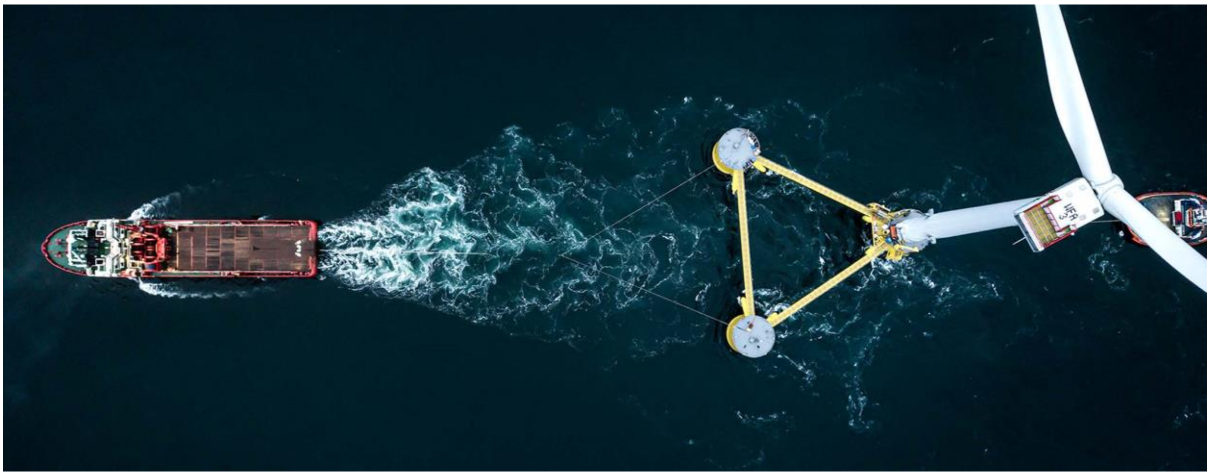


REPORT

Blue Gem Wind Project
Environmental Baseline Survey Report

BGW Document No.:	ERE-CON-ITP-CON-ENV-0031 Rev 02
Contractor Document No.:	OEL_ROVERE0420_TCR_EBS
Document Status:	IFR
Phase:	PS
Class:	1
Contractor Entity:	Offshore Wind Consultants Ltd, 6 Bevis Marks, London EC3A 7BA

Document Notes

Confidentiality Notice and Disclaimer

This document may contain proprietary information and intellectual property of Client and/or OWC.

The document has been produced by OWC for the exclusive use and benefit of Client and may not be relied on by any third party. OWC does not accept any liability or duty of care to any other person or entity other than Client.

The document should not be reproduced (in whole or in part), referred to or disclosed in any other document or made available to any third party (in any format) without the prior written consent of OWC.

Document History

Rev	Date	Authored	Reviewed	Approved	OWC Approval	Modifications
05	2020-05-22	Ross Griffin	Katie Cross Marja Aberson Sam Strutton	Sam Strutton		[Add list of modifications]

Ocean Ecology

Marine Surveys, Analysis & Consultancy

EREBUS Floating Offshore Windfarm

Environmental Baseline Survey Report

REF: OEL_ROVERE0420_TCR_EBS

T: +44 (0) 1452 740697 E: info@ocean-ecology.com W: www.ocean-ecology.com Tw: @Ocean_Ecology

Details

Version	Date	Description	Author(s)	Reviewed By
V01	25/02/2021	Draft	Elena Lo Giudice Cappelli, Karen Boswarva, Robyn Jones.	Ross Griffin
V02	26/03/2021	Draft	Elena Lo Giudice Cappelli, Karen Boswarva, Robyn Jones.	Ross Griffin
V03	12/04/2021	Final Issue	Elena Lo Giudice Cappelli, Karen Boswarva, Robyn Jones.	Ross Griffin
V04	23/04/2021	Final Issue	Elena Lo Giudice Cappelli, Karen Boswarva, Robyn Jones.	Ross Griffin
V05	10/05/2021	Final Issue	Elena Lo Giudice Cappelli, Karen Boswarva, Robyn Jones.	Ross Griffin

Updates

Section	Description	Page

Contents

Appendices (Not provided with this copy)

Appendix Ia - Project Erebus Offshore Floating Wind Farm Environmental Baseline Survey Stations

Appendix Ib - Project Erebus Offshore Floating Wind Farm Habitat Assessment Survey Stations

Appendix II – PSD grab sample survey logs.

Appendix III - PSD grab sample photos.

Appendix IV - Raw PSD data.

Appendix V - Summarised PSD data.

Appendix VI – Contaminants method statement.

Appendix VII - Raw sediment chemistry data.

Appendix VIII - Raw water chemistry data.

Appendix IX - Macrobenthic abundance data.

Appendix X - Macrobenthic biomass data gAFDW.

Appendix XI - PRIMER Routines.

Appendix XII - Cluster + SIMPROF routine & SIMPER results

Appendix XIII - Habitat Assessment DDV transect survey log.

Appendix XIV - Habitat Assessment DDV station survey log.

Appendix XV - Description of seabed imagery analysis methodologies.

Appendix XVI - Overview of HA biotopes and associated imagery.

Appendix XVII – Subtidal Field Report.

Appendix XVIII - Survey Design Audit Process

Appendix XIX – Water Sample Logs

Appendix XX - Water Profiles

Appendix XXI – Raw Water Profile Data

Appendix XXII – All seabed Imagery

Appendix XXIII – Shapefiles with metadata

List of Figures

List of Tables

List of Abbreviations

AIS	Automatic Identification System
AL	Action Level
BAC	Background Assessment Concentration
BSH	Broadscale Habitat
CSQG	Canadian Sediment Quality Guidelines
DDC	Drop Down Camera
EB	Environmental Baseline
EBS	Environmental Baseline Survey
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
EPA	Environmental Protection Agency
ERL	Effects range Low
EUNIS	European Nature Information System
EQS	Environmental Quality Standards
FLOW	Floating Offshore Wind Farm
FOCI	Features of Conservation Interest
GPS	Global Positioning System
HA	Habitat Assessment
ISQG	International Sediment Quality Guidelines
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
MBES	Multibeam Echosounder
MCZ	Marine Conservation Zone

MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
MNCR	Marine Nature Conservation Review (Marine Habitat Classification for Britain and Ireland)
NMBAQC	NE Atlantic Marine Biological Quality Control
OEL	Ocean Ecology Limited
PAH	Polycyclic Aromatic Hydrocarbon
PEL	Probable Effect Level
PSA	Particle Size Analysis
PSD	Particle Size Distribution
SAC	Special Area of Conservation
SBE	Simply Blue Energy
SPA	Special Protection Area
SSS	Side Scan Sonar
SSSI	Site of Special Scientific Interest
TEL	Threshold Effect Level
THC	Total Hydrocarbons Content
TOC	Total Organic Carbon
TOM	Total Organic Matter
TPH	Total Petroleum Hydrocarbons
UAV	Unmanned Aerial Vehicle
WFD	Water Framework Directive
WTGs	Wind Turbines Generators

1. Non-Technical Summary

This report presents the results of the macrobenthic and sediment analysis combined with the results of the habitat assessment with the aim to set out the environmental baseline conditions across the proposed Project Erebus Floating Offshore Wind Farm development to inform final routing, engineering design and the installation process of the proposed windfarm as well as providing a robust dataset for future comparison if required.

Introduction

Ocean Ecology Limited (OEL) were commissioned by Rovco on behalf of Blue Gem Wind to conduct a Habitat Assessment (HA) and Environmental Baseline Survey (EBS) of the proposed Project Erebus Floating Offshore Wind Farm. The project area is situated approximately 44 km southwest of the Pembrokeshire coastline, in an outline area of interest of approximately 43.5 km^2. Five nature conservation designations fall within or are partially overlapped by the survey area including the Pembrokeshire Marine /Sir Benfro Forol Special Area of Conservation (SAC).

Survey Strategy

A total of 116 EBS locations were proposed across the export cable corridor and array areas to be targeted with drop-down camera (DDC) and/or grab sampling. A further 82 Habitat Assessment (HA) locations were proposed to be targeted with DDC transects. The survey was undertaken during nearshore and offshore phases conducted aboard the vessels *Seren Las* (nearshore) and *Glomar Wave* (offshore) between 21st October to 11th November 2020 and from 9th November to 29th November 2020, respectively. An assessment of the water quality was also made in the section of the export cable corridor passing through the Water Framework Directive (WFD) waterbodies for a total of 26 stations sampled between 15th-16th August 2020.

Sediments

The majority of samples were comprised of sand representing European Nature Information System (EUNIS) Broadscale Habitat (BSH) A5.2 (Sand and Muddy Sand), while some stations were classified as Gravelly Sand (gS) representing EUNIS BSH A5.1 (coarse sediment) or as Mud and Sandy Mud (EUNIS BSH A5.3); only 5 out of 107 stations were classified as Gravelly Muddy Sand (gmS) representing EUNIS BSH A5.4 (Mixed Sediment).

Total Organic Carbon (TOC) concentrations ranged from 0.05 % at ST028 to 7.1 % at ST021, with an average value (± SD) of 0.7 ± 1.62 % across the survey area. Total Organic Matter (TOM) content in sediment varied between 0.1 % at ST077 and 6.3 % at ST114, with an average value (± SD) of 1.34 ± 0.81 % across the survey area. In general, the highest TOM content (> 2%) in the sediment was found at stations with the highest mud content (>20 %).

A total of eight heavy and trace metals were analysed from sediments taken at each of the 107 stations where samples were collected. These were Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn). Metal concentrations were compared to a number of reference level concentrations to assess whether their concentrations in sediments were of concern. The metal generally recorded in elevated concentrations compared to OSPAR reference values across most stations was As, which ranged from 5.6 at ST01 (Milford Haven) to 32.8 mg kg^{-1} at ST026 (mid-way along export cable route).

Polycyclic Aromatic Hydrocarbon (PAH) concentrations were also compared to reference levels to assess whether their concentrations in sediments were of concern. Only the concentration of Naphthalene averaged across the survey area was above the OSPAR Background Assessment Concentration (BAC), whereas all other PAHs had average concentrations for the survey area below guideline references.

Total Hydrocarbon Content (THC) in sediment samples ranged from 680 µg kg^{-1} at ST086 (array area) to 49,500 µg kg^{-1} at ST03 (Milford Haven), with an average value (± SD) for the whole of the survey area of 5,722 ± 7863 µg kg^{-1}. THC on average was higher in nearshore stations than at offshore stations, which is most likely due to the proximity of the nearshore stations to urban settings and therefore to potential additional sources of hydrocarbons.

Water Chemistry

Water samples were analysed across the area of the cable route that intersects Water Framework Directive (WFD) waterbodies to assess the concentration of Chlorophyll, Suspended Solids, Nutrients, THC, Metals and PAHs. Almost all stations reported determinand concentrations below detection limits and therefore below reference levels.

Macrobenthos

A diverse macrobenthic community was identified across the survey area with a total of 13,534 individuals and 361 taxa recorded. Most stations were characterised by the presence of juveniles of the brittle star Amphiuridae which occurred in 72.9 % of the samples, while the bivalve *Kurtiella bidentata* (previously called *Mysella* bidentata) was the overall most abundant taxon across the survey area.

Eight Macrobenthic Groups were identified across the survey area based on similarities in the composition of macrobenthic assemblages between sampling stations. A clear distinction was evident between nearshore (ST01 to ST032) and offshore (ST033 to ST119) stations with the latter belonging to Macrobenthic Group E, characterised by high abundances of *K. bidentata,* juveniles of Amphiuridae as well as adult individuals of the brittle star *Amphiura filiformis* and the pea urchin *Echinocyamus pusillus*. In contrast, nearshore stations located along the cable route showed a higher variability in community composition as the cable route intersected a variety of sediment habitats and environmental gradients (from intertidal to offshore).

EUNIS Habitats/Biotopes

The main habitats identified across the survey area at which seabed imagery and grab samples were obtained comprised primarily of the EUNIS biotopes A5.251 '*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand' and A5.351 '*Amphiura filiformis*, *Mysella bidentata*[1] and *Abra nitida* in circalittoral sandy mud' in the offshore section of the cable route and in the main array (ST033-119).

Stations located along the cable route within the Milford Haven Waterway (ST01-015) were characterised by various EUNIS biotopes including A5.143 '*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand' and A5.443 '*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment'.

Stations located on the outer fringes of the Milford Haven Waterway and the nearshore area of the cable route (ST018-032) were best represented by the EUNIS classifications A5.14 'Circalittoral coarse sediment', A5.25 'Circalittoral fine sand' and A5.44 'Circalittoral mixed sediments'. Low faunal abundances of key species were present in grab samples collected at these locations. These stations were therefore only assigned level 4 (biotope complex) classifications.

Annex I Habitats

Annex I bedrock and stony reef habitats were identified in areas of the cable route, mostly along the nearshore sections around the entrance to Milford Haven. The stony reef features were assessed to be of both low and medium resemblance. In general, where stony and bedrock reefs were recorded along the same transects, they were deemed to form mosaic habitats meaning it was difficult to differentiate between the two reef types given the lack of clear boundaries in the acoustic data. These features were deemed to form part of the designated Annex I 'reef' feature of the Pembrokeshire Marine /Sir Benfro Forol SAC.

Two areas of sandy habitat were identified as likely Annex I sandbank habitats along the export cable route. The first was assigned a 'High' confidence score given it intersected, and forms part of, the known Turbot Bank Annex I sandbank feature. The second area was found further along the export cable corridor but was assigned a 'Potential' confidence score due to the lack of known adjacent sandbanks.

No Annex I biogenic reef habitat was observed across the survey area.

Other Features of Interest

Evidence of a potential seagrass bed was observed close to the Sawdern Point landfall due to the presence of low-density eelgrass shoots along a single HA transect. However, due to the time of

[1] To note that the currently accepted name for *Mysella bidentata* is *Kurtiella bidentata*. In this report we maintained the original EUNIS classification and biotope description and used the name *Mysella bidentata*; however, in the main text when assessing community composition, the accepted name of *K. bidentata* was adopted.

year, it was deemed unlikely that the full extent of the potential bed was visible both in the seabed imagery and acoustic data.

No beds of maerl (Corallinacea) or native oysters (*Ostrea edulis*) were observed across the survey area although there were observations of discrete patches of live and dead maerl at one location and occasional native oysters at numerous locations along the cable route.

The invasive non-native (INNS) slipper limpet (*Crepidula fornicata*) was recorded forming aggregations along one transect in the nearshore section of the export cable route. No other INNS were observed in the seabed imagery. Based on the analysis of macrobenthic fauna (grab samples), three further non-native species were recorded across the survey area; however only one or two specimens were observed for each species among the 107 analysed stations indicating that these organisms were extremely rare and their distribution across the survey area sporadic.

2. Introduction

2.1. Project Erebus

Project Erebus is a proposed floating offshore wind (FLOW) development in the Celtic Sea region developed by Blue Gem Wind (a joint venture between Total and Simply Blue Energy (SBE)). The project area is situated approximately 44 km southwest of the Pembrokeshire coastline, in an outline area of interest of approximately 43.5 km^2. Project Erebus will include both offshore and onshore infrastructure consisting of:

- 6-10 floating Wind Turbine Generators (WTGs) with associated semi-submersible platforms and mooring infrastructure.
- Inter-array cables.
- A single export cable route to landfall.
- Onshore cabling between landfall and the grid connection.
- Onshore substation at the grid connection point.

This development consists of three key areas which encompass both nearshore and offshore marine environments:

- Nearshore export cable corridor including two landfall options at West Angle and Sawdern Point.
- Offshore export cable corridor.
- Windfarm array.

2.2. Project Background

Ocean Ecology Limited (OEL) was commissioned by Rovco on behalf of Blue Gem Wind to undertake a combined Habitat Assessment (HA) and Environmental Baseline Survey (EBS) of the proposed Project Erebus FLOW development. This was to include the provision of a full environmental spread including survey vessel for the nearshore section environmental personnel and sampling equipment for the offshore section and sample analysis for all samples collected. Environmental sampling was undertaken during two survey phases from 21st October to 11th November 2020 (nearshore area) and from 9th November to 29th November 2020 (offshore area). A water quality assessment of the section of the export cable corridor intersecting the WFD waterbodies was also undertaken between 15th and 16th August 2020.

The data collected during these surveys was intended to:

a) delineate all seabed features identified within high resolution Multibeam Echosounder (MBES) and Side Scan Sonar (SSS) data previously collected by Rovco, and from these features, assess for the presence of potentially important and environmentally sensitive features throughout both the nearshore and offshore survey areas including:

- Annex I habitats (EU Habitats Directive 1992);
- Habitats of Principle Importance (Environment (Wales) Act, 2016); and
- Threatened and/or declining species and habitats (OSPAR, 2008) or species listed on the IUCN Red List (IUCN, 2019).

b) Establish the sediment baseline conditions of the nearshore and offshores areas (including biotopes)

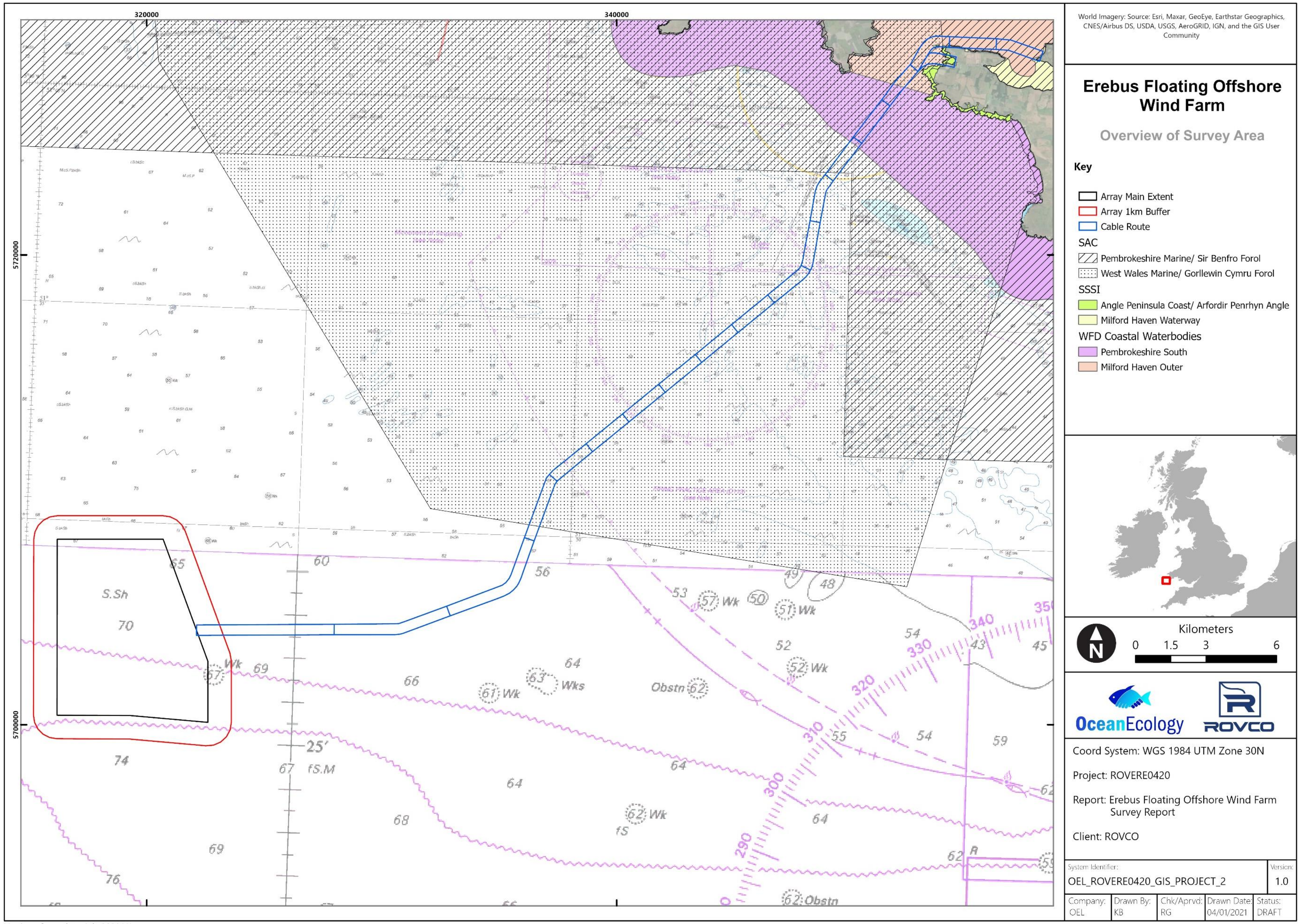
c) Establish the sediment and water quality conditions of the nearshore and offshores areas

2.3. Report Scope

This report presents the results of the macrobenthic and sediment chemistry analysis combined with the results of the HA with the aim to set out the environmental baseline conditions across the proposed Project Erebus FLOW development to inform final routing, engineering design and the installation process of the proposed windfarm as well as providing a robust dataset for future comparison if required.

The grab sampling data has undergone detailed statistical analysis to provide a comprehensive account of the biological and physio-chemical status of the seabed substrates and habitats/biotopes have been mapped through interpretation of the geophysical data, which, in combination with analysis of the environmental data have been used to delineate Habitats of Conservation Interest (HOCI) (e.g. Annex I habitats) occurring within the survey area.

The survey areas intersect the Pembrokeshire Marine /Sir Benfro Forol Special Area of Conservation (SAC), the West Wales Marine/Gorllewin Cymru Forol SAC, the Angle Peninsula Coast/Arfordir Penrhyn Angle Site of Site of Special Scientific Interest (SSSI), the Milford Haven Waterway SSSI (Figure 1) and the Skomer, Skokholm and the Seas off Pembrokeshire/Sgomer, Sgogwm a Moroedd Penfro Special Protection Area (SPA).



Version of template: July 2020 V1
C:\Users\KarenBoswarva\Documents\ArcGIS\Projects\OEL_ROVERE0420_Overview_map\OEL_ROVERE0420_GIS_PROJECT_2.aprx Originator: KarenBoswarva

Document uncontrolled when printed ISO A3 Landscape

Figure 1 Overview of the Project Erebus survey area.

3. Existing Habitat Mapping

3.1. EMODnet Habitat Mapping

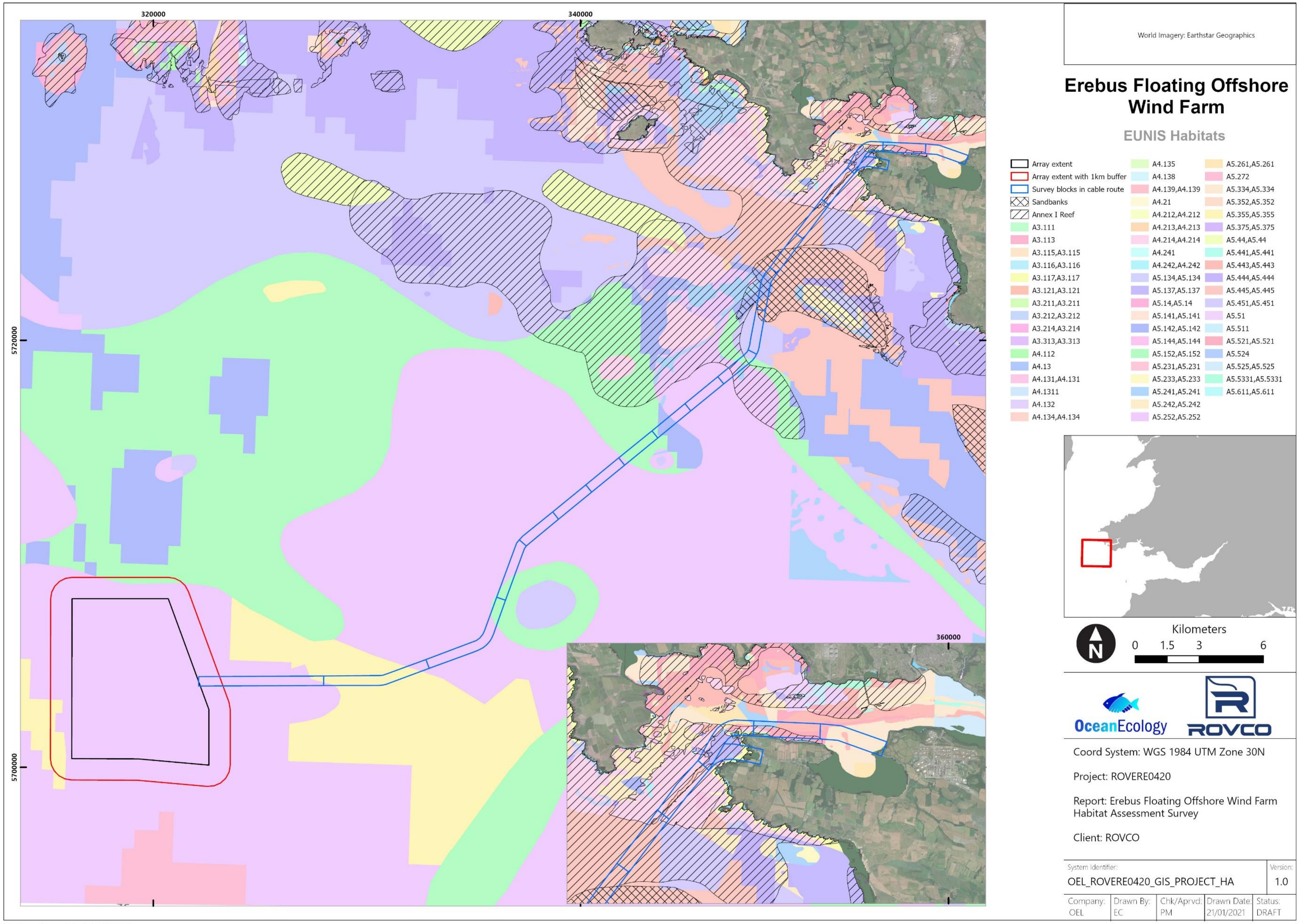
The Project Erebus survey area comprises of a number of sediment habitats in Milford Haven including European Nature Information System (EUNIS) biotope complexes A5.52 'Kelp and seaweed communities on sublittoral sediment', A5.43 'Infralittoral mixed sediments', A5.33 'Infralittoral sandy mud', A5.26 'Circalittoral muddy sand' and A5.13 'Infralittoral coarse sediment' as well as rocky habitat A4.25 'Circalittoral faunal communities in variable salinity' (Figure 2).

At the entrance to Milford Haven rocky habitats A4.214 'Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock' dominates with A3.21 'Kelp and red seaweeds (moderate energy infralittoral rock)' and A3.11 'Kelp with cushion fauna and/or foliose red seaweeds' fringing the adjacent coastline.

Moving offshore, rock habitats transition into circalittoral and offshore sediment habitats including A5.44 'Circalittoral mixed sediment', A5.25 'Circalittoral fine sand' and A5.15 'Deep circalittoral coarse sediment' (Figure 2). To note that some of the rocky and sandy habitats listed above are representative of the Annex I reef and sandbank habitats designated as features of Pembrokeshire Marine /Sir Benfro Forol SAC (see Section 4.2) (Figure 2). The EBS will refine the existing EMODnet broad scale habitat mapping for the Project Erebus survey area using a combination of geophysical data, seabed imagery, and sediment and macrofauna samples for ground truthing.

3.2. Geophysical Data

Geophysical data (MBES, SSS and backscatter) was collected along the proposed cable corridor and across the array area by Rovco on behalf of Blue Gem Wind in summer and autumn 2020 in line with the Survey Scope and relevant guidance. The seabed throughout the proposed area was broadly interpreted from the bathymetry as a gentle slope, gradually deepening from the northeast to the southwest. Nearshore, the seabed was broadly interpreted as a deep and narrow channel (~15 m) surrounded by bedrock, signifying the east channel of Milford Haven, whilst offshore the seabed was broadly interpreted as an area of rippled seabed with distinct sand wave features traversing the site. The geophysical data was overlain with the environmental data (seabed imagery Particle Size Distribution (PSD) analysis) to assist in the delineation of the principal habitats and biotopes present within the survey areas.



Version of template: July 2020 V1
C:\Users\ElenaCappelli\Desktop\OEL_ROVERE0420_GIS_PROJECT_HA\OEL_ROVERE0420_GIS_PROJECT_HA.aprx Originator: ElenaCappelli

Document uncontrolled when printed ISO A3 Landscape

Figure 2 EUNIS classification mapping from EMODnet and other features of interest across the Project Erebus survey area.

4. Nature Conservation

4.1. Protected Sites

There are several sites that receive designation under various nature conservation legislation which overlap with the survey areas (Figure 1). Under the European Habitats Directive (92/43/EEC) that came into force in 1992, as well as the Welsh Marine Act (2016), the UK is required to ensure "favourable conservation status" of habitats and species listed by these Directives.

Five nature conservation designations fall within the survey area:

- The Pembrokeshire Marine/Sir Benfro Forol SAC;
- West Wales Marine/Gorllewin Cymru Forol SAC;
- Angle Peninsula Coast/Arfordir Penrhyn Angle SSSI;
- Milford Haven Waterway SSSI;
- Skomer, Skokholm and the Seas off Pembrokeshire/Sgomer, Sgogwm a Moroedd Penfro SPA.

4.1.1. Pembrokeshire Marine/ Sir Benfro SAC

The Pembrokeshire Marine/Sir Benfro Forol SAC encompasses marine areas, sea inlets, tidal rivers, estuaries, mud flats, sand flats, lagoons, salt marshes, salt pastures and salt steppes, overall covering an extent of 1,380.4 km^2. The SAC was designated primarily to protect Annex I habitats comprising estuaries, large shallow inlets and bays, and reefs, and Annex II species comprising grey seal (*Halichoerus grypus*) and shore duck (*Rumex rupestris*).

4.1.2. West Wales Marine/ Gorllewin Cymru SAC

The West Wales Marine/Gorllewin Cymru Forol SAC encompasses marine areas and sea inlets covering 7,376 km^2. It was designated to protect the Annex II species, harbour porpoise (*Phocoena phocoena*).

4.1.3. Angle Peninsula Coast/Arfordir Penrhyn Angle SSSI

The Angle Peninsula Coast/Arfordir Penrhyn Angle SSSI is a component part of the Pembrokeshire Marine /Sir Benfro Forol SAC. It is of special interest for its geology, intertidal rock, sand, and gravel habitats and communities. It encompasses the coastline around the Angle Peninsula to the sandy beach of Freshwater West.

4.1.4. Milford Haven Waterway SSSI

The Milford Haven Waterway SSSI is also component part of the Pembrokeshire Marine /Sir Benfro Forol SAC it encompasses a variety of natural features including estuaries and marine habitats.

4.1.5. Skomer, Skokholm And The Seas Off Pembrokeshire/ Sgomer, Sgogwm a Moroedd Penfro SPA

The Skomer, Skokholm and Seas off Pembrokeshire Special Protection Area (SPA) was designated to protect European storm-petrel (*Hydrobates pelagicus*), Manx shearwater (*Puffinus puffinus*), Atlantic puffin (*Fratercula arctica*), lesser black-backed gull (*Larus fuscus*), red-billed chough (*Pyrrhocorax pyrrhocorax*), short-eared owl (*Asio flammeus*), and breeding seabird assemblages. The SPA covers 1,668 km^2 of island and sea area off the most south westerly tip of Pembrokeshire, extending beyond the 12 nautical mile boundary.

4.2. Annex I Habitats Present Within The Survey Area

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

- Estuaries (1130).
- Large Shallow Inlets and Bays (1160).
- Reefs (1170).

As well as Annex I habitats that are present as a qualifying feature but not a primary reason for site selection:

- Sandbanks which are slightly covered by sea water all the time (1110).
- Mudflats and sandflats not covered by seawater at low tide (1140).
- Coastal lagoons (1150).
- Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) (1330).
- Submerged or partially submerged sea caves (8330).

4.2.1. Sandbanks Slightly Covered By Seawater All The Time

Sandbanks slightly covered by seawater all of the time (hereafter referred to as Sandbanks) consist of sandy sediments that are permanently covered by shallow sea water, typically at depths of less than 20 m. Distinct banks, formed of elongated, round or irregular "mound" shapes arise from horizontal or sloping plains of sandy sediment. The sediment type of these habitats is the key driver of the diversity and type of associated communities present, as well as physical, chemical and hydrographic factors (e.g., exposure, temperature, topography, depth, turbidity and salinity). In UK waters this feature is categorised into four sub-types: gravelly and clean sands, muddy sands, eelgrass *Zostera marina* beds and free-living maerl (Corallinacea) beds. There are several major sandbanks within the Pembrokeshire Marine /Sir Benfro Forol SAC and thus near the survey area, including Turbot Bank (19.1 km^2) to the south east of the entrance to Milford Haven, St Gowan Shoals (16.05 km^2) to the east of Turbot Bank, and The Knoll sandbank (5.09 km^2) in the vicinity of Skokholm (Figure 2); these sandbanks likely belong to the subtype gravelly and clean sands.

These habitats are typically colonised by burrowing fauna such as worms, crustaceans, bivalve molluscs and echinoderms. Mobile shrimp, gastropods, crabs and fish also inhabit these areas as well as sandeel (*Ammodytes* sp.), a key bird prey species. Where stable coarse sediments are present, species of foliose algae, hydroids, bryozoans and ascidians may be present that comprise key nursery areas for various fish species. Such areas therefore often comprise key feeding grounds for numerous seabirds[2].

4.2.2. Large Shallow Inlets And Bays

The Pembrokeshire Marine /Sir Benfro Forol SAC includes Milford Haven, one of the best examples of a ria in the UK, and the wide, shallow, predominantly sandy embayment of St Brides Bay (Figure 2). The wide range of environmental conditions supports high community and species diversity. The species-richness of sediment communities throughout Milford Haven is particularly high, with sandy/muddy areas supporting extensive seagrass beds both in the intertidal (*Zostera noltei*) and subtidal (*Zostera marina*).

***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 noltei*. The first one 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 beds around Wales are representative of EUNIS subtidal biotope A2.6111 and EUNIS intertidal biotope A5.5331. Their distribution is limited to a handful of locations three of which are near the Project Erebus survey area: Littlewick and Longoar Bays, within Milford Haven, and Skomer.

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 (1110)
- Estuaries (1130)
- Mudflats and sandflats not covered by seawater at low tide (1140)
- Large shallow inlets and bays (1160)

[2] http://jncc.defra.gov.uk/ProtectedSites/SACselection/habitat.asp?FeatureIntCode=h1110

Specifically, *Zostera* beds are a known part of Annex I features in the Pembrokeshire/Sir Benfro Forol Marine SAC. Additionally, *Zostera* beds are also on the OSPAR list of threatened and/or declining species and habitats.

Maerl Beds

Maerl beds (Corallinacea) 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 one maerl bed formed by living *P. calcareum* is known in Wales, and is located in Milford Haven, close to the nearshore section of the export cable route survey area. 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) as Habitats of Principle Importance (Environment Wales Act, 2016) and through inclusion on the OSPAR list of threatened and/or declining species and habitats.

4.2.3. Reefs

Rocky Reef

Annex I Rocky reefs can be very variable in terms of both their structure and the communities that they support. They provide a home to many species such as corals, sponges and sea squirts, as well as giving shelter to fish and crustaceans such as lobsters and crabs. Rocky reefs and can be classified as either bedrock or stony reefs. Based on existing habitat mapping derived from EMODnet, bedrock and stony reefs are thought to occur within the nearshore sector of the Project Erebus export cable route survey area but have not been recorded further offshore or across the array area (Figure 2).

Stony Reef

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

Bedrock Reef

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

***Sabellaria* Reef**

Annex I biogenic *Sabellaria* reefs are habitats formed by sedentary filter-feeding polychaete worms belonging to the family Sabellariidae. Two species are found in Wales, the honeycomb worm (*Sabellaria alveolata*) and the Ross worm (*Sabellaria spinulosa*). Both are gregarious species and can form biogenic reef colonies that can cover hundreds of thousands of square meters of seabed (Jenkins et al. 2018) and similarly large areas of intertidal lower shore (Dubois et al. 2002).

Biogenic reefs formed by *Sabellaria* spp. are thought to benefit wider ecosystem functioning. Their structures are topographically complex, with features such as standing water, crevices and consolidated fine sediments providing microhabitats for other organisms and high levels of biodiversity (Limpenny et al. 2010, Pearce et al. 2011). The associated communities can vary according to local conditions of salinity, water movement, depth and turbidity (Natural England & Countryside Council for Wales 2009). The extent and distribution of *S. alveolata* reefs are thought to be increasing in Wales (Mercer 2016) whilst it is thought that the extent of *S. spinulosa* reefs are potentially underestimated (NRW 2019). Despite this, no aggregations of *Sabellaria* spp. have currently been known to represent Annex I biogenic reefs in Milford Haven and/or across the wider Project Erebus survey area; however, *S. spinulosa* can be present across the survey area in individual form.

Due to a decline in population over time, sensitivity to anthropogenic disturbance and biological importance, *Sabellaria* spp. reefs are afford protection under several conservation policies and legislation. *S. spinulosa* reefs are listed on the OSPAR List of Threatened and/or Declining Species and Habitats whilst *S. alveolata* reefs are listed as a Priority Habitat under Section 7 of the Environment (Wales) Act 2016 (previously NERC S42 lists) within the category of ‘Littoral Rock’. Reefs formed by both species are also considered within the Marine Protected Area network feature list for Wales (Carr et al. 2016) and are considered as Water Framework Directive (WFD) higher sensitivity habitats as ‘Polychaete reefs’.

5. Survey Design

5.1. Survey Objective

The overall purpose of the surveys conducted in August (water sampling), October and November 2020 was to acquire environmental data throughout the proposed Project Erebus survey area, in order to inform the EBS and HA survey aspects of the project Environmental Impact Assessment (EIA).

The EBS aspect of the survey had the following objectives:

(i) Collect video/stills footage and grab samples at targeted locations positioned along the proposed nearshore and offshore cable route and throughout the wind farm array area to characterise seabed sediments and associated benthic communities.

(ii) Collect water samples at 26 targeted stations as a required assessment of the water quality of the section of the export cable corridor intersecting the WFD waterbodies.

The HA aspect of the survey had the following objectives:

(i) Collect video/stills footage and grab samples at targeted locations positioned along the proposed nearshore and offshore cable route and throughout the wind farm array area to characterise seabed sediments and associated benthic communities.

(ii) Collect additional video/stills to fully delineate seabed features and allow for high confidence mapping of key features and for a robust assessment of any sensitive habitats identified (e.g., Annex I geogenic and/or biogenic reef habitats).

5.2. Survey Design

5.2.1. Benthic Sampling

The benthic sampling array was designed to provide maximum geographic coverage of the proposed nearshore and offshore cable corridors and the windfarm array (plus 1 km buffer), whilst also ensuring that all key habitats and communities likely to be encountered across the survey area were adequately ground-truthed to allow for the production of an accurate habitat map of the entire survey area. This was achieved through a review of existing habitat mapping (EMODnet) and detailed interpretation of the geophysical data collected in summer and autumn 2020. Sample selection followed an iterative process whereby OEL undertook the review of existing information and proposed sampling positions which were then signed-off by Blue Gem Wind's marine EIA consultant's MarineSpace. A full audit trail of the sample selection process is provided as Appendix I. For the purposes of survey planning, the cable route was divided up into 20 separate blocks (A1-A19) extending from the Sawdern Point landfall to the array area with the West Angle landfall encompassed by an additional block, WA1. The nearshore section of the export cable route was defined to include Blocks A1-A7 including WA1 whilst the offshore section was defined to include Blocks A8-A19.

Export Cable Corridor

EBS sampling stations were generally selected at approximately 1 km intervals along the proposed export cable corridor although each was micro sited to ensure sedimentary habitats evident in the geophysical data coverage were targeted and where relevant, bedforms and other features of interest were investigated (e.g., sand wave crests and troughs). Prior to the collection of grab samples at each EBS sampling station, imagery was collected of the seabed using a drop-down optical camera system as a means of screening for important and/or sensitive features (e.g., Annex I reefs). This meant that the EBS stations 'doubled up' as HA stations as the resulting seabed imagery could be used to confirm the presence/absence of habitats of interest.

A series of HA transects were also positioned along the export cable corridor to:

- Assess areas of and/or boundaries between high, low and heterogeneous acoustic reflectivity (usually associated with Annex I reef habitats);
- Ground-truth boundaries between predicted habitats/biotopes based on existing habitat mapping;
- Assess slopes, crests and troughs associated with notable topographic features (e.g., sand waves and potential sand banks);
- Confirm the absence of key habitats (e.g., seagrass beds) with the potential to occur in areas lacking geophysical data coverage (e.g., close to the LAT mark at the landfall locations).

Array Area

The approach to sample station selection across the array differed to that used for the export cable corridor due to the geophysical data for much of the area being of lower resolution (5 m) and reduced spatial coverage, with some areas lacking bathymetry, SSS backscatter or both. The sampling plan for the array was therefore based on an 'intelligent grid' approach that initially involved positioning EBS stations at approximately 1 km spacing to provide an even spatial coverage of sampling across the survey area. Where necessary, sample locations were then re-distributed from areas determined to be homogenous sandy sediment (based on interpretation of the geophysical data and/or existing habitat mapping) to areas of low or no geophysical data coverage whilst others were micro-sited to target particular features and/or bedforms (e.g., sand waves).

Each EBS station was also 'screened' for important and/or sensitive features (e.g., Annex I reefs) via the collection of seabed imagery using a drop-down optical camera system prior to grab sampling. As with the export cable corridor stations, this meant that the array EBS stations 'doubled up' as HA stations as the resulting seabed imagery could be used to confirm the presence/absence of habitats of interest. The spatial coverage of imagery collected at the array EBS stations was however increased compared to the approach taken for the export cable corridor stations in that imagery was collected along transects of 150-300 m rather than at single point locations. 'Screening' prior to grab sampling was not deemed necessary at all of the array EBS stations due to the presence of obvious areas of homogenous sandy seabed devoid of acoustic signatures characteristic of potentially important and environmentally sensitive features.

A total of 201 stations were selected and targeted during the survey (including 3 additional stations). A full rationale for the selection of each sampling station is provided as Appendix I.

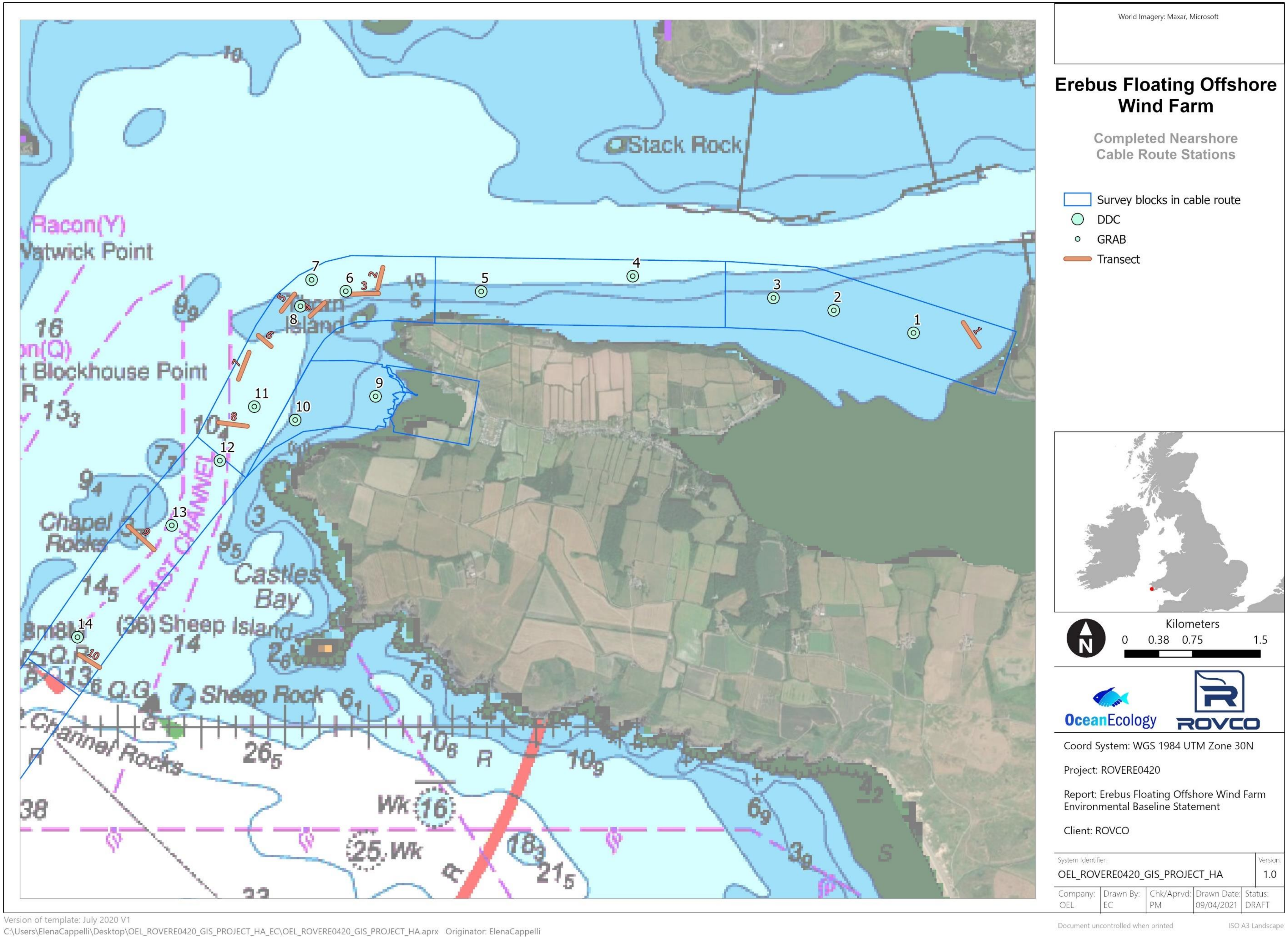
These stations consisted of EBS grab and drop-down camera (DDC) sampling, and HA transects (Table 1 and Figure 3- Figure 6). Of the 201 stations, all DDC and HA transects were completed and 9 grab samples were abandoned due to failed attempts on hard sediments.

Table 1 A summary of the stations targeted for the Project Erebus Offshore Floating Wind Farm survey.

Type	Proposed	Completed	Abandoned	Comments
Nearshore				
EBS (Grab)	21	16	5	5 abandoned due to failed attempts on hard sediments
EBS (DDC)	21	21	0	
HA (Transects)	22	25	0	3 additional transects sampled due to potential Annex I reef habitat at T020.
Offshore				
EBS (DDC)	35	35	0	
EBS (Grab)	35	34	1	1 abandoned due to failed attempts on hard sediments
HA (Transects)	13	13	0	
WTG Array Area				
EBS (DDC)	15	14	0	
EBS (Grab)	60	57	3	3 abandoned due to failed attempts on hard sediments
EBS/HA (Transects)	47	47	0	

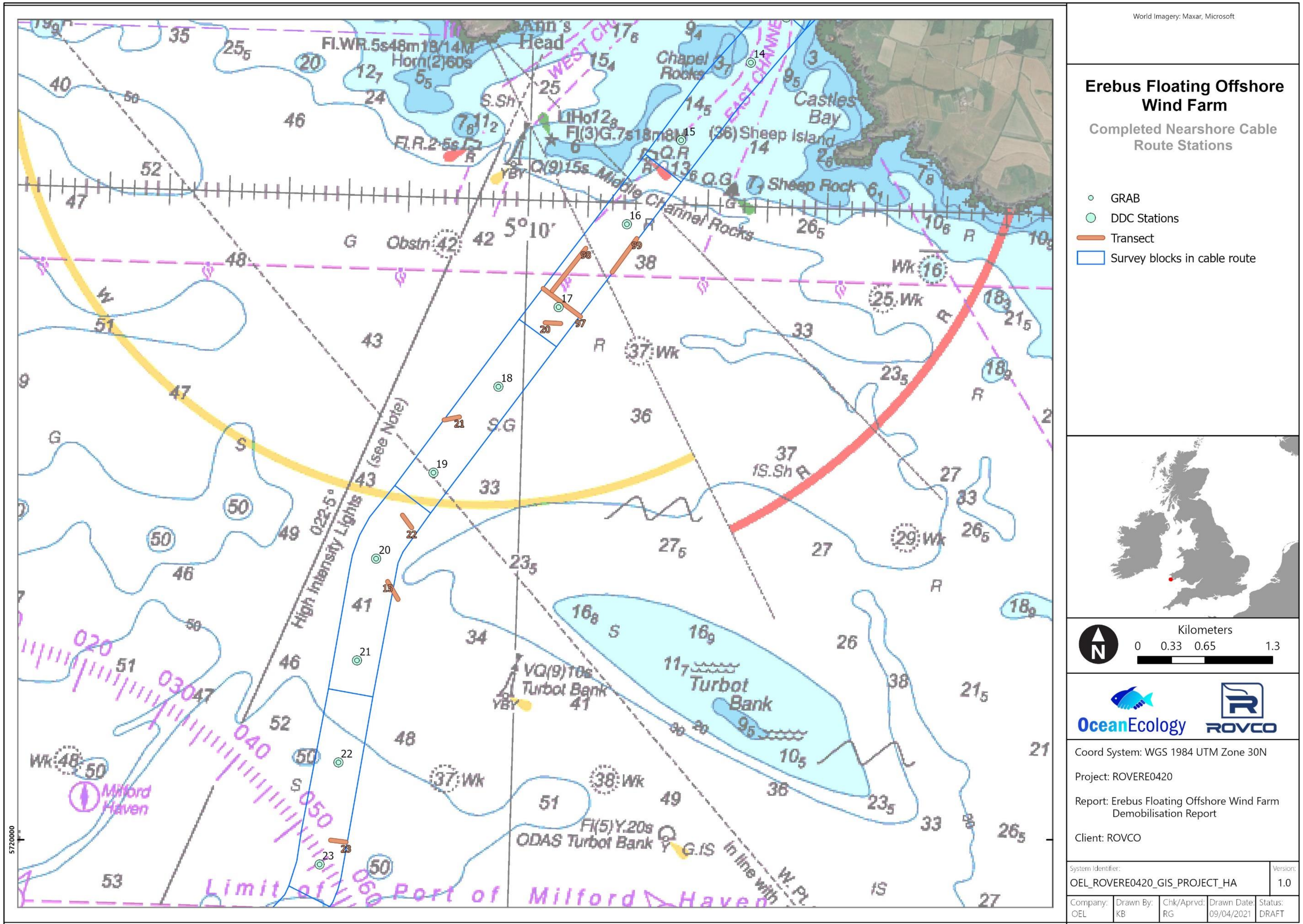
5.2.2. Water Sampling

Water quality sampling stations were selected where the proposed export cable corridor intersected the Milford Haven Outer and Pembrokeshire South Water Framework Directive (WFD) coastal waterbodies. A total of 26 sampling stations were positioned along the centre of the proposed cable routes at approximately 500 m intervals (Figure 7. Water sampling logs are provided in Appendix XIX, an overview of water profiles in included in Appendix XX and raw water profile data is available in Appendix XXI.



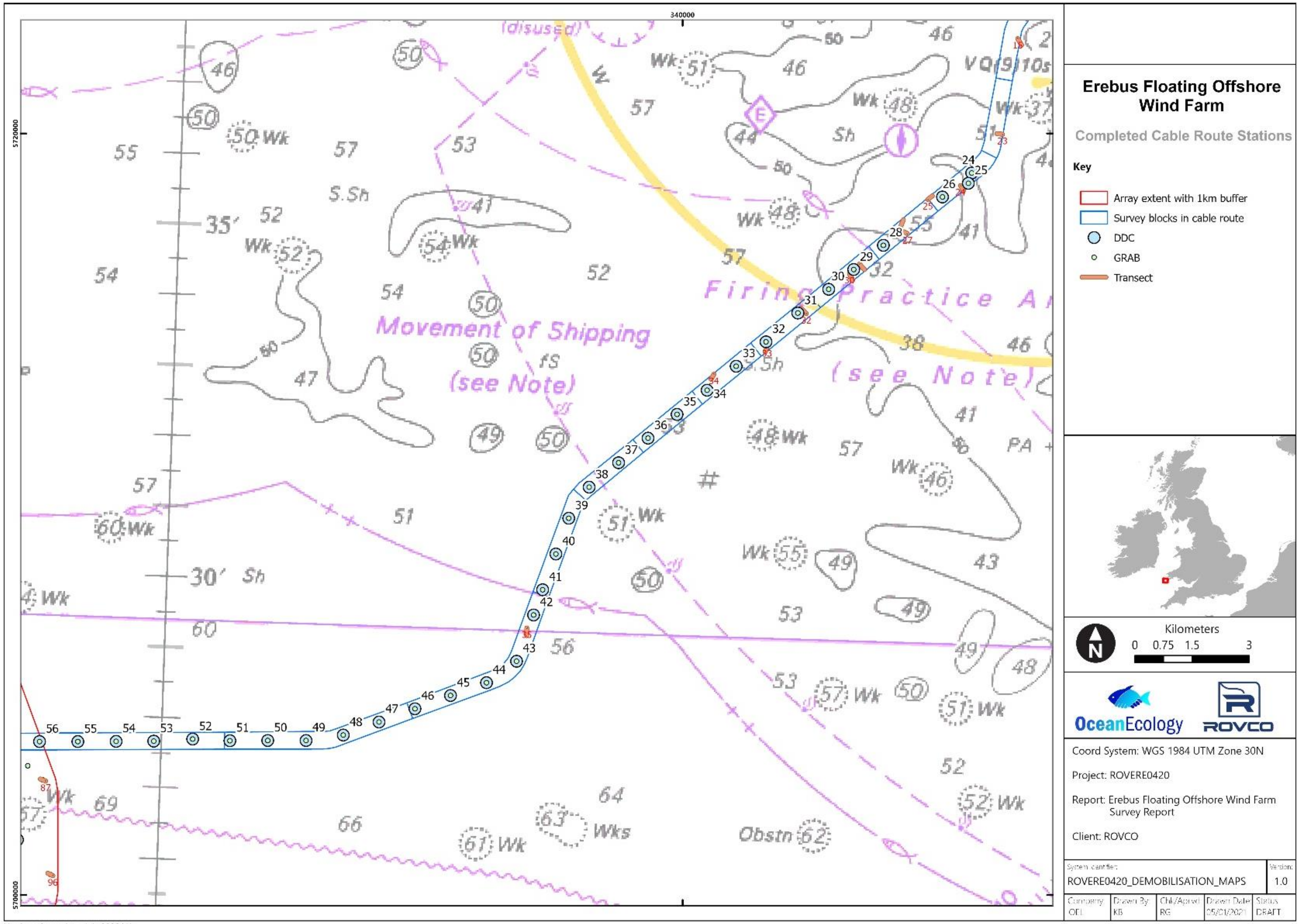
Version of template: July 2020 V1
C:\Users\ElenaCappelli\Desktop\OEL_ROVERE0420_GIS_PROJECT_HA_EC\OEL_ROVERE0420_GIS_PROJECT_HA.aprx Originator: ElenaCappelli

Figure 3 Stations sampled during the nearshore cable route section of the Project Erebus survey area.



Version of template: July 2020 V1
C:\Users\ElenaCappelli\Desktop\OEL_ROVERE0420_GIS_PROJECT_HA_EC\OEL_ROVERE0420_GIS_PROJECT_HA.aprx Originator: ElenaCappelli

Figure 4 Stations sampled during the nearshore cable route section of the Project Erebus survey area.



Version of template: July 2020 V1
Z:\Clients\Rovco\ROVERE0420 Erebus Floating Windfarm\20201229\GIS\PROJECTS\ROVERE0420_DEMOBILISATION_MAPS\ROVERE0420_DEMOBILISATION_MAPS.aprx Originator: KarenBoswarva

Document uncontrolled when printed ISO A3 Landscape

Figure 5 Stations sampled during the offshore cable route section of the Project Erebus survey area.

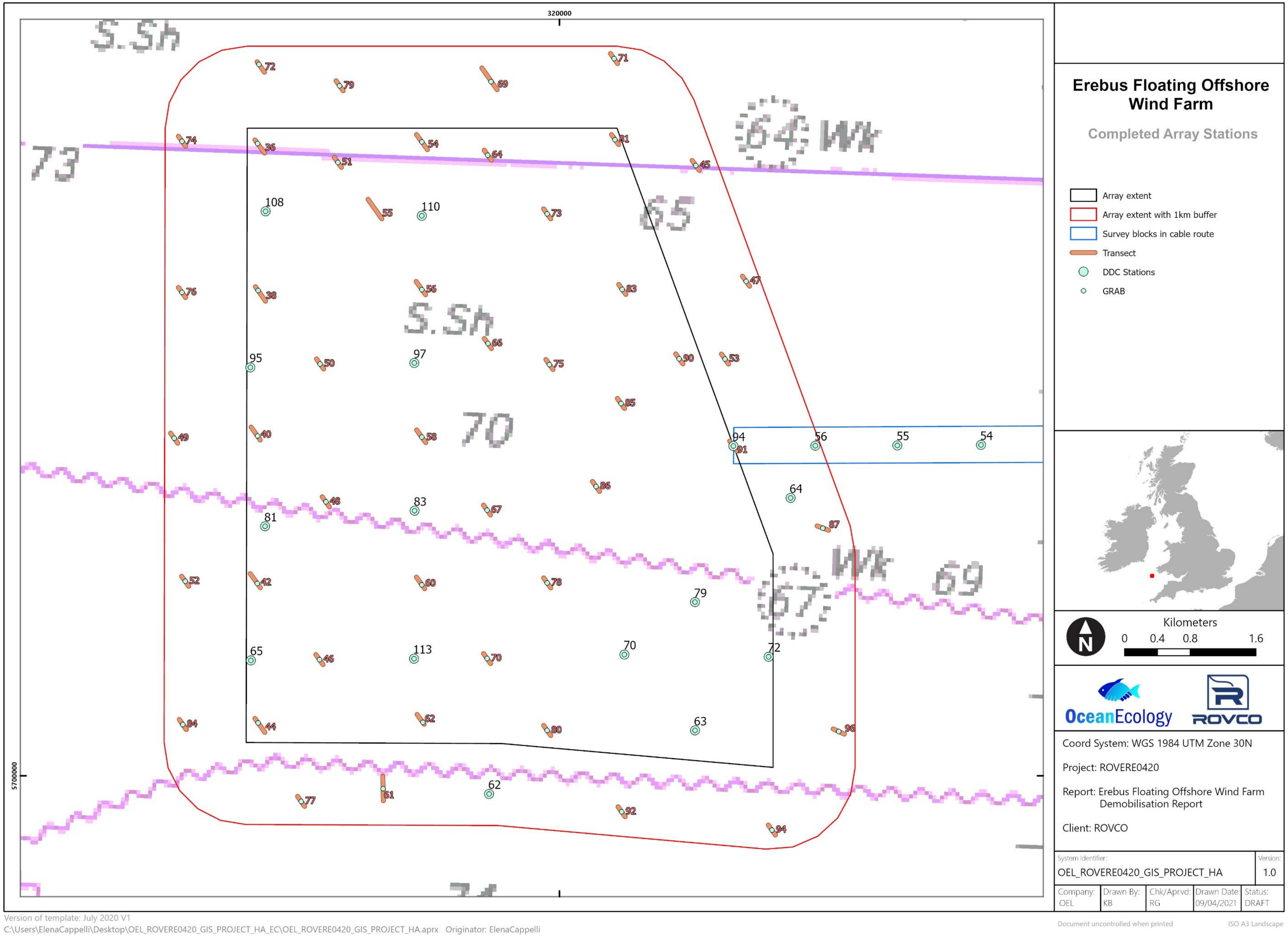
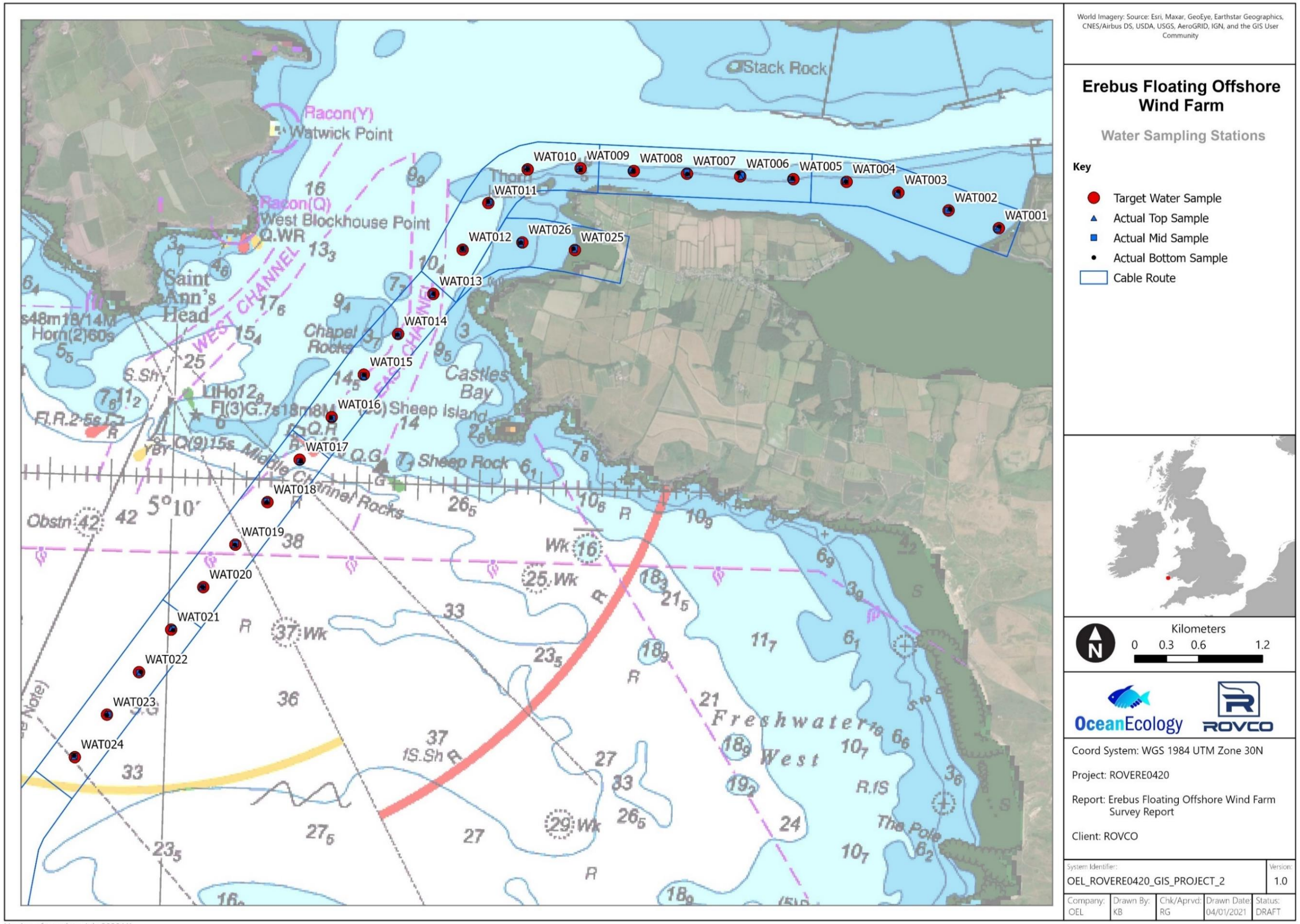


Figure 6 Stations sampled during the wind farm array section of the Project Erebus survey area.



Version of template: July 2020 V1
C:\Users\KarenBoswarva\Documents\ArcGIS\Projects\OEL_ROVERE0420_Overview_map\OEL_ROVERE0420_GIS_PROJECT_2.aprx Originator: KarenBoswarva

Figure 7 A summary of the water sampling stations situated along the nearshore section of the export cable corridor as part of the Project Erebus survey area.

6. Field Methods

6.1. Survey Vessels

All nearshore EBS, HA sampling and water sampling out to Block A5 was conducted aboard OEL's dedicated 10.4 m Marine and Coastal Agency (MCA) category 2 coded survey vessel '*Seren Las*' (Plate 1).

All offshore EBS and HA sampling out from Block A5 to A19 and including the array + 1 km buffer was conducted aboard the 66 m MCA category 1 coded DPII multi-role vessel '*Glomar Wave*' (Plate 1), contracted by Rovco. The 300 m^2 deck area enabled a full suite of sampling and backup equipment to remain fully mobilised throughout a survey. Due to its high weather tolerance, it was possible for the 'Glomar Wave' to remain offshore for extended periods resulting in minimal time spent in port once mobilised for the survey.

Plate 1 Top: Offshore survey vessel '*Glomar Wave*'. Bottom: Nearshore survey vessel '*Seren Las*'.

6.1.1. Geodetic Parameters

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

Table 2 Geodetic parameters used for the nearshore and offshore sampling phases.

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

6.2. Survey Equipment

6.2.1. Positioning

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

The '*Glomar Wave*' was equipped with a dynamic positioning (DP) system, and Fugro Bridgemate differential GPS promoting accurate positioning and fine-scale vessel movements. A Sonardyne WSM6+ Ultra-short baseline (USBL) beacon was mounted on to the frame of both the camera and grab systems prior to deployment. The GPS survey feed was sent to the Subsea Technology and Rentals (STR) Seaspyder-HD camera system, to provide a live overlay on the video footage, whilst a continuous track plot was recorded to allow for creation of retrospective overlays for video footage collected using OEL's CLOC (Clear Liquid Optical Chamber) camera system. Due to the shallower water depths from Blocks A1-A5 (including WA1), an offset position of the sampling equipment was used to determine the position of the sampling equipment on the seabed when deployed from the stern A frame of '*Seren Las*'.

6.2.2. Seabed Camera Systems

Seabed imagery (simultaneous video and stills) was collected using two high-definition optical camera systems across the cable corridor and array areas. The majority of the nearshore and some of the offshore imagery was collected using OEL's ROVTech subsea camera system, providing 1080p High Definition (HD) video and 20 Megapixel (MP) stills imagery. Due to greater turbidity in the shallower nearshore areas, the camera was mounted in a CLOC filled with fresh water to ensure imagery of suitable quality was obtained (Jones et al. 2020). Lighting from two LED strip lamps, and two lasers separated by 10 cm were projected into the field of view for illumination and scaling.

All other seabed imagery was collected using a STR Seaspyder-HD Drop Camera System, providing 1080p HD video and 18 Megapixel (MP) stills imagery. The camera was mounted on an aluminium sledge-like frame and illuminated by four high intensity, adjustable LED lamps, each emitting max 1200 lumens. Quad scaling lasers, altimeter, depth, and heading sensors were also integrated into the frame (Plate 2).

6.3. Grab Samplers

Sediment samples collected at each EBS station visited by the '*Seren Las*' were collected using 0.1 m^2 Day grab (2 replicate samples per station – 2 deployments), whereas stations visited by the '*Glomar Wave*' were collected using a dual (2 x 0.1 m^2) Van Veen (DVV) grab. The DVV enables two samples of undisturbed surface sediment to be retrieved simultaneously. At stations where the DVV was unsuitable for sampling due to the presence of coarse sediments and/or rocky seabed, a 0.1 m^2 mini-Hamon grab was deployed instead. To note that the mini-Hamon grab collects a single sample of sediment per deployment, therefore two deployments are required to obtain two replicates and the same sample volume as the DVV (Plate 2).

6.3.1. Water Quality

A 5L pre-cleaned and sterile Niskin bottle, attached to the deployment cable using bulldog clips and friction tape was used to collect water samples at each water sampling station. A YSI EXO 2 water profiler was used to obtain water column from sea surface to near seabed, measuring depth, conductivity (µS/cm), dissolved oxygen (%), turbidity (Formazin Nephelometric Unit, FNU), pH and temperature (ºC). Appendix XIX to XXI provide additional information on water samples logs and water profile data.

6.4. Sampling Approach

Detailed sampling methods are set out in the subtidal benthic survey report, provided as Appendix XVI and summarised below.

6.4.1. Drop Down Camera (DDV)

All seabed imagery was collected in consideration of the Joint Nature Conservation Committee (JNCC) epibiota remote monitoring operational guidelines (Hitchin et al. 2015). A minimum of five images were captured from each EBS station along with a minimum of 2 minutes of video where the seabed was visible. Between images, the camera was moved to ensure a good overview of the station was obtained and any heterogeneity in the substrate was identified. Along the HA transects, images were taken at least every 10 m and more often when features of interest were encountered. All video footage was reviewed *in situ* by OEL's environmental scientists.

6.4.2. Grab Sampling

All grab sample collection and processing was undertaken in consideration of version 8 of the Regional Seabed Monitoring Programme (RSMP) protocol (Cooper & Mason 2019). Grab sampling was only conducted once suitable seabed video and stills of the seabed had been collected from each sampling station and no obstructions to inhibit the collection of grab samples had been identified. Samples with a volume less than 5 L were rejected and sampling at the location reattempted. If continued attempts also failed to collect a valid sample, then the station was either repositioned, abandoned, or reattempted using the mini-Hamon grab.

At stations sampled using a Day grab, two replicate samples were retrieved at the same station: one for macrobenthic analysis and one for sediment analysis (2 deployments). At stations sampled using a DVV, two replicate samples were simultaneously collected with one deployment and one replicate was used for macrobenthic analysis while the other was for sediment analysis.

Sub-samples for chemical and particle size analysis (PSA) were taken from the same replicate grab sample, from each station. Two subsamples (A and B) for Hydrocarbons (HC) and Organics (TOC and TOM) analysis were collected using a metal scoop to a nominal depth of 2 cm and placed in a glass sample pot. Two more subsamples (A and B) for Heavy Metal (HM) analysis were collected using a plastic scoop to a nominal depth of 2 cm and placed in a plastic sample pot, followed by an additional two subsamples (A and B) for PSA. All chemical and PSA samples were frozen immediately ($<-18°C$). The other replicate sample from the same station (either the second DVV sample or second Day or mini-Hamon grab sample) was then released into a container and photographed. It was then emptied onto a 1 mm sieve net laid over 4 mm sieve table and washed through using gentle rinsing with seawater hose. The remaining sample was then photographed and backwashed into a suitably sized sample container using seawater and diluted 10% formalin solution added to fix sample, prior to laboratory analysis.

6.4.3. Water Quality Sampling

Water samples were taken at 2 m above the seabed, mid-water depth and 2 m below the surface using a 5 litre Niskin bottle attached the deployment cable using bulldog clips and friction tape. When the bottle was at the desired depth, a messenger weight was attached to the deployment wire and sent to trip the sampler.

When the equipment reached the surface, it was recovered to deck and the sampler removed, with water decanted into the required laboratory sample containers. Water samples were sub-sampled into containers for the required analyses. Samples were taken in either 1 litre amber glass bottles, 1 litre PTFE bottles or 40 ml amber vials with no headspace. Chlorophyll samples were also collected and filtered onboard using a hand operated chlorophyll pump.

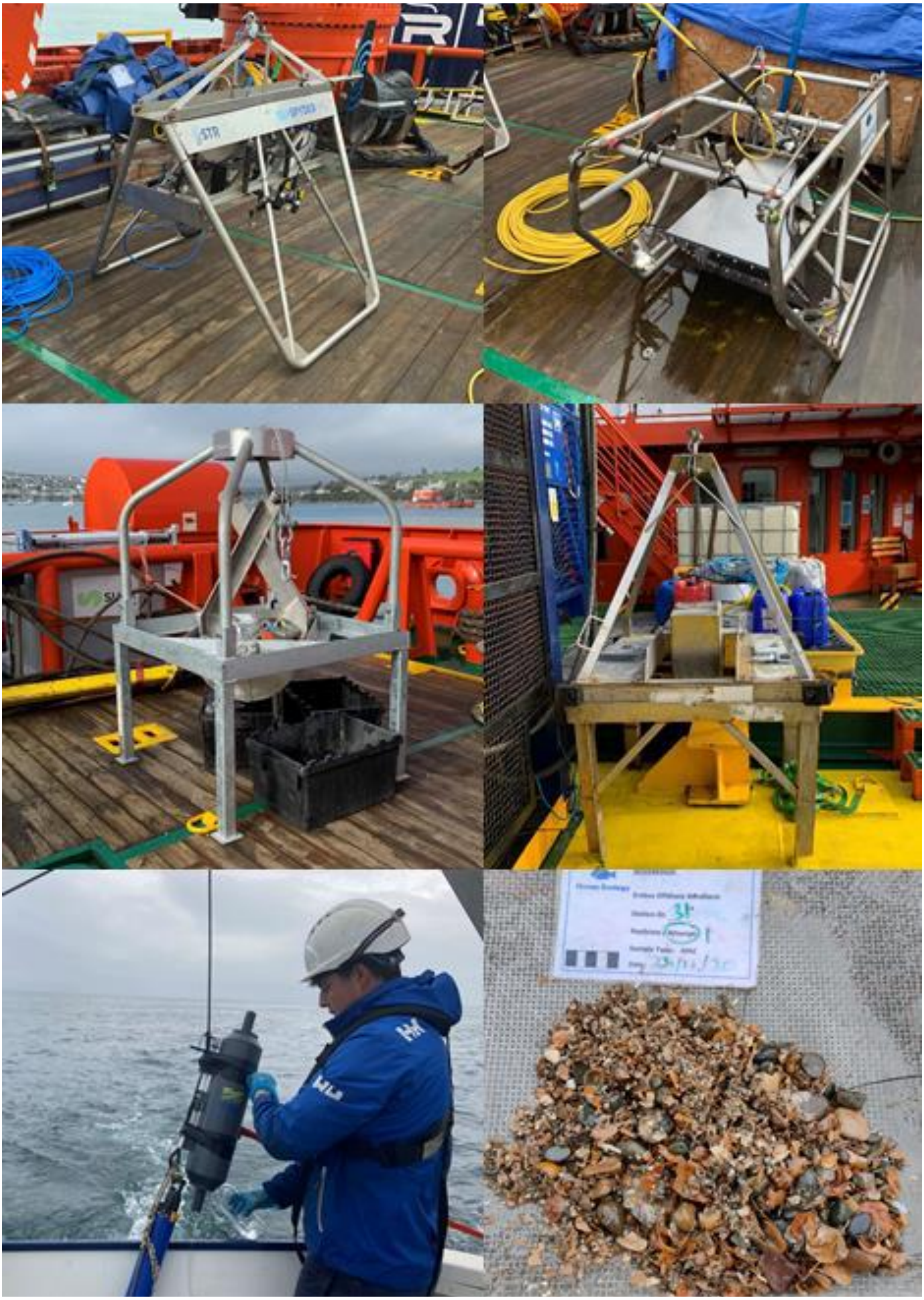


Plate 2 Top left: STR SeaSpyder camera system. Top right: OEL's ROVTech camera system equipped with CLOC. Middle left: Dual Van Veen grab sampler. Middle right: Mini-Hamon grab sampler. Bottom left: decanting of water sample into Niskin bottle. Bottom right: sieved sediment sample.

7. Laboratory and Analytical Methods

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

7.1. Particle Size Distribution (PSD) Analysis

Particle Size Distribution (PSD) analysis of sediment samples was undertaken by in-house laboratory technicians at OEL's NMBAQC (NE Marine Biological Analytical Quality Control Scheme) participating laboratory, in line with NMBAQC best practice guidance (Mason 2016).

7.1.1. Sample Preparation

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

7.1.2. Dry Sieving

The >1mm fraction was then returned to a drying oven and dried at 80°C for at least 24 hours prior to dry sieving. Once dry, the sediment sample was run through a series of Endecott BS 410 test sieves (nested at 0.5 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 3.

Table 3. Sieve series employed for Particle Size Distribution (PSD) analysis by dry sieving (mesh size in mm).

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

The sample was then transferred onto the coarsest sieve (63 mm) at the top of the sieve stack and shaken for a standardised period of 20 minutes. The sieve stack was checked to ensure the components of the sample had been fractioned as far down the sieve stack as their diameter would allow. A further 10 minutes of shaking was undertaken if there was evidence that particles had not been properly sorted.

7.1.3. Laser Diffraction

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

7.1.4. Data Merging

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

Sediment were described by their size class based on the Wentworth classification system (Wentworth 1922) (Table 4). Statistics such as mean and median grain size, sorting coefficient, skewness and bulk sediment classes (percentage silt, sand and gravel) were also derived in accordance with the Folk classification (Folk 1954).

Table 4. Classification used for defining sediment type based on the Wentworth Classification System (Wentworth 1922).

Wentworth Scale	Phi Units (φ)	Sediment Types
>64000 µm	<-6	Cobble and boulders
32000 – 64000 µm	-5 to -6	Pebble
16000 – 32000 µm	-4 to -5	Pebble
8000 – 16000 µm	-3 to -4	Pebble
4000 - 8000 µm	-3 to -2	Pebble
2000 - 4000 µm	-2 to -1	Granule
1000 - 2000 µm	-1 to 0	Very coarse sand
500 - 1000 µm	0 - 1	Coarse sand
250 - 500 µm	01-Feb	Medium sand
125 - 250 µm	02-Mar	Fine sand
63 - 125 µm	03-Apr	Very fine sand
31.25 – 63 µm	04-May	Very coarse silt
15.63 – 31.25 µm	05-Jun	Coarse silt
7.813 – 15.63 µm	06-Jul	Medium silt
3.91 – 7.81 µm	7 – 8	Fine silt
1.95 – 3.91 µm	08-Sep	Very fine silt
<1.95 µm	<9	Clay

7.2. Sediment Chemical Analysis

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

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

Based on Polycyclic Aromatic Hydrocarbon (PAH) compounds the following ratios were calculated as follows:

- The ratio between light (LWM) and heavy (HMW) PAHs is typically used as a proxy to determine the origin source of PAH compounds in sediments, ratios above 1 indicate a petrogenic source while ratios below 1 indicate a pyrogenic source. LMW PAHs include compounds with 2-3 rings while HMW PAHs include compounds with more than 4 rings (Edokpayi et al. 2016).
- Phenanthrene / Anthracene ratio: values lower than 10 indicate a pyrogenic source origin for the hydrocarbons; while values higher than ten account for hydrocarbons of petrogenic origin (Kafilzadeh et al. 2011).
- Fluoranthene / Pyrene ratio: for values higher than one, the hydrocarbons are pyrogenic in origin, for values below one, the hydrocarbons are petrogenic in origin (Kafilzadeh et al. 2011).

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

- Carbon Preference Index (CPI): the ratio between the concentration of odd-numbered and even-numbered carbon chains in n-alkanes. CPI values close to 1 indicate hydrocarbons of petrogenic origin; CPI values below 1 indicate pyrogenic origin (Fagbote 2013), while CPI values higher than 1 indicate a biogenic origin of alkanes (Al-hejuje et al. 2015).
- Pristane / Phytane ratio: values close to one indicate hydrocarbons of petrogenic origin, values higher than one indicate biogenic origin of alkanes, while ratios below one indicates pyrogenic origin. Pristane is typically found in marine organisms while phytane is a component of oil (Guerra-García et al. 2003) hence the use of this ratio to assess source origin of hydrocarbons.

7.3. Water Chemical Analysis

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

7.4. Macrobenthic Analysis

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

For each macrobenthic sample, the excess formalin was drained off into a labelled container over a 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 fresh water, 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 macrobenthos present was identified to species level, where possible, and enumerated by trained benthic taxonomists using the most up to date taxonomic literature and checks against existing reference collections. Nomenclature utilised the live link within ABACUS to the WoRMS[4] REST webservice (World Register of Marine Species), to ensure the most up to date taxonomic classifications were recorded. Colonial fauna (e.g. hydroids and bryozoans) were recorded as present (P). For the purposes of subsequent data analysis, taxa recorded as P were given the numerical value of 1.

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

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

---

[3] Marine Environmental Data and Information Network

[4] http://www.marinespecies.org

- Miscellaneous = 15.5 %

7.5. Macrobenthic Data Analysis

7.5.1. Data Truncation and Standardisation

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

7.5.2. Pre-Analysis Data Treatment

All data were collated in excel spreadsheets and made suitable for statistical analysis. All data processing and statistical analysis was undertaken using R v 1.2 1335 (R Core Team 2020) and PRIMER v7 (Clarke & Gorley 2015) software packages. To note that no replicate samples were available for macrobenthic analysis thus no mean values could be calculated per sampling station.

7.5.3. Multivariate Statistics

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

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

7.6. Determining EUNIS Classifications

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

7.7. Seabed Imagery Analysis

Digital photographic stills and video footage were successfully obtained at all EBS stations and along all HA transects and subsequently analysed to aid in the identification and delineation of EUNIS habitats and potential HOCI along the survey area. Seabed images were enhanced prior to analysis using the open-source image editing software GNU Image Manipulation Program (www.gimp.org). All seabed imagery analysis was undertaken using the Bio-Image Indexing and Graphical Labelling Environment (BIIGLE[5]) annotation platform (Langenkämper et al. 2017) and in consideration of the JNCC epibiota remote monitoring interpretation guidelines (Turner et al. 2016). Analysis of still images was undertaken in two stages. The first stage, "Tier 1", consisted of labels that referred to the whole image being assigned, providing appropriate metadata for the image. The second stage, "Tier 2", was used to assign percentage cover of 'reef' types by drawing polygons to inform the habitat assessment process. Appendix XV summarises seabed imagery analysis methodologies.

7.7.1. Annex I Habitat Assessment

Annex I Geogenic and Biogenic Reef

A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of Annex I geogenic and biogenic *S. spinulosa* reef habitats as detailed in Table 5 and Table 6, respectively. To note that there are currently no guidelines for determining the quality ('reefiness') of bedrock reef habitats, however some of criteria described in Table 5 can be adopted to assess this feature too, namely extent, patchiness and elevation. Recommendation on the assessment of low resemblance reef were also considered following Golding, Albrecht, & McBreen (2020). The annotation label tree in BIIGLE was assigned major headings for each reef type: stony reef, bedrock reef and biogenic reef. Under each reef type, labels were assigned for each of the categories required to determine whether reef habitat was present as per the tables below.

Table 5 Characteristics of bedrock and stony reef (Irving 2009).

Characteristic	'Reefiness'			
	Not a Reef	Low	Medium	High
Composition (proportion of boulders/cobbles (>64 mm or bedrock))	<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		

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

Table 6 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

Annex I Sandbanks

Annex I Sandbank habitats are characterised by three descriptors: topography, substrate/vegetation and proximity to known sandbank/similarity in benthic community (Pinder 2020). Topographic features consist of elongated, rounded or irregular 'mound' shapes which may arise from horizontal or sloping plains of sandy sediment at depths of less than 20 m (but can include channels or other areas greater than 20 m deep). Substrates are mainly composed of sand (≥ 50 %) and may support *Zostera marina* or maerl beds. Where areas of horizontal or sloping sandy habitats are closely associated with known sandbanks (proximity and/or similarity of benthic communities), they are included within the Annex I type. As a result, all geophysical and ground truthing data were reviewed to assess against these descriptors across the entire survey area. Geophysical data were mostly used to determine the topography of features, while ground truthing data were used to assess sediment type and composition and the presence of key flora and fauna. Where areas were deemed to meet some or all of the criteria, they were delineated and assigned confidence score of either 'High' or 'Potential'. Specifically, a 'high' confidence score was assigned to features meeting all of the above criteria such as displaying the topographic and sedimentary characteristics described above and located in closed proximity to known sandbanks. Conversely, a 'potential' score was attributed to features only meeting some of the above criteria such as having the same physical characteristic of known sandbanks but located in an area where not known sandbanks were recorded.

7.7.2. Habitats of Principal Importance

Section 7 of the Environmental (Wales) Act 2016 requires to assess the presence of types of habitats in Wales that are regarded as of 'principal importance' for the purpose of maintaining and enhancing biodiversity. In the survey area the following habitats of principal importance may occur among the sublittoral sediment type:
- Subtidal mixed muddy sediments.
- Subtidal sands and gravels.
- Maerl beds

None of the rocky habitats encountered across the survey area belonged to the list of habitats of principal importance - sublittoral rock.

7.8. Habitat/Biotope Mapping

All seabed imagery was assigned a EUNIS habitat and/or biotope based on the latest JNCC guidance (Parry 2019). These outputs from the BIIGLE analysis were utilised alongside the acoustic information and the ground truthing data from the grab samples to manually delineate the boundaries (polygons) of the various habitats and biotopes encountered across the Project Erebus survey area. Confidence scores were therefore assigned to all polygons to give an indication of their accuracy. Values ranged from 1 (one data source) to 3 (all data sources) depending on the following:

- Whether ground-truth data 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, ground-truth or acoustic data

Highest scores were given to polygons where all data sources identified the same habitat/biotope, with distinct boundaries. Lower scores were assigned to polygons where the boundaries were not obvious. In these cases, polygons were drawn based upon expert judgement, given the information available.

8. Results

8.1. Particle Size Distribution Data

The composition of sediment data at each grab sampling stations throughout the survey area is mapped in Figure 8. Grab sampling logs and sample photos are provided in Appendices II and III respectively and full PSD data has been provided in Appendix IV.

8.1.1. Sediment Type

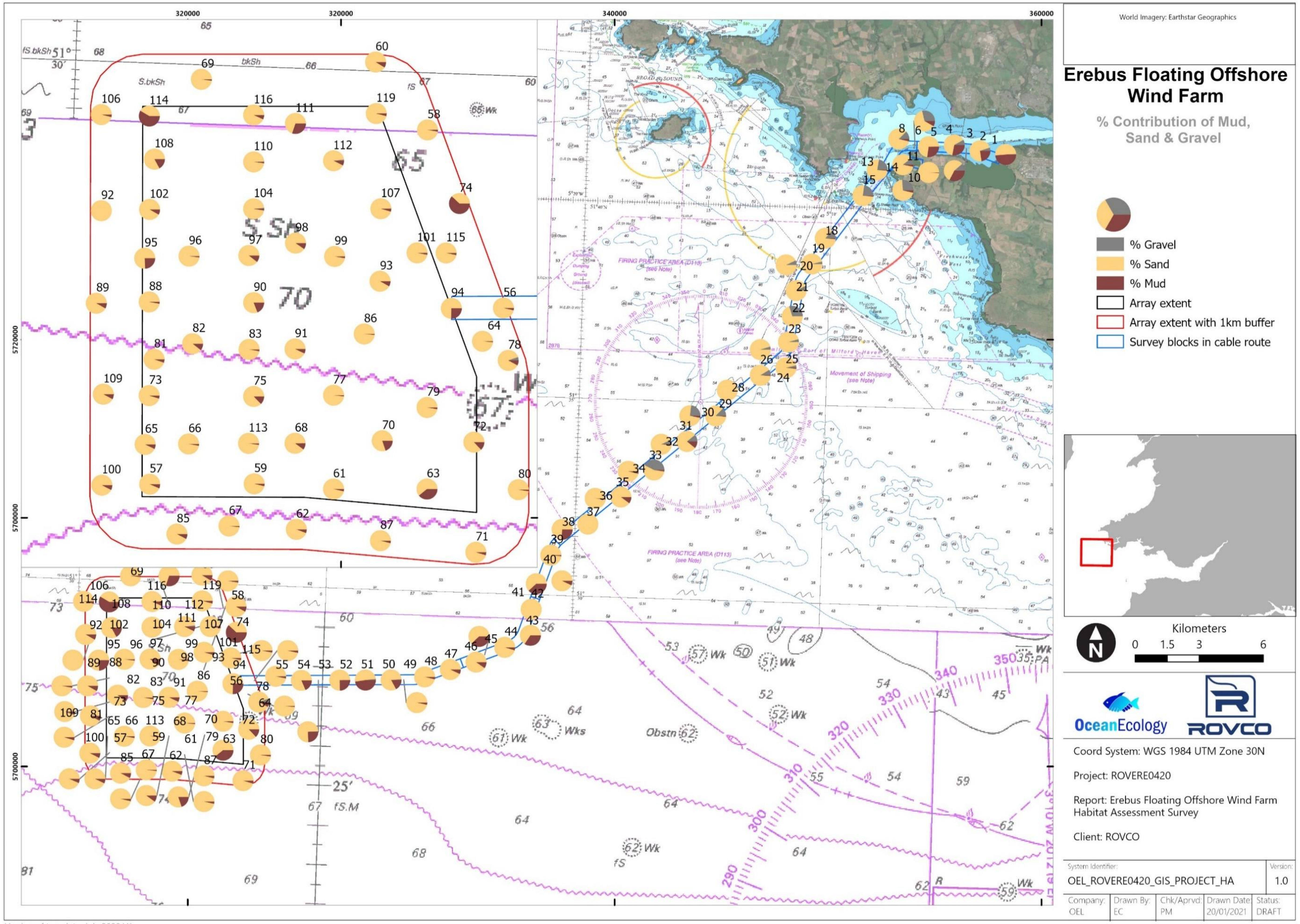
Sediment types at each grab sampling station as classified by the Folk (1954) classification are summarised in Appendix V and illustrated in Figure 9. Despite some variation in sediment types between stations, the majority of stations were dominated by sand. Mud content was highest close to land and towards the main array. Gravel content was overall low and variable along the cable route. The majority of samples were comprised of sand representing EUNIS BSH A5.2 (Sand and Muddy Sand), while some stations were classified as Gravelly Sand (gS) representing EUNIS BSH A5.1 (coarse sediment) or as Mud and Sandy Mud (EUNIS BSH A5.3); only 5 out of 107 stations were classified as Gravelly Muddy Sand (gmS) representing EUNIS BSH A5.4 (Mixed Sediment).

These sublittoral sediment types could represent 'subtidal sands and gravels' and 'subtidal mixed muddy sediments' listed as habitats of principal importance under Section 7 of the Environment (Wales) Act 2016. To note that these habitats are among the most common habitats found below the MLWS around the coast of the UK.

Most of the sediments recorded were classified as poorly to very poorly sorted (57 % of stations) as a result of the mixed composition of different size fractions of all three principal sediment types (gravel, sand and mud). However, 9 stations (8 %) were classified as moderately well sorted and comprised almost entirely of sand.

8.1.2. Sediment Composition

The percentage contribution of gravels (> 2 mm), sands (0.63 mm to 2 mm) and fines (< 63 μm) at each station are presented in Figure 8. Sand was the main sediment fraction present at most stations, comprising the largest percentage contribution across the survey area. The mean proportion (± Standard Error, SE) of sand across all stations was 86.7 % (± 1.3), while the mean (±SE) mud and gravel content across the survey area was 10.13 % (± 1.3) and 3.2 (± 0.7) respectively. Sand content was greatest at stations ST028, ST037, ST042 and ST092 and lowest at ST074. The mean grain size at sampling stations ranged from 30.82 μm at station 74 (located in the main array) to 1564.8 μm at station 33 (located along the cable route).



Version of template: July 2020 V1
C:\Users\ElenaCappelli\Desktop\OEL_ROVERE0420_GIS_PROJECT_HA\OEL_ROVERE0420_GIS_PROJECT_HA.aprx Originator: ElenaCappelli

Document uncontrolled when printed ISO A3 Landscape

Figure 8: Percentage volume of gravel (G), sand (S) and mud (M) at each sampling station across the Project Erebus survey area.

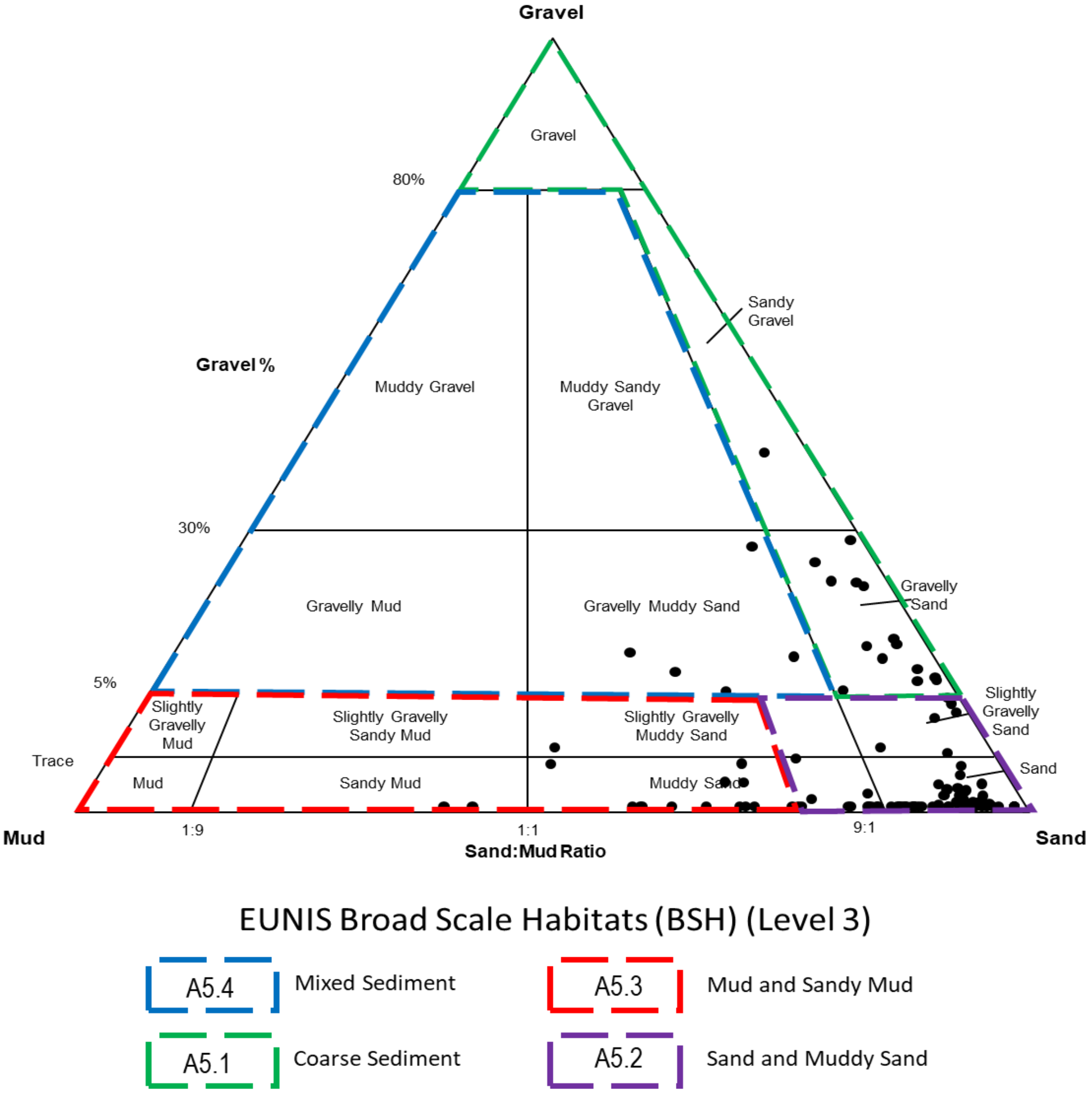


Figure 9 Folk (Folk 1954) triangle classifications of sediment gravel percentage and sand to mud ratio of samples collected across the Project Erebus Offshore Floating Wind Farm survey area, overlain by the modified Folk triangle for determination of mobile sediment BSHs under the EUNIS habitat classification system (adapted from (Long 2006)).

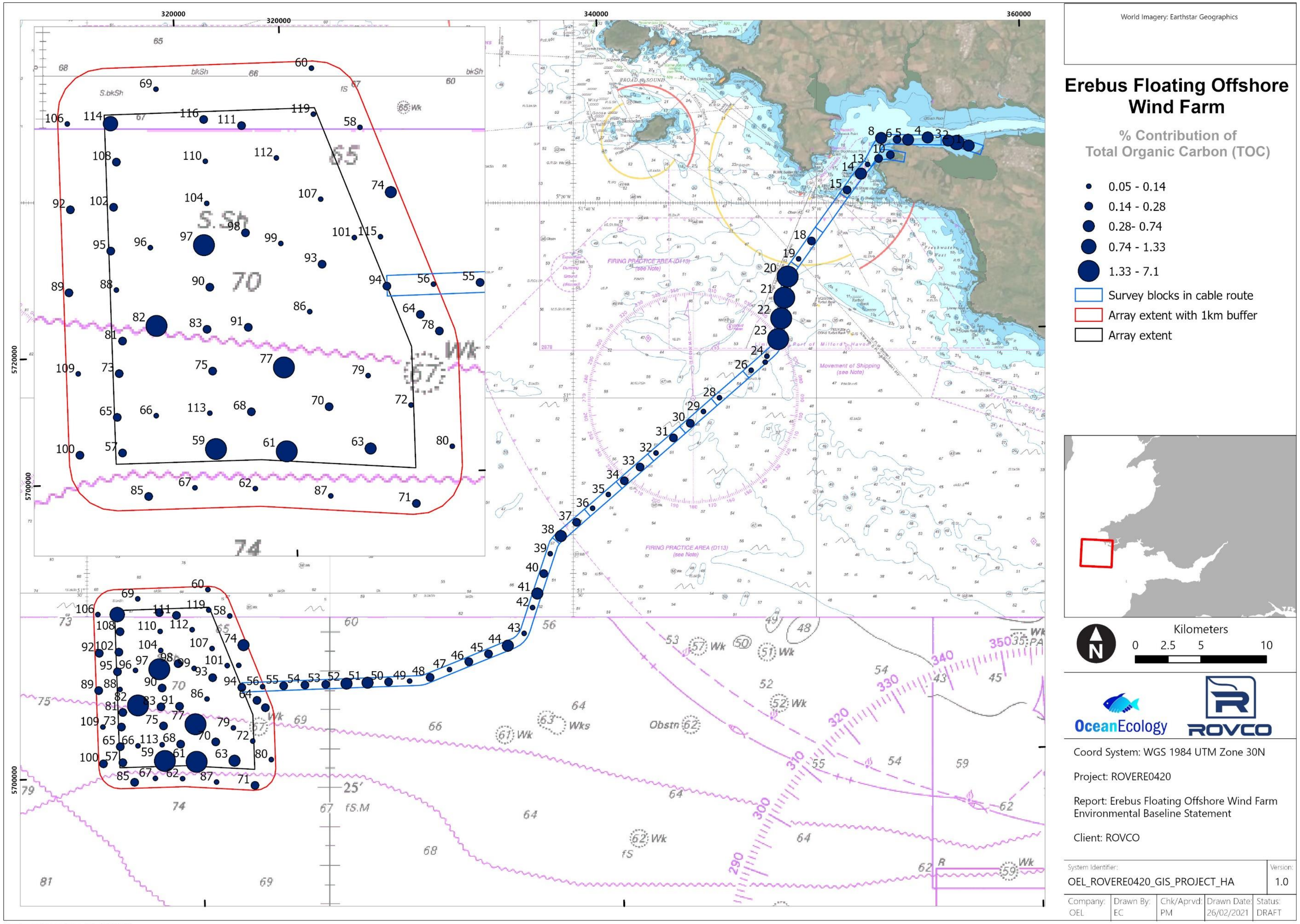
8.2. Sediment Chemistry

Sediment samples for chemical analysis were collected from 107 stations sampled along the nearshore (10 samples) and offshore (97) sections of the survey area. Grab samples taken for chemical analyses were analysed for heavy and trace metals (Section 8.2.2), Polycyclic Aromatic Hydrocarbon (PAH) (Section 8.2.3), Total Hydrocarbon Content (THC), Total Organic Carbon (TOC) and Total Organic Matter (TOM) (Section 8.2.1). Raw sediment chemistry data are provided in Appendix VII.

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

TOC concentrations ranged from 0.05 % at ST028 to 7.1 % at ST021 with an average value (± SD) of 0.7 ± 1.62 % across the survey area as a whole (Figure 10). Values were generally low (< 1.3 %) except at nine sites where TOC content of > 5 % was measured. Four of these 9 sites are in the nearshore section of the cable route (ST20-ST23), while the remaining five sites are located within the wind farm main array (ST077, ST097, ST082, ST061 and ST059). Average TOC compares well with global sediment average TOC content for the deep ocean (0.5 %) and eastern margins (2 %) (Seiter et al. 2004).

TOM content in sediment varied between 0.1 % at ST077 and 6.3 % at ST114, with an average value (± SD) of 1.34 ± 0.81 % across the survey area (Figure 11). In general, the highest TOM content (> 2%) in the sediment was found at stations with the highest mud content (>20 %), except for ST014 with TOM content of 2.2 % and mud content of only 1.2 %.



Version of template: July 2020 V1
C:\Users\ElenaCappelli\Desktop\OEL_ROVERE0420_GIS_PROJECT_HA_EC\OEL_ROVERE0420_GIS_PROJECT_HA.aprx Originator: ElenaCappelli

Figure 10 Percentage contribution of TOC at each sampling station sampled across the Project Erebus survey area.

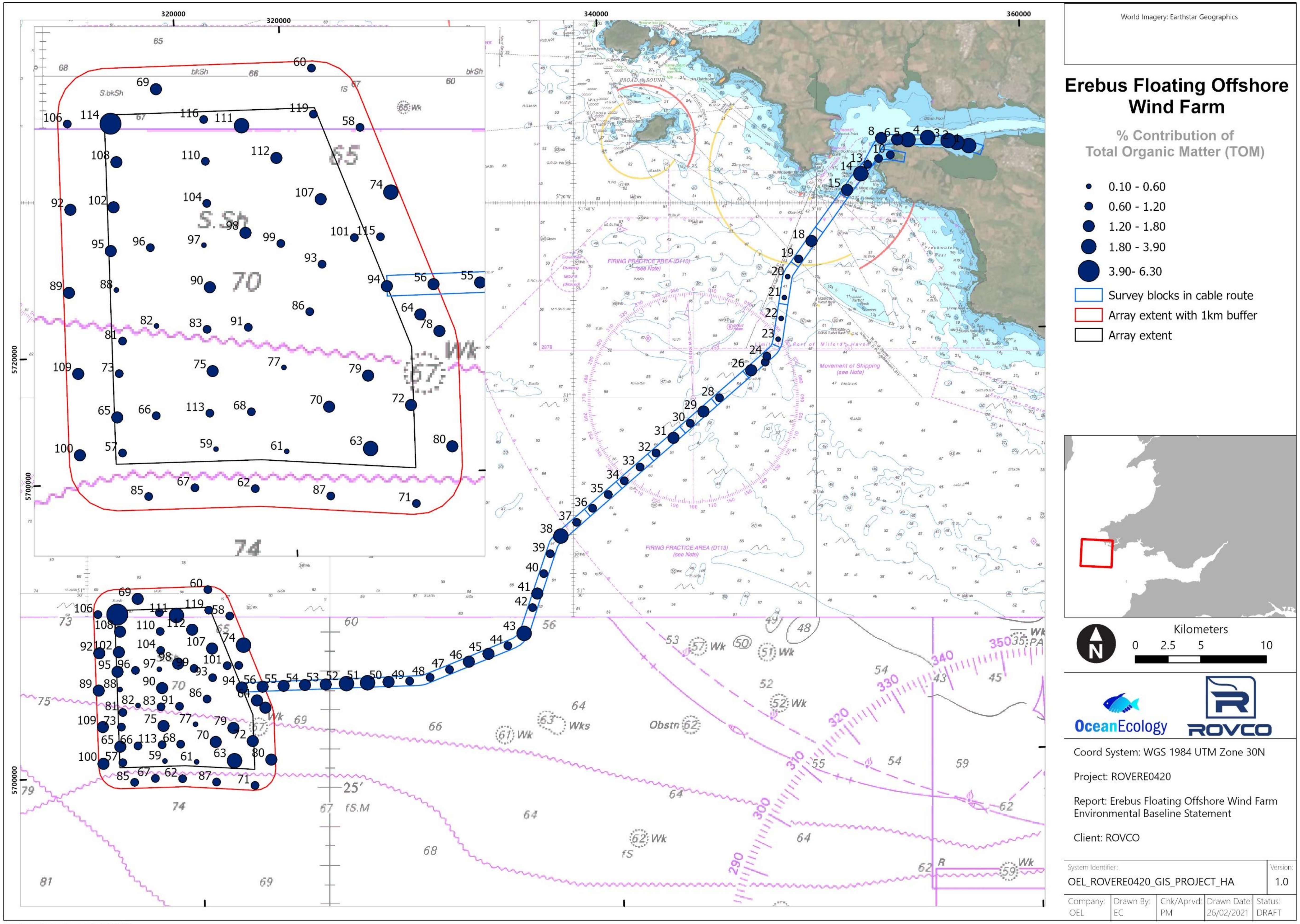


Figure 11 Percentage contribution of TOM at each sampling station sampled across the Project Erebus survey area.

8.2.2. Heavy and Trace Metals

A total of eight heavy and trace metals were analysed from sediments taken at each of the 107 stations. These were Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn).

The raw data (presented as a dry-weight concentration, mg kg^{-1}) are shown in Table 7. Where available, mean metal concentrations were compared to the OSPAR Background Assessment Concentration (BAC) (OSPAR et al. 2009), the USA Environmental Protection Agency (EPA) Effect Range Low (ERL) (NJDEP 2009), Cefas (1995) Action Level (AL) 1 and AL 2, and the Canadian sediment quality guideline (CSQG) Threshold Effect Level (TEL) and Probable Effect Level (PEL) (CCME 2001).

BACs were developed to assess the status of metal concentrations in sediment within the OSPAR framework with metal concentrations significantly below the BAC considered to be near background levels. ERLs were developed by the USA EPA for assessing the ecological significance of sediment concentrations. Concentrations below the ERL rarely cause adverse effects in marine organisms. As (98 stations) and Ni (5 stations) exceeded both BACs and ERLs while Cd (2 stations) and Cu (2 stations) concentrations exceeded BAC levels but did not exceeded ERLs (Table 7).

Cefas ALs are used as part of a 'weight of evidence' approach to assessing dredged material and its suitability for disposal to sea (Cefas 2003). Contaminant levels in dredged material which fall below AL1 are of no concern and are unlikely to influence decision-making, while contaminant levels above AL2 are generally considered unsuitable for sea disposal. Contaminant levels between AL1 and AL2 require further assessment (MMO 2015, Mason et al. 2020). As (18 stations), Cd (1 station), Cr (4 stations) and Ni (6 stations) were the metals to have been recorded in concentrations that exceeded Cefas (2003) AL 1 with no metals recorded in excess of Cefas (2003) AL2 (Table 7).

CSQG are based on field research programmes that have demonstrated associations between chemicals and biological effects by establishing cause and effect relationships in particular organisms (CCME 2001). At levels above the TEL, adverse effects may occasionally occur, whilst at levels above the PEL, adverse effects may occur frequently. The TEL has been adopted as the International Sediment Quality Guideline (ISQG) (CCME 2001). As was recorded above TEL at 102 out of 107 sampling stations while Cr, Cu and Pb were recorded above the TELs at one and two stations, but all metal concentrations including As fell below the PELs (Table 7).

Table 7 Heavy and trace metals (mg kg^{-1}) in sediments. Shading indicates values above AL1.

Analyte	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
Min	*5.6*	*0.3*	*5.7*	*2.2*	*7.2*	*0*	*3.7*	*12.7*
Max	*32.8*	*0.5*	*74*	*32.8*	*34.2*	*0*	*38.4*	*72.4*
Mean	***15.5***	**0.4**	***21.4***	***4.7***	**14.6**	***0.0***	**8.6**	**26.2**
St. Dev	*6*	*0*	*12*	*5*	*5*	*0*	*6*	*11*
OSPAR BAC	**25**	**0.31**	**81**	**27**	**38**	**0.07**	**36**	**122**
ERL	**8.2***	**1.2**	**81**	**34**	**47**	**0.15**	**21***	**150**
Cefas AL1	**20**	**0.4**	**40**	**40**	**50**	**0.3**	**20**	**130**
Cefas AL2	**100**	**5**	**400**	**400**	**500**	**3**	**200**	**800**
TEL	**7.24**	**0.7**	**52.3**	**18.7**	**30.2**	**0.1**	**-**	**124.0**
PEL	**41.6**	**4.2**	**160.0**	**108.0**	**112.0**	**0.7**	**-**	**271.0**
ROVERE0320 - ST01	5.6	<0.2	37.7	7.2	18.9	<0.08	14.7	41.9
ROVERE0320 - ST02	5.7	<0.2	32.8	6.5	15.3	<0.08	10.5	34.8
ROVERE0320 - ST03	6.8	0.4	33.5	7.6	29.1	<0.08	12.2	59.5
ROVERE0320 - ST04	10.9	<0.2	35.2	8.1	25.6	<0.08	13.2	44.7
ROVERE0320 - ST05	6.8	<0.2	37.2	7.0	20.2	<0.08	12.3	40.1
ROVERE0320 - ST06	12.1	<0.2	37.1	7.2	13.0	<0.08	14.1	38.2
ROVERE0320 - ST08	17	<0.2	34.6	7.3	21.9	<0.08	22.8	38.8
ROVERE0320 - ST10	7.2	<0.2	66.1	4.2	13.2	<0.08	10.2	25.9
ROVERE0320 - ST11	24.5	<0.2	37.3	6.8	26.7	<0.08	14.6	33.9
ROVERE0320 - ST13	16.4	<0.2	74.0	9.1	14.7	<0.08	38.4	47.9
ROVERE0420 - ST014	13.3	0.5	17	32.8	30.2	<0.08	8.4	52.6
ROVERE0420 - ST015	15.8	<0.2	5.7	2.2	19.3	<0.08	3.7	20.5
ROVERE0420 - ST018	10.3	<0.2	11.5	3	9.7	<0.08	4.9	17
ROVERE0420 - ST019	10.9	<0.2	7.6	3	8.4	<0.08	4.4	13.5
ROVERE0420 - ST020	13.4	<0.2	8.1	2.7	10	<0.08	5.4	14.5
ROVERE0420 - ST021	15.7	<0.2	10.7	2.9	10.8	<0.08	5.9	14.4
ROVERE0420 - ST022	14	<0.2	7	7.6	11.7	<0.08	22.7	15.5
ROVERE0420 - ST023	13	<0.2	7.5	2.8	11.3	<0.08	3.8	14.8
ROVERE0420 - ST024	19.6	<0.2	7.9	2.3	11.4	<0.08	4.2	14.4
ROVERE0420 - ST025	19.7	<0.2	9.8	2.5	10.2	<0.08	4.5	15.2
ROVERE0420 - ST026	32.8	<0.2	8.3	2.8	13.1	<0.08	5.9	18.3
ROVERE0420 - ST028	12.3	<0.2	8.2	2.5	7.2	<0.08	4.1	12.7
ROVERE0420 - ST029	22.8	<0.2	8.7	2.3	10.4	<0.08	5.1	15.8
ROVERE0420 - ST030	14.8	<0.2	10.3	2.4	11.2	<0.08	4.7	18.1
ROVERE0420 - ST031	12.2	<0.2	21.9	3.6	14.9	<0.08	6.7	22
ROVERE0420 - ST032	19.5	<0.2	10.9	2.2	12.3	<0.08	5.3	18.2
ROVERE0420 - ST033	14.7	<0.2	21.3	6.3	11.2	<0.08	11	24.6
ROVERE0420 - ST034	10.9	<0.2	13.7	3	13.7	<0.08	5.4	20.7
ROVERE0420 - ST035	10.9	<0.2	19.1	3.1	14.6	<0.08	6.1	22.6
ROVERE0420 - ST036	12.1	<0.2	14.6	2.7	13.7	<0.08	5.1	21.9
ROVERE0420 - ST037	13.2	<0.2	13.1	3.8	15.1	<0.08	6.8	22.1
ROVERE0420 - ST038	8	<0.2	30	6.9	22.2	<0.08	11.9	37.8

Analyte	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
ROVERE0420 - ST039	12.3	<0.2	14	3.7	13.9	<0.08	7.5	22.3
ROVERE0420 - ST040	7.9	<0.2	13.3	3.9	12	<0.08	6.3	23
ROVERE0420 - ST041	11.4	<0.2	25.8	5.3	18.5	<0.08	8.7	34.3
ROVERE0420 - ST042	19	<0.2	12.1	4.3	8.6	<0.08	6.4	17.5
ROVERE0420 - ST043	11.8	<0.2	33.1	5.8	19.5	<0.08	12.3	40.1
ROVERE0420 - ST044	11.7	<0.2	26.2	4.3	12.7	<0.08	9.2	28.9
ROVERE0420 - ST045	12.1	<0.2	22.3	4.3	14.1	<0.08	8.4	29.6
ROVERE0420 - ST046	13.4	<0.2	22.9	5.2	14	<0.08	9	31.8
ROVERE0420 - ST047	12.4	<0.2	18.9	3.1	11.3	<0.08	6	21.5
ROVERE0420 - ST048	13.7	<0.2	14.9	3.7	12.8	<0.08	7.1	25.2
ROVERE0420 - ST049	17.1	<0.2	14	3.1	15.4	<0.08	6.1	23.5
ROVERE0420 - ST050	27.1	<0.2	24.3	4.8	19.2	<0.08	10	33.6
ROVERE0420 - ST051	18.8	<0.2	42.1	6.7	26.1	<0.08	12.3	46.6
ROVERE0420 - ST052	20.7	<0.2	37.1	6.5	23.8	<0.08	10.8	43.6
ROVERE0420 - ST053	26	<0.2	23.5	4.6	20.6	<0.08	8.4	31.5
ROVERE0420 - ST054	20.4	<0.2	28.6	5.8	18.6	<0.08	8.8	33.3
ROVERE0420 - ST055	25.7	<0.2	21.2	3.8	18.6	<0.08	6.6	26.9
ROVERE0420 - ST056	25.9	<0.2	22.5	3.8	20.1	<0.08	7.3	28.1
ROVERE0420 - ST057	9.5	<0.2	20.2	3.6	11	<0.08	6.7	21.5
ROVERE0420 - ST058	29.3	<0.2	18.7	3.1	15.9	<0.08	6.5	23
ROVERE0420 - ST059	12.5	<0.2	18.5	2.8	11.5	<0.08	6.1	22.2
ROVERE0420 - ST060	12.4	<0.2	18	3.4	13.6	<0.08	5.8	23.9
ROVERE0420 - ST061	17.5	<0.2	15.6	2.8	12.3	<0.08	5.6	20.9
ROVERE0420 - ST062	14.1	<0.2	21.4	3.1	12.4	<0.08	6.6	22
ROVERE0420 - ST063	18.1	<0.2	33.9	6.2	20.8	<0.08	10.9	41.1
ROVERE0420 - ST064	32	<0.2	23.3	4.1	20.5	<0.08	8.9	26.1
ROVERE0420 - ST065	7.8	<0.2	24.2	3.8	12.1	<0.08	6.4	23.1
ROVERE0420 - ST066	12	<0.2	19.7	3.2	11.6	<0.08	7.2	24.8
ROVERE0420 - ST067	14.1	<0.2	15.1	2.6	10.7	<0.08	6.1	21.4
ROVERE0420 - ST068	12.8	<0.2	21.9	3.6	13.4	<0.08	6.9	24.8
ROVERE0420 - ST069	18.8	<0.2	12.7	3.4	17.2	<0.08	5.4	29.5
ROVERE0420 - ST070	16.8	<0.2	23.9	3.8	14.3	<0.08	8	25.3
ROVERE0420 - ST071	19.8	<0.2	18.4	3.6	14.9	<0.08	6.4	24.7
ROVERE0420 - ST072	17.5	<0.2	21.6	3.3	13.3	<0.08	6.3	23.4
ROVERE0420 - ST073	10.3	<0.2	20.9	3	11.8	<0.08	6	23.6
ROVERE0420 - ST074	17.3	<0.2	36.7	7.1	21.8	<0.08	11.5	45.1
ROVERE0420 - ST075	10.6	<0.2	18.5	3.4	12.1	<0.08	7.1	23.9
ROVERE0420 - ST077	18.4	<0.2	18.3	3	12.3	<0.08	5.4	21.2
ROVERE0420 - ST078	23.6	<0.2	29.6	3.7	15.6	<0.08	8.5	26
ROVERE0420 - ST079	23.3	<0.2	16.8	2.9	14.4	<0.08	23.2	21.7
ROVERE0420 - ST080	31.3	<0.2	17.8	3	16.3	<0.08	5.8	23.1
ROVERE0420 - ST081	10.6	<0.2	14.3	2.7	10.3	<0.08	5.7	20.9
ROVERE0420 - ST082	11	<0.2	16	3.3	12.3	<0.08	5.8	22.8

Analyte	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
ROVERE0420 - ST083	13.6	<0.2	20.1	5.2	15.6	<0.08	9.4	27.6
ROVERE0420 - ST085	10.5	<0.2	18.5	3.1	11.4	<0.08	6	21.9
ROVERE0420 - ST086	17.7	<0.2	12.5	2.6	10.1	<0.08	4.9	17.2
ROVERE0420 - ST087	16.3	<0.2	18.6	3	13.1	<0.08	7.2	22.9
ROVERE0420 - ST088	10.9	<0.2	14.4	3.3	9.3	<0.08	9.1	17.7
ROVERE0420 - ST089	10.6	<0.2	22	3.2	11.7	<0.08	6.4	24
ROVERE0420 - ST090	11.7	<0.2	21	3.5	12.5	<0.08	7.4	25.6
ROVERE0420 - ST091	12.5	<0.2	22.6	3.8	12.9	<0.08	25.6	23
ROVERE0420 - ST092	10.3	<0.2	23.6	3.6	12	<0.08	6.6	23.4
ROVERE0420 - ST093	10	<0.2	20.9	4.2	11.2	<0.08	7.3	22.8
ROVERE0420 - ST094	23	<0.2	23.8	3.7	15.2	<0.08	7	26.4
ROVERE0420 - ST095	11.4	<0.2	33.5	4.4	13.9	<0.08	7.9	28.9
ROVERE0420 - ST096	13.4	<0.2	9.8	3.1	10.7	<0.08	9.6	17.1
ROVERE0420 - ST097	12.7	<0.2	29.9	5.3	17.7	<0.08	9.1	36.3
ROVERE0420 - ST098	12.4	<0.2	20.7	3.5	13.1	<0.08	6.9	23.4
ROVERE0420 - ST099	20.1	<0.2	19.6	2.6	11.4	<0.08	6	19.1
ROVERE0420 - ST100	7.4	<0.2	25	5	11.9	<0.08	9.5	25.5
ROVERE0420 - ST101	21.2	<0.2	17.6	3	11.1	<0.08	6.1	19.5
ROVERE0420 - ST102	18.2	<0.2	23.2	3.9	13.7	<0.08	6.9	23
ROVERE0420 - ST104	11.5	<0.2	15.4	2.9	9.9	<0.08	6	18.1
ROVERE0420 - ST106	15.8	<0.2	14.5	2.7	12	<0.08	5.3	19.4
ROVERE0420 - ST107	19.2	<0.2	15.8	2.9	13.6	<0.08	6.2	22
ROVERE0420 - ST108	11.5	<0.2	15	3.7	12	<0.08	7.2	21.9
ROVERE0420 - ST109	11.2	<0.2	21	3.1	11.5	<0.08	6.2	22.6
ROVERE0420 - ST110	14.5	<0.2	18	2.8	11.4	<0.08	5.8	19.7
ROVERE0420 - ST111	12.2	<0.2	22.6	3.7	13.7	<0.08	6.4	26
ROVERE0420 - ST112	17.4	<0.2	21.1	4	9.2	<0.08	7.3	18.5
ROVERE0420 - ST113	13.4	<0.2	18	3.3	11.9	<0.08	7.1	22.1
ROVERE0420 - ST114	12.8	0.3	42.9	32.6	34.2	<0.08	20.9	72.4
ROVERE0420 - ST115	18.9	<0.2	15.7	2.7	14	<0.08	5.5	22.3
ROVERE0420 - ST116	12	<0.2	13.9	3.4	11.4	<0.08	7	20.1
ROVERE0420 - ST119	26.3	<0.2	13.2	2.6	12.5	<0.08	5.9	19.3

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

The most abundant metal was Cr which ranged from 5.7 at ST015 to 74 mg kg^{-1} at ST013 but was generally recorded in low concentrations with only 4 stations showing elevated levels compared to Cefas AL1 (Table 8). Zn was also recorded in high concentration, ranging between 12.7 at ST028 and 72.4 mg kg^{-1} at ST114 however it never exceeded any of the reference guideline levels (Table 8). The metal generally recorded in elevated concentrations across most stations was As, which ranged from 5.6 at ST01 to 32.8 mg kg^{-1} at ST026. Depending on the reference level chosen as guideline, between 9 and 102 stations exhibited elevated As concentrations. To a lesser extent, elevated Cu and Ni content were observed at a number of stations in relation to guidance levels

(Table 8). Cd concentrations were below detection limits at all stations except for ST03, ST014 and ST114, with stations ST03 and ST114 having a Cd concentration above OSPAR BAC. Pb concentration was bellow reference levels at all stations but ST114 where Pb exceeded the TEL. Concentrations of Hg and Zn were always below reference levels for all guidelines across the entirety of the survey area. Figure 12 illustrates the spatial distribution of the main heavy and trace metal concentrations across the survey area. Typically, all metals had higher concentrations at nearshore than offshore stations with the exception of As which had a higher average (±SD) value at offshore stations (15.66 ± 5.61 mg kg^{-1}) than at nearshore stations (11.3 ± 6.28 mg kg^{-1}).

Table 8 Number of stations along the nearshore and offshore sections of Project Erebus exhibiting elevated heavy and trace metals levels in comparison with OSPAR, CEFAS and Canadian/International Sediment Quality Guidelines.

Analyte	OSPAR		Cefas		CSQG	
	BAC	ERL	AL1	AL2	TEL	PEL
Arsenic	9	98*	18	0	102	0
Cadmium	2	0	1	0	0	0
Chromium	0	0	4	0	2	0
Copper	2	0	0	0	2	0
Lead	0	0	0	0	1	0
Mercury	0	0	0	0	0	0
Nickel	1	5*	6	0	-	-
Zinc	0	0	0	0	0	0

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

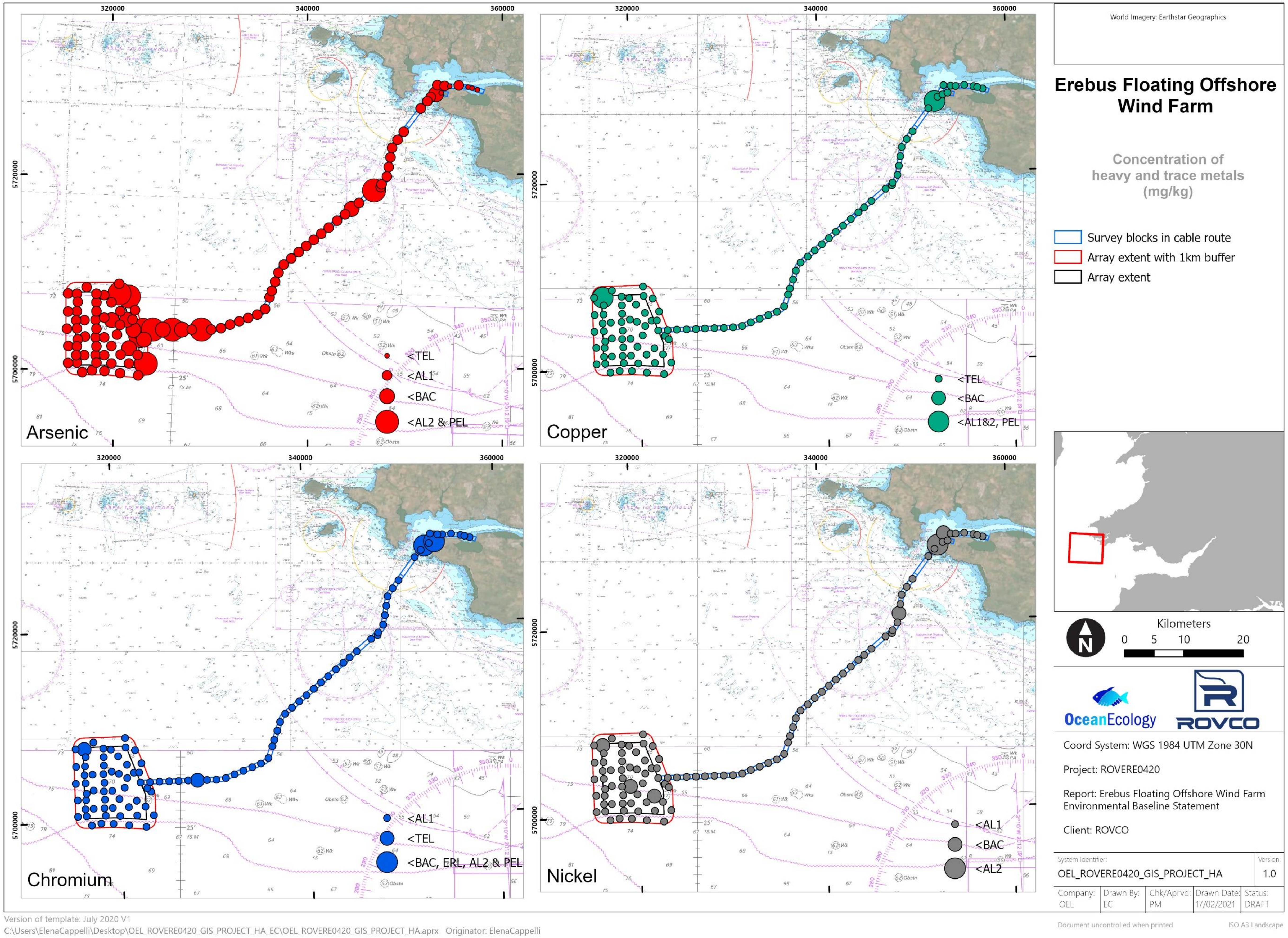


Figure 12 Concentration of the main heavy and trace metals sampled at each station across the Project Erebus survey area. Note different scales.

8.2.3. Polycyclic Aromatic Hydrocarbons (PAH)

The full range of PAHs as specified in the Department of Trade and Industry (DTI) regulations (DTI 1993) as well as by the EPA was tested for all 107 samples collected.

The results of the PAH analyses undertaken are summarised in Table 9, with full results reported in Appendix VII. Mean PAH concentrations were compared to OSPAR BAC levels and ERLs, and ISQG TEL and PEL . There are no Cefas Action Levels for PAHs, however there is a proposed revised AL1 for PAHs following the DEFRA (2003) review, so for the purpose of this work this AL1 was reported for reference. Only the concentration of Naphthalene averaged across the survey area as a whole was above the BAC, whereas all other PAHs had average concentrations for the survey area below guideline references.

The most abundant PAH was Fluoranthene with a maximum concentration of 182 $\mu g\ kg^{-1}$ at ST05; in general, it was recorded in relatively low concentrations with only 13 out of 107 stations exceeding the BAC and only 3 stations exceeding the TEL (Table 10). Phenanthrene and Pyrene were also recorded in high concentrations with maximum values of 142 $\mu g\ kg^{-1}$ at ST02 for Phenanthrene and of 137 $\mu g\ kg^{-1}$ at ST05 for Pyrene (Table 9). Phenanthrene exceeded the BAC at 13 stations and Pyrene at 18 stations; however, only Phenanthrene exceeded the TEL in 2 stations (Table 10).

The PAH generally recorded in elevated concentrations across most stations was Naphthalene (Table 10), which ranged from below 1 to a maximum of 83.5 $\mu g\ kg^{-1}$ at ST02 (Table 9 and Figure 13). Depending on the reference level chosen as guideline, between 3 (TEL) and 21 (BAC) stations exhibited elevated Naphthalene concentrations (Table 10). In general, all PAHs concentrations exceeded the OSPAR BACs in at least one station but never exceeded the ERLs. There was also no exceedance of the Canadian PELs however the concentrations of Naphthalene, Acenaphthene, Phenanthrene, Fluoranthene, Benzo[a]anthracene, Chrysene, Benzo[a]pyrene and Dibenzo[a,h]anthracene exceeded the TELs at a few stations (Table 10). In general PAHs showed higher concentrations at the nearshore stations compared to the offshore stations, similar to what observed for trace metals. Again, the proximity to urban settings can result in additional sources of PAHs that can potentially become stored in coastal sediments.

To determine the origin source of PAH compounds in sediments, the ratio between LMW and HMW PAHs was calculated. Based on this ratio, most stations (n=78) had PAHs of pyrogenic origin, while 13 stations were characterised by PAHs of petrogenic origin; in 16 stations it was not possible to calculate this ratio as some of the PAHs concentrations were below detection limits (Figure 13). Similarly, the ratios of Phenanthrene / Anthracene (Ph/Ant) and of Fluoranthene / Pyrene (Fl/Py) were also used to infer the origin source of PAH compounds. Fl/Py ratios were higher than 1 in 80 out of 107 stations indicating a pyrogenic origin source of PAHs, the remining 27 stations had undetectable concentration of Fluoranthene and/or Pyrene and therefore it was not possible to calculate the ratio. To note the similar results obtained based on LMW/HMW PAHs and on Fl/Py ratios except for stations ST018, ST030 and ST059 showing a pyrogenic source origin based on Fl/Py and petrogenic based on LMW/HMW PAHs. Ph/Ant ratios were not very reliable in assessing the source origin of PAH compounds as most stations had concentrations of Phenanthrene and/or Anthracene below detection limits. For this reason, an average ratio (±SD) was calculated for the whole survey area 23.8 ±32.79, the associated SD, higher than the average value for the survey area, confirms the unreliability of this ratio as an effective proxy for PAHs source origin in this context.

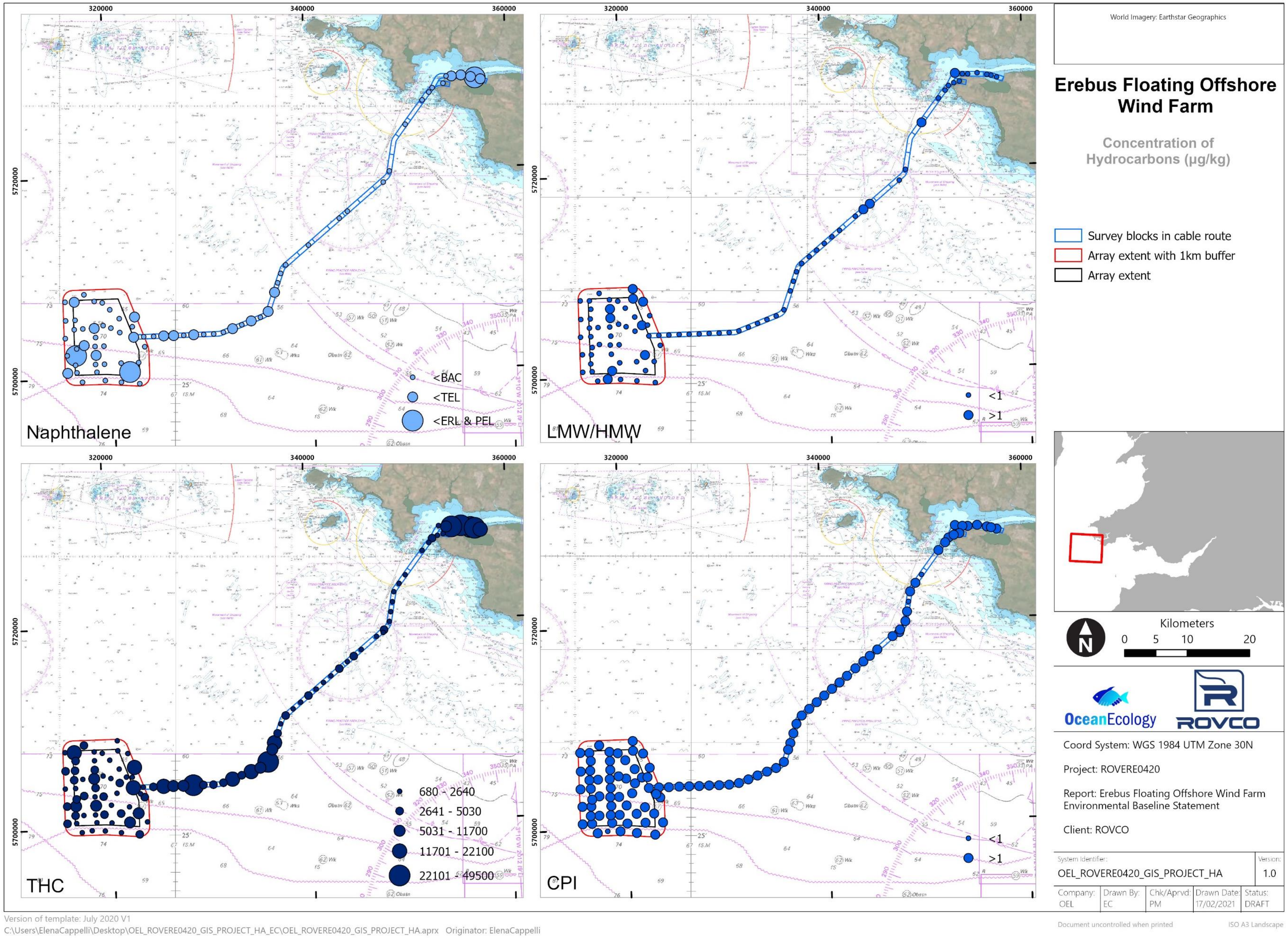


Figure 13 Concentration (µg kg^{-1}) of key hydrocarbons and relative indices and ratios (PAHs top; total hydrocarbons bottom) at each sampling station across the Project Erebus survey area. Note different scales.

Table 9 Summary of average PAH concentration (µg kg^{-1}) against OSPAR and CSQG. Shading indicates values above reference levels.

Analyte	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Dibenzothiophene	Anthracene	Fluoranthene
Min	1.00	1.20	1.37	1.05	1.02	1.02	1.01	1.00
Max	83.50	6.05	9.69	27.90	142.00	21.00	31.60	182.00
Mean	***8.09***	***3.11***	***3.99***	***5.73***	***14.66***	***4.64***	***7.24***	***18.73***
St. Dev	13.13	1.53	2.41	5.92	24.61	4.10	7.00	31.93
AL1	**100**	**100**	**100**	**100**	**100**	**100**	**-**	**100**
BAC	**8**	**-**	**-**	**-**	**32**	**-**	**-**	**39**
ERL	**160**	**-**	**-**	**-**	**240**	**190**	**-**	**600**
TEL	**34.60**	**5.87**	**6.71**	**21.20**	**86.70**	**-**	**46.9**	**113.00**
PEL	**391**	**128**	**88.9**	**144**	**544**	**-**	**245**	**1494.00**

Analyte	Pyrene	Benzo[a]anthracene	Chrysene	Benzo[a]pyrene	Indeno[123,cd]pyrene	Dibenzo[a,h]anthracene	Benzo[ghi]perylene
Min	1.03	1.01	1.02	1.05	1.01	1.08	1.01
Max	137.00	91.00	121.00	116.00	110.00	25.30	101.00
Mean	***15.64***	***14.21***	***14.52***	***13.97***	***10.92***	***5.63***	***9.76***
St. Dev	25.15	20.06	23.34	20.97	17.68	5.40	15.87
AL1	**100**	**100**	**100**	**100**	**100**	**100**	**100**
BAC	**24**	**16**	**20**	**30**	**103**	**-**	**80**
ERL	**665**	**261**	**384**	**430**	**-**	**-**	**-**
TEL	**153**	**74.80**	**108**	**88.80**	**-**	**6.22**	**-**
PEL	**1398**	**693**	**846**	**763**	**-**	**135**	**-**

Table 10 Number of stations along the nearshore and offshore sections of the survey area exhibiting elevated PAHs levels in comparison with OSPAR and Canadian Sediment Quality Guidelines.

Analyte	OSPAR		CSQG		DEFRA
	BAC	ERL	TEL	PEL	Proposed AL1
Naphthalene	21	0	3	0	0
Acenaphthylene	-	-	0	0	0
Acenaphthene	-	-	3	0	0
Anthracene			0	0	0
Fluorene	-	-	0	0	0
Phenanthrene	13	0	2	0	0
Dibenzothiophene	-	0	-	-	0
Fluoranthene	13	0	3	0	0
Pyrene	18	0	0	0	0
Benzo[a]anthracene	17	0	3	0	0
Chrysene	18	0	1	0	0
Benzo[a]pyrene	9	0	1	0	0
Indeno[123,cd]pyrene	1	-	-	-	0
Dibenzo[a,h]anthracene	-	-	11	0	0
Benzo[ghi]perylene	1	-	-	-	0

8.2.4. Total Hydrocarbons Content (THC) and Saturates

The THC in sediment samples ranged from 680 µg kg^{-1} at ST086 to 49,500 µg kg^{-1} at ST03, with an average value (± SD) for the whole of the survey area of 5,722 ± 7863 µg kg^{-1} (Figure 13). As seen for trace metals and PAHs, also THC was on average higher at nearshore stations (17,232 ± 16169.6 µg kg^{-1}) compared to the offshore ones (4,535.2 ± 5,342.16 µg kg^{-1}).

N-alkanes (saturates) in sediments had carbon chains length ranging between C11 and C37, with the dominant chains being C31 for the odd numbered chains and C16 for the even numbered chains. The highest concentration of total n-alkanes was recorded at ST03 being 2140 µg kg^{-1}, while the lowest concentration of 28.1 µg kg^{-1} was found at ST113. Average concentration of n-alkanes (± SD) for the survey area as a whole was 208 ± 321 µg kg-1. Pristane was the highest at ST03 being 352 µg kg^{-1}, while it reached a minimum of 1.01 µg kg^{-1} at ST067. The highest concentration of Phytane was measured at ST03 being 70.9 µg kg^{-1}, while the lowest was recorded at ST087 being 1.22 µg kg^{-1}.

The Carbon Preference Index (CPI) and the ratio Pristane/Phytane can be used to assess the origin source of n-alkanes in sediments. To note that in most stations the Pristane/Phytane ratio could not be calculated as samples had undetectable Pristane and/or Phytane concentrations. For this reason, only an average value of the Pristane/Phytane ratio (± SD) was calculated across the survey area being 2.6 ± 2.4. This is more than 1 thus indicating biogenic source of n-alkanes, however, to note that SD is of the same magnitude as the average value meaning that caution is needed when assessing n-alkanes origin source based on this ratio. When using the CPI to assess n-alkanes origin sources, it was found that in most stations (n=103) their origin was biogenic (CPI >1), while at stations ST018 and ST067 it was pyrogenic (CPI < 1) and at stations ST021 and ST039 was petrogenic (CPI ~ 1) (Figure 13).

8.3. Water Chemistry

Water samples for chemical analysis were collected from 26 stations () from sections of the Project Erebus FLOW which pass through the two WFD waterbodies in the nearshore area; Pembrokeshire South and Milford Haven Outer. Raw water chemistry data are provided in Appendix VIII.

8.3.1. Chlorophyll

Chlorophyll – a concentrations in the water samples were below the detection limit of <7.00 µg l^{-1} across all stations sampled except for the sample taken from the top of the water column at ST22 which recorded levels of 7.82 µg l^{-1}.

8.3.2. Suspended Solids

Suspended solid concentrations in the water samples ranged between <5 mg l^{-1} and 23 mg l^{-1} with the latter recorded in the sample taken from the bottom of the water column at ST11. The WFD Directions (Environment Agency 2015) reported that clear seawater has an annual mean concentration of suspended particle matter < 10 mg l^{-1}, while seawater of intermediate turbidity has a suspended particle matter annual mean concentration between 10 and 100 mg l^{-1}. Based on these reference levels 9 samples had suspended solid concentrations typical of seawater of intermediate turbidity, these corresponded to stations ST01 (middle and bottom samples), ST02, ST11, ST16 (bottom samples), ST15 and ST22 (middle samples), ST18 and ST23 (top samples). All other samples and stations had suspended solid concentrations < 10 mg l^{-1} indicating clear seawater.

8.3.3. Nitrogen, Nitrates and Nitrites

Ammoniacal nitrogen concentrations in the water samples ranged between 0.20 mg l^{-1} and 0.55 mg l^{-1} with an average (±SD) of 0.38 ± 0.09 mg l^{-1}. Nitrate concentrations in the water samples ranged between <0.2 mg l^{-1} and 0.4 mg l^{-1} with the latter recorded in the middle of the water column at ST17. Nitrite concentrations in the water samples were <0.01 mg l^{-1} across all samples at all stations. The WFD Directions (Environment Agency 2015) reported 4 quality standards for dissolved inorganic nitrogen concentration depending on the level of turbidity of seawater (salinity 32). Based on these quality standards, the range of ammoniacal nitrogen concentration for the survey area would correspond to a high quality standard (< 1.4 mg l^{-1}) for both clear and intermediate turbidity seawater.

8.3.4. Phosphate

Phosphate concentrations in the water samples were <0.01 mg l^{-1} at all stations except for the sample collected at the top of the water column at ST03 which presented a concentration of 0.13 mg l^{-1}.

8.3.5. Total Petroleum Hydrocarbon (TPH) (Gas Chromatography)

TPH concentrations in the water samples ranged between <0.010 mg l^{-1} and 0.25 mg l^{-1} with the latter recorded in the sample taken from the bottom of the water column at ST23.

8.3.6. Heavy and Trace Metals

A total of eight heavy and trace metals were analysed from water samples taken at each of the 26 stations. These were Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn). The raw data (presented as mg l^{-1}) are shown in Table 11.

The most abundant metals in the water samples were Arsenic and Zinc. Arsenic ranged between 0.0013 mg l^{-1} and 0.0032 mg l^{-1} across the 26 stations, whilst Zinc was consistent at <0.02 mg l^{-1} except for the middle (0.03 mg l^{-1}) and bottom (0.02 mg l^{-1}) samples taken from ST01 and ST02 respectively. These metal concentrations have been compared against Environmental Quality Standards (EQS) based on Cole et al. (1999) and UKTAG (2013) reports and are presented in Table 11.

Table 11 Heavy and trace metals (mg l^{1}) in water. Shading indicates values above reference levels.

Analyte	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
01_Surface	0.0019	<0.00004	<0.0009	0.0008	<0.0006	<0.0008	<0.0007	<0.02
01_Mid	0.0020	0.00004	<0.0009	0.0009	<0.0006	<0.0008	<0.0007	0.03
01_Bottom	0.0016	<0.00004	<0.0009	0.0008	<0.0006	<0.0008	<0.0007	<0.02
02_Surface	0.0018	<0.00004	<0.0009	0.0007	<0.0006	<0.0008	<0.0007	<0.02
02_Mid	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
02_Bottom	0.0019	0.00005	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	0.02
03_Surface	0.0019	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
03_Mid	0.0014	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
03_Bottom	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
04_Surface	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
04_Mid	0.0021	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
04_Bottom	0.0018	<0.00004	<0.0009	0.0009	<0.0006	<0.0008	<0.0007	<0.02
05_Surface	0.0020	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
05_Mid	0.0021	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
05_Bottom	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
06_Surface	0.0016	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
06_Mid	0.0016	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
06_Bottom	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02

Analyte	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
07_Surface	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
07_Mid	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
07_Bottom	0.0013	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
08_Surface	0.0014	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
08_Mid	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
08_Bottom	0.0019	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
09_Surface	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
09_Mid	0.0015	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
09_Bottom	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
10_Surface	0.0020	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
10_Mid	0.0014	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
10_Bottom	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
11_Surface	0.0013	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
11_Mid	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
11_Bottom	0.0019	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
12_Surface	0.0016	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
12_Mid	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	0.03
12_Bottom	0.0016	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
13_Surface	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
13_Mid	0.0014	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
13_Bottom	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
14_Surface	0.0017	0.0002	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
14_Mid	0.0019	<0.00004	<0.0009	0.002	<0.0006	<0.0008	<0.0007	<0.02
14_Bottom	0.0017	0.0001	<0.0009	<0.0007	<0.0006	<0.0008	0.005	<0.02
15_Surface	0.0020	0.00008	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
15_Mid	0.0016	0.00007	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
15_Bottom	0.0015	0.00007	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
16_Surface	0.0032	0.0016	0.002	0.002	0.001	<0.0008	<0.0007	<0.02
16_Mid	0.0020	0.0001	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
16_Bottom	0.0018	0.00008	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
17_Surface	0.0017	0.00007	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
17_Mid	0.0018	0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
17_Bottom	0.0021	0.0002	<0.0009	0.0008	<0.0006	<0.0008	<0.0007	<0.02
18_Surface	0.0019	0.00009	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
18_Mid	0.0016	0.0024	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
18_Bottom	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
19_Surface	0.0016	<0.00004	<0.0009	0.0007	<0.0006	<0.0008	0.004	<0.02
19_Mid	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
19_Bottom	0.0016	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
20_Surface	0.0016	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
20_Mid	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
20_Bottom	0.0016	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02

Analyte	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Units	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
21_Surface	0.0017	0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
21_Mid	0.0017	0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
21_Bottom	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
22_Surface	0.0021	0.00008	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
22_Mid	0.0018	0.00006	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
22_Bottom	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
23_Surface	0.0015	0.00005	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
23_Mid	0.0020	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
23_Bottom	0.0018	0.00005	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
24_Surface	0.0019	0.00004	<0.0009	0.001	<0.0006	<0.0008	<0.0007	<0.02
24_Mid	0.0021	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
24_Bottom	0.0019	0.00006	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
25_Surface	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
25_Mid	0.0022	0.00008	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
25_Bottom	0.0017	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
26_Surface	0.0018	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
26_Mid	0.0016	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
26_Bottom	0.002	<0.00004	<0.0009	<0.0007	<0.0006	<0.0008	<0.0007	<0.02
Min	**0.0013**	**<0.00004**	**<0.0009**	**<0.0007**	**<0.0006**	**<0.0008**	**<0.0007**	**<0.02**
Max	**0.0032**	**0.0024**	**0.002**	**0.0020**	**0.001**	**<0.0008**	**0.005**	**0.03**
Mean	**0.0018**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
St. Dev	**0.0003**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
UKTAG (2013)	**-**	**0.0001 D**	**-**	**0.00376 D**	**-**	**-**	**-**	**0.0079 D**
Cole et al (1999)	**0.025 AD**	**0.0025 DAA**	**0.015 AD**	**0.005 AD**	**0.025 AD**	**0.0003 DAA**	**0.03 AD**	**0.04 AD**
OSPAR EQS (2019)		**0.0002 D**			**0.0013 D**		**0.0086 D**	

D - Dissolved

AD- Annual dissolved concentration

DAA – Dissolved concentration as an annual average

Samples taken from the top of the water column at Station 16 and the middle of the water column for ST18 exceeded the EQS value for Cadmium based on the UKTAG values recording 0.0016 mg l^{-1} and 0.0024 mg l^{-1} respectively. Samples taken from the middle of the water column at ST01, bottom of the water column at ST02, and middle of the water column at ST12 exceeded the EQS value for Zinc based on the UKTAG (2013) values recording 0.03 mg l^{-1}, 0.02 mg l^{-1} and 0.03 mg l^{-1} respectively. All remaining samples recorded values within recommended EQS values.

8.3.7. Polycyclic Aromatic Hydrocarbons (PAH)

The full range of PAHs as specified in the Department of Trade and Industry (DTI) regulations (DTI 1993) as well as by the EPA was tested for all water samples collected across the 26 Stations.

The results of the PAH analyses undertaken are summarised in Table 12 with full results reported in Appendix VIII. PAH parent compounds in parts of the Celtic Sea have previously been recorded as 2 ng l^{-1} in 2013 (OSPAR 2019). The EQS for these substances has been identified as 0.7 ng l^{-1}. For all PAHs assessed during this analysis, values were recorded as <1 μg l^{-1}. All PAH concentrations across all stations sampled were below their associated limits of detection (LoD).

Table 12 Summary of average PAH concentration from water samples ($\mu g\ l^{-1}$)

Analyte	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Dibenzothiophene	Fluoranthene
Min	<1	<1	<1	<1	<1	<1	<1
Max	<1	<1	<1	<1	<1	<1	<1
Mean	N/A	N/A	N/A	N/A	N/A	N/A	N/A
St. Dev	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Analyte	Pyrene	Benzo[a]anthracene	Chrysene	Benzo[a]pyrene	Indeno[123,cd]pyrene	Dibenzo[a,h]anthracene	Benzo[ghi]perylene
Min	<1	<1	<1	<1	<1	<1	<1
Max	<1	<1	<1	<1	<1	<1	<1
Mean	N/A	N/A	N/A	N/A	N/A	N/A	N/A
St. Dev	N/A	N/A	N/A	N/A	N/A	N/A	N/A

8.4. Macrobenthos

8.4.1. Macrobenthic Composition

A diverse macrobenthic assemblage was identified across the Project Erebus survey area from the grab samples, with a total of 13,534 individuals and 361 taxa recorded. The mean (± SE) number of taxa was 20.3 ± 1.4 per station. Mean (± SE) abundance per station was 125.1 ± 14.98 with a mean (± SE) biomass per station of 0.4 ± 0.1 gAFDW.

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

As shown in Figure 14, the bivalve *Kuritiella bidentata* (previously called *Mysella bidentata*) was the most abundant species sampled accounting for 26.7 % of all individuals recorded. It also accounted for the maximum abundance in a single sample and greatest average density per sample (Figure 14c and Figure 14d). Another key taxon was the juveniles of the brittle star Amphiuridae *(juvenile)* which was the most frequently occurring taxon recorded in 72.9 % of samples (Figure 14b).

The sampling stations with the highest abundance were nearshore stations ST04, ST05 and offshore stations ST063, ST051 and ST070 (Figure 16), where ST04 was dominated by juveniles of the amphipod *Ampelisca* whereas the other stations were characterised by the presence of *K. bidentata*. Sampling stations with the highest richness (S, number of species/taxa) were nearshore stations ST04, ST06, ST03, ST02 and offshore ST031 with specimens belonging to 122, 67, 66, 50 and 57 different taxa, respectively (Figure 17).

Biomass ranged between 0.00031 and 3.7 gAFDW per sample, with the highest value found at nearshore station ST03 due to high mollusc biomass (Figure 18). Across the entire survey area, most of the biomass was accounted for by the group Mollusca as it was for the nearshore stations alone; in contrast offshore stations alone were dominated by the biomass of the group Echinodermata. Figure 15 illustrates the relative contributions to total abundance, diversity, and biomass of the major taxonomic groups in the macrobenthic community sampled across the survey area (all) and across nearshore (middle panel) and offshore stations (bottom panel).

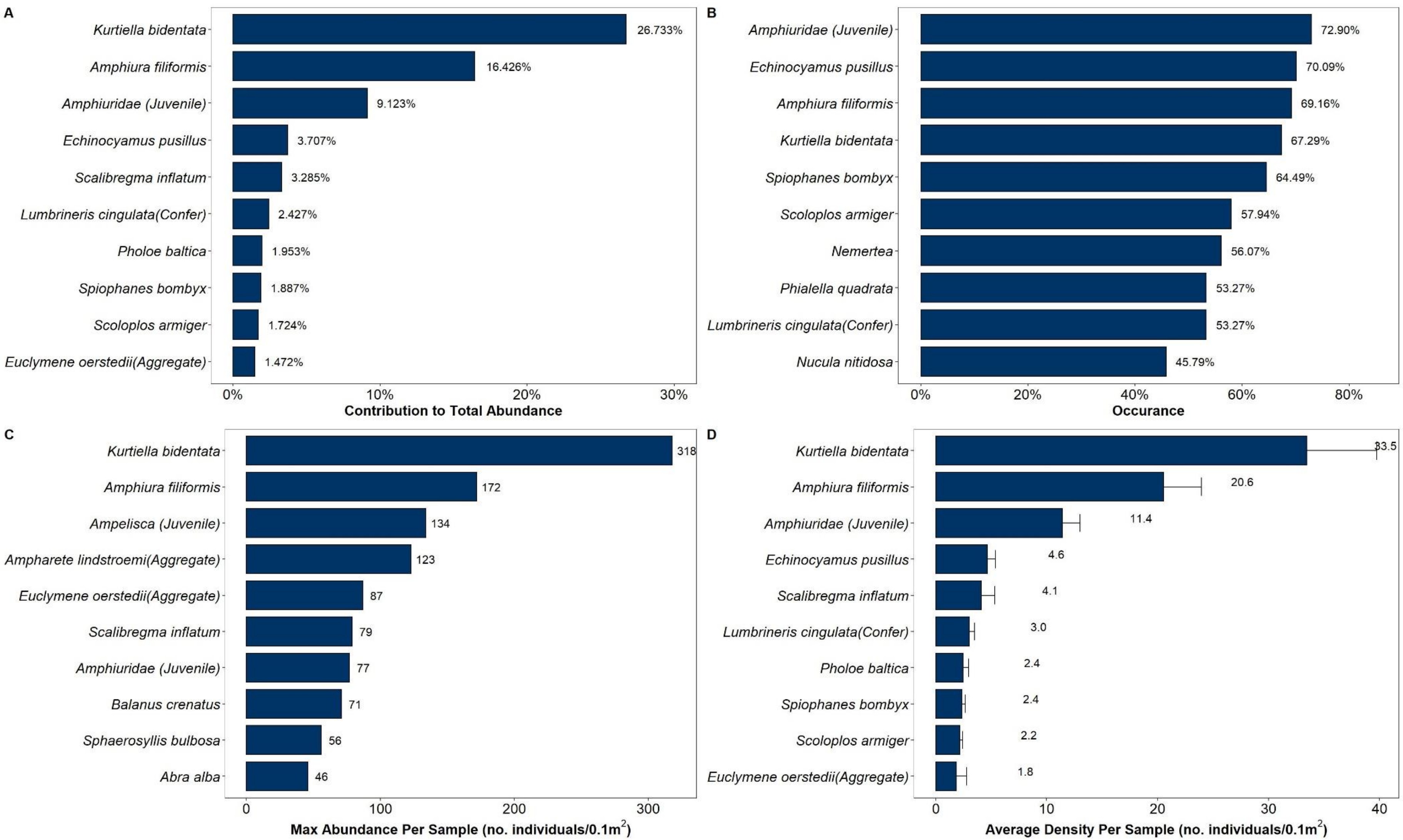


Figure 14 Percentage contributions of the top 10 macrobenthic taxa to total abundance (a) and occurrence (b) from samples collected across the Project Erebus survey area. Also shown are the maximum densities of the top 10 taxa per sample (c) and average densities of the top 10 taxa per sample (d).

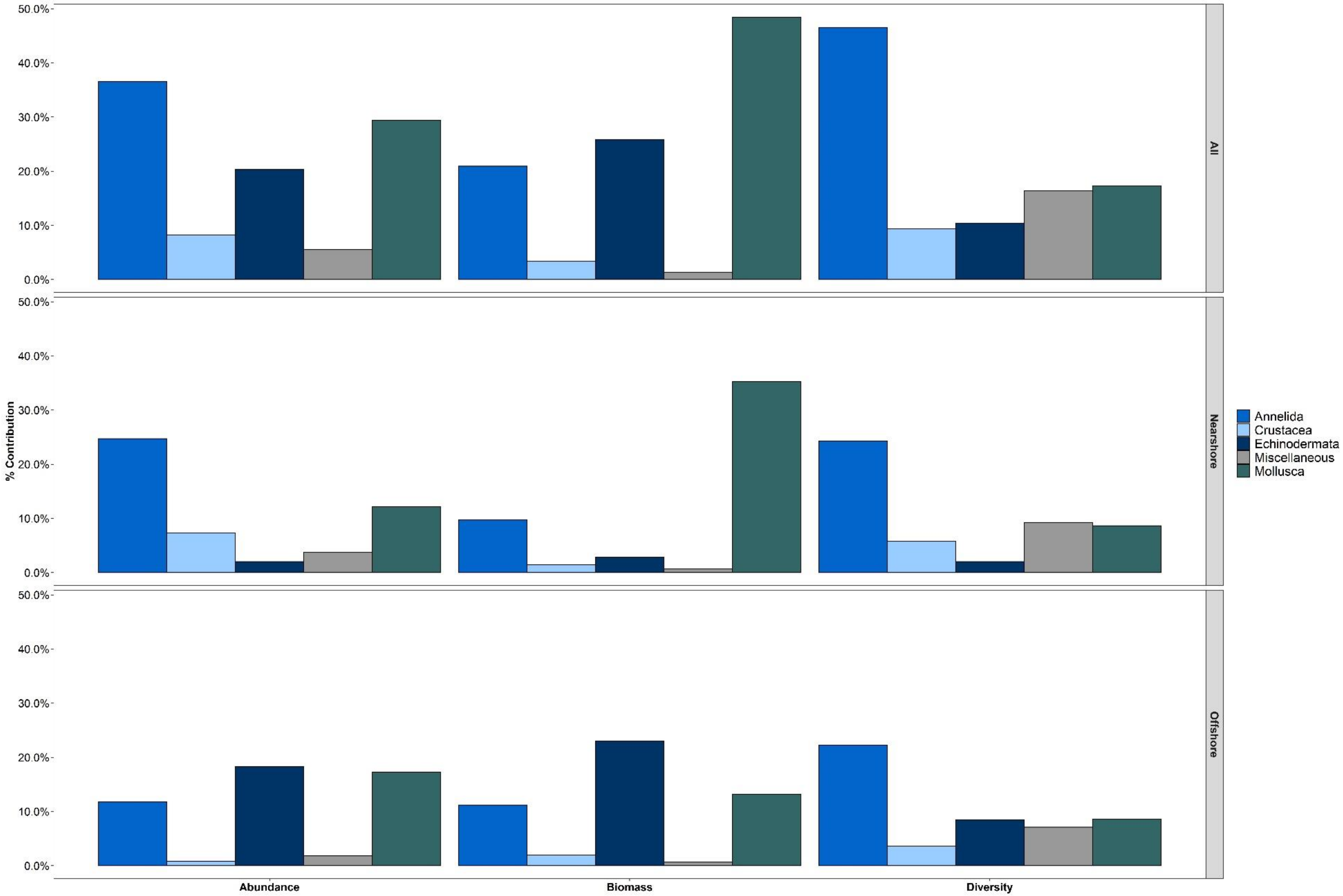


Figure 15 Relative contribution of the major taxonomic groups to the total abundance, diversity and biomass of the macrobenthos sampled across the Project Erebus survey area. Abundance counts exclude colonial taxa.

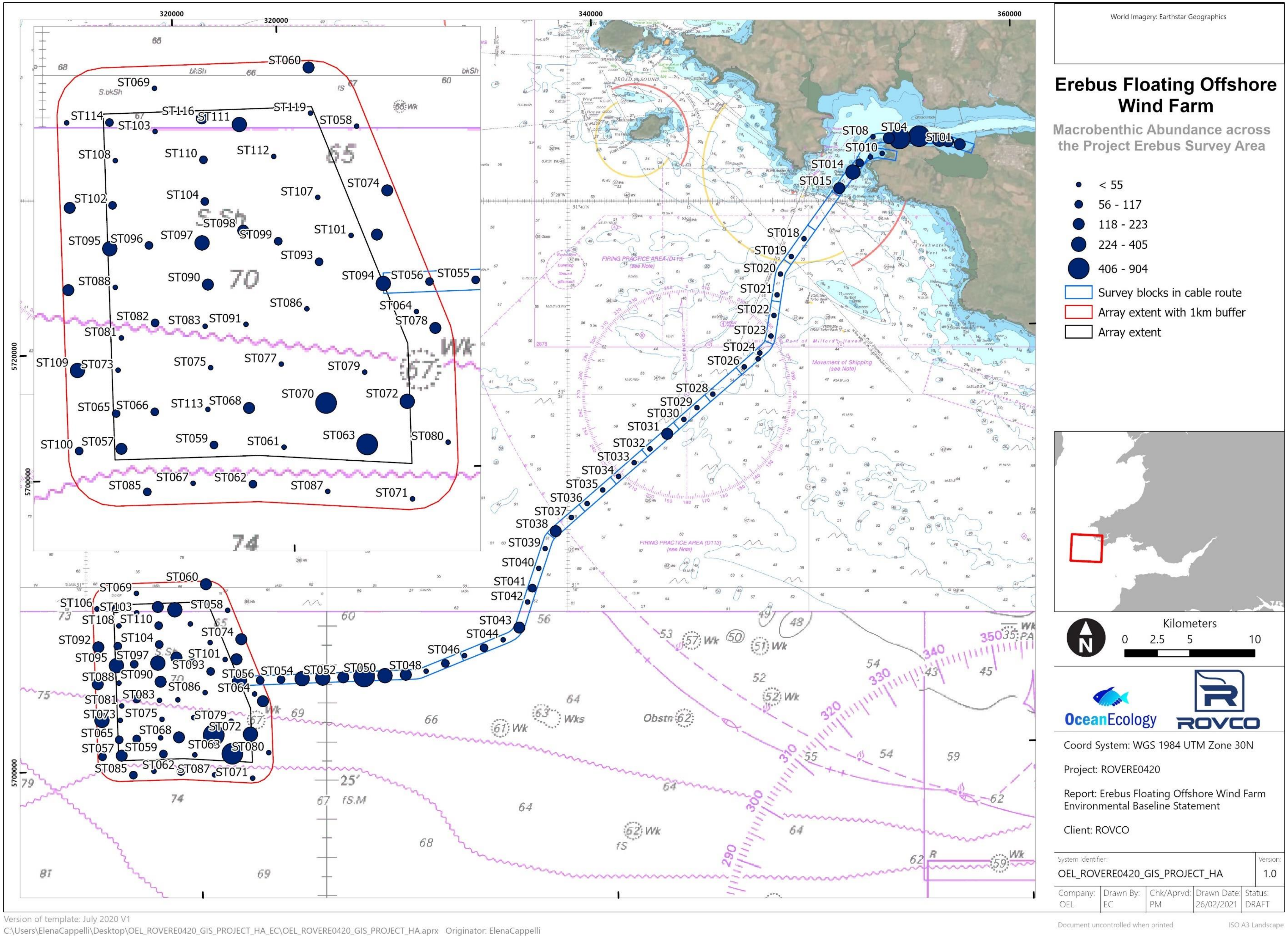


Figure 16 Comparison of macrobenthic abundance per station sampled across the Project Erebus survey area.

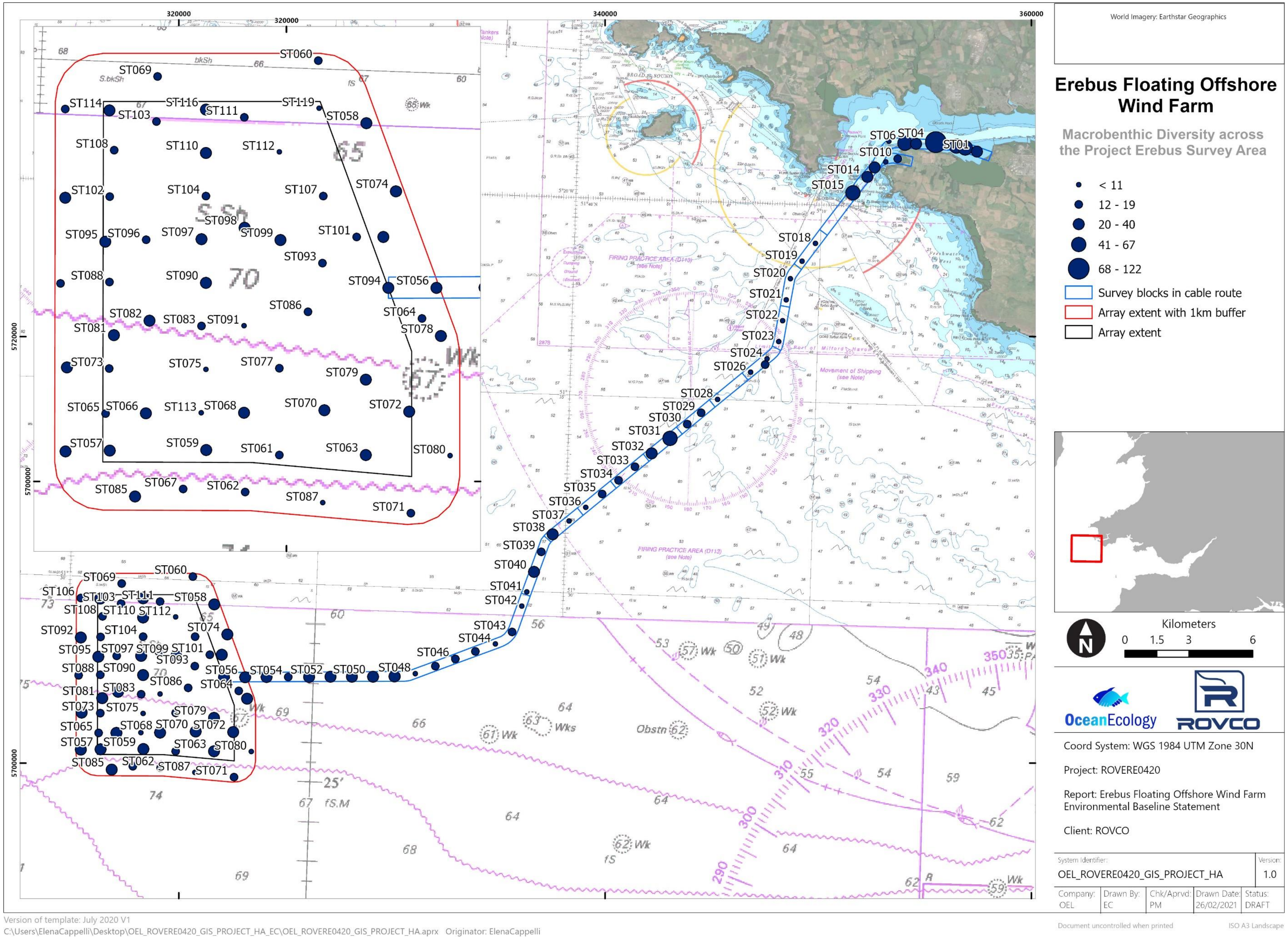
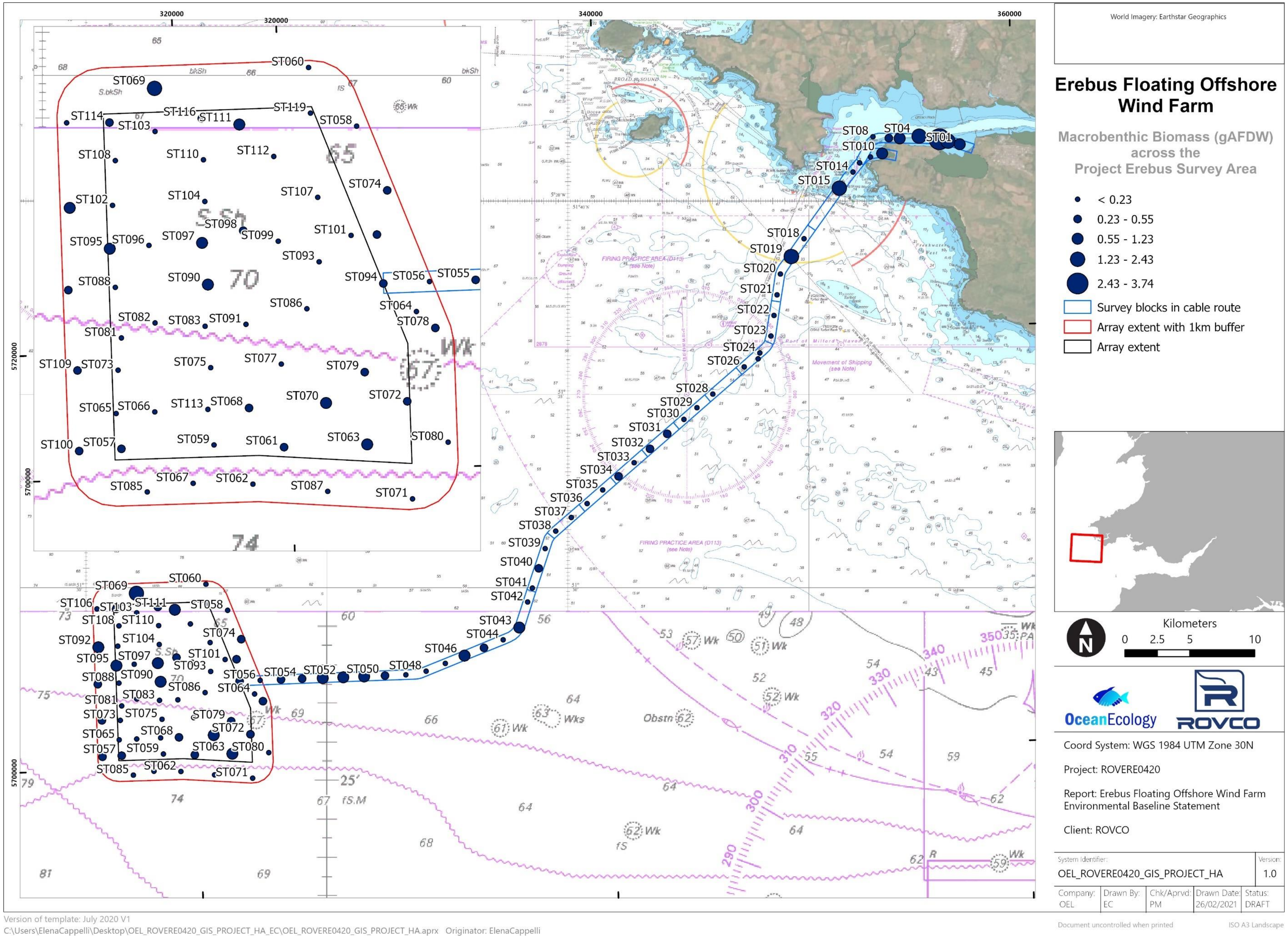


Figure 17 Comparison of macrobenthic diversity per station sampled across the Project Erebus survey area.



Version of template: July 2020 V1
C:\Users\ElenaCappelli\Desktop\OEL_ROVERE0420_GIS_PROJECT_HA_EC\OEL_ROVERE0420_GIS_PROJECT_HA.aprx Originator: ElenaCappelli

Figure 18 Comparison of macrobenthic biomass (gAFDW) per station sampled across the Project survey area.

8.4.2. Notable Taxa

Seven species of interest were identified from the 107 grab samples collected across the survey area (Table 13).

To note that 11 of the 13 individuals of the invasive and non-native species (INNS) *Crepidula fornicata* occurred in one sample collected at nearshore station ST03, while the remaining two specimens were both recorded from nearshore station ST02. Of the 24 individuals of *Sabellaria spinulosa* identified across the survey area, 13 were recorded across nearshore stations ST03, ST04 and ST06, while the remaining 11 specimens were all recorded at station ST031 located in the nearshore section of the cable route. It was not deemed that this represented an aggregation of *S. spinulosa* that would qualify as Annex I biogenic reef habitat as the individuals occurred in solitary form only rather than as aggregations of tubes (see Paragraph 8.8.2 and Plate 6 for more details). Of importance is also the shrimp *Solenocera membranacea* which is not a protected or designated species; however, it is a species typical of the Mediterranean and its known northernmost range is around Irish waters while no records of this species exist for Britain[6].

Table 13 Notable taxa found across the Project Erebus survey area.

Taxon	Major Group	Designation	N of individuals
Austrominius modestus	Arthropoda	INNS	1
Crepidula fornicata	Mollusca	INNS	13
Goniadella gracilis	Annelida	INNS	2
Sabellaria spinulosa	Annelida	OSPAR listed & Annex I in reef form	24
Solenocera membranacea	Crustacea	Unusual find in UK waters	1
Styela clava	Chordata	INNS	1
Thia scutellata	Crustacea	Nationally scarce marine species	1

[6] Data from the NBN Atlas https://nbnatlas.org/

8.5. Macrobenthic Faunal Groupings

Multivariate analysis was undertaken on the square-root transformed macrobenthic grab abundance data, to identify spatial distribution patterns in faunal assemblages across the Project Erebus survey area and identify characterising taxa present.

Cluster analysis of the macrobenthic data was performed on a Bray-Curtis similarity matrix to analyse the spatial similarities in macrobenthic communities recorded across all sampled stations. The dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF (similarity profile routine) permutation test of all nodes within the dendrogram, identified 29 statistically significantly similar groups ($p > 0.05$). To enable a broad interpretation of the communities present across the Project Erebus survey area, a similarity slice at 20 % was used to amalgamate the 29 SIMPROF groups into eight broader Macrobenthic Groups, with four stations not belonging to any group (outliers). The dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF permutation test are provided in Appendix XII.

Of these four outlier stations, one was located nearshore within Milford Haven (ST010), one was in the nearshore sector of the cable route (ST019) while the other two were offshore stations ST042 (cable route) and ST103 (main array). To note that three of the eight Macrobenthic Groups were made up of only two stations each and characterised by very low total abundance (Macrobenthic Groups A, B and H).

To visualise the relationships between the sampled macrobenthic assemblages, a non-metric multi-dimensional scaling (nMDS) plot was generated on the community abundance data (Figure 19). 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 (0.15) indicates that the two-dimensional plot provides an adequate representation of the similarity between stations. The degree of clustering of intra-group sample points demonstrates the level of within group similarity (e.g., points within Macrobenthic Groups D, E and G show distinct clustering), whilst the degree of overlap of inter-group sample points is indicative of the level of similarity between different Macrobenthic Groups (e.g. Macrobenthic Groups A, C and F).

The spatial distribution of the eight broader Macrobenthic Groups and outliers is mapped in Figure 20. SIMPER (similarity percentage analysis) was used to identify the key taxa contributing to the within group similarity (see Appendix XII for SIMPER results).

Macrobenthic Group A (2 stations) – Only two stations fell into this group, ST021 and ST024, located in the section of the cable route closer to the coast. The taxon characterising these locations was the polychaete *Polycirrus,* and accounting alone for the group average similarity of 28.57 %. To note that these two stations had extremely low abundance with the assemblage at station ST024 consisting only of one individual of *Polycirrus*, while station ST021 had an assemblage made up of 6 specimens, one per each of the following taxa: *Echinocyamus pusillus*, *Edwardsiidae*, *Hippomedon denticulatus*, *Notomastus*, Polycirrus and *Scolelepis bonnieri*.

Macrobenthic Group B (2 stations) – This was also a group made up of only two stations, namely ST028 and ST080, and characterised by polychaetes; the white catworm *Nephtys cirrosa* and the bristleworm *Scoloplos armiger* (average similarity 36.94 %). Within the wind farm array, ST080 (and the outlier ST103) is the only station not to fall into larger, Macrobenthic Group E.

Macrobenthic Group C (3 stations)- The taxa contributing most to similarities between the three sampling stations within this group (ST022, ST023 and ST025; average similarity: 30.46 %) were the bivalve *Goodallia triangularis*, *N. cirrosa* and juvenile specimens of the bivalve *Spisula*. To note that stations ST022 and ST023 were among the richest in TOC (Figure 10).

Macrobenthic Group D (6 stations)– Taxa contributing the most to the within group average similarity of 31.02 % were the polychaetes *Euclymene oerstedii* (agg.) and *Notomastus*, while the most abundant species was *K. bidentata*. All stations falling into this group are nearshore stations located in Milford Haven.

Macrobenthic Group E (80 stations)– This was the largest group identified at the 20% similarity threshold, comprising 80 of the 107 stations, all of which were located offshore. Taxa contributing the most to the similarity within this group (average similarity 36.33 %) were *K. bidentata,* juveniles of *Amphiuridae* as well as adult individuals of the brittle star *Amphiura filiformis* and the pea urchin *Echinocyamus pusillus*.

Macrobenthic Group F (6 stations) –Stations belonging to this group were located along the cable route and characterised by the polychaetes *Aonides paucibranchiata* and *Pisione remota* and the ribbon worms Nemertea (average similarity 26.89 %).

Macrobenthic Group G (3 stations)– Stations, ST013, ST014 and ST015, all located at the entrance of Milford Haven belonged to this group. Taxa contributing the most to similarities between these sampling stations (average similarity 46.87 %) were the polychaete *Polygordius* and *Sphaerosyllis bulbosa* and Nematoda (nematode worms).

Macrobenthic Group H (2 stations)– The taxa contributing the most to similarities between the two nearshore samplings station (ST08 and ST011) within this group, were the polychaetes *P. remota* and *S. bulbosa* (average similarity 26.24%).

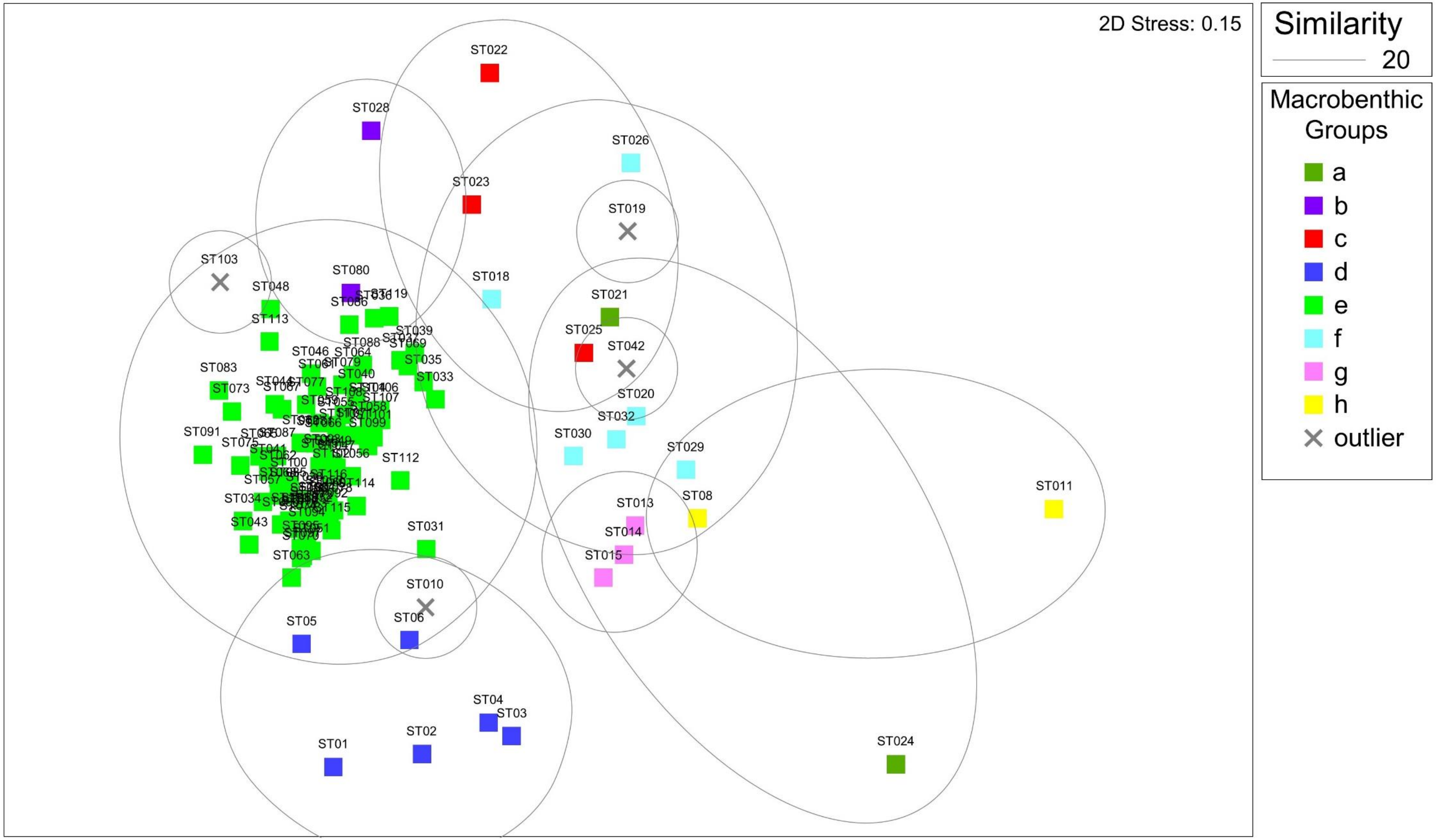


Figure 19 Two-dimensional nMDS ordination of macrobenthic communities sampled across the Project Erebus survey area, based on square root transformed and Bray-Curtis similarity abundance data. Macrobenthic Groups were identified at 20 % similarity (grey circles).

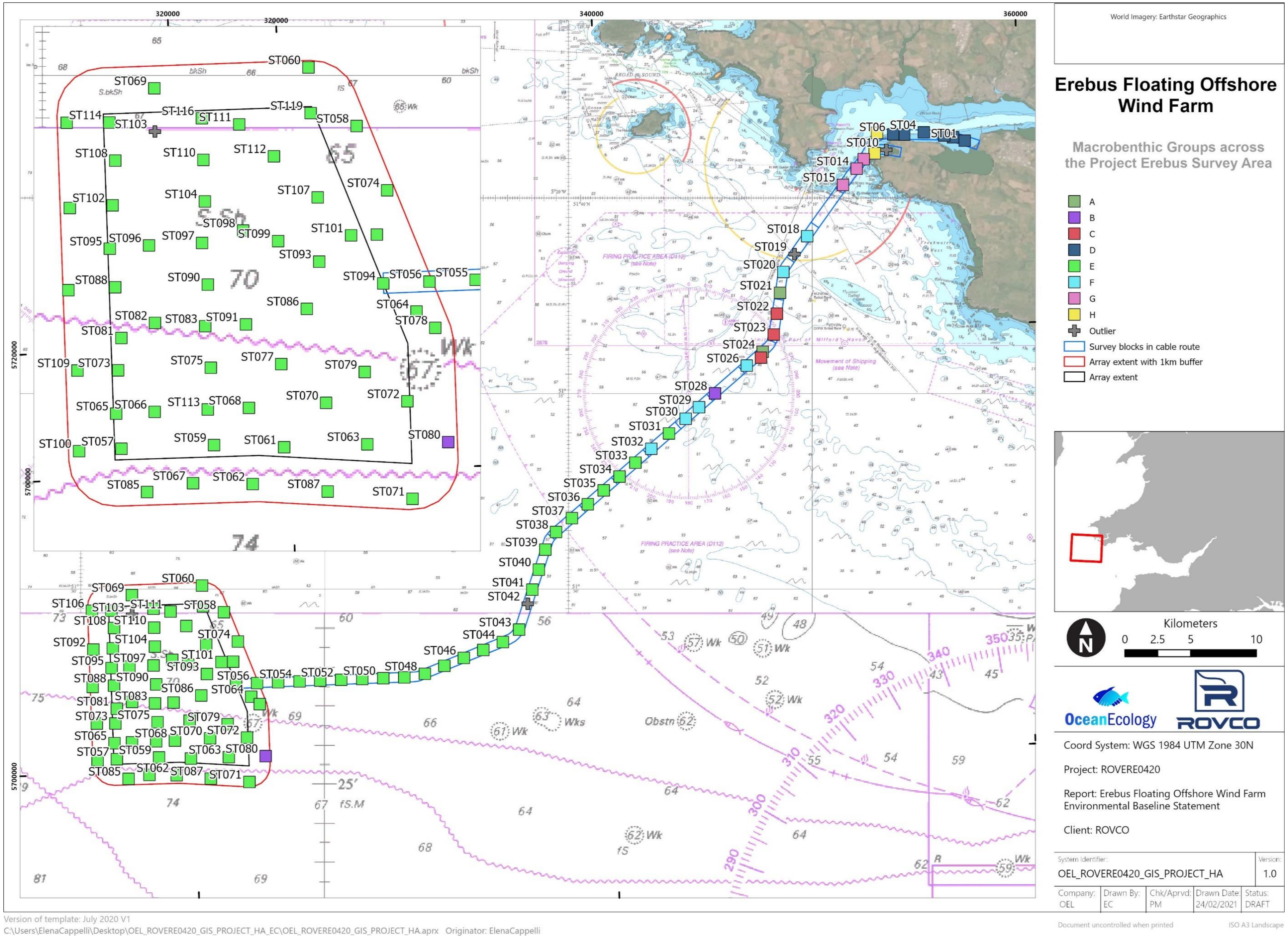


Figure 20 Spatial distribution of Macrobenthic Groups (A-H) identified for each station across the Project Erebus survey area.

8.5.1. Biotope Assignment

For each of the eight Macrobenthic Groups determined using cluster analysis, biotopes were assigned according to the JNCC classification tool (JNCC 2015) based upon their faunal and physical characteristics. Correlation of EUNIS/MNCR (Marine Nature Conservation Review) biotopes was undertaken using the JNCC correlation table (JNCC 2018).

Macrobenthic Group D - the biotope that most closely align with the community observed in this group was "A5.443 *Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment", which is consistent with the high mud content observed at these stations located within Milford Haven (ST01 to ST06; Figure 8).

Macrobenthic Group E - the biotopes that most closely align with the community observed in this group were "A5.251 *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand" and "A5.351 *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud". This correlates well with the sediment type and composition recorded at the same locations, that was identified as either BSH A5.2 Sand and Muddy Sand or BSH A5.3 Mud and Sandy Mud (See Section 8.1 and Figure 8).

Macrobenthic Group G and **Macrobenthic Group H** included stations located on the cable route within the Milford Haven Waterway (ST08 to ST015) and were characterised by the presence of polychaete *S. bulbosa*. The biotope that most closely aligned with these communities was "A5.143 *Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand", which is consistent with the relatively high content of gravel recorded at these stations (Figure 8).

All other Macrobenthic Groups (A, B, C, and G) were made up of only a few stations each and overall had low abundances of characterising species which hindered the allocation of a specific biotope to these groups. Additionally, as demonstrated by the nMDS ordination plot (Figure 19), samples belonging to these Macrobenthic Groups were interspersed with each other and did not form tight clusters. For these reasons, all the stations located in the nearshore area of the cable route (ST018 to ST032) were assigned a level 4 biotope based on their physical characteristic which include EUNIS biotope A5.14 'Circalittoral coarse sediment', A5.25 'Circalittoral fine sand' and A5.44 'Circalittoral mixed sediments'.

8.6. Seabed Imagery

Generally, seabed imagery correlated well with SSS however the ability to delineate between coarser sediments in the central area of the route and those sandier sediments furthest offshore using SSS was limited, therefore DDV transects and PSD data were fundamental in determining the sediment / substrate type. The main assessment was conducted using the still images captured during the DDC deployments / DDV transects, due to high turbidity levels, which reduces the resolution of analysis from the video imagery. The main habitats identified based on the seabed imagery are presented in Plate 3, Plate 4 and Plate 5. Example imagery from each DDC station is presented in Appendix XVI, along with taxa present, BSH description, and the EUNIS habitat description. The dive logs for all seabed imagery collected during HA and site characterisation transects are presented in Appendix XIII and XIV, respectively.

8.7. Habitat/Biotope Mapping

To map the principal habitats that occur throughout the Project Erebus survey area, a full interrogation of available geophysical data in combination with seabed imagery collected at dedicated transect locations and site characterisation sampling stations was undertaken. PSD data were also used to support these data and better understand the sediment type within the wider habitat types. The main habitats identified across the Project Erebus survey area at which both seabed imagery and grab samples were obtained, comprised primarily of the EUNIS classifications A5.251 '*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand' and A5.351 '*Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud' in the offshore section of the cable route and in the main array (ST033-119).

Stations located on the cable route within the Milford Haven Waterway (ST01-015) were characterised by various EUNIS biotopes including A5.143 '*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand', A5.334 '*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud', and A5.443 '*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment'. The INNS *Crepidula fornicata* were present at ST03, however more dense aggregations of this species are found further up the estuary (Bohn et al. 2015). With only few key species present, this station remained listed as a level 4 EUNIS classification.

Stations located on the outer fringes of the Milford Haven Waterway and the nearshore area of the cable route (ST018-032) were best represented by the EUNIS classifications A5.14 'Circalittoral coarse sediment', A5.25 'Circalittoral fine sand' and A5.44 'Circalittoral mixed sediments'. Low faunal abundances of key species were present in grab samples collected at these locations. These stations therefore remained as a level 4 EUNIS classifications.

The distribution and extent of the habitats/biotopes identified across the Project Erebus survey area based on all the available data are presented in Figure 21 to Figure 23. In total, 6 level 5 biotopes were identified across the survey area representative of 11 level 4 biotope complexes and 4 level 3 BSHs (Table 14). Section 8.8 will detail any habitat of conservation value such as Annex I habitats.

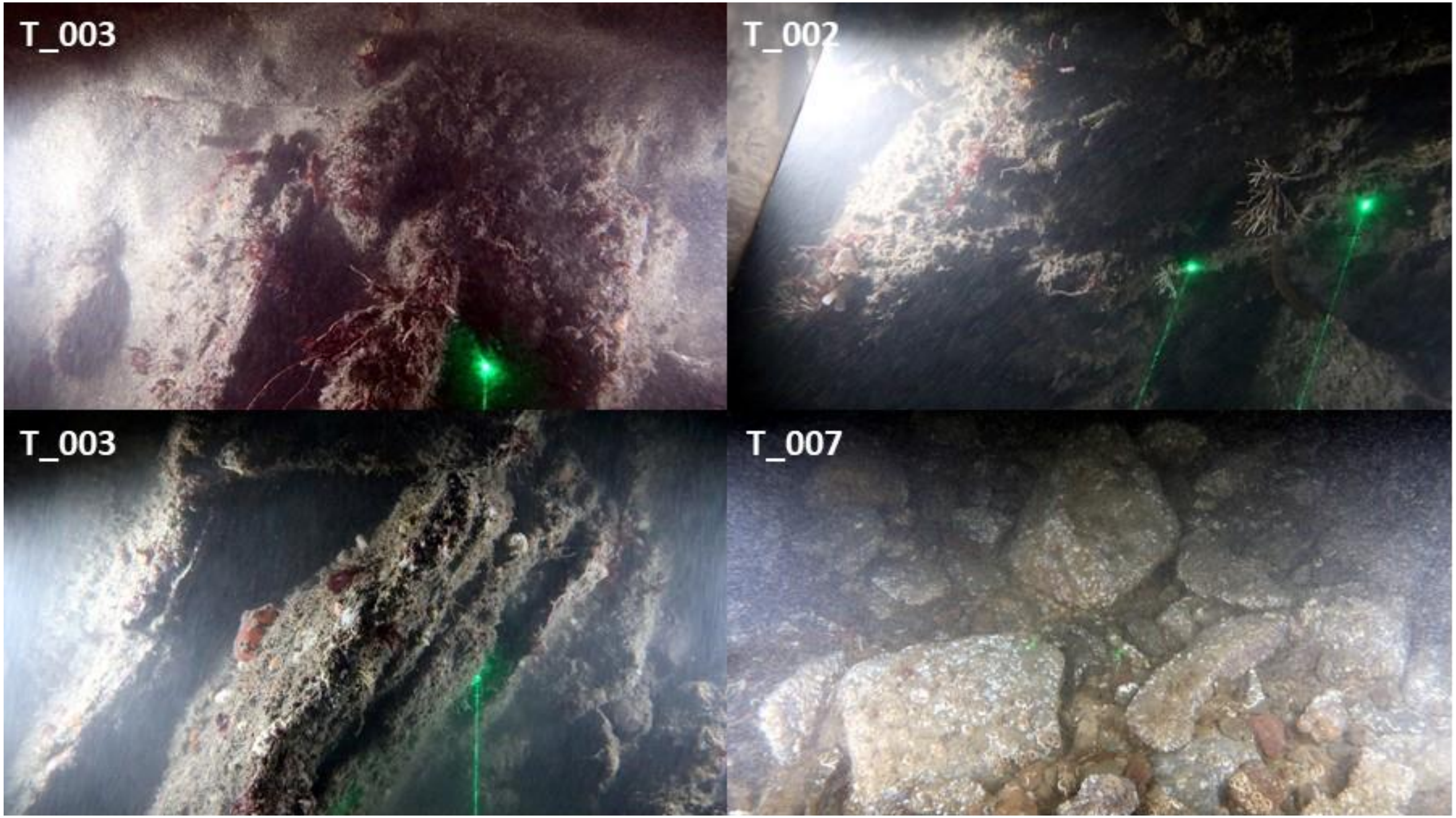


Plate 3 Example seabed imagery collected across the Erebus Floating Offshore Wind Farm survey area. From top left to bottom right: EUNIS biotope A3.12, A3.24, A4.13, A4.214.

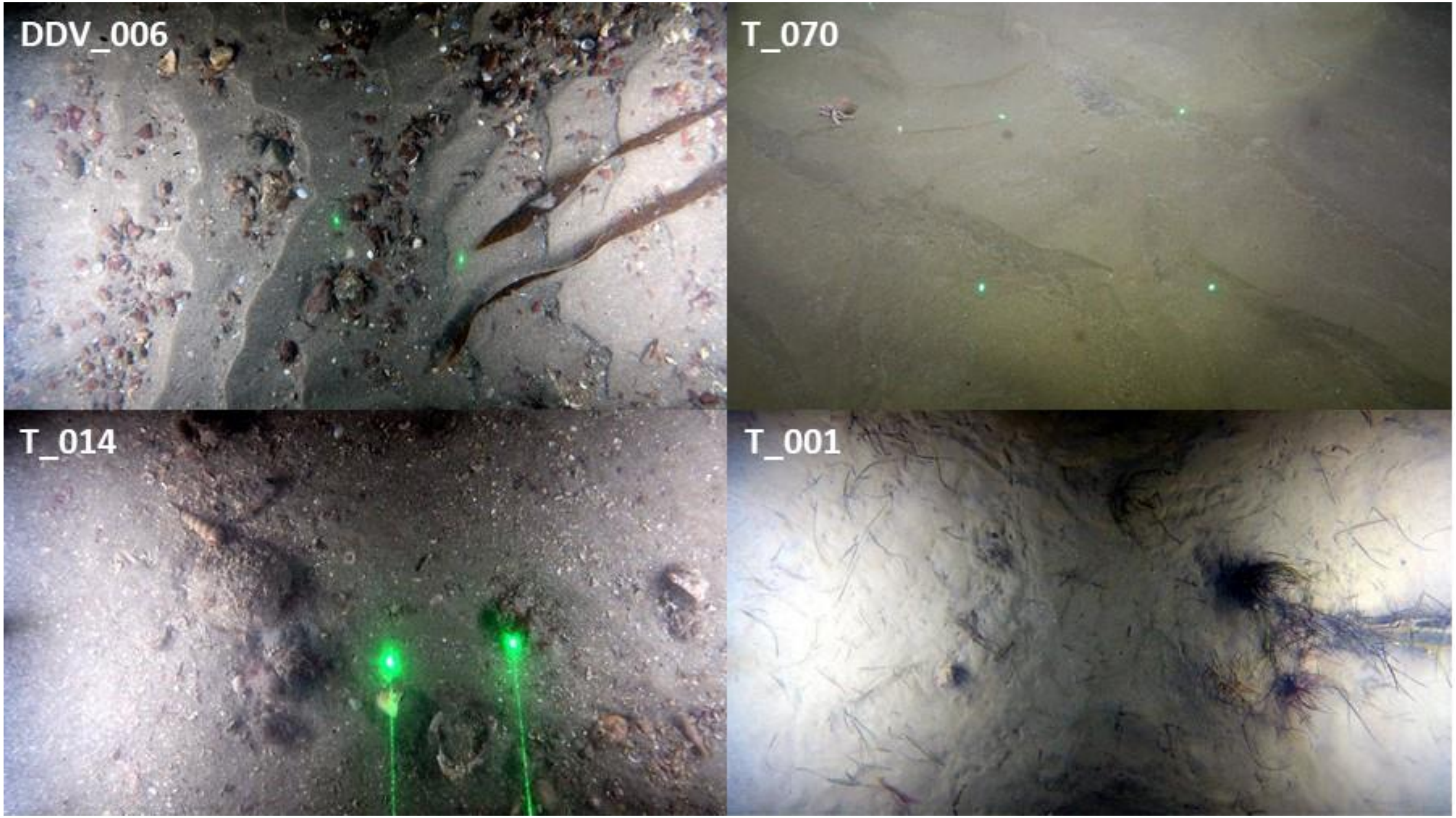
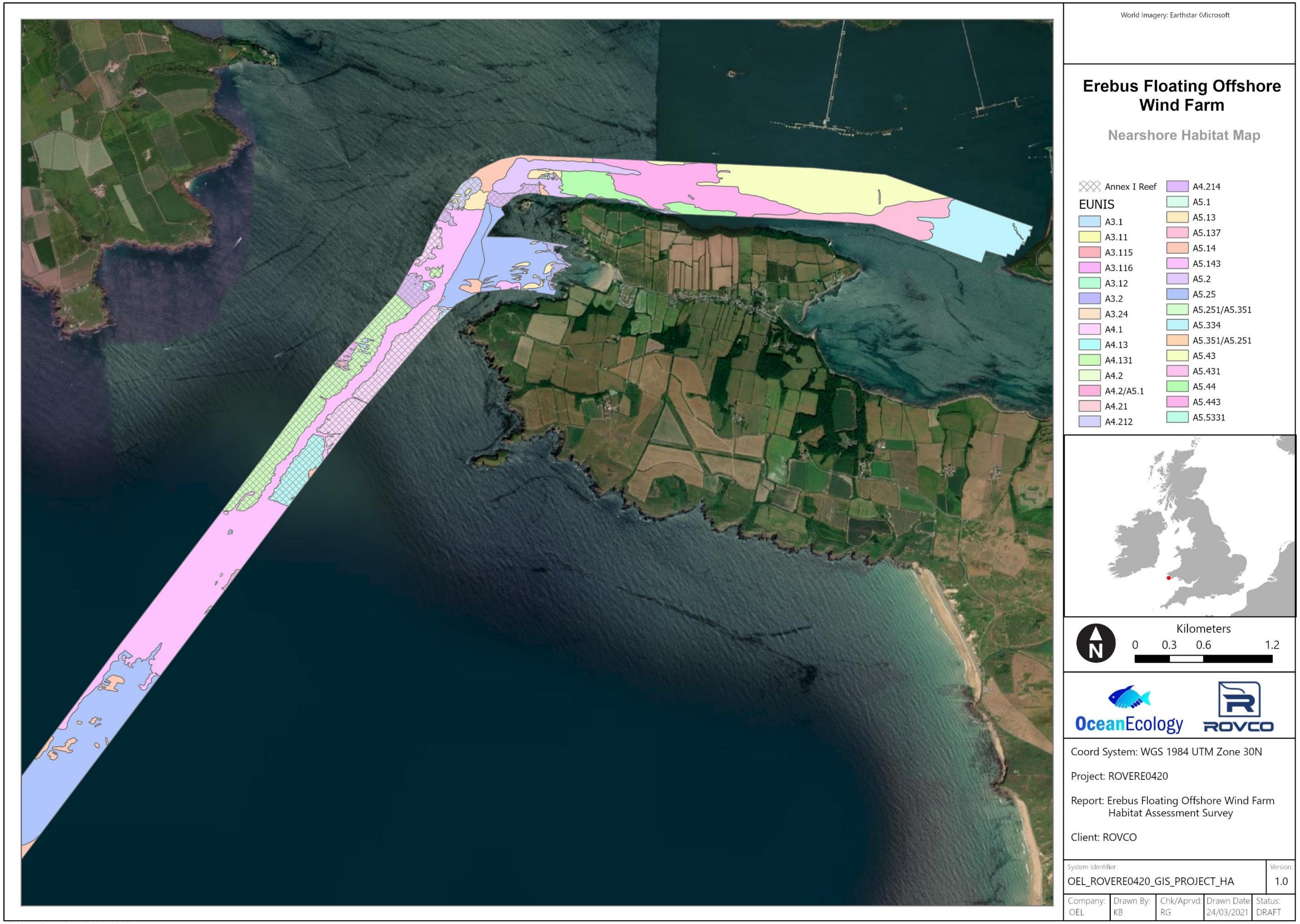


Plate 4 Example seabed imagery collected across the Erebus Floating Offshore Wind Farm survey area. From top left to bottom right: EUNIS biotope A5.13, A5.25, A5.43 and A5.53.

Table 14 EUNIS classifications (and MNCR 04/05 correlations) identified within the Erebus Floating Offshore Wind Farm Environmental Baseline Survey area.

EUNIS Level 4	EUNIS Level 5	MNCR Code	EUNIS Description
A5.13	A5.137	SS.SCS.ICS.SLan	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand
A5.14	A5.143	SS.SCS.CCS.Pkef	*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand
	-	SS.SCS.CCS	Circalittoral coarse sediment
A5.25	-	SS.SSa.CFiSa	Circalittoral fine sand
	A5.251	SS.SSa.CFiSa.EpusOborApri	*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand
A5.26	-	SS.SSa.CMuSa	Circalittoral muddy sand
A5.33	A5.334	SS.SMu.ISaMu.MelMagThy	*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud
A5.35	A5.351	SS.SMu.CSaMu.AfilMysAnit	*Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud
A5.43	-	SS.SMx.IMx	Infralittoral mixed sediments
A5.44	A5.443	SS.SMx.CMx.MysThyMx	*Mysella bidentata* and *Thyasira spp*. in circalittoral muddy mixed sediment
	-	SS.SMx.CMx	Circalittoral mixed sediments



Version of template: July 2020 V1
C:\Users\ElenaCappelli\Desktop\OEL_ROVERE0420_GIS_PROJECT_HA_EC\OEL_ROVERE0420_GIS_PROJECT_HA.aprx Originator: ElenaCappelli

Document uncontrolled when printed ISO A3 Landscape

Figure 21 EUNIS habitat / biotope and Annex I reef mapping across the near shore section of the Project Erebus survey area.

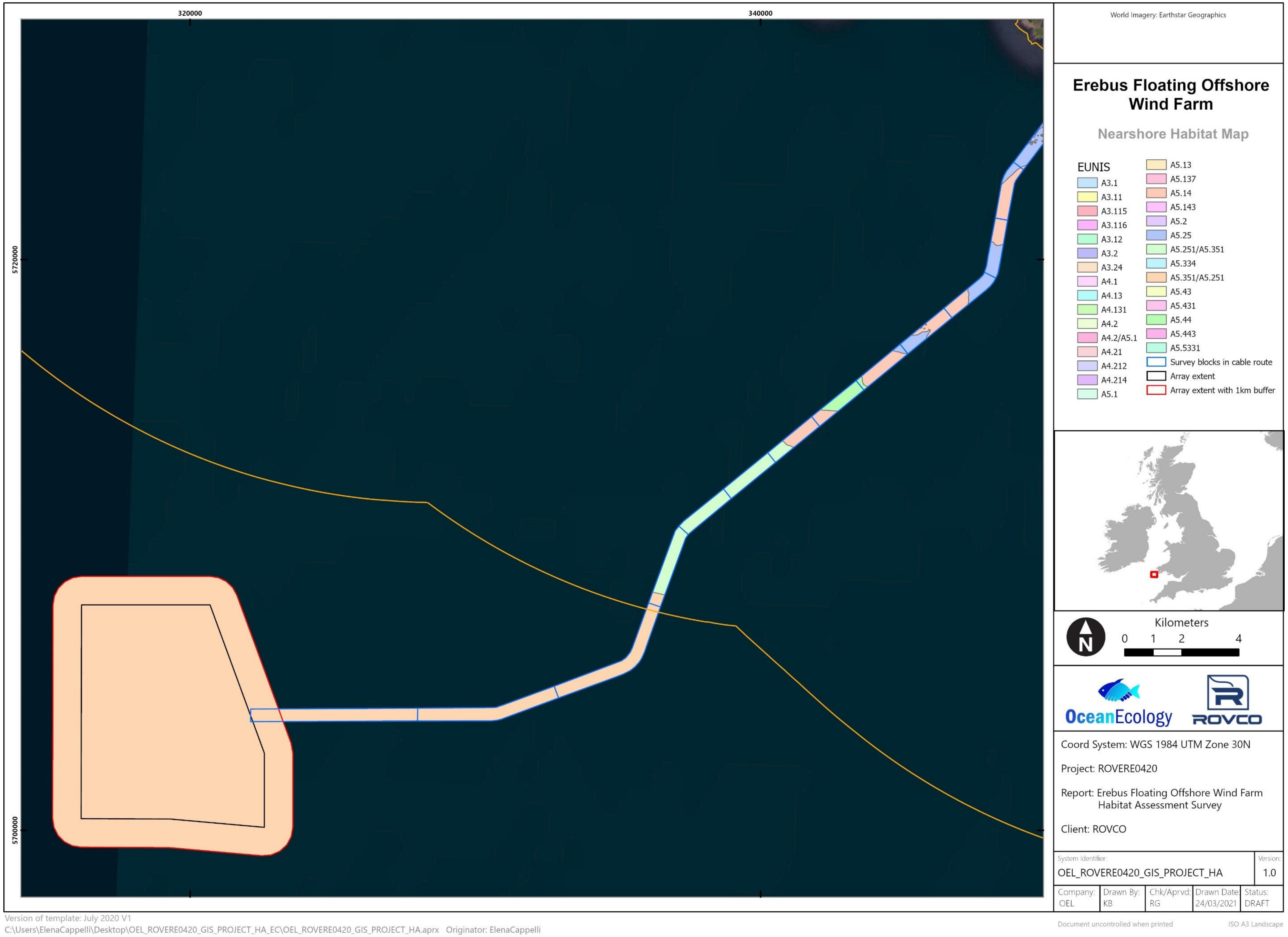


Figure 22 EUNIS habitat / biotope and Annex I reef mapping across the offshore section and array area of the Project Erebus survey area.

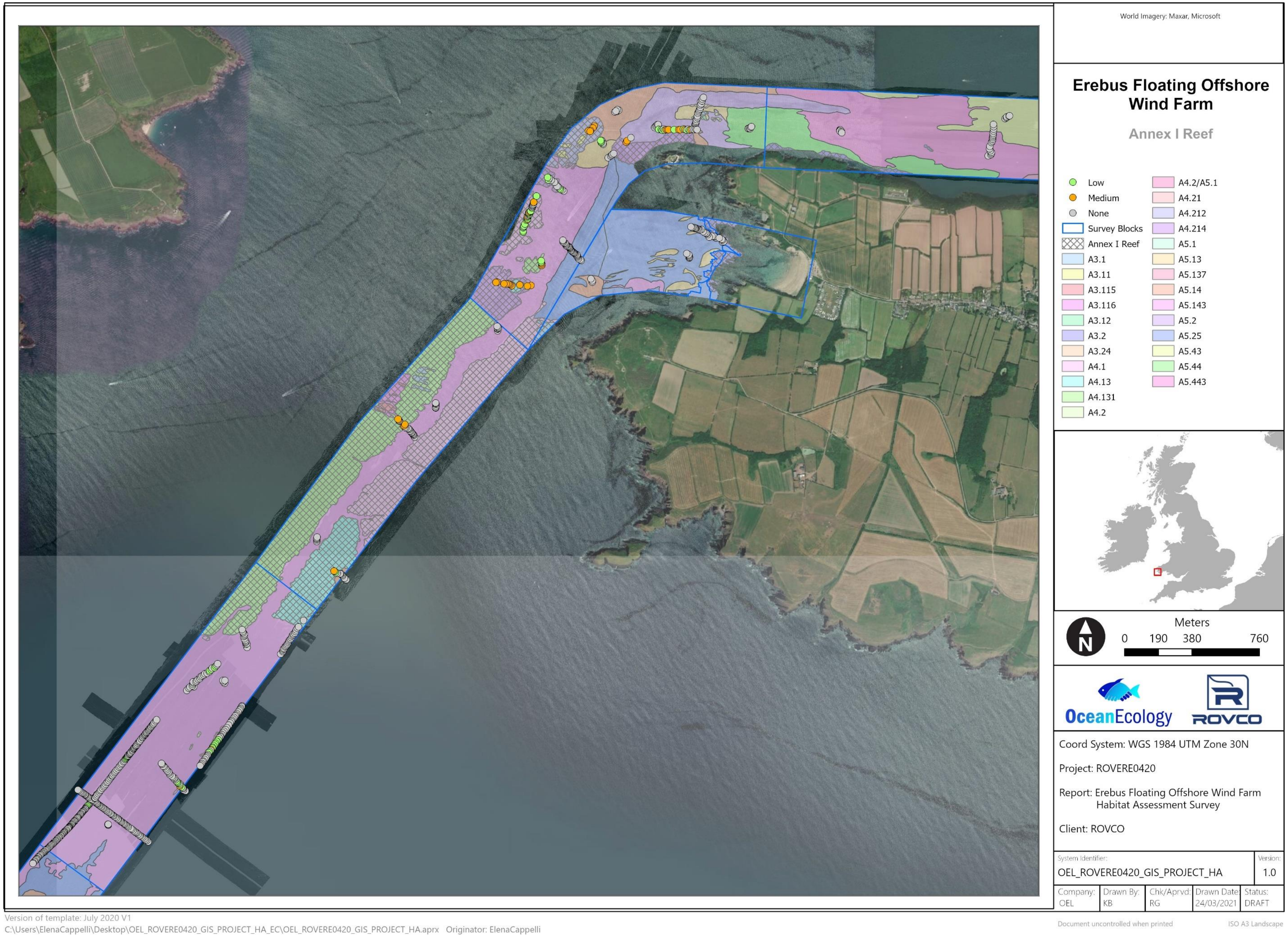


Figure 23 Annex I reef assessment across the Project Erebus survey area highlighting acoustic data and areas of non-reef.

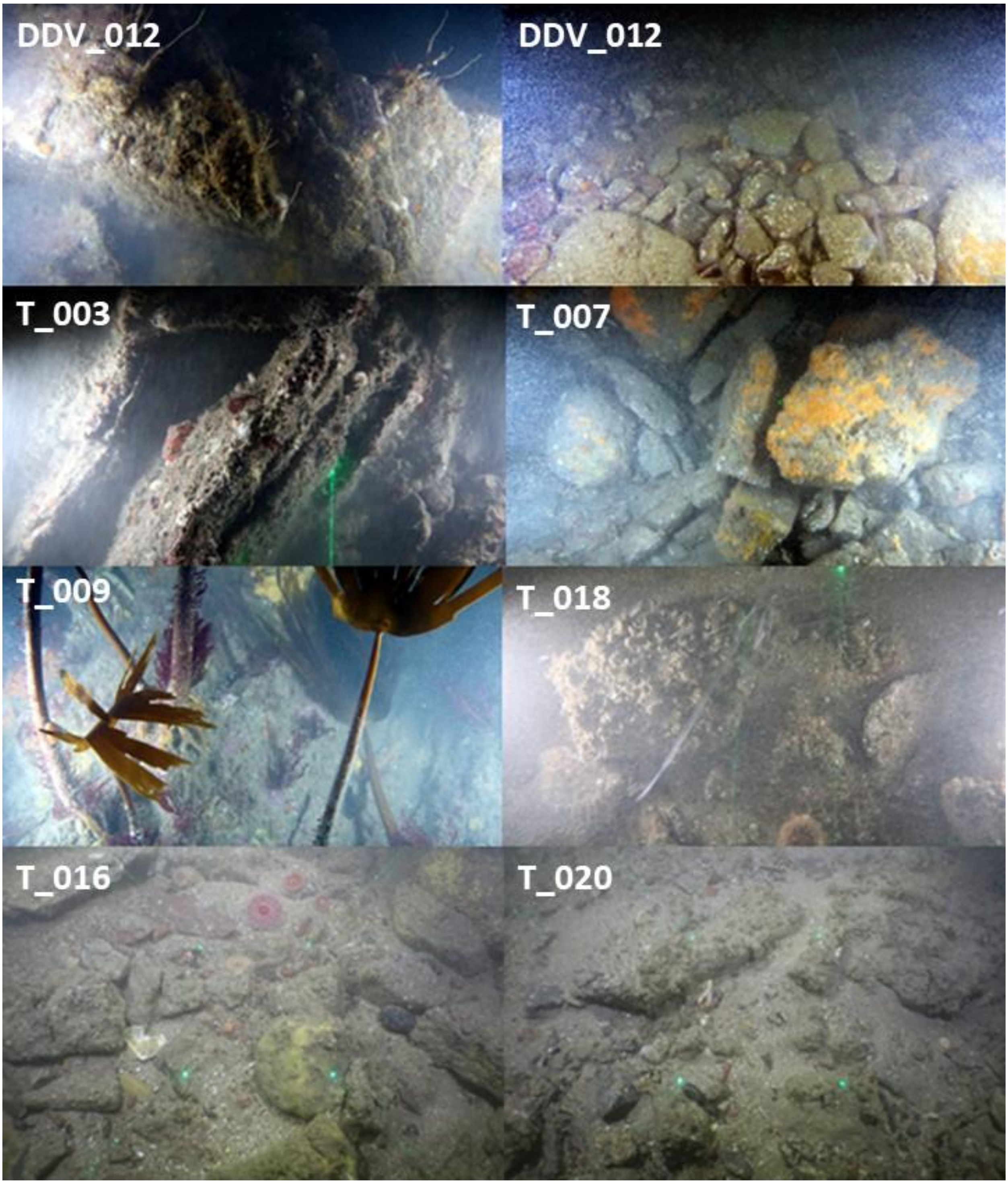


Plate 5 Example imagery showing bedrock reef, low resemblance stony reef and medium resemblance stony reef.

8.8. Habitats of Conservation Value

8.8.1. Annex I Rocky Reef

A full reef habitat assessment was conducted on all images to determine whether habitats met the criteria of Annex I rocky reef (stony and bedrock) habitats as detailed in Section 7.7.1. To note that where stony and bedrock reefs were recorded along the same transects, they were deemed to form mosaic habitats meaning it was difficult to differentiate between the two reef types given the lack of clear boundaries in the acoustic data.

Table 15 summarises areas of Annex I stony reef present across the survey area, an assessment of their 'reefiness' as defined by Irving 2009, and the presence of Annex I bedrock. Annex I stony reef were present across the survey area, mostly along the nearshore section of the cable route (Figure 23). To note that in the shallow subtidal area close to the landfall location at West Angle Bay (survey block WA01) Annex I bedrock was identified as a continuous structure extending from the subtidal to the intertidal zone. The EUNIS habitat for this area encompassing the shallow subtidal zone and the intertidal zone was assessed to be A3.2 based on Unmanned Aerial Vehicle (UAV) imagery and acoustic data (Figure 23; for details on intertidal habitats see OEL 2021). Transect T_013 located in proximity of the West Angle Bay landfall did not show evidence of Annex I bedrock as the extent of the feature observed in the seabed imagery was not large enough to qualify as Annex I (grey dots in Figure 23); nevertheless a few images of kelp on sublittoral rock were recorded at the beginning of the transect, which indicates that this rocky feature extends towards the intertidal zone rather than offshore. In total, 13 transects showed evidence of stony reef, with 4 transects (T_004, T_005, T_008 and T_009) deemed to be representative of medium resemblance stony reef, 4 transects (T_006, T_018, T_020 and T_098) of low resemblance stony reef and the remaining transects (T_003, T_007, T_010, T_019 and T_099) mix of low and medium resemblance stony reefs (Plate 5). Coverage of this habitat type was most extensive at transects T_003 and T_007. Annex I bedrock reef was identified along 11 transects from T_003 to T_010, T_016, T_017 and T_026. Coverage of this habitat type was most extensive in the area overlapped by transects T_007 to T_010

Table 15 Summary of Annex I rocky reef assessment (stony and bedrock) for each transect along which reef was observed.

Station	EUNIS habitat/biotope	Stony Reef			Bedrock
		Not a Reef	Low	Medium	
T_003	A4.214, A4.13	6	8	7	6
T_004	A3.115, A3.116, A4.13, A4.214	7	-	2	9
T_005	A3.115, A3.116, A4.212	-	-	5	17
T_006	A4.214	7	4	-	3
T_007	A4.13, A4.212, A4.214	9	14	5	13
T_008	A4.13, A4.131, A4.214	-	-	11	12
T_009	A3.115, A3.116, A4.13, A4.131, A4.212, A4.214	16	-	5	18
T_010	A4.13, A4.131	8	2	1	16
T_016	A4.13	23	-	-	4
T_017	A4.13, A4.131	14	-	-	7
T_018	A4.13, A4.214, A4.221	21	4	-	-
T_019	A4.214	21	5	1	-
T_020	A5.14/A4.214, A5.14/A4.213	92	3	-	-
T_026	A4.1	37	-	-	1
T_098	A5.14/A4.214	74	5	-	-
T_099	A5.14/A4.214, A5.14/A4.213	35	10	1	-

8.8.2. Annex I Biogenic Reef

No Annex I biogenic reef habitat was observed across the survey area following assessment criteria described in section 7.7.1. A small patch of stony reef was observed along transect T_018 with one image showing *S. spinulosa* tube aggregations; however, this area was not deemed to meet the Annex I reef qualifying criteria due to its limited extent (Plate 6). Similarly, across transect T_026 an image showing an area of mixed sediment supporting *S. spinulosa* was noted however its extent was also very limited and therefore was not deemed to meet the Annex I reef qualifying criteria (Plate 6). This is consistent with the findings based on macrobenthic analysis as presented in Paragraph 8.4.2 and Table 13.

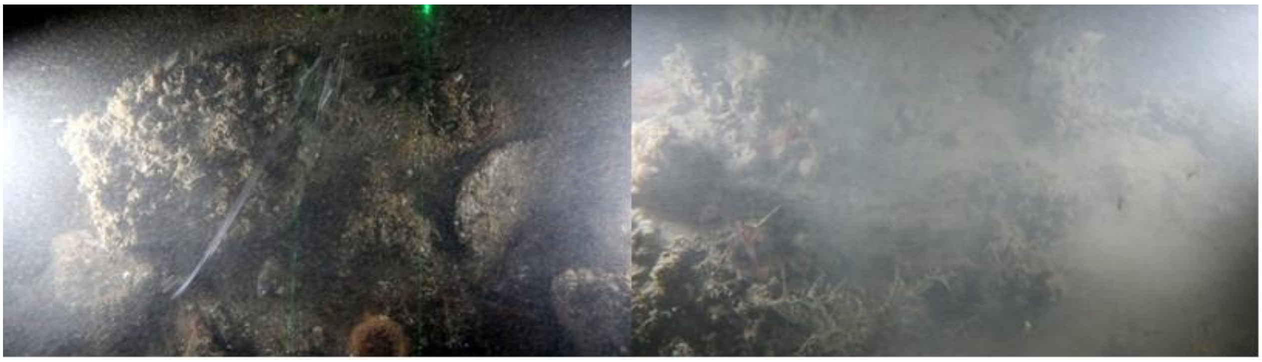


Plate 6. Two seabed images collected along the nearshore cable route depicting *Sabellaria spinulosa* tube aggregations. Left: EUNIS biotope A4.221 - *Sabellaria spinulosa* encrusted circalittoral rock (T_018); Right: EUNIS biotope A5.611 - *Sabellaria spinulosa* on stable circalittoral mixed sediment (T_026).

8.8.3. Annex I Sandbanks

Two areas of sandy habitat were identified as likely Annex I Sandbank habitats covering a combined area of 2.6 km^2 of the export cable route in consideration of the descriptors described by Pinder (2020) (Section 7.7.1). The first was assigned a 'High' confidence score given its topographic and sedimentary characteristics as well as the fact that it intersects, and forms part of, the known Turbot Bank Annex I sandbank feature (19.08 km^2). The second area was found further along the export cable corridor and was deemed to meet the topographic and sedimentary criteria but was assigned a 'Potential' confidence score due to the lack of known adjacent sandbanks. Pinder (2020) (Figure 24).

8.8.4. Seagrass Beds

Zostera marina shoots were recorded along transect T_001 extending to the shallow subtidal area of the Sawdern Point landfall (Figure 25). This area coincided with subtidal macrophyte dominated sediment and was deemed to be representative of EUNIS biotope A5.5331 '*Zostera marina/angustifolia* beds on lower shore or infralittoral clean or muddy sand'. Shoot density was generally low although several discrete patches of dense shoots were observed. Like many terrestrial plants, seagrasses senesce in the autumn and winter with storms causing dying shoots and leaves to break off and become redistributed. Given the time of the year the survey was undertaken, it is likely that the observation of low-density shoots is indicative that this area supports a seagrass bed which at the time was in a state of senescence. The majority of the plant biomass would have therefore been below the sediment surface at the time of the survey in the form of the system of rhizomes and roots whereas the more visible shoots are lost. To note that seagrass beds are habitats of principal importance for the purpose of maintaining and enhancing biodiversity in Wales under Section 7 of the Environment (Wales) Act 2016.

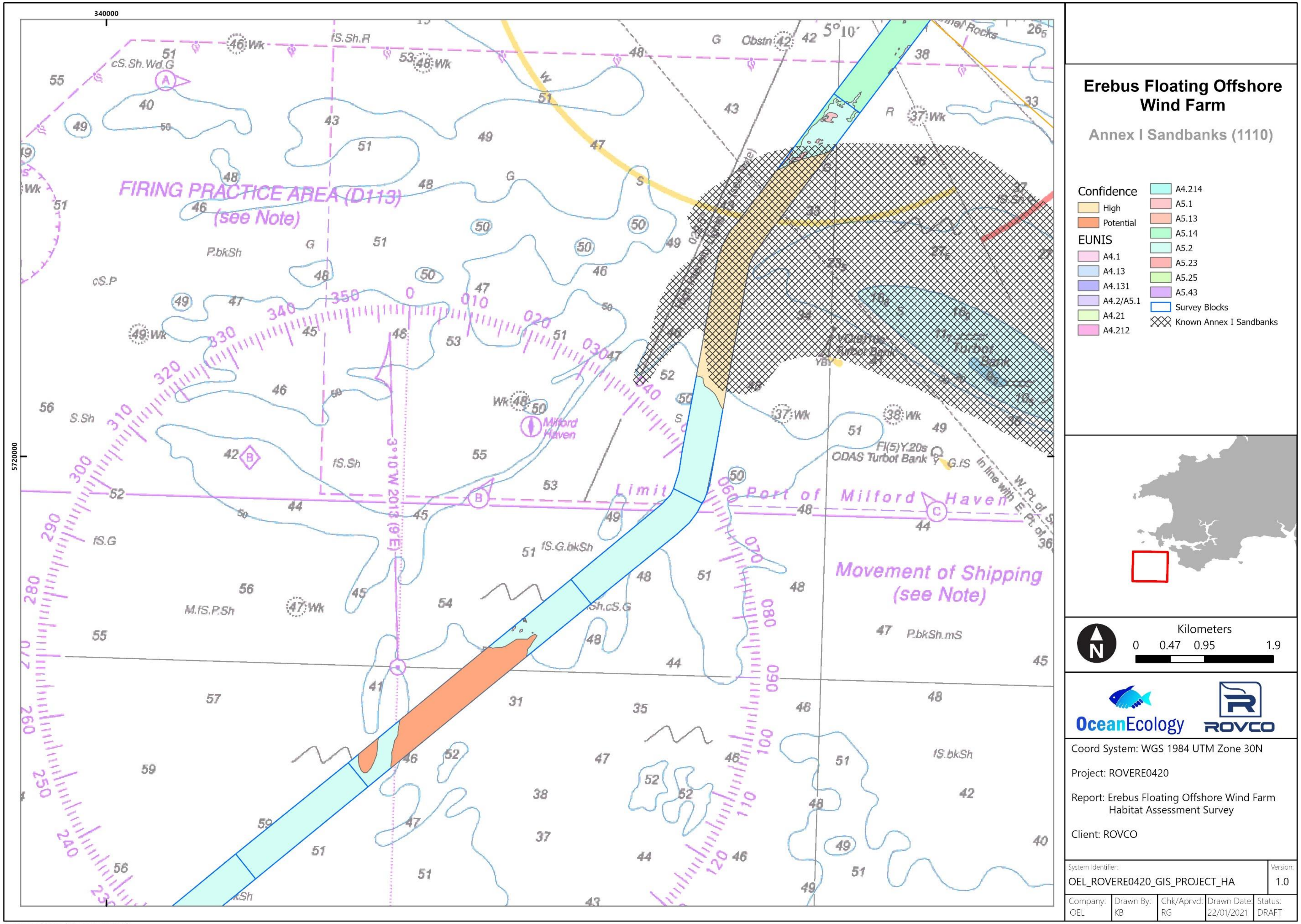
8.8.5. Maerl Beds

No maerl beds were observed across the survey area however a discrete patch of a mixture of live maerl and dead maerl rubble was observed in one seabed image taken at EBS station 003. This was not deemed to be representative of a distinct bed due to its limited extent but was recorded in relatively close proximity to the known bed in the vicinity of the South Hook Liquid Natural Gas Terminal to the north of the Sawdern Point export cable route (Figure 26). To note that maerl beds are habitats of principal importance for the purpose of maintaining and enhancing biodiversity in Wales under Section 7 of the Environment (Wales) Act 2016.

8.8.6. Other Notable Species

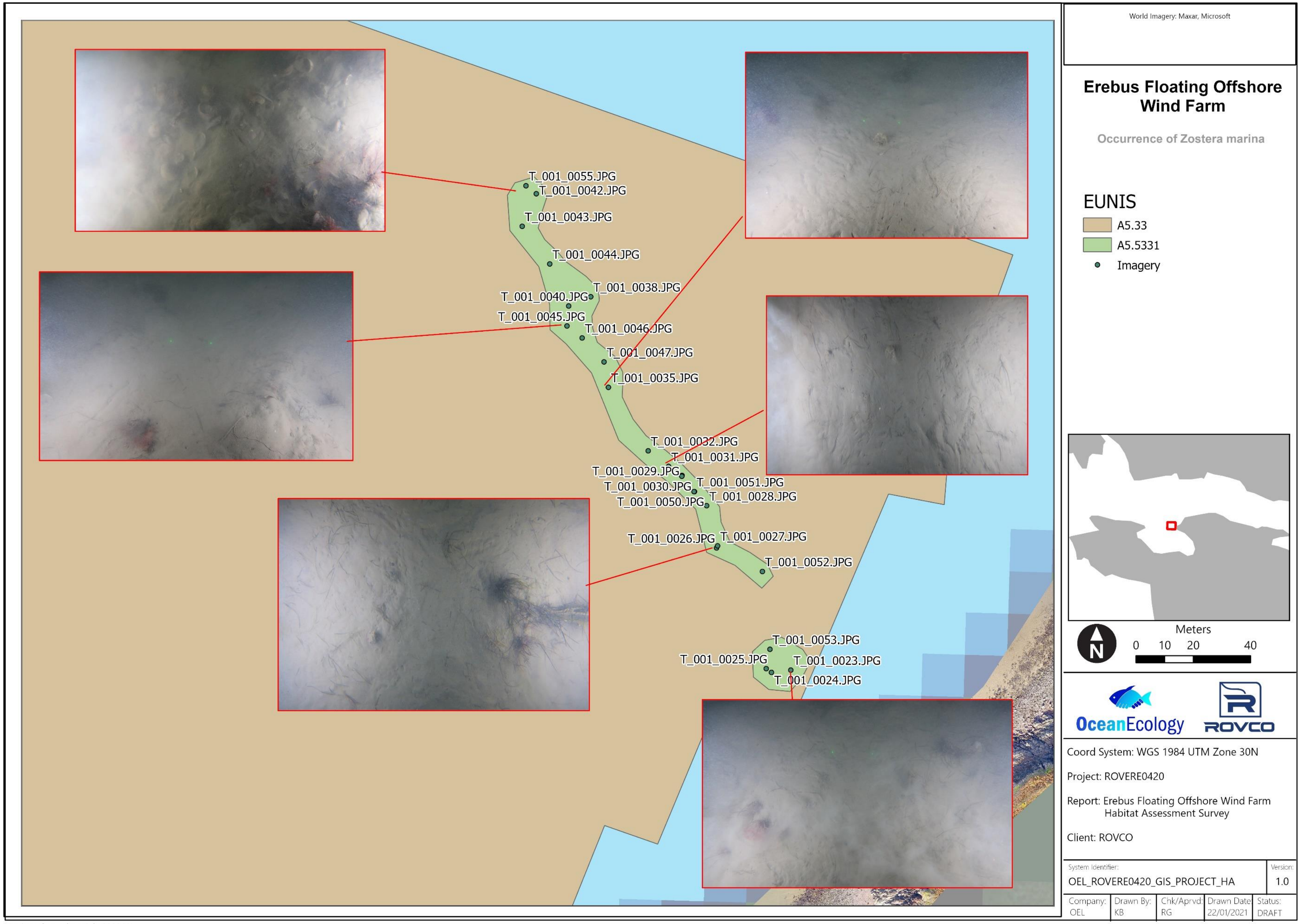
Aggregations of the INNS slipper limpet *Crepidula fornicata* were observed along transect T_014 on mixed sediments which were deemed to be representative of the EUNIS biotope A5.431 '*Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment'. This is consistent with the findings based on macrobenthic analysis from grab samples as presented in Paragraph 8.4.2 and Table 13.

Shells of the native oyster *Ostrea edulis* were observed along transects T_020, T_097, T_098 and T_099 in the nearshore section of the export cable route corresponding to the EUNIS biotope complex A5.14 'Circalittoral coarse sediment'. Of these, the majority were not deemed to be alive (20 out of 27 images) however it was difficult to clearly assess this based on images only (Figure 27). No record of *O. edulis* was found in the grab samples.



Version of template: July 2020 V1
C:\Users\KarenBoswarva\Ocean Ecology Limited\PROJECTS - Documents\Erebus Floating Offshore Wind Farm EBS and HA 2020\GIS\PROJECTS\OEL_ROVERE0420_GIS_PROJECT_HA\OEL_ROVERE0420_GIS_PROJECT_HA.aprx Originator: KarenBoswarva

Figure 24 Annex I sandbank mapping across the near shore section of the Project Erebus survey area.



Version of template: July 2020 V1
C:\Users\KarenBoswarva\Ocean Ecology Limited\PROJECTS - Documents\Erebus Floating Offshore Wind Farm EBS and HA 2020\GIS\PROJECTS\OEL_ROVERE0420_GIS_PROJECT_HA\OEL_ROVERE0420_GIS_PROJECT_HA.aprx Originator: KarenBoswarva

Document uncontrolled when printed ISO A3 Landscape

Figure 25 *Zostera marina* recorded across Transect T_001 in the vicinity of the Sawdern Point landfall location.

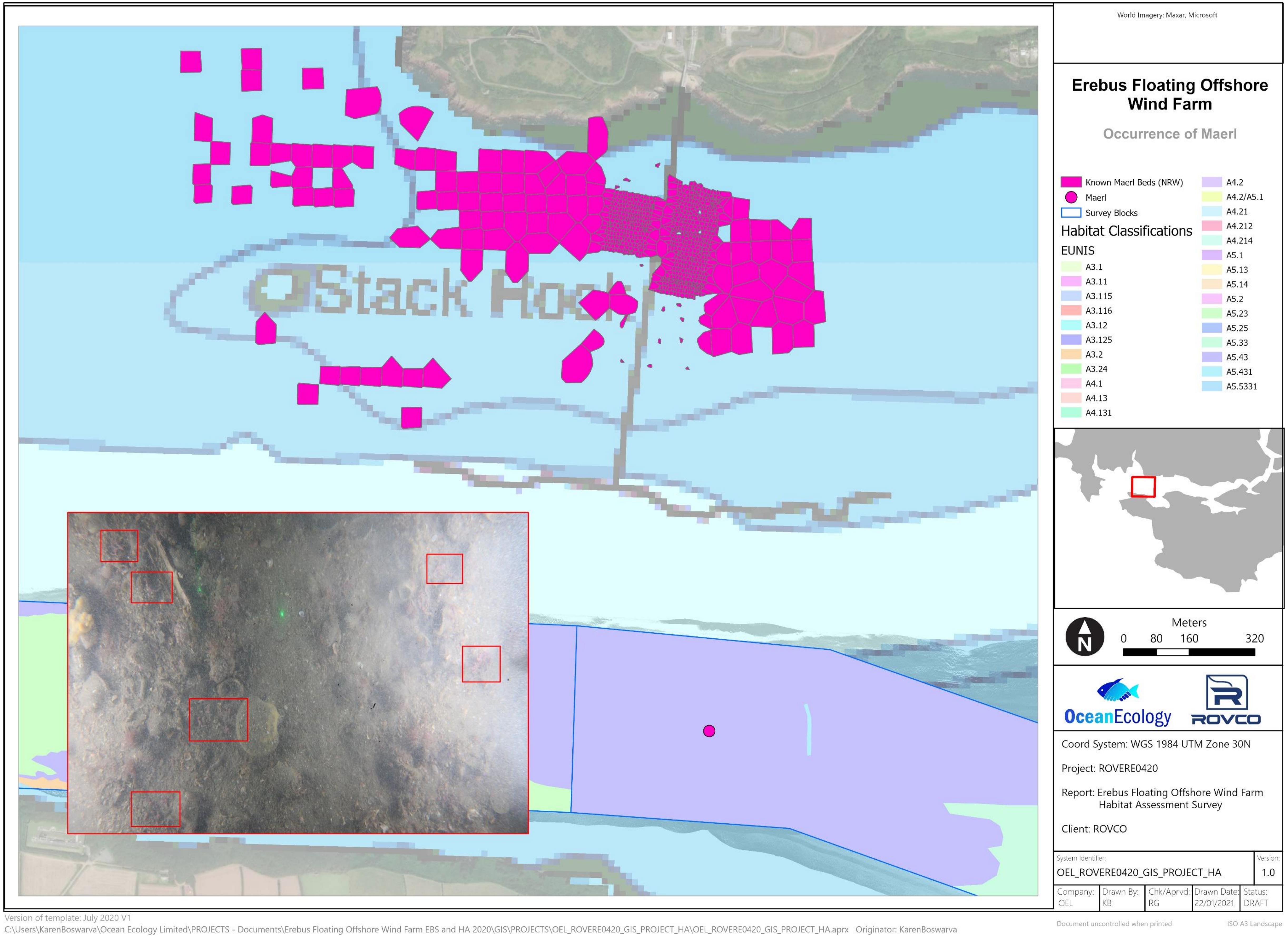


Figure 26 Occurrence of maerl recorded at EBS station 003.

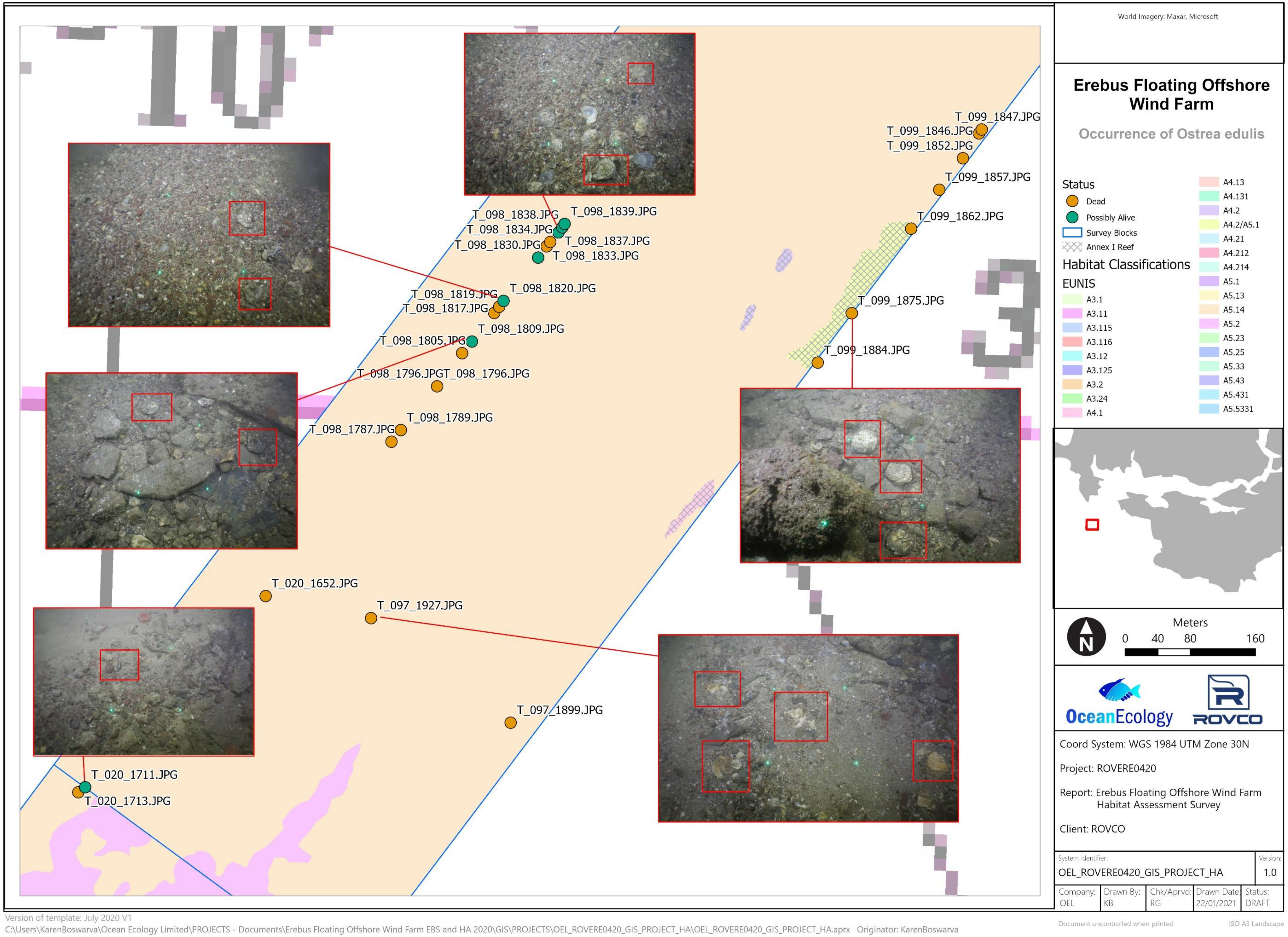


Figure 27 Occurrence of *Ostrea edulis* observed along transects T_020, T_097, T_098 and T_099.

9. Discussion

This report presents the results of the macrobenthic and sediment analysis combined with the results of the habitat assessment with the aim to set out the environmental baseline conditions across the proposed Project Erebus FLOW development to inform final routing, engineering design and the installation process of the proposed windfarm as well as providing a robust dataset for future comparison if required.

9.1. Sediments

Some variation in sediment types was observed across the survey area; however, most stations were dominated by sand (Figure 9). Mud content was highest close to land and towards the main array, while gravel content was overall low and rather variable along the cable route. Among the ten stations within Milford Haven, EUNIS BSH 'A5.4 Mixed Sediment' and EUNIS BSH 'A5.1 Coarse Sediment' were the most common occurring at four and three stations, respectively. Most offshore stations (n=71) belonged to EUNIS BSH 'A5.2 Sand and Muddy Sand', followed by EUNIS BSH 'A5.3 Mud and Sandy Mud' (n=13) and EUNIS BSH A5.1 (n=12). These types of sediment are among the most common habitats found in subtidal settings across the UK coast and fall in the list of habitats of principal importance under Section 7 of the Environment (Wales) Act 2016 'Subtidal sands and gravels' and 'Subtidal mixed muddy sediments'.

In general, stations rich in mud (> 20 %) were also the stations with the highest TOM content (> 2%). Studies based on the coastal ocean and marine environment have found a positive relationship between organic matter content and proportions of finer sediment grain size (Winterwerp & van Kesteren 2004, McBreen et al. 2008, Hunt et al. 2020) which is reflected in this broad scale pattern observed across the survey area (Figure 8 and Figure 11). Additionally, relatively high TOM content was observed in the nearshore stations located within Milford Haven. This could suggest runoff from land as a potential source of the organic matter found at these locations. Average TOC compares well with global sediment average TOC content for the deep ocean (0.5 %) and eastern margins (2 %) (Seiter et al. 2004).

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

Trace and heavy metal concentrations were typically higher at nearshore stations than at offshore stations, except for As. This spatial pattern most likely reflects the proximity of nearshore stations to urban settings which are a potential source of metals that can then be accumulated in coastal sediments. Among all metals, As was the only one with average concentration across the survey area as a whole (nearshore and offshore stations together) above reference levels, with concentrations almost always above the TEL for most stations (n=102), but only above the BAC at 9 and above AL1 at 18. To note that the TEL (7.24 mg kg^{-1}) for As is about three times lower than the BAC (25 mg kg^{-1}) and AL1 (20 mg kg^{-1}). This has possibly to do with the TEL being based on North American data and as such it may not be representative of UK conditions (Mason et al. 2020). In comparison OSPAR BAC and Cefas ALs are based on UK data and therefore are more suitable for the current assessment. No stations had As concentrations above AL2 or PEL meaning that adverse biological effects were rare. The 9 stations with As concentration above the BAC were mostly located east of the main array and in the most offshore section of the export cable route (Figure 12). No pattern emerged when comparing these stations with elevated As concentrations with the correspondent depth, TOC, TOM and mud content, which could have been related to transportation and deposition of As across the survey area. 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 high As levels at these stations, no macrobenthic anomalies were identified at these locations to suggest any adverse effects were present. All stations located in the main array and offshore section of the export cable route belonged to the same Macrobenthic Group E regardless of metal concentrations.

Among all PAHs, Naphthalene was the only one with average concentration across the survey area as a whole above reference levels, where concentrations were above the BAC at 21 stations and above the TEL at 3, while they were never above the ERL, PEL and the proposed AL1. The 21 stations with Naphthalene concentrations above the BAC were mostly localised within Milford Haven and in the offshore section of the cable route and around the edges of the main array (Figure 13). No pattern emerged when comparing stations with high Naphthalene concentrations with the correspondent depth, TOC, TOM or mud content which could have been related to transportation and deposition of Naphthalene across the survey area; no macrobenthic anomalies were identified at these locations to suggest any adverse effects were present. In fact, the same Macrobenthic Groups occurred regardless of Naphthalene (and more in general PAHs) concentrations. When assessing the origin source of PAH compounds in sediments, the ratio between LMW and HMW PAHs was found to be lower than 1, at 78 stations indicating a pyrogenic origin, while it was found to be higher than 1 at 13 stations indicating a petrogenic origin (Figure 13). PAHs of pyrogenic origin can derive from various activities which ultimately involve the combustion of organic substances at high temperatures under low oxygen conditions. These may include incomplete combustion of motor fuels, or products derived from the foundry and steel industries. Petrogenic PAHs typically include crude oil and refined crude oil products such as gasoline, heating oil, asphalt, and coal. It is not uncommon to find a mixture of petrogenic and pyrogenic PAHs sources in marine sediment (EPRI 2008, Aly Salem et al. 2014).

THC on average was higher in nearshore stations than at offshore stations, which is most likely due to the proximity of the nearshore stations to urban settings and therefore to potential additional sources of hydrocarbons. However, when assessing the source origin of hydrocarbons based on the CPI, it resulted that 103 out of 107 stations had hydrocarbons of biogenic origin. Diatom populations have been found to be a biogenic source of n-alkanes in aquatic environments especially for the n-alkanes C15-C31, which fits well with C-16 and C-31 being the most abundant alkanes across the survey area. Additionally, due to their high molecular weight, C-31 alkanes tend to precipitate easily in the sediments (Al-hejuje et al. 2015). No pattern emerged when comparing THCs with the correspondent TOC, TOM or mud content which could have been related to transportation and deposition of hydrocarbons across the survey area. No macrobenthic anomalies were identified at locations with high phytane concentrations (ST074 and ST094) suggesting no adverse effects were present. The same Macrobenthic Group E occurred across the Project Erebus main array and offshore export cable route regardless of phytane (and more in general hydrocarbons) concentrations.

Comparison between the concentrations of determinands measured in the sediments of the Celtic Sea as part of the OSPAR "Levels and trends in marine contaminants and their biological effects monitoring programme" (OSPAR 2019), to those across the survey area, showed that concentrations were consistently lower across the survey area than those recorded in the Celtic Sea region (Table 16). To note that the OSPAR Celtic Sea Region comprises Milford Haven which is in close proximity to the Project Erebus Nearshore stations, and Celtic Sea Offshore area which is close to the Project Erebus Offshore stations.

Table 16 Comparison of mean concentrations of key metals ($mgkg^{-1}$) and PAHs (μgkg^{-1}) sampled across the Project Erebus FLOW survey area with previous records from OSPAR (2019).

Analyte		Milford Haven (OSPAR)	Project Erebus Nearshore	Celtic Sea Offshore (OSPAR)	Project Erebus Offshore
Metals	As	23.49	11.30	21.76	15.66
	Cd	0.31	-	0.57	-
	Cr	207.69	42.55	95.19	19.07
	Cu	77.37	7.10	24.97	4.28
	Hg	0.13	-	0.27	-
	Ni	124.89	16.30	48.21	7.65
	Pb	63.41	19.86	45.81	14.03
	Zn	293.24	40.57	169.15	24.58
PAHs	Anthracene	159.61	14.74	27.05	5.95
	Benzo[a]anthracene	631.02	33.08	103.37	10.88
	Benzo[a]pyrene	651.25	33.48	97.05	10.72
	Benzo[ghi]perylene	391.70	26.03	93.55	7.61
	Chrysene	318.76	38.15	62.06	11.19
	Dibenzothiophene	-	8.09	16.68	3.74
	Fluoranthene	1033.74	57.92	232.15	14.15
	Indeno[123,cd]pyrene	405.26	29.15	153.57	8.48
	Naphthalene	181.47	19.86	70.29	6.68
	Phenanthrene	633.20	43.53	116.83	11.09
	Pyrene	805.10	46.24	132.27	11.76

9.2. Water Chemistry

Several guidelines exist to assess the degree of contamination and likely ecological impacts of contaminants in seawater. The Cole et al. (1999) report presents a list of guidelines relating to damages to species and habitats through deleterious changes to environmental conditions, including seawater. It outlines the water quality guidelines and standards used for the protection of the marine environment. Environmental Quality Standards (EQS) have been derived under the requirements of the Dangerous Substances Directive which classifies substances as List I and List II. The UKTAG (2013) report is written by the UK Technical Advisory Group on the WFD. It is a recommendation for the update of existing standards in the Dangerous Substrates Directive for certain dangerous substances. This update is based on stakeholder engagement and improved scientific understanding. With only a few exceptions, all the analysed water samples had contaminant (e.g., metals, PAHs) concentrations below detection limits and thus below any of the reference guidelines mentioned above.

Based on suspended solids concentration, seawater in the section of the export cable route which passes through the WFD waterbodies was overall deemed to be clear, with only 8 stations having slightly higher suspended solids concentrations indicative of intermediate turbidity of seawater. Nevertheless, when assessing concentration of ammoniacal nitrogen across the sampling stations, this was of high quality standard for both clear and intermediate turbidity seawater. To note that the Pembrokeshire/Sir Benfro Marine SAC Assessment (NRW 2018) recently reported moderate quality status for both inner and outer Milford Haven waterbodies based on dissolved inorganic nitrogen concentration.

Only Zn, Cd and Ni were found in elevated concentrations at a handful of stations. Stations with trace metals above reference values were located either within Milford Haven such as nearshore stations ST01, ST02 and ST12 with elevated Zn concentrations or at the entrance of Milford Haven such as stations ST16 and ST18 with elevated Cd concentrations, and stations ST14 and ST19 with elevated Ni concentrations. No macrobenthic anomalies were recorded among these stations suggesting no adverse effects on the communities at these locations; the same Macrobenthic Groups occurred regardless of trace metal concentrations (Figure 20).

No direct comparison of trace metal concentrations in seawater was possible because no data was available at stations in close proximity of the survey area. Nevertheless, a more regional comparison was conducted based on average metal concentrations measured in the Celtic Sea (Ireland) as part of the CEMP (Coordinated Environmental Monitoring Programme) Assessment Report 2019 (OSPAR 2019). Average Cadmium concentrations in the Celtic Sea (Ireland) have previously been recorded as 0.05 $\mu g / L^{-1}$ between 2012 and 2014 (OSPAR 2019). Average Cd concentration identified during the Project Erebus FLOW survey (n=24) was of 0.24 $\mu g / L^{-1}$, much higher than the regional average, yet lower than the OSPAR EQS. Low levels of Pb have previously been recorded between 0.02 $\mu g / L^{-1}$ and 0.1 $\mu g / L^{-1}$ in the Celtic Sea (Ireland) during the years 2013 and 2015 (OSPAR 2019). Similarly, during the Project Erebus FLOW survey, Pb was recorded below LoD across all samples and stations. Levels of Ni have previously ranged between 0.12 µg / L^{-1} and 0.34 µg / L^{-1} in the Celtic Sea (Ireland) during 2013 and 2015 (OSPAR 2019). Most stations sampled during the Project Erebus FLOW survey presented levels of Ni below LoD; however, two samples had elevated Ni concentrations of 5 µg / L^{-1}. To note that this comparison is based on a very limited number of samples (n=2), as most samples and stations across the Project Erebus survey area reported Ni concentrations below LoD and therefore caution needs to be used when evaluating these results.

9.3. Macrobenthos

A diverse macrobenthic community was identified across the survey area with a total of 13,534 individuals and 361 taxa recorded. However, most stations were characterised by the presence of juveniles of the brittle stars Amphiuridae which occurred in 72.9 % of the samples, while the bivalve *K. bidentata* was the overall most abundant species across the survey area (Figure 14). That between brittle stars and *K. bidentata* is a frequently occurring natural association.

Macrobenthic communities can be highly heterogenous as they are heavily influenced by ambient environmental conditions such as sediment composition (Cooper et al. 2011), hydrodynamic forces and physical disturbance (Hall 1994), depth (Ellingsen 2002) and salinity (Thorson 1966). Macrobenthic abundance (N) and richness (S) varied across the Project Erebus survey area (Section 8.4.1) however no obvious pattern was observed between nearshore and offshore stations (Figure 16 and Figure 17). Conversely, the eight Macrobenthic Groups identified by the multivariate cluster analysis (Section 8.5), did show a clear distinction between nearshore (ST01 to ST032) and offshore (ST033 to ST119) stations. Macrobenthic Group E represented these offshore stations and was characterised by high abundances of *K. bidentata,* juveniles of Amphiuridae as well as adult individuals of the brittle star *A. filiformis* and the pea urchin *E. pusillus* (Figure 20). In contrast, nearshore stations located along the cable route showed a higher variability in community composition as the cable route intersected a variety of sediment habitats and environmental gradients (from intertidal to offshore). Sediment composition is a key factor in determining macrobenthic community structure (Hall 1994, Cooper et al. 2011), itself defined by ambient conditions. This was clearly reflected in the Macrobenthic Groups detected along the nearshore cable route stations and notably within Macrobenthic Group D that was characterised by the dominance of *K. bidentata* and polychaetes, indicating an affinity for muddier substrates compared to Macrobenthic Groups G and H dominated by various polychaetes including *S. bulbosa* more typical of impoverished circalittoral mixed gravelly sand.

It should also be considered that the lack of replicates at each station is likely to have led to increased variability within the dataset. Grabs sample a small area and so a single replicate is less likely to be entirely representative of the broader area of seabed (Downing & Downing 1992), and only a portion of the macrobenthic community is likely to be present in a single sample which can lead to a large number of statistically significant faunal groups (SIMPROF test resulted in 29 statistically significant similar groups). Additionally, relatively few numbers of individuals and taxa in a number of samples can lead to increased numbers of statistically significant groups as indicated by the relatively loose clustering of the macrobenthic groups (Warwick 1988). This was the case for the Macrobenthic Groups A, B, C and F (Figure 19**Error! Reference source not found.**). Having said this, the sampling strategy and design adopted here met the purposes and satisfied the aims of the EBS assessment which were to characterise seabed sediments and associated benthic communities and mapping key features and sensitive habitats (e.g. Annex I geogenic and biogenic reefs). This data will be fundamental for future comparisons following the construction of the Project Erebus.

9.4. EUNIS Habitats/Biotopes

The main habitats identified across the survey area at which seabed imagery and grab samples were obtained comprised primarily of the EUNIS classifications A5.251 '*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand' and A5.351 '*Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud' in the offshore section of the cable route and in the main array (ST 033-119).

Stations located on the cable route within the Milford Haven Waterway (ST 01-015) were characterised by various EUNIS biotopes including A5.143 '*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand', A5.334 '*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud', and A5.443 '*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment'. Stations located on the outer fringes of the Milford Haven Waterway and the nearshore area of the cable route (ST 018-032) were best represented by the EUNIS biotope A5.14 'Circalittoral coarse sediment', A5.25 'Circalittoral fine sand' and A5.44 'Circalittoral mixed sediments.'

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

9.5. Annex I Habitats

Annex I bedrock and stony reef habitats were identified in areas of the cable route, mostly along the nearshore sections around the entrance to Milford Haven (Figure 23). To note that Annex I bedrock was also identified in the shallow subtidal area close to the West Angle Bay landfall (survey block WA01). Here sublittoral fringe rock extended to the infralittoral zone forming a continuous feature which can be assigned as Annex I reef (JNCC 2015). Interestingly, transect T_013 located in proximity of West Angle Bay did not show evidence of Annex I reef habitats (grey dots on Figure 23) as none of the seabed images with rocky substrates covered an area large enough to qualify as an Annex I reef. Nevertheless, these few images showing kelp on bedrock in the shallower part of the transect (T_013) proved that the rocky shore observed in the intertidal zone continues in the sublittoral zone hence forming an Annex I reef habitat (JNCC 2015; OEL 2021). The stony reefs were assessed to be of both low and medium resemblance (as per Irving (2009). In general, where stony and bedrock reefs were recorded along the same transects, they were deemed to form mosaic habitats meaning it was difficult to differentiate between the two reef types given the lack of clear boundaries in the acoustic data. These features were deemed to form part of the designated Annex I 'reef' feature of the Pembrokeshire/Sir Benfro Forol Marine SAC, which, on a whole, is currently deemed to be in an 'Unfavourable' conservation status (NRW 2018). This is largely a result of the impacts of the high levels of nutrients in the water column within the Milford Haven waterway and high levels of chemicals such as tributyltin compounds (TBT), mercury and its compounds and brominated diphenylether (BDPE) on the structure and functioning of the feature. Despite this, the rocky shores of the Milford Haven Waterway are considered to be in good condition (NRW 2018) including those at West Angle and Sawdern Point which were the object of the intertidal survey (OEL 2021).

Two areas of sandy habitat were identified as likely Annex I Sandbank habitats along the export cable route (Figure 24). The first covered an area of 1.56 km^2 and was assigned a 'High' confidence score given its topographic and sedimentary characteristics as well as the fact that it intersects, and forms part of, the known Turbot Bank Annex I sandbank feature (19.08 km^2) which is currently deemed to be in an 'Unfavourable' conservation status (NRW 2018). This is mostly due to a decline in species richness, abundance and diversity. The second area was found further along the export cable corridor and was deemed to meet the topographic and sedimentary criteria but was assigned a 'Potential' confidence score due to the lack of known adjacent sandbanks. It should be noted that this 'potential' sandbank feature is located outside the Pembrokeshire Marine /Sir Benfro Forol SAC and does not therefore constitute part of the designated Annex I Sandbank feature of the SAC.

No Annex I biogenic reef habitat was observed across the survey area. *S. spinulosa* tube aggregations were recorded in only two images and found in low numbers in five grab samples which were not deemed to meet the Annex I reef qualifying criteria (Gubbay 2007).

9.6. Other Features of Interest

The presence of low-density *Z. marina* shoots along transect T_001 extending to the shallow subtidal area of the Sawdern Point landfall suggest that a seagrass meadow may be present in this area. Like many terrestrial plants, seagrasses senesce in the autumn and winter with storms causing dying shoots and leaves to break off and become redistributed. Given the time of the year the survey was undertaken, it is likely that the observation of low-density shoots is indicative that this area supports a seagrass bed which at the time was in a state of senescence. The majority of the plant biomass would have therefore been below the sediment surface at the time of the survey in the form of the system of rhizomes and roots whereas the more visible shoots are lost. Due to the low shoot density, the characteristic acoustic signature of dense seagrass beds was not evident, nor was there any clear evidence upon review of the aerial imagery collected as part of the Project Erebus intertidal surveys that overlapped with the acoustic data. As such the mapping produced for this area was assigned a low confidence score with further survey work required during the period of peak biomass (August/September) to confirm the presence/absence of a meadow and increase the confidence in the mapping. If a seagrass bed were to be present in the area, this would be protected as a Habitat of Principal Importance under Section 7 of the Environment (Wales) Act 2016.

No beds of maerl or native oysters (*O.edulis*) were observed across the survey area although there were observations of discrete patches of live and dead maerl at one location (EBS station 003) and occasional native oysters at numerous locations along the cable route. The presence of *O. edulis* is notable given that the beds they can form are protected as Habitats of Principle Importance (Environment Wales Act, 2016) and through inclusion on the OSPAR list of threatened and/or declining species and habitats. The presence of alive or dead *O. edulis* may be indicative of a previous or nearby bed in the area.

The INNS slipper limpet (*C. fornicata*) was recorded forming aggregations along transect T_014 and individuals were also recorded in nearshore station ST03. *C. fornicata* is an invasive non-native species (INNS) that originated from the eastern USA and has been present in the UK for over a century. Initially confined to the south and south-east coast of England, it is now common in Europe. In Wales *C. fornicata* has been first found in the Menai Strait (McMillan 1939) and has locally high abundances in Milford Haven, close to the survey area (Bohn et al. 2013).

10. References

Al-hejuje MM, Hussain NA, Al-saad H. T. (2015) Total Petroleum Hydrocarbons (TPHs) , n-alkanes and Polynuclear Aromatic Hydrocarbons (PAHs) in water of Shatt Al-Arab River – part 1. Glob J Biol Agric Heal Sci.

Aly Salem DMS, Morsy FAEM, El Nemr A, El-Sikaily A, Khaled A (2014) The monitoring and risk assessment of aliphatic and aromatic hydrocarbons in sediments of the Red Sea, Egypt. Egypt J Aquat Res.

Bohn K, Richardson CA, Jenkins SR (2015) The distribution of the invasive non-native gastropod Crepidula fornicata in the Milford Haven Waterway, its northernmost population along the west coast of Britain. Helgol Mar Res 69:313–325.

Bohn K, Richardson CA, Jenkins SR (2013) The importance of larval supply, larval habitat selection and post-settlement mortality in determining intertidal adult abundance of the invasive gastropod Crepidula fornicata. J Exp Mar Bio Ecol.

Carr H, Wright H, Cornthwaite A, Davies J (2016) Assessing the contribution of Welsh MPAs towards and ecologically coherent MPA network in 2016. Jt Nat Conserv Committee.

CCME (2001) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Environ Prot.

Clarke K., Tweedley JR, Valesini FJ (2014) Simple shade plots aid better long-term choices of data pre-treatment in multivariate assemblage studies. J Mar Biol Assoc United Kingdom 94:1–16.

Clarke KR, Gorley RN (2015) PRIMER v7: User Manual/Tutorial.

Cole S, Codling ID, Parr W, Zabel T (1999) Guidelines for managing water quality impacts within UK European marine sites.

Cooper K, Mason C (2019) Regional Seabed Monitoring Programme (RSMP) Protocal for Sample Collection and Processing. Version 7.0.

Cooper KM, Curtis M, Wan Hussin WMR, Barrio Froján CRS, Defew EC, Nye V, Paterson DM (2011) Implications of dredging induced changes in sediment particle size composition for the structure and function of marine benthic macrofaunal communities. Mar Pollut Bull 62:2087–2094.

DEFRA (2003) The use of Action Levels in the Assessment of Dredged Material Placement at Sea and in Estuarine Areas under FEPA (II), Final Project Report.

Downing JA, Downing WL (1992) Spatial aggregation, precision, and power in surveys of freshwater mussel populations. Can J Fish Aquat Sci.

Dubois S, Retiere C, Olivier F (2002) Biodiversity associated with Sabellaria alveolata (Polychaeta: Sabellariidae) reefs: effects of human disturbances. J Mar Biol Assoc UK 82:817–826.

Edokpayi JN, Odiyo JO, Popoola OE, Msagati TAM (2016) Determination and distribution of polycyclic aromatic hydrocarbons in rivers, sediments and wastewater effluents in Vhembe District, South Africa. Int J Environ Res Public Health.

Eleftheriou A, Basford D. (1989) The macrobenthic infauna of the offshore northern North Sea. J Mar Biol Assoc 69:123–143.

Ellingsen K (2002) Soft-sediment benthic biodiversity on the continental shelf in relation to environmental variability. Mar Ecol Prog Ser 232:15–27.

Environment Agency (2015) The Water Framework Directive (Standards and Classification) Directions (England and Wales). Water Framew Dir.

EPRI (2008) Examination of the Sources of Polycyclic Aromatic Hydrocarbon (PAH) in Urban Background Soil. Palo Alto, CA.

Fagbote O (2013) Characterization and Sources of Aliphatic Hydrocarbons of the Sediments of River Oluwa at Agbabu Bitumen Deposit Area, Western Nigeria. J Sci Res Reports.

Folk R. (1954) The distribution between grain size and mineral composition in sedimentary rock nomenclature. J Geol 62:344–359.

Golding N, Albrecht J, McBreen F (2020) Refining the criteria for defining areas with a 'low resemblance' to Annex I stony reef. JNCC Rep No 656.

Gubbay S (2007) Defining and managing Sabellaria spinulosa reefs: Report of an inter-agency workshop. JNCC Rep No405 44:22.

Guerra-García JM, González-Vila FJ, García-Gómez JC (2003) Aliphatic hydrocarbon pollution and macrobenthic assemblages in Ceuta harbour: A multivariate approach. Mar Ecol Prog Ser.

Hall SJ (1994) Physical disturbance and marine benthic communities: life in unconsolidated sediments. Ocean Mar Biol An Annu Rev 32:179–239.

Hitchin R, Turner J, Verling E (2015) Epibiota Remote Monitoring from Digital Imagery: Operational Guidelines. NMBAQC JNCC.

Holstein J (2018) Worms: Retriving Aphia Information from World Register of Marine Species. package ve.

Hunt C, Demšar U, Dove D, Smeaton C, Cooper R, Austin WEN (2020) Quantifying Marine Sedimentary Carbon: A New Spatial Analysis Approach Using Seafloor Acoustics, Imagery, and Ground-Truthing Data in Scotland. Front Mar Sci.

Ines Z, Amina B, Mahmoud R, Dalila S-M (2013) Aliphatic and Aromatic Biomarkers for Petroleum Hydrocarbon Monitoring in Khniss Tunisian-Coast, (Mediterranean Sea). Procedia Environ Sci.

Irving R (2009) The identification of the main characteristics of stony reef habitats under the Habitats Directive. Summary report of an inter-agency workshop 26-27 March 2008. JNCCJNCC Rep No 432:44.

Jenkins C, Eggleton J, Barry J, O'Connor J (2018) Advances in assessing Sabellaria spinulosa reefs for ongoing monitoring. Ecol Evol 8:7673–7687.

JNCC (2018) Marine habitat correlation tables version 201801

JNCC (2015) The Marine Habitat Classification for Britain and Ireland Version 15.03. https://mhc.jncc.gov.uk/

Jones R., Hawes J, Griffin R., Unsworth RK. (2020) Improving benthic biodiversity assessments in turbid aquatic environments. Press:1–13.

Junttila J, Carroll J, Dijkstra N (2015) Variability of present and past PAH (Polyaromatic hydrocarbons) concentrations in sediments of the SW Barents Sea. Nor Geol Tidsskr.

Kafilzadeh F, Shiva AH, Malekpour R (2011) Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Water and Sediments of the Kor River, Iran. Middle-East J Sci Res.

Langenkämper D, Zurowietz M, Schoening T, Nattkemper TW (2017) BIIGLE 2.0 - Browsing and Annotating Large Marine Image Collections. Front Mar Sci 4:83.

Limpenny DS, Foster-Smith RL, Edwards TM, Hendrick VJ, Diesing M, Eggleton JD, Meadows WJ, Crutchfield Z, Pfeifer S, Reach IS (2010) Best methods for identifying and evaluating Sabellaria spinulosa and cobble reef. Aggreg Levy Sustain Fund Proj MAL0008:134.

Long D (2006) BGS detailed explanation of seabed sediment modified folk classification. Folk.

Mason C (2016) NMBAQC's Best Practice Guidance - Particle Size Analysis (PSA) for Supporting Biological Analysis.

Mason C, Lonsdale J, Vivian C, Griffith A, Warford L (2020) Review of Action Levels used for assessing dredging and disposal marine licences.

McBreen F, Wilson JG, Mackie ASY, Nic Aonghusa C (2008) Seabed mapping in the southern Irish Sea: Predicting benthic biological communities based on sediment characteristics. In: *Hydrobiologia*.

McMillan NF (1939) Early records of crepidula in english waters. J Molluscan Stud.

Mercer T (2016) Intertidal monitoring , Pen Llyn a ' r Sarnau SAC August 2013.

MMO (2015) High Level Review of Current UK Action Level Guidance. A report produced for the Marine Management Organisation. MMO Project No: 1053.

Natural England, Countryside Council for Wales (2009) The Severn Estuary / Môr Hafren European Marine Site - Natural England & the Countryside Council for Wales' advice given under Regulation 33(2)(a) of the Conservation (Natural Habitats, &c.) Regulations 1994, as amended.

NJDEP (2009) Ecological Screening Criteria (ESC).

NRW (2019) GN030a Benthic habitat assessment guidance for marine developments and activities: A guide to characterising and monitoring intertidal rocky shore habitats and rockpools. 1–46.

NRW (2018) Pembrokeshire Marine / Sir Benfro Forol Special Area of Conservation: Indicative site level feature condition assessments 2018. 67.

OEL (2021) Erebus Floating Offshore Wind Farm Intertidal Habitat Report.

OSPAR (2019) Levels and trends in marine contaminants and their biological effects – CEMP Assessment report 2018. Monit Assess Ser.

OSPAR, Webster L, Fryer R, Davies I, Roose P, Moffat C (2009) Background Document on CEMP Assessment Criteria for QSR 2010. Monit Assess Ser.

Page DS, Boehm PD, Douglas GS, Bence AE, Burns WA, Mankiewicz PJ (1999) Pyrogenic polycyclic aromatic hydrocarbons in sediments record past human activity: A case study in Prince William Sound, Alaska. Mar Pollut Bull.

Parry ME V (2019) Guidance on Assigning Benthic Biotopes using EUNIS or the Marine Habitat Classification of Britain and Ireland (Revised 2019).

Pearce B, Hill J., Wilson C, Griffin R., Earnshaw S, Pitts J (2011) Sabellaria spinulosa Reef Ecology and Ecosystem Services. The Crown Estate.

Pinder J (2020) Method for creating version 3 of the UK Composite Map of Annex I Sandbanks slightly covered by seawater all of the time.

R Core Team (2020) R: A Language and Environment for Statistical Computing.

Rees HL, Eggleton JD, Rachor E, Vanden Berghe E (2007) Structure and Dynamics of the North Sea Benthos. ICES Coop Res Rep no 288:258.

Seiter K, Hensen C, Schröter J, Zabel M (2004) Organic carbon content in surface sediments - Defining regional provinces. Deep Res Part I Oceanogr Res Pap.

Thorson G (1966) Some factors influencing the recruitment and establishment of marine benthic communities. Netherlands J Sea Res.

Turner JA, Hitchin R, Verling E, van Rein H, Hitching R, Verling E, van Rein H (2016) Epibiota remote monitoring from digital imagery: Interpretation guidelines.

UKTAG (2013) Updated Recommendations on Environmental Standards River Basin Management (2015-21) Final Report UK Technical Advisory Group on the Water Framework Directive.

Venkatesan MI (1988) Occurrence and possible sources of perylene in marine sediments-a review. Mar Chem.

Warwick RM (1988) Analysis of community attributes of the macrobenthos of FrierfjordILangesundfjord at taxonomic levels higher than species.

Wentworth C. (1922) A scale of grade and class terms for clastic sediments. J Geol 30:377–392.

Winterwerp JC, van Kesteren WGM (2004) Introduction to the Physics of Cohesive Sediment Dynamics in the Marine Environment.

Worsfold T, Hall D (2010) Guidelines for processing marine macrobenthic invertebrate samples: a Processing Requirements Protocol.