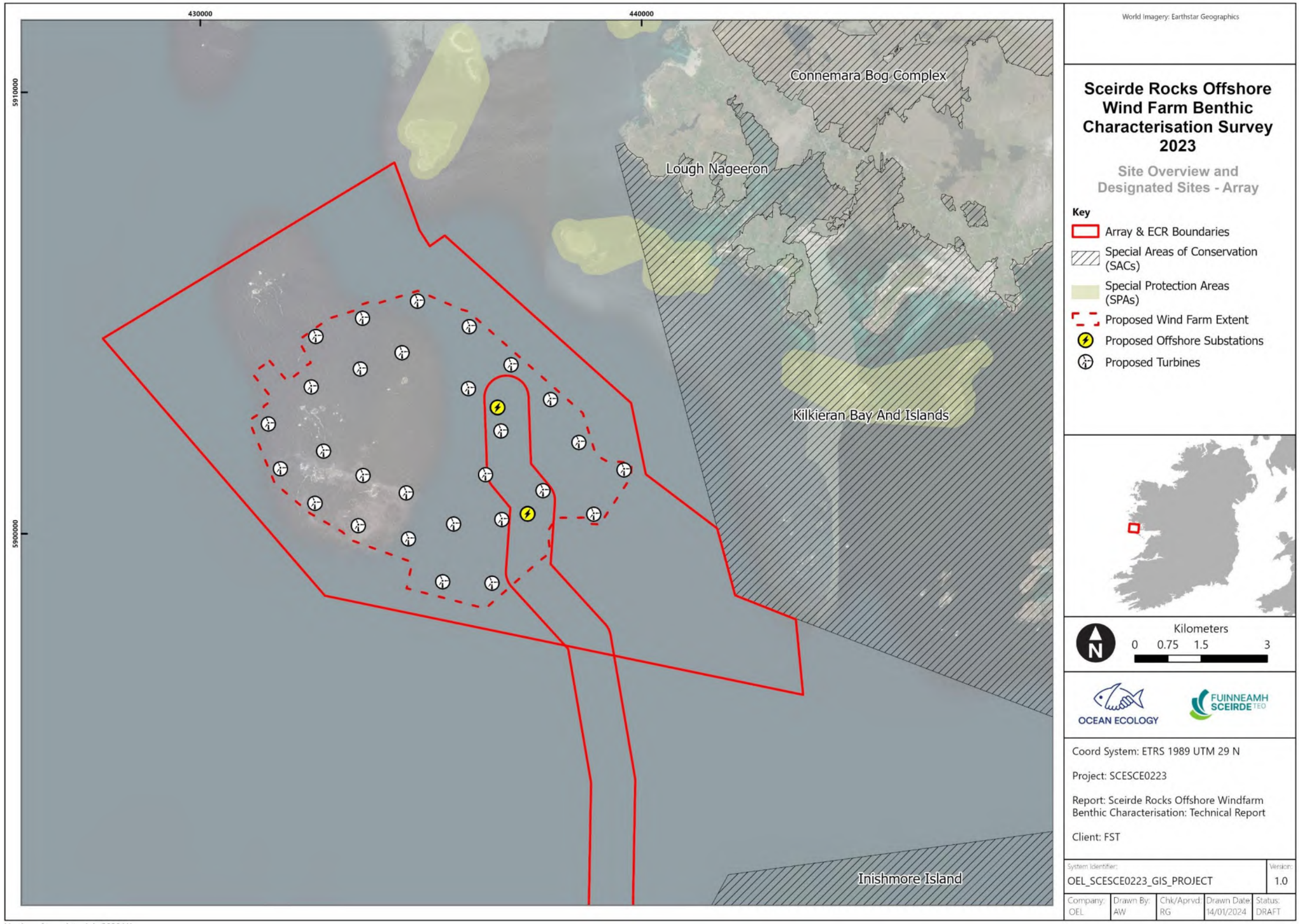


**Figure 1** Proposed turbine and offshore substation locations within the SROWF array in relation to designated sites.

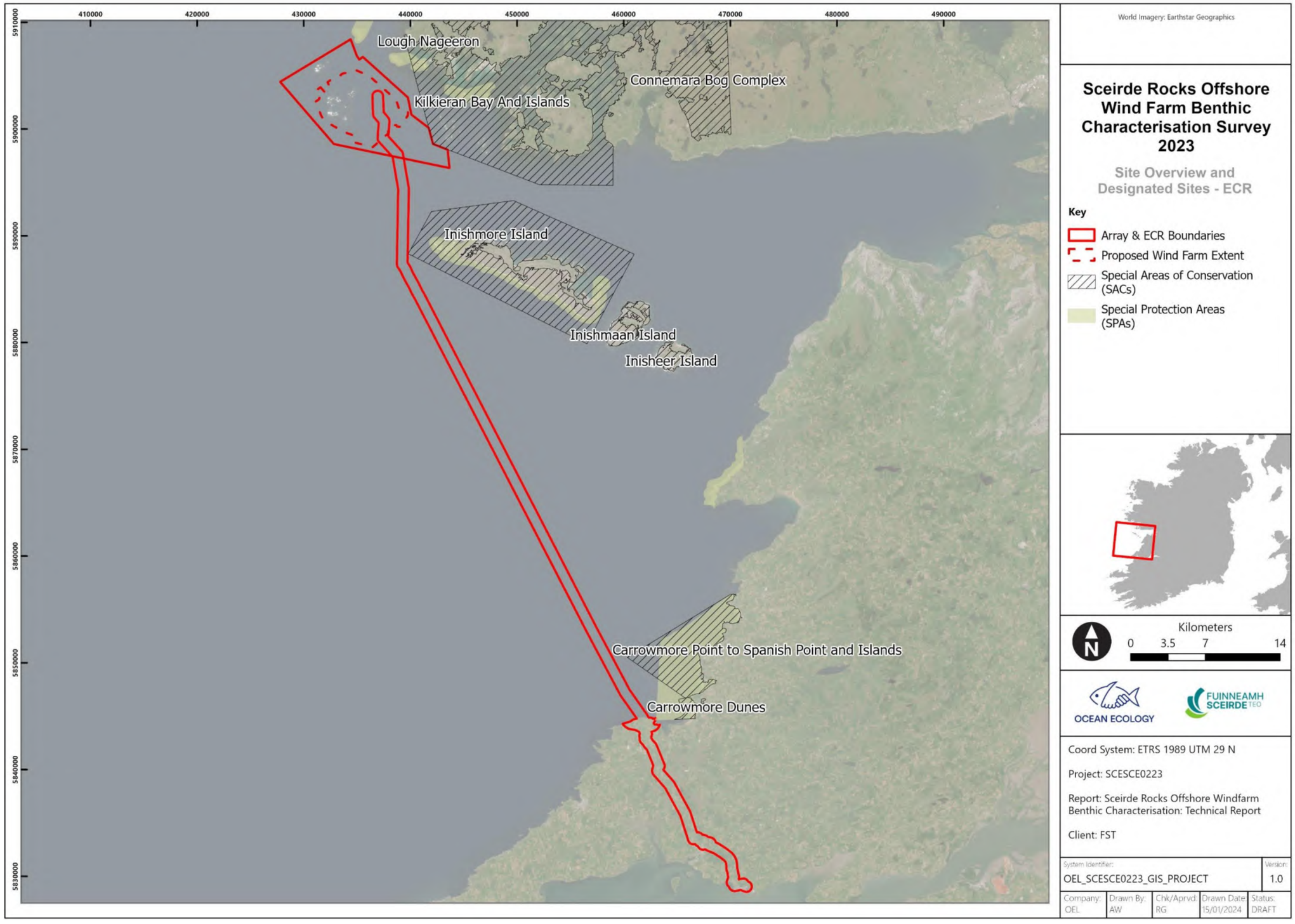


**Figure 2** Location of the proposed SROWF array and ECR survey areas and nearby designated sites.

# 3. Current Understanding

## 3.1. Seabed Features

The following seabed features have been identified across the survey area based on geophysical data provided by FST:

- One wreck within the array area.
- Seabed obstruction both buried and, on the surface, including cables and pipelines.
- Unexploded Ordinance (UXO) (surface or buried) deemed to be of low risk.
- Soft sediments.
- Boulders.
- Scour.
- Outcrop of bedrock and thin sediment cover.
- Steep seabed gradient to west of site (associated with the Skerd Rocks Fault).
- Angular rocks protruding water surface.
- Dangerous shoals around Sceirde Rocks.

## 3.2. Relevant Conservation Legislation

European Commission (EC) 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. 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 in Ireland.

Under the 1992 OSPAR convention to Protect the Marine Environment of the North East Atlantic, Ireland has established a number of its designated SAC's as OSPAR MPA's.

### 3.2.1. Designated Sites

The proposed SROWF site does not overlap with any designated site however it is situated close to several SACs with marine components and SPAs as discussed below and presented in Figure 1 and Figure 2.

**Kilkieran Bay and Islands SAC**

Kilkieran Bay and Islands (KBI) SAC was designated in 2014 for its marine and coastal habitats of high conservation value. The area is an extensive coastal complex encompassing many Annex I designated features including tidal mudflats and sandflats, coastal lagoons, large shallow inlets and bays and reefs. Key marine habitats include extensive maerl, maerl debris, and mixtures of gravel and mud with maerl which have created unique habitats that support diverse burrowing communities and species identified as rare throughout the rest of Ireland. Subtidal seagrass

(*Zostera marina*) is present in numerous areas and co-occurs with maerl. Beds of native oyster (*Ostrea edulis*) occur in the inner bay. The rocky shores, reefs, and lagoons support highly diverse and rare algal and animal communities. Muddy sediments support diverse polychaete and bivalve communities as well as the rare fireworks anemone (*Pachycerianthus multiplicatus*). The islands and inlets are also important for seabird colonies, in particular breeding terns. Annex II qualifying species include harbour seal (*Phoca vitulina*) and Eurasian otter (*Lutra lutra*). The proposed SROWF boundary is 40 m from the KBI SAC.

**Inishmaan Island SAC**

Inishmaan Island SAC was designated in 2014 for its marine and coastal habitats of major scientific importance. Inishmaan Island is one of three Aran Islands situated 15 km off the west coast of Co. Clare. The marine component of the designation is the presence of Annex I reefs consisting of karstic Carboniferous limestone exposed to high wave action which are highly porous and display good zonation of rich and varied communities of algae and fauna. The proposed SROWF ECR boundary is 12.8 km from the Inishmaan Island SAC.

**Inishmore Island SAC**

Inishmore Island SAC was designated in 2015 for its marine and coastal habitats of high conservation value including Annex I coastal lagoons and reefs. Inishmore Island is the largest of the Aran Islands situated 8 km off the coast of Co. Galway. The infralittoral and sublittoral reefs support diverse and unique communities of flora and fauna that are extremely exposed to wave action. Two exceptional communities are observed in the infralittoral; Ireland's only record of the purple sea urchin (*Paracentrotus lividus*) and reefs of extremely exposed shallow infralittoral communities dominated by *Alaria esculenta* with red seaweed and animal turf. In deeper waters the pink sea fan (*Eunicella verrucosa*) is widespread and species rich. The island's reef habitats also include several submerged sea caves containing unique and diverse marine fauna. The Inishmore SPA intersects the Inishmore Island SAC and is designated to protect several species of seabird. The proposed SROWF ECR boundary is situated adjacent to the south-westerly boundary of the Inishmore Island SAC and 1.3 km from the Inishmore SPA.

**Inisheer Island SAC**

Inisheer Island SAC was designated in 2014 for its marine and coastal habitats of high conservation value including Annex I coastal lagoons and reefs. Inisheer Island is the smallest of the three Aran Islands located 10 km of the west coast of Co. Clare. The marine component of the designation is the presence of Annex I reefs which display good zonation of rich and varied communities of algae and fauna despite being exposed to high wave action. The proposed SROWF ECR boundary is 15.6 km from the Inisheer Island SAC.

**Carrowmore Dunes SAC**

Carrowmore Dunes SAC was designated in 2014 for its marine and coastal habitats of high conservation value including Annex I reefs. The predominantly coastal site is situated on the southwest coast of Co. Clare and extends 500 m from the shore to include shallow marine waters. The intertidal reefs support rare communities of algae and invertebrates that are moderately exposed to wave action. *Z. marina* is observed on the intertidal sandflats comprised of fine to coarse sand, but its distribution is scarce. The Mid Clare Coast SPA intersects the Carrow Dunes SAC and is designated to protect seabirds, geese, and wading bird populations. The proposed SROWF ECR boundary is 3.1 km from Carrowmore Dunes SAC and 560 m from the Mid Clare Coast SPA.

**Carrowmore Point to Spanish Point and Islands SAC**

Carrowmore Point to Spanish Point and Islands (CPSPI) SAC was designated in 2014 for its marine and coastal habitats of high conservation value including Annex I coastal lagoons and reefs. The site is situated along the Co. Clare coastline and comprises of a strip of coastline, several offshore islands, rocks, and the marine waters of Mal Bay. The intertidal reefs support communities that are very to moderately exposed to wave action. The lower shore and subtidal fringe display high species richness, whilst subtidal reefs support deep exposed reef communities of erect sponges and pink sea fan (*E. verrucosa*) as well as several rare species including the sponge *Tetilla zetlandica*. The rocks and islands are haul out locations for grey seals (*Halichoerus grypus*). Mid-Clare coast SPA is co-located within the CPSPI SAC. The area is of high ornithological importance supporting internationally and nationally important populations of seabirds, geese, and wading birds. The proposed SROWF ECR boundary is 1.2 km from the CPSPI SAC.

**Slyne Head to Ardmore Point Islands SPA**

The Slyne Head to Ardmore Point Islands SPA intersects the KBI SAC, it is designated to protect several tern species and the barnacle goose. The proposed SROWF boundary is from the Slyne Head to Ardmore Point Islands SPA.

### 3.2.2. Potential Annex I Habitats within the Survey Area

Several important and sensitive habitats are known to be present within the vicinity of the survey area, these include Annex I habitats that are a primary reason for selection of sites:

- Tidal mudflats.
- Coastal Lagoons.
- Large Shallow Inlets and Bays.
- Reefs (rocky/biogenic).

These Annex I features and component species are described below and displayed within Figure 3 and Figure 4.

#### 3.2.2.1. Tidal Mudflats and Sandflats

Intertidal mudflats and sandflats are submerged at high tide and exposed at low tide. They occur extensively along open coast and lagoonal inlets. The structure ranges from mobile, coarse-sand beaches on wave exposed coasts to stable, fine sediment mudflats in estuaries and marine inlets. Plant and animal communities vary according to the type of sediment and water salinity. Muddy sands support populations of blue mussel (*Mytilus edulis*) and seagrass species (*Zostera* spp.).

Tidal mudflat and sandflat features have a patchy distribution that occur throughout Kilkieran Bay, Carrowmore Dunes, and CPSPI SACs. Kilkieran Bay sandflats are dominated by intertidal sands and associated polychaete communities, Carrowmore Dunes SAC contains a small area of intertidal sandflats with occasional seagrass, and CPSPI SAC mud and sandflats support nationally important bird populations.

#### 3.2.2.2. Coastal Lagoons

Coastal lagoons are areas of shallow, coastal salt water separated from the sea by sandbanks, shingle, or rocks. Lagoons vary based on their salinity and geological features which restrict water movement causing lagoons to vary from brackish to hypersaline. Therefore species abundance, diversity and community composition are determined by the specific conditions within each lagoon system. Vegetation may include beds seagrass species *Zostera* spp., tasselweed (*Ruppia* sp., and pondweeds *Potamogeton* spp.). Several algal species including fucoids, sugar kelp, red and green algae occur in rockier lagoons. Dominant fauna includes mysid shrimps, small crustaceans, worms, bivalve molluscs, and some fish species.

Two coastal lagoons are situated within Kilkieran Bay SAC, four within the Inishmore SAC and one within Inisheer SAC, all of which differ in their geological, environmental, and ecological features and functions.

#### 3.2.2.3. Large Shallow Inlets and Bays

Large shallow inlets and bays are habitat complexes comprising a mosaic of subtidal and intertidal habitats. They occur on large coastal indentations that are typically sheltered from wave action. Habitat and species diversity can vary between sites due the combined influence of local environmental and geographical factors resulting in high community and species diversity. Within Kilkieran Bay this includes important populations of, seagrass maerl, and native oysters.

***Zostera* (Seagrass) Beds**

Seagrass (or eelgrass) beds are biogenic habitats formed by angiosperms adapted to saline conditions. In the UK, two species of seagrass are known to form beds: *Zostera marina* and *Zostera noltii*. The first species is found in fully marine conditions in the intertidal to sublittoral zone, the second species occurs higher on the shore being tolerant to desiccation. *Zostera* sp. beds are representative of EUNIS subtidal biotope A2.6111 and EUNIS intertidal biotope A5.5331.

Seagrass beds are identified as a habitat which provides many important ecosystem services (e.g., carbon sequestration, flood/storm defence), and support diverse communities of algae and fauna, including species of conservation concern (e.g., seahorses) and serve as nursery grounds for numerous commercial species. They are classed as vulnerable habitats, sensitive to multiple stressors (e.g., pollution, climate warming, increased sediment turbidity). In recognition of their ecological and economic importance, *Zostera* beds are afforded protection under the Habitats Directive as they are encompassed by Annex I habitats:

- Sandbanks
- Estuaries
- Mudflats and sandflats not covered by seawater at low tide
- Large shallow inlets and bays

Specifically, *Zostera* beds are a component of the Annex I features identified in the Kilkieran Bay and Islands SAC, of which it occurs in a number of areas, including a co-occurrence with maerl which, in the UK has only been identified in populations around Ireland. Additionally, *Zostera* beds are included within the OSPAR list of threatened and/or declining species and habitats.

**Maerl Beds**

Maerl beds are formed by calcareous red algae that grow as unattached nodules (occasionally crusts) forming dense but relatively open beds of coralline algal gravel. Beds of maerl form on a variety of sediments and occur on the open coast and in tide-swept channels of marine inlets (the latter are often stony). In fully marine conditions, the dominant maerl is typically *Phymatolithon calcareum* or *Lithothamnion coralloides*. Maerl beds support diverse communities of burrowing infauna, especially bivalves, and interstitial invertebrates including suspension feeding polychaetes and echinoderms.

Only three sites are known throughout Ireland where three species of maerl (*L. corallioides*, *Lithophyllum dentatum*, and *Lithophyllum fasciculatum* co-occur, this includes extensive areas of Kilkieran Bay. This diversity and the range of maerl deposits that occur (live maerl, mixtures of maerl, gravel, and mud) including banks of maerl debris contain diverse and rare communities of species. Due to their fragility and sensitivity to disturbance but also to their role in enhancing biodiversity, maerl beds are granted protection under the EC Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (92/43/ECC) and through inclusion on the OSPAR list of threatened and/or declining species and habitats.

**Native Oyster Beds**

The European flat oyster also known as the native oyster (*Ostrea edulis*) is a filter-feeding, reef forming, bivalve mollusc of high conservation concern due to wide-spread population loss caused by centuries of commercial overexploitation. *O. edulis* is associated with highly productive estuarine and shallow coastal water habitats. Reefs formed by *O. edulis* are identified as important

habitat for increasing biodiversity by providing shelter and nursery grounds and providing ecosystem services by stabilising sediments (preventing erosion) and filtering water (improving water quality).

*O. edulis* is a constituent or characterising species of marine community types within qualifying interests (Annex I (Habitats Directive) Habitats) for SACs. European Communities (Birds and Natural Habitats Regulations 2011 (S.I.No. 477 of 2011)). and included on the OSPAR list of threatened and/ or declining species and habitats. All commercially fished oyster beds in Ireland occur within SACs. Maintaining favourable conservation status of oyster habitats is a requirement under conservation objectives defined for these habitats.

Wide-spread restoration projects are underway throughout the British Isles. In Ireland this includes the Galway Bay Oyster Restoration Project, a collaboration between community, state, and scientific institution which aims to restore oyster populations that once existed in huge quantities in Galway Bay. The area spans 50 km from the Burren in Co. Clare to Galway City.

The only self-recruiting beds of *O. edulis* in Ireland occur within in the Inner Kilkieran Bay area of the SAC.

#### 3.2.2.4. Rocky Reefs

Rocky reefs can be variable in terms of their structure and the communities that they support. They provide substrate for many sessile species such as corals, sponges, and sea squirts as well as shelter to more mobile species such as fish and crustaceans. Rocky reefs can be classified as either stony or bedrock reefs.

Annex I reefs occur throughout the survey area and are the primary designation feature of several SACs. The distribution of Annex I reef is displayed in Figure 3 and Figure 4.

**Stony Reef**

Stony reef habitats occur when stable hard substrata, namely cobbles and boulders > 64 mm in diameter arise from the surrounding habitat, creating a habitat colonised by a variety of species. Numerous SAC sites have been designated in Irish waters to protect stony reef habitats and associated communities. Reefs are of significant national importance and are in many cases hot spots for the biodiversity supporting assemblages of various coral, sponges, ascidians, cnidaria, bryozoans, polychaetes, hydroids, molluscs, fish, and crustaceans including Cirripedia (barnacles). These associated communities vary dramatically according to environmental variables and may incorporate species that occupy a range of trophic levels. The complexity of habitat created by stony reefs often supports a higher abundance of mobile fauna such as echinoderms and various crabs, hermit crabs, and squat lobsters, as well as fish species for which these species represent key prey items.

**Bedrock Reef**

Similar to stony reef, Annex I bedrock reef habitat occurs where bedrock arises from the surrounding seabed, providing a stable habitat for attachment for a diverse range of epibiota. Bedrock reefs and associated biological communities can be highly variable due to the diverse nature of these habitats in terms of topography, structural complexity, and exposure to tidal streams. In the photic zone, communities associated with bedrock reefs are often dominated by attached algae, and often support various invertebrate species such as corals, sponges, and sea squirts. These epibiotic communities further increase structural complexity and represent key prey items that in turn attract more mobile and commercially valuable species such as fish and crustaceans.

### 3.2.2.5. Biogenic Reefs

A general definition of biogenic reefs made by (Holt et al., 1998) includes: "*Solid, massive structures which are created by accumulations of organisms, usually arising from the seabed or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed. The structure of the reef may be composed almost entirely of the reef-building organism and its tubes or shells, or it may to some degree be composed of sediments, stones and shells bound together by the organism*."

Subtidal biogenic reef species include polychaetes (*Serpula vermicularis* and *Sabellaria spinulosa)*, and bivalves (*Mytilus* spp. and *Modiolus modiolus)*.

***Serpula vermicularis* Reef**

*Serpula vermicularis* is a polychaete worm that secretes a calcareous tube. Individual tubes are common and widespread throughout Ireland and the UK in general. However, within several locations throughout Ireland and Scotland large aggregations of *S. vermicularis* have been observed which have formed reef structures up to 2 m in diameter. These rare reefs typically occur on soft, muddy habitats and less so on rocks within sheltered bays. As worms settle and grow on already established ones the reef grows upwards and outwards to form a rounded clump of white tubes, similar to a coral head. The larger reefs tend to collapse outwards from the centre, but the collapsed sections continue growing. The reefs provide shelter and substrate for other marine wildlife where there is little other solid attachment, and become covered with orange sponges, colonial and solitary sea squirts, hydroids, and seaweeds. Mobile animals live between the tubes in the centre of the reef; particularly common are brittle stars, terebellid worms, small spider crabs, squat lobsters, hermit crabs, starfish, and a range of marine snails.

*S. vermicularis* reefs are sensitive to both anthropogenic (water quality, fishing gear) and natural environmental (storms, freshwater runoff) disturbance and are, therefore identified as a qualifying Annex I biogenic reef feature. One such area of known *S. vermicularis* reef occurs within Kilkieran

Bay. This habitat typically occurs within sheltered bays and is therefore unlikely to occur within the present study, given the relatively exposed nature of the survey area.

***Sabellaria spinulosa* Reef**

Dense subtidal aggregations of tubes created by the Ross worm *S. spinulosa* may form biogenic reefs that can stabilise cobble, pebble and gravel habitats and provide a consolidated habitat for epibenthic species (Pearce et al., 2011). These reefs form solid, raised structures above the surrounding seabed, thus increasing local habitat complexity and creating a biogenic habitat onto which various other species may become established. Those *S. spinulosa* reefs of greatest conservation importance are those which occur on predominantly sediment or mixed sediment areas that allow settlement of fauna that would not otherwise occur in such areas. Biological assemblages in areas of *S. spinulosa* reefs therefore often support a rich diversity of flora and fauna compared to surrounding areas of relatively homogenous sediment habitat.

Such reefs form in areas of favourable environmental conditions, largely areas of muddy sand with coarse material for attachment and high suspended sediment concentrations for tube construction. The species is common around the British Isles, however, due to their historic losses, sensitivity to anthropogenic disturbance and biological importance, *S. spinulosa* reefs have been identified as a qualifying Annex I biogenic reef feature. There are no previous records of *S. spinulosa* occurring within or in the vicinity of the survey area.

***Modiolus modiolus* Reef (beds)**

The horse mussel (*Modiolus modiolus*) can form dense beds/reefs at depths of 5-70 m in full saline, moderately tide-swept areas. Although a widespread and common species, true beds that form a distinctive biotope are limited. In some areas of very strong currents, extensive areas of stony and gravelly sediment are bound together by more-or-less completely recessed *M. modiolus*, creating waves or mounds with steep faces up to one metre high and many metres long. These areas of semi-recessed and recessed beds may in some cases extend over hundreds of hectares. *M. modiolus* is a long-lived species and individuals within beds are frequently 25 years old or more. Juvenile *M. modiolus* are heavily preyed upon, especially by crabs and starfish, until they are about 3–6 years old, but predation is low thereafter. Recruitment is slow and may be very sporadic; there may be poor recruitment over a number of years in some populations. The byssus threads secreted by *M. modiolus* have an important stabilising effect on the seabed, binding together living *M. modiolus*, dead shell, and sediments. This rich food source, together with the varied habitat, means that extremely rich associated faunas occur that can include hundreds of species. Four major biotopes supporting mussel beds have been identified (A5.621 '*M. modiolus* beds with hydroids and red seaweeds on tide swept circalittoral mixed substrata', A5.622 '*M. modiolus* on open coast circalittoral mixed sediment', A5.623 '*M. modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata'; and A5.624 '*M. modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata').

The beds are considered a type of Annex I biogenic reef habitat as well as an OSPAR listed habitat. The qualifying criteria for classifying *M. modiolus* beds/ reefs (as reported within Morris, 2015) are as follows:

- Live adult *M. modiolus* individuals are present;
- The associated reef biota/communities are distinct from the surrounding habitat; and
- The distinct region containing *M. modiolus* is greater than 25m$^2$ in extent.

Records of *M. modiolus* occur throughout KBI and Inishmore Island SACs.

***Mytilus edulis* Reef**

The blue mussel (*Mytilus edulis*) is a suspension feeding bivalve found as individuals and as dense beds forming biogenic reefs (Holt et al., 1998). *M. edulis* beds occur from the shoreline to the sub-littoral (Connor et al., 2004). The beds enhance local biodiversity by providing an additional substrate for colonisation by a wide array of infaunal and epifaunal species such as barnacles, limpets, polychaetes, and other bivalves as well as stabilising and modifying sedimentary substrates, whilst 'mussel mud' supports a diverse range of infauna. They are the preferred prey item of many species including starfish, crabs, demersal fish, dog whelks and birds. Therefore, they are listed as an Annex I habitat under the EU habitats Directive and are included on the OSPAR (Annex V) list of threatened and declining species and habitats. Records of *M. edulis* occur throughout KBI and Inishmore Island SACs.

### 3.2.3. Potential OSPAR Threatened and/or Declining Species and Habitats

***Arctica islandica***

The ocean quahog (*A. islandica*) is one of the longest-lived molluscs 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 Ireland. This species slow growth rate and low juvenile survival rate, combined with the threat of mechanical damage and incidental catch of by bottom fishing gear has meant that this vulnerable species is now experiencing a decline, prompting increased attention to its conservation.

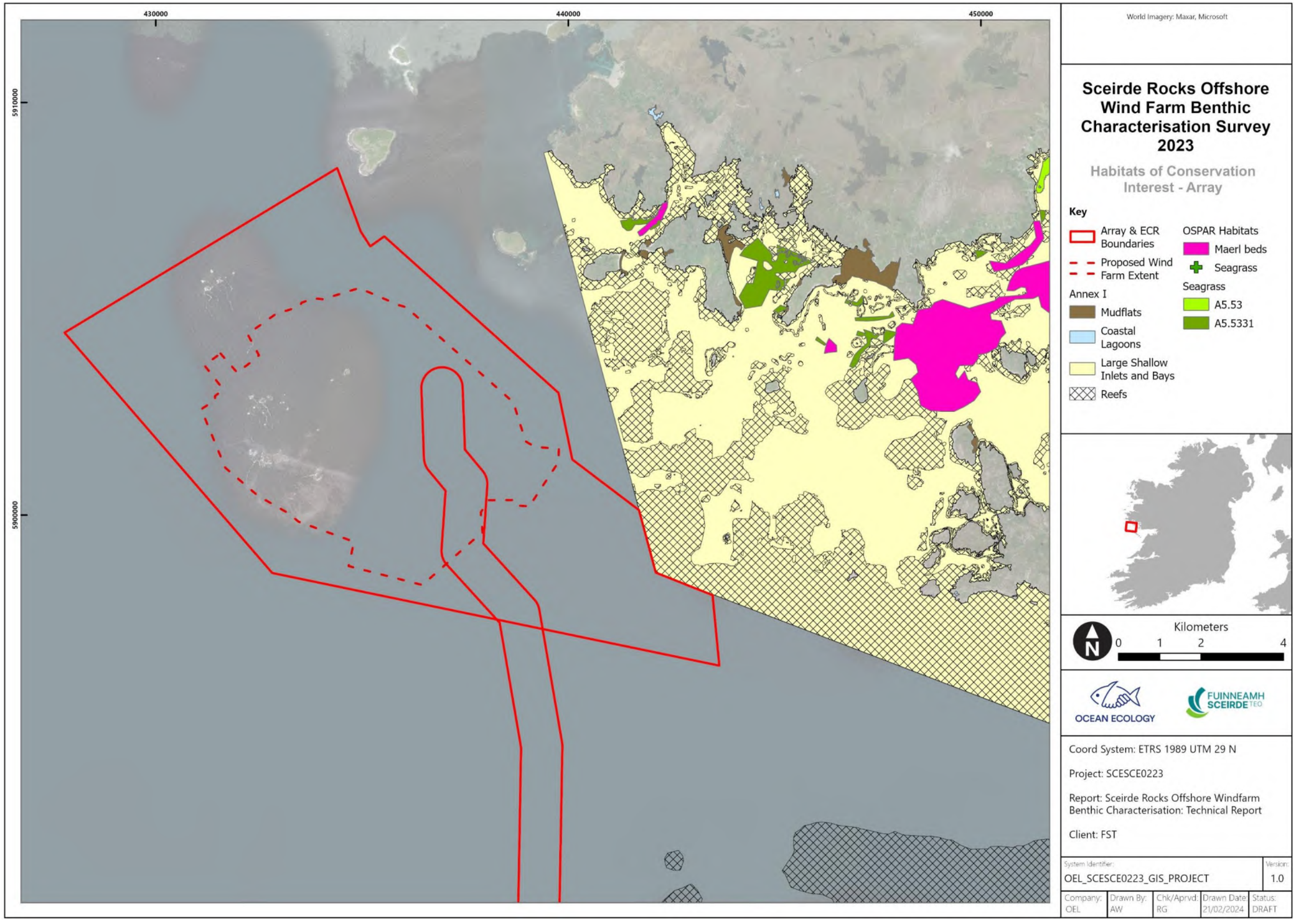


**Figure 3** Existing mapping of habitats of conservation interest within the vicinity of the proposed array area of SROWF.

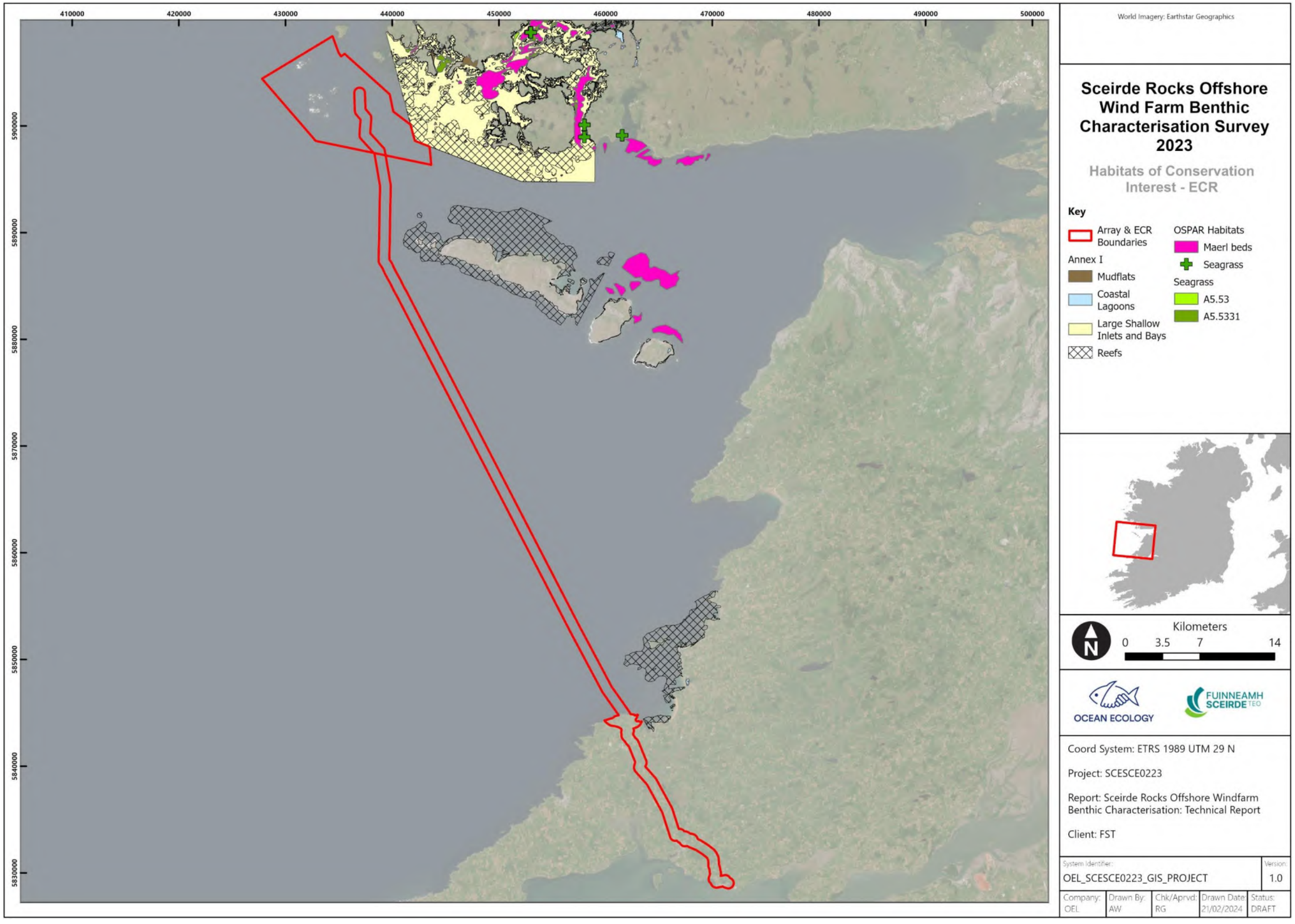


**Figure 4** Existing mapping of habitats of conservation interest within the vicinity of the proposed ECR area of SROWF.

## 3.3. Existing Data

### 3.3.1. Predictive Habitat Mapping

The 2021 EUSeaMap broad-scale predictive model classifies and maps intertidal and subtidal habitats according to the 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. Information from EMODnet was not available from within the array area, however, just beyond the shoreward eastern boundary lies a coastal region comprised of a variety of predicted habitat types. The most commonly occurring were infralittoral and circalittoral rock (EUNIS A3.1 and A4.1) and infralittoral and circalittoral mixed sediments (A5.43 and A5.44). The upper reaches of the ECR are predicted to be A4.1 'Atlantic and Mediterranean high energy circalittoral rock' shifting towards muddier sediments, predicted to belong to EUNIS A5.37 'Deep circalittoral mud' through the central region of the ECR. There is then a predicted transition to A5.27 'Offshore circalittoral sand', then to either A5.25 'Circalittoral fine sand' or A5.26 'Circalittoral muddy sand. in the southern section of the ECR, where it makes landfall (Figure 7 and Figure 8).

### 3.3.2. 2022 Geophysical Campaign

Results of the 2022 Geophysical campaign were used to inform expected site conditions and select suitable sampling locations. Interpretation of the findings from the 2022 geophysical campaign are mapped in Figure 5 and Figure 6.

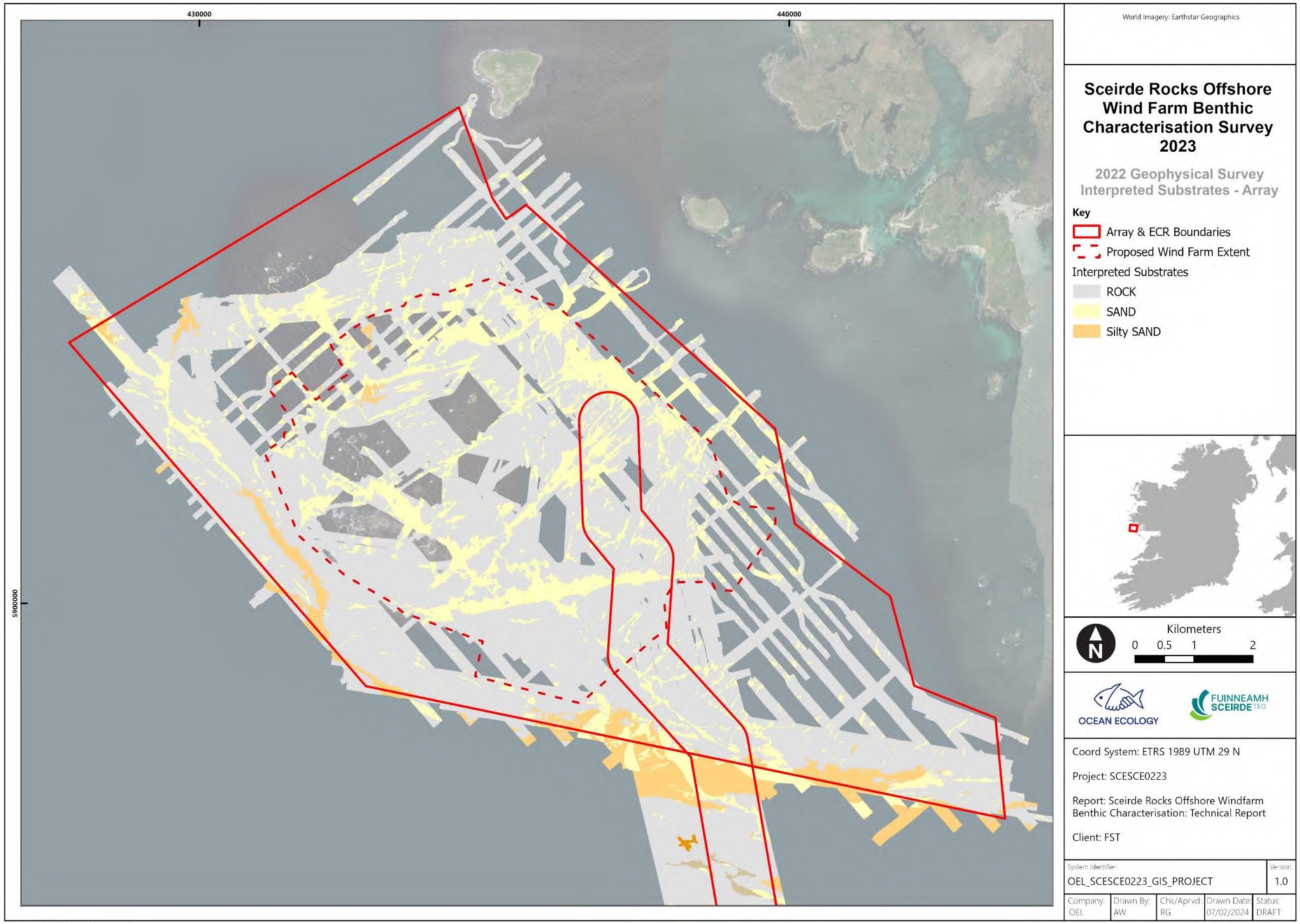


**Figure 5** Interpreted substrate from data acquired during the 2022 geophysical campaign (Array).


**Figure 6** Interpreted substrate from data acquired during the 2022 geophysical campaign (ECR).

# 4. Survey Design

## 4.1. Overview

The benthic sampling plan was developed to provide maximum geographic coverage of the proposed survey area, whilst also ensuring that all key habitats and communities likely to be encountered across the survey area were adequately targeted. The key principles underpinning the survey design were therefore to:

- Provide adequate spatial coverage of the array area;
- Ensure representative sampling of all main sediment types is undertaken; and
- Ensure representative examples of all potential features of conservation interest (e.g., Annex I reefs) are adequately ground-truthed.

## 4.2. Rationale

The sampling plan was produced based on a stratified sampling approach across the proposed SROWF array and ECR survey areas with micro siting of sampling stations informed by a detailed review and interpretation of the outputs of the 2022 geophysical campaign and in consideration for all surface, subsurface and subsea hazards, and their respective exclusion / buffer zones. Whilst interpretation of geophysical data described much of the survey area as rocky substrate, grab sampling was conducted in areas identified as sedimentary in nature, where grab samples could be successfully obtained. Areas of rocky substrate and potential reef features were instead targeted using DDC transects.

The following components, provided by FST, were assessed in the development of the sampling plan:

- 2022 geophysical campaign processed multibeam echosounder (MBES) bathymetry and side scan sonar (SSS) imagery in mosaiced Geo tiff format (Figure 11, Figure 12, Figure 13 and Figure 14),
- 2022 geophysical campaign processed magnetometer and SSS feature analysis to identify potential subsea hazards and potential UXO,
- Interpreted seabed classification from 2022 geophysical campaign (Figure 5 and Figure 6),
- GIS shapefiles and rasters in ESRI format of the scoping boundaries; and
- All previous survey and/or technical reports available for the area.

Additionally, GIS shapefiles and rasters in ESRI format were obtained through a thorough data mining exercise and included: all surface and subsurface infrastructure within the SCOWF boundary or within close proximity to it; the latest relevant conservation designation boundaries, species and habitats of conservation concern (Annex I/OSPAR designation features and/or Annex II/OSPAR species) from Ireland's Marine Atlas, EUSeaMap 2021 BSH map of predicted EUNIS habitats (https://emodnet.ec.europa.eu), and EMODnet Heritage

Shipwrecks GDB. Additional information on habitat and species was obtained from the National Biodiversity Network Atlas (https://nbnatlas.org/).

The sampling consisted of DDC, grab and water sampling locations and DDC transects.

## 4.3. Sampling Approach

Prior to the collection of sediment samples, high-resolution seabed imagery (stills and video) was collected using DDC at each sampling station 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. Sixty-five combined DDC and grab sampling stations were targeted, of which 35 were positioned in the array and 30 along the ECR. All grab stations were targeted for macrobenthic, Particle Size Distribution (PSD), Total Organic Carbon (TOC) and Environmental DNA (eDNA) analysis. A subset of 22 of the grab stations were also targeted for sediment chemistry analysis.

An additional 36 DDC transects were sampled throughout the SROWF survey area in order to categorise key features of interest (potential biogenic/ geogenic reef) identified in the geophysical data. Of these, 21 transects were positioned in the array and 15 along the ECR. The full rationale for selection of each station and DDC transect are shown in Appendix I. Sampling stations are mapped in Figure 1 and Figure 2.

Water sampling was conducted across the array and ECR survey areas at every other DDC/grab station (33 stations in total). Two water samples were collected at each sampling station: one at the subsurface and the other 2 m above the seabed Further water samples were collected at 10 of the 33 stations for water eDNA analysis. Water eDNA samples were collected as a single replicate at three water depths at each sampling station: subsurface, mid-water, and 2 m above the seabed Table 1).

**Table 1** Target sample station breakdown across the SROWF survey area.

| Type | Stations | Reps | Total |
|---|---|---|---|
| DDC (Screening) | 65 | 1 | 65 |
| DDC (Transects) | 36 | 1 | 36 |
| Grabs (Macrofauna) | 65 | 3 | 195 |
| Grabs (TOC, PSD) | 65 | 1 | 65 |
| Grabs (Full Sediment Chemistry) | 22 | 1 | 22 |
| Sediment eDNA Samples | 65 | 3 | 195 |
| Water Samples | 33 | 2 | 66 |
| Water eDNA Samples | 10 | 3 | 30 |

## 4.4. Timing

The sampling was undertaken during periods of favourable weather between the 9th and 20th of October 2023.

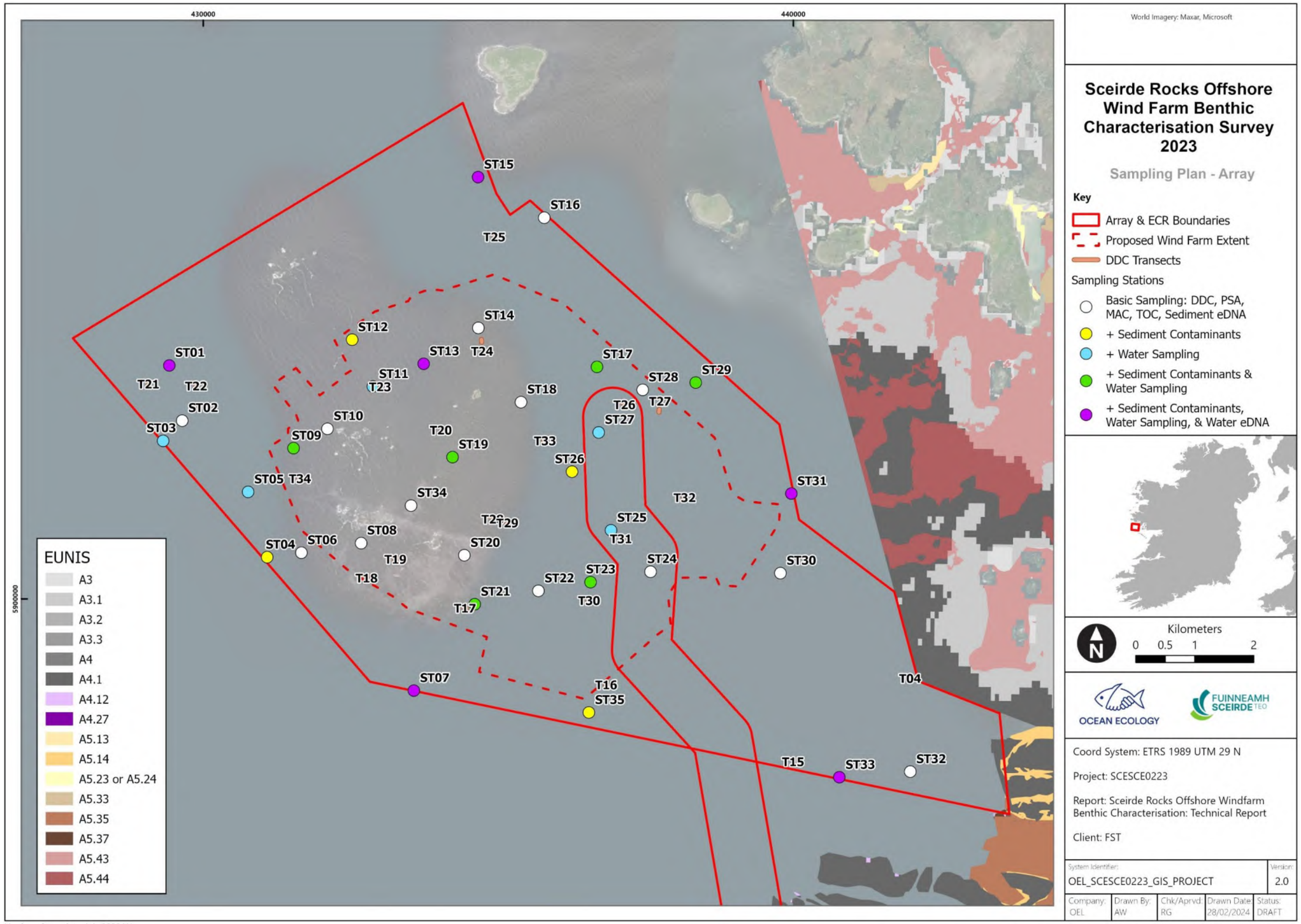


**Figure 7** Planned sampling station locations in proximity of the SROWF array survey area.

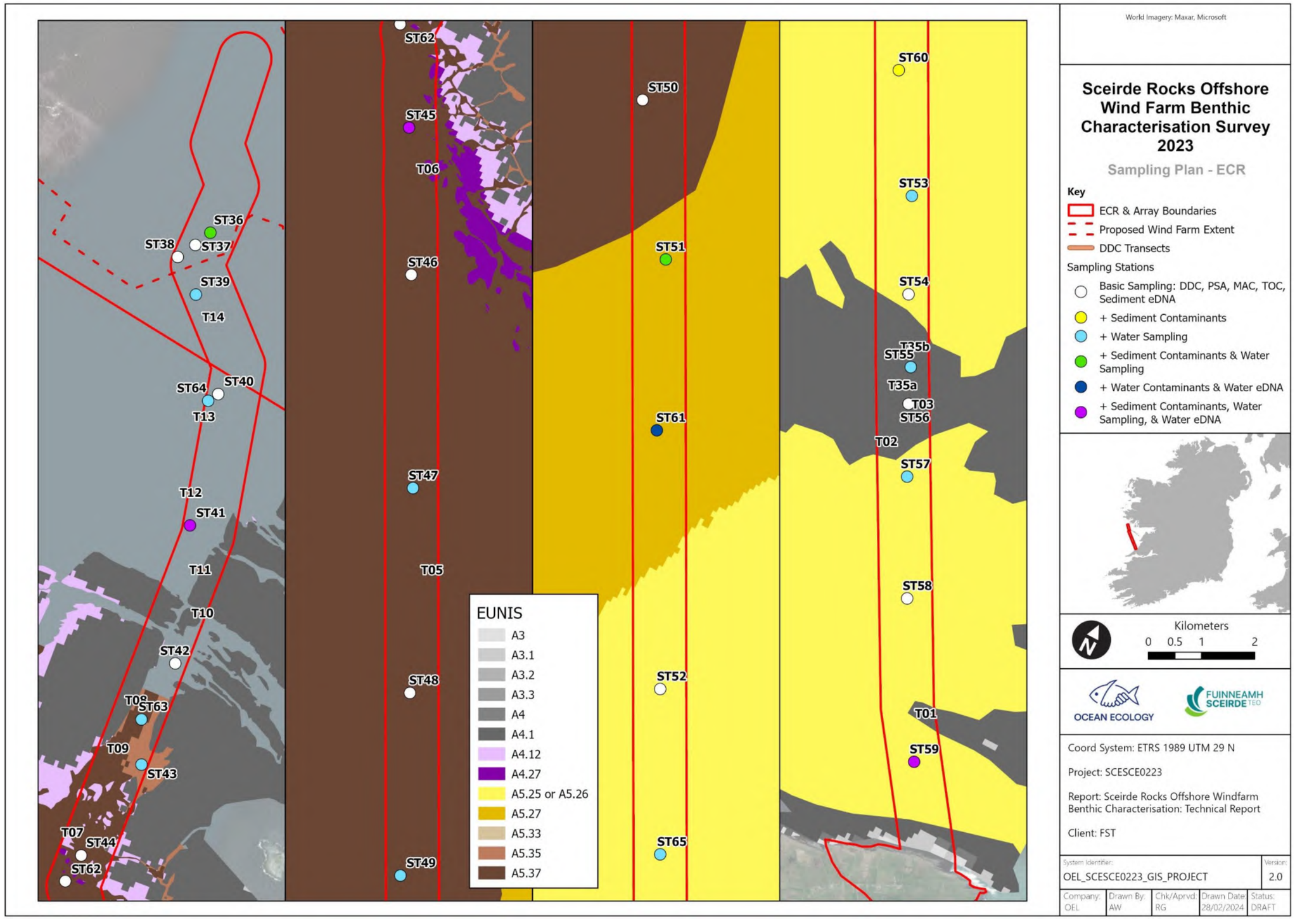


**Figure 8** Planned sampling station locations in proximity of the SROWF ECR survey area.

# 5. Field Methods

## 5.1. Project Parameters

### 5.1.1. Horizontal Datum

**Table 2** Project horizontal geodetic parameters.

| Parameter | Value |
|---|---|
| Datum | ETRS89 |
| Ellipsoid | GRS80 |
| Spheroid | GRS80 |
| Semi Major Axis (a) | 6378137.0 |
| Semi Minor Axis (m) | 6356752.314245719 |
| Inverse Flattening (1/f) | 298.257222101 |
| Angular unit | Degree |

.

**Table 3** Project horizontal projection parameters

| Parameter | Value |
|---|---|
| Projection | ETRS89/ UTM Zone 29 N |
| Longitude at Central Meridian | 009° 00.000000′ E |
| Latitude of Origin | 000° 00.000000′ N |
| False Northing and Easting (m) | 0; 500,000 |
| Scale Factor | 0.9996 |
| Linear Unit | Metre |
| Time Datum | Universal Time Coordinated (UTC) |

### 5.1.2. Datum Transformation Parameters

All data is referenced to ETRS89, Universal Transverse Mercator (UTM) 29N, with no datum transformation needed.

### 5.1.3. Vertical Datum

All altitude and depth data above seabed are referenced to LAT. All depth data below the seabed is referenced to LAT where available, depths may be reported as derived from ultra-short baseline (USBL) beacon.

### 5.1.4. Unit Format and Conversions

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

**Table 4** Project unit format and convention details.

| **Unit Formats and Conventions** | |
|---|---|
| Geographical Coordinates | Latitude N DD˚MM.mmmmmm' to 6 decimal places.<br>Longitude E/W DD˚MM.mmmmmm' to 6 decimal places. |
| Grid Coordinates | Meters in the following format:<br>Easting EEE EEE.eee m to 3 decimal places.<br>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:<br>'Y' is positive forward.<br>'X' is positive to starboard.<br>'Z' values are positives upwards from the waterline. |
| Time | UTC (GMT). |

## 5.2. Survey Vessels

A combination of three survey vessels were mobilised for sampling: the *Ocean Navigator,* the *MV Situla,* and the *MV Roman Rebel* (Plate 1 and Plate 2). Due to weather conditions experienced on site, no sampling operations were undertaken on board the *Ocean Navigator*.

**Table 5** Vessel details *MV Situla*.

| | |
|---|---|
| **Vessel Name** | *MV Situla* |
| **Area of Operation** | Offshore |
| **Ops Duration** | 24 h |
| **Call Sign** | HO8727 |
| **IMO Number** | 9246188 |
| **Mobilisation Port** | Galway |
| **Length** | 38.1 m |
| **Beam** | 9.5 m |
| **Draft** | 2.9 m |
| **Mobilisation Date** | 10th October 2023 |


**Plate 1** *MV Situla* alongside in the Port of Galway.

**Table 6** Vessel details. *MV Roman Rebel.*

| | |
|---|---|
| **Vessel Name** | *MV Roman Rebel* |
| **Area of operation** | Offshore |
| **Ops Duration** | 24 h |
| **Call Sign** | 2ICA5 |
| **IMO Number** | 9714824 |
| **Mobilisation Port** | Crosshaven, Cork |
| **Length** | 27.5 m |
| **Beam** | 10 m |
| **Draft** | 3 m |
| **Mobilisation Date** | 7th October 2023 |

**Plate 2** Survey vessel *MV Roman Rebel* alongside in the Port of Galway.

## 5.3. Survey Navigation

### 5.3.1. Surface Positioning

The *MV Situla* was equipped with 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.

On the *MV Roman Rebel*, positional checks were carried out by Green Rebel surveyors during vessel mobilisation. The vessel used two independent global navigation satellite systems (GNSS), each installed on the vessel's main mast. These GNSS are C-Nav 3050 and Hemisphere R330u. The inertial navigation system (INS) attitude and heading reference system (AHRS) used was iXBlue HydrINS (mounted to the walls of the MBES moonpool shafts and allowing for a theoretical common reference point to be used for both the port and starboard hulls).

### 5.3.2. Subsea Positioning

The *MV Situla* was equipped with an Easytrak Nexus 2 Lite USBL system and 1329A Omni-directional +/- 90 ° Micro Beacons for subsea positioning of the sampling equipment. 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 transceiver was mounted to a cage which was deployed through the hull via a moon pool.

The USBL was fully calibrated prior to survey operations and a Valeport SWiFT sound velocity profiler (SVP) was used for taking sound of speed measurements throughout the survey. Readings were obtained daily from both the up-cast and down-cast.

On the *MV Roman Rebel*, a USBL was provided and operated by Green Rebel and used for positioning. A Konsberg μPAP 201-3 USBL transceiver was mounted to a cage which was deployed through the hull via a moon pool. This transceiver transmitted to Konsberg cNODE Micro or cNODE MiniS 34 beacons that were mounted onto sampling equipment to provide accurate subsea positioning. A summary of the USBL equipment to be used can be found in the mobilisation report by Green Rebel.

### 5.3.3. Navigation Software

Aboard the *MV Situla*, 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.

On the *MV Roman Rebel, t*he online navigation software QPS Qinsy was used for subsea positioning and navigation as well as recording continuous track plots of the sampling equipment and recording sampling fixes.

On both vessels, fix positions were to be taken at the point that the grab landed on the seabed for all grab attempts (unsuccessful and successful). Continuous second by second positional log files were also taken from the position of the relevant USBL beacon mounted on the grab an DDC frame.

### 5.3.4. Positional Checks & Calibrations

For the *MV Situla*, the GPS had 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 VRU and gyro.

## 5.4. Seabed Imagery Collection

Each vessel was equipped with OEL's SubC Rayfin PLE camera system, set up to obtain 1080p High Definition (HD) video and 21 Megapixel (MP) still images.

The camera system (Plate 3) 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 light emitting diode (LED) strip lamps and a 10 cm point laser scaling array that was projected into the field of view 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 case of a power surge.

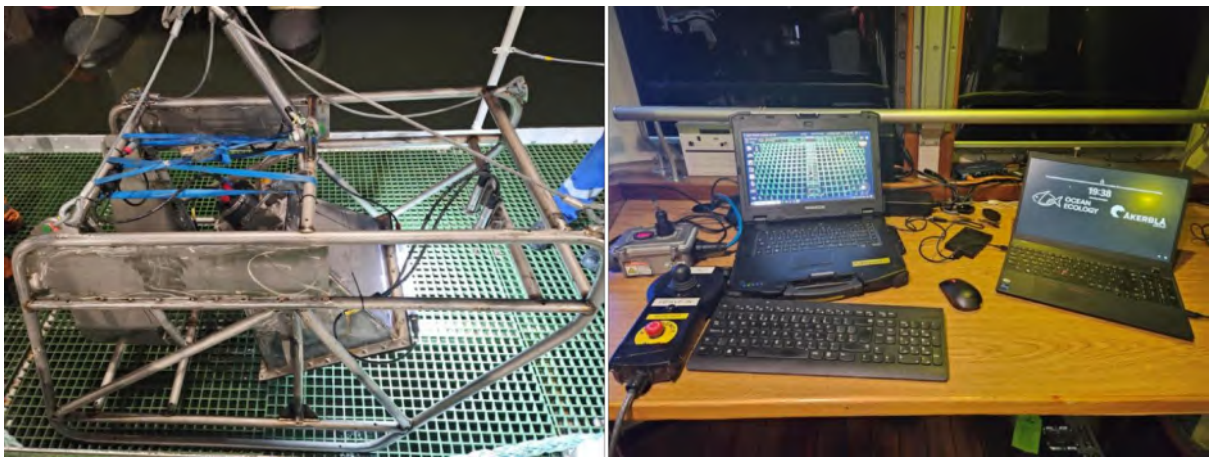

**Plate 3** Left: OEL CLOC camera system. Right: The camera system topside setup.

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 each vessel. During the deployment, all footage underwent a preliminary review *in situ* by OELs onboard Environmental Scientists. Videos were recorded in a digital format direct to topside hard disk drives (HDDs) and were 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.

## 5.5. Sediment Sampling

On the *MV Situla*, sediment samples were collected from within 25 m of the target sampling location using OEL's 0.1 $m^2$ Day grab sampler (Plate 4). A single deployment of the Day grab yielded a single sample of approximately 5-10 L at each station. As such, four grab deployments were required at each station, with the initial three sediment samples utilised for macrobenthic analysis and the fourth for PSD as well as chemical contaminant and eDNA analysis.

On the *MV Roman Rebel*, a larger 0.2 $m^2$ dual Van Veen (DVV) grab sampler (Plate 5) was utilised. This was made possible by the greater load lifting capabilities of the winch aboard this vessel. A single deployment of this grab sampler yielded two replicate samples, each of approximately 5-10 L. As such, only two deployments were required at each station.

Stations ST15, ST036, ST037and ST56 where sampling initially failed using the DVV or Day Grab were revisited on the *Roman Rebel* using a 0.1 $m^2$ mini-Hamon Grab after reviewing the seabed imagery to assess for suitable habitat for grab sampling (Plate 5). A single deployment of the mini-Hamon grab yielded a single sample of approximately 5-10 L at each station. As such, four grab deployments were required at each station, with the initial three sediment samples utilised for macrobenthic analysis and the fourth for PSD, chemical contaminant and eDNA analysis. Using this approach sediment samples collected with DVV, Day Grab or Hamon Grab were comparable and the full suite of analyses could be carried out.

On each vessel, the grab system was deployed and retrieved from the hydraulic 'A' frame on the aft deck using the deck mounted STR winch in a similar approach to the camera system deployment previously detailed.

To ensure consistency in sampling, grab samples were screened by the lead Environmental Scientist 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 (> 25 m).

At least three attempts were made at each station, with a further single attempt made approximately 50 m from the original sample station before a station was to be abandoned. No pooling of samples took place. If samples of less than 5 L were continually achieved, these samples would be retained and assessed to establish whether the sample volume was acceptable to allow subsequent analysis.

**Plate 4** Left: OEL's 0.1 $m^2$ Day grab sampler fastened to the aft deck of the *MV Situla*. Right: OEL's 0.2 $m^2$ DVV grab sampler being deployed as part of wet testing from the aft deck of the *MV Situla.*

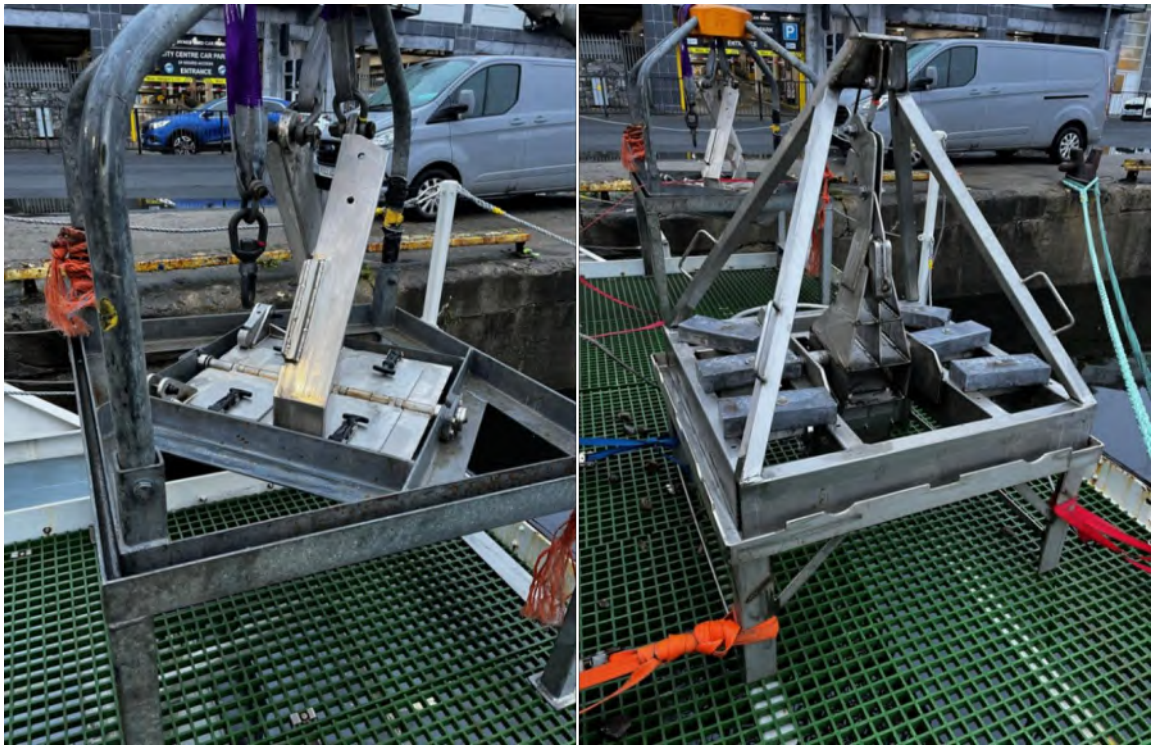

**Plate 5** Left: OEL's 0.2 $m^2$ Dual Van Veen grab sampler on the deck of the *MV Roman Rebel*. Right: OEL's 0.2 $m^2$ mini-Hamon grab sampler, mobilised as a redundancy sampler.

Initial grab sample processing of 'A', 'B' and 'C' replicate grabs for macrobenthos 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 unreleased sample with station details and scale bar.
- The sample was released into a bucket and a photo was taken of the released sample with station details and scale bar.
- The sample was emptied onto a 1.0 mm sieve net laid over a 4.0 mm sieve table and washed through using gentle rinsing with a seawater hose. The sample was photographed post-sieving.
- The 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 were taken including station number, fix number, number of attempts, sample volume, sediment type, conspicuous fauna, any sign of protected features, and water depth.

Initial grab sample processing of 'D' replicate grabs for chemical contaminants, PSD, TOC and sediment eDNA was undertaken onboard the survey vessel in line with the following methodology:

- Initial visual assessment of sample size and acceptability made.
- Inspection cover lifted and a photograph of the full unreleased sample with station details and scale bar taken.
- General assessment of sample size and acceptability made, ensuring sediment surface was undisturbed and no obvious sign of contamination.
- A 'primary' sub-sample of sediment decanted into the appropriate sample containers provided by the laboratory and frozen immediately at -20°C in an onboard freezer. A second 'back-up' sub-sample taken from the remaining sediment following the same process and retained in case of requirement for re-analysis or in the event of any primary subsamples becoming compromised during transit / storage prior to analysis.
- The containers were acid cleaned and solvent-rinsed before use, sealed with a foil liner where appropriate and tightened appropriately to avoid potential loss of determinands, contamination of samples, or both. A temperature of 25°C was not to be exceeded at any stage of storage or transportation.
- From the remaining sediment sample approximately 40 ml of sediment was collected and transferred into a falcon tube using a spatula that has been rinsed with diluted bleach solution and then rinsed twice with distilled water. Any excess water was carefully poured off and the tube lid closed.
- The above was repeated two more times ensuring the three replicates were evenly spaced across the sample surface (middle and sides of the grab bucket) and that no visible organisms were collected. The three falcon tubes were then placed into a labelled and

sealed zip lock bag, with excess air expelled. The zip lock bag containing the samples was frozen immediately at -20°C in an onboard freezer and subsequently transferred to an ultra-lower temperature freezer (maintained at -80°C or below) upon return to the laboratory.

- Of the remaining sample, 500 - 750 ml was removed for PSD analysis and transferred to a labelled tray.

## 5.6. Water Sampling

Water samples were taken at 2 m above the seabed and 2 m below the surface using a 5 L Niskin bottle attached to the deployment cable using bulldog clips and friction tape. Sampling depth was determined using the live depth measurements received from the USBL. When the equipment was at the desired depth a messenger weight was attached to the deployment wire and sent to trip the sampler. Sufficient time was allowed for this to travel to the sampler, depending on water depth. When the equipment reached the surface, it was recovered to deck and the sampler removed. Two water samples (A replicate for analysis and backup B replicate) were collected from each sampled water depth.

Once the Niskin bottle was recovered to deck the water samples were decanted into pre-labelled 1 L plastic sample bottles and the sample frozen immediately at -20°C in an onboard freezer, samples were kept frozen until transfer to the analysis laboratory.

## 5.7. Water eDNA Sampling

At each station, water eDNA samples were taken at 2 m above the seabed, mid-water depth and 2 m below the surface using a 5 L Niskin bottle attached to the deployment cable using bulldog clips and friction tape. Sampling depth was determined using the live depth measurements received from the USBL. When the equipment was at the desired depth a messenger weight was attached to the deployment wire and sent to trip the sampler. Sufficient time was allowed for this to travel to the sampler, depending on water depth. When the equipment reached the surface, it was recovered to deck and the sampler removed. A single water eDNA sample was collected from each sampled water depth.

For each replicate, a Vampire Pump was attached to the outlet of the Niskin bottle and eDNA sample processed as follows:

- Pump run slowly by pressing the drive unit trigger slowly to fill the hose with water.
- When the hose was filled, filter inlet attached to hose adaptor.
- Pump run slowly to begin with.
- When the flow of water leaving the filter outlet (wide end) slowed, pump speed decreased to reduce the build-up of pressure.
- Once all water had passed through the filter, or the filter was fully clogged, hose removed and all water drained from hose. Pump continued to run until no more water exited from the filter. Filter detached from hose.

Preservative solution was applied to the filer and the filter then placed into the specimen bag and sample frozen immediately at -20°C in an onboard freezer and subsequently transferred to an ultra-lower temperature freezer (maintained at -80°C or below) upon return to the laboratory.

# 6. Laboratory and Analytical Methods

## 6.1. Seabed Imagery Analysis

All seabed imagery analysis was undertaken using the Bio-Image Indexing and Graphical Labelling Environment (BIIGLE) annotation platform (Langenkämper et al., 2017) and in consideration of the latest Marine Biological Analytical Quality Control (NMBAQC)/JNCC Epibiota Quality Assurance Framework (QAF) guidance and identification protocols available on the NMBAQC website. Analysis of still images was undertaken in two stages. The first stage, "Tier 1", consisted of labels that refer to the whole image being assigned providing appropriate metadata for the image including EUNIS habitat classifications assigned in line with (Parry, 2019). The second stage, "Tier 2", was used for enumerating epibiotal abundance and cover within each image and to assign percentage cover of reef types.

A full reef habitat assessment (HA) was conducted on all DDC imagery to determine whether habitats met the definitions of Annex I reef habitats as detailed in Table 7, Table 8 and Table 9. The latest JNCC guidance on the characterisation of 'low resemblance' Annex I stony reef (Golding et al., 2020) and *Modiolus* reef (Morris, 2015) were also considered.

The annotation label tree used during analysis contained major headings for each of the reef types. Under each reef type, labels were assigned for each of the categories required to determine whether Annex I reef habitat was present (Table 7, Table 8 and Table 9).

**Table 7** 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 8** 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 |

**Table 9** Characteristics of *Modiolus modiolus* reef/ beds (Morris, 2015).

| Characteristic | 'Reefiness' | | | |
|---|---|---|---|---|
| | Not a bed | Unlikely | Medium | High |
| Presence of live adults | No | Yes | 5 – 10 | > 10 |
| Biota/community distinct from surrounding habitat | No | Yes | Yes | Yes |
| Extent ($m^2$) | < 25 | >25 | >25 | >25 |
| Patchiness (% Cover) -open coast | 0 | <30 | 30-70 | 70-100 |
| Patchiness (% Cover) -sheltered/semi-enclosed | 0 | <5 | 5-40 | >40 |
| Elevation* | NA | None | Low Relief | High Relief |

*Note that the elevation of sheltered communities will be elevated in all instances

### 6.1.1. Tier 1 Analysis

The first stage, "Tier 1", consisted of assigning labels that referred to the whole image, providing appropriate metadata for the image. Metadata "Image Labels" include:

- Broadscale Habitat (BSH) type.
- Substrate type (and percentage cover in 10% intervals).
- Bedforms present.
- The presence of any Annex I habitats.
- Image quality categories (including "Not Analysable" category).

Depending on the presence of reef, this also included:

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

### 6.1.2. Tier 2 Analysis

The second stage, "Tier 2", was used to assess epibiotal abundance data as "annotations" within each image for all visible flora and fauna. This was undertaken as follows:

- Using the BIIGLE Annotation Platform, (detailed below) enumeration of all visible taxa was undertaken using points for enumerable "count" taxa and polygons for ground-covering taxa; to enable calculation of percentage cover for these taxa.
- Where an individual of a "count" taxon overlay a ground-cover taxon, then this individual was still counted (i.e., a point annotation was added for the count taxa over the polygon of the ground-cover taxon).

The substratum observed in each still image was recorded as a percentage cover of CATAMI (Althaus et al., 2015) substratum types where possible. Determination of sediment type (such as

coarse, mixed, sand etc.) was facilitated using the adapted Folk sediment trigon (Long, 2006) incorporated into a sediment category correlation table. Percentage cover of the different substrate types was used to determine and assign EUNIS codes and BSH.

### 6.1.3. Maerl Beds Assessment

A maerl bed assessment was conducted on seabed imagery where maerl was identified using the system recently developed by Natural England (NE) for categorising maerl habitats in England (Axelsson, 2021) (Table 10). Using this maerl classification system, labels were assigned to images with maerl to assign category types as follows:

- Physical size (either ≥ 25, <25, patchy, sparse or scattered)
- Structure (3D with depth equal to or greater than 10 cm, 3D with depth less than 10 cm or 2D)
- Underlying substratum (rock, sediment or maerl)
- % cover live maerl (< 1, ≥ 1, ≥ 20 or 0)
- % cover dead maerl (< 1, ≥ 1, ≥ 5, ≥ 20 or 0).

Physical size of maerl beds was determined based on a combined analysis of video footage and consecutive images for DDC transects or images taken at a DDC station. An image assigned a physical size of, for example, ≥ 25 $m^2$ is a representative snapshot of a wider maerl bed that fulfils this physical size.

**Table 10** Categories of maerl bed habitats in England (Axelsson, 2021).

| Category | Group | Maerl bed habitat | Physical size | Structure | % Cover | Live/dead* | Substratum |
|---|---|---|---|---|---|---|---|
| A | 1 | **Dense Maerl** 'live & dead' | ≥25m$^2$ | 3D; raised; ≥10cm depth | ≥20% | ≥5% live | Maerl |
| | 2 | **Dense Maerl** 'dead' | ≥25m$^2$ | 3D; raised; ≥10cm depth | ≥20% | 0% live ≥20% dead | Maerl |
| | 3 | **Dense Maerl** 'live & dead' | <25m$^2$ | 3D; raised; ≥10cm depth | ≥20% | ≥5% live | Maerl |
| B | 1 | **Maerl Sediment** 'live and dead' | ≥25m$^2$ | 3D / 2D | ≥5% ≤20% | 5% Live and dead | Gravel, sand, mud, mixed |
| | 2 | **Maerl Sediment** 'dead' | ≥25m$^2$ | 2D | ≥5% ≤20% | Dead | Gravel, sand, mud, mixed |
| | 3 | **Maerl Sediment** 'live and dead' | Patchy | 2D | ≥5% ≤20% | Dead | Gravel, sand, mud, mixed |
| C | 1 | **Sparse Maerl** 'live and dead' | Sparse | 2D | <5% ≥1% | Live and/or dead | Gravel, sand, mud, mixed |
| | 2 | **Scattered Maerl** 'live and dead' | Scattered | 2D | <1% | Live and/or dead | Gravel, sand, mud, mixed |
| D | 1 | **Maerl Veneer** Live and dead, static | ≥25m$^2$ | 2D | ≥20% | ≥5% live | Rock |
| | 2 | **Maerl Veneer** | ≥25m$^2$ | 2D | ≥20% | ≥5% live | Rock |

| Category | Group | Maerl bed habitat | Physical size | Structure | % Cover | Live/dead* | Substratum |
|---|---|---|---|---|---|---|---|
| | | Live and dead, mobile | | | | | |
| | 3 | **Maerl Veneer** 'live and dead, static' | patchy | 2D | ≥5% ≤20% | ≥5% live | Rock |
| E | 1 | **Potential Maerl** *Lithothamnion* sp. Or *Phymatolithon* sp. | Lacking detail | | Lacking detail | Live and/or dead | Any suitable, near horizontal |

## 6.2. 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, 2022).

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 11.

**Table 11** 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 v9.1 software.

Sediment descriptions are defined by their size class based on the Wentworth classification system (Wentworth, 1922). 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 12** 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 |

## 6.3. Chemical Contaminants Analysis

All sediment chemical contaminant analysis was undertaken by SOCOTEC who are validated by the Marine Management Organisation (MMO) for conducting chemical analysis of sediments for marine licencing purposes. Sediment samples were processed and analysed for Total Hydrocarbon Content (THC), Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), organotins, Organochlorine Pesticides (OCPs) and Heavy and Trace Metals. A description of the methods used to test for each chemical determinand is provided in Table 13.

Where available, chemical contaminants were compared to the OSPAR Background Assessment Concentration (BAC) (OSPAR, 2009), the USA Environmental Protection Agency (EPA) Effect Range Low (ERL) (NJDEP, 2009), Marine Institute Ireland Lower and Upper Level (Cronin et al., 2006 as per 2019 addendum), and the Canadian sediment quality guideline (CSQG) Threshold Effect Level (TEL) and Probable Effect Level (PEL) (CCME, 2001). To note that ERL, TEL and PEL are based on field research programmes based on North American data that have demonstrated associations between chemicals and biological effects by establishing cause and effect relationships in particular organisms (CCME, 2001). This means they provide a measure of environmental toxicity compared to the other reference levels which instead provide information on the degree of contamination of the sediments. At levels above the TEL, adverse effects may occasionally occur, whilst at levels above the PEL, adverse effects may occur frequently; concentrations below the ERL rarely cause adverse effects in marine organisms. Additionally, the TEL has been adopted as the International Sediment Quality Guideline (ISQG) (CCME, 2001), while ERL has been adopted by OSPAR to assess the ecological significance of contaminant concentrations in sediments, where concentrations below the ERL rarely cause adverse effects in marine organisms. For these reasons ERL, TEL and PEL are presented here as reference values despite being based on North American data.

BACs were developed to assess the status of contaminant concentrations in sediment within the OSPAR framework with concentrations significantly below the BAC considered to be near background levels for the North-East Atlantic. Irish Marine Institute levels are used as an approach to assessing dredged material and its suitability for disposal to sea (Cronin et al., 2006 as per 2019 addendum). The lower level is the concentration of contaminant within a sediment below which biological effects would not be anticipated. The upper level is the level above which, contaminants are likely to have a biological effect (Cronin et al., 2006 as per 2019 addendum).

**Table 13** Chemical contaminant analysis methods.

| Determinand | Limit of Detection (LoD) | Method/ Instrument |
|---|---|---|
| Metals Suite (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn) | 0.01-2mg/kg | Aqua-regia extraction & ICP-MS |
| Organotins DBT, TBT) | 0.001 mg/kg | Acid digest and solvent extraction GC-MS |
| PAHs (EPA 16) | 1µg/kg | Solvent extraction & GC-MS |
| Total Hydrocarbon Content | 1mg/kg | Solvent Extraction & GC-FID |
| PCBs (25 congeners inc. ICES 7) | 0.00008mg/kg | Solvent extraction & GC Triple Quad |

### 6.3.1. TOC Analysis

TOC was determined by Loss on Ignition (LOI) analysis as per the following process.

- Samples were transferred to aluminium trays, homogenised by hand and dried in an oven at 100° C for 24 hours.
- A sample of dried sediment was then placed in a mortar and pestle and ground down to a fine powder.
- 1 g of this ground sediment was weighed into a pre-weighed crucible and placed in a muffle furnace at 450° C for a period of 6 hours.
- The sediment samples were then allowed to cool in a desiccator for 1 hour before being weighed again.
- The organic carbon content of the sample was determined by expressing as a percentage of the weight of the sediment after ignition over the initial weight of the sediment.

### 6.3.2. Heavy and Trace Metals

A total of 10 main heavy and trace metals were analysed from sediments taken across the survey area. These were Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), Zinc (Zn), Aluminium (Al) and Lithium (Li).

### 6.3.3. Hydrocarbons

Indices and ratios were calculated to assess source origin of hydrocarbons in the sediment sampled across the survey area. Generally, there are three sources of hydrocarbons depending on their origin: biogenic, petrogenic and pyrogenic. Hydrocarbons of biogenic origin are the produce of biological processes or early diagenesis in marine sediments (e.g., perylene) (Junttila et al., 2015; Venkatesan, 1988). Hydrocarbons of petrogenic origin are the compounds present in oil and some oil products following low to moderate temperature diagenesis of organic matter in sediments

resulting in fossil fuels. Hydrocarbons of pyrogenic origin are the product of incomplete combustion of organic material (Fagbote, 2013), such as forest fires and incomplete combustion of fossil fuels.

Based on PAH compounds the following ratios were calculated as follows:

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

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

## 6.4. Water Sample Analysis

All water quality analysis was undertaken by SOCOTEC, in accordance with the methods of (Grasshoff et al., 1999). A description of the methods used to test for each determinand is provided in Table 14.

**Table 14** Water quality sample analysis methods.

| Water Analysis | LoD | Standard Analysis Methodology |
|---|---|---|
| Dissolved inorganic nutrients including Nitrate, Nitrite, Ammoniacal Nitrogen, Chloride, Phosphate | Nitrate(0.2), Nitrite(0.01), Ammoniacal Nitrogen(0.01), Chloride(1), Phosphate(0.03) mg/l | Automated discrete colorimetric analysis using KONE analyser |
| Total Alkalinity | 2mg/l | Titration with Sulphuric Acid to required pH |
| Total Organic Carbon* | 0.4mg/l | Acid persulphate oxidation |

* Instead of dissolved inorganic carbon (DIC).

## 6.5. Environmental DNA

eDNA extraction and analysis was conducted by industry specialists Nature Metrics.

### 6.5.1. Metabarcoding

**Water eDNA**

Two metabarcoding assays for the water samples were employed and aimed at detecting the full breadth of marine vertebrates present across the survey area including fish (excluding sharks and rays), marine mammal and marine bird species.

DNA from each filter was extracted using a commercial DNA extraction kit with a protocol modified to increase DNA yields. An extraction blank was also processed for the extraction batch. DNA was purified to remove PCR inhibitors using a commercial purification kit. Purified DNAs were amplified with PCR for a hypervariable region of the 12S rRNA gene to target fish species.

A standard analysis, including 12 replicate PCRs per sample was performed. All PCRs were performed in the presence of both a negative control and a positive control sample (a mock community with a known composition). Amplification success was determined by gel electrophoresis. PCR replicates were pooled and purified, and sequencing adapters were added. Success was determined by gel electrophoresis. Amplicons were then purified and checked again by gel electrophoresis; these were then quantified using a Qubit high sensitivity kit according to the manufacturer's protocol.

All purified index PCRs were pooled into a final library with equal concentrations. The final library was sequenced using an Illumina MiSeq V3 kit at 10.5 pM with a 20% PhiX spike inside. Sequence data was processed using a custom bioinformatics pipeline for quality filtering, Operational Taxonomic Units (OUT) clustering, and taxonomic assignment.

**Sediment eDNA**

Two metabarcoding assays for sediment samples were employed: eukaryotes and invertebrates.

Following removal of buffer, sediments were rinsed with 10X phosphate buffered saline (PBS), homogenised, and DNA was extracted from approximately 10g of the resulting homogenate. A negative control was processed with each batch of samples to monitor for exogenous DNA contamination. Extraction yields were checked by measuring DNA concentration using a Qubit fluorometer with the Qubit dsDNA broad range assay kit.

Replicate PCRs for each sample and extraction blank were amplified via a two-step PCR process, amplification was performed with a commercially available Hot Start DNA polymerase targeting the mitochondrially encoded Cytochrome c oxidase subunit I (mt-COI) gene for invertebrates and the 18S ribosomal RNA (18S rRNA) gene for eukaryotes.

### 6.5.2. Bioinformatics

Sequence data was processed using a custom bioinformatics protocol for quality filtering, Operational Taxonomic Unit (OTU) clustering (97 %) and taxonomic assignment. Similar sequences were clustered into an OTU at a defined similarity threshold and these units were approximately equivalent to species and treated as such in analyses. Taxonomic assignments were not always possible, as this depends on the availability of reference sequences and the similarity between closely related species in the amplified marker.

The Global Biodiversity Information Facility (GBIF) taxonomic backbone was used for consistency between databases. Results from both searches were combined and assignments made to the lowest possible taxonomic level where there was consistency in the matches. Conflicts were flagged and resolved manually. Minimum similarity thresholds of 98 %, 95 %, and 92 % were required for species, genus, and higher-level assignments respectively. Any identifications that were based on fewer than three reference matches were also flagged.

## 6.6. Macrobenthic Analysis

All elutriation, extraction, identification, and enumeration were undertaken at OEL's NE Atlantic NMBAQC scheme participating laboratory in line with the NMBAQC Processing Requirement Protocol (Worsfold & Hall, 2010). All processing information and macrobenthic records was recorded using OEL's cloud-based data management application ABACUS that employs 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 fauna present was identified to species level, where possible, and enumerated by trained benthic taxonomists using the most up to date taxonomic literature and checks against existing reference collections. Nomenclature utilised the live link within ABACUS to the 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 was given the numerical value of 1. A full reference collection was retained including at least one example specimen of each taxon.

Biomass was then measured as blotted wet weight in grams to at least 4 decimal places for all countable taxa 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).

The conversion factors applied are as follows:

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

### 6.6.1. Data Truncation and Standardisation

The macrobenthic taxon 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.

### 6.6.2. Pre-Analysis Data Treatment

All data were collated in excel spreadsheets and made suitable for statistical analysis. All data processing and statistical analysis was undertaken using R v 1.2 1335 (R Core Team, 2022) and PRIMER v7 (K. R. Clarke & Gorley, 2015) software packages.

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) 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 the family *Ophiuridae, Amphiuridae* and the heart urchin *Spatangoida* appeared in the top ten of the most dominant taxa across both survey areas, a 2STAGE analysis was conducted to compare the two data sets (with and without juveniles) which revealed a high level of similarity (99 % for array and 98 % for ECR) between the two and therefore juveniles were retained in the dataset for all further analyses and discussion.

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.

### 6.6.3. Univariate Statistics

For calculation of univariate statistics, the full range of replicates samples was utilised without averaging by station. Abundance, Diversity and Biomass metrics were then averaged by station to assess within station variability expressed as standard error (SE). Large SEs would indicate significant changes in metrics between replicate samples and therefore a rather different macrobenthic community between replicate samples from the same station. In contrast, a small SE would indicate the presence of a more homogeneous macrobenthic community between replicate samples from the same station.

### 6.6.4. Multivariate Statistics

Prior to multivariate analyses, data were displayed as a shade plot with linear grey-scale intensity proportional to macrobenthic abundance to determine the most efficient pre-treatment (transformation) method. Considering the relatively high SE on average abundance data by station, the best pre-treatment transformation method was deemed to be dispersion weighting to account for the contribution of common and rare taxa in replicate samples from the same station, whilst allowing the underlying community structure to be assessed (K. Clarke et al., 2006). To note abundance data was not averaged by station but all replicate samples were included in the analysis and dispersion weighting applied to raw abundance data.

The PRIMER v7 software package (K. R. 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.

### 6.6.5. Determining EUNIS Classifications

Sampling stations were grouped based on their macrobenthic assemblage composition using hierarchical clustering; the SIMPER routine was then applied to identify key and characterising taxa that contributed the most to the similarity within each group. EUNIS classifications were then assigned to each sampling station based on their macrobenthic group and key, characterising taxa as well as based on their sediment type and composition following the latest JNCC guidance (Parry, 2019).

## 6.7. Habitat Mapping

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 BSH and biotope assignments derived from the PSD analysis and macrobenthos multivariate analysis, alongside existing habitat maps (EMODnet) and acoustic data interpretation. Seabed features were assigned to the most accurate classification possible.

Polygons were drawn around each feature (habitat/biotope) visible in the acoustic data and assigned a EUNIS classification on consideration of the following :

- Existing habitat mapping (derived from EMODnet);
- Review and interpretation of geophysical data; and
- Seabed imagery.
- PSA and Multivariate analysis of macrobenthic data

Confidence scores were assigned to all polygons to give an indication of their accuracy. Values ranged from low (single data source) to high (multiple data sources) depending on the following:

- Whether ground-truth data (seabed imagery and grab samples) was available within the polygon
- Whether multiple data sources confirmed/suggested the presence of the same habitat/biotope within a polygon
- Whether the boundaries of the habitat/biotope were clearly defined either by seabed imagery or acoustic data.

When confidence was low, polygons were drawn based upon expert judgement, given the information available.

All mapping processes were conducted in ESRI ArcPro Version 3.1.2.

# 7. Results

Digital photographic stills and video footage were successfully obtained at all 65 targeted DDC stations and were reviewed *in situ* to assess for the presence of protected or sensitive habitats (e.g., Annex I reef features), and suitability for grab sampling. Furthermore, all the 36 targeted DDC transects were completed successfully.

Fifty-eight of the 65 proposed grab stations were successfully sampled, most of which were obtained within a maximum of three attempts, with all sample volumes > 5 L. Four of the seven stations at which a grab sample was not obtained were assessed as not being suitable for grab sampling due to the identification of potential Annex I geogenic reef features in the pre-screening of DDC imagery (ST016, ST025, ST034, ST055). At the remaining three stations (ST02, ST08, ST038), it was not possible to obtain grab samples due to the jaws failing to close fully because of the presence of pebbles/cobbles in the samples despite having attempted sampling using a Day grab, DVV grab and a mini-Hamon grab.

Three DDC/grab stations were re-positioned during the survey with the permission of the client due to water depths at the target locations being unsuitable for sampling from the MV *Situla* or *Roman Rebel*. These were DDC/grab stations ST010 and ST019, and camera transect T020 (with the new target named T036). The decision was made to reposition these stations due to their close proximity to exposed rocks.

Water samples for chemical analysis and water eDNA sampling were successfully collected at all of the proposed stations. Water sampling station ST019 was also repositioned as above.

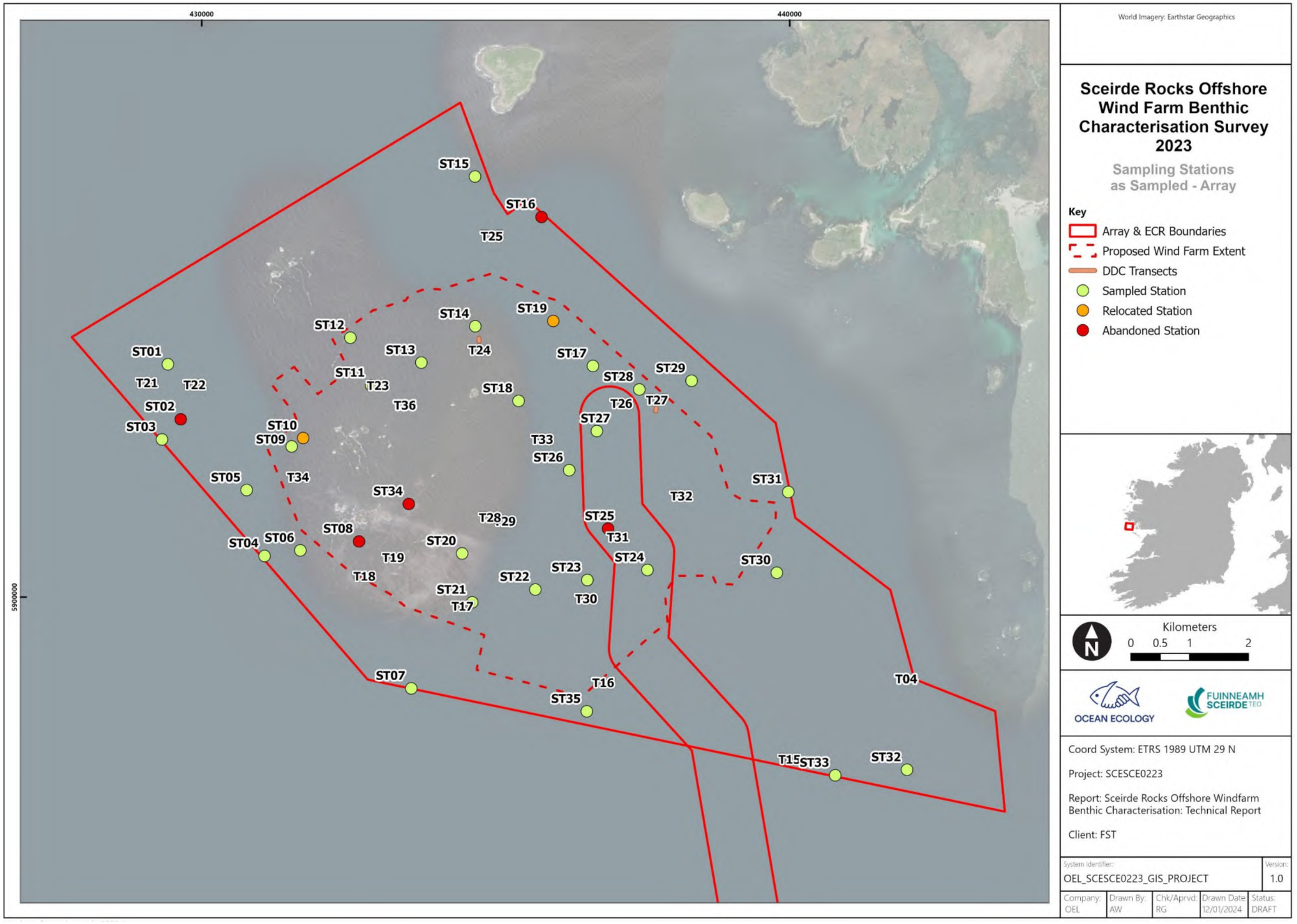


**Figure 9** Abandoned and relocated sampling stations (array).

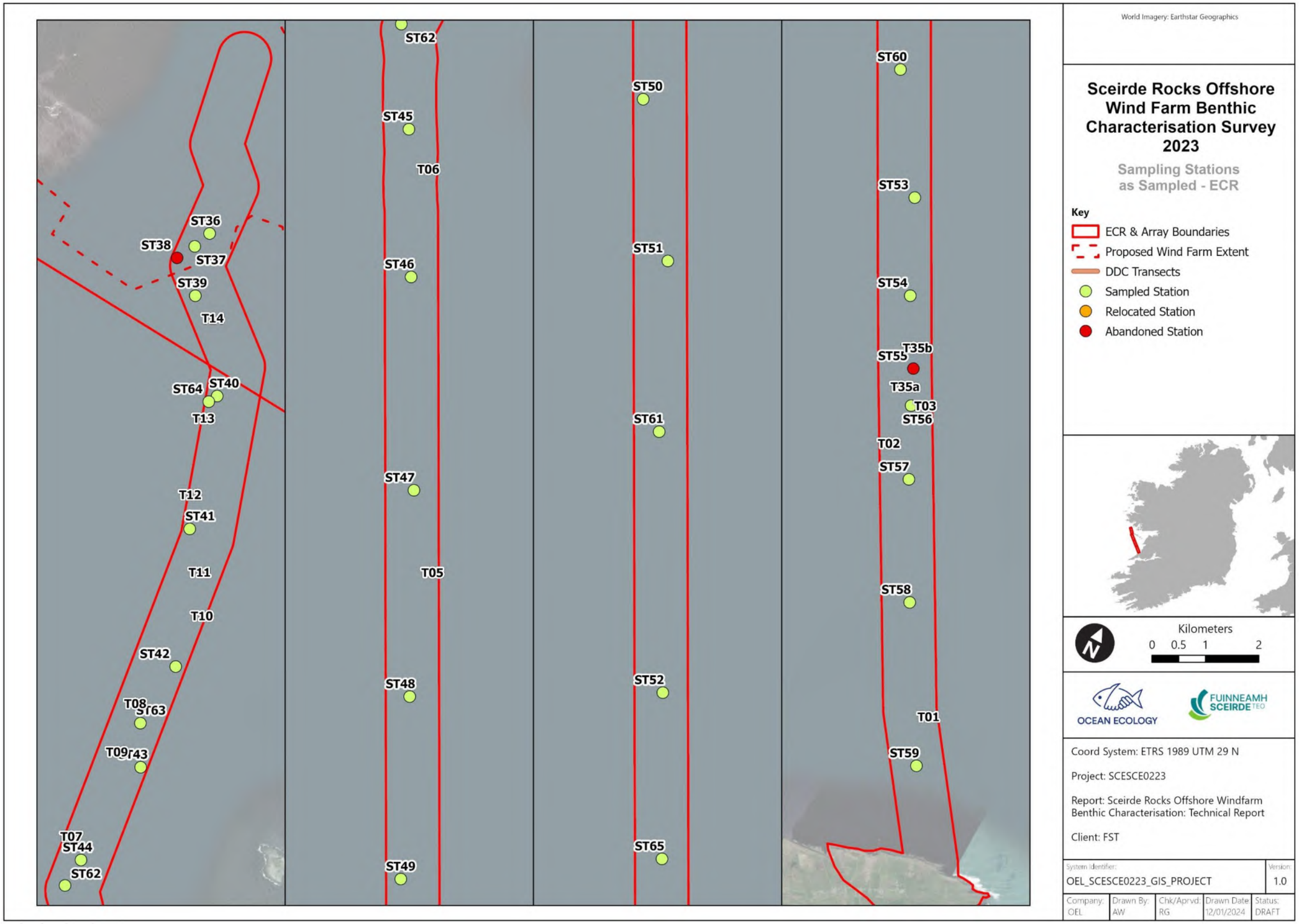


**Figure 10** Abandoned and relocated sampling stations (ECR).

## 7.1. Geophysical Data

SSS and MBES data were collected by EGS International Ltd. during the 2022 geophysical campaign covering the array and ECR survey areas. Additional bathymetry data were also sourced from INFOMAR to improve coverage along the ECR. These data were interpreted together with the seabed imagery and sediment and macrobenthos data to inform the seabed habitat assessment and mapping process (Figure 11, Figure 12, Figure 13 and Figure 14).

Within the array, SSS data suggested that most of the survey area was characterised by rocky substrates as indicated by a generally higher reflectivity signature and visibly rough surface. This was interspersed with areas of sand and silty sand represented by lower reflectivity and smoother surface. The northernmost section of the ECR, where it intersects the array, and the region immediately south of this, was characterized by higher reflectivity signatures and a distinctly rough surface indicative of rocky substrate. Moving southward, the majority of the ECR displayed generally lower reflectivity signatures suggesting the presence of silty sands. Along the length of the ECR there were two distinct features present in the SSS data: one displaying a reflectivity signature indicative of sands and another suggesting the presence of sand and gravels (Figure 11 and Figure 13). To note that while SSS data covered the full extent of the ECR it did not fully cover the array area extent but only the proposed wind farm extent (Figure 11).

Bathymetry data obtained within the array correlated with SSS data from the same area and showed potential rocky substrate with depths as low as 2 m within the middle and shoreward regions. Depth significantly increased at the seaward region of the array area to the south and southwest with depths dropping off sharply to a maximum of 86 m. Depths were relatively uniform along the length of the ECR, reaching a maximum of 100 m. Sharp gradients in depth were seen at each end of the route, where it intersects the array area and makes landfall in the south (Figure 12 and Figure 14).


**Figure 11** SSS data acquired during the 2022 geophysical campaign (array).

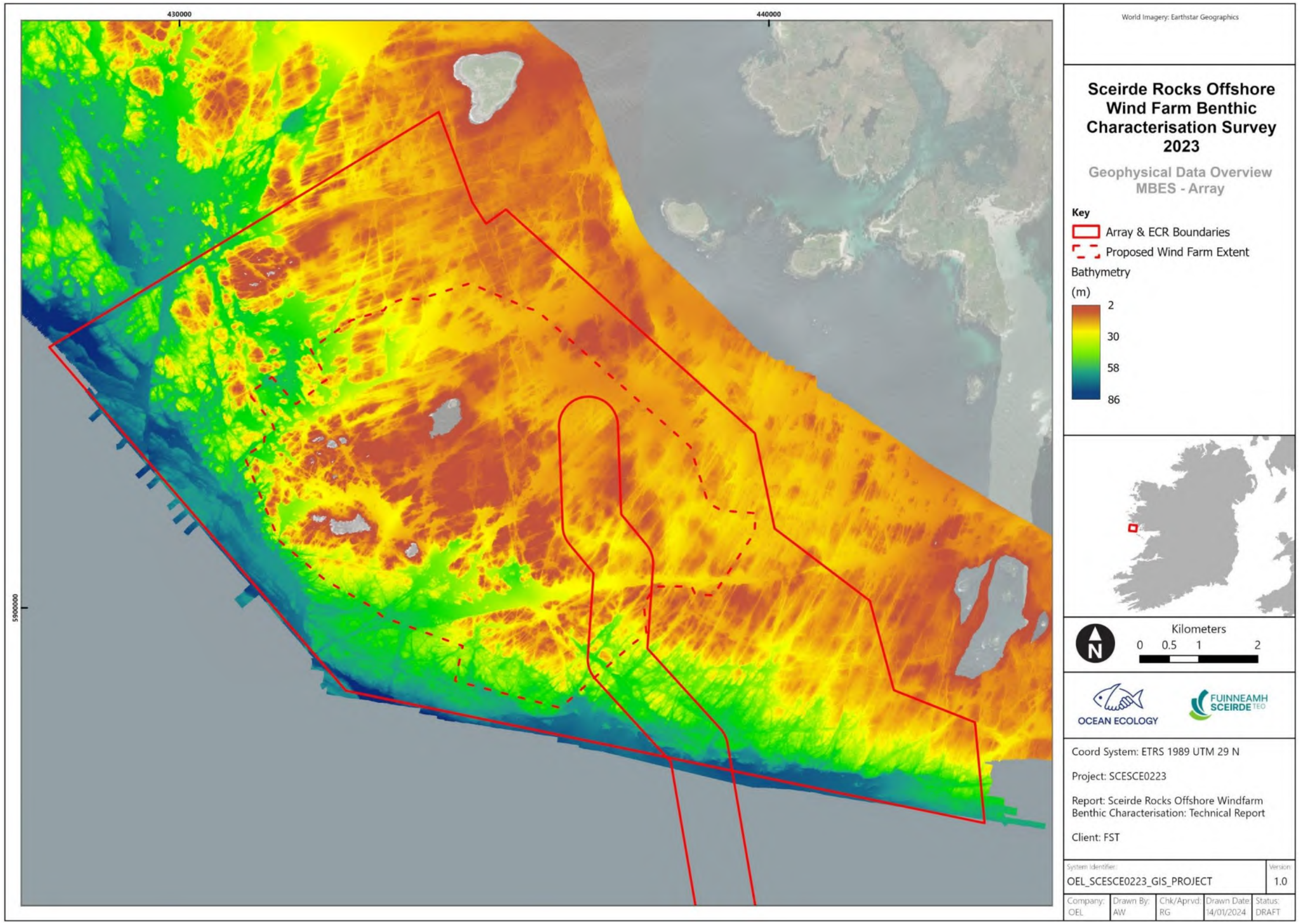


**Figure 12** MBES data acquired during the 2022 geophysical campaign (array).

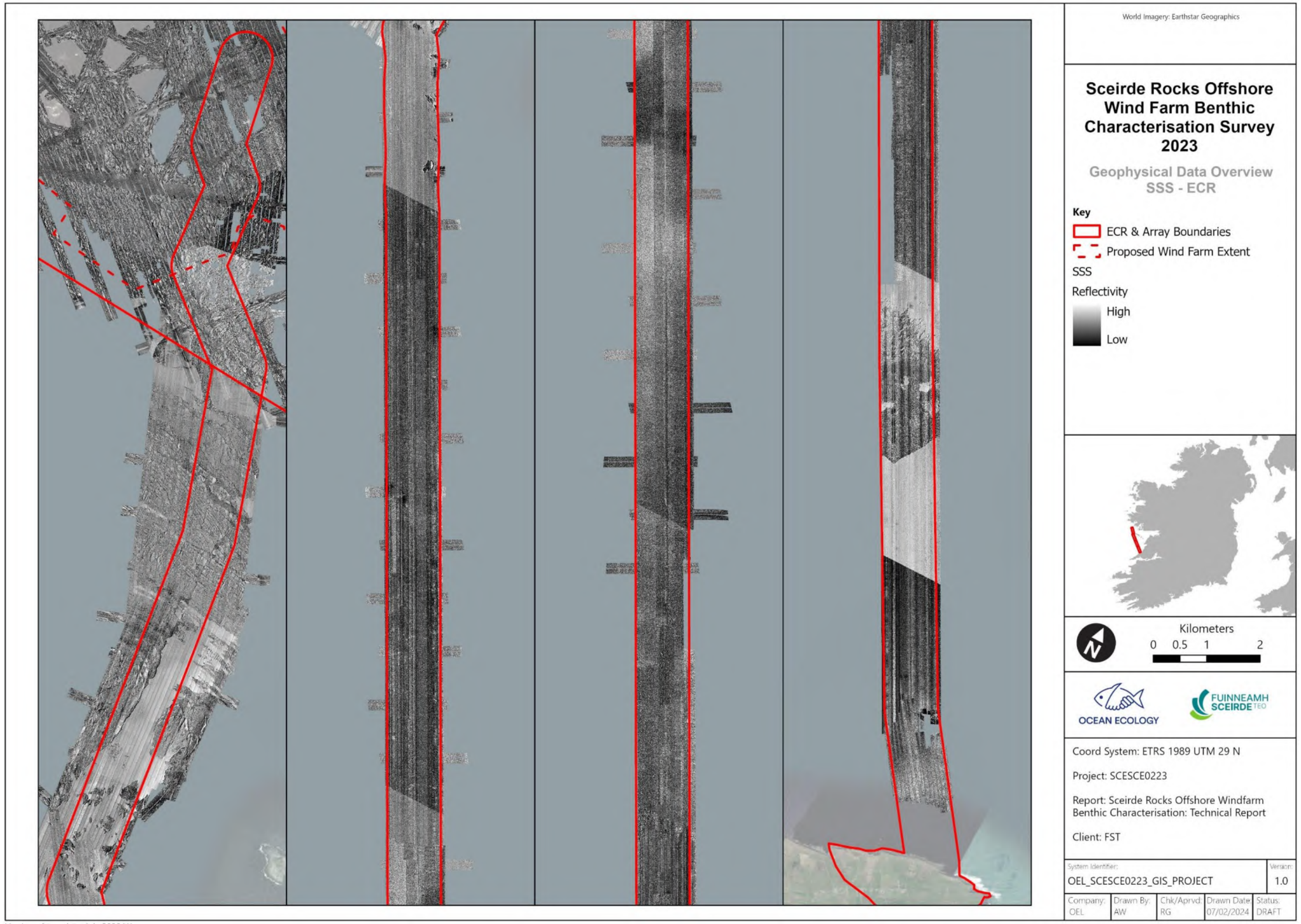


**Figure 13** SSS data acquired during the 2022 geophysical campaign (ECR).

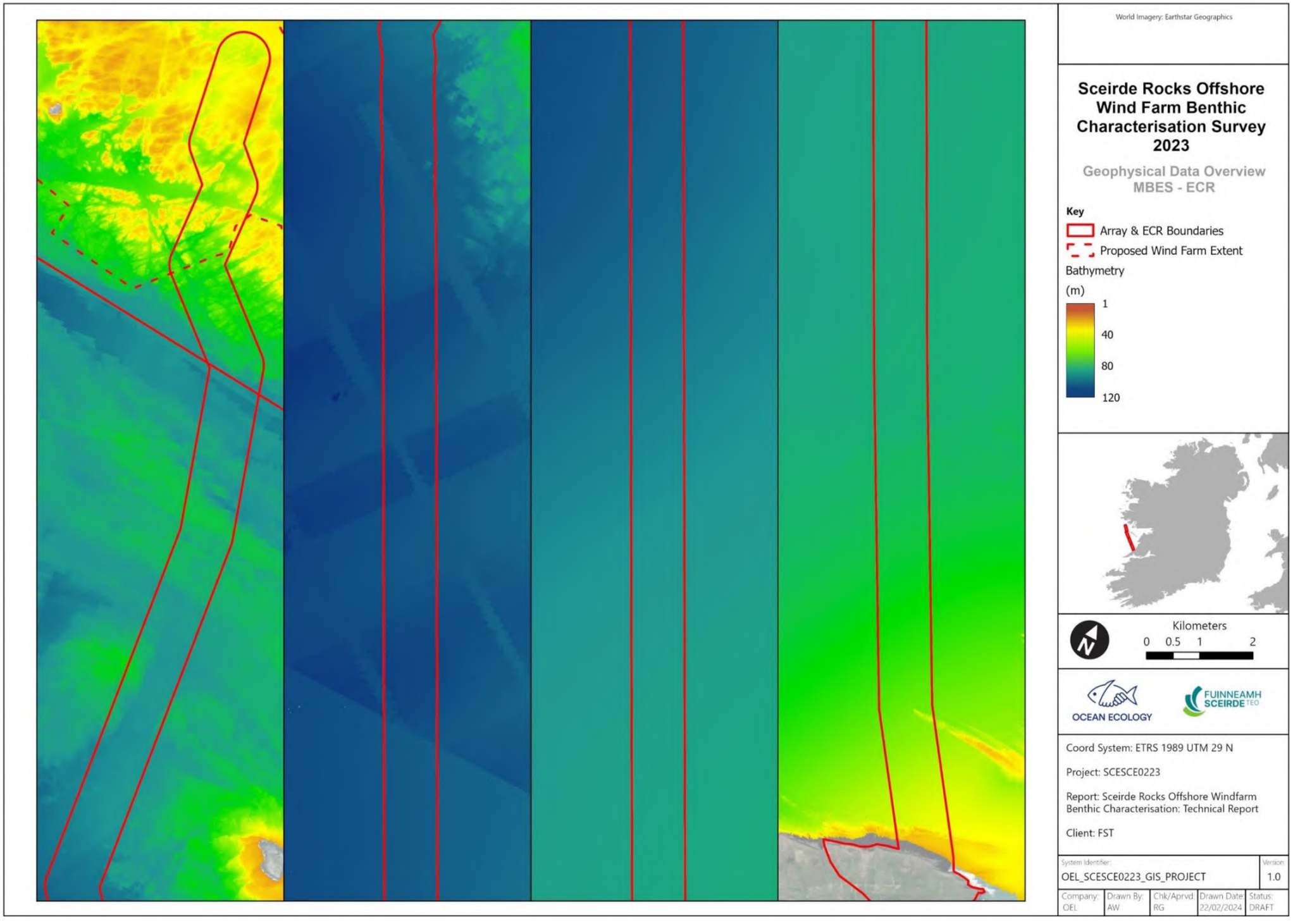


**Figure 14** MBES data acquired during the 2022 geophysical campaign (ECR) and sourced from INFOMAR.

## 7.2. Seabed Imagery

Digital photographic stills and video footage were successfully obtained at all 65 of the targeted DDC stations (grab station pre-screening aimed at targeting sediments) and all the 36 targeted DDC transects (within areas of rocky substrate and possible reef features) resulting in the collection of 780 still images and 119 videos. Full DDC still logs can be found in Appendix II and video logs in Appendix III. Seabed imagery analysis results are mapped in Figures 14 – 20. Findings of the image analysis including BSH description and the EUNIS habitat description are presented in Appendix IV. Full results of the Annex I reef assessment, carried out on all images collected across DDC stations and transects, can be found in Appendix V.

### 7.2.1. Stations

**Array**

At stations within the array area, a total of four EUNIS BSH, six EUNIS Level 4 habitats and two EUNIS Level 5 biotope complexes were identified in the seabed imagery. The most commonly encountered of these was A5.14 'Circalittoral coarse sediment' identified in 103 of the 177 images collected across stations within the array area followed by A5.15 'Deep circalittoral coarse sediment' identified in a further 31 images (Table 15).

Most of the centre and north of the array was identified as A5.14 'Circalittoral coarse sediment' with stations along the westernmost boundary (furthest offshore) identified as the deeper component of this habitat complex A5.15 'Deep circalittoral coarse sediment'. Interspersed within the coarse sediments in the centre of the array, the EUNIS level 5 habitat A4.214 'Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock' was observed at stations ST016 and ST025. Of conservation importance, the biotope complex A5.51 'Maerl beds' was also recorded in all images collected at station ST027 (Figure 15).

Fourteen of the images analysed at stations within the array were identified as meeting the requirements for low (11 images) and medium (three images) stony reef as outlined in (Irving, 2009) and Section 6.1 (Appendix V). The images were collected at stations ST016, ST025 and ST034 which were representative of the circalittoral rock biotope complex EUNIS A4.214 'Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock' at stations ST016 and S0T25 and of a stony reef area intersperse with circalittoral coarse sediments at station ST034.

The most common epifauna captured in the still imagery included tube worms of the family Serpulidae, cup corals and bivalves of the order Venerida.

**Table 15** EUNIS BSH and biotope complexes identified in seabed imagery collected at stations within the SROWF array area.

| BSH | EUNIS Code | EUNIS Description |
|---|---|---|
| A4.2 | A4.214 | Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock |
| A5.1 | A5.14 | Circalittoral coarse sediment |
| | A5.141 | *Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles |
| | A5.15 | Deep circalittoral coarse sediment |
| A5.2 | A5.25 | Circalittoral fine sand |
| | A5.27 | Deep circalittoral sand |
| | A5.37 | Deep circalittoral mud |
| A5.5 | A5.51 | Maerl beds |

**ECR**

At stations along the ECR, five EUNIS BSH, eight EUNIS Level 4 habitats, one EUNIS Level 5 and one EUNIS Level 6 biotope complexes were identified during seabed imagery analysis. The most common habitat type was A5.37 'Deep circalittoral mud', identified in 80 of the 153 images collected from stations along the SROWF ECR. The remaining images were identified as a wide range of habitat types including muddy, sandy, mixed and coarse sediments (Table 16).

Images collected from the northernmost region of the ECR, where it intersects the array area and just south of this, were identified as coarse sediments and sands representative of EUNIS habitats A5.14, A5.15 and A5.27, with one image collected from ST036 identified as the rocky biotope complex A4.2146 '*Caryophyllia smithii* with faunal and algal crusts on moderately wave-exposed circalittoral rock'. Most of the length of the ECR was identified as mud habitats representative of A5.37 'Deep circalittoral mud', whilst the southernmost region, where it approaches landfall, was identified as circalittoral mixed sediments, sandy mud and muddy sand representing A5.44, A5.26 and A5.35. Station ST055 in the southern region of the ECR was identified as a mosaic between the habitat complexes A4.214 and A5.44.

Six of the images analysed along the ECR met the requirements for low stony reef as outlined in (Irving, 2009) and summarise in Section 6.1. Five of these were collected at station ST055 and identified as the mosaic habitat of A4.214 and A5.44, while one image from ST036 was identified as biotope A4.2146 '*Caryophyllia smithii* with faunal and algal crusts on moderately wave-exposed circalittoral rock' (Table 16).

The most common epifauna captured in the still imagery included tube worms of the family Serpulidae which were recorded in 13 images. Faunal burrows were recorded in 45 images with stations ST047, ST048, ST049 and ST050 displaying burrows that could support the presence of sea pens and burrowing megafauna. Except for ST047 where the slender sea pen *Virgularia mirabilis* was noted in low density, no visible associated fauna was observed at any of the stations. For these stations to qualify as the OSPAR sea pen and burrowing megafauna habitat,

mud must be heavily bioturbated by burrows and conspicuous populations of sea pens must also be present which was not the case at the above-mentioned stations. One hundred and one images showed no visible epifauna.

**Table 16** EUNIS BSH and biotope complexes identified in seabed imagery collected at stations along the SROWF ECR.

| BSH | EUNIS Code | EUNIS Description |
|---|---|---|
| A4.2 | A4.214 | Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock |
| | A4.2146 | *Caryophyllia smithii* with faunal and algal crusts on moderately wave-exposed circalittoral rock |
| A5.1 | A5.14 | Circalittoral coarse sediment |
| | A5.15 | Deep circalittoral coarse sediment |
| A5.2 | A5.26 | Circalittoral muddy sand |
| | A5.27 | Deep circalittoral sand |
| A5.3 | A5.35 | Circalittoral sandy mud |
| | A5.37 | Deep circalittoral mud |
| A5.4 | A5.44 | Circalittoral mixed sediments |
| | A5.45 | Deep circalittoral mixed sediments |

### 7.2.2. Transects

**Array**

At DDC transects within the array area, a total of seven EUNIS BSHs, four EUNIS Level 4, 8 EUNIS Level 5 and two EUNIS Level 6 biotope complexes were recorded during seabed imagery analysis. The most commonly recorded habitat was A4.212 '*Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock' recorded in 66 of the 268 images obtained. This was closely followed by A3.116 'Foliose red seaweeds on exposed lower infralittoral rock', recorded in 53 images and A4.121 in 50 images (Table 17).

The majority of images collected along transects were described as rocky habitats of varying depths and varying epibenthic communities. Within the centre and shoreward region of the array area, where depths were generally shallower, infralittoral rock biotopes characterised by seaweeds were observed, such as A3.116 and A3.1161 (please see
Table 17 for full description). Additionally, the maerl bed biotope complex A5.511 was identified along transect T33. Transects in the offshore and deeper regions of the central array area were largely described as circalittoral rock habitats characterised by sponges and crustose communities. These included the EUNIS biotope complexes A4.121 and A4.212 (Figure 15, Figure 16, Figure 17, Figure 18, Figure 19 and Table 17). Along transects T30 and T34, a number of images were described as a mosaic between the circalittoral rocky biotope A4.212 characterised by sponge and crustose communities and the infralittoral rocky biotope A3.116 supporting red seaweed.

Of the 260 images obtained from transects within the array area, a total of 223 were identified as meeting the criteria for reefs as per (Irving, 2009) and Section 6.1. Of these, 158 were classified as bedrock occurring as both infralittoral and circalittoral rock habitats. Medium stony and low stony reefs (52 and two images respectively), as well as a mosaic between bedrock and medium stony reefs (11 images), were also recorded during imagery analysis. The spatial distribution of Annex I reef habitats across the array area is represented in Figure 20.

The most common epifauna captured along the transects locates within the array area were tube worms of the family Serpulidae and cup corals (*C. smithii*).

**Table 17** EUNIS BSH and biotope complexes identified in seabed imagery collected along transects within the SROWF array.

| BSH | EUNIS Code | EUNIS Description |
|---|---|---|
| A3.1 | A3.116 | Foliose red seaweeds on exposed lower infralittoral rock |
| | A3.1161 | Foliose red seaweeds with dense *Dictyota dichotoma* and/or *Dictyopteris membranacea* on exposed lower infralittoral rock |
| A3.7 | A3.716 | Coralline crusts in surge gullies and scoured infralittoral rock |
| A4.1 | A4.12 | Sponge communities on deep circalittoral rock |
| | A4.121 | *Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock |
| | A4.139 | Sponges and anemones on vertical circalittoral bedrock |
| A4.2 | - | Atlantic and Mediterranean moderate energy circalittoral rock |
| | A4.21 | Echinoderms and crustose communities on circalittoral rock |
| | A4.212 | *Caryophyllia smithii,* sponges and crustose communities on wave-exposed circalittoral rock |
| | A4.214 | Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock |
| | A4.2146 | *Caryophyllia smithii* with faunal and algal crusts on moderately wave-exposed circalittoral rock |
| | A4.215 | *Alcyonium digitatum* and faunal crust communities on vertical circalittoral bedrock |
| A5.1 | A5.14 | Circalittoral coarse sediment |
| | A5.15 | Deep circalittoral coarse sediment |
| A5.2 | A5.25 | Circalittoral fine sand |
| A5.5 | A5.511 - | *Phymatolithon calcareum* maerl beds in infralittoral clean gravel or coarse sand |


**Figure 15** EUNIS classifications derived from seabed imagery collected from stations across the SROWF array survey area. Pie charts indicate the percentage of images at each station that fell into each of the EUNIS classifications.

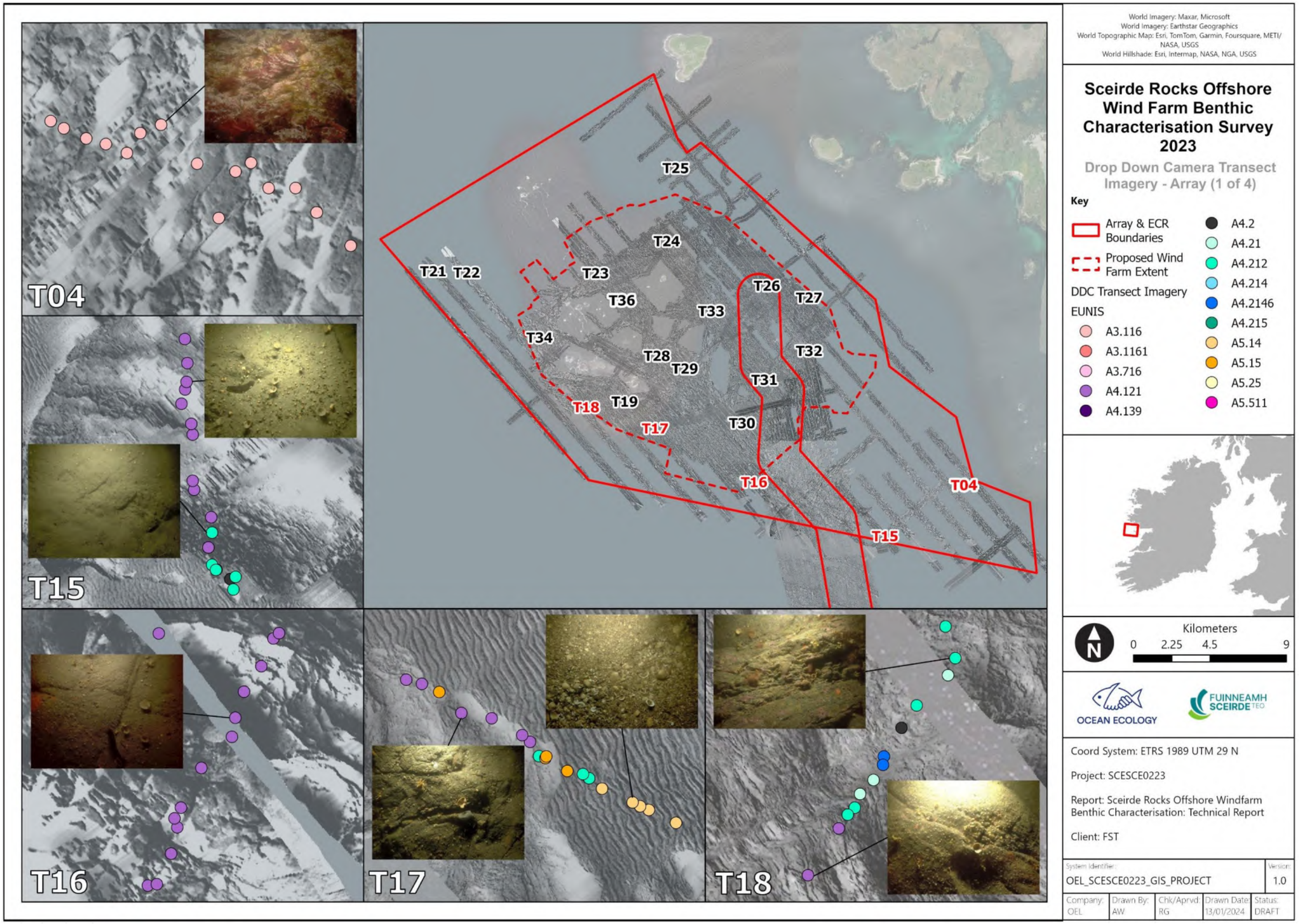


**Figure 16** EUNIS classifications derived from seabed imagery collected from transects across the SROWF array survey area (1/4).

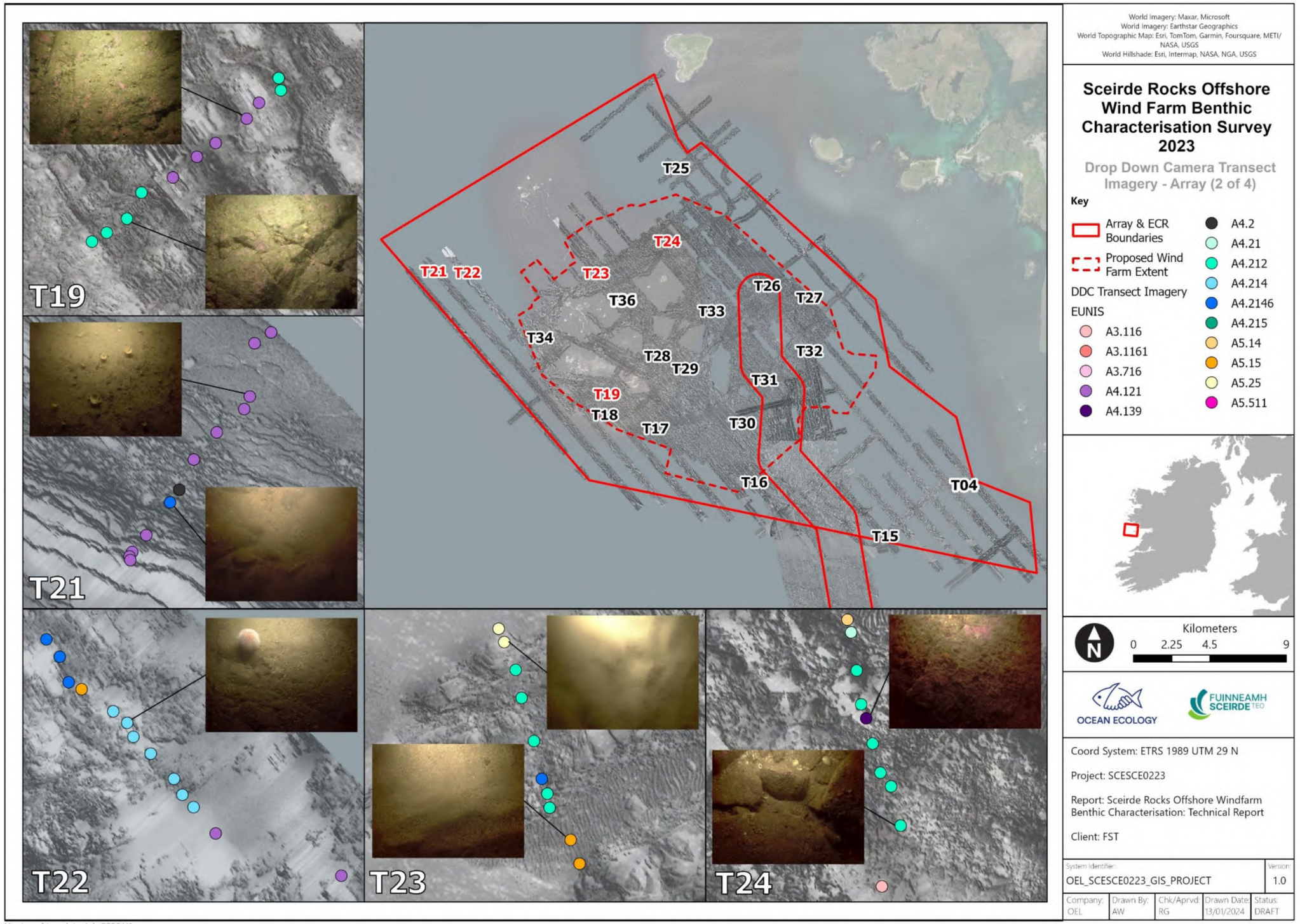


**Figure 17** EUNIS classifications derived from seabed imagery collected from transects across the SROWF array survey area (2/4).

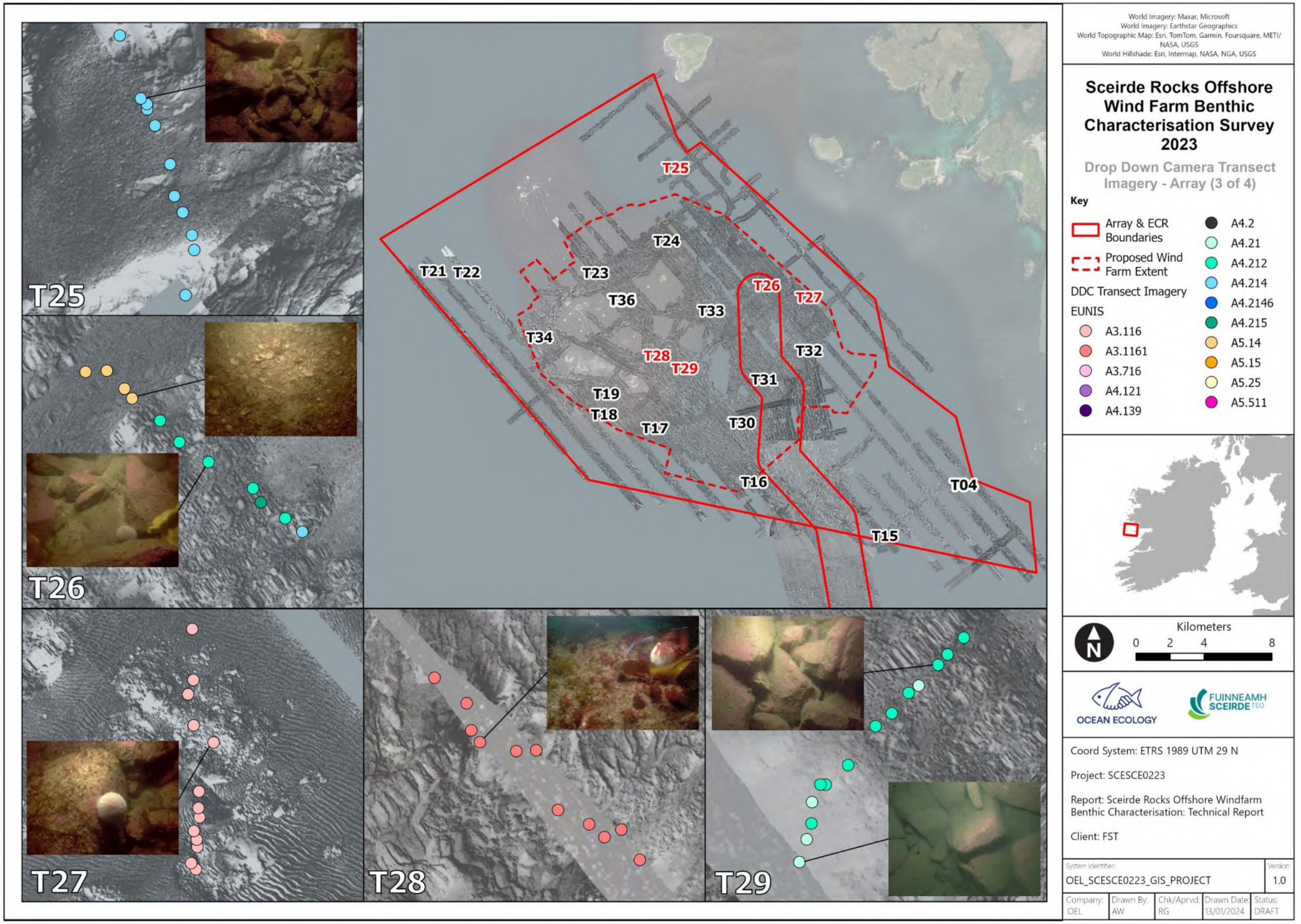


**Figure 18** EUNIS classifications derived from seabed imagery collected from transects across the SROWF array survey area (3/4).

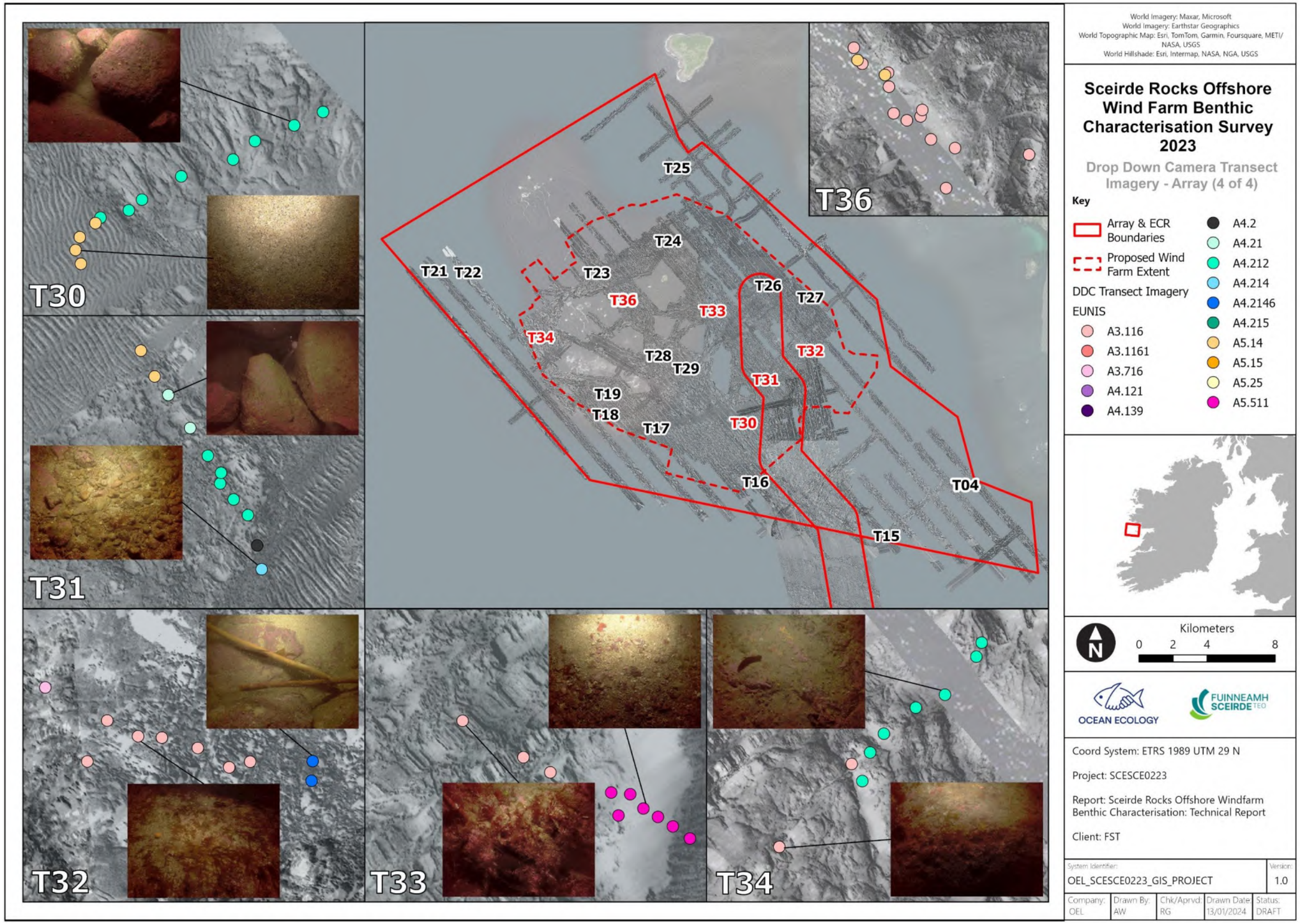


**Figure 19** EUNIS classifications derived from seabed imagery collected from transects across the SROWF array survey area (4/4).

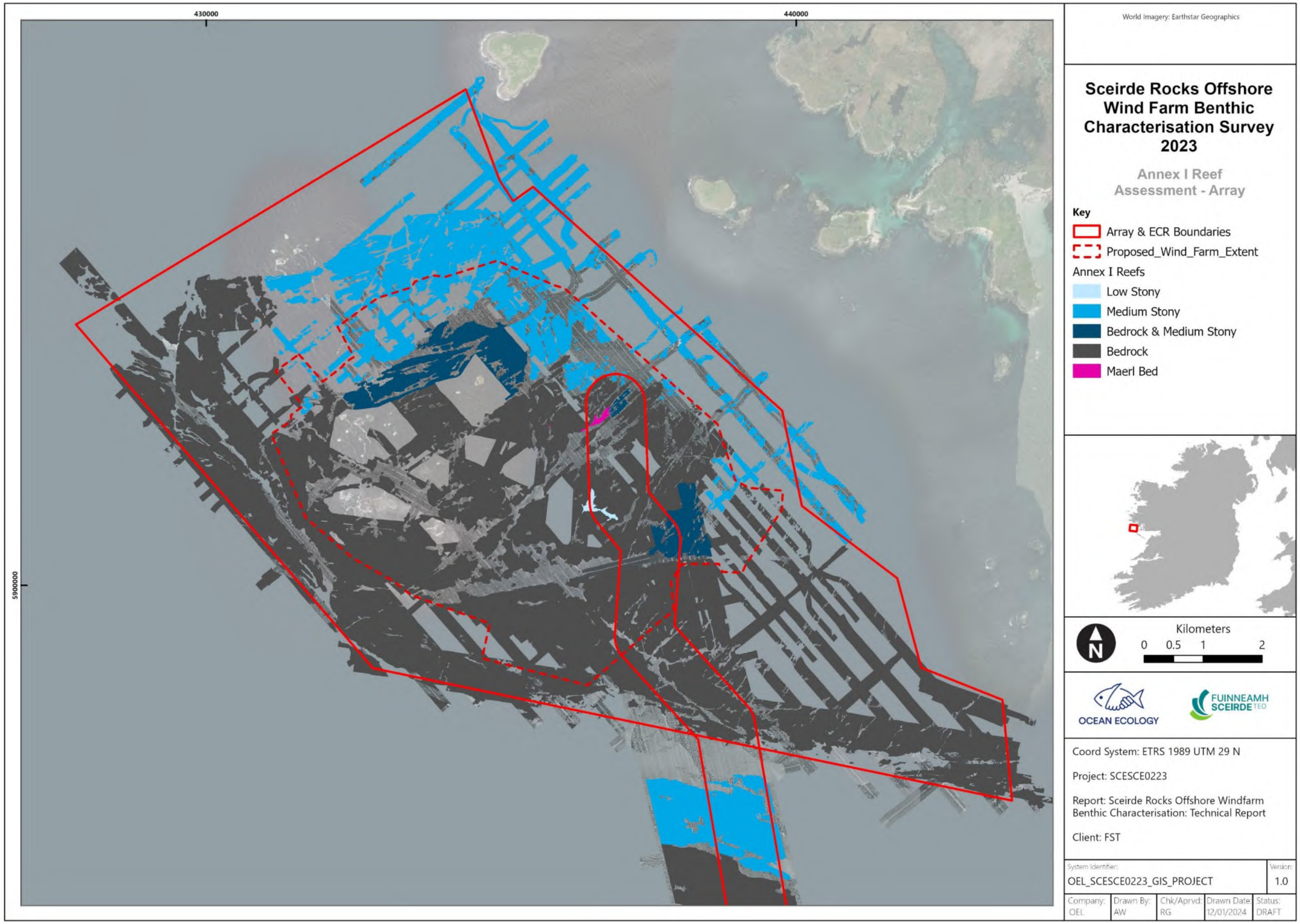


**Figure 20** Annex I reef assessment derived from seabed imagery collected from stations across the SROWF array survey area.

**ECR**

At DDC transect located along the length of the ECR, a total of five EUNIS BSH, five EUNIS Level 4, four EUNIS Level 5 and one EUNIS Level 6 biotope complexes were identified in the seabed imagery. Of the 174 images collected along the DDC transects within the ECR area, the most commonly occurring biotope complex was A4.121 '*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock', identified in 99 still images (Table 18).

Images collected from transects in the northern region of the ECR were typically classified as deep circalittoral rock habitats characterised by sponges and crustose communities including the Level 5 EUNIS biotope complexes A4.121 and A4.212. Transects from the centre of the ECR were typically described as A5.37 'Deep circalittoral mud' interspersed with areas of circalittoral rock and varying faunal communities including A4.121 and A4.2146. In the south, approaching where the ECR makes landfall, images collected from DDC transects described the seabed as circalittoral muddy sand and coarse sediment with patches of rocky habitat most commonly described as A4.121 '*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock' (Figure 22, Figure 23, Figure 24 and Table 18).

A number of habitat mosaics were identified in the seabed imagery. These included mosaics between the circalittoral rocky biotope A4.121 '*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock' and A5.15 'Deep circalittoral coarse sediments, as well as between A4.121 and A5.37 'Deep circalittoral mud'.

Of the 174 images obtained from transects along the ECR, a total of 128 were identified as meeting the criteria for reefs as per (Irving, 2009) and Section 6.1. This included 72 classified as bedrock reef, 48 as medium stony reef, five as low stony reef and three as a mosaic between bedrock and low stony reef. The spatial distribution of Annex I reef habitats across the ECR is represented in Figure 25.

The most common epifauna captured in the still imagery were cup corals (*Caryophyllia smithii*) and tube worms of the family Serpulidae.

**Table 18** EUNIS BSH and biotope complexes identified in seabed imagery collected along transects within the SROWF ECR survey area.

| BSH | EUNIS Code | EUNIS Description |
|---|---|---|
| A4.1 | - | Atlantic and Mediterranean high energy circalittoral rock |
| | A4.12 | Sponge communities on deep circalittoral rock |
| | A4.121 | *Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock |
| A4.2 | - | Atlantic and Mediterranean moderate energy circalittoral rock |
| | A4.212 | *Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock |
| | A4.214 | Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock |
| | A4.2146 | *Caryophyllia smithii* with faunal and algal crusts on moderately wave-exposed circalittoral rock |
| A5.1 | A5.15 | Deep circalittoral coarse sediment |
| A5.2 | A5.26 | Circalittoral muddy sand |
| | A5.27 | Deep circalittoral sand |
| A5.3 | A5.37 | Deep circalittoral mud |

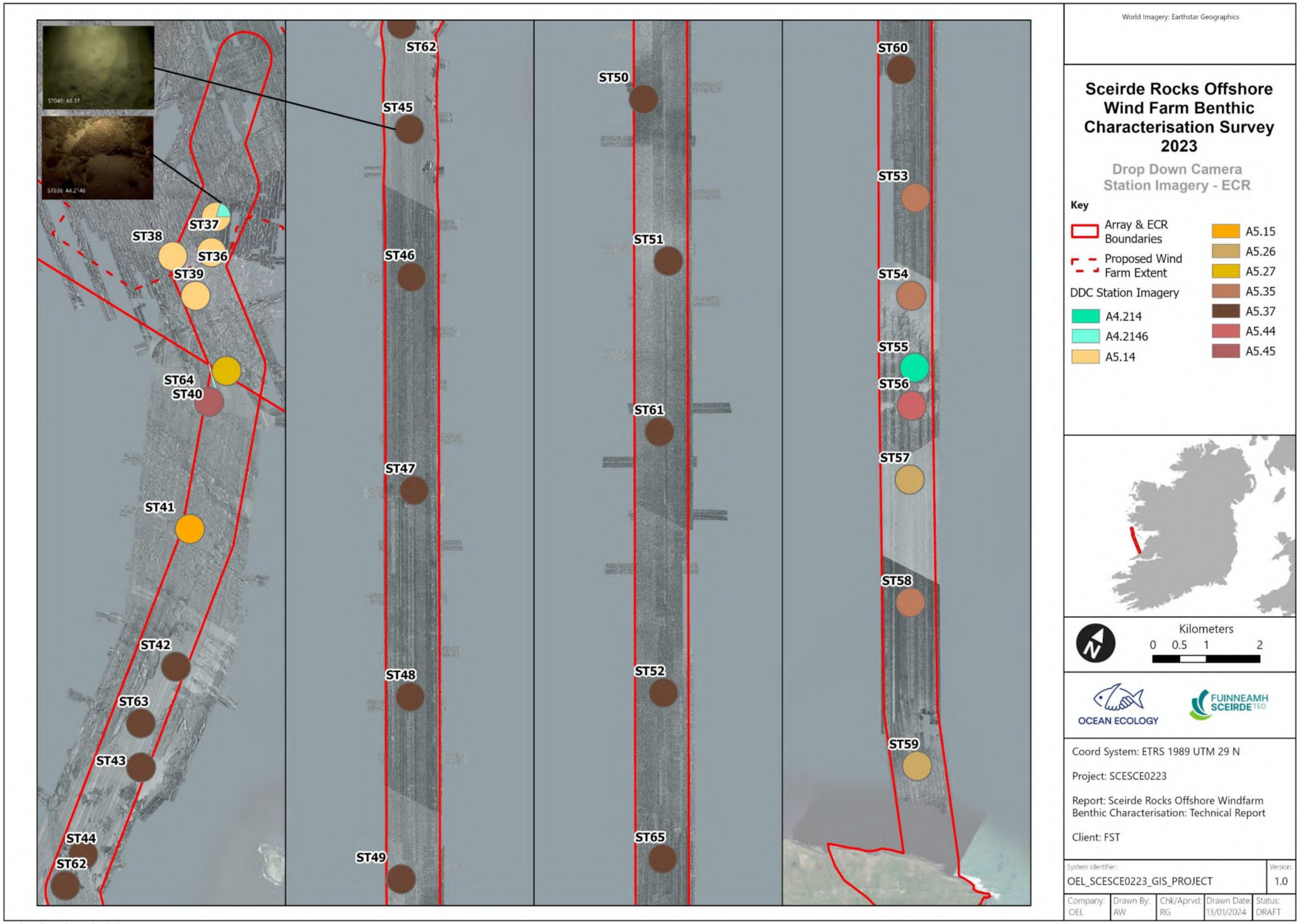


**Figure 21** EUNIS classifications derived from seabed imagery collected from stations along the SROWF ECR. Pie charts indicate the percentage of images at each station that fell into each of the EUNIS classifications.

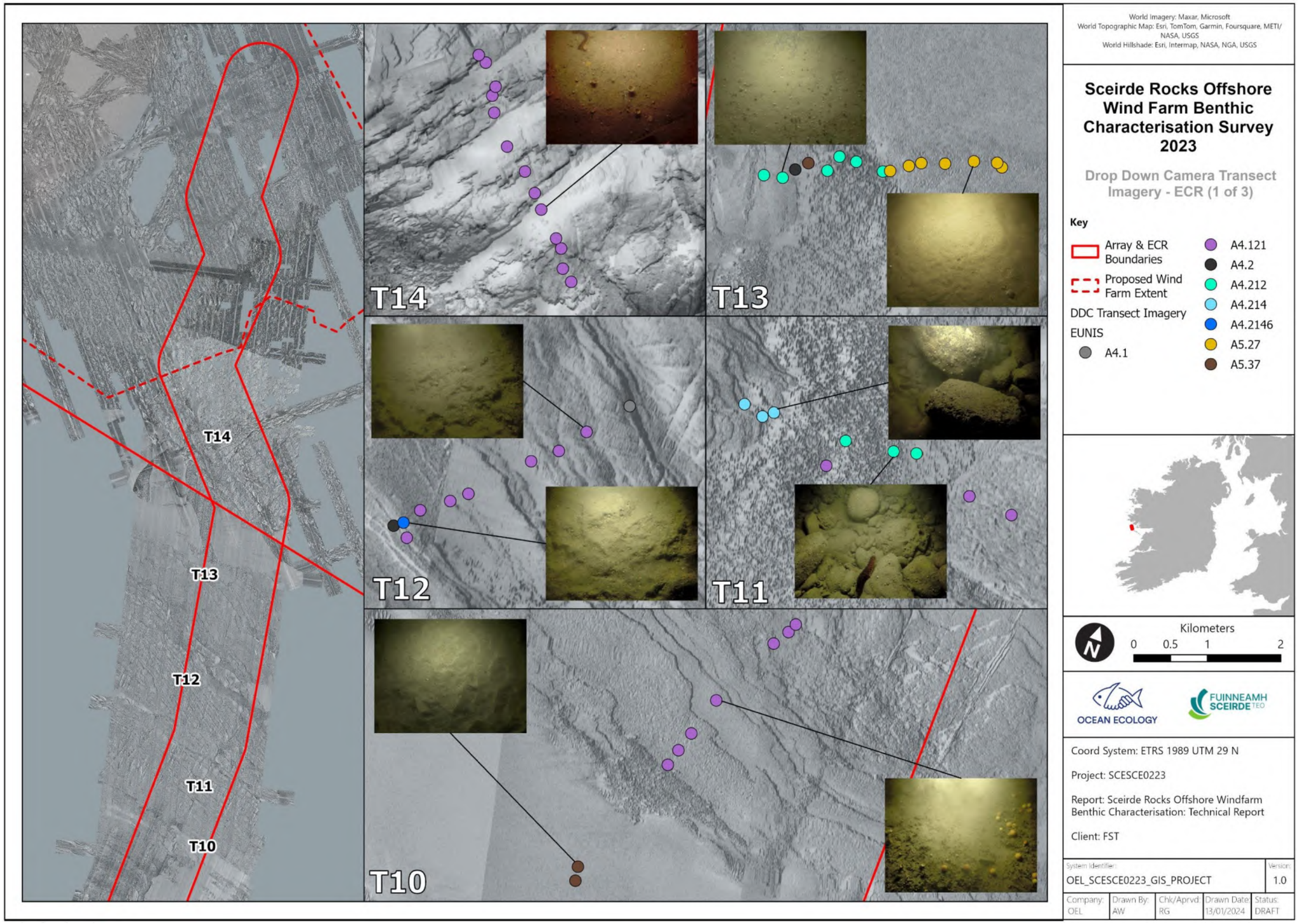


**Figure 22** EUNIS classifications derived from seabed imagery collected from transects along the SROWF ECR survey area (1/3).

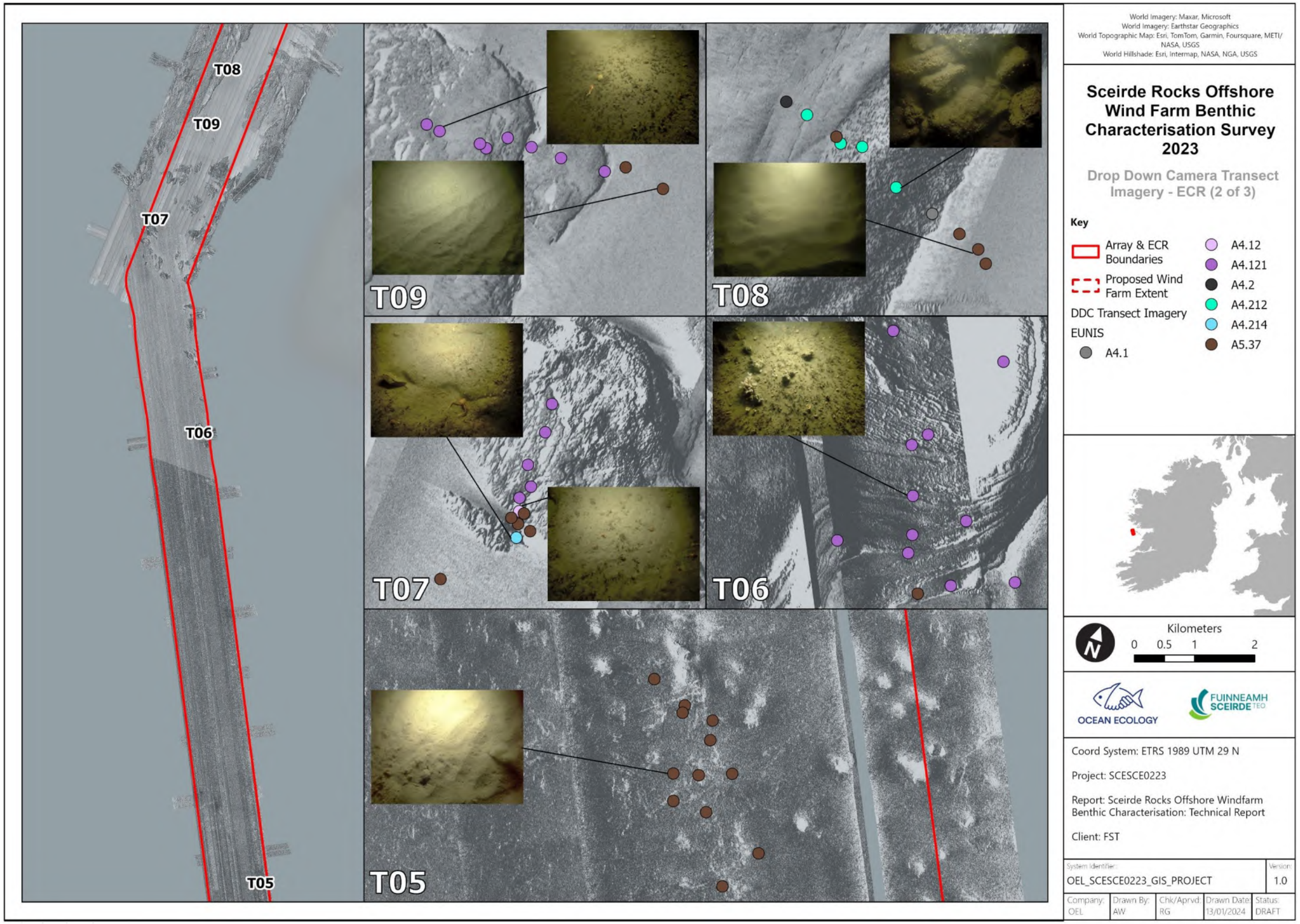


**Figure 23** EUNIS classifications derived from seabed imagery collected from transects along the SROWF ECR survey area (2/3).

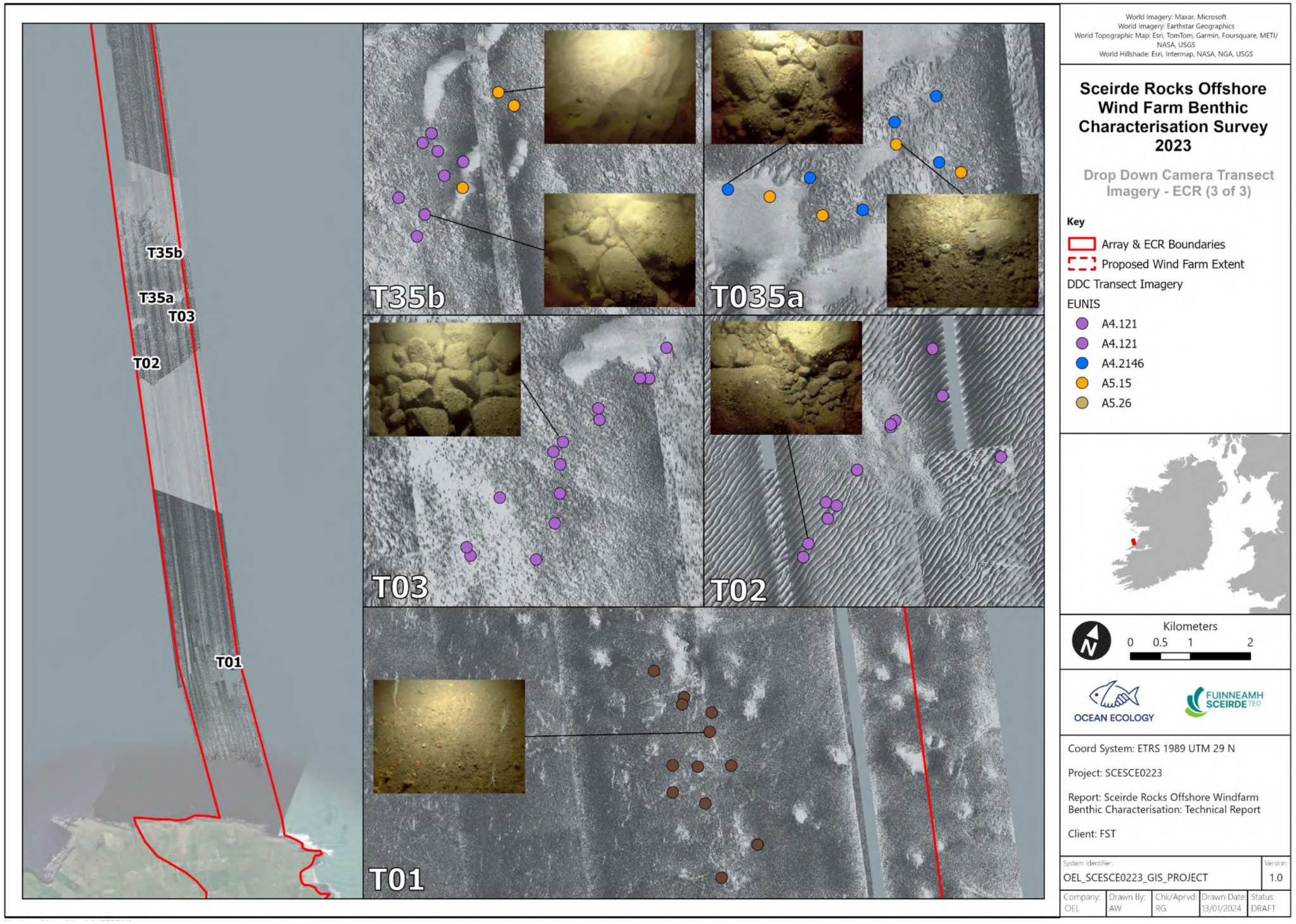


**Figure 24** EUNIS classifications derived from seabed imagery collected from transects along the SROWF ECR survey area (3/3).

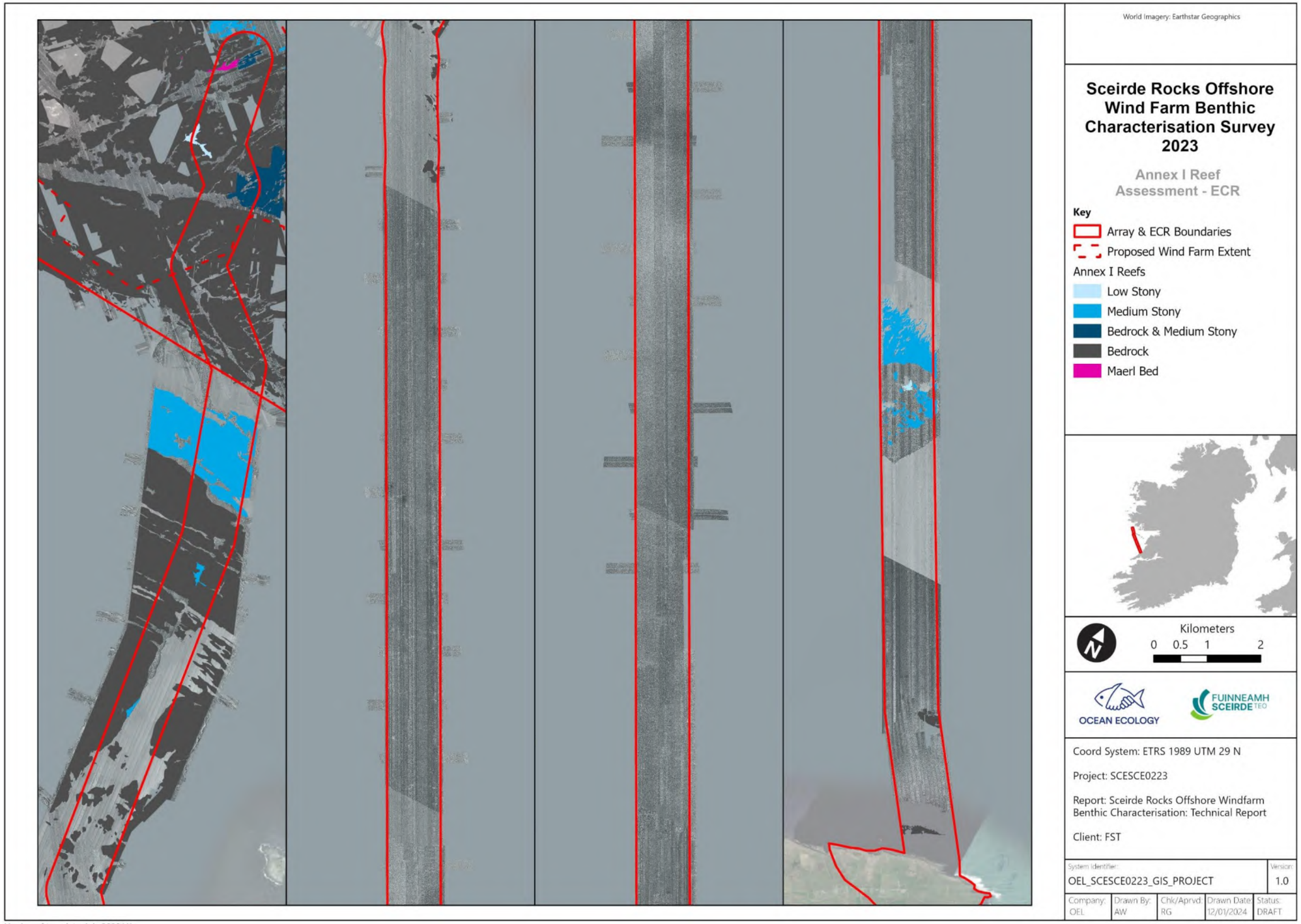


**Figure 25** Annex I reef assessment derived from seabed imagery collected from stations across the SROWF ECR survey area.

## 7.3. Other Features of Note

### 7.3.1. Sea Fans

Sea fans, including individuals identified as the pink sea fan *Eunicella verrucosa,* were identified in the seabed imagery. An in-depth assessment of this species was conducted (Appendix VI) ultimately determining the total number of individuals per station (Figure 26 and Figure 27). Where it was not possible to identify sea fans to species level due either to the imagery quality or the small size of individuals, the label 'sea fan' was assigned; otherwise, *E. verrucosa* was identified to species level. It is noteworthy that the small individuals of sea fans recorded across the survey area bore resemblance to S*wiftia pallida*, however confidence in this identification was low and therefore the identification of these smaller individuals was left at a higher level.

Images collected from DDC transects within the array area identified a total of 37 sea fans, one of which was identified as *E. verrucosa*. The maximum number of sea fans per image was 13, recorded along transect T22. All sea fans recorded within the array were observed at transects positioned furthest offshore, near the western most boundary of the site (Figure 26).

A total of 17 sea fans were identified across a number of images obtained from DDC transects along the ECR, particularly transects in the north and south of the route. Of these, 13 were identified as *E. verrucosa* (Figure 27).

### 7.3.2. Maerl

A full maerl assessment was undertaken on all imagery to quantify the percentage of live versus dead maerl cover, maerl structure and extent, and identify the maerl substrate type to categorise and assign stations to potential maerl habitats (Appendix VII). Maerl was observed at all five images collected at station ST026 with less than 1 % coverage of live and dead maerl and categorised as C2 'Scattered Maerl' and therefore not forming a maerl bed habitat. Scattered Maerl was also observed in one image at station ST029 where only dead maerl was recorded with less than 1 % coverage. At station ST027 all five images reported the presence of 2D and 3D maerl structures (encrusting, hedgehog maerl and maerl nodules) with cover of live maerl ranging from 5 % to 20 % and an estimated extent of 40,917 $m^2$. Station ST027 was therefore categorised as a mix of A3, B1, B2 and B3 categories indicating the presence of a potential maerl bed habitat. EUNIS habitat A5.51 'Maerl beds' was therefore assigned to station ST027.

Along transect T26 maerl was noted in four images as Scattered or Sparse Maerl with very little live maerl cover and up to 5 % cover of dead maerl. Conversely bed forming maerl was observed along T33 where up to 5 % live maerl cover was recorded as well as dead maerl falling into category B1, B3 and C3. The estimated extent of maerl at this site was 729 $m^2$. Images with maerl collected along T33 were therefore assigned to EUNIS habitat A5.511 '*Phymatolithon calcareum* maerl beds in infralittoral clean gravel or coarse sand'. No other

stations or transects were located within the extent of these two potential maerl beds (Figure 28).

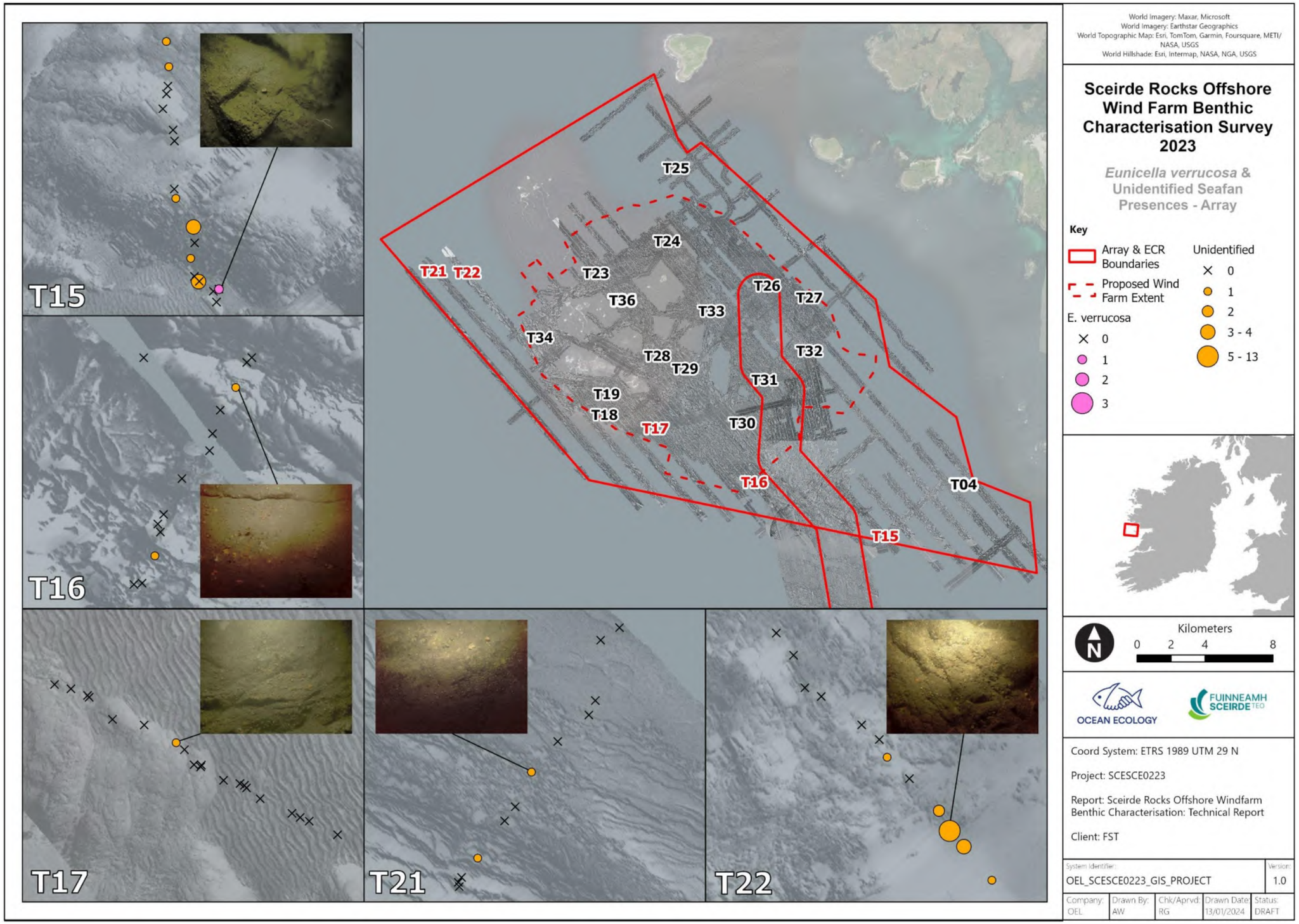


**Figure 26** Number of Sea fans, including the pink sea fan *Eunicella verrucosa* identified in seabed imagery obtained at DDC transect within the SROWF array area.

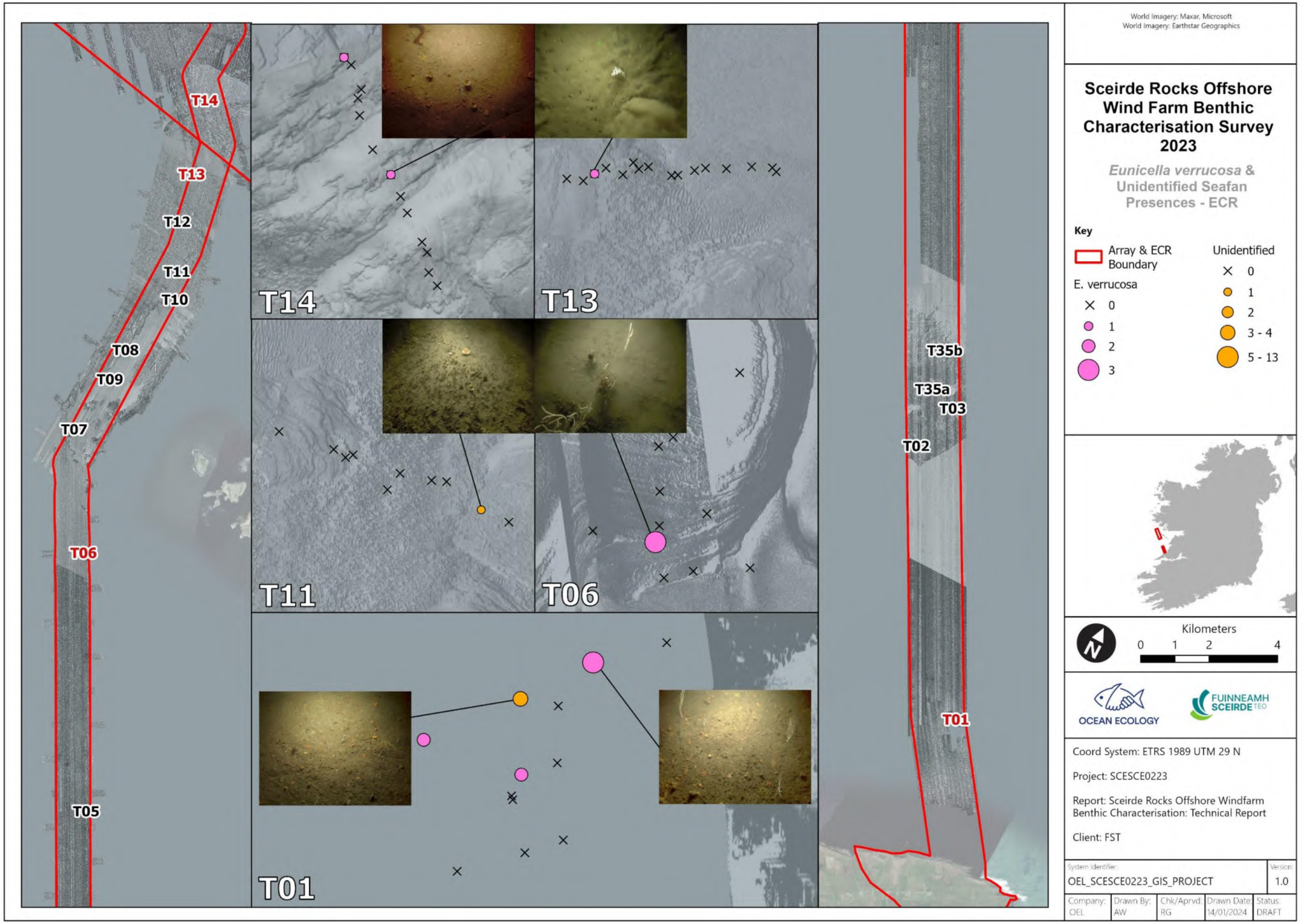


**Figure 27** Number of Sea fans, including the pink sea fan *Eunicella verrucosa* identified in seabed imagery obtained at DDC transect along the SROWF ECR.


**Figure 28** The extent of maerl habitats within the SROWF array area as identified in seabed imagery analysis.

## 7.4. PSD analysis

Fifty-eight grab samples were obtained during the SROWF survey, resulting in a total of 58 sediment samples which were analysed for full particle size classification. Thirty of these samples were collected from within the array area and 28 from the ECR. Full grab logs are provided in Appendix VIII. Example images of all sampled sediment types are presented in Plate 6 with full particle size data provided in Appendix IX and summary data provided in Appendix X.

### 7.4.1. Sediment Type

Sediment types, as classified using the Folk triangle (Folk, 1954) for each station sampled across the survey area are presented in Figure 29. Each Folk classification was converted to BSH Type (EUNIS Level 3) using the adapted Folk triangle (Long, 2006) (Figure 29). Sediment textural groups and BSH's are mapped in Figure 30, Figure 31, Figure 32 and Figure 33.

**Array**

Of the 30 samples collected within the array area, 21 were representative of BSH A5.1 'Coarse sediment', seven of A5.2 'Sand and muddy sand', one representative of A5.3 'Mud and Sandy Mud' and one A5.4 'Mixed Sediment'. The most frequently occurring sediment type was Gravelly Sand (gS) recorded at 11 of the 30 sampling locations, closely followed by Sandy Gravel (sG) recorded at a further 10. The remaining stations were comprised of Slightly Gravelly Sand ((g)S) (n = 4), Sand (S) (n = 2), Muddy Sand (mS) (n = 2) and Muddy Sandy Gravel (msG) (n = 1).

As a general spatial trend, sediments within the centre of the array area were largely heterogenous, consisting of sand and gravel textural groups representative of BSH A5.1 and A5.2 with little to no mud content. A slight increase in mud content was seen at the southern boundary of the array area with stations representing the textural group Muddy Sand (Figure 30 and Figure 32).

**ECR**

Of the 28 samples collected along the ECR, 15 were representative of BSH A5.2 'Sand and Muddy Sand', seven were classed as A5.3 'Mud and Sandy Mud' and 6 as A5.1 'Coarse Sediment'. Muddy Sand (mS) was the most commonly described sediment type, recorded in 11 samples. The remaining samples consisted of Slightly Gravelly Sand ((g)S) (n = 6), Slightly Gravelly Muddy Sand ((g)mS) (n = 5), Gravelly Sand (gS) (n = 3), Sandy Gravel (sG) (n = 2) and Gravel (G) (n – 1).

Sediments were generally heterogenous along the length of the ECR, dominated by sand textural groups with varying contributions of gravel and mud. Gravelly sands representing BSH A5.1 were more common at the northern tip of the ECR where it intersected the array, and

Sand representative of BSH A5.2 at the southern landfall region. The centre of the route largely consisted of Muddy Sands classified as BSH's A5.2 and A5.3 Figure 31 and Figure 33.

### 7.4.2. Sediment Composition

Sediments across the survey area as a whole were characterised predominantly by sands, with varying though often high contributions of mud and gravel. The percentage of gravels (>2 mm), sands (0.63 mm to 2 mm), and fines (< 63 µm) at each station are presented in Figure 34. The mean proportion (± Standard Error, SE) of sands across all stations was 76 % (± 3 %), the mean proportion (± SE) of gravel and mud content across the survey area was 16 % (± 3 %) and 8 % (± 2 %) respectively. Spatial trends of sediment composition are mapped in Figure 35 and Figure 36.

**Array**

Within the array area, sediments were largely dominated by sand with a relatively high gravel content and low mud content. The mean proportion (± Standard Error, SE) of sand across all array stations was 75 % (± 19 %), the mean proportion (± SE) of gravel 23 % (± 20 %) and mud was 3 % (± 6 %) respectively (Figure 35).

**ECR**

Along the ECR, sand was the most dominant sediment type followed by mud and then gravel. The mean proportion (± Standard Error, SE) of sand at the ECR stations was 78 % (± 20 %), the mean proportion (± SE) of gravel 8 % (± 21 %) and mud was 14 % (± 13 %) respectively (Figure 36).


**Plate 6** Examples of sediment types found from released grab samples. Top left: Gravel (G). Top middle-left: Gravel (G). Top middle-right: Sandy Gravel (sG). Top right: Gravelly Sand (gS). Bottom left: Sand (S). Bottom middle-left: Muddy Sand (mS), Bottom middle-right: Muddy Sand (mS). Bottom right: Sandy Mud (sM).

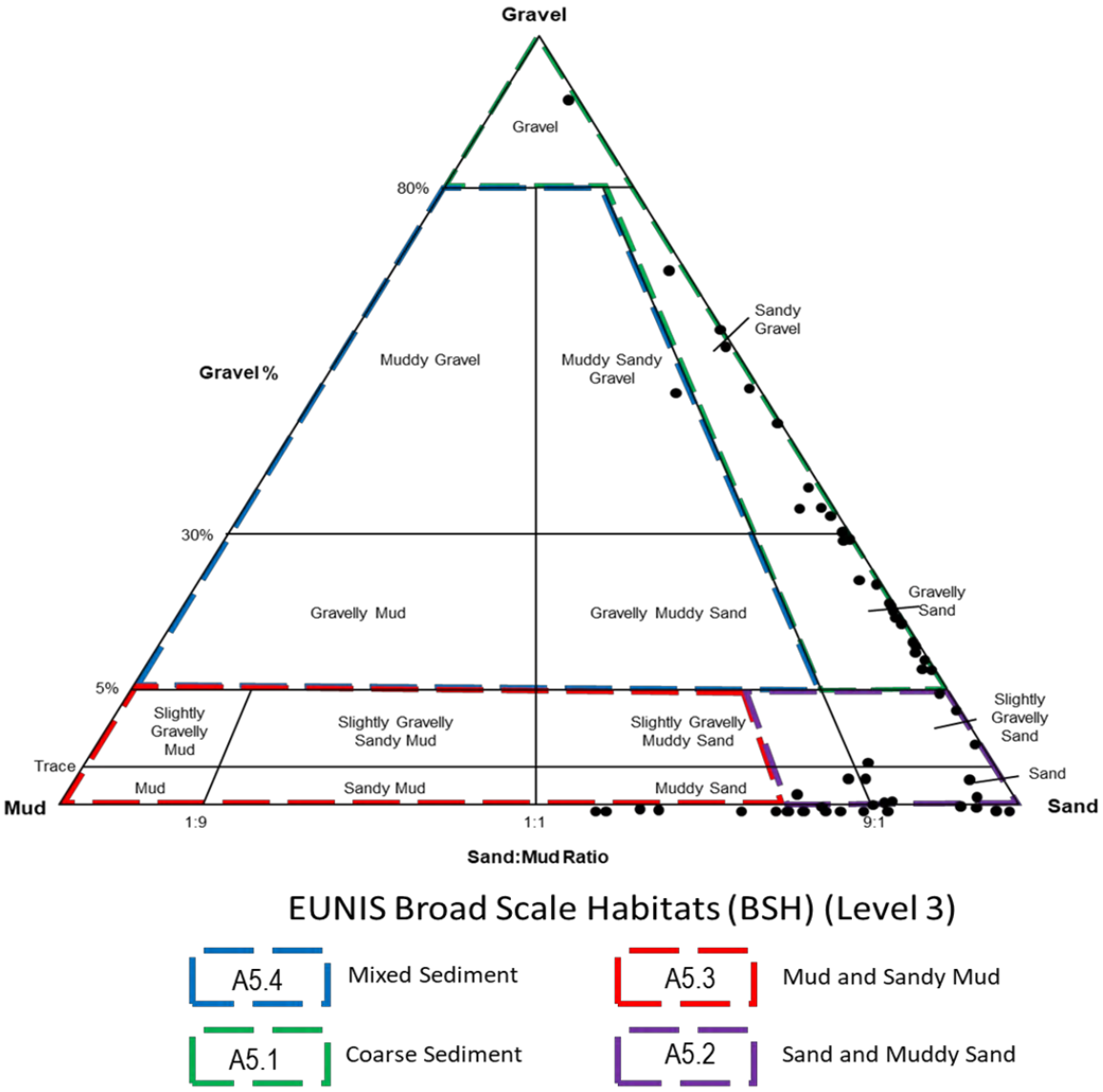


**Figure 29** (Folk, 1954) triangle classifications of sediment gravel percentage and the sand-to-mud ratio of samples collected across the SROWF sampling area, overlain by the modified Folk triangle for determination of mobile sediment BSHs under the EUNIS habitat classification system (adapted from (Long, 2006).

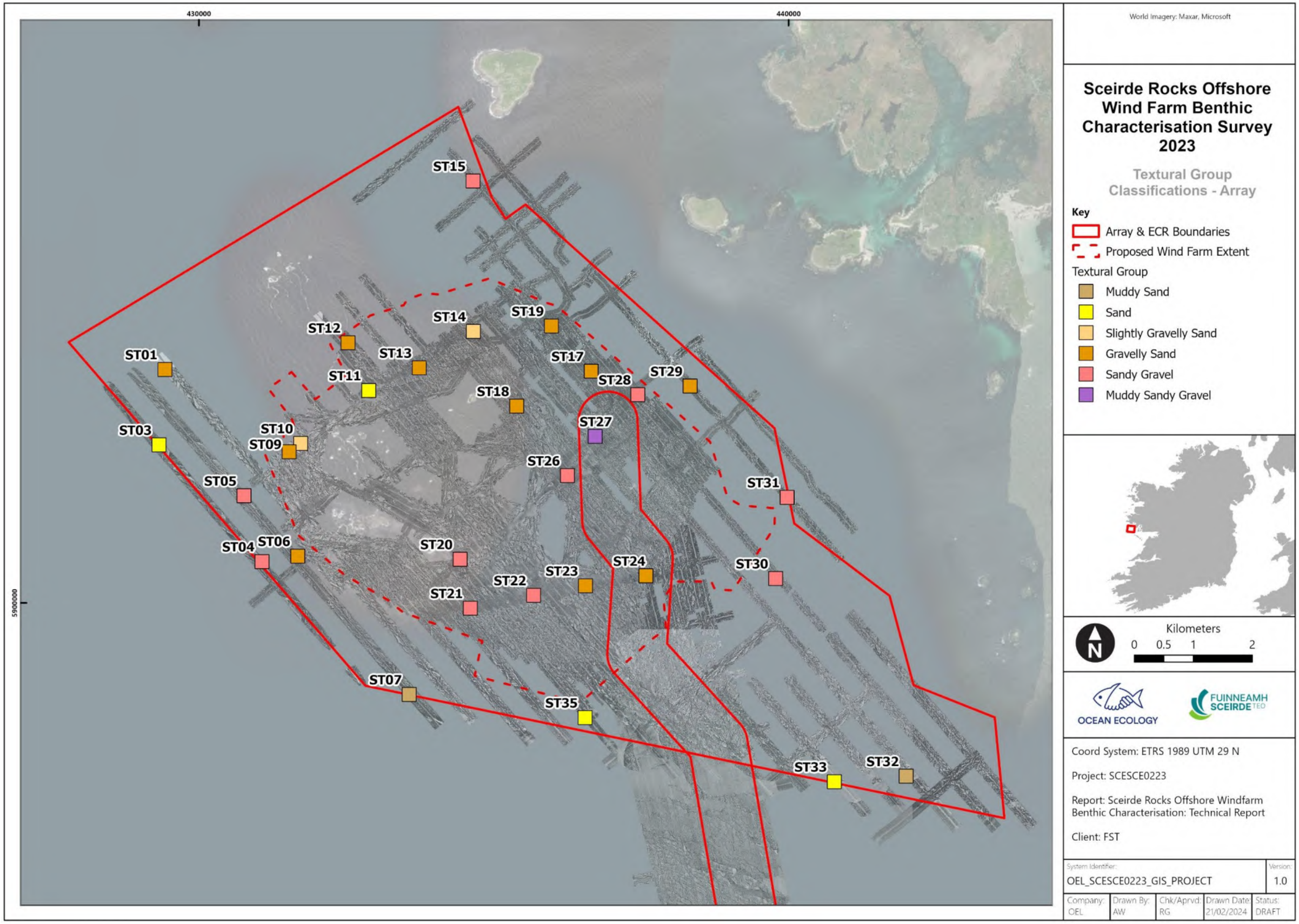


**Figure 30** Textural Groups as determined from PSD analysis of samples acquired during the survey (Array).

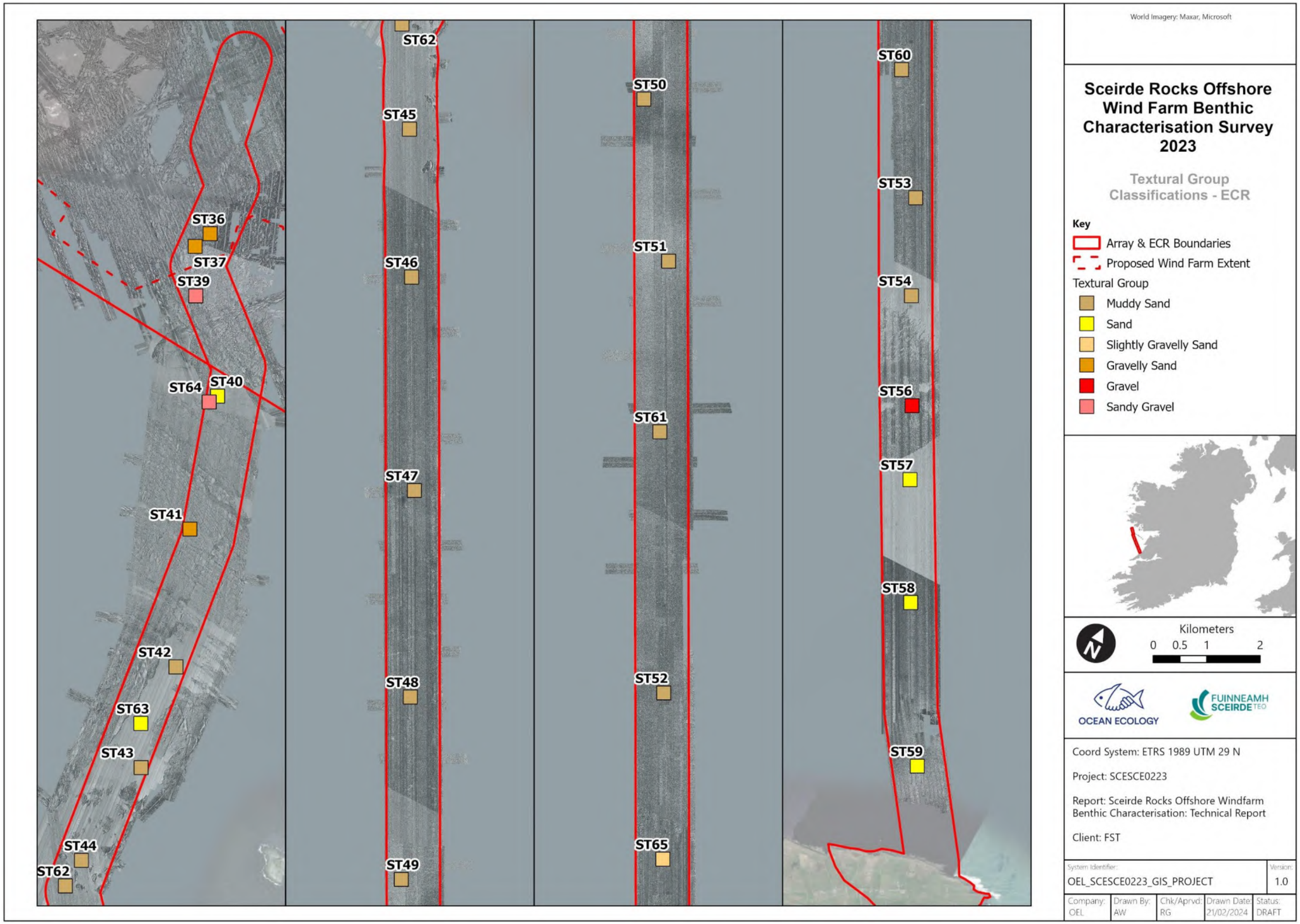


**Figure 31** Textural Groups as determined from PSD analysis of samples acquired during the survey (ECR).

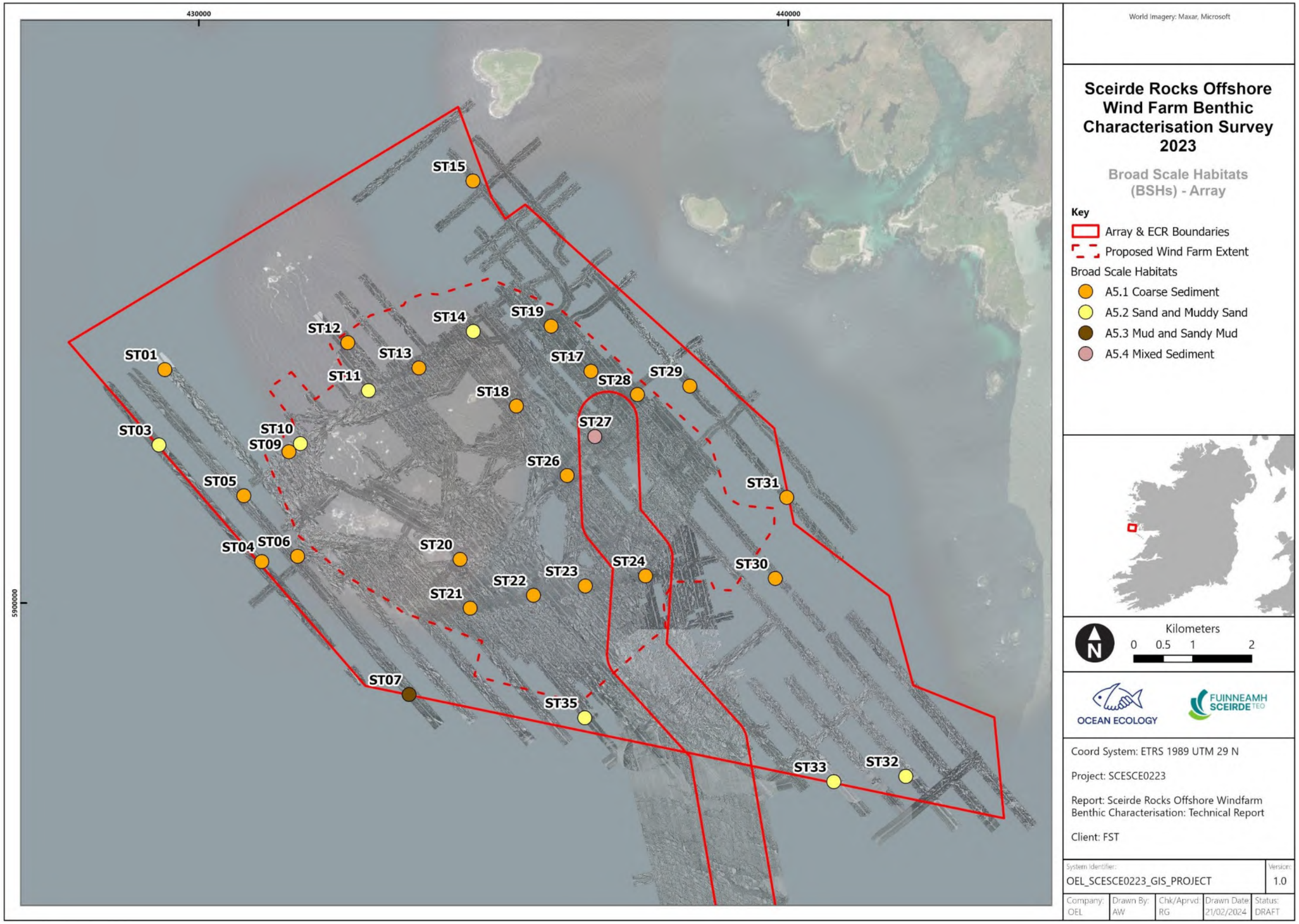


**Figure 32** BSH classification as determined based on PSD of sampled collected during the survey (Array).

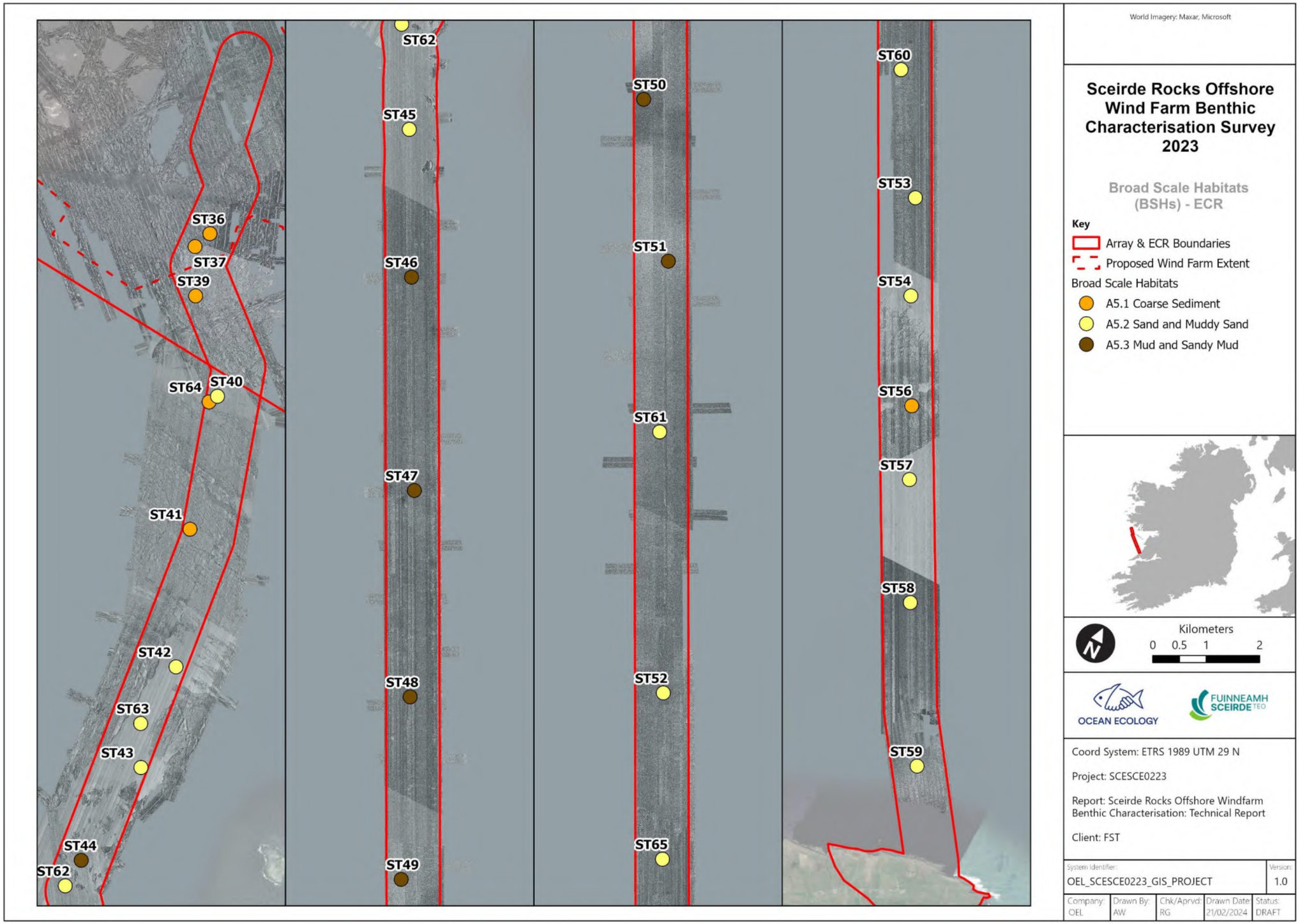


**Figure 33** BSH classification as determined based on PSD of sampled collected during the survey (ECR).

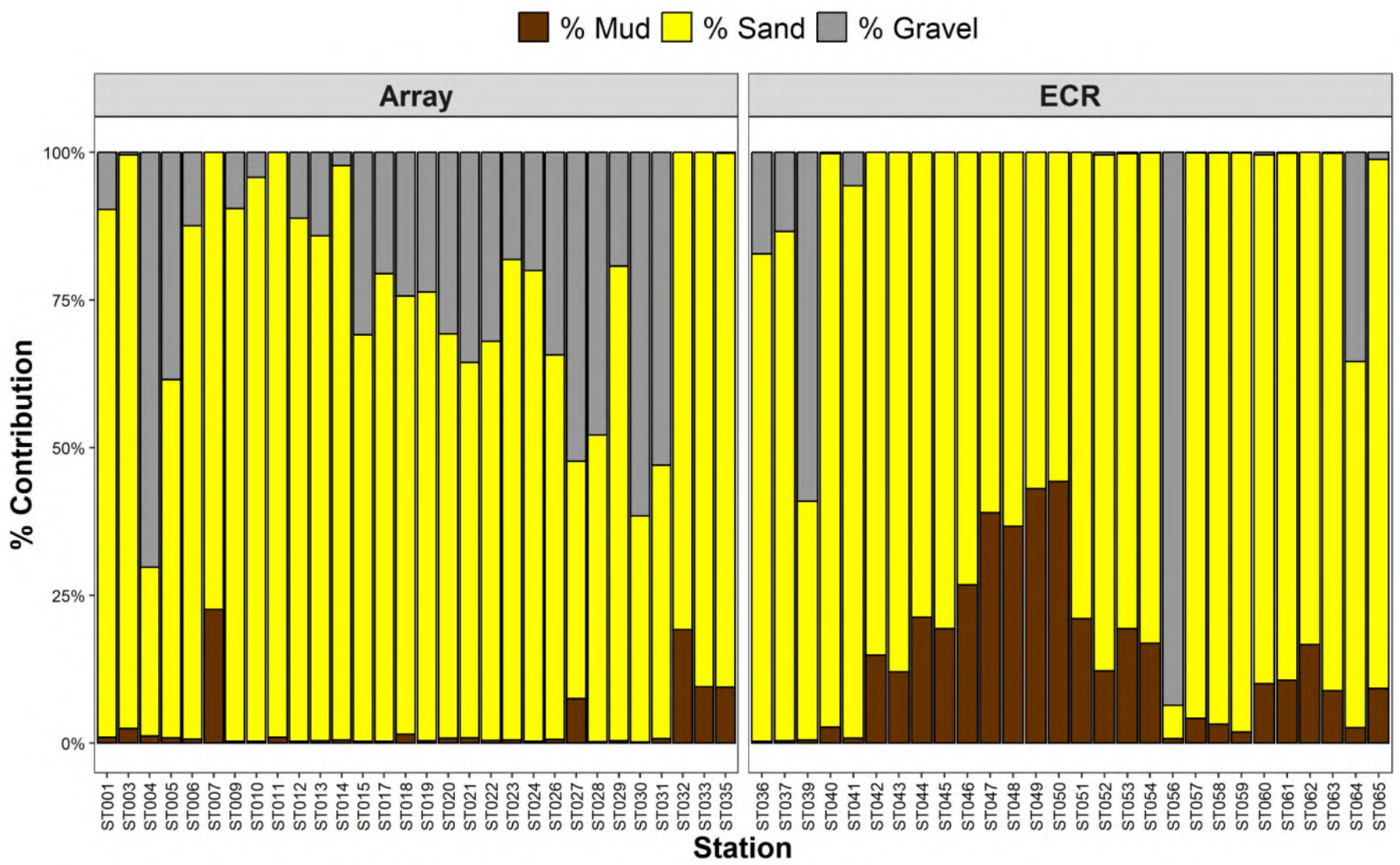


**Figure 34** Relative contribution to the volume of sediment at each sampling station across the array and ECR survey areas.

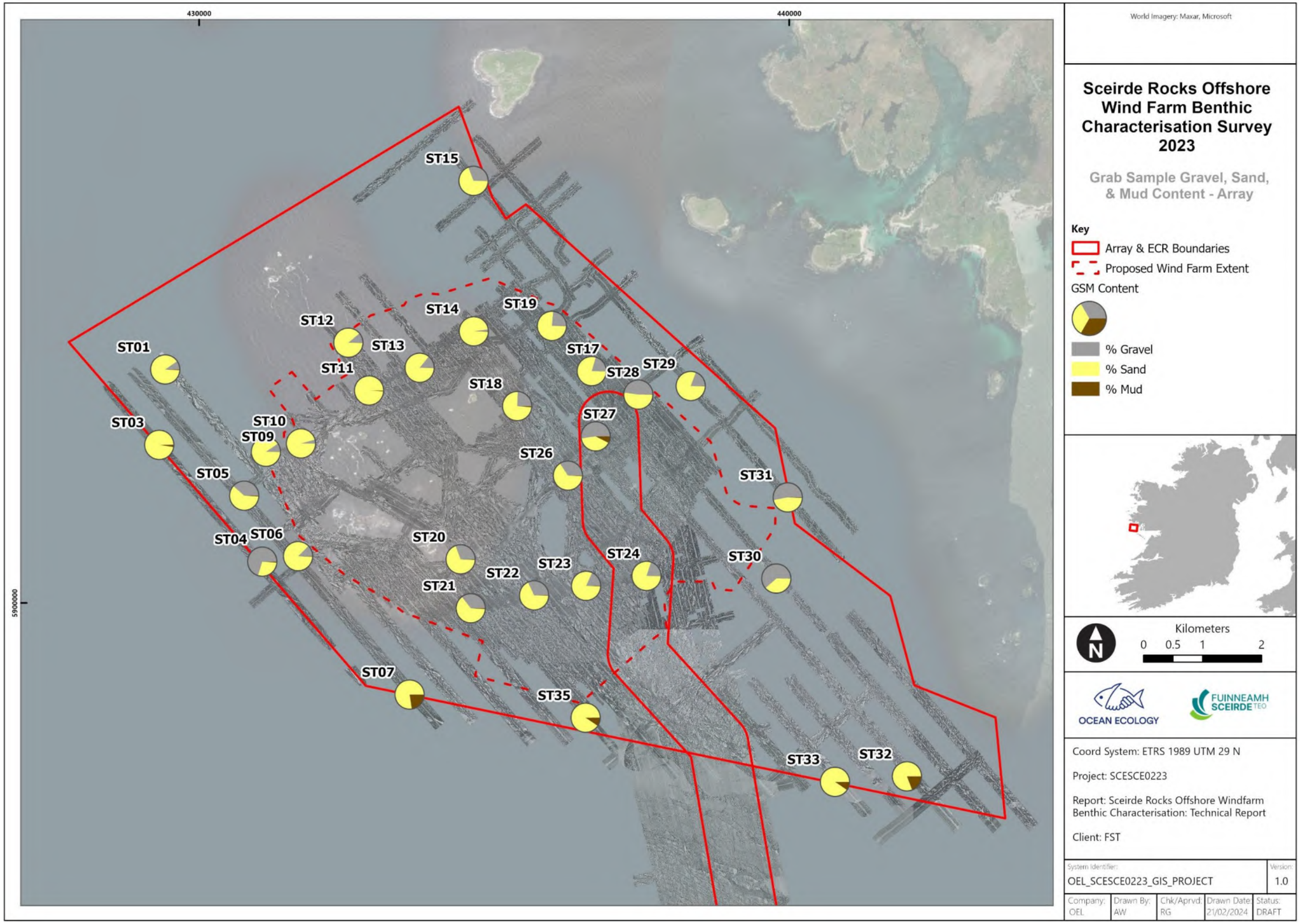


**Figure 35** The principal sediment components (gravel, sand, mud) as determined from PSD analysis of samples acquired during the survey (Array).

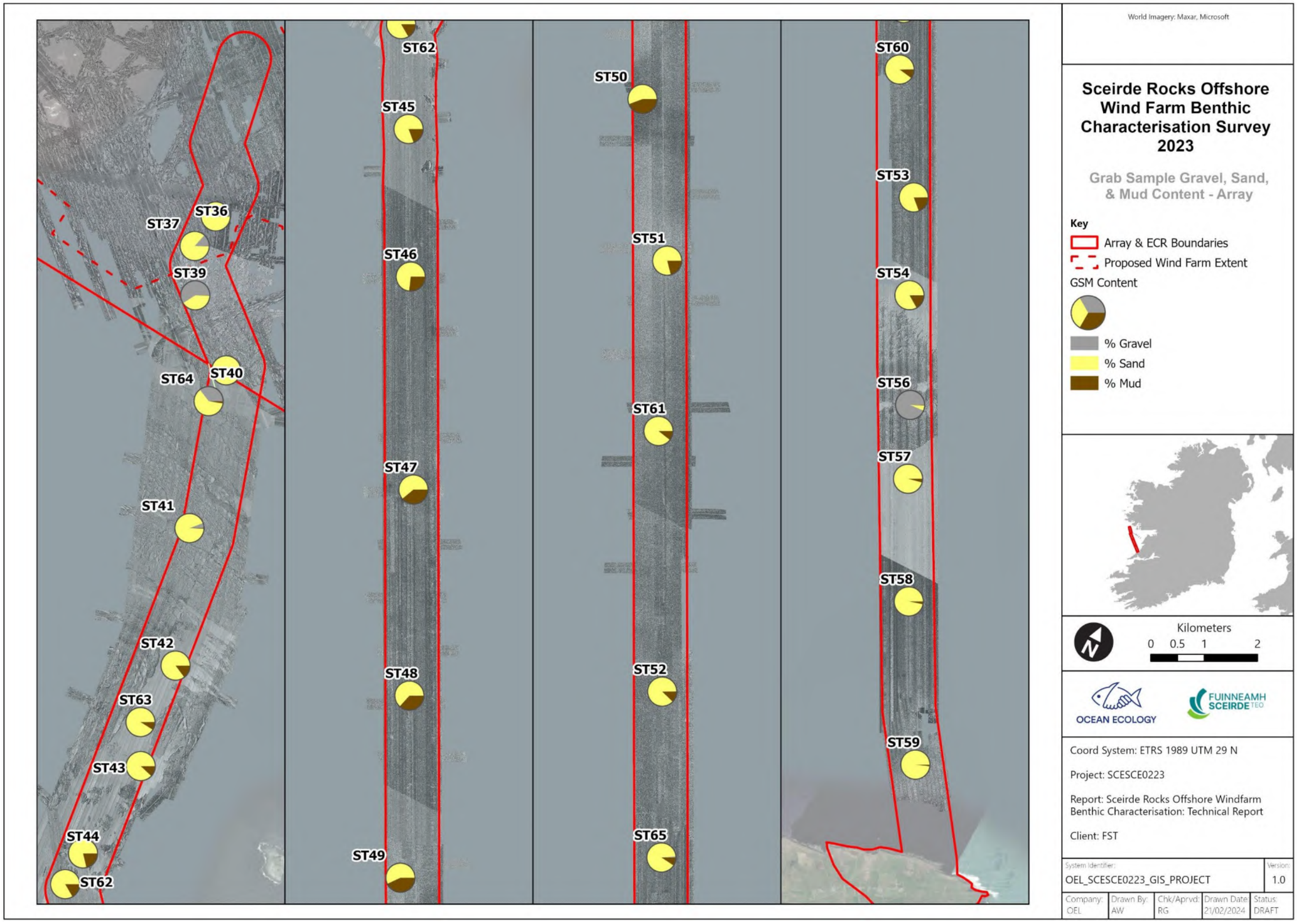


**Figure 36** The principal sediment components (gravel, sand, mud) as determined from PSD analysis of samples acquired during the survey (ECR).

## 7.5. Sediment Chemistry

Fifty-eight grab samples were obtained during the SROWF survey, resulting in 58 sediment samples for TOC analysis and 22 for full sediment chemistry analysis. Grab samples taken for chemical analyses were analysed for TOC, heavy and trace metals, PAHs and THCs, organotins and OCPs. Raw sediment chemistry data are provided in Appendix XI.

### 7.5.1. Total Organic Carbon

**Array**

Total Organic Carbon ranged from 0.28 % at station ST030 to 0.79 % at station ST032. The mean (± SE) TOC at stations within the array area was 0.5 % ± 0.02 %.

**ECR**

At stations along the ECR, TOC ranged from 0.2 % at stations ST052, ST060, ST061 and ST065, to 0.58 % at station ST045. The mean (± SE) TOC was 0.38 % ± 0.02 %.

### 7.5.2. Heavy and Trace Metals

A total of eight heavy and trace metals were analysed from sediment samples and could be compared to national and international reference levels. These were: Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) and Zinc (Zn). Additionally, Aluminium (Al) and Lithium (Li) were also analysed, however, no background level concentrations or thresholds exist for these and so they were excluded from any comparisons below.

**Array**

Averaged data for the eight main heavy and trace metals (dry-weight concentration, mg $kg^{-1}$) are shown in Table 19 together with available reference levels. Stations exceeding reference levels are highlighted in red. Stations ST001 and ST004 exceeded Irish Lower Level for As with station ST001 also exceeding OSPAR BAC. None of the other samples analysed exceeded reference levels for any of the measured contaminants.

The most abundant metal was As which ranged from 9.8 mg $kg^{-1}$ at station ST017 to 29.9 at station ST001. The mean (± SE) concentration across all stations was 15.1 mg $kg^{-1}$ ± 1.2 mg $kg^{-1}$. This was followed by Zn which ranged from 5.7 mg $kg^{-1}$ at station ST017 to 22.5 mg $kg^{-1}$ at station ST035 with a mean (± SE) concentration across all stations of 12.3 mg $kg^{-1}$ ± 1.6 mg $kg^{-1}$.

Al concentrations were highest at station ST035, recorded at to 25300 mg $kg^{-1}$, whilst Li was found in highest concentration at station ST031 (13.2 mg $kg^{-1}$).

Hg concentrations were < LoD at all stations, while Cu concentration were below detection limits at 11 of the 16 stations meaning that the average value presented in Table 19 is based on the four stations where Cu was measurable.

**Table 19** Summary of heavy and trace metal concentrations (mg $kg^{-1}$) at Array stations. Red shading indicates concentrations above Irish AL1.

| Station | As | Cd | Cr | Cu | Pb | Hg | Ni | Zn |
|---|---|---|---|---|---|---|---|---|
| ST001 | 29.9 | 0.17 | 10.4 | 1.6 | 10.7 | < 0.01 | 7.7 | 19.6 |
| ST004 | 20.4 | 0.18 | 9.0 | 0.7 | 7.3 | < 0.01 | 8.3 | 20.8 |
| ST007 | 13.3 | 0.12 | 24.1 | 1.7 | 9.1 | < 0.01 | 6.9 | 22.1 |
| ST009 | 10.5 | 0.06 | 2.8 | < 0.7 | 4.0 | < 0.01 | 4.9 | 6.2 |
| ST012 | 16.3 | 0.06 | 3.3 | < 0.7 | 5.5 | < 0.01 | 5.8 | 7.9 |
| ST013 | 12.4 | 0.05 | 6.3 | < 0.7 | 4.6 | < 0.01 | 4.6 | 9.8 |
| ST015 | 11.1 | 0.05 | 4.4 | < 0.7 | 5.7 | < 0.01 | 3.3 | 10.6 |
| ST017 | 9.8 | 0.07 | 2.2 | < 0.7 | 3.3 | < 0.01 | 3.6 | 5.7 |
| ST019 | 12.6 | 0.07 | 2.5 | < 0.7 | 4.4 | < 0.01 | 6.1 | 6.9 |
| ST021 | 14.0 | 0.07 | 5.8 | < 0.7 | 5.1 | < 0.01 | 6.9 | 8.6 |
| ST023 | 13.4 | 0.07 | 3.4 | < 0.7 | 3.2 | < 0.01 | 3.7 | 6.2 |
| ST026 | 15.7 | 0.07 | 3.7 | < 0.7 | 4.8 | < 0.01 | 2.9 | 8.2 |
| ST029 | 13.9 | 0.07 | 2.7 | < 0.7 | 4.4 | < 0.01 | 4.8 | 6.6 |
| ST031 | 18.1 | 0.05 | 8.4 | 1.1 | 11.8 | < 0.01 | 9.7 | 19.4 |
| ST033 | 14.8 | 0.09 | 18.7 | < 0.7 | 6.0 | < 0.01 | 5.9 | 15.2 |
| ST035 | 15.5 | 0.07 | 49.5 | 1.3 | 7.6 | < 0.01 | 9.3 | 22.5 |
| Min | 9.8 | 0.05 | 2.2 | < 0.7 | 3.2 | < 0.01 | 2.9 | 5.7 |
| Max | 29.9 | 0.18 | 49.5 | 1.7 | 11.8 | < 0.01 | 9.7 | 22.5 |
| Mean | 15.1 | 0.1 | 9.8 | 1.3 | 6.1 | < 0.01 | 5.9 | 12.3 |
| SE | 1.2 | 0.0 | 3.0 | 0.2 | 0.6 | - | 0.5 | 1.6 |
| Lower Level | 20 | 0.7 | 120 | 40 | 60 | 0.2 | 40 | 160 |
| Upper Level | 70 | 4.2 | 370 | 110 | 218 | 0.7 | 60 | 410 |
| OSPAR BAC | 25 | 0.31 | 81 | 27 | 38 | 0.07 | 36 | 122 |
| ERL | 8.2* | 1.2 | 81 | 34 | 47 | 0.15 | 21* | 150 |
| TEL | 7.24* | 0.7 | 52.3 | 18.7 | 30.2 | 0.1 | - | 124 |
| PEL | 41.6 | 4.2 | 160 | 108 | 112 | 0.7 | - | 271 |

*The ERL and TEL's for As and Ni are below the BACs therefore As and Ni concentrations are usually assessed only against the BAC.

**ECR**

Averaged data for the 8 main heavy and trace metals (dry-weight concentration, mg $kg^{-1}$) measured at ECR stations are shown in Table 20. Station ST041 exceeded Irish Lower Level for As and station ST060 exceeded Irish Lower Level, OSPAR BAC, EPA ERL and CSQG TEL and PEL thresholds for Cr.

Cr was the most abundant metal ranging from 4.4 mg $kg^{-1}$ at station ST036 to 198 at station ST060. Concentrations recorded at ST060 were significantly higher than other stations bringing the mean (± SE) concentration across all stations to 48.4 mg $kg^{-1}$ ± 27.6 mg $kg^{-1}$. This was followed by Zn which ranged from 8.7 mg $kg^{-1}$ at station ST036 to 33.7 mg $kg^{-1}$ at station ST060 with a mean (± SE) concentration across all stations of 20.6 mg $kg^{-1}$ ± 3.4 mg $kg^{-1}$.

Al concentrations were also highest at station ST060, measured at 22200 mg $kg^{-1}$, whilst Li was highest at station ST059 with a concentration of 19.1 mg $kg^{-1}$. Hg concentrations were < LoD at all stations and Cu was < LoD at station ST059.

**Table 20** Summary of heavy and trace metal concentrations (mg kg-1) at ECR stations. Shading indicates values above Irish AL1.

| Station | As | Cd | Cr | Cu | Pb | Hg | Ni | Zn |
|---|---|---|---|---|---|---|---|---|
| ST036 | 13.5 | 0.07 | 4.4 | 1.4 | 4.2 | < 0.01 | 3.7 | 8.7 |
| ST041 | 20.4 | 0.10 | 6.8 | 1.4 | 7.0 | < 0.01 | 4.3 | 12.0 |
| ST045 | 12.1 | 0.12 | 21.6 | 2.8 | 6.3 | < 0.01 | 9.4 | 22.7 |
| ST051 | 14.3 | 0.12 | 34.2 | 3.7 | 8.4 | < 0.01 | 10.5 | 25.6 |
| ST059 | 19.2 | 0.09 | 25.4 | < 0.7 | 5.1 | < 0.01 | 9.6 | 20.6 |
| ST060 | 17.5 | 0.24 | 198 | 1.6 | 13.7 | < 0.01 | 11.4 | 33.7 |
| Min | 12.1 | 0.07 | 4.4 | 1.4 | 4.2 | < 0.01 | 3.7 | 8.7 |
| Max | 20.4 | 0.24 | 198 | 3.7 | 13.7 | < 0.01 | 11.4 | 33.7 |
| Mean | 16.2 | 0.1 | 48.4 | 2.2 | 7.5 | < 0.01 | 8.2 | 20.6 |
| SE | 1.2 | 0.0 | 27.6 | 0.4 | 1.3 | - | 1.2 | 3.4 |
| Lower Level | 20 | 0.7 | 120 | 40 | 60 | 0.2 | 40 | 160 |
| Upper Level | 70 | 4.2 | 370 | 110 | 218 | 0.7 | 60 | 410 |
| OSPAR BAC | 25 | 0.31 | 81 | 27 | 38 | 0.07 | 36 | 122 |
| ERL | 8.2* | 1.2 | 81 | 34 | 47 | 0.15 | 21* | 150 |
| TEL | 7.24* | 0.7 | 52.3 | 18.7 | 30.2 | 0.1 | - | 124 |
| PEL | 41.6 | 4.2 | 160 | 108 | 112 | 0.7 | - | 271 |

*The ERL and TEL's for As and Ni are below the BACs therefore As and Ni concentrations are usually assessed only against the BAC.

### 7.5.3. PAHs

The full range of EPA PAHs was tested and raw data reported in Appendix XI. PAH concentrations were compared to Irish Lower Level (no Upper Level available for PAHs), OSPAR BAC, EPA ERL and CSQG TEL and PEL where possible. It should be noted that a large number of the PAHs analysed were measured < LoD. In instances where PAHs concentrations were measurable, the values remained well below reference levels across all stations.

**Array**

Of the 16 array stations analysed for sediment PAHs, only stations ST007 and ST033 contained measurable concentrations. The sum of all 16 measured PAHs at these stations was 8.29 µg $kg^{-1}$ and 3.29 µg $kg^{-1}$ respectively, significantly lower than the Irish Lower Level concentration of 4,000 µg $kg^{-1}$.

Ratios to infer the source origin of hydrocarbons based on PAHs could not be calculated for any stations within the array as at least one value within the ratio was < LoD in all cases.

**ECR**

Four of the six ECR stations sampled for sediment contaminants contained measurable levels of PAHs. The highest total concentration of all 16 PAHs was 23.08 µg $kg^{-1}$ recorded at station ST045. Whilst this was significantly the highest concentration recorded across the survey area, it is still two orders of magnitude less than the Irish Lower Level threshold. OSPAR BAC, ERL, TEL and PEL thresholds for the individual contaminants were also not exceeded at any station.

The ratio of Fluoranthene / Pyrene was computable at ST045 and gave a value of 1.78, suggesting that in this case, hydrocarbons were of pyrogenic origin.

### 7.5.4. THCs

**Array**

THC concentrations within the array area ranged from 221 µg $kg^{-1}$ at station ST013 to 4,430 µg $kg^{-1}$ at ST007. The mean (± SE) concentration across all stations was 1,176 µg $kg^{-1}$ ± 317 µg $kg^{-1}$.

**ECR**

THC concentrations were between 1,070 µg $kg^{-1}$ at station ST036 and ST041, and 4,560 µg $kg^{-1}$ at ST045. The mean (± SE) concentration was 2,770 µg $kg^{-1}$ ± 600 µg $kg^{-1}$.

### 7.5.5. PCBs

PCBs were measured < LoD at all but station ST026 (within the array area). The total concentration of the seven measured PCBs was 1.32 µg $kg^{-1}$, below the Irish Lower Level

concentration of 7 µg $kg^{-1}$. At this station, concentrations exceeded OSPAR BAC for PCB138, PCB153 and PCB180. ERL, TEL and PEL thresholds were not exceeded.

### 7.5.6. Organotins

Dibutyltin (DBT) and tributyltin (TBT) were < LoD at all stations across the array and ECR.

### 7.5.7. OCPs

OCP concentrations were < LoD at nearly all stations sampled, and were below Irish Lower Level thresholds at all stations where OCP were measurable (Irish Lower and Upper Level thresholds only available for the OCPs γ-Hexachlorcyclohexane and Hexachlorobenzene).

**Array**

Within the array area, station ST026 was the only one with measurable levels of OCPs, the highest of which was p,p'-Dichlorodiphenyldichloroethane measured at 0.21 µg $kg^{-1}$.

**ECR**

At stations along the ECR, the OCP γ-Hexachlorcyclohexane was recorded at ST051 (0.12 µg $kg^{-1}$) and p,p'-Dichlorodiphenyltrichloroethane at stations ST036 (0.12 µg $kg^{-1}$) and ST060 (0.14 µg $kg^{-1}$).

## 7.6. Macrobenthos

Fifty-eight grab samples were obtained in replicates of three during the SROWF survey, resulting in a total of 174 samples which were analysed for macrobenthic abundance, diversity and biomass. Ninety of these samples were collected from within the array area and 84 from the ECR. Grab logs are provided in Appendix VIII.

### 7.6.1. Macrobenthic Composition

**Array**

A diverse macrobenthic community was identified across the array area with a total of 19,700 individuals and 444 taxa recorded. The mean (± SE) number of taxa per station was 33 ± 2 taxa, mean (± SE) abundance was 219 ± 22 individuals per station and mean (± SE) biomass was 3.1723 ± 0.9409 gAFDW. The full abundance and biomass matrices are provided in Appendix XIII and Appendix XIV respectively, presenting the abundance of each taxon and biomass per major group (Annelida, Crustacea, Mollusca, Echinodermata and Miscellaneous) in all samples collected across the array area.

As shown in Figure 37, individuals of the phylum Nematoda were the most abundant taxon sampled accounting for 24.8 % of all individuals recorded. This was followed by individuals belonging to the family of polychaetes Polygordius which accounted for 12.8 % of total

abundance. Nemertea (ribbon worms) were the most frequently occurring species appearing in 87.8 % of all samples closely followed by Nematoda (85.6 %) and Polygordius (84.4 %). Nematoda also showed the highest average density of 54.8 individuals per 0.1 $m^2$ whilst the long-clawed porcelain crab *Pisidia longicornis* was the species recorded the maximum number of times in a single sample with 983 individuals recorded at station ST027, replicate B.

Figure 39 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 43 % of all individuals recorded whilst Miscellaneous taxa accounted for approximately 28 %. Annelida taxa also contributed the most to the overall diversity of the macrobenthic assemblages accounting for 50 %. Whilst contributing the least to overall abundance (6 %), Echinodermata taxa contributed the greatest to the total biomass of macrobenthic assemblages accounting for 42 %.

The highest mean (± SE) abundance was observed at station ST027 (n = 810 ± 319), followed by station ST029 (n = 532 ± 61) (Figure 40). The highest number (± SE) of taxa was also recorded at station ST027 with a total of 120 (± 3) different taxa identified. Mean (± SE) biomass was greatest at station ST008 with a total AFDW of 25.3487 ± 24.4821 gAFDW (Figure 40).

**ECR**

A diverse macrobenthic community was identified across the ECR with a total of 6,967 individuals and 313 taxa recorded. The mean (± SE) number of taxa per station was 26 ± 1 taxa, mean (± SE) abundance was 83 ± 7 individuals per station and mean (± SE) biomass was 0.7290 ± 0.1160 gAFDW.

Figure 38 shows that juveniles of the brittle star family Amphiuridae were the most abundant taxon sampled accounting for 12.2 % of all individuals recorded. Juvenile Amphiuridae were also the most frequently occurring species appearing in 76.2 % of all samples, followed by Nemertea which occurred in in 72.6 % of all samples. Amphiuridae juveniles showed significantly the highest average density of 10.1 individuals per 0.1 $m^2$ whilst Nematoda and Polygordius were the taxon recorded the maximum number of times in a single sample with 115 and 108 individuals recorded respectively.

Annelida taxa contributed the most to overall abundance, accounting for approximately 50 % of all individuals recorded, as well as to the overall diversity (52 % contribution). Miscellaneous taxa contributed the most to total biomass, accounting for 37 %, followed by Annelida at 33 % (Figure 39).

The highest mean (± SE) abundance was observed at station ST064 (n = 235 ± 107). Station ST049 had the highest number (± SE) of taxa was per station with a total of 39 (± 3) different taxa identified, closely followed by ST064 with 38 ± 12. Mean (± SE) biomass was greatest at station ST037 with a total AFDW of 3.0130 ± 2.3708 gAFDW. (Figure 40).

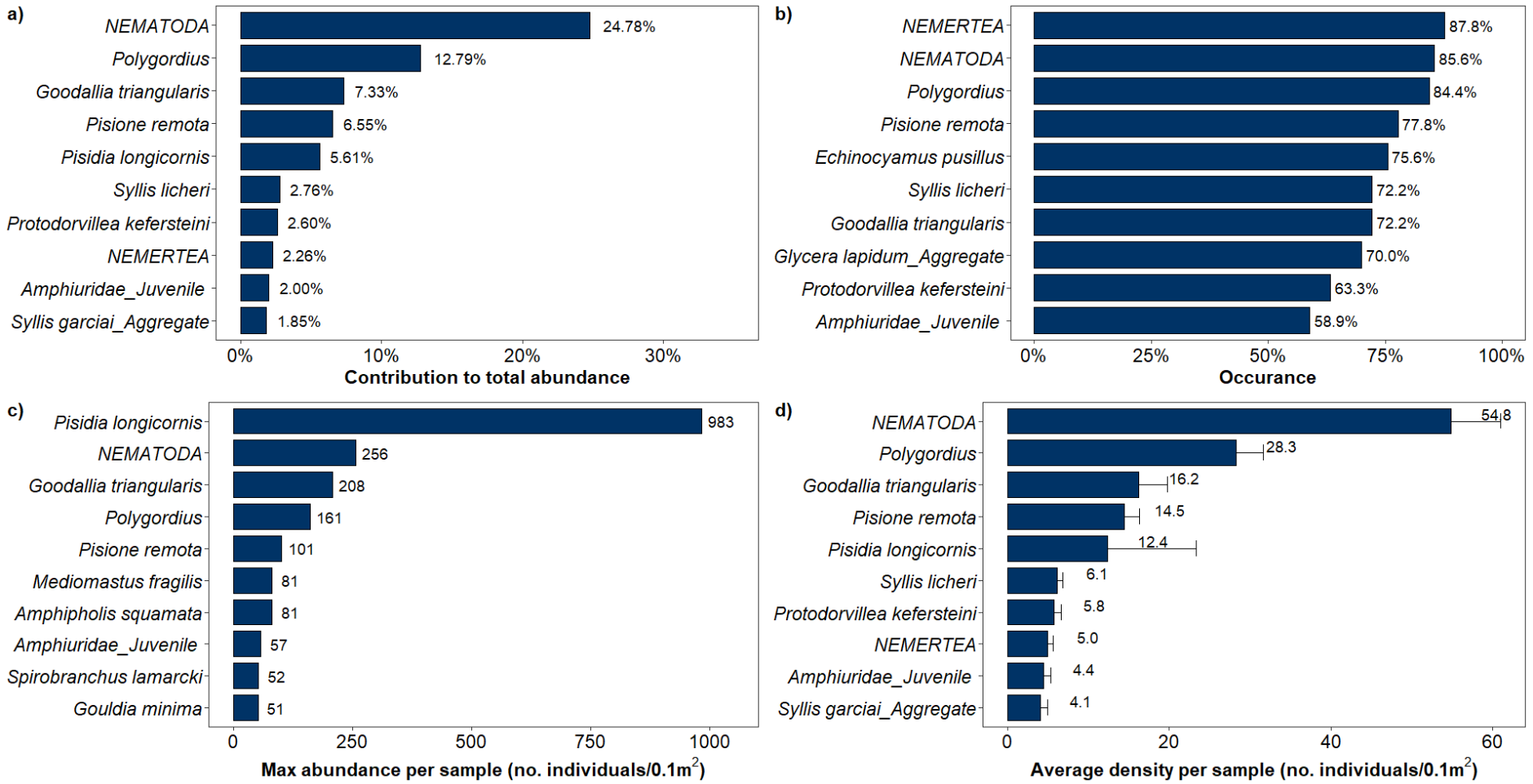


**Figure 37** Percentage contributions of the top 10 macrobenthic taxa to total abundance (a) and occurrence (b) from samples collected across the SROWF array survey area. Also shown are the maximum densities of the top 10 taxa per sample (c) and average densities of the top 10 taxa per sample (d).

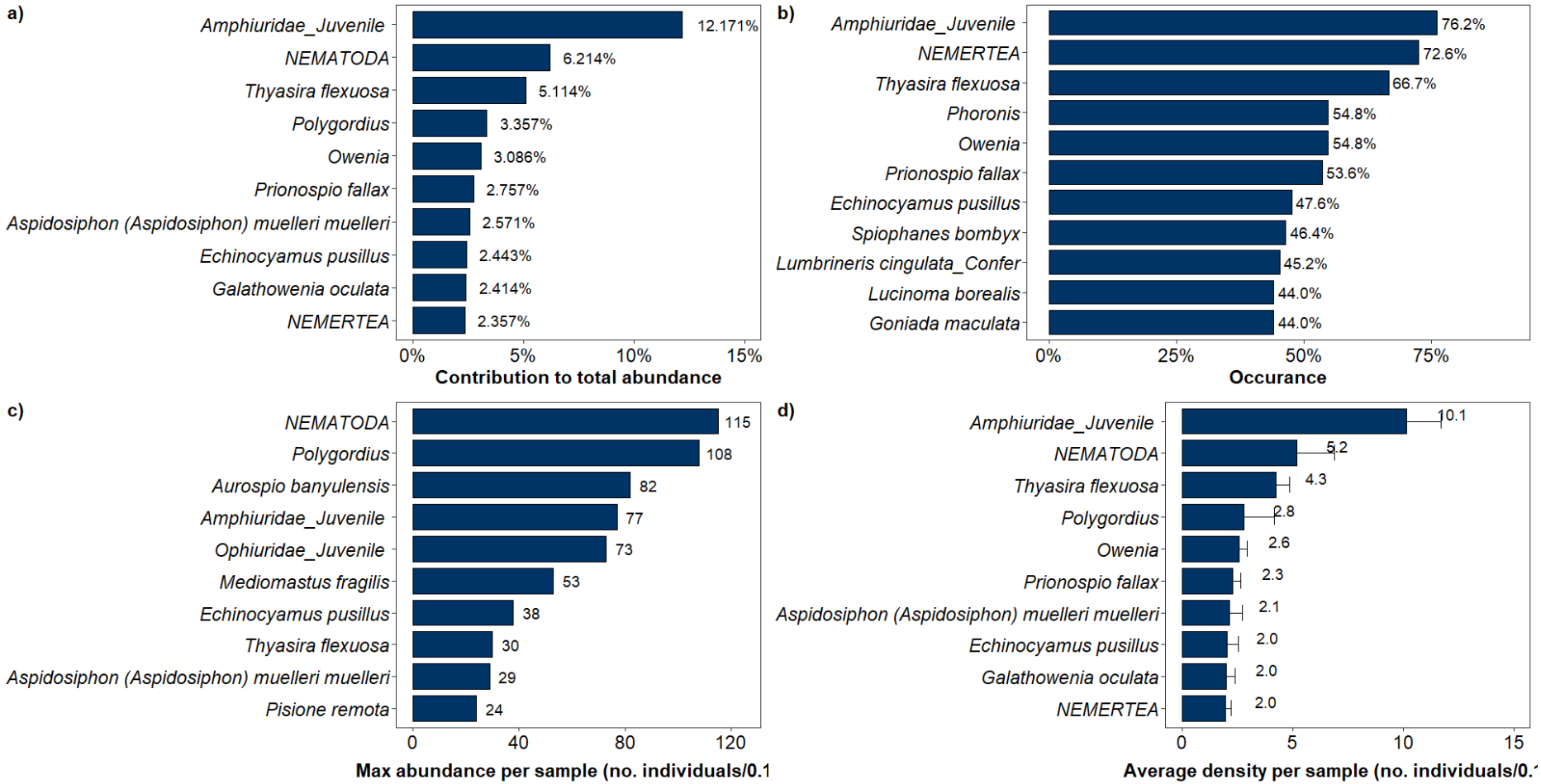


**Figure 38** Percentage contributions of the top 10 macrobenthic taxa to total abundance (a) and occurrence (b) from samples collected along the SROWF ECR. Also shown are the maximum densities of the top 10 taxa per sample (c) and average densities of the top 10 taxa per sample (d).

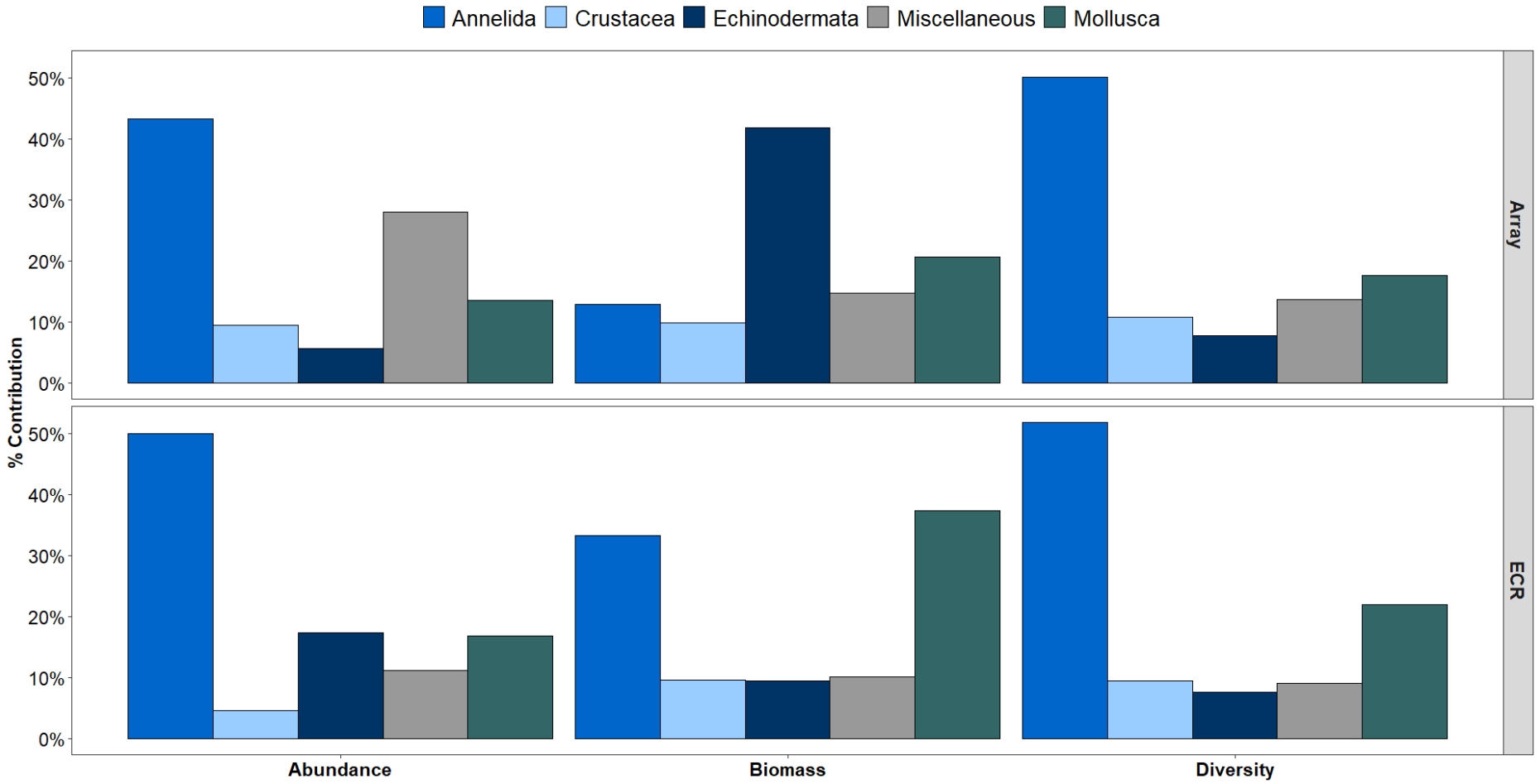


**Figure 39** Relative contribution of the major taxonomic groups to the total abundance, diversity and biomass of the macrobenthos sampled across the SROWF array and ECR.

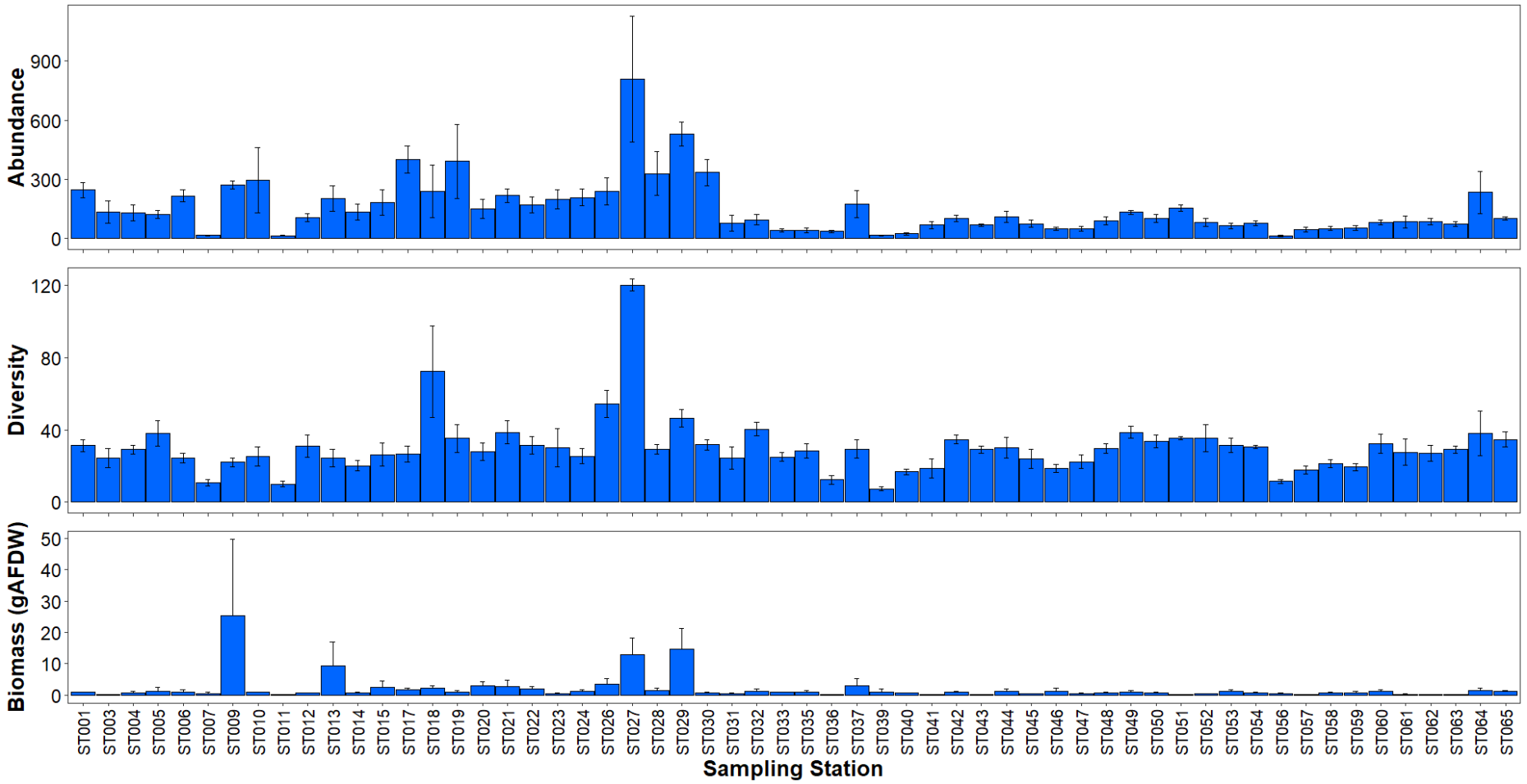


**Figure 40** Abundance, diversity and biomass averaged per station across the survey area. Bars represent standard error (SE). Stations ST001 – ST035 are within the array area and ST036 to ST065 along the ECR.

### 7.6.2. Notable Taxa

**Array**

Within the array survey area, four taxa of interest were identified. One individual identified as the Ross worm *Sabellaria spinulosa* was recorded at station ST027 (replicate B). The invasive, non-native species (INNS) polychaete *Goniadella gracilis* was observed 42 times in low abundance (≤ 3 individuals) in 28 of the 62 analysed samples, recorded at 17 stations distributed across the array area.

Twelve juveniles belonging to the family of clams Veneridae were found throughout the survey area, with five individuals recorded at ST027. One individual brown shrimp (*Crangon crangon*) was identified at station ST010. Both are considered economically important species.

**ECR**

Four taxa of interest were identified in samples collected at stations along the ECR. Three juvenile *Arctica islandica* (Ocean quahog) were recorded along the ECR at stations ST049, ST051 and ST061. The INNS *Monocorophium sextonae* (amphipod) and *G. gracilis* were recorded along the ECR, with one (ST056, replicate C) and 9 specimens counted in total, respectively. *G. gracilis* were present at ST037, ST041 and ST064 (six individuals). Juveniles of the economically important family of clam Veneridae were recorded three times along the ECR.

### 7.6.3. Macrobenthic Groupings

Multivariate analysis was undertaken on the macrobenthic grab abundance data, which was first transformed using dispersion weighting (Section 6.6.4). to identify spatial distribution patterns in the macrobenthic assemblages across the survey area and identify characterising taxa present.

**Array**

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 samples within the array survey area. The dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF (similarity profile routine) permutation test of all nodes within the dendrogram, identified 20 statistically significantly similar groups ($p > 0.05$) and seven outlier stations that did not belong to any group. A dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF permutation test are provided in Appendix XV To enable a broad interpretation of the community present across the survey area, a similarity slice at 21 % was used to amalgamate the 20 SIMPROF groups and seven outliers which yielded to four broader macrobenthic groups and six outlier stations.

To visualise the relationships between the sampled macrobenthic assemblages, a nMDS plot was generated on the community abundance data (Figure 41). 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 (0.2) 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. In general, the degree of clustering of intra-group sample points demonstrates the level of within group similarity (e.g., points within Macrobenthic Group A show distinct clustering), whilst the degree of overlap of inter-group sample points would indicate the level of similarity between different Macrobenthic Groups (not seen in the below plot).

SIMPER analysis was used to identify the key taxa contributing to the within group similarity of each of the four macrobenthic groups; the full SIMPER results are provided in Appendix XVI.

**Macrobenthic Group A** (68 samples) - Characterising taxa present in samples belonging to this group were the polychaete family Polygordius and *Glycera lapidum*. Average similarity of this group was 26.07 %.

**Macrobenthic Group B** (5 samples) - The taxa contributing most to similarities between the five samples within this group (average similarity: 28.50 %) were the bryozoan *Fenestrulina malusii* and *Schizomavella*.

**Macrobenthic Group C** (3 samples) – Dominant taxa contributing within this group were juvenile catworms of the genus *Nephtys* and the bivalve *Timoclea ovata* all together contributing to over 57 % of the within group average similarity of 34.78 %.

**Macrobenthic Group D** (8 samples) – Characterising taxa present in these samples (average similarity 27.31 %) were the amphipod *Harpinia antennaria*, horseshoe worm of the genus *Phoronis* and the polychaete worm *Poecilochaetus serpens*.

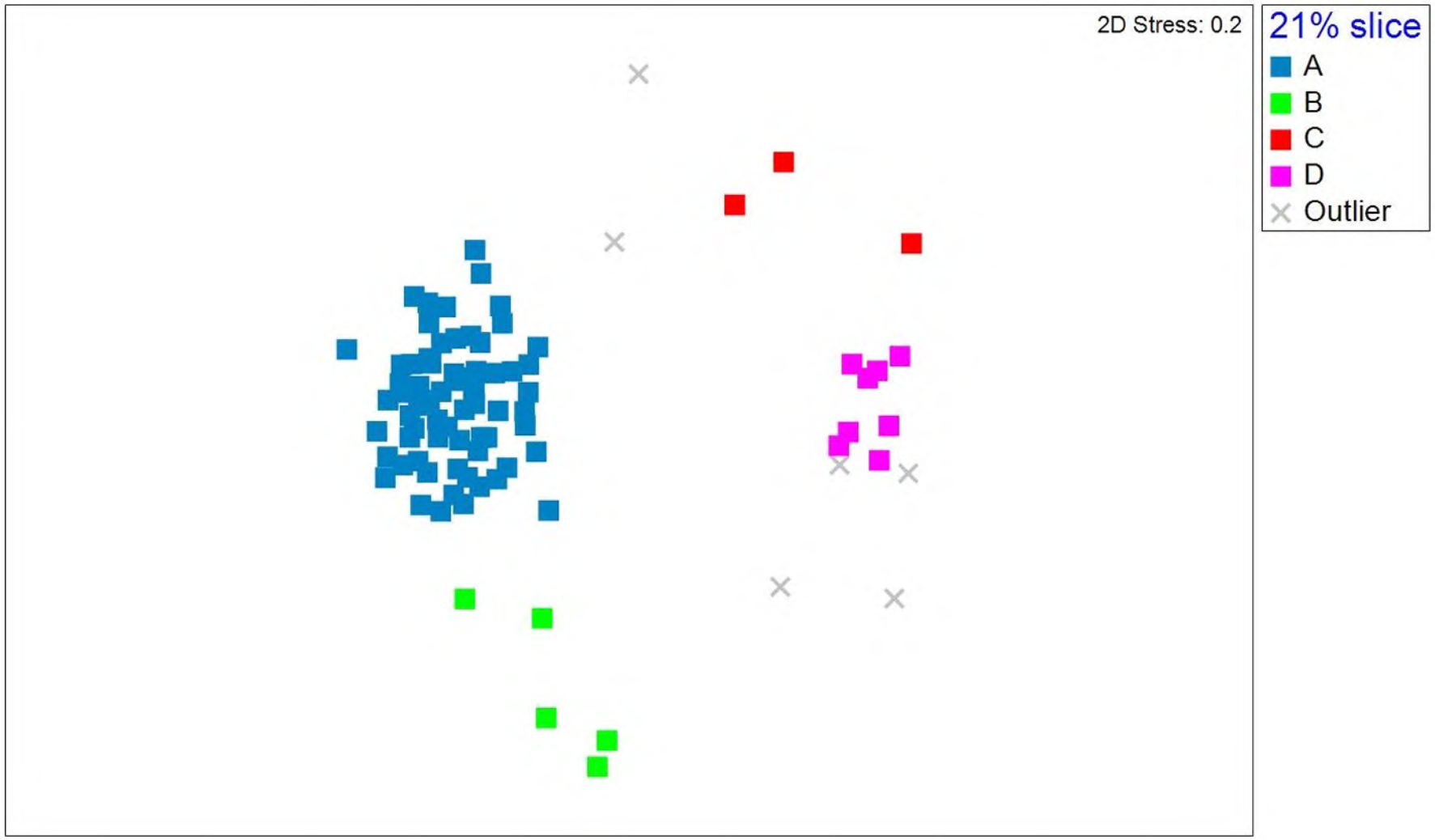


**Figure 41** Two-dimensional nMDS ordination of macrobenthic communities sampled across the array survey area, based on dispersion weighting and Bray-Curtis similarity abundance data. Samples symbolised based on similarity slice at 21 %. Squares indicate samples falling within groups and rosses indicate outliers.


**Figure 42** Macrobenthic community groups sampled across the array area.

**ECR**

Cluster analysis of macrobenthic data was also performed on samples along the ECR. The resulting dendrogram and associated Type 1 SIMPROF identified 13 statistically significantly similar groups ($p > 0.05$) and two outlier samples that did not belong to any group. A dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF permutation test are provided in Appendix XV. SIMPER results of the key taxa contributing to group similarity are shown in Appendix XVII

The nMDS plot for macrobenthic samples collected along the ECR is shown in Figure 43. The stress value of the nMDS ordination plot is 0.21. This relatively high stress value is most likely due to the presence of several groups (clusters) made only of a few stations owning the high diversity in the macrobenthic community observed along the ECR. Full SIMPER analysis is presented in Appendix XVII.

**Macrobenthic Group A** – All three replicates of ST056 fell into this group, which was characterised by the bristleworm *Scalibregma inflatum*, the amphipod *Ampelisca spinipes* and the polychaete *Malmgrenia mcintoshi*, all together contributing to 64 % of the within group similarity of 19.35 %.

**Macrobenthic Group B** – All three replicates of ST040 fell into this group with an average similarity of 24.39 %. The hydrozoan *Lovenella clausa*, the bivalve *Lucinoma borealis* and the horseshoe worm *Phoronis* contributed to 56 % of the group similarity.

**Macrobenthic Group C** – All three replicates of stations ST057 and ST059 and replicates A and B of station ST058 fell into this group The top species contributing to this groups average similarity of 27.39 % were the bristleworm *Spiophanes bombyx,* the gastropod *Euspira nitida,* Nemertea, and the pea urchin *Echinocyamus pusillus*.

**Macrobenthic Group D** – Only two samples belonged to this group: replicate C of stations ST047 and ST058. The overall similarity of this group was 30.88 %, driven largely by the presence of the amphipod *Perioculodes longimanus*, the basket shell *Varicorbula gibba* and Nemertea.

**Macrobenthic Group E** – Only two samples belonged to this group: replicate C of stations ST045 and ST046. The average similarity of 43.66 % in this group was largely contributed to by the amphipod *Hippomedon denticulatus*, the bivalves *Myrtea spinifera* and *Abra nitida,* and the polychaete *Goniada maculata*.

**Macrobenthic Group F** (29 samples) – All three replicates of stations ST048, ST049 and ST050 fell into this group together with replicate B of stations ST047 and ST051. The taxa contributing the most to the group average similarity of 32.42 % were Nemertea, the polychaetes *Prionospio fallax* and *Owenia,* the bivalves *V. gibba* and *Thyasira flexuosa*.

**Macrobenthic Group G** – All three replicates of stations ST044, ST061 and ST062 fell into this group together with replicates A and B of stations ST045 and ST046, replicates A and C of station

ST051, replicate A of stations ST047 and ST063, and replicate B of station ST065. The taxa contributing most to the group average similarity of 29.82 % were the polychaetes *Owenia* and *G. maculata* the bivalves *L. borealis* and *T. flexuosa* and the amphipod *H. antennaria*.

**Macrobenthic Group H** – All three replicates of stations ST042 and ST043 as well as replicates B and C of stations ST063 belonged to this group with an average similarity of 34.40 %. The main species driving overall similarity were *Phoronis*, the polychaetes *Sthenelais limicola, P. fallax* and *Owenia* and the bivalves *T. flexuosa* and *Nucula nitidosa*.

**Macrobenthic Group I** – All three replicates of stations ST052, ST053, St and ST060 as well as replicates A and C of stations ST065 belonged to this group with an average similarity of 32.19 %. The main taxa contributing to this group were the polychaete *Lumbrineris cingulata* and *S. limicola*, the bivalve *T. flexuosa, Phoronis*, and the amphipod *H. antennaria*.

**Macrobenthic Group J** – Only replicates A and B of station ST039 fell into this group with an average similarity of 18.19 % and characterised by the polychaete *Eunice vittata*.

**Macrobenthic Group K** - Only replicates A and B of station ST041 fell into this group with an average similarity of 30.80 % and characterised by the polychaete *Aglaophamus agilis*.

**Macrobenthic Group L** – Replicates A and B of Station ST037, replicates A and C of ST064 and replicate C of ST041 fell into this group with average similarity of 35.74 %. Characterising taxa were Nemertea and Nematoda as well as the polychaetes *Protodorvillea kefersteini, G. lapidum* and *Polycirrus*.

**Macrobenthic Group M** – All three replicates of station ST036 and replicate C of ST037 belonged to this group characterised by the bivalves *Clausinella fasciata* and *Goodallia triangularis* and the polychaete *Syllis licheri*.

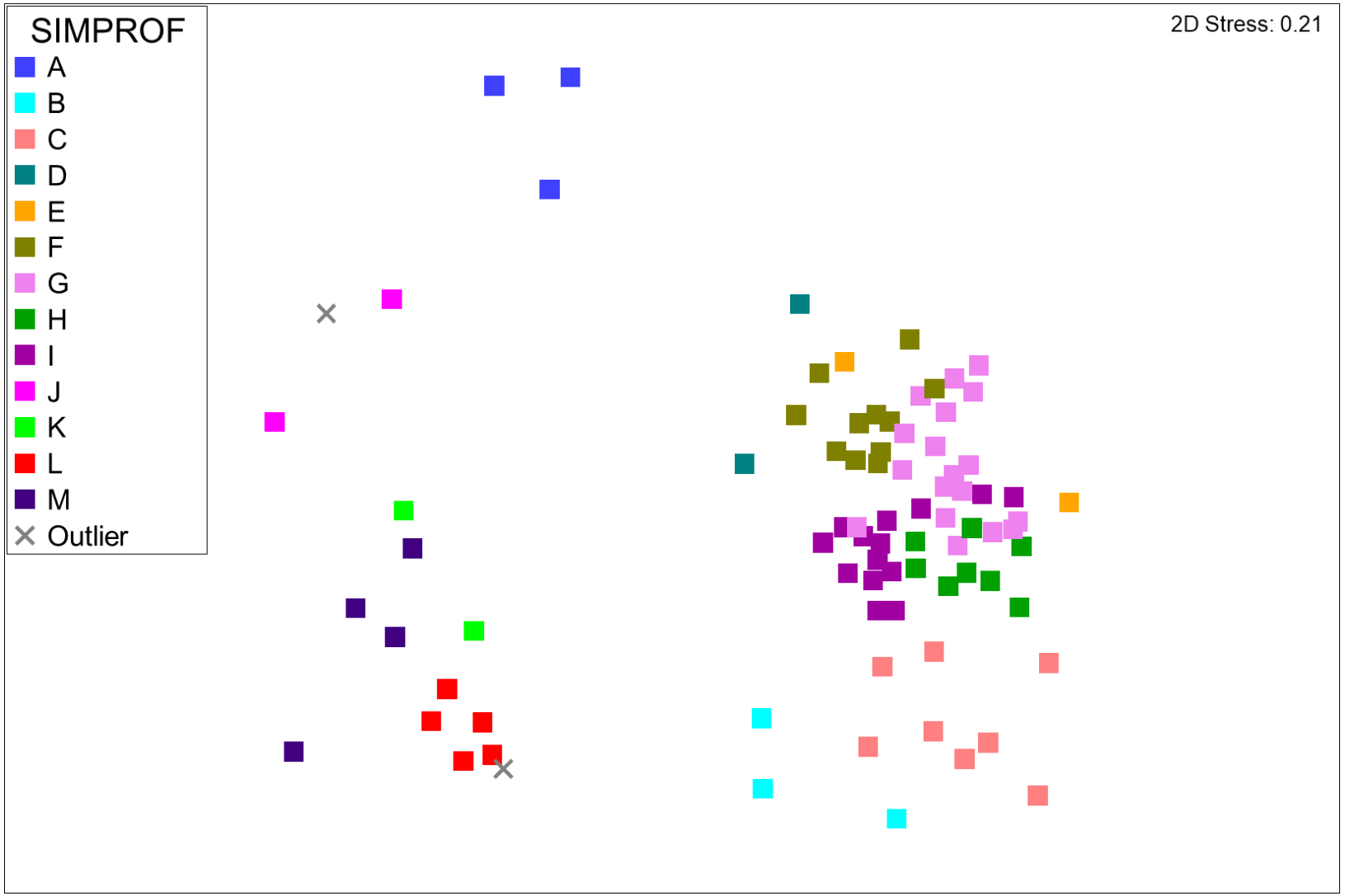


**Figure 43** Two-dimensional nMDS ordination of macrobenthic communities sampled along the ECR, based on dispersion weighting and Bray-Curtis similarity abundance data. Samples symbolised based on results of SIMPROF routine.

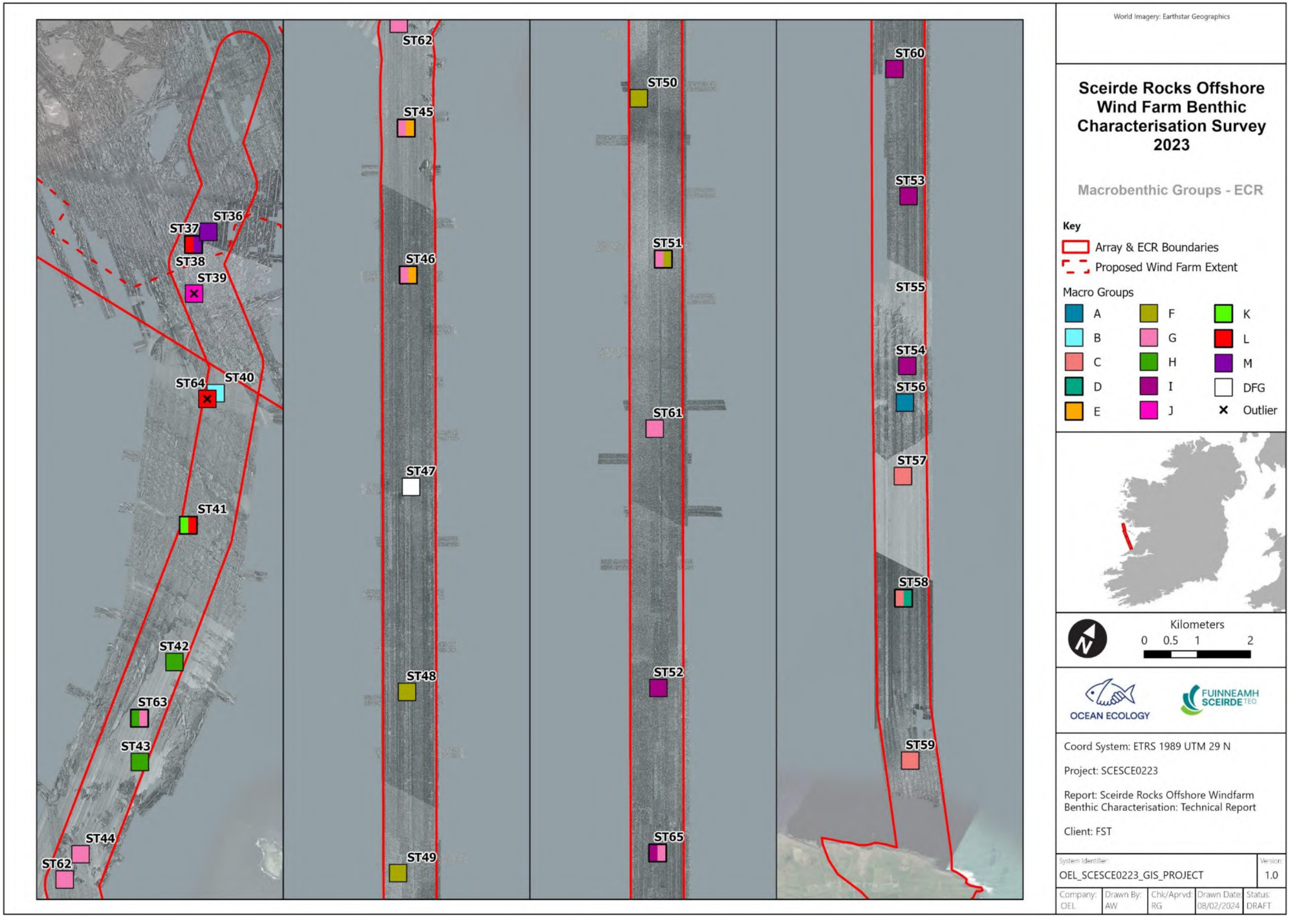


**Figure 44** Macrobenthic community groups sampled across the ECR area.

### 7.6.4. Biotope Assignment

For each of the Macrobenthic Groups determined using cluster analysis, biotopes and habitats were assigned in line 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 42 and Figure 44.

All outlier stations were assigned to their corresponding EUNIS code as derived from sediment PSD imagery analysis and bathymetry data as the macrobenthic multivariate analysis did not show any pattern in the community composition that could be used to assign a biotope.

Similarly, most of the macrobenthic groups which were made up of only a handful of samples were assigned the EUNIS code derived from sediment PSD and imagery analyses and bathymetry data as their macrobenthic assemblages were not dominated by any key taxa typically associated to a known biotope.

**Array**

The biotope A5.143 '*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand' most closely aligned with the community observed in Macrobenthic Group A. This biotope is described as typical of coarse gravelly or shelly sand (sometimes with a slight mud content), along open coasts in depths of 10 to 30 m. This aligns with sediment PSD and imagery analysis as well as geophysical data which describe the majority of samples within this group as A5.15 'Deep circalittoral coarse sediment' and A5.14 'Circalittoral coarse sediment'. Key characterising taxa of this biotope included *P. kefersteini*, Nemertea and *G. lapidum*, all of which were key taxa driving similarity within this group. Physical mismatch was observed within this group at stations ST003, ST010 and ST014 described by PSD data as A5.25 'Circalittoral fine sand' but containing taxa typical of coarse sediment habitats.

Macrobenthic Group D most closely aligned with the community characterising EUNIS biotope A5.253 'Medium to very fine sand, 100-120 m, with polychaetes *Spiophanes kroyeri*, *Amphipectene auricoma*, *Myriochele* sp., *Aricidea wassi* and amphipods *Harpinia antennaria'*. This biotope aligns with sediment PSA and imagery analysis which describe samples within this group as A5.25 'Circalittoral fine sand' or A5.26 'Circalittoral muddy sand'. Characterising taxa of this biotope were found in samples within this group including *Amphictene auricoma* and *H. antennaria*.

It was not possible to assign biotopes to Macrobenthic Groups B and C as the taxa contributing to similarity within these groups were not characterising of any known EUNIS biotopes. Macrobenthic group B was made of all three replicates of station ST027 and replicates A and B of station ST018. These samples were characterised by coarse sediments, encrusted by maerl in the case of ST027, which was therefore assigned to Level 4 EUNIS codes A5.51 'Maerl beds' while station ST018 was left as A5.14 'Circalittoral coarse sediment'. Samples collected from

ST011 which make up Macrobenthic Group C were assigned the Level 4 EUNIS code A5.25 'Circalittoral fine sand'. All samples collected at station ST007 were outliers. This station was assigned the Level 4 EUNIS code A5.37 'Deep circalittoral mud'.

**ECR**

Macrobenthic Group C most closely aligned with EUNIS biotope A5.251 '*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand'. This habitat is most commonly observed in circalittoral and offshore medium to fine sand (from 40 m to 140 m) aligning with ground truthing data which described samples within this group as fine and muddy sand. Taxa within this group were similar to those characterising this biotope with *E. pusillus*, *S. bombyx* and *E. nitida* driving within group similarity.

Macrobenthic Group F most closely aligned with EUNIS biotope A5.377 '*Myrtea spinifera* and polychaetes in offshore circalittoral sandy mud'. This biotope is found in deep offshore habitats characterised by sandy mud supporting a community made of *M. spinifera, Chaetozone setosa* and *A. nitida* which were recorded in the samples belonging to this group. This was further supported by the results of PSD and seabed imagery analysis indicated mud sediments as the dominant substate.

Macrobenthic Group H most closely aligned with EUNIS biotope A5.272 '*Owenia fusiformis* and *Amphiura filiformis* in deep circalittoral sand or muddy sand'. This biotope is found in areas of muddy sand in offshore waters supporting a community including *Owenia, Diplocirrus glaucus, S. bombyx* and *T. flexuosa* which were all recorded in the samples belonging to this group. This was further supported by the results of PSD and seabed imagery analysis indicated sand and muddy sand at these locations.

Macrobenthic Group L most closely aligned with EUNIS biotope A5.143 '*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand'. This biotope is characterised by the presence of *P. kefersteini* and polychaetes such as *G. lapidum* which were found to characterise macrobenthic group L and consistent with the findings based on PSA and imagery analysis.

## 7.7. Sediment eDNA

eDNA was extracted from all grab samples collected across the survey area for a total of 30 sediment eDNA samples collected across the array and 28 along the ECR. The full data is provided in Appendix XVIII while an overview of the main findings is included below.

None of the notable taxa recorded in the macrobenthic grab samples were recorded in the sediment eDNA samples. In contrast, maerl was recorded in the sediment eDNA samples at station ST004, ST026 and ST027. Maerl was observed in the seabed imagery collected at both stations ST026 and ST027 corroborating the maerl assessment presented in Section 7.3.2; however, the record of maerl eDNA at station ST004 was unexpected and possibly a sign of advection of eDNA material from other sources as station ST004 was located at a water depth of 79 m, too deep for maerl to survive. Other notable taxa recorded in the sediment eDNA samples included two INNS of Japanese seaweeds: *Fibrocapsa japonica,* and *Dasysiphonia japonica*; the deep-sea amoeba from the Sea of Japan *Squamamoeba japonica* and the mite *Demodex brevis* which could indicate sample contamination as this organism is typically found on human skin. *Demodex brevis* was only recorded at station ST061 meaning that if sample contamination occurred was only limited to this sample.

## Habitat Mapping

Habitat mapping was produced based on the interpretation of seabed imagery analysis, sediment and macrobenthic data and data collected during the 2022 geophysical campaign conducted by FST. To note that in areas where acoustic data was not collected like the northern part of the array area, confidence in the assignment of habitats and biotopes was overall low.

**Array**

The habitat/biotope map for the array area is provided in **Error! Reference source not found.**, while Figure 20 shows the spatial distribution and type of Annex I reefs across the array area.

Along the northeastern shoreward boundary, and centre of the survey area, the area interpreted as 'Sand' based on review of the acoustic data was ground-truthed as BSH A5.1 'Coarse sediment' based on PSD analysis. Analysis of seabed imagery and bathymetry data further corroborated these stations as EUNIS level 4 habitat A5.14 'Circalittoral coarse sediment', while the macrobenthic community indicated the presence of biotope A5.143 '*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand'. Interspersed within these habitats were a number of stations classified by PSD analysis as BSH A5.2 'Sand and muddy sand'. Given the water depth of these stations and results of the seabed imagery analysis, they were deemed to represent EUNIS habitats A5.25 'Circalittoral fine sand' and A5.26 'Circalittoral muddy sand'. The large area of rock substrate identified based on the acoustic data was assigned to biotope A4.214 'Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock' to the north of the survey area grading into A4.212 '*Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral

rock' towards the centre and A4.121 '*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock' to the south. The shallower rocky substrate in the middle of the array area was deemed to represent biotope A3.116 'Foliose red seaweeds on exposed lower infralittoral rock'. In the western offshore region of the survey area the area interpreted as 'Sand' and 'Silty Sand' based on review of acoustic data was ground-truthed as BSH A5.1 based on PSD data. Seabed imagery and macrobenthic community analyses and bathymetry data allowed for the assignment of this area to EUNIS Level 4 habitat A5.15 'Deep circalittoral coarse sediment' and A5.143. The southern boundary of the array area was interpreted as 'Sand' and 'silty Sand' in line with PSD analysis which described sediments in this region as BSH A5.2 'Sand and muddy sand' likely representative of either A5.25 'Circalittoral fine sand' or A5.26 'Circalittoral muddy sand' and A5.27 'Deep circalittoral sand'. In a few instances the fine sand substrate supported a macrobenthic community representative of biotope A5.253 'Medium to very fine sand, 100-120 m, with polychaetes *Spiophanes kroyeri*, *Amphipectene auricoma*, *Myriochele* sp., *Aricidea wassi* and amphipods *Harpinia antennaria'* (**Error! Reference source not found.**). Additionally, PSD analysis of station ST027 described the sediments as A5.4 'Mixed sediments', however upon further inspection of the seabed imagery the EUNIS biotope complex A5.51 'Maerl beds' was assigned as maerl was observed over the mixed sediments (Section 7.3.2 provides more information on the maerl bed habitat).

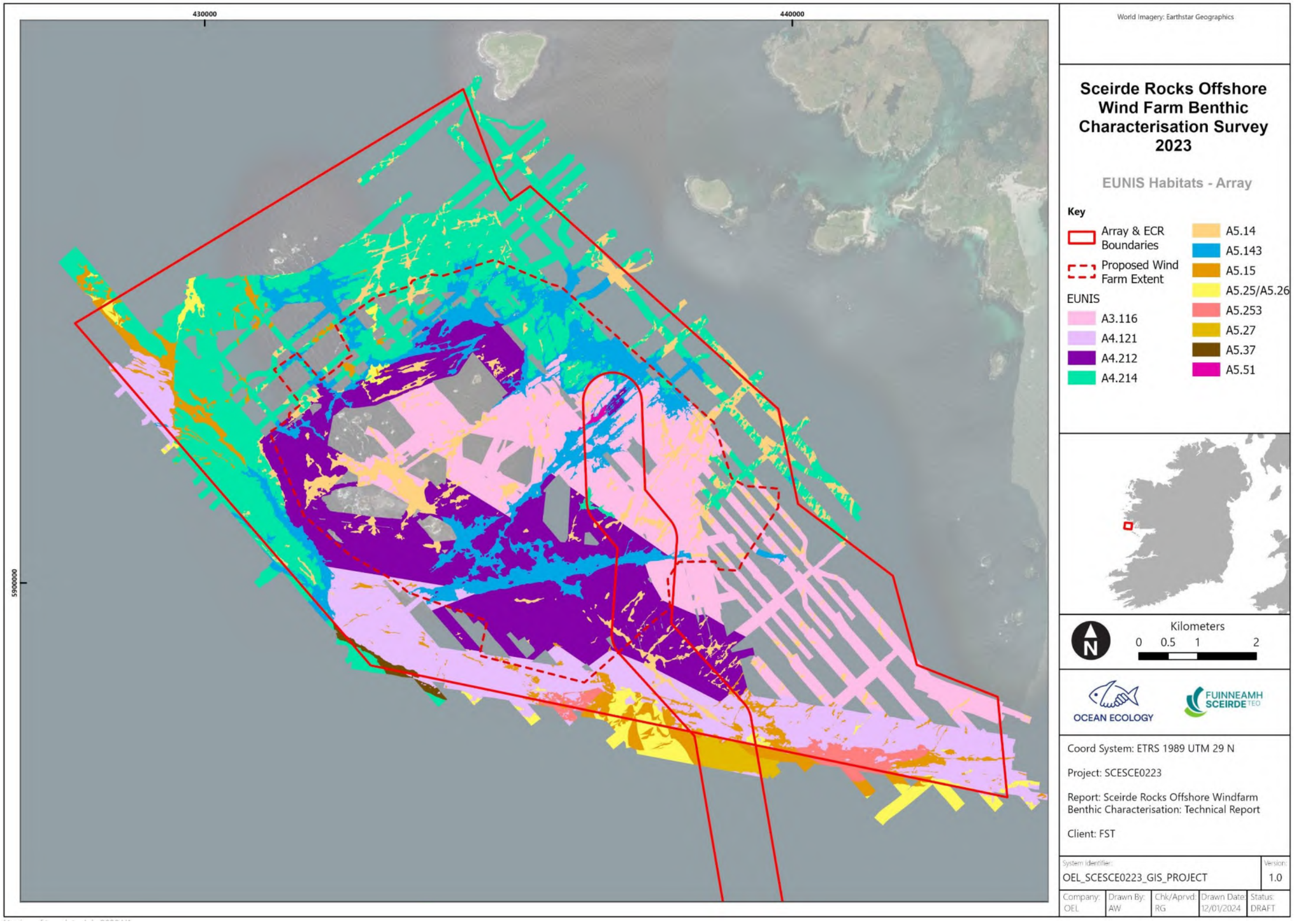


**Figure 45** EUNIS biotope mapping across the array area of the propose SROWF site.

**ECR**

The habitat/biotope map for the ECR is provided in Figure 46**Error! Reference source not found.**, while Figure 25 show spatial distribution and type of Annex I reef habitats along the ECR.

The northernmost region of the ECR, where it intersects the array area, was interpreted as rock interspersed with small areas of 'Sand', 'Silty Sand' and 'Sandy Gravel' based on the acoustic data. As already mentioned in Section 7.2.2, the rock habitats observed in this region were classified as rock habitats complexes A3.166, A4.121 and A4.212. The areas of 'Sand' and 'Gravelly Sand' were ground-truthed by PSD analysis as BSH A5.1 'Coarse sediments'. This was further corroborated by seabed imagery analysis and assigned to the EUNIS Level 4 habitats A5.14 'Circalittoral coarse sediment' and A5.15 'Deep circalittoral coarse sediments' depending on water depth. In a few instances this could be further assign to biotope A5.143 based on the macrobenthic community. Area of 'Silty Sand' were ground-truthed as EUNIS Level 4 habitat A5.27 'Deep circalittoral sand'. The central region of the ECR saw a transition in the interpreted substrate from 'Rock' to 'Silty Sand'. Seabed imagery analysis and PSD analysis ground-truthed these areas as EUNIS habitats A5.37 'Deep circalittoral mud' in the north and A5.26 'Circalittoral muddy sand' more towards the south (**Error! Reference source not found.**). The macrobenthic community across this section of the ECR reflected the presence of muddy sand and sandy mud but was not indicative of any specific biotope. With depths decreasing as the ECR approached landfall, stations in the southern region of the ECR were largely described as A5.26 'Circalittoral muddy sand' and A5.251 '*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand' confirming the acoustic data interpretation of silty sand. The patch of sandy gravel interpreted in the acoustic data in the middle of the southern region of the ECR was ground-truthed as a rock habitat based on seabed imagery representative of biotope A4.121 '*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock' encompassing a small area identified as A4.2146 '*Caryophyllia smithii* with faunal and algal crusts on moderately wave-exposed circalittoral rock'.

The habitat/biotope map for the array area is provided in Figure 45**Error! Reference source not found.**.

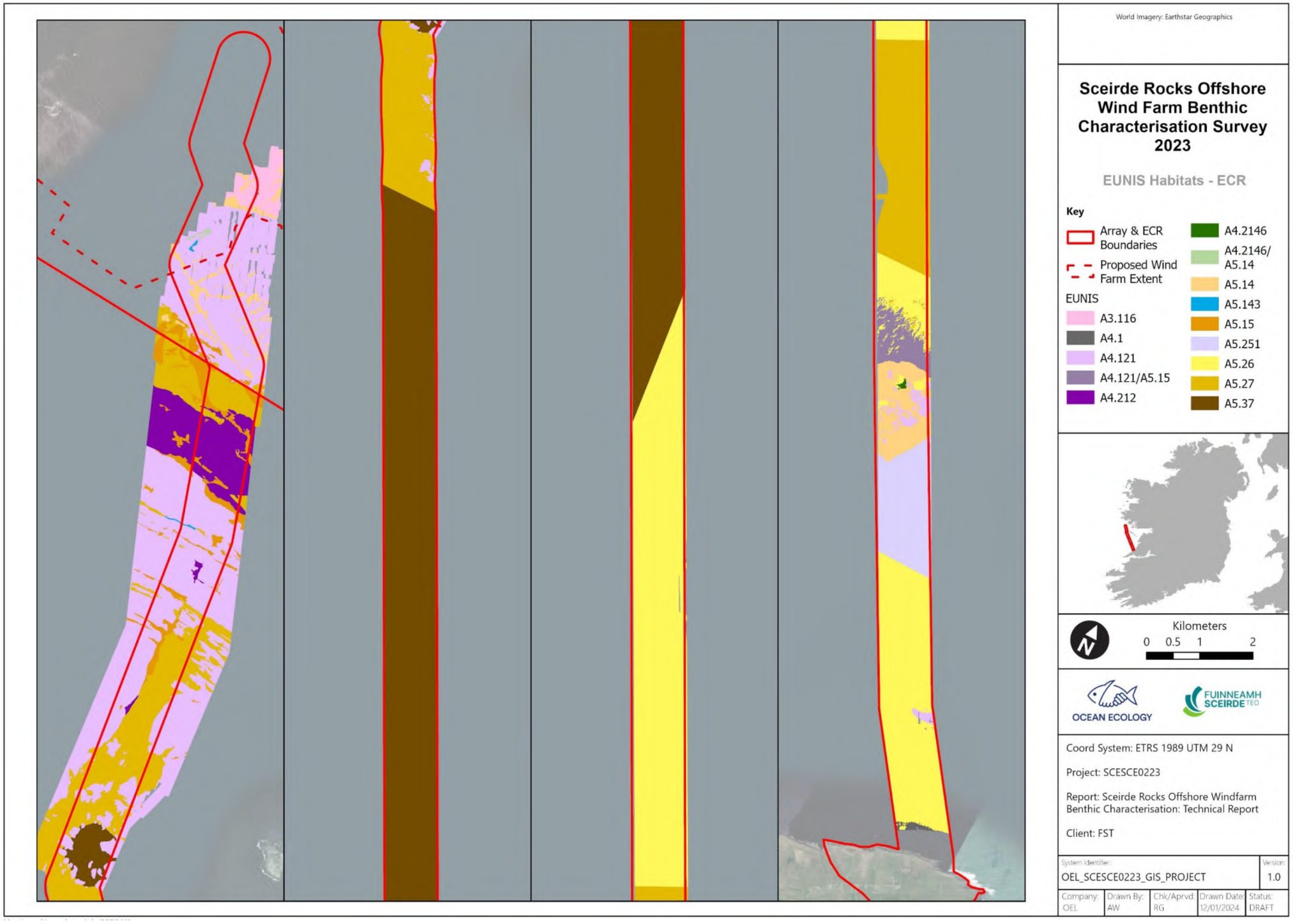


**Figure 46** EUNIS biotope mapping across the ECR of the propose SROWF site.

## 7.7. Water Sampling

Water samples for chemical analysis were collected from 33 stations, 17 within the array and 16 along the ECR with samples taken from the top and bottom of the water column resulting in 66 samples for analysis. Full water sampling data are provided in Appendix XII and water profiles are provided in Appendix XIX.

**Array**

Within the array, TOC ranged from < LoD at both depths at stations ST023 and ST025 and the top of ST021 to 1.47 $mgl^{-1}$ at the bottom of station ST015.

Nitrate as $NO_3$ was < LoD at the majority of stations, with the bottom of ST009 showing the highest concentration of 8.70 $mgl^{-1}$. Likewise, Orthophosphate as P was < LoD in all but two samples, ST027 bottom and ST031 bottom, with concentrations of 0.01 $mgl^{-1}$ and 0.05 $mgl^{-1}$ respectively. Chloride as Cl ranged from 8,770 $mgl^{-1}$ at the bottom of station ST033 to 17,300 $mgl^{-1}$ at the bottom of ST007. Nitrite as $NO_2$ was < LoD at all stations.

**ECR**

TOC at stations along the ECR was < LoD in 15 of the 32 samples analysed, with a maximum concentration of 1.24 $mgl^{-1}$ at the top of station ST059.

Nitrite as $NO_2$ was < LoD at all stations as was Nitrate as $NO_3$. Orthophosphate as P was < LoD in 29 samples, with the highest concentration of 0.02 $mgl^{-1}$ recorded at both the top of ST036 and bottom of ST045. Chloride as Cl was between 8,630 $mgl^{-1}$ (ST043 top) and 18,200 $mgl^{-1}$ (ST041 top).

## 7.8. Water eDNA

Water eDNA was analysed at 10 stations with samples collected at the top, middle and bottom of the water column at each station as detailed in Section 5.7.

### 7.8.1. Fish Community

An examination of the eDNA results led to the identification of a diverse fish community derived from 43 OTUs representative of fish taxa. To note that no target species were detected in the bottom sample of station ST061. The most prevalent fish species among these OTUs were the European Pilchard, Atlantic Horse Mackerel, and Ballan Wrasse (Table 21). Full eDNA results are provided in Appendix XX. Of the fish identified, one was deemed to be of conservation importance while a further 20 species were also listed as species of commercial importance in Europe (Table 21). It should be noted that for 8 of the most common fish taxa there was low confidence in their identification as it was based on fewer than three matches to sequences in the reference database, and/or limited geographic occurrence records for the taxon (Table 21).

A large variability was observed in fish species found in each sample (top, middle and bottom) from the same station (Figure 47). No clear pattern was observed between samples as at some stations it was the top sample which reported the highest fish species diversity whereas at other stations it was either the middle or bottom one. However, the European Pilchard was highly abundant at all three depths (Figure 47).

**Table 21** Most relevant fish taxa identified across the survey area based on eDNA analysis. Asterisk (*) identifies taxa with low confidence in the identification of their OTUs, as it was based on fewer than three matches to sequences in the reference database, and/or limited geographic occurrence records for the taxon.

| Fish | Common Name | Status | Number of samples in which taxon occurred |
|---|---|---|---|
| *Sardina pilchardus* | European Pilchard | Commercial | 25 |
| *Trachurus trachurus* | Atlantic Horse Mackerel | Commercial | 14 |
| *Labrus bergylta* | Ballan Wrasse | | 14 |
| *Scomber scombrus* | Atlantic Mackerel | Commercial | 13 |
| *Ammodytidae* | | | 11 |
| *Pollachius pollachius* | Pollack | Commercial | 7 |
| *Salmo salar* | Atlantic Salmon | Annex II/OSPAR/Commercial | 6 |
| *Trisopterus minutus* | Poor Cod | Commercial | 5 |
| *Ammodytes tobianus** | Lesser Sand Eel | Commercial | 5 |
| *Ctenolabrus rupestris* | Goldsinny Wrasse | | 5 |
| *Labrus mixtus* | Cuckoo Wrasse | | 5 |
| *Symphodus melops* | Corkwing Wrasse | | 5 |
| *Chirolophis ascanii** | Yarrell's Blenny | | 4 |
| *Taurulus bubalis* | Long-Spined Bullhead | | 3 |
| *Melanogrammus aeglefinus* | Haddock | Commercial | 2 |
| *Raniceps raninus** | Tadpole Fish | | 2 |
| *Ciliata septentrionalis** | Northern Rockling | Commercial | 2 |
| *Molva molva** | Common Ling | Commercial | 2 |
| *Belone belone* | *Garfish* | Commercial | 1 |
| *Sprattus sprattus* | European Sprat | Commercial | 1 |
| *Trisopterus esmarkii** | Norway Pout | Commercial | 1 |
| *Trisopterus luscus* | Pouting | Commercial | 1 |
| *Thunnus thynnus* | Atlantic Bluefin Tuna | Commercial | 1 |
| *Lepidorhombus whiffiagonis* | Megrim | Commercial | 1 |
| *Scophthalmus maximus** | Turbot | Commercial | 1 |
| *Zeugopterus punctatus** | Common Topknot | Commercial | 1 |
| *Salmo trutta* | Brown Trout | Commercial | 1 |
| *Helicolenus dactylopterus* | Blackbelly Rosefish | Commercial | 1 |

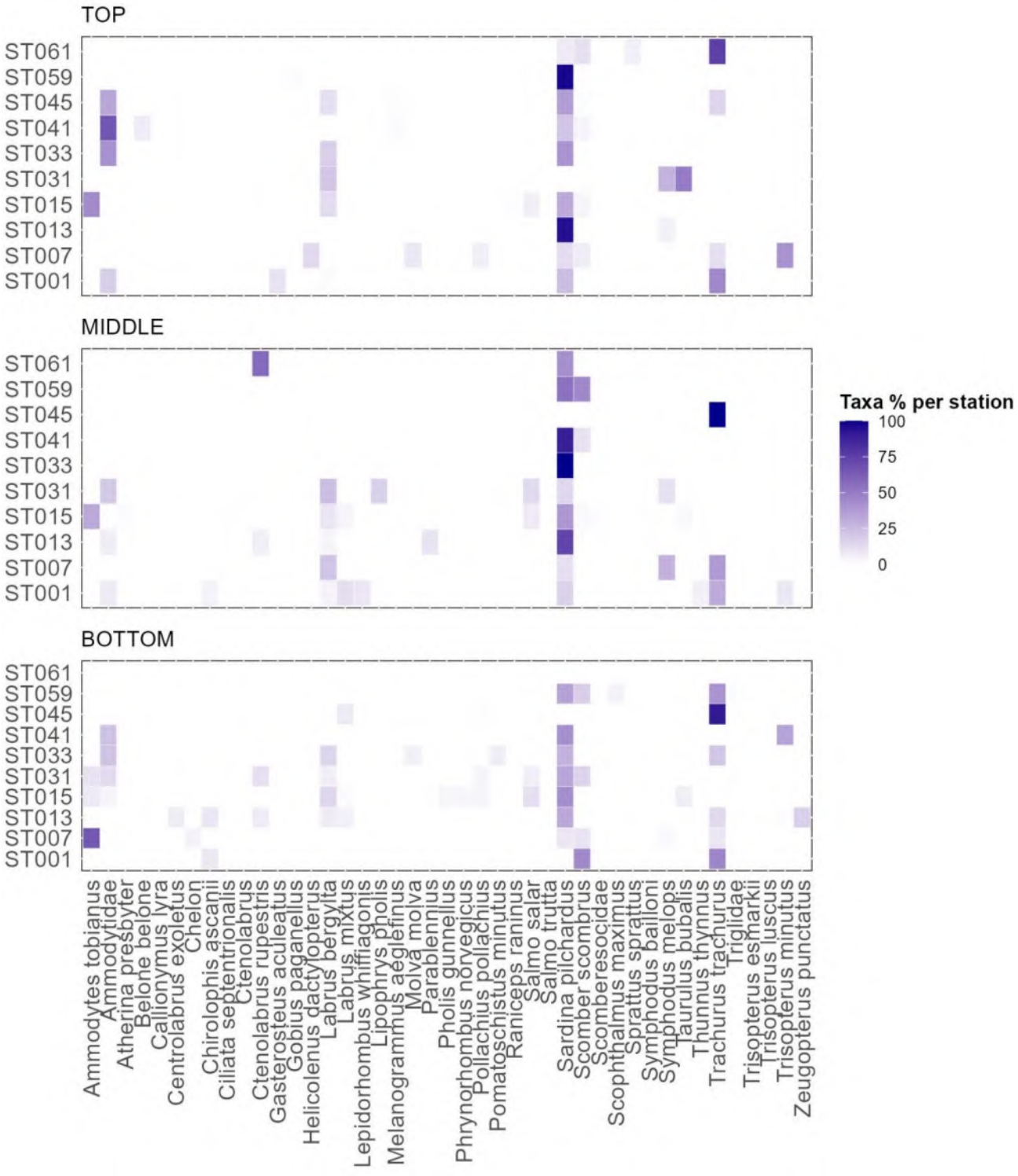


**Figure 47** Fish percentage abundance heat map: Analysis of top, middle, and bottom depths at each station. Colour intensity indicates the percentage of sequences per sample based on all DNA sequences within an individual sample (the sum of one station (row) is 100 %).

### 7.8.2. Other Species of Interest

eDNA was also analysed on a vertebrate array which yielded results for fish, birds, marine mammals as well as terrestrial animals. At four stations, ST031 (mid sample), ST061 (bottom sample), ST041 (bottom sample), and ST045 (top and middle samples) the water samples yield no amplifiable DNA and therefore no species were reported for those five samples.

Of the 39 fish taxa identified in this analysis, 11 species were not recorded in the above fish assessment but recorded in the vertebrate array, namely the Imperial Scaldfish *Arnoglossus imperialis*, the Boarfish *Capros aper*, the Fivebeard Rockling *Ciliata mustela*, the Three-Bearded Rockling *Gaidropsarus vulgaris*, the Two-Spotted Goby *Gobiusculus flavescens*, the Greater Sandeel *Hyperoplus immaculatus*, the European Hake *Merluccius merluccius*, the Striped Red Mullet *Mullus surmuletus*, the Tompot Blenny *Parablennius gattorugine*, the Portuguese Blenny *Parablennius ruber*, and the Sea Stickleback *Spinachia spinachia* (Figure 48).

Of these, the Imperial Scaldfish, the European Hake, and the Striped Red Mullet are of commercial value in Europe, with the European Hake and the Striped Red Mullet presenting limitations on the total allowable catch. To note that 7 of these OTUs were of low confidence in their identification as it was based on fewer than three matches to sequences in the reference database, and/or limited geographic occurrence records for the taxon (Appendix XX).

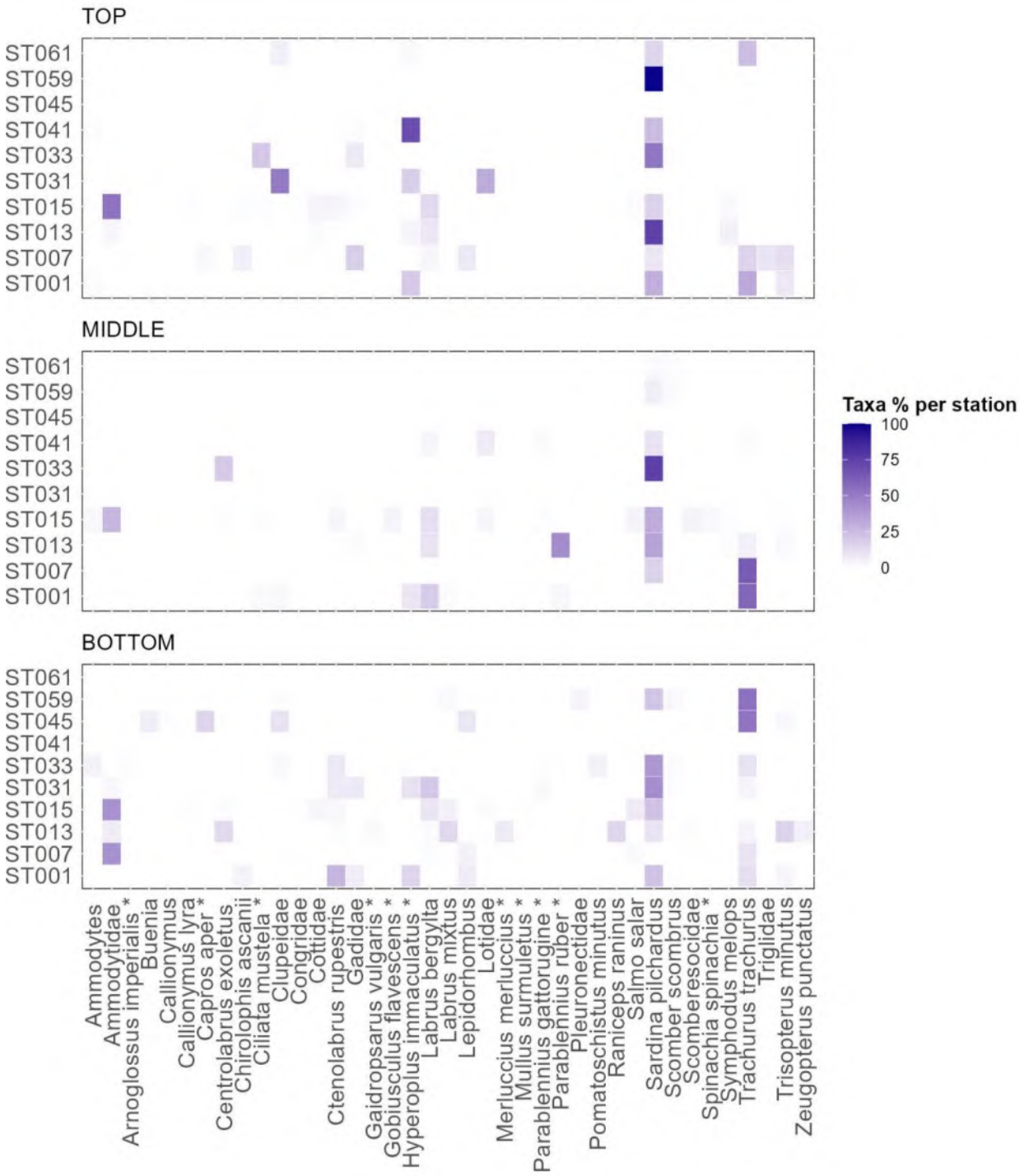


**Figure 48** Fish percentage abundance heat map: eDNA vertebrate analysis of top, middle, and bottom depths at each station. Taxa represented with an asterisk are exclusive to the vertebrate assay analysis only. Colour intensity indicates the percentage of sequences per sample based on all DNA sequences within an individual sample (the sum of one station (row) is 100 %).

### Marine Mammals

Only three marine mammal taxa were identified across the survey area: seals from the family Phocidae, the Common Minke Whale *Balaenoptera acutorostrata* and the common dolphin *Delphinus delphis* (Table 22 and Figure 49A). All of these are protected under EU Habitats Directive

**Table 22** Marine mammal taxa identified across the survey area based on eDNA analysis.

| Taxa | Common Name | N of samples in which taxa occurred |
|---|---|---|
| *Phocidae* | | 2 |
| *Balaenoptera acutorostrata* | Common Minke Whale | 4 |
| *Delphinus delphis* | Common Dolphin | 12 |

### Birds

Seven bird taxa were identified across the survey area (Table 23 and Figure 49B) with the Common Guillemot and the Bar-Tailed Godwit protected by Annex I under the EU Birds Directive

**Table 23** Bird taxa identified across the survey area based on eDNA analysis.

| Taxa | Common Name | N of samples in which taxa occurred |
|---|---|---|
| *Uria aalge* | Common Guillemot | 2 |
| *Laridae* | | 1 |
| *Arenaria interpres* | Ruddy Turnstone | 1 |
| *Limosa lapponica* | Bar-Tailed Godwit | 1 |
| *Passeridae* | | 1 |
| *Sturnidae* | | 2 |
| *Turdus* | | 2 |

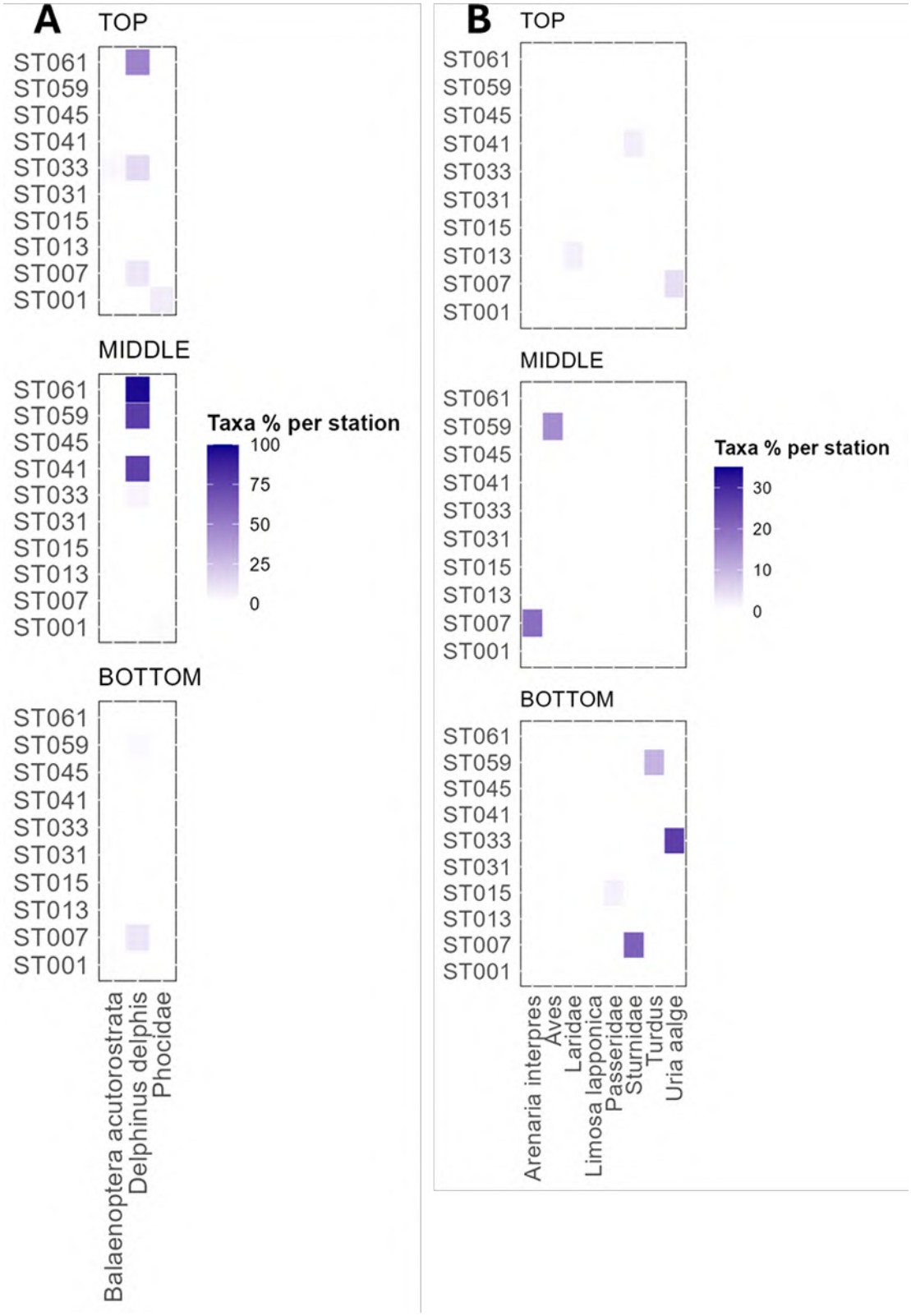


**Figure 49** Percentage abundance heat map for marine mammals (A) and birds (B). eDNA vertebrate analysis of top, middle, and bottom depths at each station. Colour intensity indicates the percentage of sequences per sample based on all DNA sequences within an individual sample.

# 8. Discussion

This report presents the results and interpretation of the seabed imagery, sediment PSD, macrobenthic, sediment contaminant and water analyses with the aim of characterising habitats and biological communities and their variability across the survey area.

## 8.1. Sediment PSD

Gravel content was generally high within the centre of the array, with a maximum of 70.2 % recorded at station ST004. Due to this, 21 of the 30 stations sampled were classified as Sandy Gravel or Gravelly Sand representing BSH A5.1 'Coarse sediment'. Mud content increased significantly with decreasing gravel content at stations along the southernmost boundary of the array area, close to the proposed ECR.

Sediments at stations in the northernmost section of the ECR, where it intersects the array area, were largely comprised of sands with varying and often high gravel content representing BSH A5.1 'Coarse sediment' as found for the array area. Moving south along the ECR, mud content increased and was at its highest in the centre of the ECR, whilst gravel content dropped to < 1 % at most stations. These stations in the centre of the ECR were largely described by the textural group Muddy Sand, representing BSH A5.2 'Sand and Muddy Sand' and A5.3 'Mud and Sandy Mud'. At the southern end of the ECR, in the region closest to the cable landfall, mud content began to decrease with the southernmost stations (ST057, ST058 and ST059) described as Sand. Station ST056 within the ECR survey area was described by the textural group Gravel, within an area mostly dominated by muddy sediments. This sample however was collected from within an area described in seabed imagery as Annex I Low Stoney Reef (Figure 21, Figure 24, Figure 25 and **Error! Reference source not found.**).

None of the soft sediment habitats encountered across the survey area are protected in Ireland.

## 8.2. Sediment Chemistry

Several guidelines exist to assess the degree of contamination and likely ecological impacts of contaminants in marine sediments. These regulations defined the levels below which effects are of no concern and/or rarely occur (Lower Level, BAC, TEL) and the levels above which adverse biological effects are considerable and/or occur frequently (Upper Level, ERL, PEL). *Ad hoc* decisions need to be made when contaminant concentrations fall between these levels. A recent study by the Marine Institute made amendments to the Lower Level values for As and Ni, increasing them so that they are more consistent with OSPAR BAC levels and levels set by other OSPAR contracting parties (Cronin et al., 2006 as per 2019 addendum). TEL and ERL values have been used for reference where possible throughout this assessment as these are the only guideline values that provide a measure of environmental toxicity compared to

OSPAR BAC and Marine Institute Levels that instead provide information on the degree of contamination in the sediments.

Among all metals measured within the array area, As was the only metal with concentrations above reference levels at stations ST001 and ST004. At station ST001, concentrations exceeded both the Lower Level and OSPAR BAC whilst ST004 only marginally exceeded the Lower Level threshold by 0.4 mg $kg^{-1}$. No obvious pattern emerged when comparing stations with elevated As concentrations with mud content, TOC or PAH concentrations. Both stations were located in the northwestern region of the survey area, however, none of the surrounding stations experienced elevated concentrations. Along the ECR, As concentrations only marginally exceeded the Lower Level threshold at station ST041 by 0.4 mg $kg^{-1}$, however, there was no obvious correlation with mud content, TOC or PAH concentrations. At station ST060, Cr exceeded Lower Level, OSPAR BAC, ERL, TEL and PEL thresholds, with a concentration of 198 mg $kg^{-1}$. This was significantly greater than the second highest concentration of 34.2 mg $kg^{-1}$ measured at ST051. With relatively low mud content and low levels of other contaminants recorded at this station, as well as its position in the centre of the ECR, relatively far from terrestrial sources of contamination, the cause of this unusually high concentration is not obvious. Elevated metal sediment concentrations do not necessarily imply toxicity to benthic communities (Rees et al., 2007) as the bioavailability of these metals is more important than simply concentration levels. Despite the elevated As and Cr recorded at four stations across the survey area as a whole, no macrobenthic anomalies were identified to suggest any adverse effects were present. No stations had metals concentrations above Upper Level concentrations, overall meaning that no adverse biological effects were expected.

The majority of PAHs measured were < LoD and in instances where measurable concentrations were recorded, values remained below all thresholds at all stations across the array and ECR. Ratios of hydrocarbons are typically used to assess the source origin of hydrocarbons and gain a better understanding of whether these contaminants are derived from anthropogenic activities or are of natural origin (Kafilzadeh et al., 2011). However, as hydrocarbons were overall low across the survey area this assessment could only be carried out at one station, overall indicating that hydrocarbon concentrations across the survey area are of no concern. All PCBs were measured < LoD at all but station ST026 in the centre of the array. Here the total concentration of all PCBs was below the Irish Lower Level concentration however three individual PCBs exceeded the OSPAR BAC. None of the other measured contaminants were elevated at this station and no macrobenthic anomalies were observed. Organotins and OCPs were measured < LoD at almost all stations, and where measurable, remained well below national and international thresholds.

## 8.3. Macrobenthos

A diverse macrobenthic assemblage was identified across the survey area as a whole with a total of 19,700 individuals and 444 taxa recorded in the array and 6,967 individuals and 313 taxa recorded along the ECR. Within the array, Nemetoda were significantly the most abundant taxa and had by far the highest average density per sample. They were also the second most commonly occurring taxa with the second highest maximum abundance per sample. The taxa recording the maximum abundance per sample was the long-clawed porcelain crab, *P. longicornis,* with 983 individuals recorded in replicate B of station ST027. This record was significantly higher than that recorded at any other station. Station ST027 contained by far the most diverse macrobenthic community across the array survey area, as well as recording the highest abundance of taxa. Seabed imagery obtained from this station identified the EUNIS habitat A5.51 'Maerl beds' in all five of the analysed images. The complex 3D structure of maerl beds provides a wide range of niches for infaunal species and therefore supports diverse microbenthic communities (Birkett et al., 1998).

Along the ECR, juvenile brittle stars belonging to the family Amphiuridae were the most abundant and commonly occurring taxa across samples. Amphiuridae brittle stars such as *A, filiformis* (also common in samples collected at ECR stations) are typically found buried in fine muddy sands at depths greater than 15 m. This aligns with sediment PSD, imagery and geophysical data analysis which describes many of the stations as A5.37 'Deep circalittoral mud' and A5.26 'Circalittoral muddy sand'.

Overall, macrobenthic assemblages within the array contained a significantly higher abundance of taxa, as well as much more diverse communities than samples collected from along the ECR. 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). This was reflected in the macrobenthic communities observed across the survey area where sediment composition was a key factor in determining the macrobenthic community structure. Multivariate analysis on macrobenthic data identified four broader macrobenthic groups across the array area with a clear distinction between stations dominated by coarse sediments (Macrobenthic Groups A and B) and those characterised by sand (Macrobenthic Groups C and D). Coarser sediments supported a community characterised by Polygordius, *P. kefersteini*, Nemertea and *G. lapidum*, while sandy sediments were characterised by *Timoclea ovata*, *H. antennaria, Spiophanes bombyx* and *A. auricoma*. To note that Macrobenthic Group B included ST027 where a maerl bed was identified and the highest diversity in community composition recorded. A higher number of macrobenthic groups was identified across the ECR compared to the array area due to the much larger area covered by the ECR which spanned from the shallow circalittoral zone close to landfall to offshore areas where it intersected the array area. This resulted in several of the macrobenthic groups along the ECR being made of a handful of stations which were not characterised by any key species

that could be used to assign biotopes. Nevertheless, two major clusters were observed in the nMDS ordination plot based on macrobenthic groups (Figure 43) with macrobenthic groups to the left of the ordination plot including stations dominated by coarse sediments supporting *Clausinella fasciata, P. kefersteini, G. lapidum, Eunice vittata, Aglaophamus agilis* and *Scalibregma inflatum* and groups to the right of the ordination plot characterised by sandy mud and muddy sands supporting *P. fallax, Owenia, Phoronis, L. cingulata, S. bombyx* and *L. clausa*.

Across the proposed SROWF site two INNS were recorded: the polychaete *G. gracilis* and the amphipod *M. sextonae*. The former is native of South Africa and the northeast coast of the USA with the first record in Irish waters dating back to the 1970's (Walker, 1972). The latter is native to New Zealand and was first described in (Costello, 1993). It is believed that this species originally arrived in Irish waters in 1982, likely by natural means from southwest Britain. This species has become abundant on Irelands south-west coast and competes with native amphipods (Minchin, 2007). Among species that are considered economically important, juveniles of Veneridae clams were found across the proposed SROWF site while only one individual of individual the brown shrimp C. *crangon* was found in the array area. Two notable taxa were also found across the survey area: the Ross worm *S. spinulosa* and three juveniles of the Ocean quahog *A. islandica*. They are both listed under the OSPAR list of threatened and/or declining species and habitats (2008) and *S. spinulosa* is also protected as an Annex I species under the EU Habitat Directive when occurring in reef form; however, only one individual was counted in the array area and no signs of reef forming features were observed.

## 8.4. Habitat Mapping

An integrated interpretation of acoustic data (SSS and MBES), seabed imagery, PSD and macrobenthic data indicated a complex seabed across the proposed SROWF. Most of the array was interpreted as a rock substrate representative of habitat A3.116 'Foliose red seaweeds on exposed lower infralittoral rock' in shallow waters and of A4.121, A4.212 and A4.214 in deeper waters. These rocky habitats were interspersed with deep circalittoral and circalittoral coarse sediments corresponding to EUNIS habitats A5.15 and A5.14, respectively. In a few instances the macrobenthic community suggested the presence of biotope A5.143 '*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand' where circalittoral coarse sediment were present. While the rock habitats were correctly inferred from the acoustic data, coarse sediments were not, as it can be difficult to distinguish sandy gravel and gravelly sand signatures in the SSS data. However, both PSD and seabed imagery analyses indicated the presence of coarse sediments within most of the array. The south of the array area was instead dominated by sand and assigned to habitats A5.25 'Circalittoral fine sand' and A5.26 'Circalittoral muddy sand' and A5.27 'Deep circalittoral sand' in deeper waters. In a few instances it was possible to assign the biotope A5.253 'Medium to very fine sand, 100-120 m, with polychaetes *Spiophanes kroyeri*, *Amphipectene auricoma*, *Myriochele* sp., *Aricidea wassi* and amphipods *Harpinia antennaria*' were fine sand was recorded. To note that in some

instances areas interpreted as A5.37 based on seabed imagery analysis were characterised as muddy sand based on PSD data as it can be particularly difficult to visually distinguish sandy mud and fine/muddy sand. This meant that PSD data was used as the primary information source to delineate soft substrates where seabed imagery and sediment analyses did not align. It is noteworthy that the rock habitats observed across the array met the qualifying criteria of Annex I reefs being a complex of bedrock reef and low and medium stony reefs. As the array does not fall within the boundaries of a designated site, these features are not awarded protection as designated features under the EU Habitats Directive, however comparable features are known to occur within the Kilkieran Bay and Islands SAC and are a qualifying reason for the designation of the site with the conservation objective to maintain the favourable conservation condition of the reefs (NPWS, 2014a). Additionally, at station ST027 and along close by transect T033 the habitat complexes A5.51 'Maerl beds' and A5.511 '*Phymatolithon calcareum* maerl beds in infralittoral clean gravel or coarse sand' were observed consisting of pink encrusting algae, hedgehog maerl, maerl nodules and maerl gravel. Maerl is listed as an Annex V species under the EU Habitats Directive and in Ireland has been assessed to be in a bad status and declining due to deterioration in the environmental qualities that would support the spread of these species (NPWS, 2019). The two maerl beds observed in the array are located approximately 7 km from the closest known maerl communities occurring within the Kilkieran Bay and Islands SAC whose conservation objectives include maintaining the extent and conserve the quality of these features To note that in the acoustic data similar reflectivity signatures to those observed in correspondence of the maerl bed have been noted elsewhere across the array area indicating that further investigations are needed to better define the number and extent of maerl beds across the array area and the proposed SROWF site more in general (NPWS, 2014a). Further evidence is needed to better understand whether maerl is present in other areas of the proposed SROWF site.

Habitats and biotopes along the cable route greatly varied ranging from rocky substrates in the north to mud and muddy sand sediments in the south. The northernmost region of the ECR was interpreted as rock biotopes representing EUNIS classification A.3116 'Foliose red seaweeds on exposed lower infralittoral rock' and A4.121 '*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock' interspersed with A5.14 'Circalittoral coarse sediments'. As seen for the array, while the rock substrate was correctly inferred from the acoustic data and ground-truthed by the seabed imagery, coarse sediments were wrongly interpreted as sand due to the difficulties in discerning the reflectivity signals of sandy gravels from those of gravelly sand. The central part of the ECR was inferred as 'silty Sand' and ground-truthed as a combination of A5.27 'Deep circalittoral sand' in the upper deeper central region and A5.26 'Circalittoral muddy sand' in the lower shallower central region with A5.37 'Deep circalittoral mud' in between. As seen before, PSD analysis was the best method to define the habitats present along the ECR as seabed imagery analysis led to a slight overestimation of mud habitats due to the difficulties in visually separate mud from muddy sand. The southernmost region of the ECR was assigned to EUNIS biotope A5.251 '*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand' confirming the interpretation of

the acoustic data while the area of gravel and gravelly sand was revealed to be an area of hard substrate representative of EUNIS biotope A4.121 '*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock' interspersed with A4.2146 '*Caryophyllia smithii* with faunal and algal crusts on moderately wave-exposed circalittoral rock'. The rock habitats observed across the ECR met the qualifying criteria of Annex I reefs being a complex of bedrock, low and medium stony reefs. As the ECR does not fall within the boundaries of a designated site, these features are not afforded protection under the EU Habitats Directive, however geogenic reefs are a qualifying reason for the designation of the 5 SACs located to the east of the ECR with the conservation objectives to maintain the favourable conservation condition of the reefs (NPWS, 2014c, 2014b, 2014e, 2014d, 2015).

A comprehensive sea fan assessment was undertaken on all still images collected across the proposed SROFW site where *E. verrucosa* occurrences where enumerated. The pink sea fan is known to colonise the reefs present within the Inishmore Island SAC and Carrowmore Point to Spanish Point and Islands SAC and is listed as 'Vulnerable' in the IUCN Red List. *E. verrucosa* was observed in relatively higher numbers (two-three specimens per image) along transects T06 and T01 which were the closest to the two aforementioned SACs. This might indicate that this species occurs beyond the boundaries of these two SACs however more evidence would be required to better understand whether the distribution of this species extends across all of the reefs observed along the ECR and adjacent to the Inishmore Island and Carrowmore Point to Spanish Point and Islands SACs.

## 8.5. Water eDNA

The use of eDNA has become increasingly popular as a non-invasive and effective method for surveying and monitoring of species in their natural habitats as organisms shed their DNA into their environments as shed cells, waste matter, blood, gametes and decaying material (JNCC, 2022). eDNA metabarcoding methods allow the rapid and cost-efficient collection of information on species diversity and composition of fish assemblages in aquatic habitats, which is of particular importance given the current increase in anthropogenic disturbance and associated declines in aquatic biodiversity in these ecosystems. To note that the eDNA analysis presented here was targeted to vertebrates and bony fish meaning that elasmobranchs (rays and skates) might not be as readily detected. In general elasmobranchs are often difficult to detect using eDNA as they do not shed large amounts of DNA compared to other taxa.

The persistence of DNA in the water column depends on a multitude of factors, including environmental conditions, water movement, and the specific type of DNA present. Generally, DNA can remain detectable for varying durations, which can range from a few hours to several weeks or even months. The degradation rates of DNA are contingent upon elements such as ultraviolet (UV) radiation, water temperature, and the presence of nucleases and other enzymatic activities in the water. Additionally, exposure to sunlight and high temperatures can accelerate the degradation process. Conversely, in colder and darker environments, the

degradation of DNA may decelerate, allowing it to persist for longer periods (Littlefair et al. 2021, Monuki et al. 2021).

The results of the eDNA analysis indicated the presence of a diverse fish community including one Annex II species (Atlantic Salmon) and 20 species of commercial importance. Additionally, three of the detected fish species are listed on the IUCN Red List; these were the Atlantic Horse Mackerel, Haddock, and the Atlantic Salmon. It is worth noting the robust presence of the European Pilchard across all three water depth and in the majority of the stations. This is particularly significant due to its high commercial value. Conducting eDNA sampling at multiple depths yielded valuable insights into the distribution and dynamics of genetic material in the water column. Sampling at various depths facilitates the assessment of how DNA profiles might differ with depth, potentially indicating the presence or movement of different organisms at various water depths. Additionally, it aids in the identification of the sources and sinks of genetic material, offering insights into the behaviour and ecological interactions of organisms within the marine environment.

Marine mammals and birds were also identified as part of the eDNA analysis. The analysis confirmed the presence of Minke Whale, the Common Dolphin, and seals from the genus *Phocidae*, consistent with observations by AQUAFACT as part of the marine mammal monitoring of the Galway Bay in 2019 (O'Brien et al., 2019) Notably, both the eDNA analysis and the 2019 Galway Bay report highlighted the Common Dolphin as one of the most abundant species in the survey area, the presence of the Minke Whale and seals. While the Galway Bay report specifically identified the Harbour Porpoise, the eDNA results did not yield any signal of the Harbour Porpoise. In terms of birds, the species identified through the eDNA analysis are common to Ireland. Among the taxa identified to a species level the Ruddy Turnstone and the Bar-Tailed Godwit are commonly observed in coastal settings and the Common Guillemot primarily resides at sea, occasionally coming ashore solely for the purpose of nesting during the breeding season in May (British Trust for Ornithology).

Data presented in this report demonstrates that eDNA metabarcoding provided a non-destructive means of collecting insightful fish community information. There are however limitations to the use of this technique which should be considered when interpreting the findings, namely that the resulting data can only provide a qualitative understanding of the community diversity with true abundance not quantified and only represented as a 'strong/weak' DNA signal.

It was also noteworthy that DNA of terrestrial animals was detected in the water samples as it raises questions over the reliability of the results. It is difficult to identify the specific vectors for DNA of terrestrial species being present across the site although a possible explanation includes the presence of DNA in waste matter of predators that might have fed on prey or decaying material from terrestrial sources and/or vessels navigating across the survey area. This includes predation by birds as they are known to serve as significant agents in transporting terrestrial material to marine ecosystems through their droppings. These droppings can

contain the DNA of the organisms consumed by the birds, thereby facilitating the transfer of terrestrial genetic material into the marine environment (Leempoel et al., 2020; Polanco F. et al., 2021). This idea is further supported by the observation that terrestrial mammal species were primarily detected in the top of the water column rather than at greater depths.

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