LLŶR FLOATING OFFSHORE WIND PROJECT

Llŷr 1 Floating Offshore Wind Farm

Environmental Statement

Volume 6: Appendix 19B – 2023 OEL Offshore Benthic Characterisation Survey

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Prepared by: Llŷr Floating Wind Ltd

FLOVENTIS ENERGY

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Glossary of project terms

Term	Definition
The Applicant	The developer of the Project, Llŷr Floating Wind Limited.
Array	All wind turbine generators, inter array cables, mooring lines, floating sub-structures and supporting subsea infrastructure within the Array Area, as defined, when considered collectively, excluding the offshore export cable(s).
Array Area	The area within which the wind turbine generators, inter array cables, mooring lines, floating sub-structures and supporting subsea infrastructure will be located.
Floventis Energy	A joint venture company between Cierco Ltd and SBM Offshore Ltd of which Llŷr Floating Wind Limited is a wholly owned subsidiary.
Landfall	The location where the offshore export cable(s) from the Array Area, as defined, are brought onshore and connected to the onshore export cables (as defined) via the transition joint bays.
Llŷr 1	The proposed Project, for which the Applicant is applying for Section 36 and Marine Licence consents. Including all offshore and onshore infrastructure and activities, and all project phases.
Marine Licence	A licence required under the Marine and Coastal Access Act 2009 for marine works which is administered by Natural Resources Wales (NRW) Marine Licensing Team on behalf of the Welsh Ministers.
Offshore Development Area	The footprint of the offshore infrastructure and associated temporary works, comprised of the Array Area and the Offshore Export Cable Corridor, as defined, that forms the offshore boundary for the S36 Consent and Marine Licence application.
Offshore Export Cable	The cable(s) that transmit electricity produced by the WTGs to landfall.
Offshore Export Cable Corridor (OfECC)	The area within which the offshore export cable circuit(s) will be located, from the Array Area to the Landfall.
Onshore Development Area	The footprint of the onshore infrastructure and associated temporary works, comprised of the Onshore Export Cable Corridor and the Onshore Substation, as defined, and including new access routes and visibility splays, that forms the onshore boundary for the planning application.
Onshore Export Cable(s)	The cable(s) that transmit electricity from the landfall to the onshore substation.
Onshore Export Cable Corridor (OnECC)	The area within which the onshore export cable circuit(s) will be located.
proposed Project	All aspects of the Llŷr 1 development (i.e. the onshore and offshore components).
Onshore Substation	Located within the Onshore Development Area, converts high voltage generated electricity into low voltage electricity that can be used for the grid and domestic consumption.
Section 36 consent	Consent to construct and operate an offshore generating station, under Section 36 (S.36) of the Electricity Act 1989. This includes deemed planning permission for onshore works.

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List of Abbreviations

BAC	Background Assessment Concentration
BDL	Below Detection Limits
BSH	Broadscale Habitats
CLOC	Clear Liquid Optical Chamber
CPI	Carbon Preference Index
DDC	Drop-down Camera
ECR	Export Cable Route
ERL	Effect Range Low
EUNIS	European Nature Information System
FOCI	Feature of Conservation Importance
HA	Habitat Assessment
HD	High Definition
LAT	Lowest Astronomical Tide
MBBS	Multi-beam backscatter
MBES	Multi-beam Echosounder
OEL	Ocean Ecology Ltd
OWF	Offshore Wind Farm
PAH	Polyaromatic Hydrocarbon
PEL	Probable Effect Level
PSD	Particle Size Distribution
SAC	Special Area of Conservation
SOCI	Species of Conservation Importance
SPA	Special Protection Area
SSS	Side-scan Sonar
SSSI	Site of Special Scientific Interest
TEL	Threshold Effect Level
TOC	Total Organic Carbon
USBL	Ultra-short Baseline

1. Non-Technical Summary

Introduction

Ocean Ecology Limited (OEL) were commissioned by N-Sea on behalf of Floventis Operates Ltd. to undertake a benthic characterisation survey of the Llŷr 1 and Llŷr 2 project areas, including the array, export cable corridor and landfall areas for the Offshore Wind Farm (OWF) developments. The Llŷr project areas are located in the approaches to the Bristol Channel in the Celtic Sea approximately 40 km offshore at water depths averaging 60 m to 70 m. The Export Cable Route (ECR) is located in water depths ranging between 15 m to 60 m and will run north towards Pembroke. Four nature conservation designations fall within or are partially overlapped by survey area including the Pembrokeshire Marine Special Area of Conservation (SAC).

Survey Strategy

A total of 30 stations across the ECR and OWF areas were sampled by Drop-Down Camera (DDC) and sediment grab sampling, with 8 located along the ECR and the remaining 22 in the OWF area. A further 6 Habitat Assessment (HA) locations were sampled with DDC transects. All 30 grab stations were successfully sampled for Total Organic Carbon (TOC), Particle Size Distribution (PSD) and macrobenthic analyses with a subset of 10 stations were sampled for sediment chemistry analysis. All survey operations were conducted onboard the DPII offshore support vessel *Braveheart spirit* between the 9th and 16th of December 2022, mobilising out of the port of Swansea. Note that a separate nearshore survey was conducted in January 2023, the results of which will be reported separately.

Sediment

Some variation in sediment type was observed between sampling stations with those located closer to shore along the cable route having typically coarser sediments than stations located within the OWF array area. The majority of stations were characterised by sand representing broad scale habitat (BSH) A5.2 (Sand and Muddy Sand). Four stations were classified as A5.1 (Coarse Sediment), two stations as A5.3 (Mud and Sandy Mud) and one station as A5.4 (Mixed Sediment).

TOC was measured at all sampled stations and ranged from 0.02 % to 0.59 % with an average value (± standard error, SE) of 0.16 ± 0.02 % across all stations slightly lower than the average TOC content of 0.5 %. for the deep ocean. of A total of 8 heavy and trace metals were measured at a subset of 10 stations distributed across the OWF and ECR areas including Aluminium (Al), Arsenic (As), Barium (Ba), 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. Only Arsenic exceeded reference levels and was above the CEFAS Action Level (AL) 1 (20 mg kg^{-1}) at four stations within the OWF area but was below CEFAS AL 2 reference level.

Polycyclic Aromatic Hydrocarbon (PAH) concentrations were also compared to reference levels to assess whether their concentrations in sediments were of concern. The only reference level to be exceeded was the Threshold Effect Level (TEL), with Naphthalene exceeding the TEL reference level at one station within the OWF area. None of the other PAH concentrations exceeded any of the reference levels.

The total oil in sediment samples analysed ranged from 4,190 µg kg^{-1} to 1,010 µg kg^{-1} with an average value (± SE) for the survey area of 2,111 ± 331.18 µg kg^{-1} within the regional range for the Celtic Sea. N-alkanes (saturates) in sediments had carbon chains length ranging between C12 and C36, with the dominant chains being C28 for the even numbered chains and C29 for the odd numbered chains. The highest concentration of total n-alkanes was recorded within the area (94.4 µg kg^{-1}), while the lowest concentration of 11.9 µg kg^{-1} was found part the way along the ECR. These values are within the expected range of n-alkanes for the Celtic Sea.

Organotins and Polychlorinated Biphenyl (PCB) concentrations were assessed and found to be below the limit of detection at all analysed stations.

Macrofauna

A mixed macrobenthic community was identified across the Llŷr survey area with a total of 5,195 individuals recorded over 226 taxa. Echinodermata taxa contributed most to abundance accounting for approximately 47 % of all individuals recorded. Annelida taxa contributed the most to the overall diversity of the macrobenthic assemblages at 46 %, and Mollusca taxa dominated the biomass accounting for the 42 % of the total.

Macrobenthic Groups identified by the multivariate analysis showed a clear distinction between stations. Macrobenthic Groups A and B represented the more offshore stations with Macrobenthic Groups A characterised by *Echinocyamus pusillus* and *Ophelia borealis* supported by fine sand and Macrobenthic Groups B characterised by high abundances of Amphiuridae and *Kurtiella bidentata* supported by muddier sediments. In contrast, nearshore stations fell into either Macrobenthic Group C or were outliers characterised by a macrobenthic community showing an affinity for coarser or more mixed sediments. Overall, the macrobenthic communities observed across the survey area are known to occur in the region depending on the substrate present.

European Nature Information System (EUNIS) Habitats/Biotopes

The EUNIS classification A5.26 'Circalittoral muddy sand' was the dominant seabed habitat identified, occupying the majority of the ECR and entirety of the OWF area. The most nearshore section of the ECR was characterised by A5.44 'Circalittoral mixed sediment'. Areas of A5.25 'Circalittoral fine sand' were identified and associated largely with potential sandbank features. Small areas of A4.13 'Mixed faunal turf communities on circalittoral rock', indicative of rocky reef features, were also observed. This was consistent with existing habitat mapping for the region.

Annex I Habitats

Two areas of sandy habitat were identified as likely Annex I Sandbank habitats along the ECR. 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 offshore along the ECR but was assigned a 'Potential' confidence score due to the lack of known adjacent sandbanks.

Small areas of Annex I bedrock and stony reef habitats were identified along areas of the cable route. The stony reefs were assessed to be of low 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. When falling within the SAC boundary, these features were deemed to form part of the designated Annex I 'reef' feature of the Pembrokeshire Marine SAC.

No Annex I biogenic reef habitat was observed across the survey area. Aggregations of *Sabellaria spinulosa* tubes were noted along one DDC transect however the patchy cover and limited extent meant that this area was not deemed to meet the criteria to be classified as an Annex I biogenic reef habitat.

Other Features of Interest

No native oyster beds were observed across the survey area. No invasive non-native species (INNS) were observed in the grab samples or seabed imagery.

2. Introduction

2.1. Project Overview

The Llŷr 1 and Llŷr 2 projects are part of a proposed offshore wind farm (OWF) development project by Floventis Operates Ltd. (hereafter, Floventis). The project comprises two separate 100 Mega Watt (MW) sites located south of Pembroke, on the Welsh coast. The Llŷr projects are located approximately 40 km offshore, in the approaches to the Bristol Channel in the Celtic Sea, at water depths averaging 65 m. The proposed Export Cable Route (ECR) spans water depths ranging between 15-60 m and will run north towards Pembroke. Each of the Llŷr sites will test new floating platform and mooring technologies, and explore innovative designs, materials, and construction approaches.

2.2. Project Background

Ocean Ecology Limited (OEL) were commissioned by N-Sea on behalf of Floventis, to undertake a benthic characterisation survey of the survey area, including the OWF, ECR, and landfall areas for both the Llŷr 1 and Llŷr 2 development areas. The findings will inform the Environmental Impact Assessment (EIA) in support of future consenting applications of the Llŷr project.

This report provides a summary of the survey methodologies employed during the offshore survey and presents mapping of the habitats encountered and an overview of baseline conditions of sediment and macrobenthos across the survey area. This was achieved through detailed interpretation of Drop-Down Camera (DDC) imagery, alongside high-resolution Multibeam Echosounder (MBES), Multibeam Backscatter (MBBS) and Side-Scan Sonar (SSS) data collected by N-Sea. This allowed for the determination of European Nature Information Systems (EUNIS) habitats and biotopes (where possible), and subsequent creation of full coverage mapping across the survey area including the delineation of important and environmentally sensitive features (e.g., Annex I habitats). The results of the macrobenthic and physicochemical analyses of the sediment samples collected have been used to update the habitat/biotope mapping presented in this report and define baseline conditions.

2.3. Aims and Objectives

The key objectives of the offshore benthic characterisation element of the survey were to:

- Provide an initial description of the seabed habitats within the offshore OWF and ECR areas based on DDC imagery;

- Identify and assess the status of species and habitats of conservation importance visible in DDC imagery, including Annex I protected species and habitats (e.g., *Sabellaria spinulosa* biogenic reef, or stony reef), and Annex V species[1] of the Habitats Regulations, species listed under Schedule 5 of the Wildlife & Countryside Act[2], OSPAR species and habitats[3] and designated features of the marine protected area (MPA) network;
- Confirm the presence / absence of any benthic invasive non-native species (INNS), benthic species non-native to UK waters, and benthic species non-native to the local habitat types (e.g., hard-substrate specialists in a wider sedimentary habitat).

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

3. Current Understanding

3.1. Existing Habitat Mapping

The 2021 EUSeaMap[4] broad-scale predictive model classifies and maps intertidal and subtidal habitats according to the EUNIS classification criteria. The system identifies keystone species that have been evidenced to inhabit areas with certain environmental conditions and can, therefore, act as an indicator of overall community composition. The EUSeaMap data indicated that the habitats present across the proposed survey area primarily consisted of deep circalittoral sand (A5.27), circalittoral fine sand (A5.25), circalittoral muddy sand (A5.26), and circalittoral coarse sediment (A5.14), as shown in Figure 1.

[4] EMODnet EUSeaMap viewer is available here.

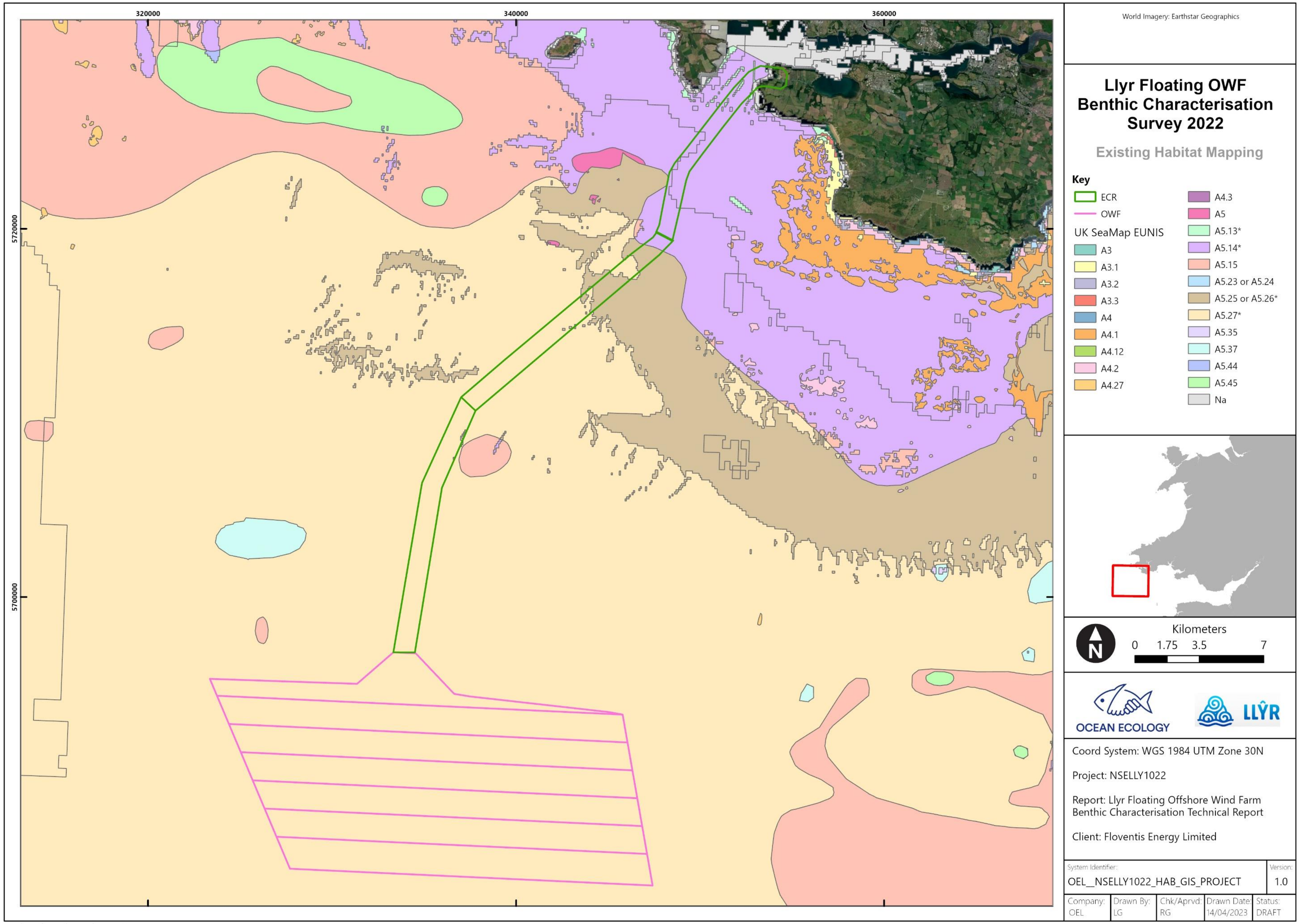

Figure 1 Known EUNIS classification mapping across the Llŷr ECR and OWF. * indicate BSH areas intersected by the ECR and OWF areas.

3.2. Designated Sites

3.2.1. Skomer, Skokholm, and the Seas off Pembrokeshire Special Protection Area

The proposed survey area intersects the eastern extent of the Skomer, Skokholm, and the Seas off Pembrokeshire special protection area (SPA) (Figure 2 and Figure 3) which is classified for the protection of the European storm-petrel (*Hydrobates pelagicus*), the Manx shearwater (*Puffinus puffinus*), the Atlantic puffin (*Fratercula arctica*), the lesser black-backed gull (*Larus fuscus*), the red-billed chough (*Pyrrhocorax pyrrhocorax*), the short-eared owl (*Asio flammeus*), and breeding seabird assemblages. The SPA extends beyond the 12 nautical mile boundary, lying partly in Welsh territorial waters and partly in UK offshore waters, meaning Natural Resources Wales (NRW) and the Joint Nature Conservation Committee (JNCC) are responsible for providing statutory advice.

3.2.2. Bristol Channel Approaches Special Area of Conservation

The proposed OWF intersects the Bristol Channel Approaches special area of conservation (SAC) that lies along the south-west coasts of Wales and England (Figure 2 and Figure 3). This site connects the Bristol Channel from Carmarthen Bay, in the north, to the northern coasts of Devon and Cornwall, in the south. The site has been designated for the protection of Annex II harbour porpoise (*Phocoena phocoena*) and is within the Celtic and Irish Seas Management Unit. Natural England (NE), NRW and JNCC have joint responsibility in producing statutory advice for this site.

3.2.3. West Wales Marine SAC

The proposed ECR, making landfall in west Wales, intersects the West Wales Marine SAC, which is situated off the coast of Wales extending from the Llŷn peninsula, in the north, to Pembrokeshire, in the south-west (Figure 2 and Figure 3). The SAC has been designated as an area of importance for Annex II *P. phocoena*. NRW along with the JNCC have respective advisory responsibilities for this site.

3.2.4. Pembrokeshire Marine / Sir Benfro SAC

The proposed ECR intersects the Pembrokeshire Marine / Sir Benfro SAC which extends from north of Abereiddy, on the north Pembrokeshire coast, to east of Manorbier in the south (Figure 2 and Figure 3). This multiple-interest site has been selected for the presence of 8 marine habitat features and 7 species features. Primary qualifying Annex I habitats include estuaries, large shallow inlets and bays, and reefs. Primary qualifying Annex II species include the grey seal (*Halichoerus grypus*) and the shore duck (*Rumex rupestris*). The relevant advisory body for the Pembrokeshire Marine / Sir Benfro SAC is NRW.

3.2.5. Limestone Coast of South Wales Limestone Coast of South West Wales / Arfordir Calchfaen de Orllewin Cymru SAC

The proposed ECR is situated 2.83 km west of the Limestone Coast of South West Wales SAC, which extends from Castlemartin at the western end of southern Pembrokeshire to the Bishopston Valley on the south east coast of Gower (Figure 2 and Figure 3). This multiple-interest site comprises a series of SSSI's and has been selected for the presence of 6 habitat features and 3 species features. The primary qualifying marine Annex I habitat for this site is 'submerged or partially submerged sea caves. Primary qualifying Annex II species include the greater horseshoe bat (*Rhinolophus ferrumequinum*) and early gentian (*Gentianella anglica*). The relevant advisory body for Limestone Coast of South West Wales/ Arfordir Calchfaen de Orllewin Cymru SAC is NRW.

3.2.6. Angle Peninsula Coast / Arfordir Penrhyn Angle Site of Special Scientific Interest

The Angle Peninsula Coast site of special scientific interest (SSSI) is a component part of the Pembrokeshire Marine 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 and intersects the proposed ECR along the Milford Haven coastline (Figure 2 and Figure 3). The relevant advisory body for the Angle Peninsula Coast / Arfordir Penrhyn Angle SSSI is NRW.

3.2.7. Milford Haven Waterway SSSI

The Milford Haven Waterway SSSI is also a component part of the Pembrokeshire Marine SAC. It is of special interest for a variety of natural features, including estuaries and marine habitats. This site is situated 142 m north of the proposed ECR, encompassing the coastline of the Milford Haven Waterway. NRW are the advisory body for Milford Haven Waterway SSSI.

3.2.8. Broomhill Burrows SSSI

The Broomhill Burrows SSSI is a component of the Limestone Coast Of South West Wales / Arfordir Calchfaen De Orllewin Cymru SAC. It is of special importance for Annex I fixed dune habitat and Annex II petalwort (*Petalophyllum ralfsii*). It is situated 2.83 km east of the proposed ECR and encompasses the sandy Beach of Freshwater West. NRW are the advisory body for Broomhill Burrows SSSI.

3.2.9. Features of Conservation Interest (FOCI)

Several historic records of species of conservation interest (SOCI) were identified within proximity to the proposed ECR and OWF, using Natural England Marine Habitats and Species Open Data (MHSOD).

Records within close proximity to the survey area comprised the ocean quahog (*Arctica islandica*), the European spiny lobster *(Palinurus elephas*), and the black seabream *(Spondyliosoma cantharus*) (Figure 4 and Figure 5).

3.2.10. Annex I Habitats

Several important and sensitive habitats are known to be present within the vicinity of and/or intersected by the survey area (Figure 4 and Figure 5), which comprise Annex I habitats that are a primary reason for selection of designated sites. These include:

- Estuaries
- Large shallow inlets and bays
- Reefs

In addition, Annex I habitats that are present as a qualifying feature are also encompassed in the area. These include:

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

3.2.10.1. Sandbanks Slightly Covered by Seawater All the Time

Sandbanks slightly covered by seawater all the time (hereafter referred to as sandbanks) consist of sandy sediments that are permanently covered by shallow seawater, 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, in addition to local 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 (Corallinaceae) beds.

There are several major sandbanks within the Pembrokeshire Marine SAC and, thus, near the survey area, including the Turbot Bank (19.1 km^2), which overlaps the ECR survey area, St Gowan Shoals (16.05 km^2) in the east of Turbot Bank, and The Knoll sandbank (5.09 km^2) in the vicinity of Skokholm Island. 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 shrimps, gastropods, crabs, and fish also inhabit these areas, as well as sandeels (*Ammodytes* sp.) – a key bird-prey species.

Where stable coarse sediments are present, species of foliose algae, hydroids, bryozoans, and ascidians may be present, which are representative of key nursery areas for various fish species. Such areas, therefore, often comprise key feeding grounds for numerous seabirds.

3.2.10.2. Large Shallow Inlets and Bays

The Pembrokeshire Marine 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. The wide range of environmental conditions supports high biodiversity. 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 (*Z. marina*).

Maerl Beds

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

Only one maerl bed formed by living *P. calcareum* is known in Wales and located in Milford Haven, 1.44 km northeast of the proposed ECR (Figure 4 and Figure 5). This habitat is of poor condition and has experienced substantial decline in range and abundance due to human impacts. 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.

3.2.10.3. Reefs

Geogenic Reef

Geogenic 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. They can be classified as either bedrock, or stony reefs. Based on existing habitat mapping derived from EMODnet, rocky habitats including bedrock and stony reefs are thought to occur within in the nearshore sector of the Llŷr ECR survey area but have not been recorded further offshore or across the OWF area (Figure 4 and Figure 5). Note that the nearshore environmental assessment will be carried out separately to this report, following completion of a dedicated nearshore survey that was completed in February 2023.

Stony Reef

Stony reef habitats occur when stable hard substrata, namely cobbles and boulders > 64 mm in diameter arise from the surrounding habitat, creating a habitat colonised by a variety of species. Numerous SAC sites have been designated in UK waters to protect stony reef habitats and associated communities. Such communities can be highly diverse, supporting assemblages of various corals, 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 ascidians.

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**

Sabellaria reefs are biogenic 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 (*S. 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 known *Sabellaria* spp. reefs have previously been recorded across the wider Llŷr Project survey area.

Due to their historic losses, sensitivity to anthropogenic disturbance, and biological importance, *Sabellaria* spp. reefs are afforded protection under several conservation policies and legislations. For example, *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'.

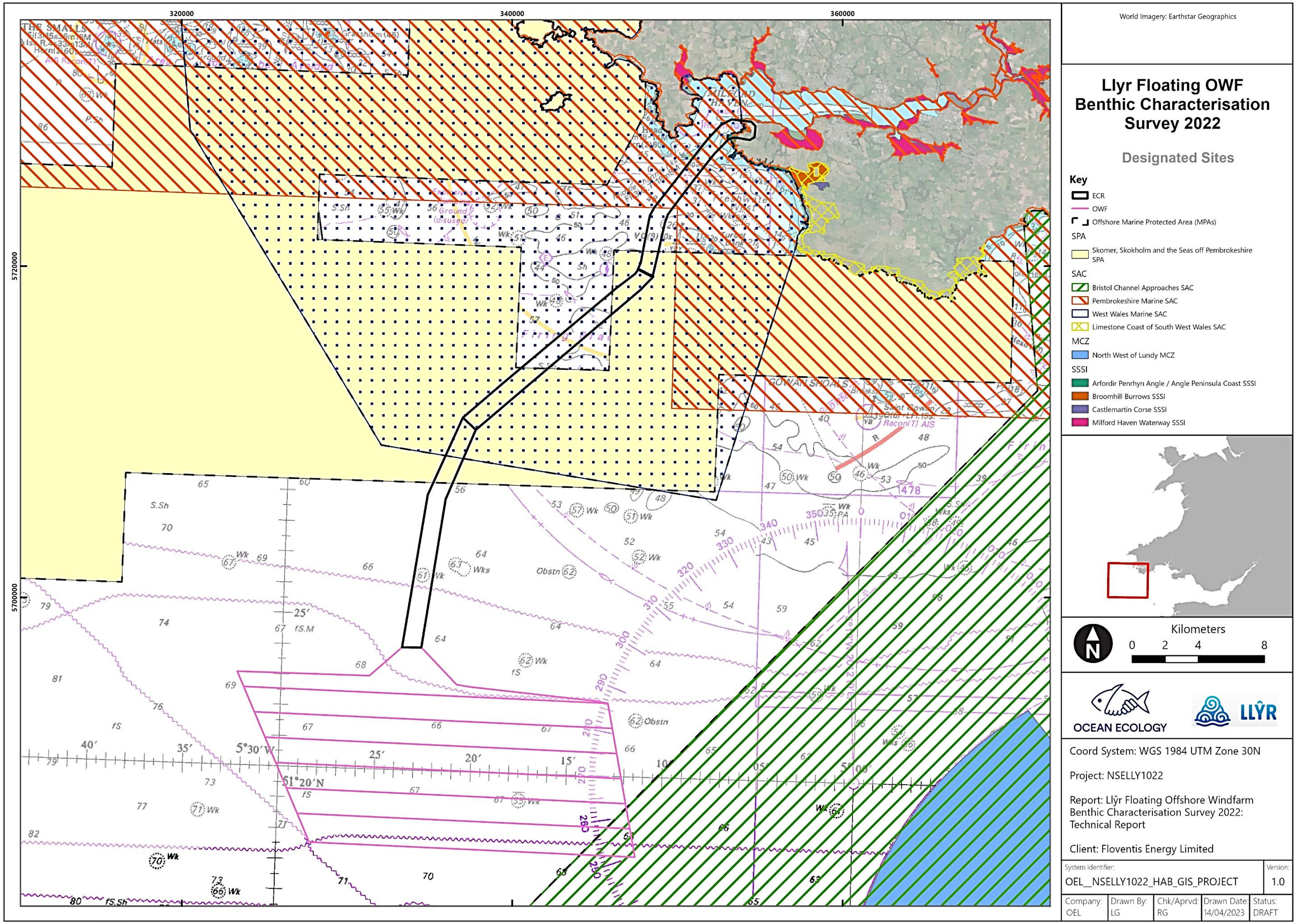

Figure 2 Designated sites in proximity to the Llŷr ECR and OWF survey area.

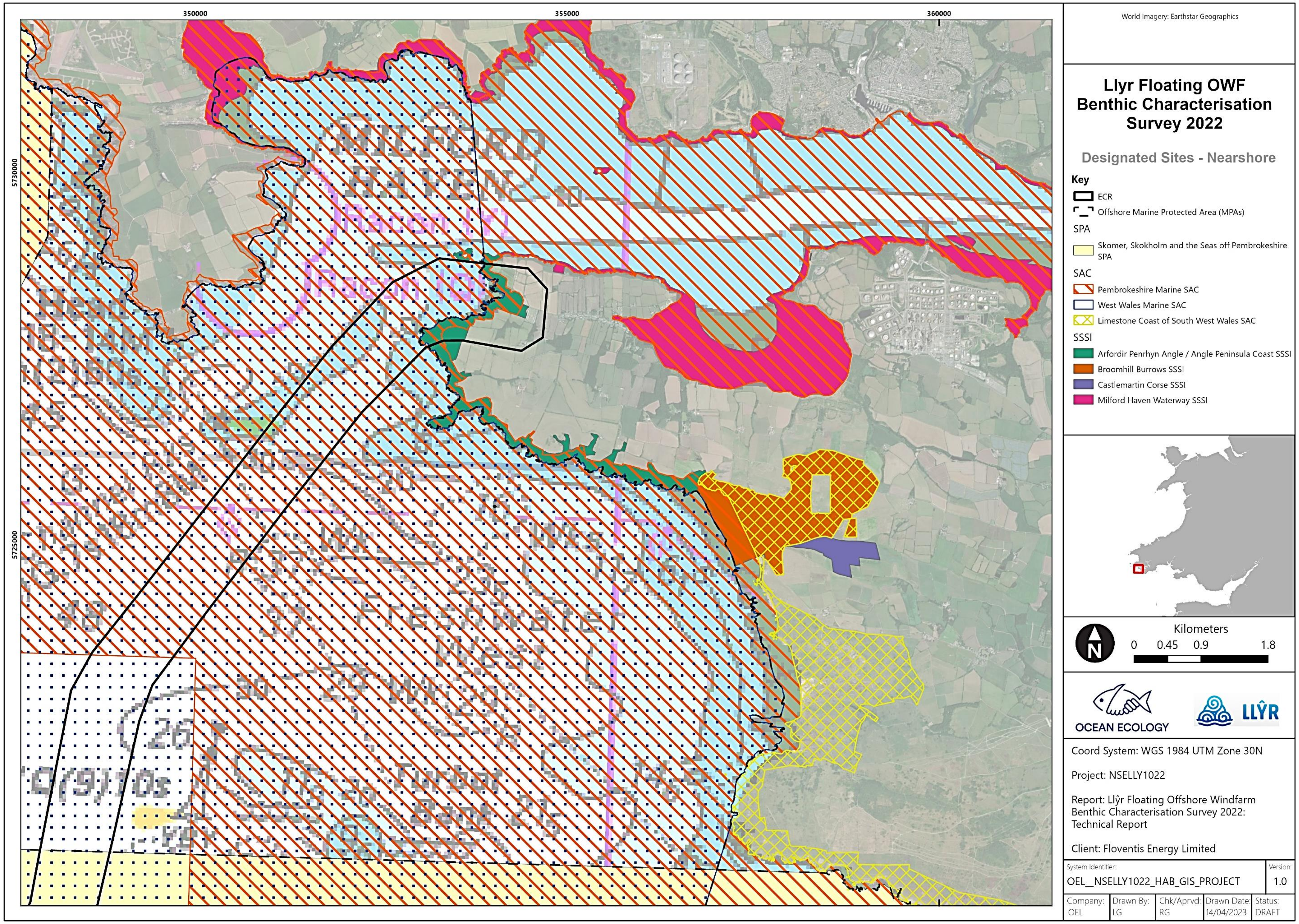

Figure 3 Nearshore focus of designated sites in proximity to the Llŷr ECR.

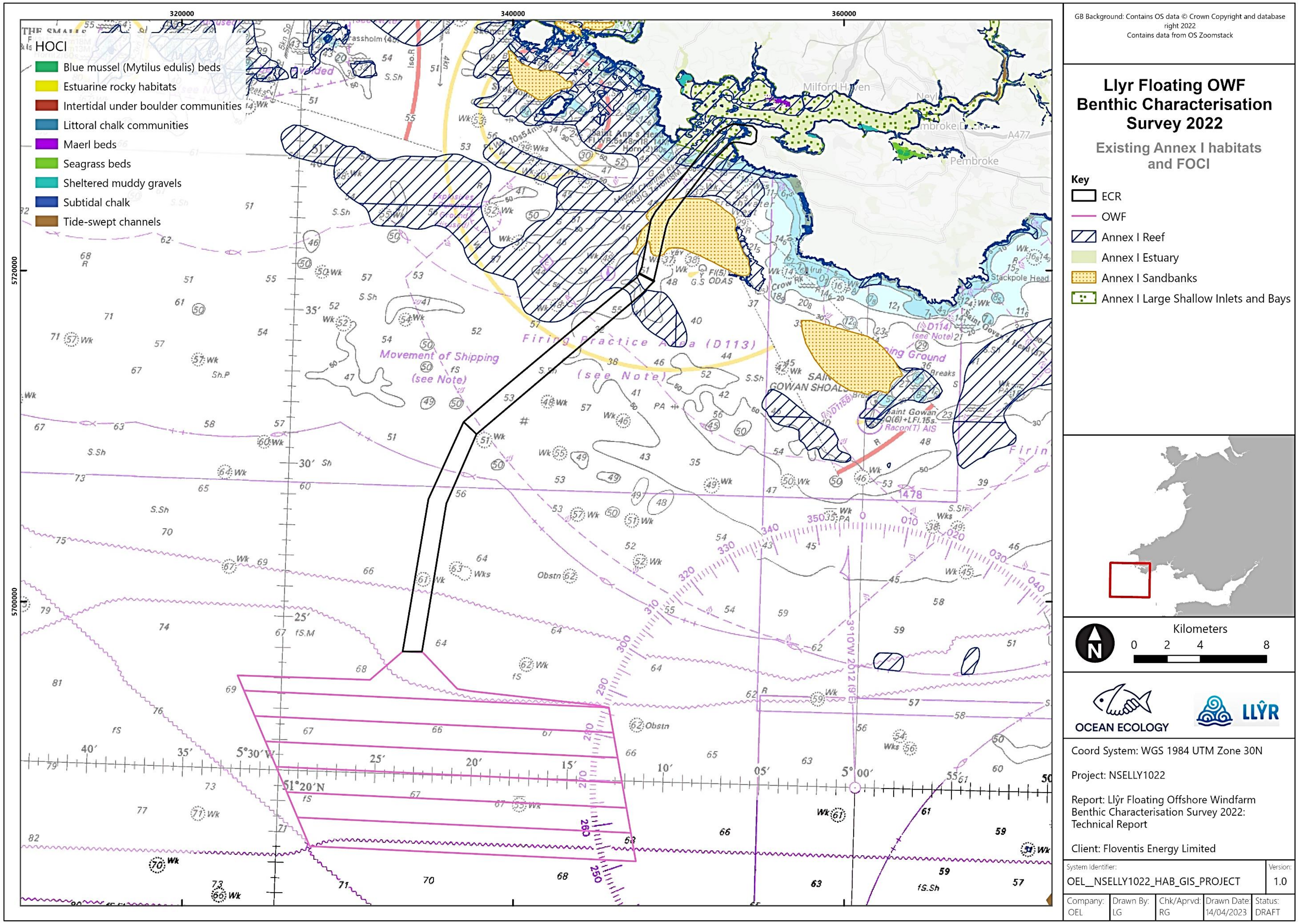

Figure 4 Annex I habitats and FOCI in proximity to the Llŷr ECR and OWF survey area.

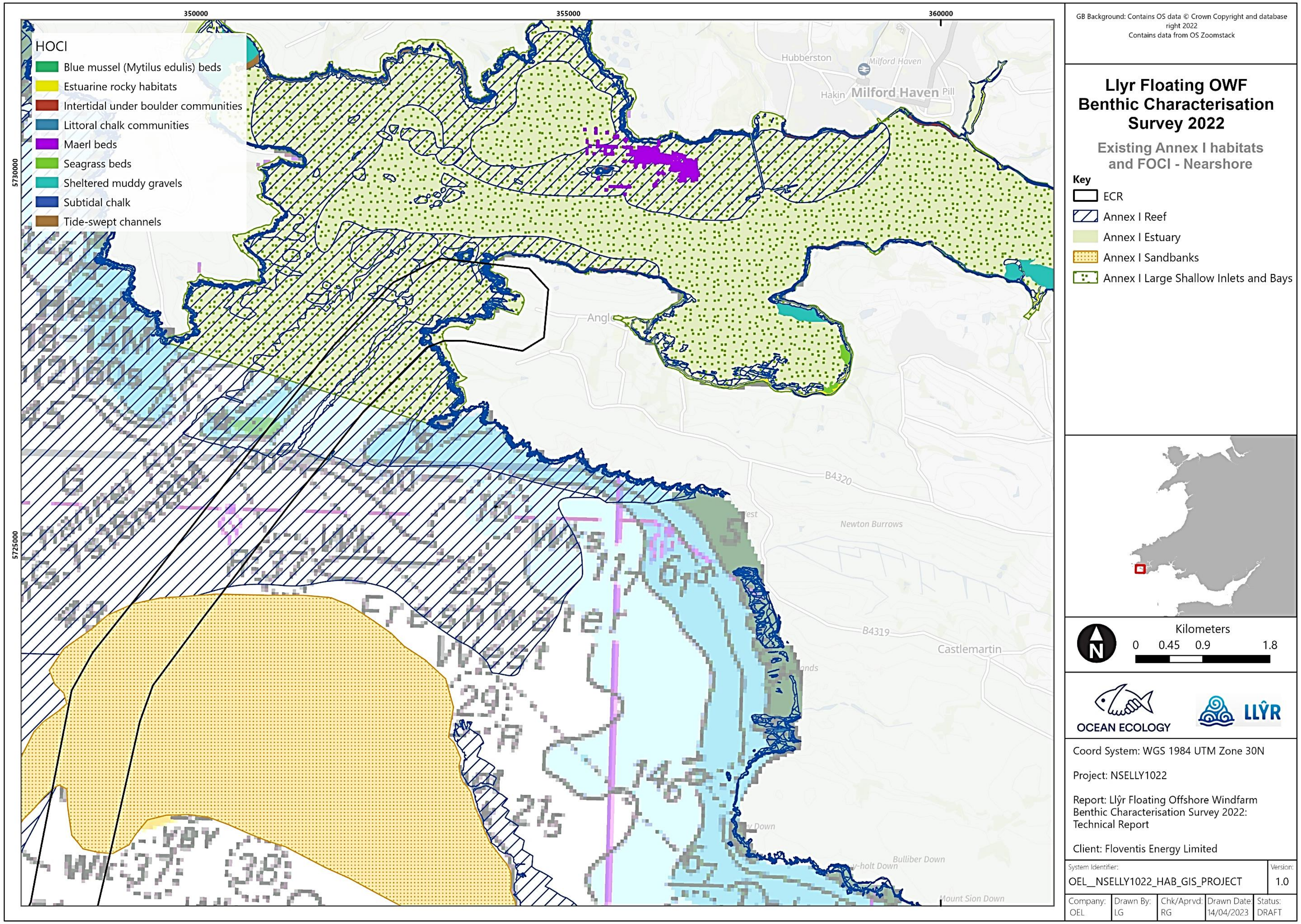

Figure 5 Nearshore focus of Annex I habitats and FOCI in proximity to the Llŷr ECR.

4. Survey Design

4.1. Overview

The benthic sampling plan was developed in consideration of Phase I of Natural England's "Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards" (Natural England 2021) to provide maximum geographic coverage of the proposed survey area, whilst also ensuring that all key habitats and communities likely to be encountered across the survey area are adequately targeted. The key principles underpinning the survey design were therefore to:

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

4.2. Rationale

The sampling plan was produced based on a stratified sampling approach across the proposed project OWF and ECR areas with micrositing of sampling stations informed by a detailed review and interpretation of the geophysical data collected by N-Sea throughout September to December 2022. Sampling stations were also located in consideration of all surface, subsurface, and subsea hazards and their respective exclusion / buffer zones.

The full catalogue of information assessed in the development of the sampling plan included:

- 2022 geophysical campaign processed MBES bathymetry, SSS, MBBS, and magnetometer data in mosaiced geotiff format;
- 2022 geophysical campaign processed magnetometer and SSS feature analysis to identify potential subsea hazards and Unexploded Ordnance (UXO);
- Interpreted seabed classification from 2022 geophysical campaign;
- All available GIS shapefiles and rasters in ESRI format, including: the OWF and ECR areas; planned and existing infrastructure, to include all oil and gas surface and subsurface infrastructure within the project boundary, or within close proximity to it; the latest relevant MPA boundaries; admiralty charts for the survey area (if available).

4.3. Sampling Design

The sampling plan was developed to ensure sampling was representative of the varying depths and habitats in a stratified design, whilst also considering the surface and subsurface infrastructures and hazards, and any other notable features identified from the geophysical data review.

The DDC investigation prior to grab sampling was to provide additional information on the sediment / substrate surface, and to determine suitability to collect grab samples (i.e., confirm the absence of subsea hazards and protected habitats not identified during the geophysical data review).

MBES and SSS were reviewed simultaneously to microsite samples around a stratified grid, which was initially overlain on the survey area. SSS and MBES were reviewed manually to identify areas of differing sediment type and seabed elevation. Sediment / substrate type was inferred from SSS based on the reflectivity (coarser sediments showing greater reflectivity), and seabed elevation was determined by review of MBES which presents water depth. A representative number of stations were attributed to each of the main Broadscale Habitats (BSH) to ensure coverage of the OWF area was proportional to the dominant BSH present, whilst also considering adequate spatial coverage. A subset of stations were selected to analyse sediment contaminants by targeting areas of fine sediment. Six DDC transects were positioned to ground-truth and delineate potential rocky and biogenic reef features and confirm the presence / absence of key features of conservation interest (e.g., *S. spinulosa* reefs, pink sea fan colonies, and fragile sponge and anthozoan communities).

A total of 30 DDC stations (Table 1, Figure 6) and 6 DDC transects (Table 2) were sampled, which resulted in the collection of 431 still images and 60 videos. As it was not possible to delineate the seabed feature from Transect T005, a further transect was approved running perpendicular (T005a). The first attempt of T005a (during slack water) produced poor quality imagery therefore the transect was reattempted during a running tide and produced imagery of suitable quality. Data from all images was taken into account when completing this report.

Grab samples were collected at the same 30 stations investigated by the DDC after assuring that no features of interest, hazards and / or obstacles were present.

Table 1 Station locations (UTM 30N).

Station	Location	Block	Target Easting	Target Northing
ENV001	OWF	G	346064.8	5685897
ENV002	OWF	G	340520.4	5684707
ENV003	OWF	G	330771.4	5685155
ENV004	OWF	E	342852.7	5688842
ENV005	OWF	E	333864.9	5689054
ENV006	OWF	E	328568.2	5688806
NVV007	OWF	D	345353.9	5690431
ENV008	OWF	D	338297.3	5689962
ENV009	OWF	D	330319.2	5690628
ENV010	OWF	C	325001.5	5691781
ENV011	OWF	C	335019.4	5691521
ENV012	OWF	C	342276.9	5690879
ENV013	OWF	A	333856.6	5696549
ENV014	OWF	A	343373.5	5693702
ENV015	OWF	A	325656.1	5695175
ENV016	OWF	F	327115.3	5687863
ENV017	OWF	F	330036.4	5687925
ENV018	OWF	F	343869.2	5686399
ENV019	OWF	B	330064.3	5692962
ENV020	OWF	B	336124.6	5693504
ENV021	ECR	B	345046.2	5693092
ENV022	ECR	F	336833.1	5685939
ENV023	ECR	N	348220.6	5719800
ENV024	ECR	N	348578	5723017
ENV025	ECR	N	350624	5725293
ENV026	ECR	M	345893.4	5717936
ENV027	ECR	M	342192.8	5714970
ENV028[5]	ECR	M	338447.1	5711326
ENV029	ECR	S	335263.3	5706295
ENV030	ECR	S	334187.8	5700849

Table 2 Ground-truthing transects (UTM 30N).

Transit	ECR	Easting Start	Northing Start	Easting End	Northing End
T001	ECR_N	348505	5719969	348338	5720080
T002	ECR_N	348050	5721541	348187	5721480
T003	ECR_N	351099	5725529	351244	5725564
T004	ECR_M	345601	5717803	345721	5717714
T005	ECR_M	342963	5715730	343095	5715658
T005a	ECR_M	343032	5715778	342936	5715571

[5] To note, the DDC and grab station ENV028 was sampled within the agreed 1-km buffer of subsea cables. The final sample location was 300 m from the subsea cable, and this should be considered for future repeat monitoring for these stations.

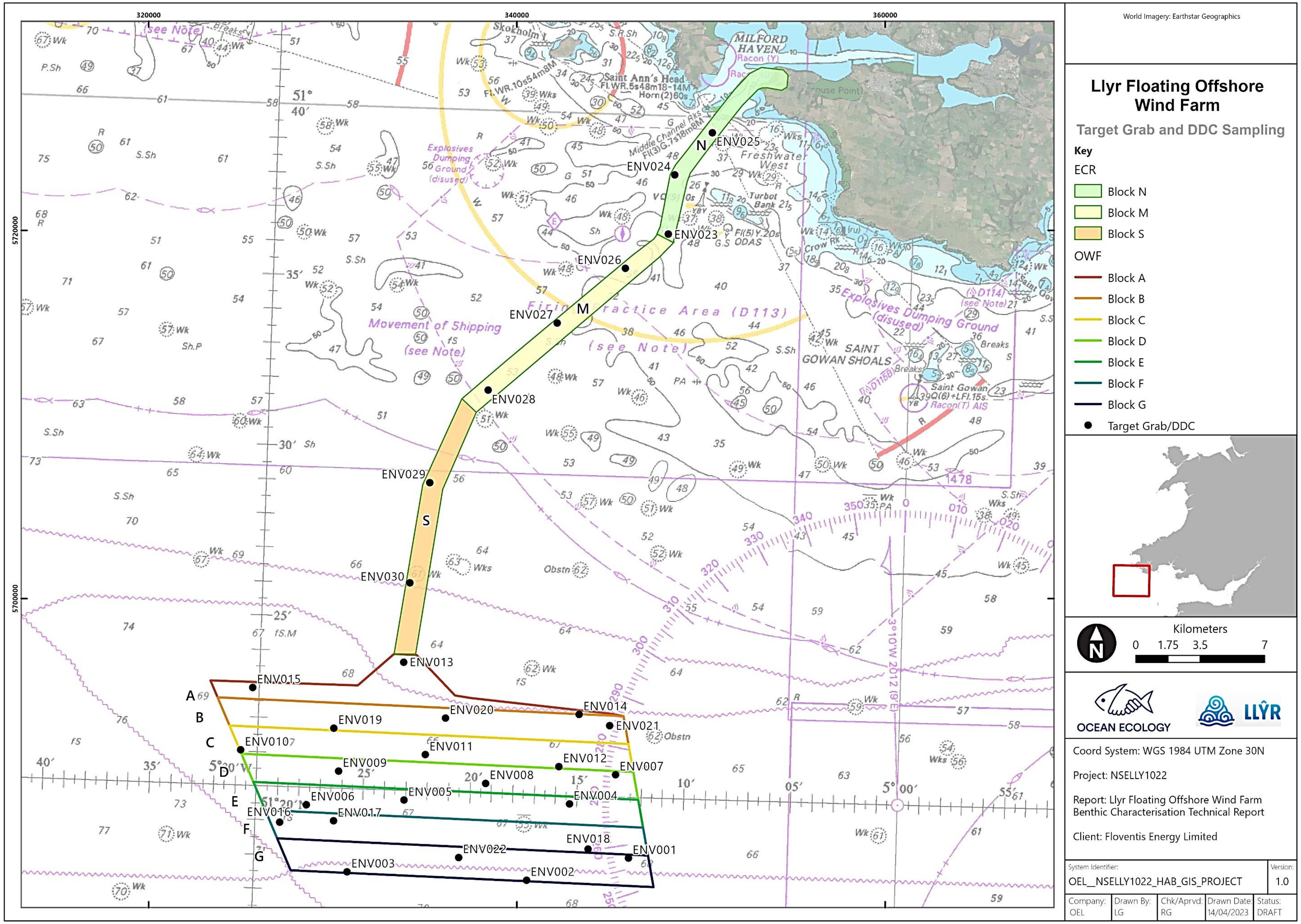

Figure 6 Target sample locations and survey area blocks across the Llyr offshore survey area.

5. Field Methods

5.1. Survey Vessel

All survey operations were conducted aboard the vessel *Braveheart Spirit* (Table 3, Plate 1) which was mobilised out of the port of Swansea on the 8th of December 2022.

Table 3 Vessel details

Vessel Name	Braveheart Spirit
Length	73.2m
Beam	16.5m
Draft	4.2m
Mobilisation Port	Swansea, Wales
Mobilisation Date	08/12/2022

Plate 1 Survey vessel Braveheart Spirit.

5.2. Project Parameters

5.2.1. Horizontal Datum

All coordinates were based on WGS84 with projected grid coordinates based on Universal Transverse Mercator (UTM) zone 30 N with a Central Meridian of 03˚ W. A summary of the geodetic and projection parameters is outlined in Table 4.

Table 4 Geodetic parameters.

GPS Satellite System Geodetic Parameters	
Geodetic Datum	WGS84
Ellipsoid	GRS_1980
Semi-Major Axis (a)	6,378,137.000 m
Semi-Minor Axis (b)	6,356,752.314 m
Eccentricity (e2)	0.006 694 380
Inverse Flattening (1 / f)	298.257 223 563
Projection	Universal Transverse Mercator (UTM)
Zone	30 N
Central Meridian (CM)	3° West
Latitude of Origin	0° North
False Easting	500,000 m
False Northing	0 m
Scale Factor on CM	0.9996

5.2.2. Datum Transformation Parameters

All data were referenced to WGS84, UTM 30N, with no datum transformation need. No conversion or test coordinate was provided by the Client.

5.2.3. Vertical Datum

All altitude and depth data above seabed was referenced to Lowest Astronomical Tide (LAT). All depth data below the seabed were referenced to LAT with depth below seabed included in brackets. LAT was derived using a Vertical Offshore Reference Model (VORF).

5.2.4. Unit Format and Conversions

Units used throughout this report are expressed using the conventions outlined in Table 5.

Table 5 Project unit format and convention details.

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

5.3. Subsea positioning

An Ultra-Short Baseline (USBL) was provided and operated by N-Sea to provide subsea positioning of the sampling equipment. A HiPAP Kongsberg 501 USBL system transmitted to Micro Beacons that were mounted near the end of the crane wire above the block to provide accurate subsea positioning of the sampling equipment.

5.4. Survey Equipment

All sampling equipment employed during the survey was deployed over the vessel's starboard rescue zone and aft deck using the vessel's subsea cranes. A list of environmental sampling equipment mobilised for the survey is presented in Table 6.

Table 6 Equipment list mobilised on the *Braveheart Spirit*.

Equipment	Model
Camera System (Primary)	OELs Clear Liquid Optical Chamber (CLOC) with High Definition (HD) video and high-resolution stills camera (SubC Rayfin Powerline Ethernet (PLE)).
Camera System (Redundancy)	HD video and high-resolution stills camera (ROVTECH RSL)
Grab Sampler	0.2 m^2 Dual Van Veen grab (DVV)
Grab Sampler	0.1 m^2 mini-Hamon grab (redundancy)
Survey Software	QINSy
Subsea Positioning	Wire mounted USBL beacon HiPAP Kongsberg 501

5.4.1. Seabed Imagery Collection

All seabed imagery was collected using OEL's freshwater housing camera system which features a SubC RayfinPLE camera system, set up to obtain 1080p HD video and 20 Megapixel (MP) stills images. It was mounted in a CLOC (otherwise known as a "freshwater lens") filled with fresh water to ensure imagery of suitable quality was obtained regardless of turbidity (Jones et al. 2021). The frame also included LED strip lamps and a 9.5 cm point laser scaling array that was be projected into the field of view. The camera was powered with the use of an Uninterruptable Power Supply (UPS) to ensure no damage was caused should the vessel have lost power or caused a power surge.

The CLOC was height- and angle-adjustable, providing a variety of options for view, lighting, and focal length to maximise data quality with respect to prevailing conditions (e.g., high turbidity). Following a review of seabed imagery during the survey, adjustments to the lighting angle were made to improve illumination within the centre of images.

The DDC was powered by a coax cable running from the aft deck winch into the crane deck container and lowered to the seabed using a deck crane situated on the aft deck. An umbilical system was available as a backup.

The DDC was powered using an umbilical during a single DDC transect due to a power shortage in the aft deck winch, meaning the coax cable could not be used. On return to port, the winch system was switched out and all further deployments were successfully conducted using a coax connection. Where the umbilical was used the DDC was deployed from the starboard side of the mid deck using the deck crane and winch. The DDC umbilical was run through a pully block mounted on the deck crane.

Full DDC survey logs are presented in Appendices I and II.

5.4.2. Grab Equipment

All sediment sampling was conducted using a 0.2 m^2 DVV grab (Plate 2). The DVV is favourable for medium to fine sediments and was ideal for the collection of chemical samples as it allowed for the collection of samples with undisturbed surface sediments. Upon contact with the seabed, the tension from the wire was released, causing the sampling bucket to pivot through 90º, pushing seabed sediment into the bucket, which closed to form a tight seal to avoid sediment / sample loss. A 0.1 m^2 Hamon Grab was stored onboard as a redundancy system but was not required.

Plate 2 Left: OEL's freshwater housing camera system. Right: 0.2 m^2 DVV Grab.

5.5. DDC Sampling

All seabed imagery was collected in consideration of the JNCC epibiota remote monitoring operational guidelines (Turner et al. 2016). At each DDC station, a minimum of two minutes of video footage and five seabed stills images were obtained. The vessel was moved within a 20 m radius of the target location to adequately characterise the target area. Along the transects, images were taken every 5-10 m and more often when features of interest were encountered. All video footage was reviewed *in situ* by OEL's environmental scientists.

The primary camera system was deployed as follows:

- The vessel approached the target location, and the deck personnel were alerted to prepare lifting equipment and camera.
- The camera was raised using the deck crane and winch and lowered into the water column to within 10 m of the seabed.
- Video recording was then started, and the camera lowered until gently landing on the seabed.
- The camera was then kept on the seabed to wait for any suspended sediments in the field of view to disperse before a still image was taken.
- For DDC stations: The camera was raised from the seabed between capturing still images while the vessel manoeuvred within a 20 m target radius to ensure broad coverage around the target location.
- For DDC transects: The camera was then raised from the seabed and was moved along the transect at a speed of 0.37 - 0.56 km h^{-1}. Where possible the seabed was kept in view throughout.
- Following the capture of the final image, the camera was lifted, video recording was stopped, and the camera was retrieved to the surface.

- The HIAB crane and winch operators then took the tension on the wire and recovered to surface.
- The bridge then confirmed sea conditions were suitable for retrieval and the camera system was recovered aboard.
- The camera frame was then lowered onto the deck and the tension released.

5.6. Grab Sampling

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

- The sample was less than 5 L – i.e., the sample represented less than half the 10-L capacity of the grab used.
- The jaws failed to close completely or were jammed open by an obstruction, allowing fines to pass through (washout, or partial washout).
- The sample was taken at an unacceptable distance from the target location (beyond 20 m).

This sampling procedure and methodology adheres to the NRW guidance on benthic habitat assessments for marine developments, ensuring robust and consistent data collection to support environmental and ecological impact assessments.

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

5.6.1. Grab Sample Processing (Particle Size Distribution and Macrobenthic Samples)

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

Successful grab per station:

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

5.6.2. Grab Sample Processing (Chemical Contaminants)

Detailed notes were taken of visible sediment conditions and seabed features, obvious fauna and habitat-related features whilst in the field. Sample processing was undertaken onboard the survey vessel using the following methodology:

- Inspection cover lifted and general assessment of sample size and acceptability made ensuring sediment surface was undisturbed and there was no obvious sign of contamination, ensuring that no grease, oils, or lubricants entered the sample once the inspection cover was open.
- pH / Redox probe placed into sediment sample and allowed to settle for two minutes before taking readings in field logs.
- Sediment samples were sub-sampled and decanted into the recommended sample containers provided by SOCOTEC – the contaminant laboratory specialists for the required analyses as below:
    - Moisture Content
    - Total Organic Carbon (TOC)
    - Trace and heavy metals
    - Polycyclic aromatic hydrocarbons (PAHs)
    - Total Hydrocarbon Content (THC) (including saturates)

All samples taken for physicochemical analysis were stored frozen at - 20° C in amber glass containers. These containers were acid-cleaned and solvent-rinsed before use, sealed with a foil liner and tightened appropriately to avoid potential loss of determinants, contamination of samples, or both. A temperature of 25° C was not exceeded at any stage of storage or transportation.

6. Laboratory and Analytical Methods

6.1. PSD Analysis

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

Frozen sediment samples were first transferred to a drying oven and thawed at 80° C for at least 6 hours before visual assessment of sediment type. Before any further processing (e.g., sieving or sub-sample removal), samples were mixed thoroughly with a spatula and all conspicuous fauna (>1 mm) which appeared to have been alive at the time of sampling removed from the sample. A representative sub-sample of the whole sample was then removed for laser diffraction analysis before the remaining sample screened over a 1-mm sieve to sort coarse and fine fractions. Care was taken so as not to overload the sieve and allow continual flow of < 1 mm sediment through, until the water run clear.

6.1.1. Dry Sieving

The > 1 mm fraction was then returned to a drying oven and dried at 80° C for at least 24 hours before dry sieving. Once dry, the sediment sample 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 7.

Table 7 Sieve series employed for PSD analysis by dry sieving.

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

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

6.1.2. Laser Diffraction

The sub-sample for laser diffraction was first screened over a 1-mm sieve and the fine fraction residue (< 1 mm sediments) was transferred to a suitable container and allowed to settle for 24 hours before excess water was syphoned from above the sediment surface until a paste texture 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.

6.1.3. 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 at 0.5 φ intervals from - 5.5 (45 mm) to > 14.5 (< 0.04 µm). Once data were merged, PSD statistics, and sediment classifications were generated from the percentages of the sediment determined for each sediment fraction using Gradistat v9 software.

Sediment descriptions were defined by their size class based on the Wentworth classification system (Wentworth 1922) (Table 8). Statistics such as mean and median grain size, sorting coefficient, skewness, and bulk sediment classes (percentage silt, sand, and gravel) were derived following the Folk classification (Folk 1954).

Table 8 The classification used for defining sediment type based on the Wentworth Classification System (Wentworth 1922).

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

6.2. Chemical Contaminants Analysis

A sub-sample of 10 samples from the 30 grabs samples collected were assessed for chemical contaminants (see Appendix XVI for methods).

6.2.1. Hydrocarbons

Indices and ratios were calculated to assess source origin of hydrocarbons in the sediment sampled across the Llŷr survey area (Ines et al. 2013, Al-hejuje et al. 2015).

Generally, there are three sources of hydrocarbons depending on their origin: biogenic, petrogenic, and pyrogenic. Hydrocarbons of biogenic origin are the produce of biological processes or early diagenesis in marine sediments (e.g., perylene) (Venkatesan 1988, Junttila et al. 2015). Hydrocarbons of petrogenic origin are the compounds present in oil and some oil products following low to moderate temperature diagenesis of organic matter in sediments resulting in fossil fuels. Hydrocarbons of pyrogenic origin are the product of incomplete combustion of organic material (Page et al. 1999, Junttila et al. 2015), such as forest fires and incomplete combustion of fossil fuels.

Based 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 one indicate hydrocarbons of petrogenic origin, CPI values below one indicate pyrogenic origin (Fagbote 2013), CPI values higher than one 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.

Based on PAH compounds the following ratios were calculated:

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

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

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

6.2.2. Heavy Trace Metals

A total of 8 main heavy and trace metals were analysed from sediments taken at each of the 13 sampling stations. These were: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn).

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), DEFRA (2003) 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). To note that ERL, TEL, and PEL are based on field research programmes based on North American data that have demonstrated associations between chemicals and biological effects by establishing cause-and-effect relationships in particular organisms (CCME 2001). This means they provide a measure of environmental toxicity compared to the other reference levels which instead provide information on the degree of contamination of the sediments. At levels above the TEL, adverse effects may occasionally occur, whilst at levels above the PEL, adverse effects may occur frequently; concentrations below the ERL rarely cause adverse effects in marine organisms. Additionally, the TEL has been adopted as the International Sediment Quality Guideline (ISQG) (CCME 2001), while ERL has been adopted by OSPAR to assess the ecological significance of contaminant concentrations in sediments, where concentrations below the ERL rarely cause adverse effects in marine organisms. For these reasons ERL, TEL, and PEL are presented here as reference values despite being based on North American data.

BACs were developed to assess the status of contaminant concentrations in sediment within the OSPAR framework with concentrations significantly below the BAC considered to be near background levels for the north-east Atlantic. CEFAS ALs are used as part of a “weight of evidence” approach to assessing dredged material and its suitability for disposal to sea (DEFRA 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 at-sea disposal.

6.3. 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[6] 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).

[6] Marine Environmental Data and Information Network.

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[7] (World Register of Marine Species) REST webservice, to ensure the most up to date taxonomic classifications were recorded. Colonial fauna (e.g., hydroids, 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 0.0001 g. As a standard, the conventional conversion factors as defined by (Eleftheriou & Basford 1989) were applied to biomass data to provide equivalent dry weight biomass (Ash Free Dry Weight, AFDW). The conversion factors applied are as follows:

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

6.4. Macrobenthic Data Analysis

6.4.1. 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.

6.4.2. Pre-Analysis and 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] http://www.marinespecies.org

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

Newly settled juveniles of macrobenthic species may at times dominate the macrobenthos, however the OSPAR (2004) guidelines suggest they should be considered an ephemeral component due to heavy post-settlement mortality and not therefore representative of prevailing bottom conditions (OSPAR 2004). OSPAR (2004) further states that "Should juveniles appear among the ten most dominant organisms in the data set, then statistical analyses should be conducted both with and without these in order to evaluate their importance". As juveniles of Amphiuridae and Ophiuridae appeared in the top 10 most dominant taxa across the survey area, a 2STAGE analysis was conducted to compare the two data sets (with and without juveniles) which revealed a 96 % of similarity between the two and therefore juveniles were retained in the dataset for all further analyses and discussion.

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

6.4.3. 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 were 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 III.

6.4.4. 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).

6.5. Seabed Imagery Analysis

All seabed imagery analysis was undertaken using the Bio-Image Indexing and Graphical Labelling Environment (BIIGLE) annotation platform (Langenkämper et al. 2017), and in line with JNCC epibiota remote monitoring interpretation guidelines (Turner et al. 2016). A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of Annex I reef habitats as detailed in Table 9 and Table 10. Stony reef classification was further assessed following the work of Brazier (2020) and Golding et al. (2020), and reef assessments adjusted according to expert opinion when certain criteria as outlined by Irving (2009) are met or not met. Similarly, *S. spinulosa* reef assessments were made in consideration of Jenkins et al. (2018) and Collins (2010). The annotation label tree used during analysis had major headings for each of reef type. Under each reef type labels were assigned for each of the categories required to determine whether reef habitat was present. The full label tree used in the project can be found in Appendix IV.

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

Table 9 Characteristics of stony reef (Irving 2009).

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

Table 10 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

6.6. Determining Habitat Classifications

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

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

6.7. Habitat Mapping

All habitat mapping was undertaken in ESRI ArcPro Version 3.0.3 by a habitat mapping specialist and reviewed by a secondary senior environmental scientist. This involved overlaying EUNIS classifications and habitat assessment scores assigned to each sampling location on the mosaiced SSS and MBES data allowing for delineation of areas representative of similar acoustic signatures aligned to those at each DDC / grab station. Each sampling location was assigned to a EUNIS habitat / biotope based on the available data (still images and existing EMODnet mapping). Following this, an Annex I habitat assessment was carried out at each sampling location and where the criteria for Annex I habitats were met (Table 9, Table 10), then these locations were additionally assigned as Annex I habitats. Finally, this classification was overlaid on the mosaiced SSS and MBES data to delineate large scale habitats and features of interest.

6.8. Herring Spawning Habitat and Acceptable Limits of Change

Following Reach et al. (2013), herring spawning suitable grounds were categorised as “Prime”, “Sub-prime”, “Suitable”, and “Unsuitable” based on sediment composition (Table 11).

Table 11 Herring preference habitat according to sediment composition (Reach et al. 2013).

% Particle Contribution	Habitat Sediment Preference	Habitat Sediment Classification	Folk 1954 Classification
< 5 % mud, > 50 % gravel	Prime	Preferred	Gravel – Part Sandy Gravel
< 5 % mud, > 25 % gravel	Sub-Prime	Preferred	Part Sandy Gravel – Part Gravelly Sand
< 5 % mud, > 10 % gravel	Suitable	Marginal	Part Gravelly Sand
> 5 % mud, < 10 % gravel	Unsuitable	Unsuitable	All other sediment types

6.9. Sandeel Spawning Habitat

The guidelines for suitable spawning grounds for sandeel are presented within Table 12. Sandeel spawning habitats were additionally assessed using the methods outlined by Greenstreet et al. (2010) whereby the sediment rations of coarse sands and fine sand and silts is considered, as opposed to the full particle size range.

Table 12 Sandeel preference habitat according to sediment composition (Latto et al. 2013).

% Particle Contribution	Habitat Sediment Classification	Folk 1954 Classification
<1 % mud, > 85 % Sand	Preferred	Sand
<4 % mud, > 70 % Sand	Preferred	Gravelly Sand and Slightly Gravelly Sand
<10 % mud, > 50 % Sand	Marginal	Sandy Gravel
>10 % mud, < 50 % Sand	Unsuitable	Other

7. Results

7.1. Particle Size Distribution Data

The sediment composition at each grab sampling stations across the survey area are plotted in Figure 7 and Figure 8, and mapped in Figure 9 and Figure 10. Grab sampling logs and sample photos for 30 stations are provided in Appendices V and VI respectively and full PSD data has been provided in Appendices VII and VIII.

7.1.1. Sediment Type

Sediment types at each grab sampling station as classified by the (Folk 1954) classification are summarised in Appendix VIII and illustrated in Figure 7. Little variation in sediment types occurred between stations, with the majority of them being primarily characterised by sand.

Most samples (n = 23) were comprised of sand representing EUNIS BSH A5.2 (Sand and Muddy Sand). Of these, most stations (n = 16) were classified as Slightly Gravelly Sand ((g)S), n = 5 as Sand (S), and n = 2 as Slightly Gravelly Muddy Sand ((g)mS). Of the remaining stations, n = 4 were classified as Coarse Sediment (EUNIS A5.1), n = 2 as Mud and Sandy Mud (EUNIS A5.3), and n = 1 as Mixed Sediment (EUNIS A5.4) (Figure 9).

40 % of the samples recorded were classified as moderately sorted and comprised almost entirely of sand. Remaining stations classified as moderately well sorted (23.3 %), poorly sorted (23.3 %), and very poorly sorted (13.3 %). This variation results from a mixed composition of different size fractions of all three principal sediment types (gravel, sand, and mud).

7.1.2. 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 sands across all stations was 91 % (± 2), the mean (± SE) gravel and mud content across the survey area was 3 % (± 1) and 6% (± 2) respectively. Sand content was greatest at station ENV04 and lowest at ENV017. Mean grain size across the survey area ranged from 34 μm at station ENV017 to 925.97 μm at station ENV025 Figure 10. Gravel content was highest close to land, at ENV025, making up 35 % of the sediment. Mud content was low overall, except for two stations ENV017, where it constituted 55.6 % of the sediment, and ENV028, at 24.4 %.

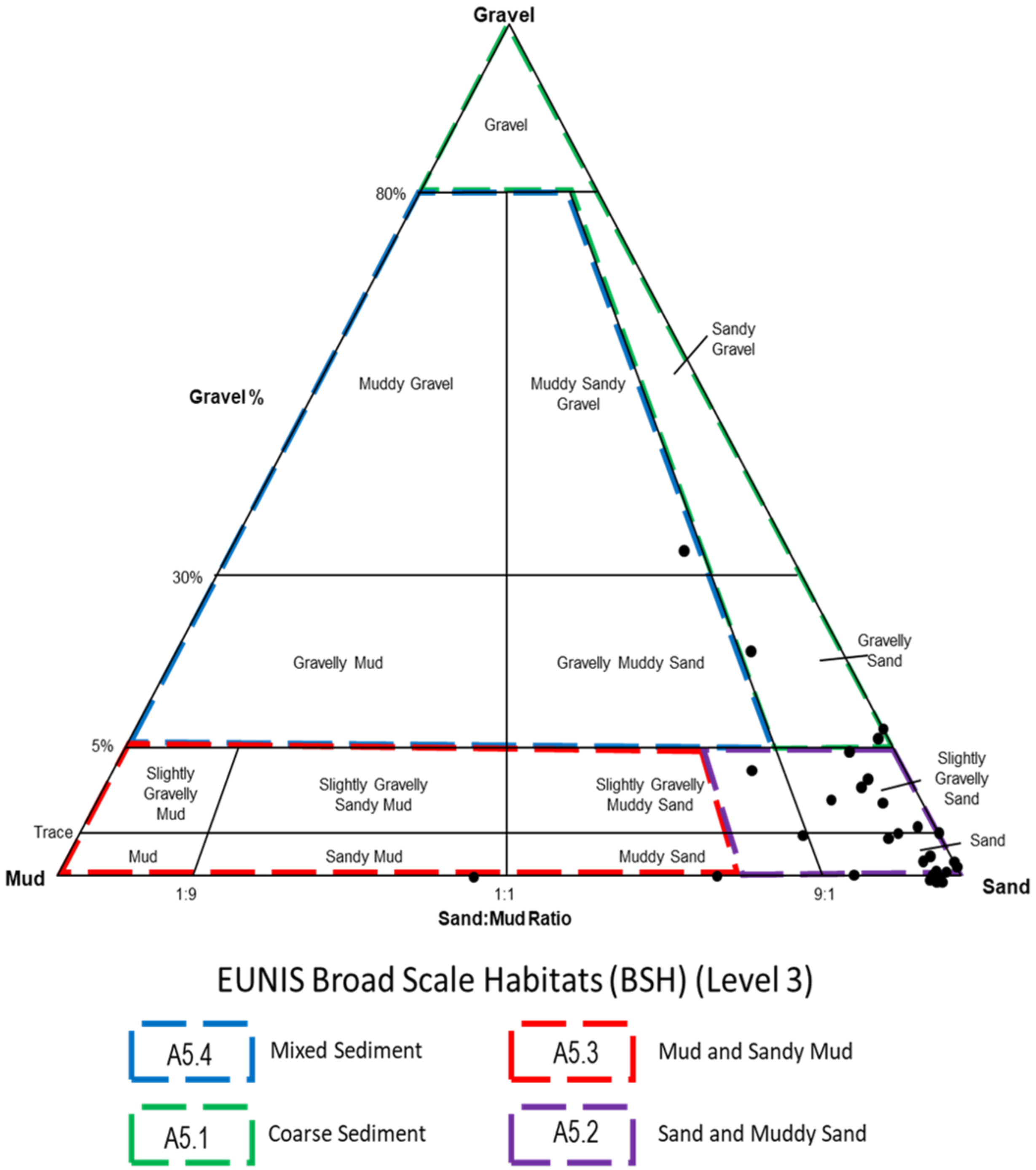

Figure 7 Folk (1954) triangle classifications of sediment gravel percentage and sand to mud ratio of samples collected across the survey area, overlain by the modified Folk triangle for determination of mobile sediment BSHs under the EUNIS habitat classification system (adapted from (Long 2006)).

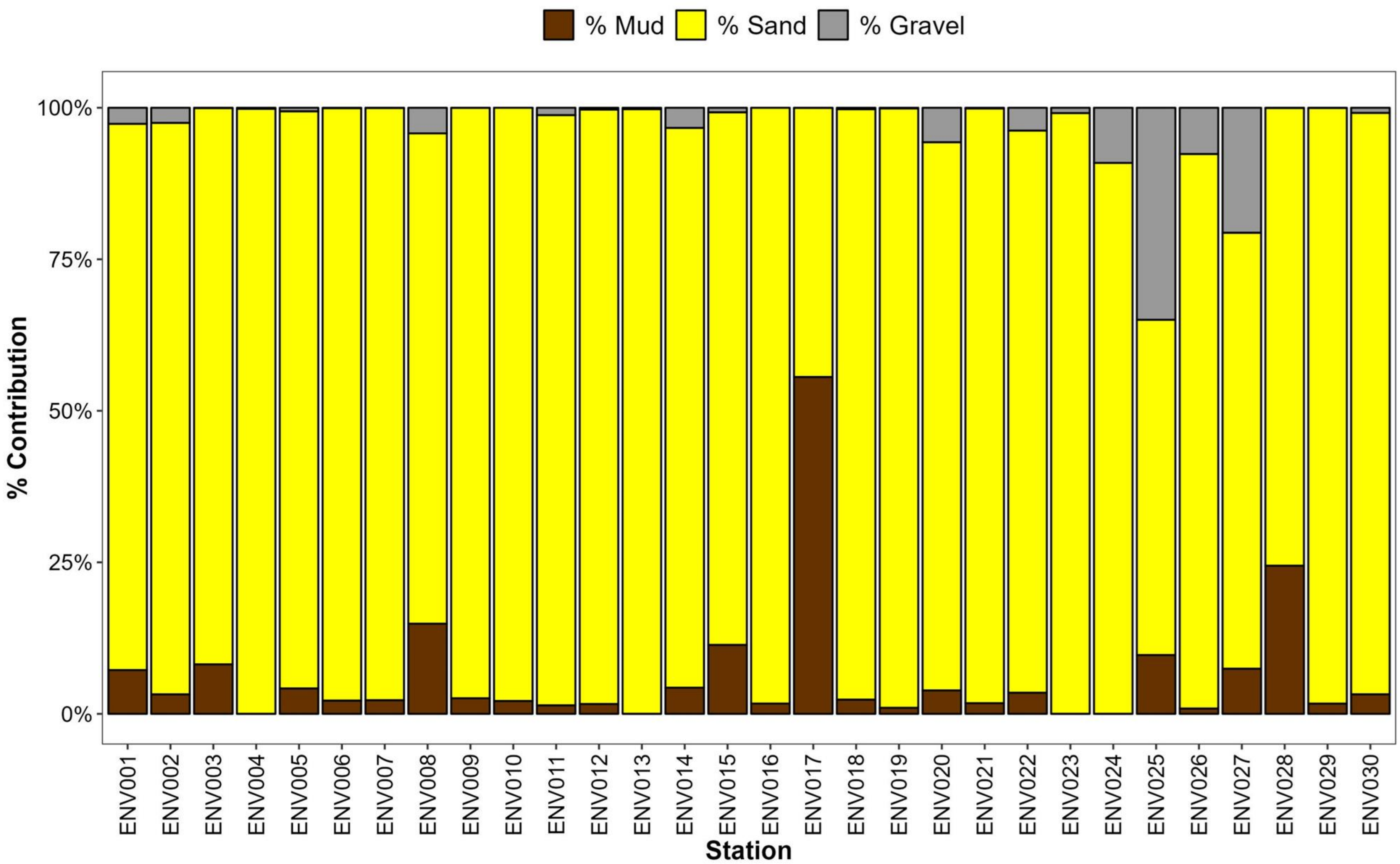

Figure 8 Percentage volume of gravel (G), sand (S), and mud (M) at each sampling station across the survey area.

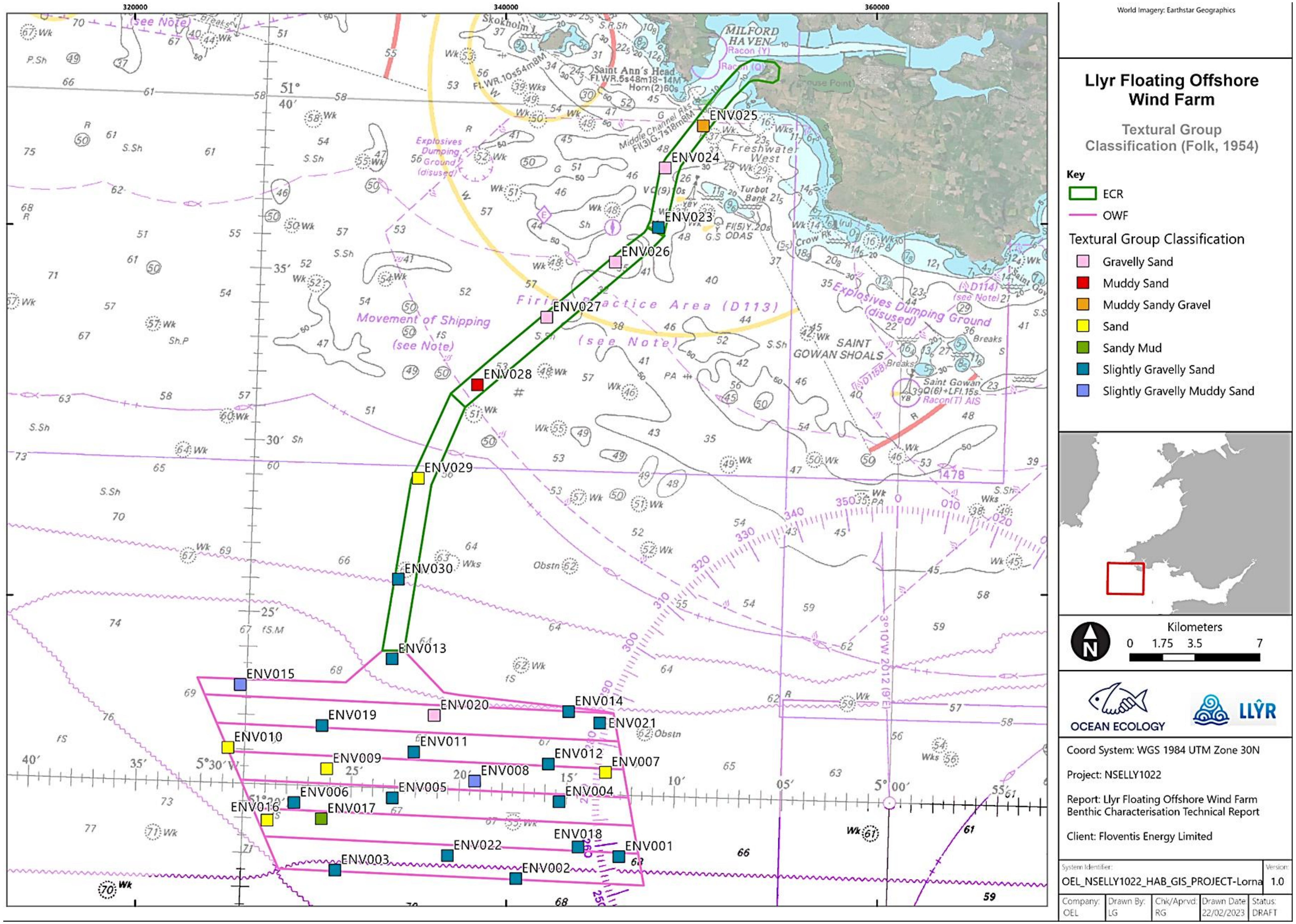

Figure 9 Textural group classification at each sampling station across the survey area.

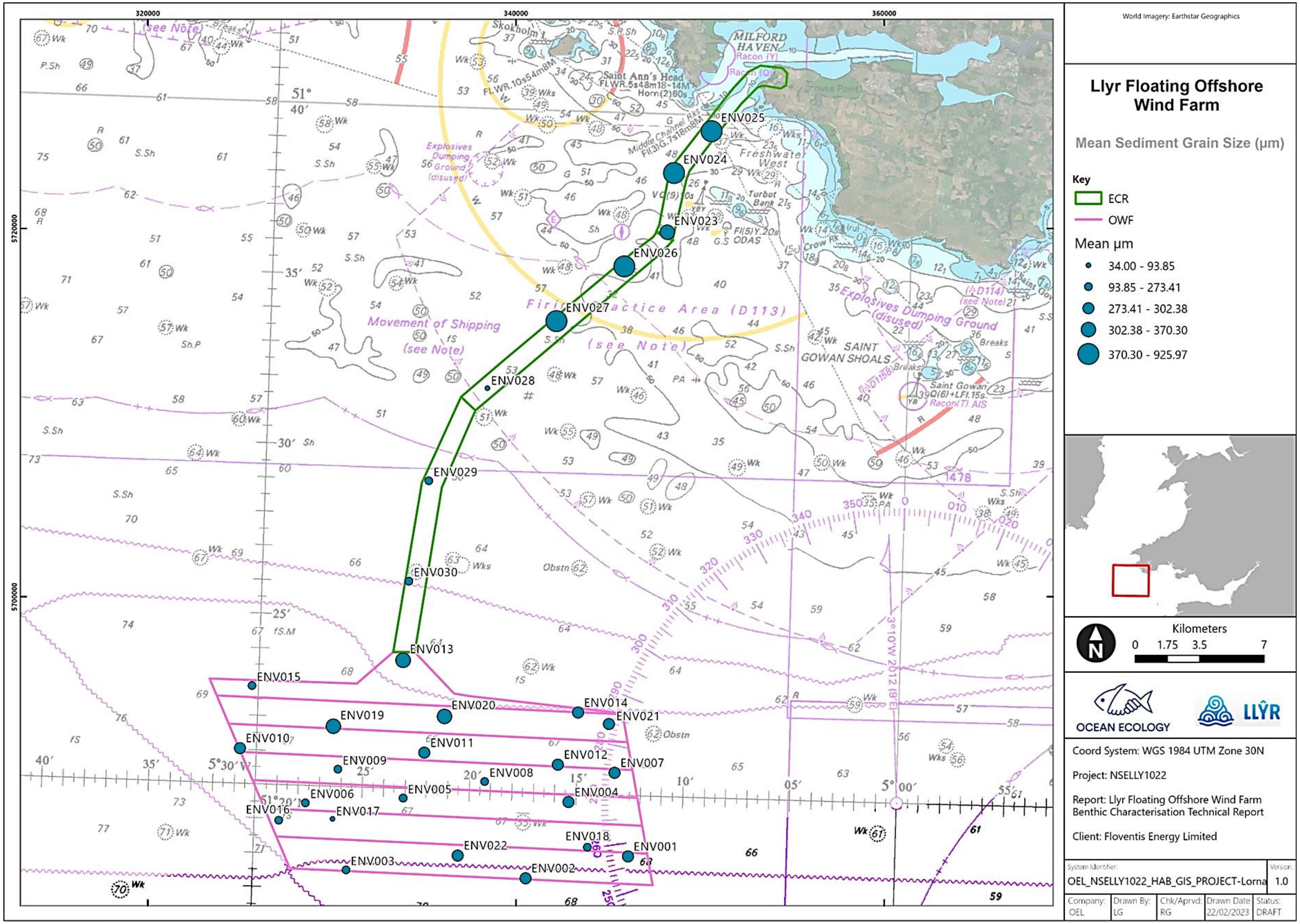

Figure 10 Mean grain size (µm) at each sampling station across the survey area

7.2. Herring Spawning Suitable Grounds

The (Folk 1954) classification applied to the PSD data was used to determine the four herring spawning ground habitats as detailed in Reach et al. (2013). Table 13 summarises the number of stations falling under each category. All 30 stations were deemed unsuitable, having either > 5 % mud, or < 10 % gravel. A breakdown of Folk sediment classification and herring habitat spawning preference per sampling station is provided in Appendix IX.

Table 13 Herring spawning ground preference habitat according to sediment composition.

% Particle Contribution	Habitat Preference	N of Stations
< 5 % mud, > 50 % gravel	Prime	0
< 5 % mud, > 25 % gravel	Sub-Prime	0
< 5 % mud, > 10 % gravel	Suitable	0
> 5 % mud, < 10 % gravel	Unsuitable	30

7.3. Sandeel Spawning Suitable Grounds

Table 14 summarises the number of suitable, marginal and unsuitable stations for sandeel spawning habitat. Overall, twenty stations across the survey area were deemed as suitable spawning ground for sandeel whilst six stations were marginal and four stations, ENV008, ENV015, ENV017 and ENV028 were deemed as unsuitable habitat for sandeel spawning. A breakdown of Folk sediment classification and sandeel habitat spawning preference per sampling station is provided in Appendix IX. Sandeel spawning habitats were further assessed based on the work of Greenstreet et al. (2010). The classification of stations based on the Greenstreet classification framework are outlined in Table 15. Whilst station groupings are not identical between the two analysis methodologies here, the overall trend remains the same and many of the same stations feature in the most suitable and least suitable categories for sandeel spawning.

Table 14 Sandeel spawning ground preference habitat according to sediment composition.

% Particle Contribution	Habitat Preference	N of Stations	Stations	Area Identified (ECR/Array/Both)
< 1 % mud, > 85 % Sand	Preferred	6	04, 13, 19, 23, 24, 26	Both
< 4 % mud, > 70 % Sand	Preferred	14	02, 06, 07, 09-12, 16, 18, 20-22, 29, 30	Both
< 10 % mud, > 50 % Sand	Marginal	6	01, 03, 05, 14, 25, 27	Both
> 10 % mud, < 50 % Sand	Unsuitable	4	08, 15, 17, 28	Both

Table 15 Sandeel spawning ground habitat preference based on the Greenstreet et al. 2010 methodology.

Habitat Preference	N of Stations	Stations	Area Identified (ECR/Array/Both)
Prime	2	24, 26	ECR
Sub-prime	3	13, 19, 23	Both
Suitable	16	01, 02, 04-07, 10-12, 14, 16, 20-22, 27, 30	Both
Unsuitable	9	03, 08, 09, 15, 17, 18, 25, 28, 29	Both

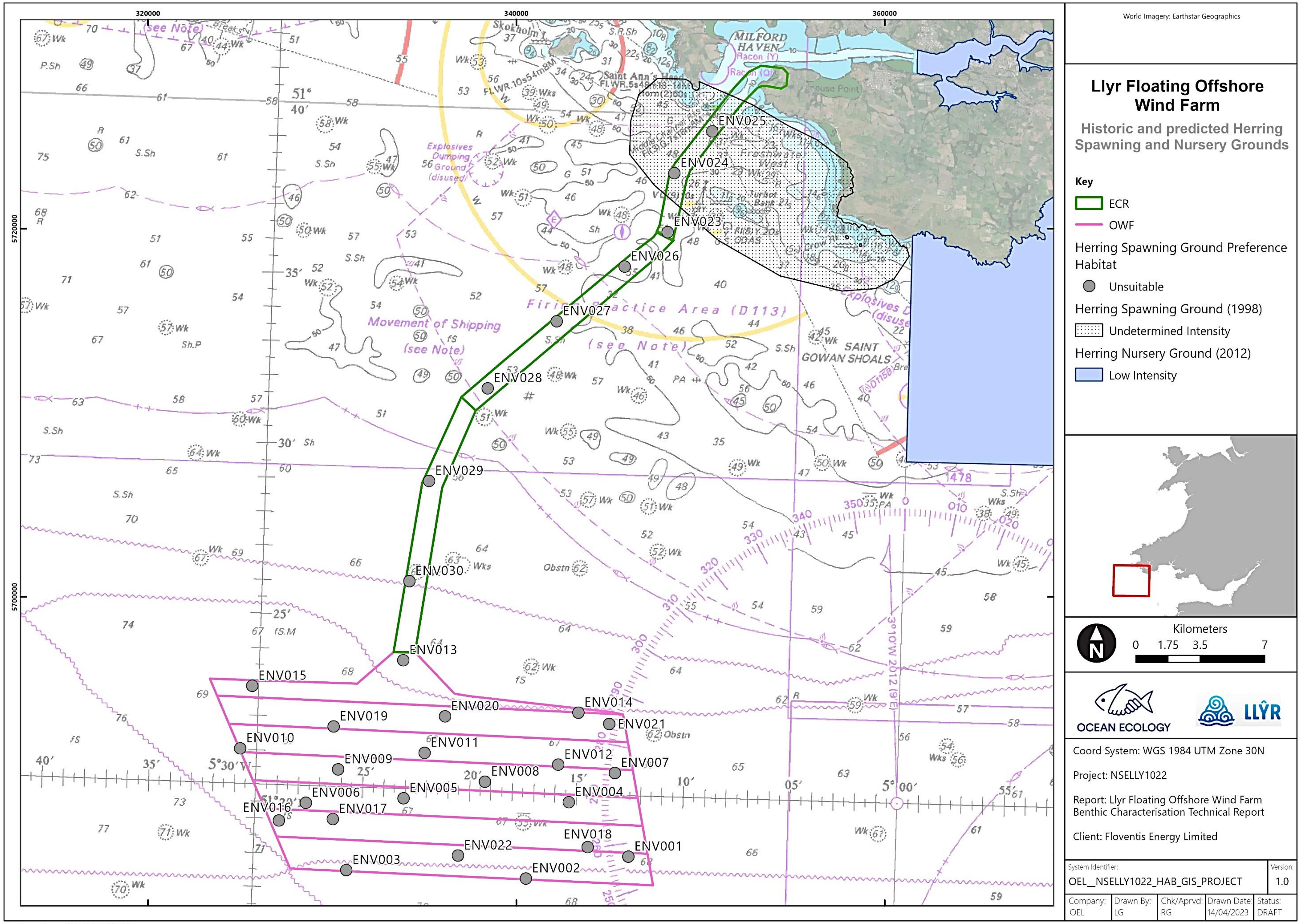

Figure 11 Herring spawning ground habitat preference overlain with existing herring spawning ground preference data from CEFAS and UKOOA.

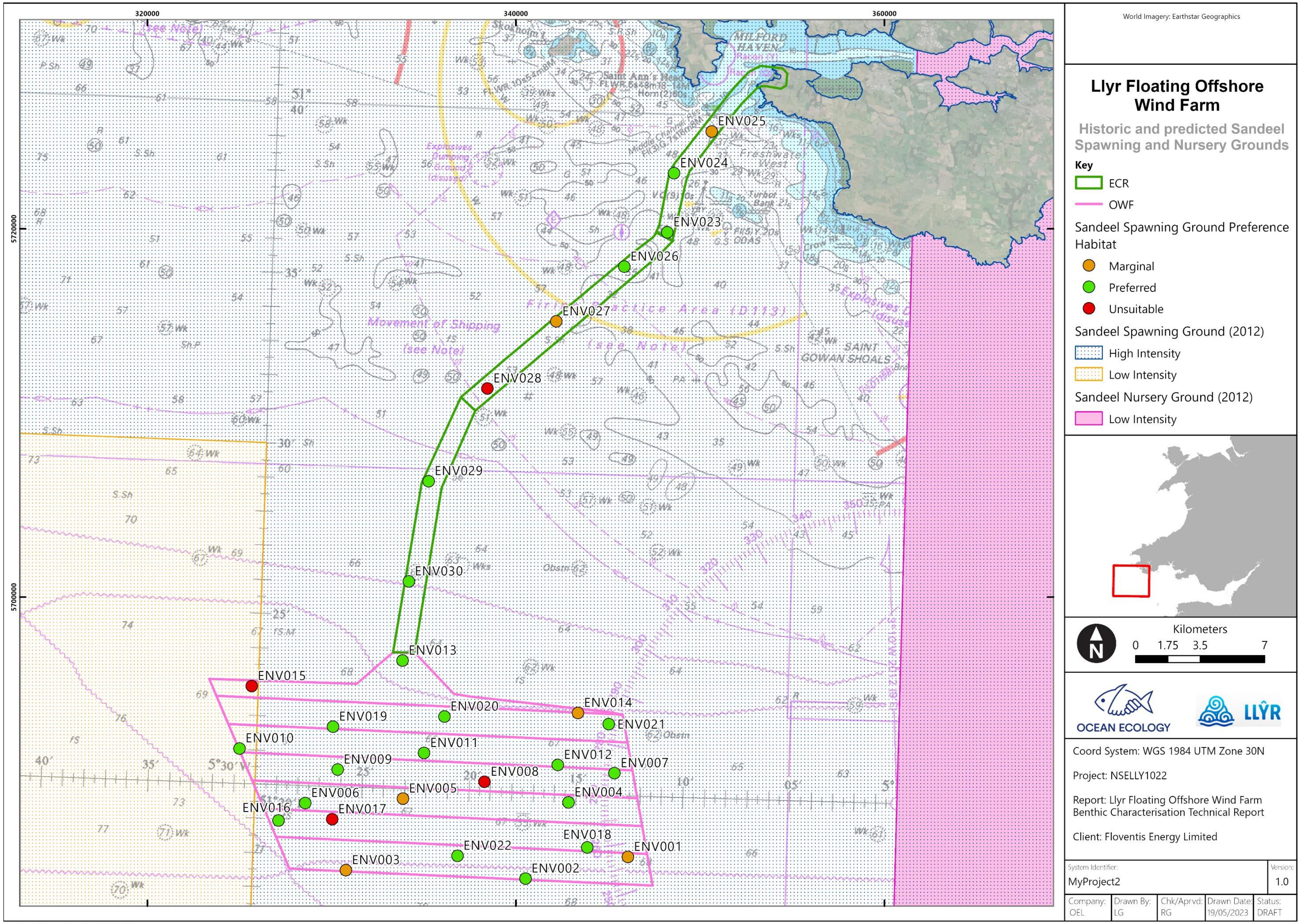

Figure 12 Sandeel spawning ground habitat preference overlain with existing spawning ground preference data from CEFAS.

7.4. Sediment Chemistry

7.4.1. Total Organic Carbon and Total Organic Matter

TOC was measured at all stations across the survey area and ranged from 0.02 % at station ENV019 to 0.59 % at station ENV017 with an average value (± SE) of 0.16 ± 0.02 % across all stations (Figure 13).

Total Organic Matter (TOM) ranged between 1.2 % at stations ENV007 and ENV029 and 3.9 % at station ENV017 with an average value (± SE) for the survey area of 1.8 ± 0.11 %.

In general, the highest TOC and TOM content in the sediment was found at stations with the highest mud content (> 20 %).

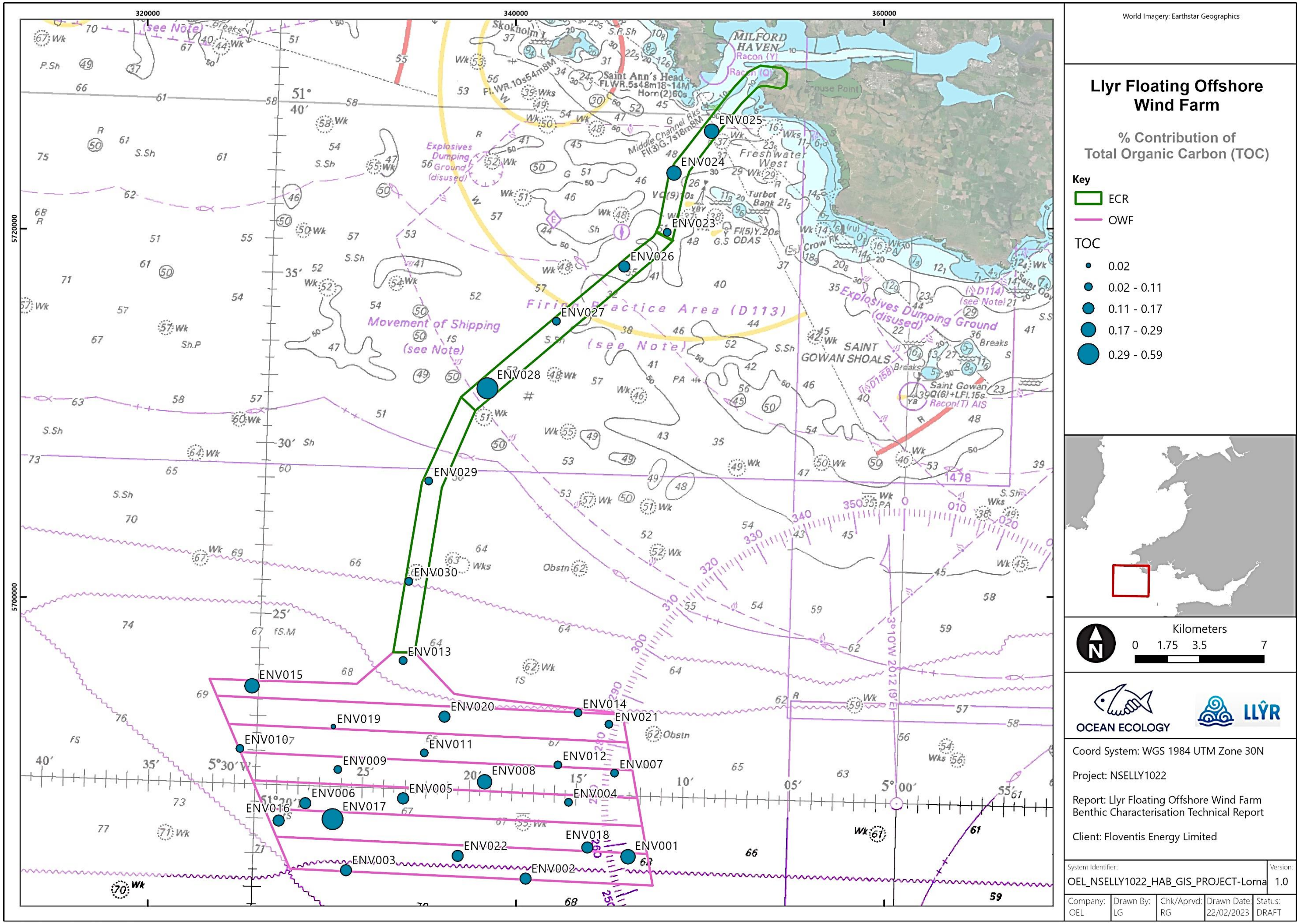

Figure 13 Overview of TOC across the survey area.

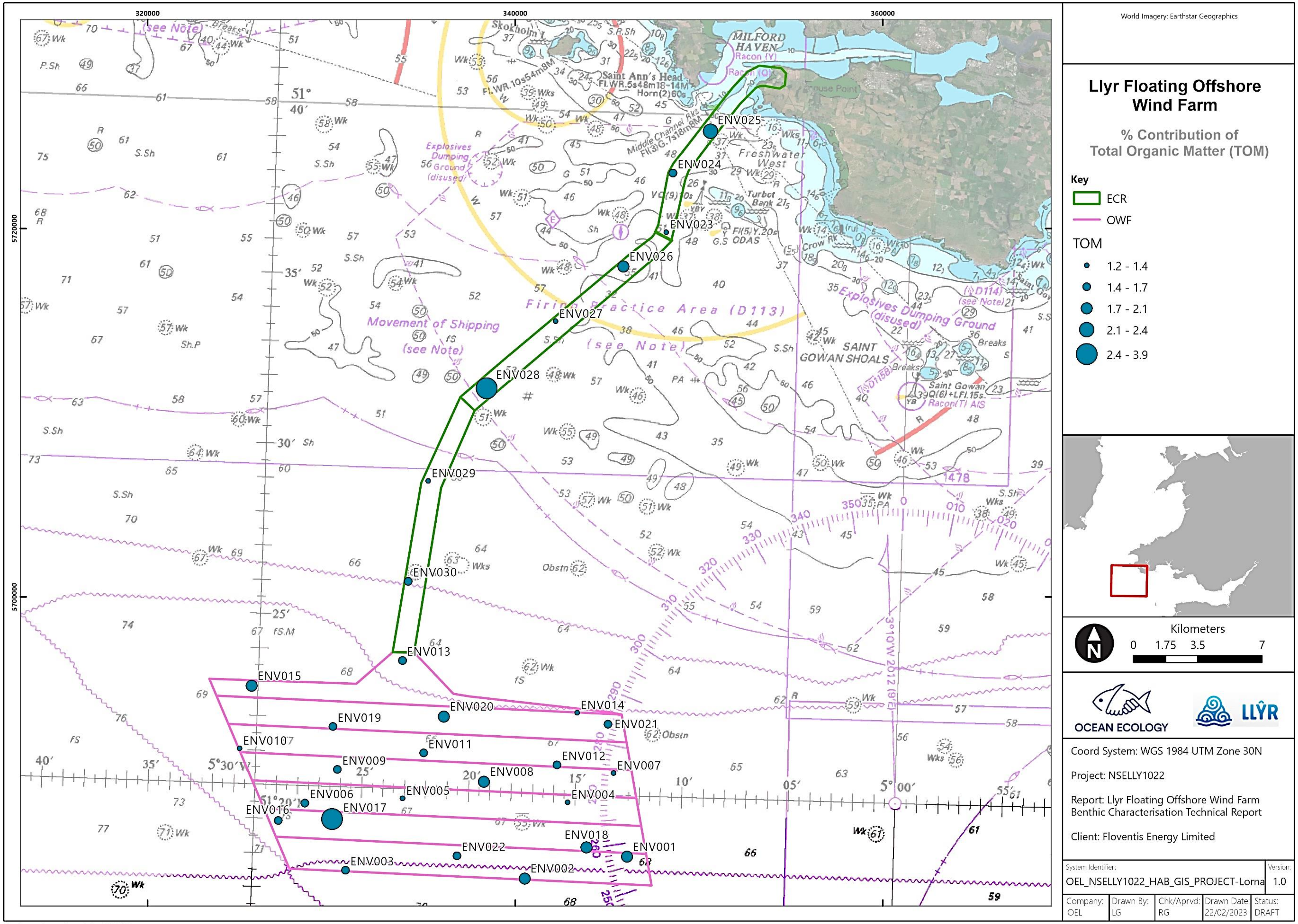

Figure 14 Percentage contribution of TOM across the survey area.

7.4.2. Heavy and Trace Metals

A total of 8 main heavy and trace metals were analysed from sediments taken at each of the 10 sampling stations. These were: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn).

Raw data for the 8 main heavy and trace metals (dry-weight concentration, mg kg^{-1}) are shown in Table 16 together with available reference levels (see Section 6.2.2 for details on national and international reference levels). None of the main heavy and trace metals exceeded reference levels with the exception of As which was above the CEFAS AL 1 (20 mg kg^{-1}) at four stations: ENV001, ENV007, ENV013 and ENV014 located to the east of the OWF area. As concentrations were below CEFAS AL 2 reference level at all stations. As had an average concentration across the survey area of 18.45 mg kg^{-1}.

The most abundant metal was Zn which ranged from 29.8 mg kg^{-1} at ENV029 to 16.0 mg kg^{-1} at ENV024, however, it was always recorded well below any of the reference levels (Table 17). As was recorded in relatively high concentrations, ranging between 8.6 mg kg^{-1} at ENV024 and 27.5 mg kg^{-1} at ENV007, exceeding reference levels at four stations as noted above. The third most abundant metal was Pb which varied from 7.2 mg kg^{-1} at ENV010 and 14.9 mg kg^{-1} at ENV001, however Pb did not exceed reference levels. The spatial distribution of the four most abundant metals is presented within Figure 15.

No clear trend was observed between the concentration of heavy and trace metals and the amount of mud in the sediments.

Table 16 Main heavy and trace metals (mg kg^{-1}) in sediments. Shading indicates values above AL1. BDL = Below Detection Limits.

Station	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
ENV001	27.1	0.1	9.2	5.7	14.9	0.04	6.7	27.7
ENV003	19.3	0.11	12.6	5.3	10.8	0.02	7.6	28.5
ENV005	19.9	0.11	9.9	4.8	11.2	BDL	6.1	26.4
ENV007	27.5	0.15	10	4.2	13.6	BDL	7.2	27.9
ENV010	14.4	0.11	9.5	4.6	7.2	BDL	5.5	19.7
ENV013	21.6	0.08	11.7	5.1	11.4	BDL	6.6	27
ENV014	21.4	BDL	9.6	4.7	12.2	BDL	7	28.2
ENV024	8.6	0.25	3.1	3.6	8.6	BDL	4	16
ENV027	10.9	0.09	7.7	5	8.2	BDL	8.6	23.7
ENV029	13.8	0.05	8.4	3.7	9.8	BDL	7.2	29.8
Min	8.6	0.05	3.1	3.6	7.2	0.02	4	16
Max	27.5	0.25	12.6	5.7	14.9	0.04	8.6	29.8
Mean	18.45	0.12	9.17	4.67	10.79	0.03	6.65	25.49
SE	2.03	0.04	0.81	0.21	0.77	0.01	0.40	1.40
CEFAS AL1	20	0.4	40	40	50	0.3	20	130
CEFAS AL2	100	5	400	400	500	3	200	800
OSPAR BAC	25	0.31	81	27	38	0.07	36	122
OSPAR ERL	8.2*	1.2	81	34	47	0.15	21*	150
TEL	7.24	0.7	52.3	18.7	30.2	0.13	-	124
PEL	41.6	4.2	160	108	112	0.7	-	271

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

Table 17 Number of stations across the Llŷr survey area exhibiting elevated heavy and trace metals levels in comparison with OSPAR, CEFAS and Canadian/International Sediment Quality Guidelines.

Metal	CEFAS		OSPAR BAC		CSQG	
	AL1	AL2	BAC	ERL	TEL	PEL
As	4	0	2	10	10	0
Cd	0	0	0	0	0	0
Cr	0	0	0	0	0	0
Cu	0	0	0	0	0	0
Pb	0	0	0	0	0	0
Hg	0	0	0	0	0	0
Ni	0	0	0	0	0	0
Zn	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.

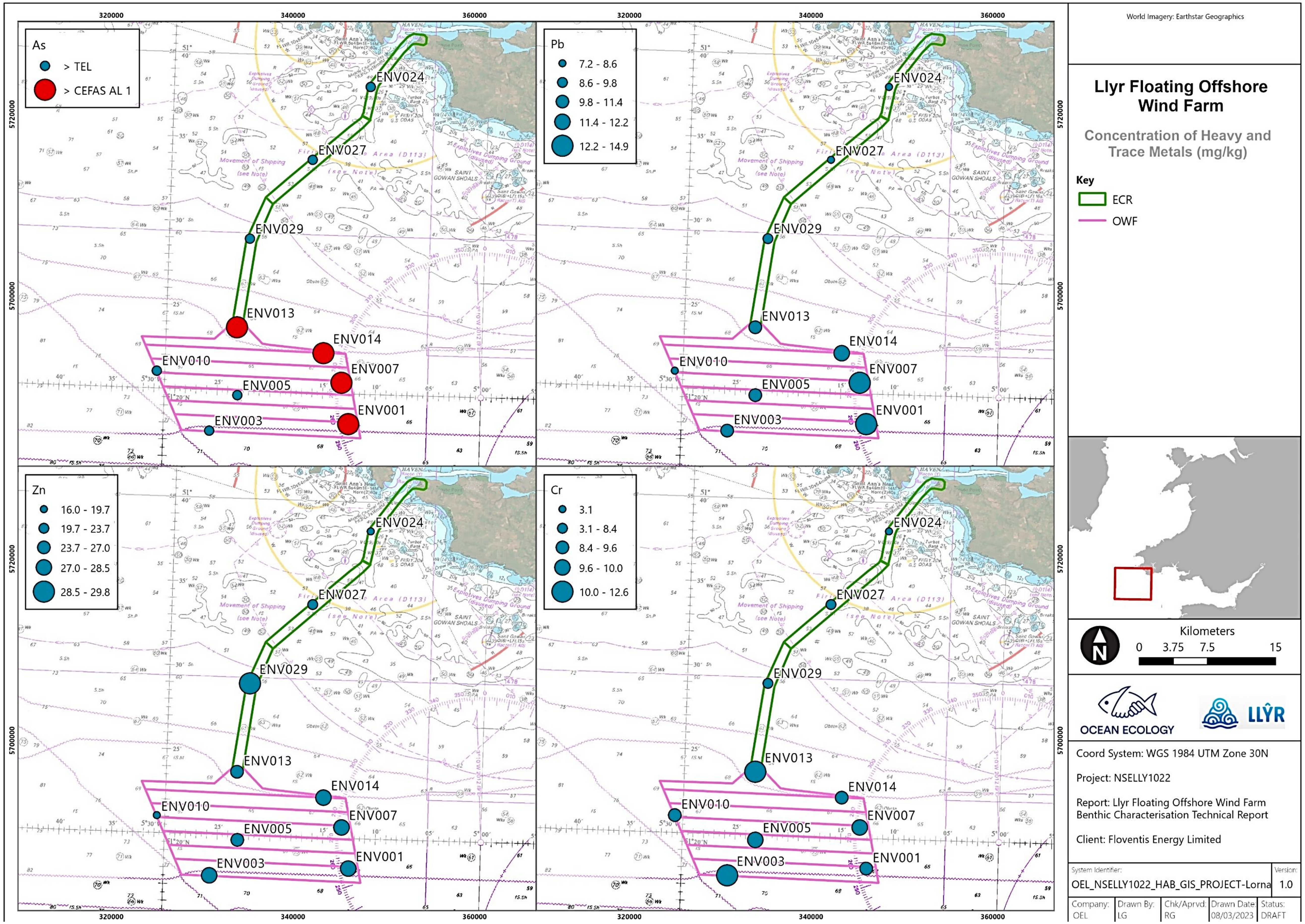

Figure 15 Concentration of the key heavy and trace metals sampled across the survey area. Note different scales for each chemical.

7.4.3. Polycyclic Aromatic Hydrocarbons (PAHs)

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 10 contaminant sub-samples collected.

The results of the PAHs analysis undertaken are reported in Appendix X. PAH concentrations were compared to CEFAS AL1 (no CEFAS AL2 available for PAHs), OSPAR BAC levels and ERLs, and TEL and PEL where possible (Table 18). The only reference level to be exceeded was the TEL, with Naphthalene exceeding the TEL reference level at station ENV001. However, none of the other PAH concentrations exceeded any of the reference levels.

The most abundant PAHs were: Fluoranthene with a mean concentration across the survey area of 3.67 $\mu g\ kg^{-1}$ and a maximum concentration of 10.8 $\mu g\ kg^{-1}$ at ENV003, Phenanthrene with a mean concentration across the survey area of 3.42 $\mu g\ kg^{-1}$ and a maximum concentration of 10.5 $\mu g\ kg^{-1}$ at ENV001 and Pyrene with a mean concentration across the survey area of 2.70 $\mu g\ kg^{-1}$ and a maximum concentration of 7.98 $\mu g\ kg^{-1}$ at ENV003. None of these PAHs exceeded reference levels.

To determine the origin source of PAH compounds in sediments, the ratio between LMW and HMW PAHs was calculated at all sub-samples stations excluding ENV007 and ENV029 where this ratio was not calculated due to measurements Below Detection Limits (BDL). Based on this ratio four stations were characterised by PAHs of pyrogenic origin (LMW / HMW < 1) ENV001, ENV003, ENV005 and ENV014 whereas the remaining four stations were characterised by PHAs of a petrogenic origin (LWM / HMW >1).

Similarly, the ratios of Phenanthrene / Anthracene (Ph / Ant) indicated a pyrogenic origin of PAHs as this ratio was below 10 at four stations ENV003, ENV005, ENV010 and ENV024 and a petrogenic origin at station ENV001. However, it should be noted that concentrations were below detection limits at five stations and therefore it was not possible to calculate Ph / Ant at these locations.

The Fluoranthene / Pyrene ratio (Fl / Py) was not calculated at stations ENV007, ENV027 and ENV029 due to measurements BDL. Where the Fl/PY ratio was calculated, all ratios were a greater than one (7 out of 10) indicating pyrogenic origin source of PAHs across the survey area (Table 18).

The spatial distribution of Naphthalene and PAH based indices across the 10 sub-sampled stations are presented within Figure 16.

Table 18 Summary results of PAHs analysis.

Analyte	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene
Min	BDL	BDL	BDL	BDL	BDL	BDL
Max	7.21	***1.16***	BDL	***1.78***	***10.50***	***2.50***
Station of Max	ENV001	ENV003	-	ENV001	ENV001	ENV003
CEFAS AL1	**100**	**100**	**100**	**100**	**100**	**100**
BAC	**8**	-	-	-	**32**	**5**
ERL	**160**	-	-	-	**240**	**85**
TEL	**34.6**	**5.87**	**46.9**	**21.2**	**86.7**	**46.9**
PEL	**391**	**128**	**245**	**144**	**544**	**245**

Analyte	Fluoranthene	Pyrene	Benzo[a]anthracene	Chrysene (inc. Triphenylene)	Benzo[b]fluoranthene	Benzo[k]fluoranthene
Min	BDL	BDL	BDL	BDL	BDL	BDL
Max	***10.80***	***7.98***	***6.44***	***7.93***	***6.44***	***5.49***
Station of Max	ENV003	ENV003	ENV003	ENV003	ENV003	ENV003
CEFAS AL1	**100**	**100**	**100**	**100**	-	-
BAC	**39**	**24**	**16**	**20**	-	-
ERL	**600**	**665**	**261**	**384**	-	-
TEL	**113**	**153**	**74.8**	**108**	-	-
PEL	**1494**	**1398**	**693**	**846**	-	-

Analyte	Benzo[e]pyrene	Benzo[a]pyrene	Perylene	Ideno[123,cd]pyrene	Dibenzo[a,h]anthracene	Benzo[ghi]perylene
Min	BDL	BDL	BDL	BDL	BDL	BDL
Max	***4.43***	***5.24***	***1.32***	***3.44***	***BDL***	***3.90***
Station of Max	ENV003	ENV003	ENV003	ENV001	-	ENV001
CEFAS AL1	-	**100**	-	**100**	**100**	**100**
BAC	-	**30**	-	**103**	-	**80**
ERL	-	**430**	-	-	-	-
TEL	-	**88.8**	-	-	**6.22**	-
PEL	-	**763**	-	-	**135**	-

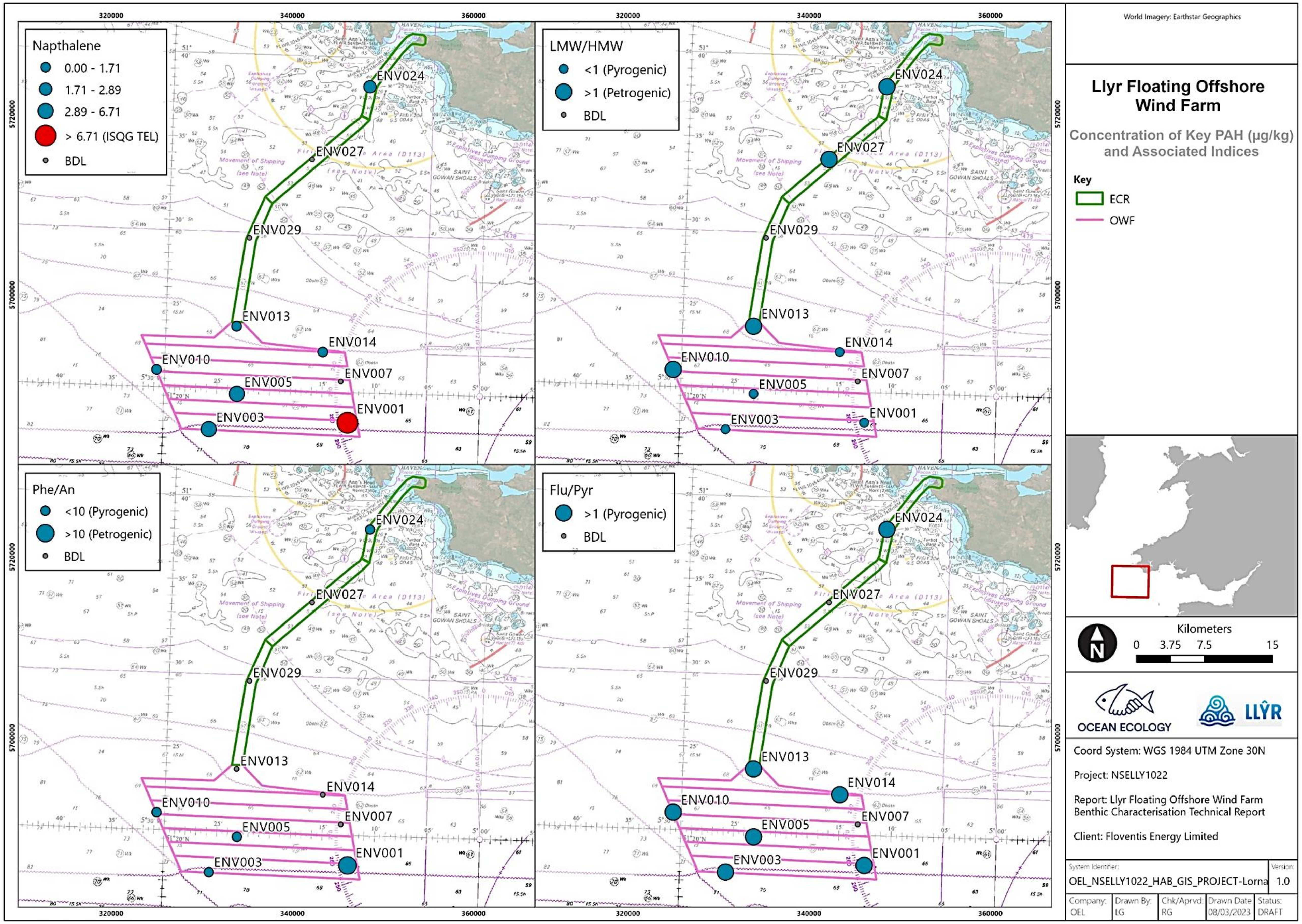

Figure 16 Location of PAH concentrations (µg kg^{-1}) in sediment across the survey area.

7.4.4. Total Hydrocarbons (THC)

THC in sediment samples ranged from 4,190 µg kg^{-1} at station ENV001 to 1,010 µg kg^{-1} at station ENV007 with an average value (± SE) for the survey area of 2,111 ± 331.18 µg kg^{-1} (Table 19).

N-alkanes (saturates) in sediments had carbon chains length ranging between C12 and C36, with the dominant chains being C28 for the even numbered chains and C29 for the odd numbered chains. The highest concentration of total n-alkanes was recorded at station ENV001 being 94.4 µg kg^{-1}, while the lowest concentration of 11.9 µg kg^{-1} was found at station ENV027. The average concentration of n-alkanes (± SE) for the survey area was 40.63 ± 10.20 µg kg^{-1} (Table 19).

Pristane was the highest at station ENV001 being 6.07 µg kg^{-1}, and the lowest at station ENV029 where was recorded BDL. Phytane was measured below the level of detection at all sub-sampled stations and therefore the Pristane / Phytane ratio could not be calculated.

Conversely, the CPI could be calculated to assess n-alkanes origin sources, and it was found that the origin of n-alkanes was biogenic (CPI >1) at all stations sub-sampled across the survey area. No stations had a pyrogenic source of n-alkanes (CPI < 1).

The spatial distribution of the total oil, N-alkanes and CPI are presented in Figure 17.

Table 19 Summary of Total Hydrocarbon concentrations (µg kg^{-1}) in sediments across stations sampled.

Station	Total Oil	Total n alkanes	Carbon Preference Index
ENV001	4190.0	94.4	1.3
ENV003	2960.0	92.9	1.8
ENV005	3280.0	66.9	1.3
ENV007	1010.0	14.5	5.8
ENV010	2150.0	34.3	2.0
ENV013	1900.0	31.7	2.4
ENV014	1510.0	14.1	12.4
ENV024	1620.0	29.7	1.3
ENV027	1470.0	11.9	5.3
ENV029	1020.0	15.9	8.3
Min	1010.0	11.9	1.3
Max	4190.0	94.4	12.4
Mean	2111.0	40.6	4.2
SE	331.2	10.2	1.2

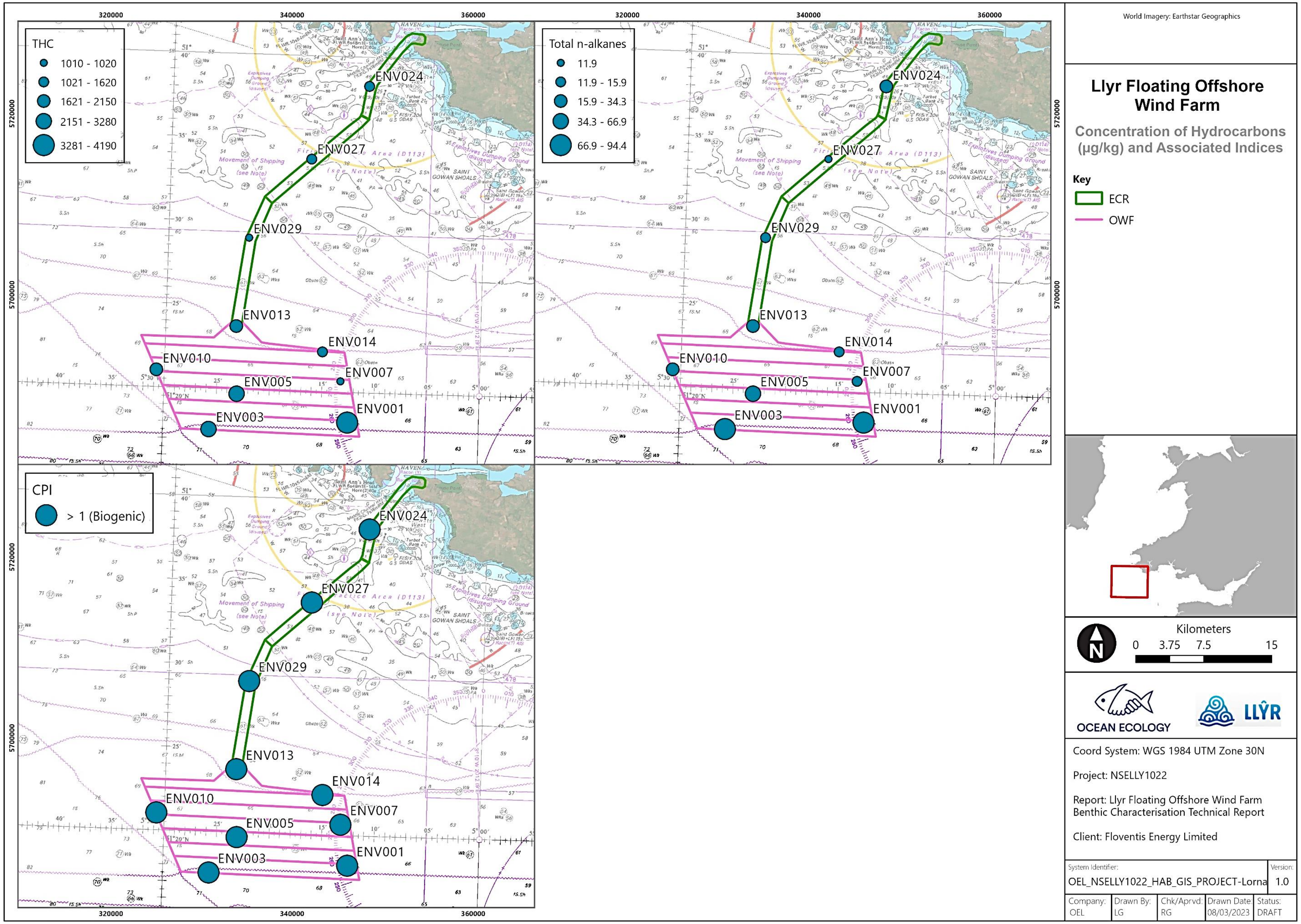

Figure 17 Concentrations of hydrocarbons and associated indices for stations sampled across the survey area. Note different scales.

7.4.5. PCBs

All PCBs were below the detection limit at all stations.

7.4.6. Organotins

All organotins were below the detection limit at all stations.

7.5. Macrobenthos

7.5.1. Macrobenthic Composition

A diverse macrobenthic assemblage was identified across the survey area from the 30 macrobenthic samples collected, with a total of 5,195 individuals and 226 taxa recorded. The mean (± SE) number of taxa per station was 26 ± 3, mean (± SE) abundance per station was 173 ± 38 and mean (± SE) biomass per station was 0.4009 ± 0.0900 gAFDW.

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

The sampling stations with the highest abundance were stations ENV017, ENV025 and ENV008. Stations ENV008 and ENV017 were dominated by Echinodermata whereas station ENV025 was dominated by Annelida taxa (Figure 19). Echinodermata was the most dominant major taxonomic group in terms of abundance at the majority of OWF stations, with the exception of stations ENV007 and ENV011 where annelids were the most abundant group. The most dominant taxonomic group along the ECR varied, but was never Echinodermata, with Annelida being the dominant group at the majority of ECR stations (Figure 19). Sampling stations with the highest richness (number of taxa) were stations ENV025, ENV015 and ENV008 with specimens belonging to 115, 42, and 32 different taxa, respectively (Figure 20). Biomass ranged between 0.0234 and 2.2312 gAFDW per sample, with the highest value found at station ENV025 due to high Mollusca biomass (Figure 20).

As shown in Figure 21 juvenile specimens of the brittle star family Amphiuridae were the most abundant taxon sampled accounting for 30.6 % of all individuals recorded. They were also one of the most frequently occurring taxa recorded in 30 % of samples and accounted for the greatest average density per sample. Other key taxa were the two-toothed Montagu shell *Kurtiella bidentata* which reported the maximum abundance per sample and occurred in 30 % of the samples, and the polychaete *Scoloplos armiger* which also occurred in 30 % of samples.

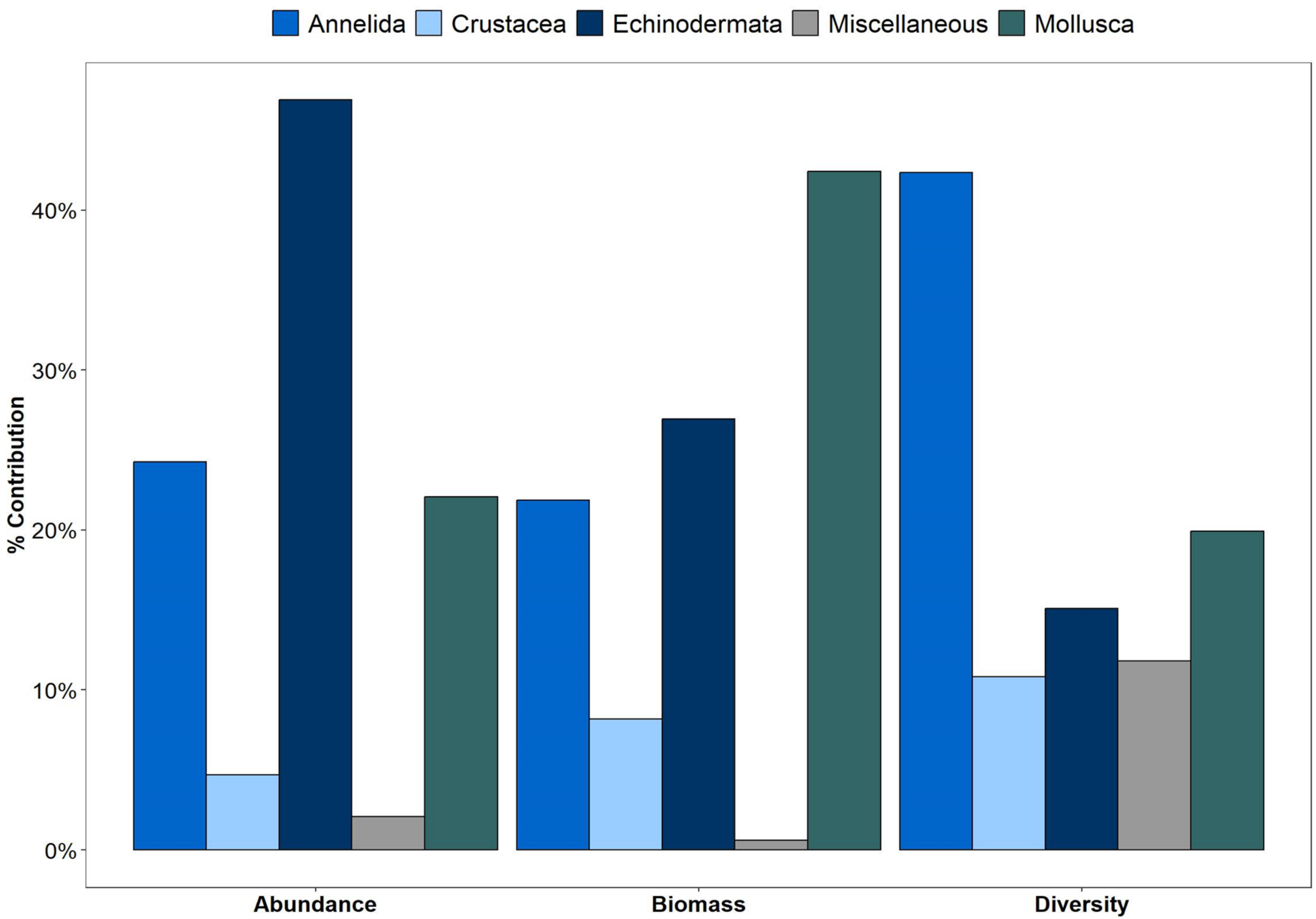

Figure 18 Relative contribution of the major taxonomic groups to the total abundance, diversity and biomass of the macrobenthos sampled across the survey area. Abundance counts exclude colonial taxa.

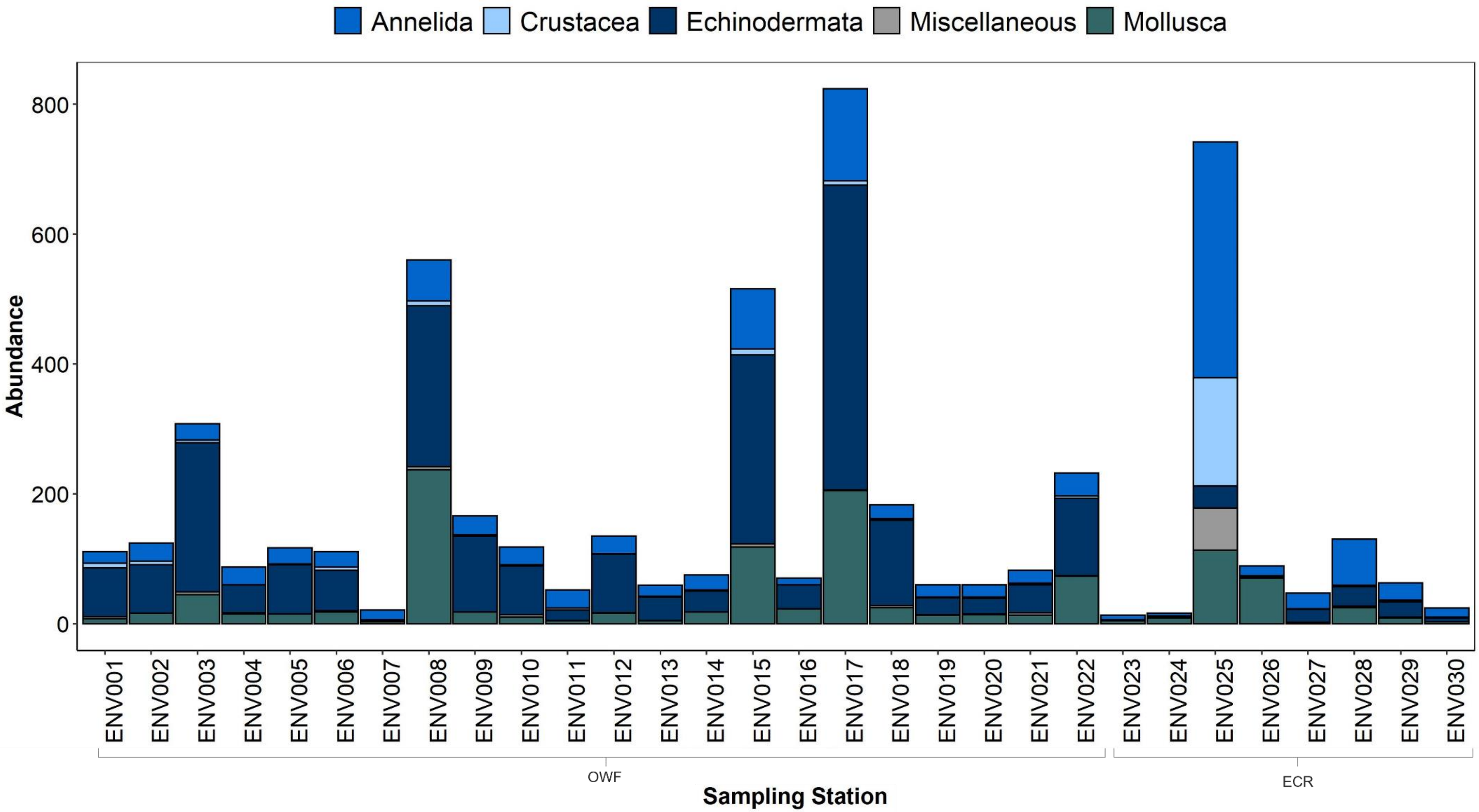

Figure 19 Total abundance of the major macrobenthic taxonomic groups by station. Abundance counts exclude colonial taxa.

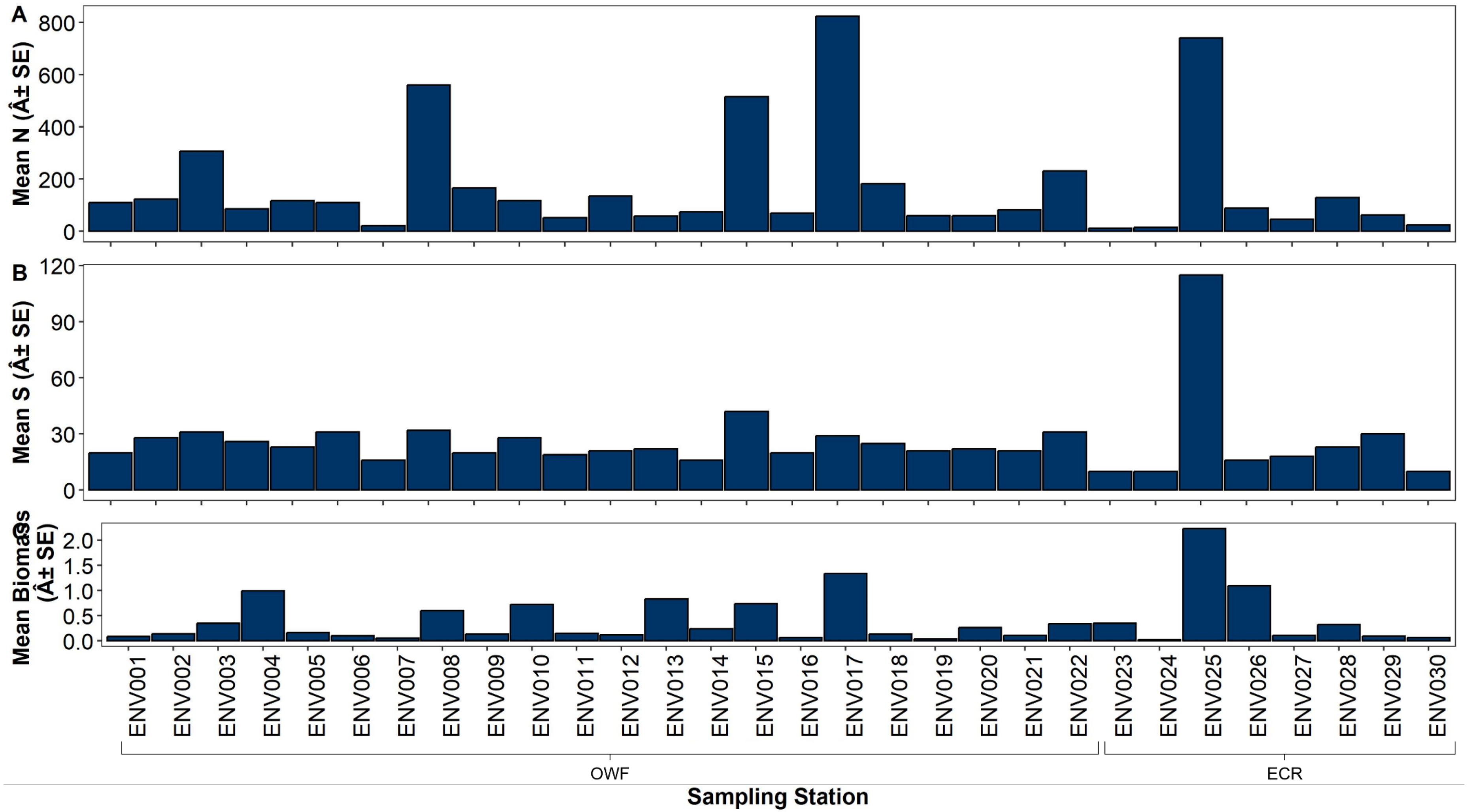

Figure 20 Abundance, diversity and biomass (gAFDW) per station across the Llŷr survey area.

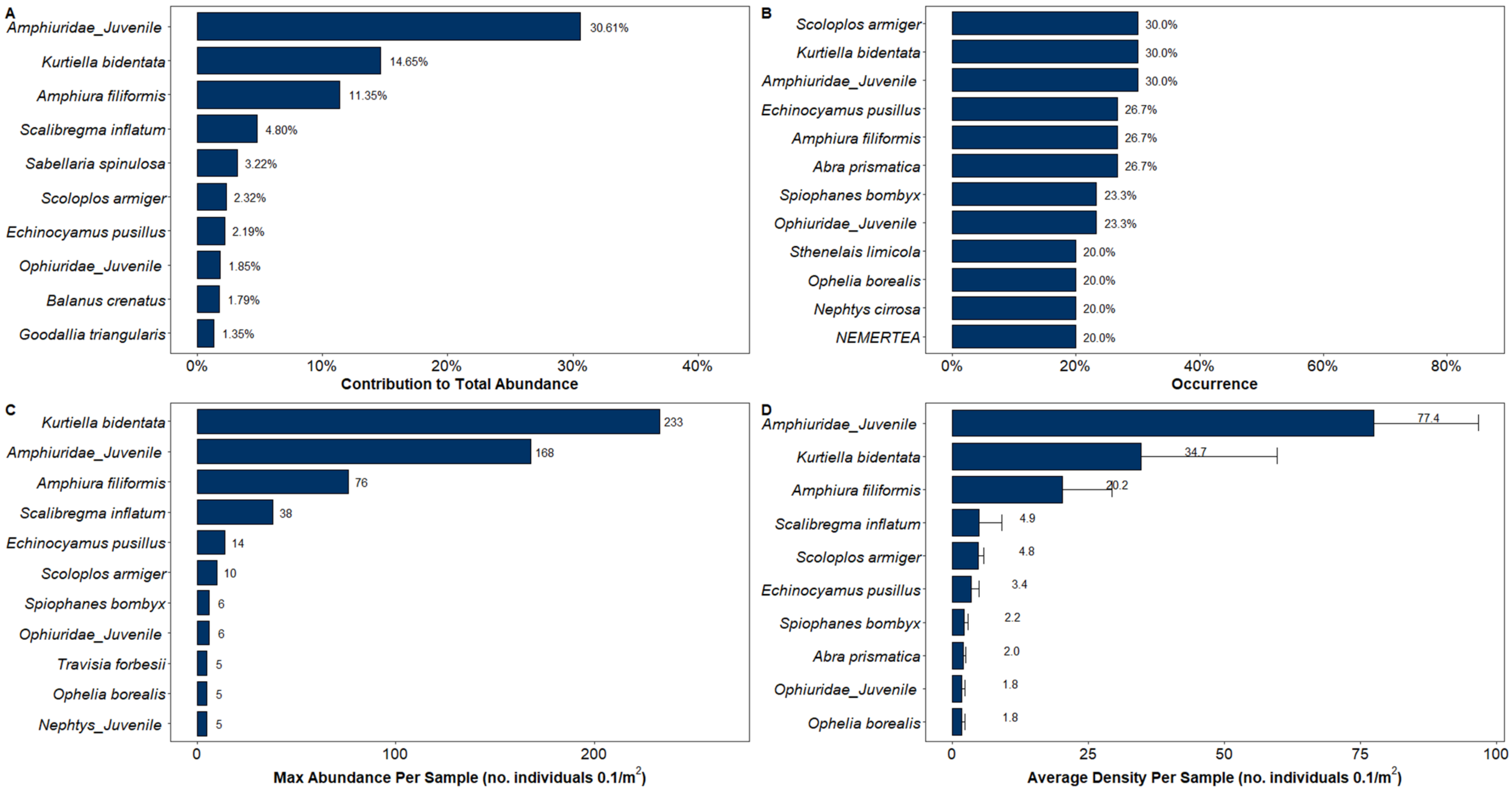

Figure 21 Percentage contributions of the top 10 macrobenthic taxa to total abundance (a) and occurrence (b) from samples collected across the survey area. Also shown are the maximum densities of the top 10 taxa per sample (C) and average densities of the top 10 species per sample (D).

7.6. Macrobenthic Groupings

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

Cluster analysis of the macrobenthic data was performed on a Bray-Curtis similarity matrix to analyse the spatial similarities in macrobenthic communities recorded across all sampled stations. The dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF (similarity profile routine) permutation test of all nodes within the dendrogram, identified three statistically significantly similar groups ($p > 0.05$) and two outlier stations that did not belong to any group. A dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF permutation test is presented in Figure 23. The remaining two stations ENV023 and ENV027 were considered outliers. The spatial distribution of these outlier stations and the macrobenthic groups is presented in Figure 22.

To visualise the relationships between the sampled macrobenthic assemblages, a non-metric multi-dimensional scaling (nMDS) plot was generated on the abundance data (Figure 24). 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 (0.12) indicates that the two-dimensional plot provides a good representation of the similarity between stations. In general, the degree of clustering of intra-group sample points demonstrates the level of within group similarity, whilst the degree of overlap of inter-group sample points is indicative of the level of similarity between different macrobenthic groups (e.g., between Macrobenthic Groups A and B).

SIMPER (similarity percentage analysis) was used to identify the key taxa contributing to the within group similarity of the macrobenthic group and outliers recognised; the full SIMPER results are provided in Appendix XIII.

Macrobenthic Group A (19 stations) - Characterising taxa present at the stations belonging to this group were Amphiuridae, the two-toothed Montagu shell *K. bidentata*, and the polychaete *S. armiger*. The average similarity of this group was 48 %.

Macrobenthic Group B (6 stations) – was characterised by Amphiuridae, the two-toothed Montagu shell *K. bidentata*, and the brittle star *Amphiura filiformis*.

Macrobenthic Group C (3 stations) - Characterising taxa present at the three stations belonging to this group were the bivalves *Goodallia triangularis* and *Spisula*, and the pea urchin *Echinocyamus pusillus*.

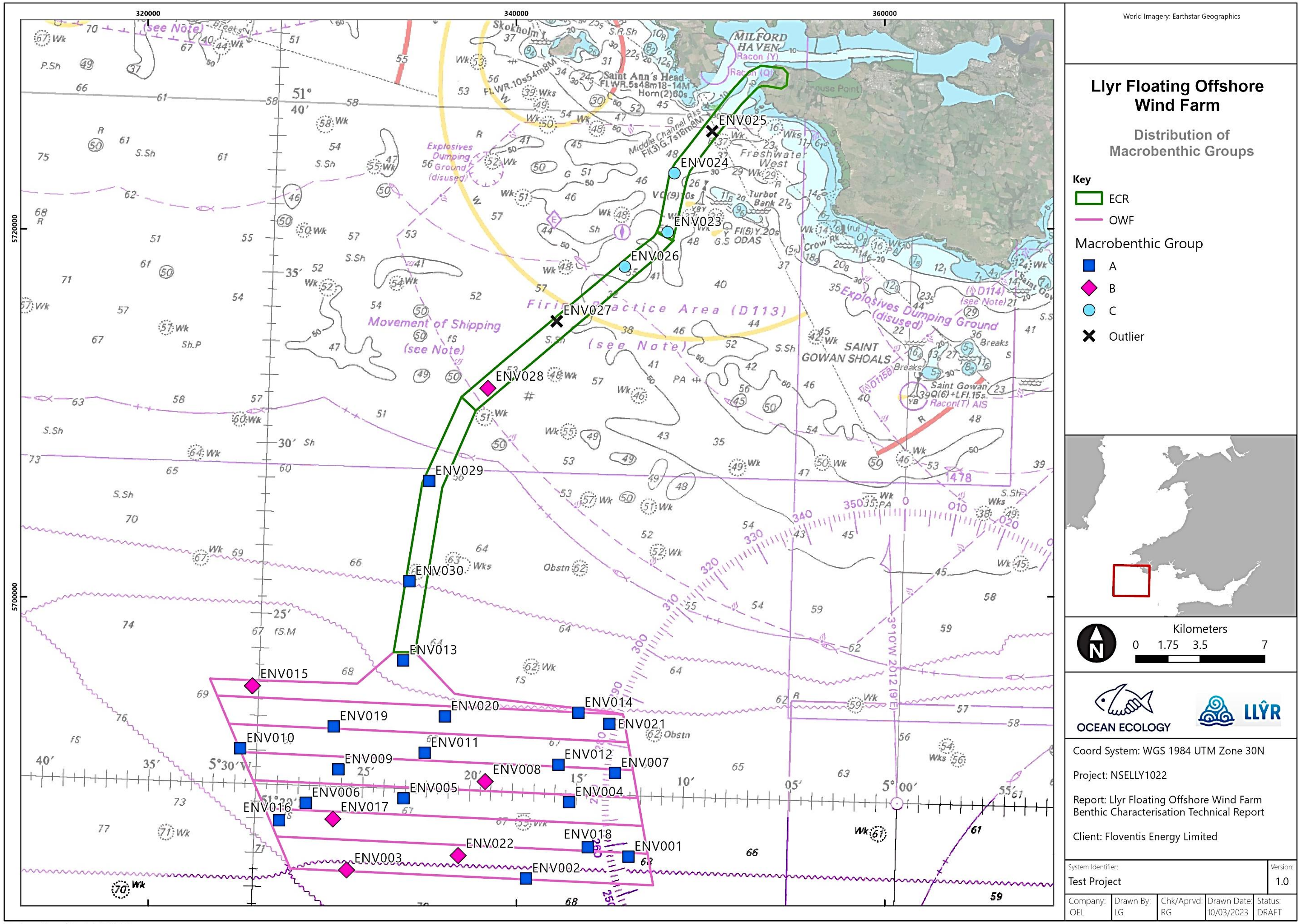

Figure 22 Spatial distribution of habitat and biotopes identified across the survey area based on macrobenthic community grouping.

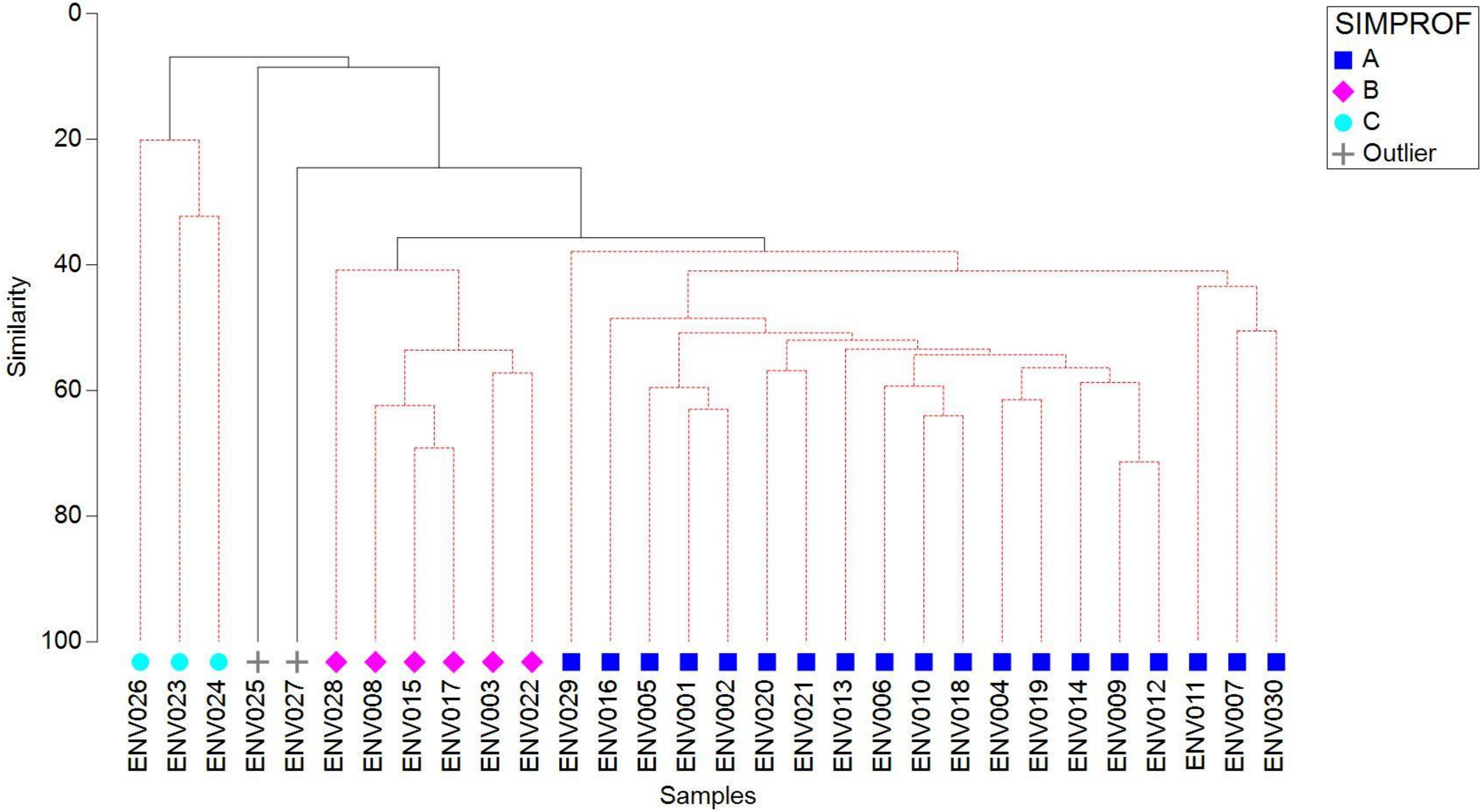

Figure 23 Cluster dendrogram showing similarity in macrobenthic community between stations. Based on a Bray-Curtis similarity matrix of square-root transformed abundance data. Symbolised by SIMPROF similarity groupings.

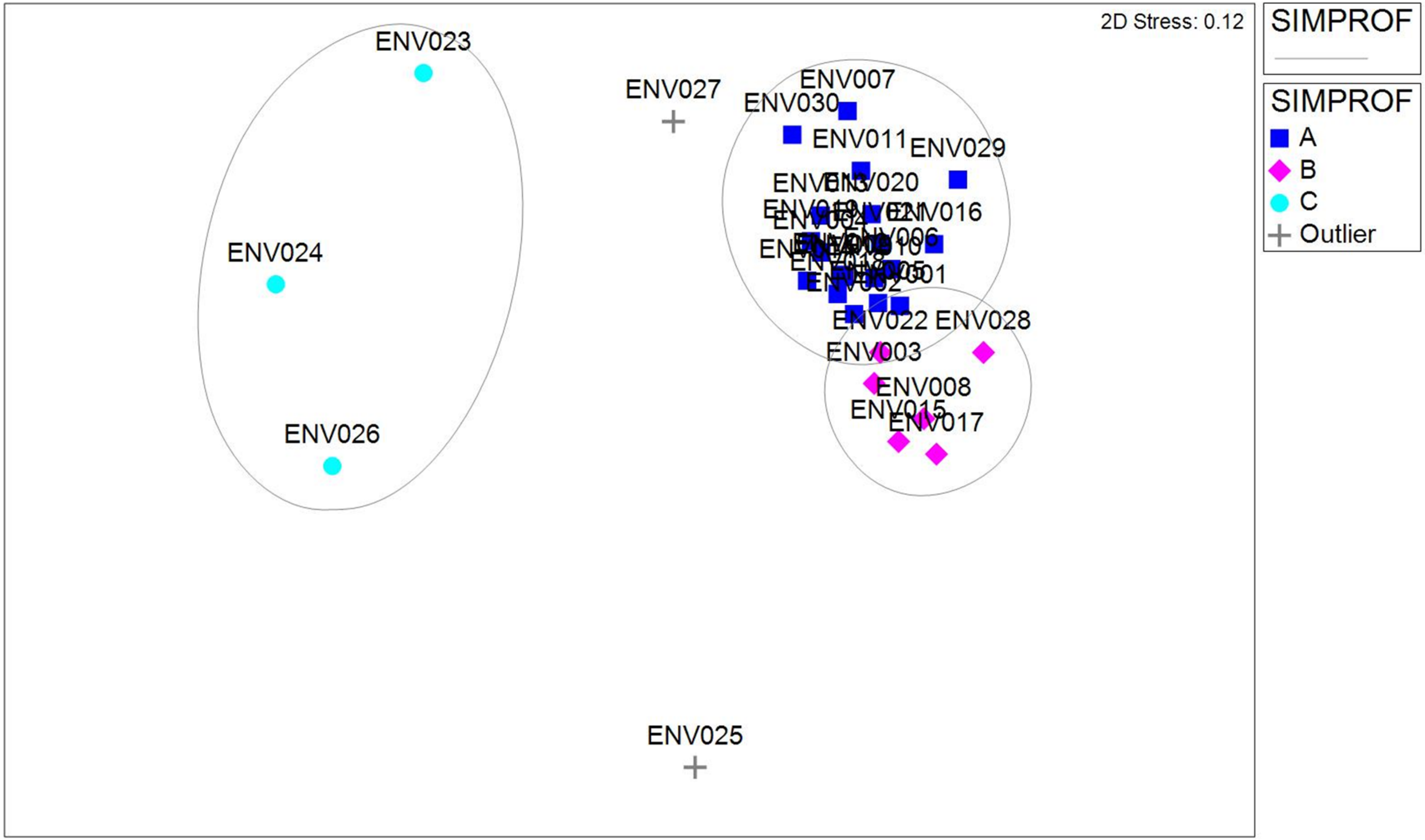

Figure 24 Two-dimensional nMDS ordination of macrobenthic communities sampled across the survey area, based on square root transformed and Bray-Curtis similarity abundance data. Crosses indicate outliers.

7.7. Biotope Assignment

For the Macrobenthic Groups determined using cluster analysis and the SIMPER routine, biotopes and habitats were assigned in line with JNCC guidance based upon the faunal and physical characteristics (Parry 2019). The spatial distribution of the habitat and biotopes encountered across the survey area is mapped in Figure 26.

Both outlier stations (ENV025 and ENV027) were assigned to their corresponding BSH based on sediment analysis as the macrobenthic multivariate analysis did not show any pattern in the community composition that could be used to assign a biotope. When considered individually, station ENV027 was most closely aligned to the biotope A5.251 '*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand' based on the high abundance of *E. pusillus* and *O. borealis* at this station, as well as the sediment classification as gravelly sand based on PSD data. Community level abundance was however overall low at this station. By contrast, the macrobenthic community at station ENV025 was dominated by *Sabellaria spinulosa* which when combined with the mixed sediment (muddy sandy gravel) determined from PSD data indicates the biotope A5.611 '*Sabellaria spinulosa* on stable circalittoral mixed sediment'. This also aligns well with the seabed imagery which assigned the same biotope to this station (Section 7.10). However, given only one sample was analysed at each station the biotope assignments at each of the two outlier stations should be interpreted with low confidence.

Macrobenthic Group A - The biotope that most closely aligned with the community observed within macrobenthic group A was "A5.251 – *Echinocyamus pusillus, Ophelia borealis and Abra prismatica* in circalittoral fine sand". This biotope is described as typical of circalittoral and offshore medium to fine sand which is consistent with the sediment found at the stations falling into this group (Sand, Slightly gravelly sand, and Gravelly sand; Figure 25). Additionally key characterising taxa of A5.251 such as *E. pusillus* and *Ophelia borealis* were among the taxa contributing the most to average similarity within Macrobenthic Group A.

Macrobenthic Group B - Macrobenthic group B was determined as EUNIS code A5.351 "*Amphiura filiformis*, *Mysella bidentata*, and *Abra nitida* in circalittoral sandy mud". This biotope is described as occurring in muddy sands in moderately deep water which is consistent with the sediments found at the stations falling into this group (Sandy mud, Muddy sand, and Slightly gravelly muddy sand; Figure 25), reporting the highest mud content across the survey area. Additionally characterising key taxa of A5.351 such as *A. filiformis* and *K. bidentata* were all driving community average similarity within Macrobenthic Group B.

Macrobenthic Group C - Macrobenthic group C was made up of only three stations and no key taxa were observed that would allow for the assignment of a specific biotope. Therefore stations ENV024 and ENV026 were determined as EUNIS classification A5.1 'Sublittoral coarse sediment' based on sediment data (Gravelly sand; Figure 25) while station ENV023 was assigned to EUNIS classification A5.2 'Sublittoral sand' (Slightly gravelly sand; Figure 25).

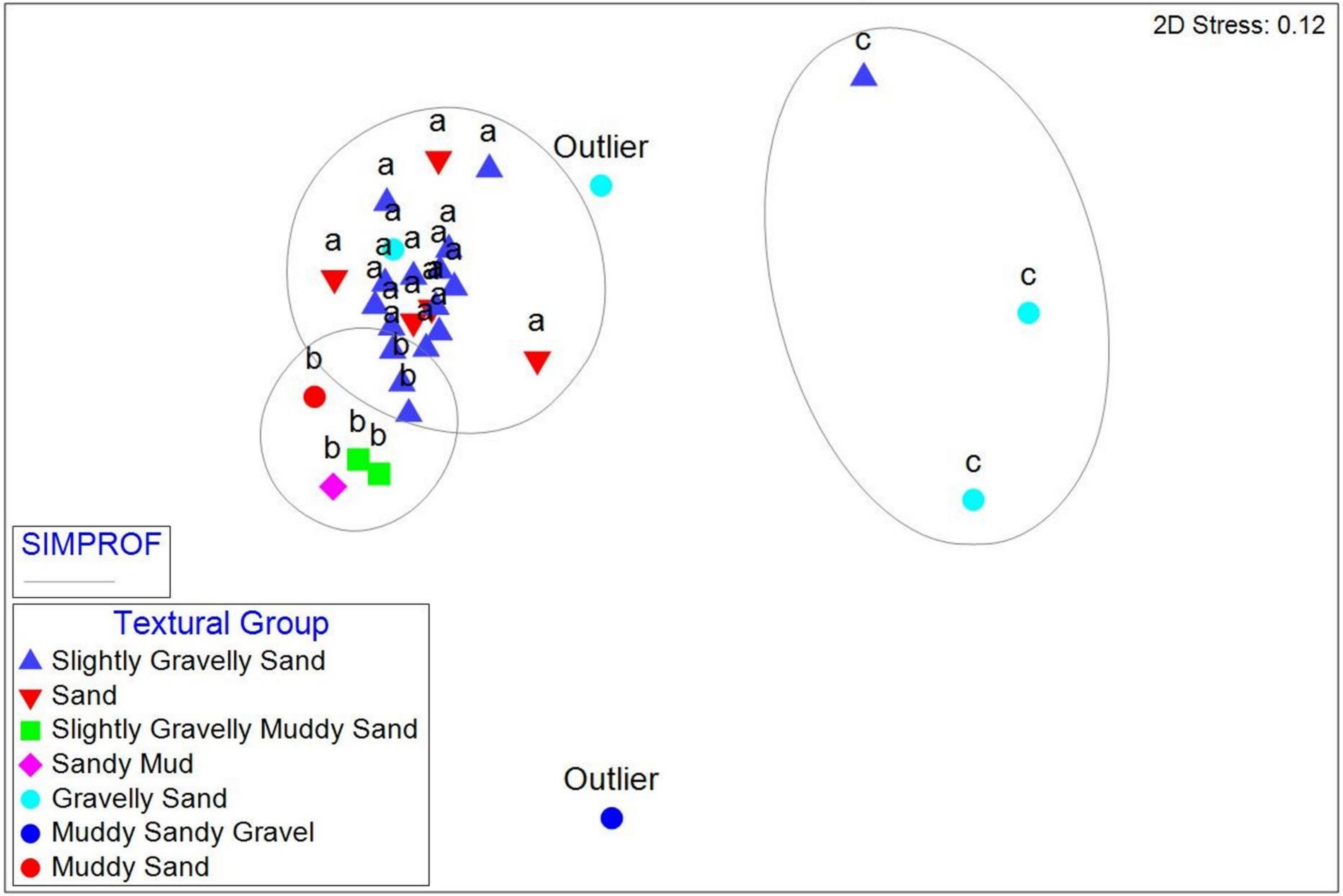

Figure 25 Two-dimensional nMDS ordination of macrobenthic communities sampled across the survey area, based on square root transformed and Bray-Curtis similarity abundance data. Labelled by SIMPROF (macrobenthic) grouping and symbolised by Folk textural group classification as determined by PSD analysis.

7.8. Notable Taxa

Notable taxa are defined as those species with significant conservation or economic importance. In the 30 grab samples collected throughout the survey area, a single species of notable interest was identified: *S. spinulosa* (Table 20).

A total of 169 specimens of *S. spinulosa* were identified across the survey area based on grab samples with 163 individuals counted at station ENV025 and the reminder occurring between ENV007 (one individual), ENV022 (one individual), ENV027 (two individuals) and ENV029 (two individuals).

Table 20 Notable taxa found across the survey area.

Taxon	Major Group	Designation	N of individuals
Sabellaria spinulosa	Annelida	OSPAR threatened and/or declining	169

7.9. Geophysical Data

The SSS and MBES data collected by N-Sea during the geophysical survey campaign covered the entire OWF area and the majority of the ECR up to approximately 2 km from the coast. A dedicated nearshore survey covered the remainder of the ECR and landfall areas and a separate report will present the findings. These data were initially utilised for the identification of subsea hazards and seabed features of interest in when designing the sampling plan and were interpreted together with the seabed imagery to inform the seabed habitat assessment and mapping process.

The SSS displayed typically uniform reflectivity across the OWF and through much of the southern extent of the ECR. Features of interest presenting as strong reflectivity signature and interpreted as potential bedrock and biogenic reef were identified in the centre and to the north of the ECR, which were investigated by DDC transects. Large sand bedforms were identified throughout the ECR.

Bathymetry data displayed a largely featureless area within the OWF and much of the ECR, with the exception of regular small rippled bedforms. Larger bedforms along the ECR, also noted in SSS data, in some cases present as raised from the seabed in MBES data, indicative of potential sandbank features.

Two small wrecks were identified using SSS, MBES data and admiralty charts, in the southern extent of the ECR and south-east of the OWF and taken into account when completing the habitat map.

All features of interest identified in the geophysical data (including potential Annex I reef features) were sampled by DDC transects in order to ground truth the acoustic signatures and support habitat mapping. The full extent of features was discerned using the geophysical data around areas that were sampled by DDC imagery.

7.10. Seabed Imagery

DDC sampling was successfully conducted at 30 stations and 6 transects, resulting in the collection of 432 still images and 73 videos. Full DDC video logs can be found in Appendix I and stills logs in Appendix II.

Three attempts were undertaken at T005a to ensure good quality footage was obtained. In the final imagery assessment, attempt T005a(3) was included in the analysis, with attempts T005a and T005a(2) not considered due to the non-analysable quality of the imagery. In this case, image analysis was undertaken on a total of 398 images.

Generally, the seabed imagery correlated well with the geophysical data collected across the survey area. The habitat assessment was conducted using the still images captured during the DDC deployments with the main habitats identified based on the seabed imagery presented in Table 21. Findings of the image analysis including BSH description and the EUNIS habitat description are presented in Appendix XIV, with Annex I reef assessments in Appendix XV.

Six BSHs, two EUNIS Level 3 (biotope complexes), 4 EUNIS Level 4 and two EUNIS Level 5 were identified in the seabed imagery collected across the OWF and ECR areas (Table 8).

The most commonly encountered of these was A5.26 'Circalittoral muddy sand' identified in 288 images and widely distributed across the OWF and southern extent of the ECR. This was followed by A5.44 'Circalittoral mixed sediment' identified in 40 images (Figure 26).

Seabed imagery generally aligned well with grab samples, with the BSH A5.2 'Sublittoral sand' being the most widely reported BSH in both PSD data and seabed imagery analysis. Seabed imagery analysis generally overestimated the sediment mud content with the classification of A5.26 'Circalittoral muddy sand' compared to A5.25 'Circalittoral fine sand' which was identified for the majority of stations based on PSD and macrofaunal data. However, the classification as A5.25 and, more specifically, A5.251 was supported by infaunal data which is not possible to interpret in seabed imagery alone. Areas of A5.611 '*Sabellaria spinulosa* on stable circalittoral mixed sediment' were identified in both seabed imagery and sediment samples in the north of the ECR.

Table 21 EUNIS BSH and biotope complexes identified in seabed imagery across the OWF and ECR areas.

BSH	EUNIS Code	EUNIS Description	Area Identified
A4.1	-	High energy circalittoral rock	ECR
	A4.13	Mixed faunal turf communities on circalittoral rock	ECR
A4.2	-	Moderate energy circalittoral rock	ECR
A5.1	A5.14	Circalittoral coarse sediment	ECR
	A5.141	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	ECR
A5.2	A5.26	Circalittoral muddy sand	ECR and OWF
A5.4	A5.44	Circalittoral mixed sediments	ECR and OWF
A5.6	A5.611	*Sabellaria spinulosa* on stable circalittoral mixed sediment	ECR

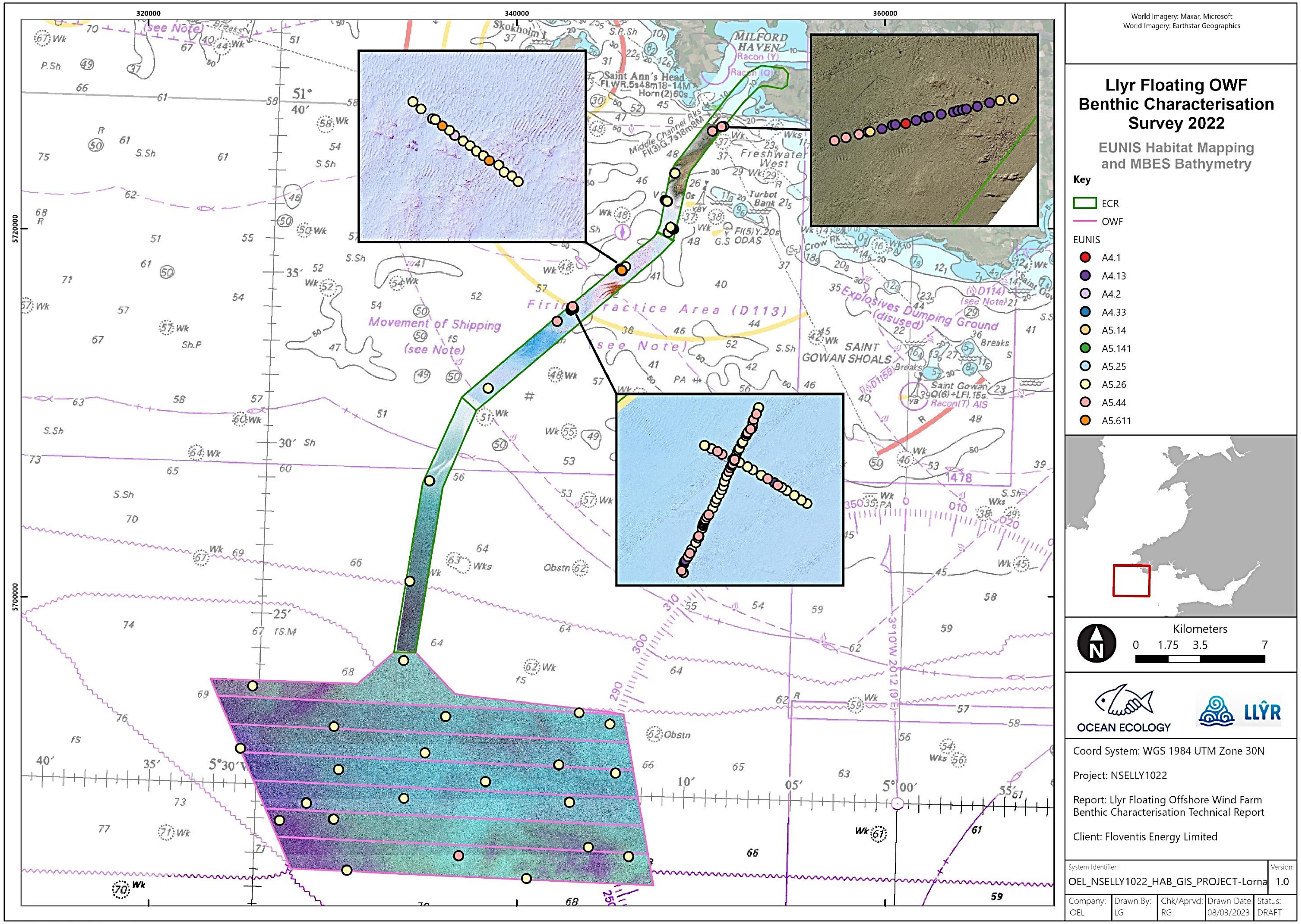

Figure 26 EUNIS codes assigned to DDC imagery collected across the survey area. Overlaid on MBES bathymetry data.

7.10.1. Annex I Reef

Potential Annex I reef features were found in 43 images (10.8%) across the survey area (Figure 27). Of these:

- Bedrock was found in 27 images across transects T003, T005 and T005a. Of these, 25 (6.28 %) were determined as bedrock reef.
- Stony reef was found in 14 images across transects T002 and T003. Of these, 3 (0.75 %) were determined as areas of low stony reef habitat.
- *S. spinulosa* tube aggregations were found in two images along T004 but these were not deemed to qualify as Annex I biogenic habitat due their limited extent.
- Note that across the survey area, bedrock reef was frequently observed as having a thin sand veneer, indicating that bedrock may have been present across a wider area than what was observable. All Annex I reef assessments were undertaken in line with the criteria set out in Section 6.5.

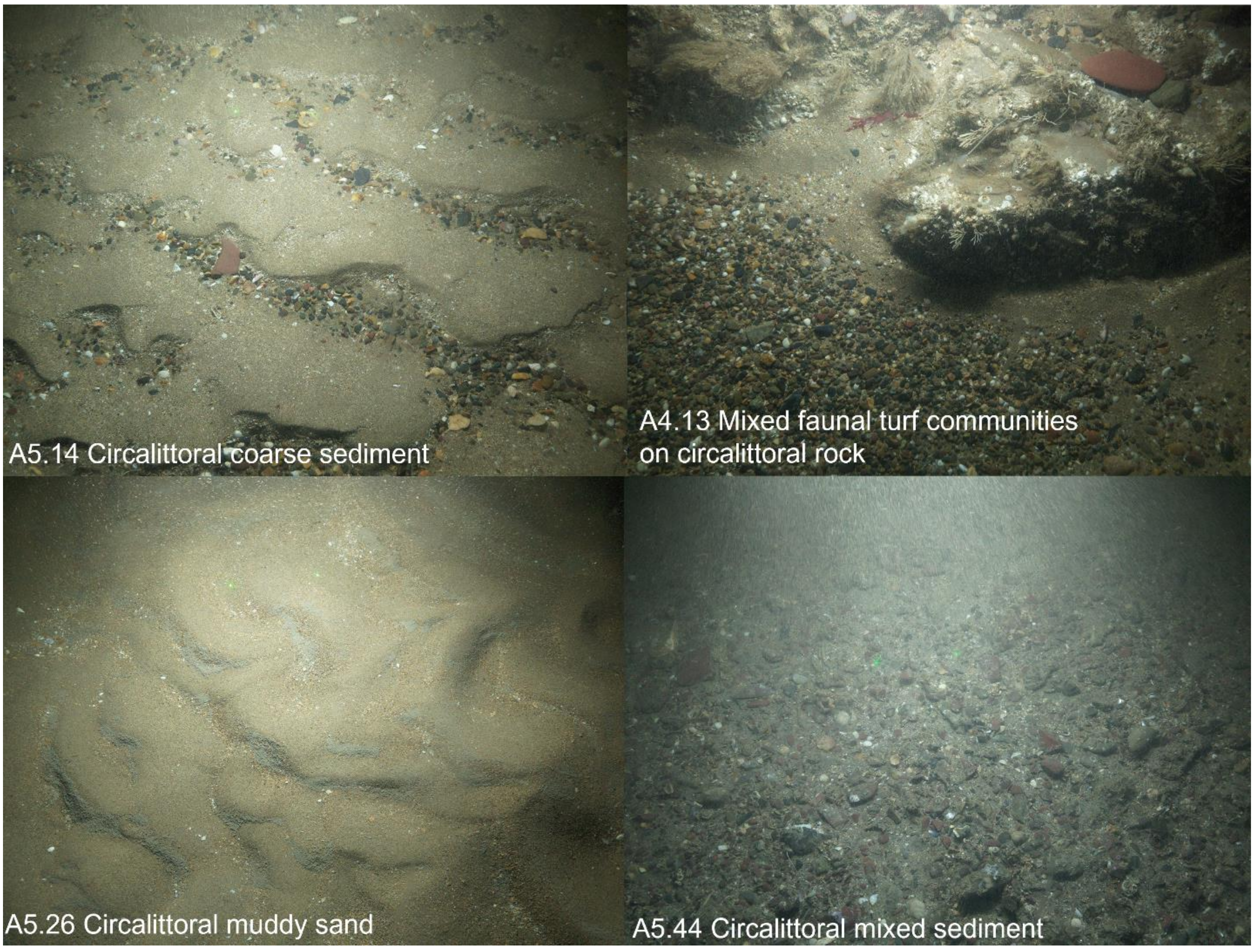

Plate 3 Example imagery of the main EUNIS found across the survey area obtained from T02, T02, ENV030 and ENV025, respectively.

7.10.2. Conspicuous Taxa

Several species/groups of fauna were regularly sighted in the seabed video and captured in the still imagery, including acorn barnacles, faunal turf, brittle stars (*Ophiura* sp.), Sabellidae and hermit crabs (Paguridae). No observations of epibenthic INNS were recorded during the assessment (Appendix XVII).

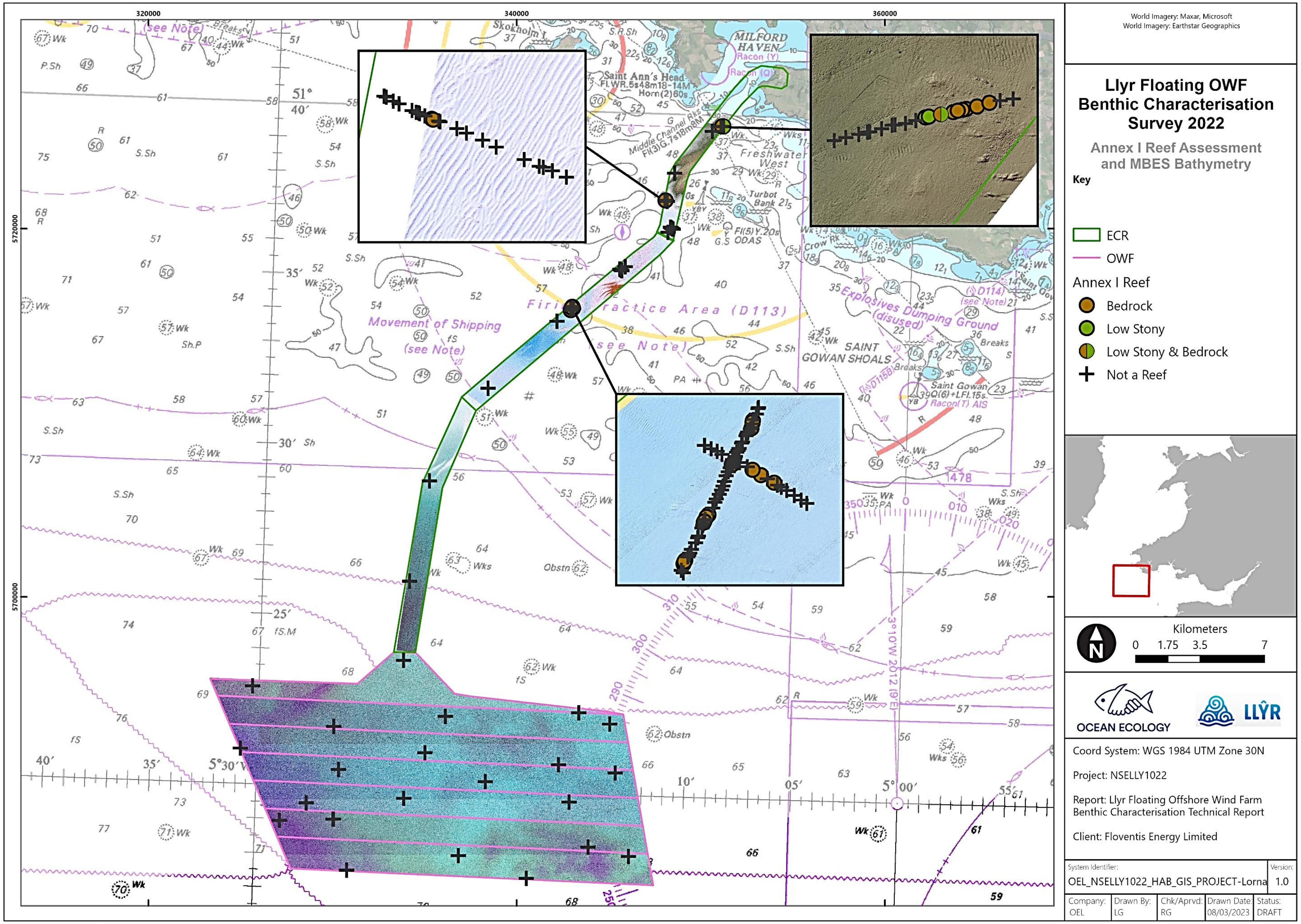

Figure 27 Annex I reef found across survey area. Overlaid on MBES bathymetry data.

7.11. Habitat Mapping

To map the principal habitats that occurred across the survey area, a full interrogation of available PSD, macrobenthic, and geophysical data in combination with review of DDC imagery was undertaken. Biotopes at the discrete grab locations were assigned a greater level of detail, based on PSD and macrobenthic data, compared to wider habitat mapping based on acoustic data and seabed imagery.

Based on acoustic data and seabed imagery alone, the main array and offshore extent of the ECR were characterised as sublittoral sandy sediment such as A5.25 (Figure 28). Along the northern section of the ECR, coarser habitat types were recorded, such as A5.44 'Circalittoral Mixed Sediment', as well as the rocky habitat A4.13 'Mixed Faunal Turf Communities on Circalittoral Rock'. Areas of sand ripples were identified across the entire survey area, with larger ripples to the northeast of the proposed OWF.

Through interrogation of the PSD and macrobenthic data, sublittoral sediment types were further refined to a finer level of EUNIS classification. Nineteen out of 30 stations were classified as A5.251 '*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in Circalittoral Fine Sand', 5 stations were designated as A5.351 '*Amphiura filiformis, Mysella bidentata* and *Abra nitida* in Circalittoral Sandy Mud' and the remaining stations towards the north of the ECR as A5.1 'Circalittoral Coarse Sediment'.

The distribution and extent of the habitats/biotopes identified across the survey area, based on all the available data, are presented in Figure 28. Descriptions of each of these habitat/biotope types are presented in Table 22, along with the corresponding EUNIS classification assigned to each. Habitat/biotope mapping shapefiles are provided as Appendix XVIII.

Table 22 Main EUNIS classifications (and MNCR 04/05 correlations) identified within the Llŷr OWF and ECR.

EUNIS Level 3	EUNIS Level 4	EUNIS Level 5	MNCR Code	EUNIS Description	Area Identified (ECR/OWF/Both)
A4.1			CR.HCR	High energy circalittoral rock	ECR
	A4.13		CR.HCR.XFa	Mixed faunal turf communities on circalittoral rock	ECR
A5.1			SS.SCS	Sublittoral coarse sediment	ECR
A5.2			SS.SSa	Sublittoral sands and muddy sands	ECR
A5.2	A5.25		SS.SSa.CFiSa	Circalittoral fine sand	Both
		A5.251	SS.SSa.IMuSa.EcorEns	*Echinocardium cordatum* and *Ensis spp*. in lower shore and shallow	Both

EUNIS Level 3	EUNIS Level 4	EUNIS Level 5	MNCR Code	EUNIS Description	Area Identified (ECR/OWF/Both)
				sublittoral slightly muddy fine sand	
A5.3	A5.35	A5.351	SS.SMu.CSaMu.AfilKurAnit	*Amphiura filiformis, Kurtiella bidentata* and *Abra nitida* in circalittoral sandy mud	Both
A5.4			SS.SMx	Sublittoral mixed sediment	ECR
	A5.44	-	SS.SMx.CMx	Circalittoral mixed sediment	ECR

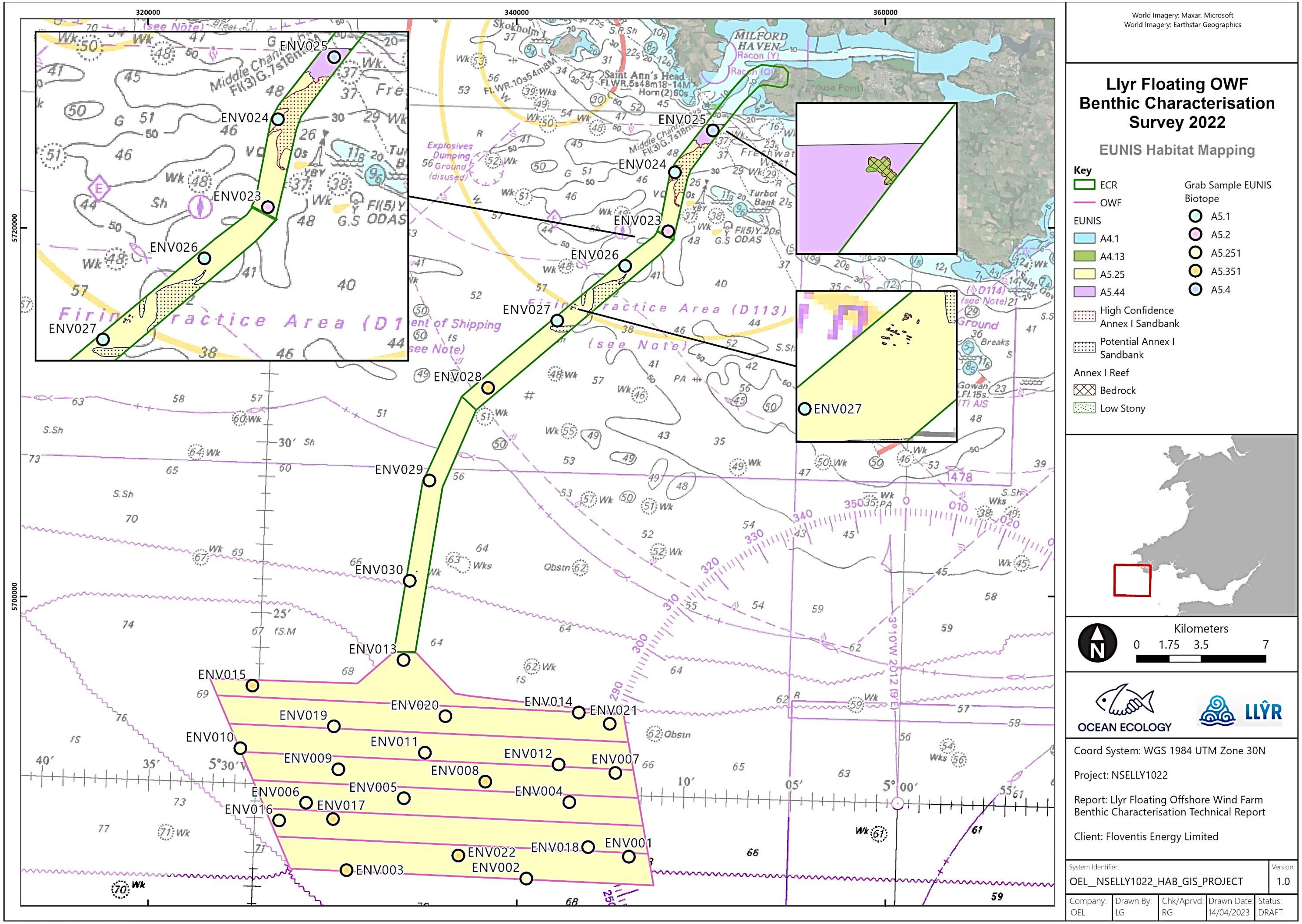

Figure 28 EUNIS classification mapping across the survey area.

7.11.1. Habitats of Conservation Importance

7.11.1.1. Annex I Reef

Annex I Stony Reef and Bedrock Reef

A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of Annex I reef (stony and bedrock) habitats as detailed in Table 9. 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. Areas of Annex I stony reef were present across the survey area, located within the nearshore section of the cable route and within ECR zone M (Figure 29). In total, two transects showed evidence of stony reef (T002, T003), with both transects deemed to be representative of low resemblance stony reef based on expert judgement due to coverage being low overall (< 30 m^2). Coverage of this habitat type was most extensive at transect T_003.

Annex I bedrock reef was identified along transects T003 and T005(3)a. The first was assigned a 'High' confidence score given its distinct topographic characteristics as well as the fact that it intersected an area of existing potential Annex I bedrock and/or stony reef (Figure 29). The Annex I bedrock reef recorded along transect T003 was found within the boundaries of the Pembroke Marine SAC where reefs are a primary qualifying feature. Coverage of this habitat type was most extensive in the area covered by transect T005(3)a, where additional areas of bedrock were mapped beyond the extent of ground-truth points. These additional areas were deemed to meet the criteria detailed in Table 9 and as such, were classified as Annex I reef.

Annex I Biogenic Reef

No Annex I biogenic reef habitat was observed across the survey area following reef qualifying criteria set out by (Gubbay 2007) (Table 10). Two images showing an area of mixed sediment supporting *S. spinulosa* tube aggregations (A5.611) were recorded along transect T004; however, this area was not deemed to meet the Annex I reef qualifying criteria due to patchiness and limited extent.

Annex I Sandbank

Two areas of sandy habitat were identified as likely Annex I sandbank habitats, covering a combined area of 4.55 km^2 of the export cable route in consideration of the descriptors described by Pinder (2020). EUNIS habitat A5.25 was assigned without ground truthing points to areas deemed as sandbank features based on consideration of SSS acoustic signatures. Based on the uniform bedforms observed in the acoustic data and the surrounding A5.25 habitat, it is likely these sandbanks are of the subtype gravelly and clean sands. The first was assigned a 'High' confidence score given its topographic characteristics as well as the fact that it intersects, and forms part of the known Turbot Bank Annex I sandbank which is a qualifying feature of the

Pembroke Marine SAC. The latter area was found further south along the ECR and was deemed to meet the topographic criteria but was assigned a 'Potential' confidence score due to the lack of known adjacent sandbanks (Pinder 2020) (Figure 30).

7.12. Section 7 of the Environment (Wales) Act 2016

Throughout the survey area, none of the taxa and species recorded were included under Section 7 of the Environment (Wales) Act 2016, which details organisms of principal importance for the purpose of maintaining and enhancing biodiversity in Wales. In terms of habitats, however, one identified in the survey area was listed under Section 7 of the same Act: "Sublittoral sands and gravels". This specific habitat was predominantly recorded at the stations where BSH A5.1 and A5.2 were identified, comprising a total of 27 stations covering the majority of the ECR and OWF area. Specifically, the 'sublittoral sands and gravels' habitat was found at four stations under BSH A5.1 and at 23 stations under BSH A5.2.Other Features of Note

Visual inspection of MBES bathymetry data resulted in the identification of a suspected wreck within ECR, with a length of 38 m. A second wreck was identified using an admiralty chart with small areas of potential debris identified in the MBES data.

The benthic sampling did not yield any other significant features or organisms of interest, with no fish (e.g., *Ammodytes* spp.) being collected in the samples taken. Similarly, no oyster beds or individuals were identified across the survey area nor were any INNS.

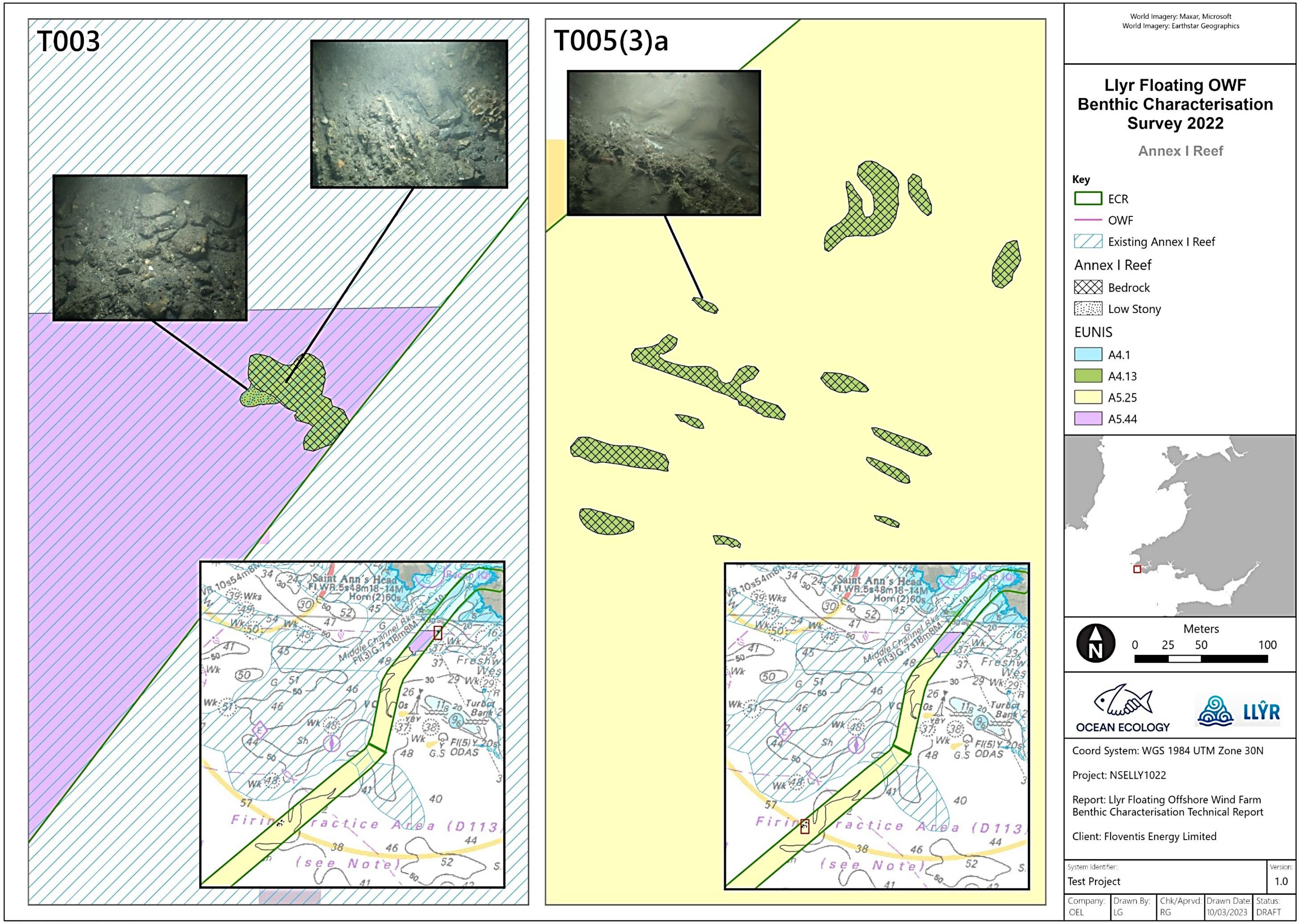

Figure 29 Areas of Annex I reef habitat mapped along the ECR.

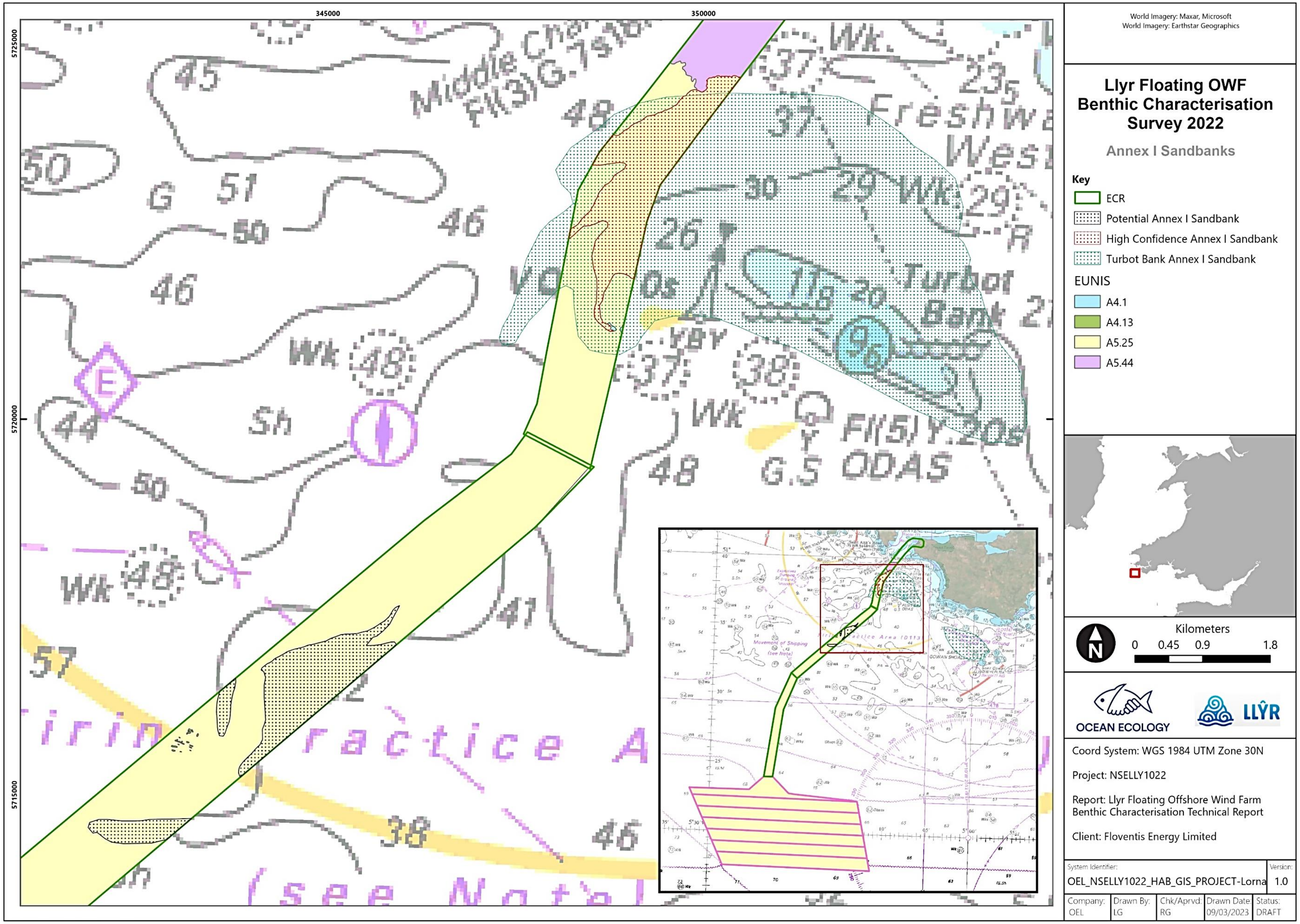

Figure 30 Annex I sandbanks habitat mapped along the ECR.

8. Discussion

This report presents the results and interpretation of the seabed imagery, macrobenthic and sediment analyses with the aim to set out the environmental baseline conditions across the proposed Llŷr OWF. The findings will inform the EIA in support of future consenting applications of the Llŷr project as well as providing a robust dataset for future comparison if required.

8.1. Sediments

There was little variation in sediment composition across the survey area, with most stations characterised by sand. Mud contribution to sediment was substantial only at one station (ENV017), where it represented more than half (~ 56 %) of the total composition. Similarly, gravel content was low at most stations, with higher percentages in proximity of the coast. However, in contrast to mud, gravel never contributed to more than 35 % of the sediment.

In general, nearly all stations could be classified as sand and muddy sand (BSH A5.2) using the EUNIS habitat classification framework. Consequently, from a conservation perspective, the survey area could be distinguished by "Subtidal sands and gravels" habitats of principal importance under the Section 41 Habitats and Species. Notably, however, this classification is not unique to the area and represents the most common type of habitat around the coast of the British Isles.

Sediment characteristics were also used to infer whether the seabed would be a suitable herring and / or sandeel spawning ground. There were no areas of seabed sampled that were determined to be suitable for herring spawning due to the relative low contribution of gravel (< 10 %) and relatively high mud content (> 5 %) across most stations. Conversely 26 stations were deemed to be suitable or marginally suitable for sandeel spawning.

8.2. Sediment Chemistry

TOC content was overall low across the survey area ranging from 0.02 % to 0.59 %, in range with the global sediment average TOC content of the deep ocean (0.5 %) but lower than the average content of the coastal ocean (2 %) (Seiter et al. 2004). In general, stations rich in mud (> 20 %) were also the stations with the highest TOC (> 0.4 %) and TOM (> 3%) content. Studies based on the coastal ocean and marine environment have found a positive relationship between organic matter and carbon 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.

Several guidelines exist to assess the degree of contamination and likely ecological impacts of contaminants in marine sediments. These regulations defined the levels below which effects are of no concern and/or rarely occur (AL1, BAC, TEL) and the levels above which adverse biological effects are considerable and/or occur frequently (AL2, ERL, PEL). *Ad hoc* decisions need to be made when contaminant concentrations fall between these levels.

To note that CEFAS ALs1 are typically the most conservative measures to assess sediment contamination and often result in “false positives” meaning that non-toxic sediment samples fail to pass this screening test. Conversely, ALs2 tend to be rather permissive allowing samples with relatively high contaminant concentrations to fall between AL1 and AL2 and thus requiring expert judgment to further assess their potential toxicity (MMO 2015, Mason et al. 2020). Recent studies have been revising these ALs with the goal of reducing the range of concentrations falling between AL1 and AL2 and minimise the number of samples requiring an *ad hoc* treatment; however, no policy has been made yet based on these recommendations and suggestions (MMO 2015, Mason et al. 2020).

Among all metals measured during the survey across the 10 sub-samples, As was the only metal with concentrations above reference levels at one or more stations. Specifically, As was above CEFAS AL1 at four stations and OSPAR BAC at two stations. As was also above the TEL reference level at all 10 measured stations. However, As concentrations exceeding the TEL may be attributable to TEL being based on North American data and as such it may not be fully representative of UK conditions (Section) (MMO 2015, 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 obvious pattern emerged when comparing stations with elevated As concentrations with mud content. However, spatially the four most abundant metals across the survey area, Zn, Pb, Cr, and As, typically presented lower concentrations at stations along the ECR. An east to west gradient of Pb, As, Zn Cr was noted within the OWF with station along the western side of the OWF presenting the top four metals in lower concentrations. Elevated metal sediment concentrations do not necessarily imply toxicity to benthic communities (Rees et al. 2007) as the bioavailability of these metals is more important than simply concentration levels. Despite the elevated As levels at four stations, no macrobenthic anomalies were identified at these locations to suggest any adverse effects were present.

No stations had metals concentrations above CEFAS AL2, meaning that adverse biological effects were rare. However, TEL and ERL values have been used for reference where possible throughout this assessment as these are the only guideline values that provide a measure of environmental toxicity compared to OSPAR BAC and CEFAS ALs that instead provide information on the degree of contamination in the sediments.

Only Naphthalene of the measured PAHs exceeded the BAC at stations ENV001. No macrobenthic anomalies were identified at this location to suggest any adverse effects were present. When assessing the origin source of PAH compounds in sediments, where calculation was possible, the ratio between LMW and HMW PAHs was found to be lower than 1 at three stations indicating a pyrogenic origin, whereas the ratio was found to be greater than 1 at 5 stations indicating a petrogenic origin.

Results of the Ph/Ant ratio suggested that station ENV001 was indicative of PAHs of a petrogenic origin with the ratio calculated > 10 whereas the remaining stations where calculation was possible were defined by PAHs of a pyrogenic origin < 10. Fl / Py ratio was higher than 1 at all stations also indicating a pyrogenic source of PAHs. 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. All organotins and PCB`s measured were below the detection limit.

THC was slightly higher in the OWF array than along the ECR with a biogenic source origin of hydrocarbons based on the CPI. 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-28 and C-29 being the most abundant alkanes across the survey area (Al-hejuje et al. 2015).

8.3. Macrobenthos

A diverse macrobenthic assemblage was identified across the survey area from 30 macrobenthic samples collected, with a total of 5,195 individuals and 226 taxa recorded. The most abundant and frequent taxon sampled with the greatest average density per sample was juveniles of the brittle star Amphiuridae. The two-toothed Montagu shell *K. bidentata* was second to juveniles of Amphiuridae for abundance and density per sample. Echinodermata taxa contributed the most to abundance and overall diversity of the macrobenthic assemblages, whilst Mollusca taxa dominated by biomass, accounting for over 40 % of the total biomass.

Macrobenthic communities can be highly heterogenous as they are heavily influenced by ambient environmental conditions such as sediment composition (Cooper et al. 2011), hydrodynamic forces and physical disturbance (Hall 1994), depth (Ellingsen 2002), and salinity (Thorson 1966).

This was reflected in the macrobenthic communities observed between stations located along the ECR and within the OWF where sediment composition was a key factor in determining the macrobenthic community structure at these locations. Macrobenthic Group C, located in the nearshore section of the ECR, indicated an affinity for coarser substrates while Macrobenthic Groups A and B, within the OWF, were typical of finer substrates with variable mud content. The coarser sediments supported a community characterised by *G. triangularis, Spisula* and *E. pusillus*, whilst finer sediments were characterised by Amphiuridae, *K. bidentata E. pusillus* and *O. borealis*.

One notable taxon was identified across the survey area. The Ross worm *S. spinulosa* is a protected species when occurring in reef form under the OSPAR list of threatened and/or declining species and habitats (2008) and as an Annex I species under the EU Habitat Directive.

The latter directive has been transposed into UK law under the Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended)[8]. area was not deemed to meet the Annex I reef qualifying criteria due to patchiness and limited extent.

Although *S. spinulosa* tube aggregations were noted in both the seabed imagery and grab samples, particularly at station ENV025, their patchy cover and limited extent meant they were not deemed to meet the Annex I reef qualifying criteria.

No INNS were recorded across the survey area, nor were oysters or oyster beds, or species listed under Section 7 of the Environment (Wales) Act 2016 including sandeel.

8.4. Habitat Mapping

Acoustic and seabed imagery data clearly indicated the dominance of sandy sediments across the survey area. This was corroborated by the PSD data which showed the dominance of A5.2 across most of the survey area. Combined interpretation of geophysical, seabed imagery and PSA data indicated that the dominant biotope complex across the survey area was A5.25 'Circalittoral fine sand'. Areas of A5.25 were mapped to cover the entirety of the OWF and the vast majority of the ECR, with only small areas of A4.13 'Mixed faunal turf communities on circalittoral rock' representing reef features, interspersed within the dominating A5.25 area in a small section of the ECR.

Two potential Annex I sandbanks were identified along the ECR (Figure 30) with the sandbank located further north intersecting the Turbot Sandbank a qualifying feature of the Pembrokeshire Marine SAC (Section 2.1.4).

Small areas of Annex I bedrock and stony reef habitats were identified along areas of the ECR, but these stony reefs were assessed to be of low resemblance. When falling within the SAC boundary, these features were deemed to form part of the designated Annex I 'reef' feature of the Pembrokeshire Marine SAC. The reef features identified were not extensive, however it is expected this will be a more prevalent feature in the nearshore ECR and landfall areas (to be reported separately).

The spatial resolution of DDC ground truthing sampling points covered the majority of habitats and features interpreted in acoustic data despite being limited in coverage. This, coupled with the generally homogenous reflectivity of the seabed in acoustic data, allowed habitat mapping polygons to be drawn in most cases with a medium to high degree of confidence. Habitat mapping therefore shows EUNIS level 3 classifications as polygons for which a combination of acoustic data, seabed imagery and PSD data was used to delineate their boundaries, overlayed with higher-level classifications at individual stations based on macrobenthic data.

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

Macrobenthic group A was assigned to EUNIS classification A5.251 due to the presence of *E. pusillus* and *O. borealis* and supported by sandy sediments.

Conversely, Macrobenthic group B was assigned to EUNIS A5.351 due to the community being dominated by as *A. filiformis* and *K. bidentata* and supported by muddier sediments (> 5 % mud content). It should be noted that *A. filiformis* and *K. bidentata* also occurred in relatively high abundance within Macrobenthic group A. SIMPROF analysis grouped stations ENV024, ENV023 and ENV026 together into macrobenthic group C but investigation of the macrobenthic community of this group presented no key species which could be used to assign a biotope to the group confidently. Therefore, sediment data was used to assign a lower level of classification to these stations.

The two outlier stations could not be assigned to any specific biotope. Both outlier stations were situated closer to shore along the cable route and were allocated sediment descriptions of coarse or mixed sediments with station ENV0027 assigned A5.1 'Coarse sediment' and station ENV025 assigned A5.4 'Mixed sediment'. This was supported by the imagery analysis which showed the dominance of epifauna closer to shore.

Although biotopes at the discrete grab locations within the OWF and the southern extent of the ECR were assigned at a greater level of detail based on macrobenthic data, it was not possible to define the boundaries of these features as they were not discernible in the homogenous acoustic data (Figure 28). Within the final habitat assessment, a small area characterised by A5.44 'Circalittoral mixed sediment' was identified within the north of the ECR, nearest to shore. This area is expected to extend beyond what is currently mapped, when data from the dedicated nearshore survey is analysed and interpreted. EUNIS habitat A5.1 'Sublittoral coarse sediment' was assigned at stations ENV024, ENV026 and ENV027 based on sediment analysis as no key taxa were observed in the macrobenthic assemblage found at these locations.

Existing habitat mapping indicated the majority of the OWF and ECR to comprise of the EUNIS classification A5.27 'Deep circalittoral sand', compared to A5.25 as mapped here. This is a deviation based on depth, with the BSH of A5.2 'Sublittoral sand' consistent between the two habitat maps. Large areas of A5.14 'Circalittoral coarse sediment' are apparent in the 2021 EUSeaMap (Figure 1), which were not observed within this survey. Isolated areas of harder ground including Annex I reef features were observed but on a much smaller scale to that which is mapped in the EUSeaMap.

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