LLŶR FLOATING OFFSHORE WIND PROJECT

Llŷr 1 Floating Offshore Wind Farm

Environmental Statement

Volume 6: Appendix 19A – 2023 OEL Nearshore Benthic Characterisation Survey

August 2024

Prepared by: Llŷr Floating Wind Ltd

FLOVENTIS ENERGY

Document Status

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Prepared for	Llŷr Floating Wind Limited
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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.

OCEAN ECOLOGY

Marine Surveys, Analysis & Consultancy

Llŷr Floating Offshore Wind Farm - Nearshore Benthic Characterisation Survey

Technical Report

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Updates

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Abbreviations

BAC	Background Assessment Concentration
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
ICES	International Council for the Exploration of the Sea
LAT	Lowest Astronomical Tide
MBBS	Multi-beam backscatter
MBES	Multi-beam Echosounder
NMBAQC	NE Atlantic Marine Biological Analytical Quality Control
OEL	Ocean Ecology Ltd
OWF	Offshore Wind Farm
PAH	Polyaromatic Hydrocarbon
PEL	Probable Effect Level
PSD	Particle Size Distribution
PRP	Processing Requirement Protocol
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

The Llŷr 1 and Llŷr 2 projects are part of a proposed offshore wind farm development by Floventis Operates Limited, located off the coast of Pembroke in Wales. These projects aim to generate 100 MW each and serve as test beds for new floating platform and mooring technologies. Ocean Ecology Limited (OEL) was contracted to conduct a benthic characterisation survey for the nearshore component of both project areas contributing to the Environmental Impact Assessment (EIA). The survey examined seabed habitats, assessed conservation significance, and confirmed the absence of non-native species (INNS), informing the planning and construction of the wind farms and the Export Cable Route (ECR).

Survey Strategy

The benthic sampling plan was carefully designed in line with Natural England's and Natural Resources Wales' guidelines, aiming to achieve optimal geographic coverage of the survey area near Milford Haven. This approach ensured that all key habitats and marine communities were adequately targeted. Using geophysical data, 11 drop-down camera (DDC) transects, and 6 sediment grab stations were strategically positioned to maximise spatial coverage and ensure that sampling of the full range of sediment types, depths and habitats across the nearshore area were sampled. This stratified approach accounted for surface, subsurface, and subsea hazards, as well as potential protected habitats and features of conservation interest, such as Annex I reefs. Note that a separate offshore survey was conducted in January 2023, the results of which have been reported separately.

Sediment

The survey area exhibited a range of sediment compositions, with most stations characterised by sand. In terms of the European Nature Information System (EUNIS) habitat classification system, the majority of stations fell under the sand and muddy sand category (broadscale habitat – BSH – A5.2), which corresponds to the habitat of conservation importance "Subtidal sands and gravels". However, this habitat type is common along the British Isles coast. As for fish spawning grounds, one station was deemed prime for herring spawning due to its higher gravel content, while four stations were suitable for sandeel spawning, excluding the station with a high gravel content (NS_05).

Sediment Chemistry

The surveyed area showed low total organic carbon (TOC) content, aligning with global sediment averages for deep oceans but lower than coastal ocean averages. Various guidelines exist to assess marine sediment contamination, with some levels indicating negligible concern and others signifying considerable adverse effects. Among the metals tested, only arsenic exceeded reference levels at two stations; however, no adverse biological effects were found.

Hydrocarbons were predominantly of biogenic origin, and all measured polycyclic aromatic hydrocarbons (PAHs), organotins, and polychlorinated biphenyls (PCBs) were below detection limits.

Macrobenthos

The macrobenthos across the survey area exhibited a diversity typical of impoverished communities, with 63 individuals and 29 taxa found across five samples. Diversity was influenced by substrate type: three stations were characterised by mobile sand, and two of coarse sediment. The sandy stations, with low diversity, were deemed to be representative of EUNIS habitat types "Infralittoral mobile clean sand with sparse fauna" (A5.231) and/or "Infralittoral mobile sand in variable salinity" (A5.221). The gravelly stations also displayed relatively low diversity and were deemed to be representative of either "Sparse fauna on highly mobile sublittoral shingle" (A5.131), circalittoral (A5.14) and/or infralittoral coarse sediment (A5.13). However, these classifications are tentative due to insufficient macrobenthic diversity and abundance data. Among the surveyed stations, nematodes were most abundant at one station, which had the highest number of individuals. Biomass was generally low, except at station NS_02, where relatively large shelled molluscs (e.g., *Tritia reticulata*, Veneridae) were present.

2. Introduction

2.1. Project Overview

The Llŷr 1 and Llŷr 2 projects are part of a proposed offshore wind farm development by Floventis Operates Limited. The projects consist of two separate sites, each with a capacity of 100 Mega Watts (MW), located off the coast of Pembroke in Wales (Figure 1). The Llŷr projects are situated approximately 40 km offshore in the Celtic Sea, at water depths averaging 65 m.

To bring the power generated by the wind farms to the grid, Floventis plans to construct an Export Cable Route (ECR) running north towards Pembroke. The proposed ECR will span water depths ranging between 15-60 m.

The Llŷr projects will serve as test beds for new floating platform and mooring technologies. The aim is to explore innovative designs, materials, and construction approaches that can improve the efficiency and sustainability of offshore wind farms.

2.2. Project background

Ocean Ecology Limited (OEL) was contracted by N-Sea, representing Floventis, to conduct a benthic characterisation survey of the Llŷr 1 and Llŷr 2 survey areas as part of a two-part assignment. The first appointment focused on offshore structures, while this report addresses the nearshore works. The assessment covered the offshore wind farm (OWF), Export Cable Route (ECR), and landfall locations for both Llŷr 1 and Llŷr 2 development zones. The information gathered from the survey will contribute to the Environmental Impact Assessment (EIA), which is necessary for future consenting applications for the Llŷr project.

This report offers an overview of the survey methodologies used during the nearshore investigation and includes maps of the habitats observed and baseline conditions for sediment and macrobenthos throughout the survey area. Detailed analysis of Drop-Down Camera (DDC) imagery, combined with high-resolution Multibeam Echosounder (MBES), Multibeam Backscatter (MBBS), and Side-Scan Sonar (SSS) data collected by N-Sea, allowed for the identification of European Nature Information Systems (EUNIS) habitats and biotopes, wherever feasible. As a result, comprehensive mapping was developed for the entire survey area, which incorporated the delineation of crucial and environmentally sensitive features such as Annex I habitats. In addition, a dedicated survey covered the remainder of the ECR and offshore (>2 km from the coast) area, the findings of which are provided in a separate report.

The outcomes of the macrobenthic and physicochemical examinations of the sediment samples collected during the survey were utilised to refine the habitat/biotope mapping presented in this report and to establish baseline conditions. Additionally, the report highlights environmentally sensitive areas that warrant special consideration to mitigate potential impacts on the seabed from the proposed Llŷr project.

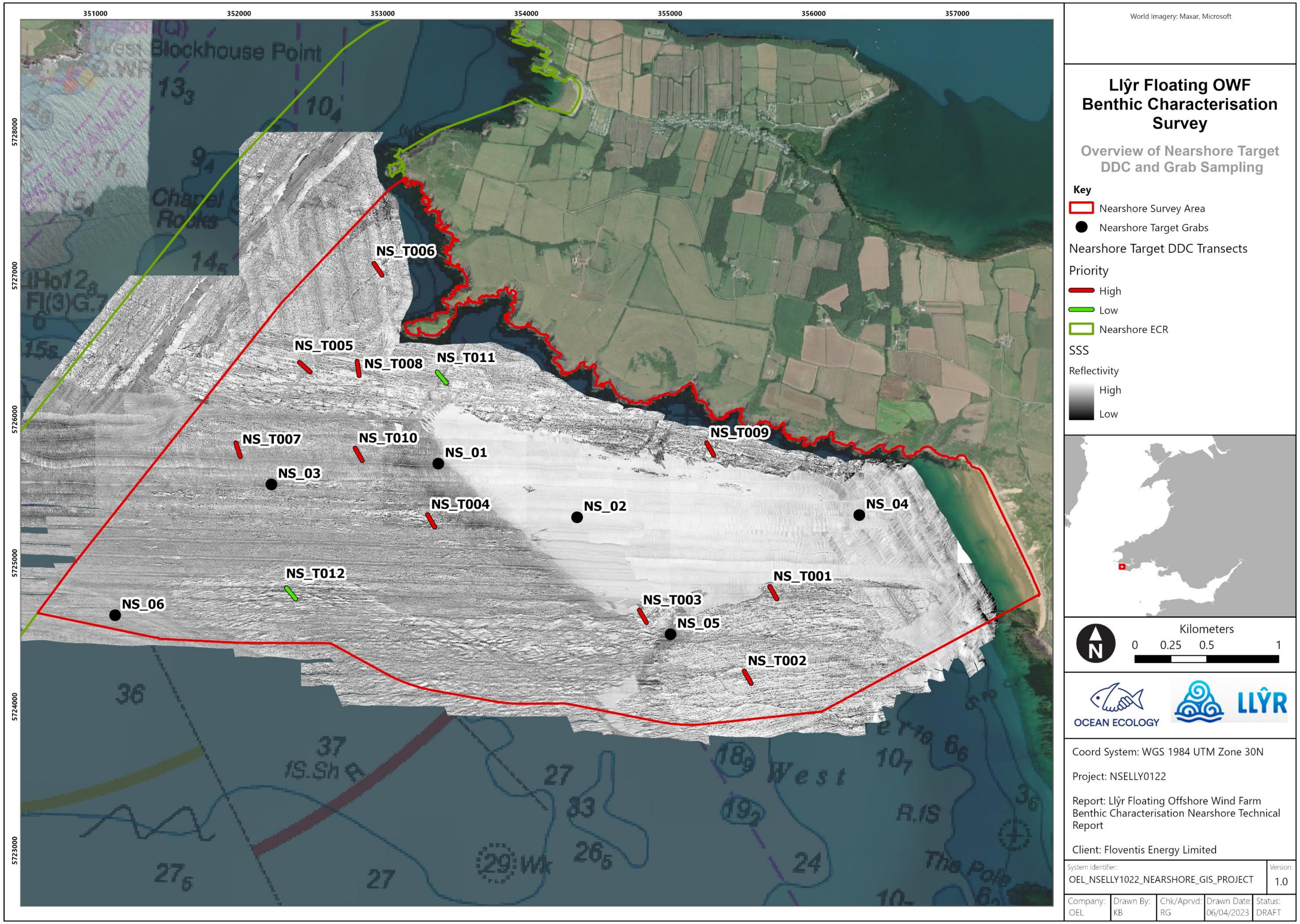

Figure 1 Overview of the Llŷr nearshore survey area and grab sampling approach.

2.3. Aims and Objectives

The primary objectives of the nearshore benthic characterisation component of the survey included:

- Providing an initial description of the seabed habitats within the nearshore section of the ECR;
- Identifying and evaluating the status of species and habitats of conservation significance within the nearshore section of the ECR . This encompassed Annex I protected species and habitats (e.g., *Sabellaria spinulosa* biogenic reef or stony reef), Annex V[1] species 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;
- Confirming the presence or absence of benthic invasive non-native species (INNS), benthic species not native to UK waters, and benthic species not native to local nearshore habitat types (e.g., hard-substrate specialists within a broader sedimentary habitat).

[1] https://jncc.gov.uk/our-work/article-17-habitats-directive-report-2019-specie/
[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 marine 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 survey area primarily consisted of circalittoral coarse sediment (A5.14), Atlantic and Mediterranean high energy circalittoral (A4.1) and infralittoral rock (A3.1), low energy infralittoral rock (A3.3) and infralittoral coarse sediment (A5.13), as shown in (Figure 2).

[4] EMODnet EUSeaMap viewer is available here.

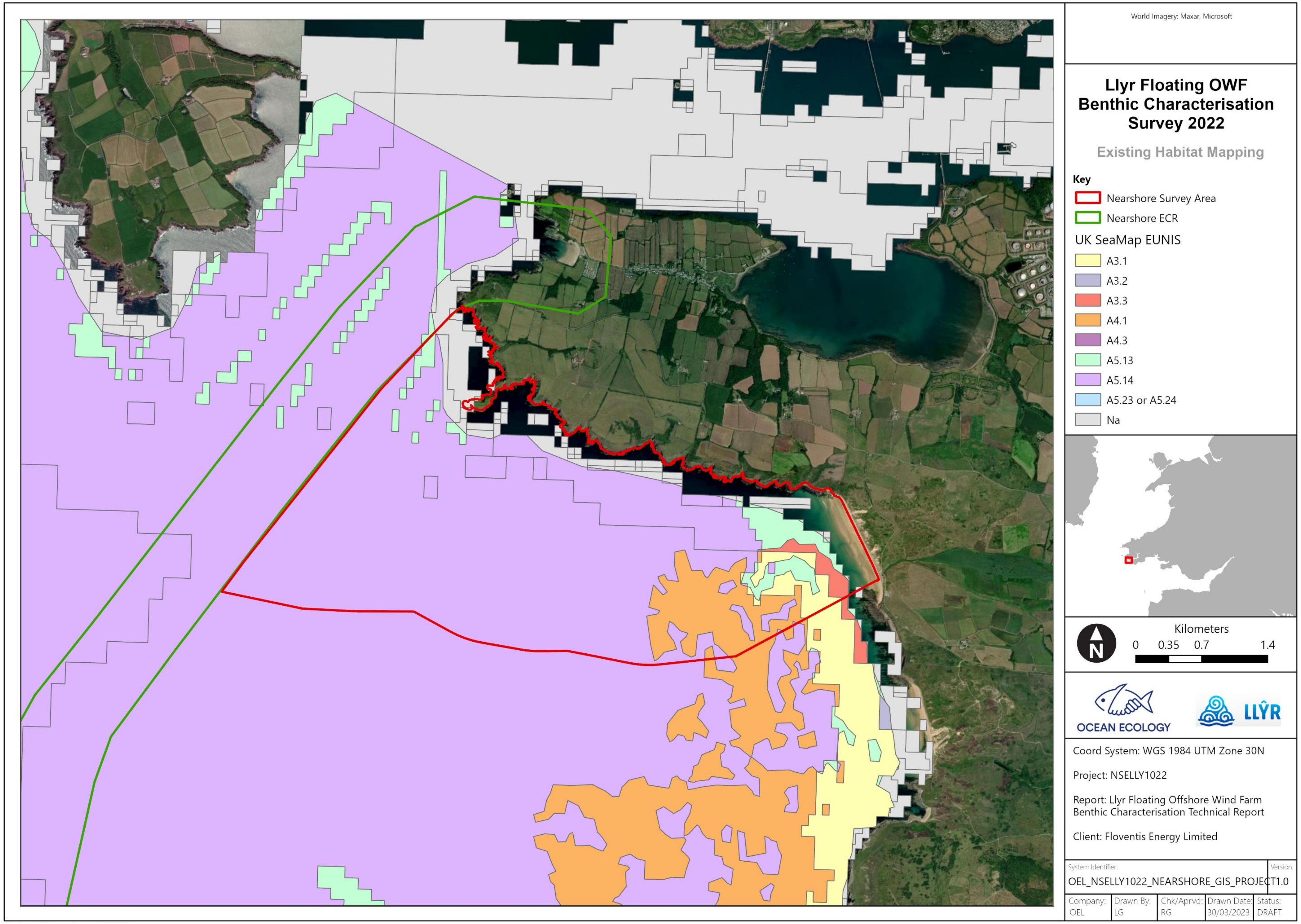

Figure 2 Known EUNIS classification mapping across the Llŷr nearshore survey area.

3.2. Designated Sites

3.2.1. Pembrokeshire Marine/Sir Benfro SAC

The survey area 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 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.

3.2.2. 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. 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.

3.2.3. West Wales Marine SAC

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

3.2.4. 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 northern extent of the survey area, across the Milford Haven coastline (Figure 3). The relevant advisory body for the Angle Peninsula Coast/Arfordir Penrhyn Angle SSSI is NRW.

3.2.5. 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 intersects the east of the survey area, encompassing the sandy Beach of Freshwater West (Figure 3). NRW are the advisory body for Broomhill Burrows SSSI.

3.2.6. 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 (Figure 3). NRW are the advisory body for Milford Haven Waterway SSSI.

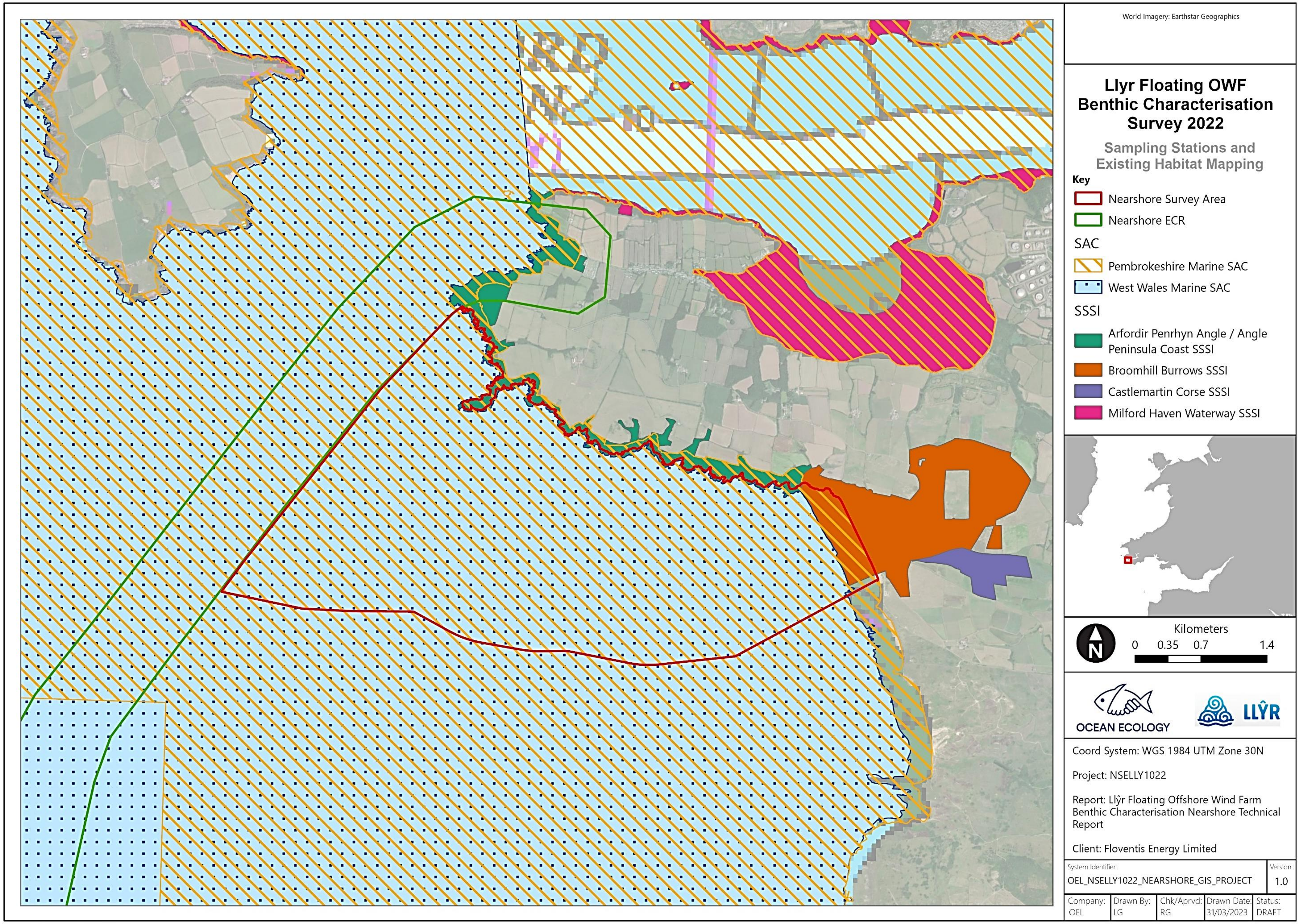

Figure 3 Designated sites across the Llŷr nearshore survey area.

3.2.7. Features of Conservation Interest (FOCI)

Several historic records of species of conservation interest (SOCI) were identified within proximity to or intersecting the survey area, using Natural England Marine Habitats and Species Open Data (MHSOD) and NRW Environment (Wales) Act Section 7 and OSPAR: Marine Species and Habitats data. One record of ocean quahog (*Arctica islandica*) was identified within the ECR (FIGURE 4). Records within close proximity to the survey area comprised European spiny lobster *(Palinurus elephas*), red seaweed (*Cruoria cruoriiformis*) and mearl (*Phymatolithon calcareum*) and (*Lithothamnion corallioides*) (Figure 4 and Figure 5).

Mearl beds were recorded 1.75 km north of ECR, within the Pembrokeshire Marine SAC (Figure 4). Seagrass beds were recorded 1.57 km east of the ECR and 1.59 km north of the nearshore survey area, within the Pembrokeshire Marine SAC (Figure 4).

Subtidal Mixed Muddy Sediment

Records of Subtidal Mixed Muddy Sediment habitat of 'Principal Importance' were identified across the southwest of the survey area and the adjacent ECR (Figure 4). This habitat may support a wide range of infauna and epibiota, including polychaetes, bivalves, echinoderms, anemones, hydroids and Bryozoa and is afforded protection under the Environment (Wales) Act (2016), Section 7.

Fragile Sponge and Anthozoan Communities

Records of Fragile Sponge and Anthozoan Communities habitat of 'Principal Importance' were identified across the north of the survey area and within the adjacent ECR (Figure 4). These communities are found on bedrock and are dominated by large, slow growing species such as branching sponges and sea fans. This habitat is afforded protection under the Environment (Wales) Act (2016), Section 7 and also corresponds with Habitats Directive Annex I: Reefs.

3.2.8. Annex I Habitats

Several important and sensitive habitats, all qualifying as Annex I habitats, are known to be present within the vicinity of and/or intersected by the survey area (Figure 5). The first group of habitats are primary reasons for the selection of designated sites and include:

- Estuaries
- Large shallow inlets and bays
- Reefs

Additionally, the second group of habitats are present as qualifying features within the vicinity of and/or intersected by the survey 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.

3.2.8.1. 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 lies 149 m south of the survey area (Figure 5). 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.

3.2.8.2. Large Shallow Inlets and Bays

Large shallow inlets and bays are habitat complexes comprising of an interdependent mosaic of habitats which can include several features listed as Annex I habitats in their own right. Large shallow inlets and bays are typically found within indentations on sheltered coastlines. Water depth is usually shallow (<30 m) with low freshwater influence. Three sub-types meet the Annex I criteria, these are; embayments (inlets with narrow entrances), fjardic sea lochs (shallow basins and sills carved by glaciers), and ria/voe (drowned river valley in areas of high relief). Milford Haven and St Brides Bay are situated within the Pembrokeshire Marine SAC.

The former is one of the best examples of a ria in the UK, whilst the latter consists of wide, shallow, predominantly sandy embayment. 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 noltii*) 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 (**Error! Reference source not found.** and **Error! Reference source not found.**). 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.

3.2.8.3. Estuary

Estuaries are habitat complexes comprising of an interdependent mosaic of habitats which can include several features listed as Annex I habitats in their own right. Estuaries are the downstream areas of river valleys, extending from the limit of brackish water. Estuaries are formed by geomorphological and hydrographic factors. Four sub-types meet the Annex I criteria, these are coastal plain (flooding of pre-existing valleys), bar-built (sediment bar at mouth), complex (formed by physical influence), ria (drowned river valleys characteristic of south-west Britain the outer parts of which conform to Annex I large shallow inlets and bays). Estuaries are a primary designating factor for both the Pembrokeshire Marine SAC and Milford Haven Waterway SSSI.

3.2.8.4. 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 NRW, rocky habitats, including bedrock and stony reefs, are thought to occur within in the nearshore survey area (Figure 5).

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.

***Mytilus edulis* Reef**

The blue mussel (*Mytilus edulis*) is a suspension feeding bivalve found as individuals and as dense beds forming biogenic reefs (Hill et al. 1998). *M. edulis* beds occur from the shoreline to the sub-littoral (Connor et al. 2004). The beds enhance local biodiversity by providing an additional substrate for colonisation by a wide array of infaunal and epifaunal species such as barnacles, limpets, polychaetes, and other bivalves as well as stabilising and modifying sedimentary substrates, whilst 'mussel mud' supports a diverse range of infauna. They are the preferred prey item of many species including starfish, crabs, demersal fish, dog whelks and birds. *M. edulis* beds are afforded protection as a Section 41 priority habitats and Annex I reef features under the Habitats Directive as well as being included on the OSPAR Annex V list of threatened and declining species and habitats.

M. edulis reef has not been previously mapped within the survey area, however, has been recorded 6.14 km north-east of the survey area within the Pembrokeshire Marine SAC and Milford Haven Waterway SSSI.

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 (*Sabellaria spinulosa*). Both are gregarious species and can form biogenic reef colonies that can cover hundreds of thousands of square meters of seabed (Jenkins et al. 2018b), 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 2021). Despite this, no known *Sabellaria* spp. reefs have previously been recorded across 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”.

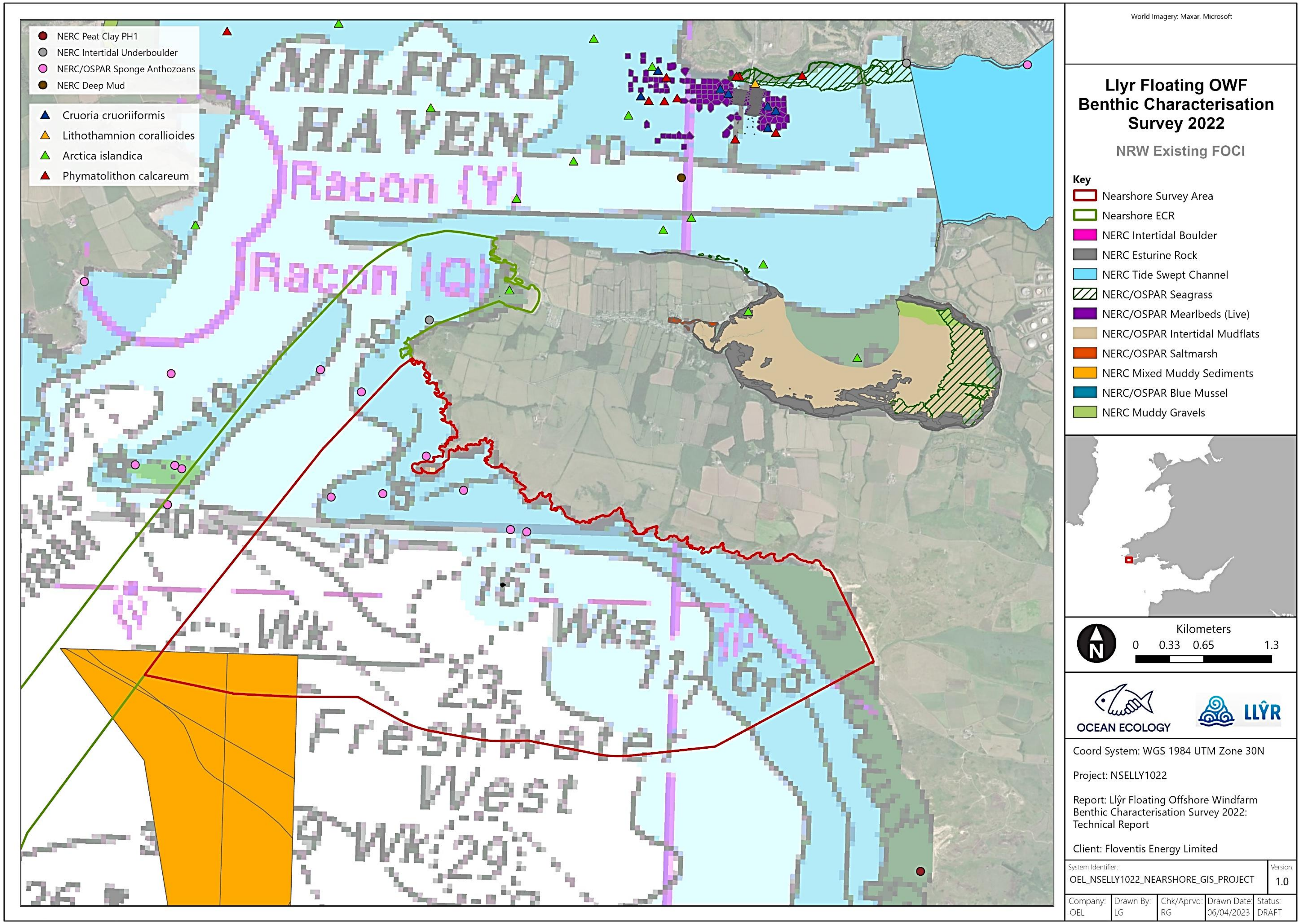

Figure 4 FOCI habitats of principle importance (NRW) across the Llŷr nearshore survey area.

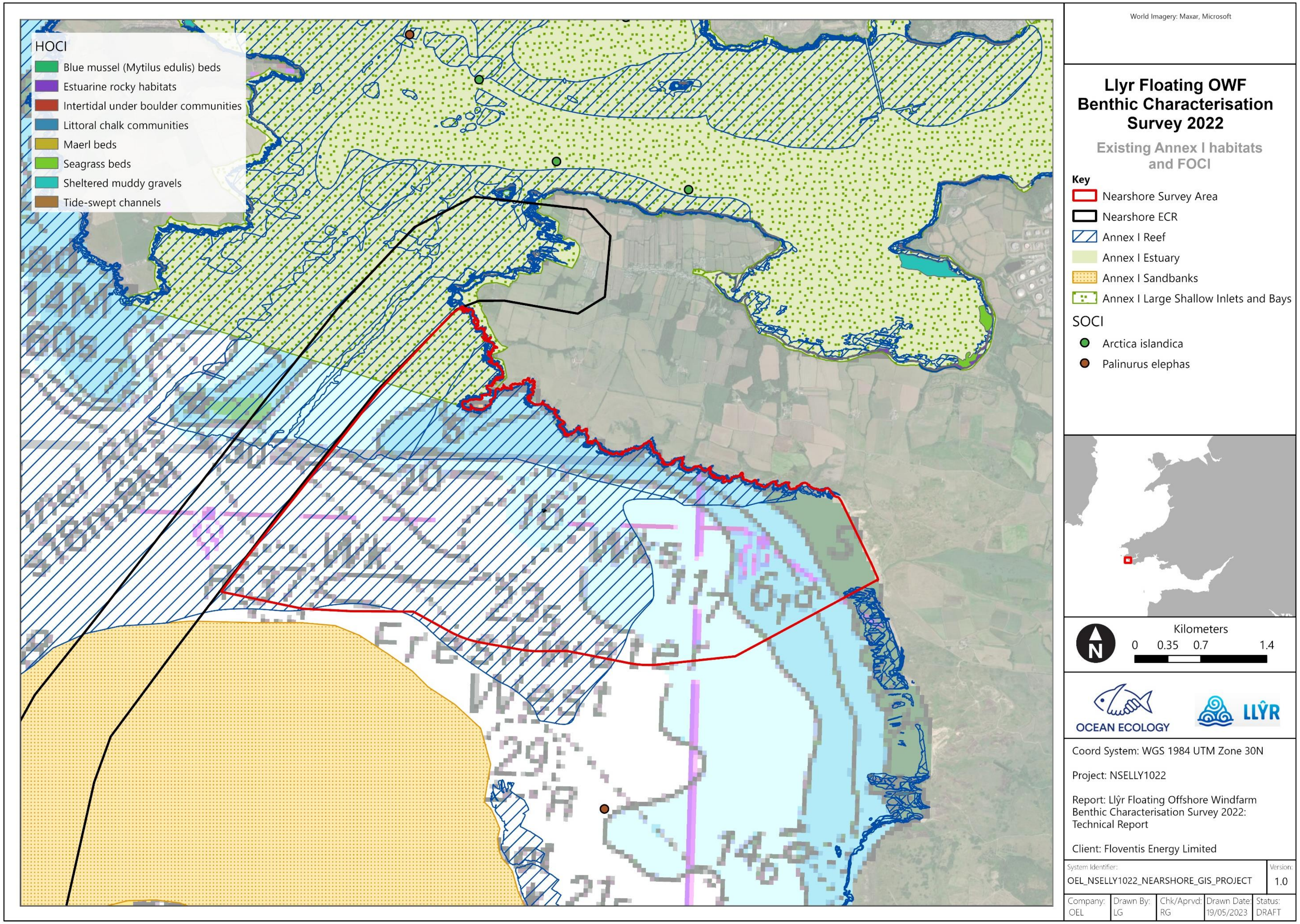

Figure 5 Protected Annex I habitats and FOCI (Natural England) across the Llŷr nearshore survey area.

4. Survey Design

4.1. Overview

The benthic sampling plan was devised in line with Phase I of Natural England's "Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards" (Natural England 2021) and Natural Resources Wales "Benthic habitat assessment guidance for marine developments and activities" (NRW 2019). This approach aimed to achieve optimal geographic coverage of the proposed survey area, located south of the Angle Peninsula in southwest Wales, near Milford Haven, while also ensuring that all key habitats and communities likely to be found across the area were targeted. Consequently, the fundamental principles guiding the survey design were to:

- Provide comprehensive spatial coverage of the OWF and ECR areas;
- Ensure representative sampling of all primary sediment types;
- Ensure that representative examples of all potential features of conservation interest (e.g., Annex I reefs) were adequately ground-truthed.

The nearshore environmental phase of the benthic characterisation survey was planned for 11 drop-down camera (DDC) priority transects and 6 sediment grab stations. However, one grab failed due to hard ground and cobbles, and one transect was not sampled due to time constraints. Stations and transects were positioned and distributed across the survey area following a detailed review of geophysical data to highlight features of interest and different seabed sediments to inform accurate habitat mapping of the area.

At each benthic grab sampling station, seabed imagery was collected with a DDC system before a grab sampler was deployed to ensure the target location was clear of any obstructions or protected habitats (e.g., Annex I). DDC transects were used to investigate larger features of interest identified within the geophysical data.

4.2. Rationale

The sampling plan was created using a stratified sampling approach across the survey arae, with micrositing of sampling stations informed by a detailed review and interpretation of the geophysical data collected by N-Sea between September and December 2022. Sampling stations were also positioned with consideration for all surface, subsurface, and subsea hazards and their respective exclusion or buffer zones.

The information assessed during the development of the sampling plan included:

- 2022 geophysical campaign processed MBES bathymetry, SSS, MBBS, and magnetometer data in mosaic geotiff format;
- 2022 geophysical campaign processed magnetometer and SSS feature analysis to identify potential subsea hazards and Unexploded Ordnance (UXO);

- Interpreted seabed classification from the 2022 geophysical campaign;
- All available GIS shapefiles and rasters in ESRI format, including: the OWF and ECR areas; planned and existing infrastructure, incorporating all oil and gas surface and subsurface infrastructure within the survey area boundary or in close proximity to it; the latest relevant MPA boundaries; admiralty charts for the survey area (if available).

4.3. Sampling Design

The sampling plan ensured diverse representation across various depths and habitats through a stratified method, while considering surface and subsurface structures, hazards, and notable aspects identified from geophysical data analysis. Prior to grab sampling, DDC examination provided supplementary details on sediment and substrate surfaces, verifying the absence of unidentified subsea hazards and protected habitats.

Five stations were sampled using grab samplers for Particle Size Distribution (PSD) and macrobenthic analysis. Additional samples for chemical contaminant analysis were collected at three of the five stations. The DDC examination captured imagery along 10 priority transects, allowing for the delineation of rocky and potential biogenic reef formations.

5. Field Methods

5.1. Survey Vessel

All survey operations were conducted aboard the vessel *Coastal Observer* (Table 1, **Error! Reference source not found.**) which was mobilised out of Neyland Marina, Milford Haven, on the 5th of February 2023.

Table 1 Vessel details.

Vessel Name	*Coastal Observer*
Length	10.1m
Beam	5.73m
Draft	1.19m
Mobilisation Port	Milford Haven, Wales
Mobilisation Date	05/02/2023

Plate 1 Nearshore survey vessel Coastal Observer.

5.2. Project Parameters

All coordinates adhered to the WGS84 geodetic system, with projected grid coordinates relying on the Universal Transverse Mercator (UTM) Zone 30N, featuring a Central Meridian of 03°W. A comprehensive summary of the geodetic and projection parameters can be found in

Table 2.

Table 2 Projection horizontal projection parameters.

Parameter	Universal Transverse Mercator (UTM)
Projection	Universal Transverse Mercator (UTM) zone 30N
Longitude of Central Meridian	003° 00.000000' W
Latitude of Origin	000° 00.000000' N
False Easting	500 000.00 m
False Northing	0.00 m
Scale Factor at Central Meridian	0.9996
Linear Units	Meter

5.3. Subsea Positioning

Vessel and subsea positioning services were delivered by Ultrabeam Hydrographic. An Ultra-Short Baseline (USBL) system was employed to ensure precise subsea positioning of the sampling equipment on the seabed. This included a Sonardyne Mini Ranger 2 USBL transducer and Sonardyne WSM6+ beacons mounted close to the termination of the lift wire.

5.4. Survey Equipment

A detailed compilation of the environmental sampling equipment deployed for the survey can be found in Table 3.

Table 3 Equipment list mobilised on the Coastal Observer.

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)).
Grab Sampler	0.1 m^2 Day grab
Subsea Positioning	Sonardyne Mini Ranger 2 USBL and Sonardyne WSM6+ beacons

5.4.1. DDC System

Seabed imagery was captured using a freshwater housing DDC system, equipped with a SubC Rayfin Power Line Ethernet (PLE) camera system, configured to record 1080p High Definition (HD) video and 21 Megapixel (MP) still images. The camera was housed within a Clear Liquid Optical Chamber (CLOC), also known as a "freshwater lens", filled with fresh water to ensure high-quality imagery even in turbid conditions. The frame featured LED strip lamps and a 10 cm point laser scaling array projected into the field of view. An Uninterruptible Power Supply (UPS) was employed to protect the camera system from potential damage due to power loss or surges.

The CLOC's height and angle were adjustable, offering a range of viewing, lighting, and focal length options to optimise data quality under various conditions, such as high turbidity. During the survey, a review of the seabed imagery prompted adjustments to the lighting angle, enhancing the illumination at the centre of the images.

The DDC system was deployed from the vessel's aft deck, utilising the stern A-frame and deck winch to lower or raise the DDC frame. A separate camera umbilical was managed manually on deck.

5.4.2. Grab Equipment

All sediment sampling was conducted using a 0.1 m² Day grab (Plate 2). Upon contact with the seabed, the tension from the wire was released, causing the sampling bucket to pivot through 90°. This action pushed seabed sediment into the bucket, which then closed to form a tight seal, preventing sediment or sample loss.

Plate 2 Left: OEL's freshwater housing camera system. Right: 0.2 m² Day Grab

5.4.3. DDC Sampling

All seabed imagery was collected in consideration of the Joint Nature Conservation Committee (JNCC) epibiota remote monitoring operational guidelines (Hitchin et al. 2015). At each DDC station, a minimum of two minutes of video footage and five seabed stills images were obtained. The vessel was manoeuvred within a 20 m radius of the target location to adequately characterise the area. Along the transects, images were captured every 5-10 m and more frequently when features of interest were encountered. OEL's environmental scientists reviewed all video footage in real time on site.

5.4.4. Grab Sample Processing

To ensure consistency in sampling, grab samples were evaluated by the lead environmental scientist and deemed unacceptable if:

- The sample was less than 5 L, meaning 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). If 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 determine if the sample volume was acceptable for subsequent analysis. No pooling of samples was undertaken.

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.

Initial grab sample processing was carried out onboard the survey vessel, following this methodology.

Successful grab per station:

- Initial visual assessment of sample size and acceptability was made.
- A photograph of the sample with station details and scale bar was taken.
- Sub-samples were removed for PSD and TOC analysis and transferred to a labelled tray.
- Samples were emptied onto a 1.0 mm sieve net laid over a 4.0 mm sieve table and washed through gentle rinsing with a seawater hose.
- The remaining sample for faunal sorting and identification was backwashed into a suitably sized sample container, and a 10% formalin solution was added to fix the sample prior to laboratory analysis.
- Sample containers were clearly labelled internally and externally with the date, sample ID, and project name.

5.4.5. Chemical Sample Processing

During the sampling, a subset of three stations were chosen to retain chemical contaminant subsamples (primary A replicate and backup B replicate samples) from a second grab sample. Sample processing was carried out using the following methodology:

- Inspecting the cover to ensure the sediment surface was undisturbed and free of grease, oils, or lubes before lifting it and making a general assessment of sample size and acceptability.

- Placing the pH/Redox probe into the sediment sample and allowing it to settle for two minutes before taking readings in field logs.

- Sub-sampling and decanting the sediment samples into recommended sample containers provided by SOCOTEC, the contaminant analysis laboratory, for the required analyses including Moisture Content, Total Organic Matter (by loss on ignition), Total Organic Carbon (TOC), Total content and the content of the labile form of heavy metals (Pb, Cu, Zn, Ni, Cd, Cr, As, Hg), Organotins (DBT, TBT), Polycyclic Aromatic Hydrocarbons (PAHs), Total Hydrocarbon Content (THC), and Polychlorinated Biphenyls (PCBs 25 including the ICES 7).

All samples taken for physico-chemical analysis were stored frozen at -20°C in an onboard freezer. The backup subsamples were stored frozen in line with MMO requirements to facilitate re-analysis or in case of primary subsamples becoming compromised during transit or storage prior to analysis.

6. Laboratory and Analytical Methods

6.1. Particle Size Distribution (PSD) Analysis

PSD analysis of sediment samples was carried out by in-house laboratory technicians at OEL's MMO Validated laboratory, adhering to NMBAQC best practice guidance (Mason 2016).

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

The >1 mm fraction was subsequently returned to a drying oven and dried at 80° C for a minimum of 24 hours before dry sieving. Once dry, the sediment sample was processed 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 employed are provided in Table 4.

Table 4 Sieve series employed for PSD analysis by dry sieving.

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

The sample was then placed onto the coarsest sieve at the top of the sieve stack and shaken for a standardised period of 20 minutes. The sieve stack was inspected to ensure the components of the sample had been fractionated as far down the sieve stack as their diameter would permit. An additional 10 minutes of shaking was carried out if there was evidence that particles had not been properly sorted.

The sub-sample for laser diffraction was initially 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. Following this, excess water was siphoned from above the sediment surface until a paste-like texture was achieved. The fine fraction was subsequently analysed by laser diffraction using a Beckman Coulter LS13 320. For silty sediments, ultrasound was employed to agitate particles and prevent aggregation of fines.

The dry sieve and laser data were subsequently 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 combined, PSD statistics and sediment classifications were generated from the percentages of the sediment determined for each sediment fraction using Gradistat v9 software.

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

Table 5 The classification used for defining sediment type based on the Wentworth Classification System (Wentworth 1922).

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

6.2. Spawning Habitat

6.2.1. Herring

Following Reach et al. (unpublished), herring spawning suitable grounds were categorised as “Prime”, “Sub-prime”, “Suitable”, and “Unsuitable” based on sediment composition (Table 6).

Table 6 Herring preference habitat according to sediment composition.

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

6.2.2. Sandeel

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 7).

Table 7 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

6.3. Chemical Contaminants

A sub-sample of 3 samples from the 5 grab samples collected were assessed for chemical contaminants (see Appendix I for methods).

6.3.1. Hydrocarbons

Indices and ratios were calculated to assess the 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 produced by 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), and 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 indicate 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 the 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).

6.3.2. Trace and Heavy Metals

A total of 8 main heavy and trace metals were analysed from sediments taken at each of the three 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 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). It should be noted that ERL, TEL, and PEL are based on field research programmes using 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 at sea (DEFRA 2003).

Contaminant levels in dredged material that 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.

6.4. Macrobenthic Analysis

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

For each macrobenthic sample, the excess formalin was drained off into a labelled container over a 1 mm mesh sieve in a well-ventilated area. The samples were then re-sieved over a 1 mm mesh sieve to remove all remaining fine sediment and fixative. The low-density fauna was separated by elutriation with fresh water, poured over a 1-mm mesh sieve, transferred into a Nalgene, and preserved in 70% Industrial Denatured Alcohol (IDA). The remaining sediment from each sample was subsequently separated into 1 mm, 2 mm, and 4 mm fractions, and sorted under a stereomicroscope to extract any remaining fauna (e.g., high-density bivalves not "floated" off during elutriation).

All macrobenthos present was identified to species level, where possible, and enumerated by trained benthic taxonomists using the most up-to-date taxonomic literature and checks against existing reference collections. Nomenclature utilised the live link within ABACUS to the WoRMS [5](World Register of Marine Species) REST web service, 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 %

[5] https://www.marinespecies.org/

- Miscellaneous = 15.5 %

6.5. Macrobenthic Data Analysis

6.5.1. Data Truncation and Standardisation

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

6.5.2. Pre-analysis and Data Treatment

All data were collated in Excel spreadsheets and made suitable for statistical analysis. All data processing and statistical analysis were undertaken using R v. 1.2 1335 (R Core Team 2022) and PRIMER v7 (Clarke & Gorley 2015) software packages. It is important to note that no replicate samples were available for macrobenthic analysis; thus, no mean values could be calculated per sampling station.

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

Juvenile macrobenthic species may sometimes dominate the macrobenthos. However, the OSPAR (2004) guidelines advise considering them as an ephemeral component due to their high post-settlement mortality, which makes them less representative of prevailing bottom conditions. According to OSPAR (2004), if juveniles rank among the ten most dominant organisms in a data set, statistical analyses should be conducted both with and without them to evaluate their significance.

In this study, juveniles from Balanomorpha and Ophiurina suborders appeared in the top 10 most dominant taxa across the survey area. To compare the two data sets (with and without juveniles), a 2STAGE analysis was performed, revealing a ~98% similarity between them. Consequently, juveniles were retained in the dataset, as their inclusion did not significantly alter the results.

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.

6.5.3. Multivariate Statistics

Prior to multivariate analyses, data were displayed as a shade plot with linear grey-scale intensity proportional to macrobenthic abundance (Clarke et al. 2014) to determine the most efficient pre-treatment (transformation) method.

Macrobenthic abundance data from grab samples 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 II.

6.5.4. 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).

6.6. 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 8 and Table 9. 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 8 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 9 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

6.7. 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

6.8. Habitat Mapping

All habitat mapping was undertaken in ESRI ArcPro Version 3.1.0 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 mosaicked 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 8), 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.

7. Results

7.1. Sediment Characterisation

Grab sampling logs and sample photos for the 5 stations sampled are provided in Appendices IV and V respectively and full PSD data have been provided in Appendices VI and VII.

7.1.1. Sediment Type

The sediment types found at each grab sampling station, as categorised by Folk's (1954) classification system are represented graphically in **Error! Reference source not found.**, and mapped in Figure 7 and Figure 8. Of the five stations examined, three displayed similarities with their sediment composition consisting almost entirely of sand. These stations were classified as EUNIS BSH A5.2 (Sand and Muddy Sand), and all fell under the Sand (S) category in terms of textural group classification (**Error! Reference source not found.**). The other two stations were identified as EUNIS BSH A5.1 (Coarse Sediment); one featured Gravelly Sand (gS), while the other was characterised by Gravel (G). Of the collected samples, 40% were classified as moderately sorted, while the remaining samples ranged between poorly sorted (40%) and moderately well sorted (20%).

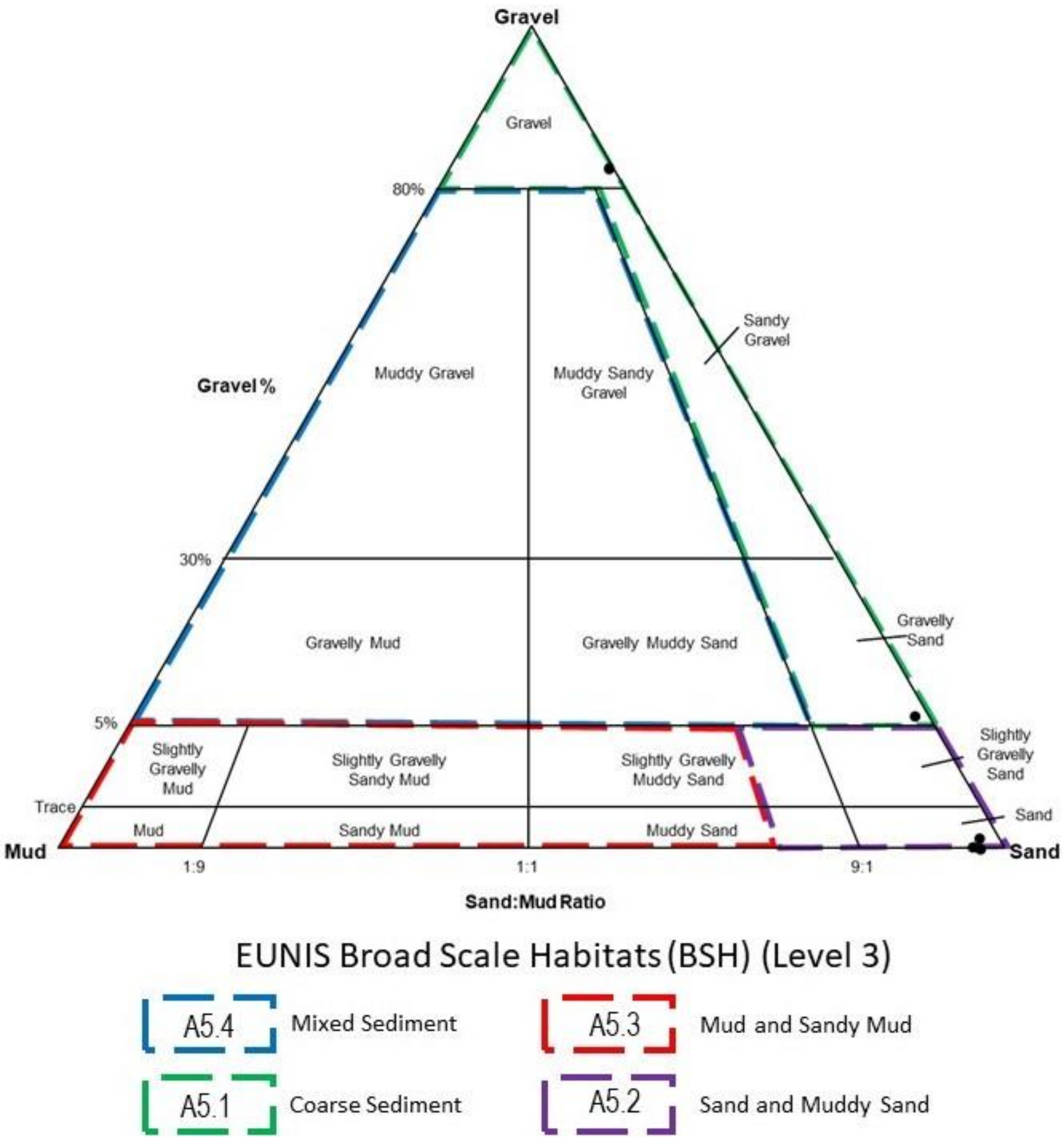

Figure 6 Folk (1954) triangle classifications of sediment gravel percentage and sand to mud ratio of samples collected across the survey area, overlain by the modified Folk triangle for determination of mobile sediment BSHs under the EUNIS habitat classification system (adapted from (Long 2006)).

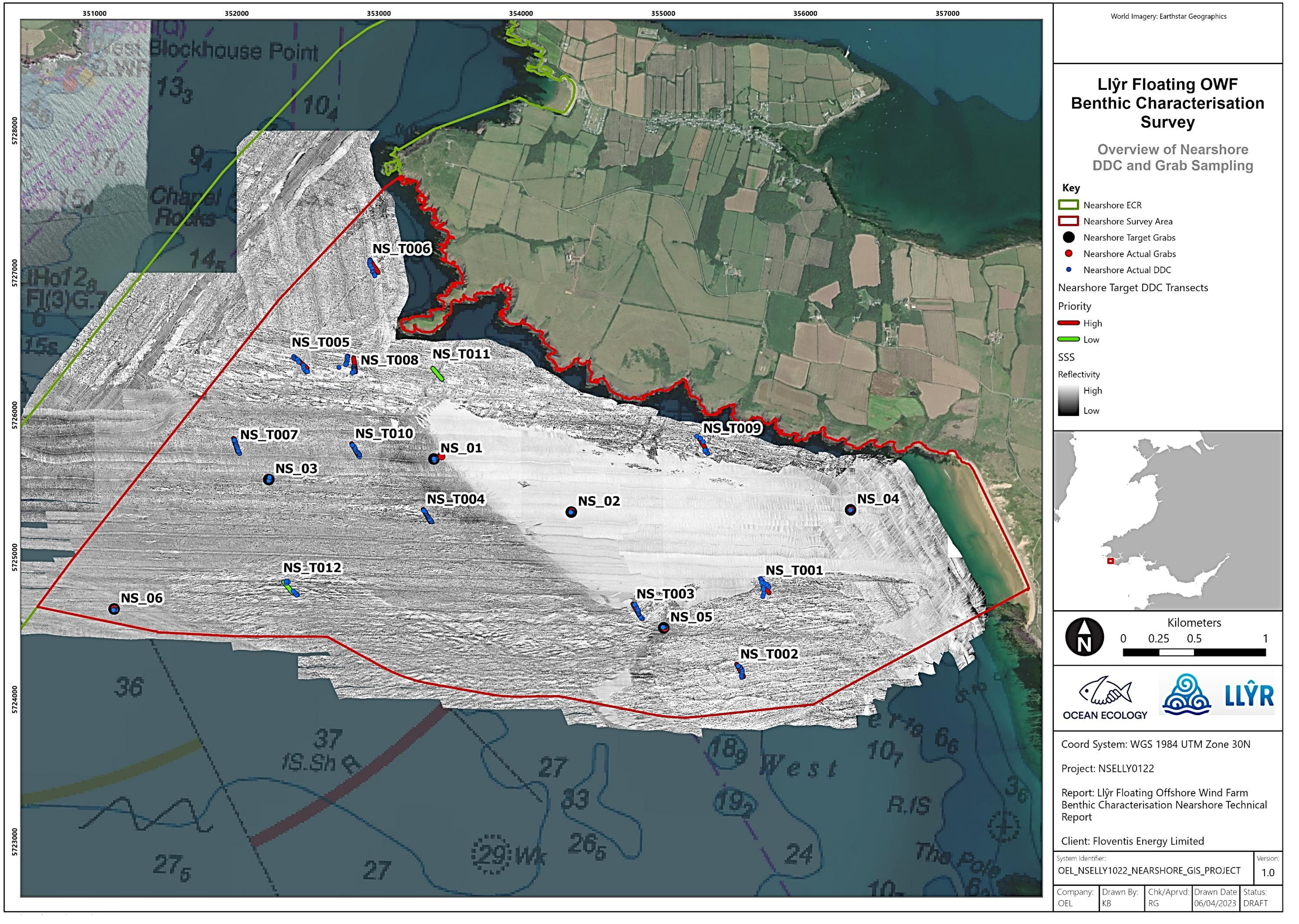

Figure 7 Summary of sampling conducted in the nearshore survey area.

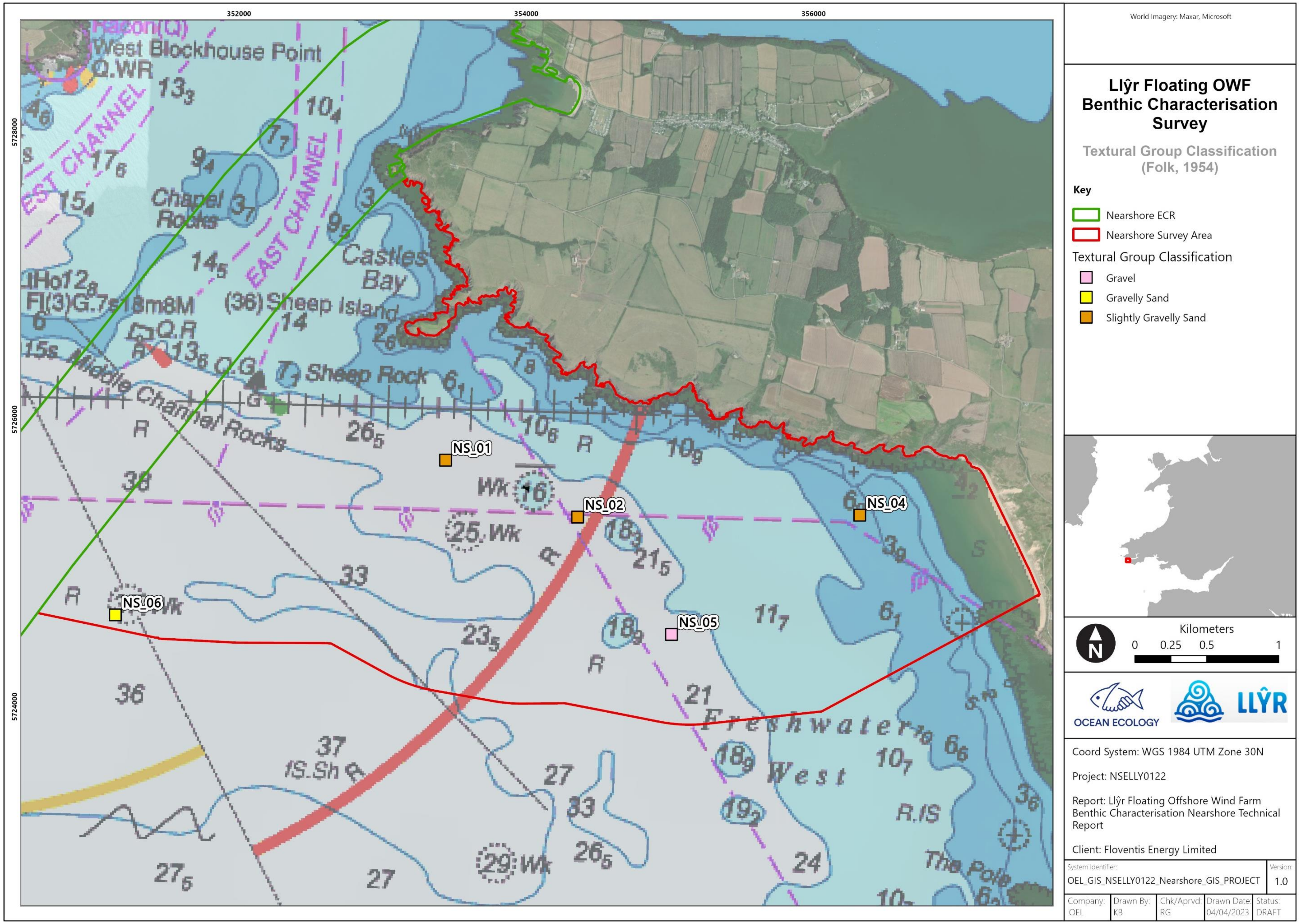

Figure 8 Textural groups of sediments identified throughout the survey area.

7.1.2. Sediment Composition

Error! Reference source not found. displays the percentage contribution of gravels (>2 mm), sands (0.63 mm to 2 mm), and fines (<63 µm) at each station. Sand was the predominant sediment fraction at most stations, accounting for the highest percentage contribution throughout the surveyed area. The average proportion (± Standard Error, SE) of sands across all stations was 80% (± 16.3), while the mean (± SE) gravel and mud content across the area were 19% (± 16.6) and 1% (± 0.3), respectively. The highest sand content was observed at station NS_04 (98.4%) and the lowest at NS_05 (15.2%) Gravel content reached its peak near the ECR area, at NS_05, constituting 85% of the sediment. Overall, mud content remained low.

The average grain size across the surveyed area exhibited variation, with values ranging from 187.4 µm at station NS_01 to 8468.7 µm at station NS_05 (**Error! Reference source not found.**).

7.2. Spawning Habitat

7.2.1. Herring

Four of the five stations were deemed unsuitable for herring spawning grounds as they did not contain enough gravel (Table 10). Herring spawning ground preference habitat according to sediment composition. In contrast, station NS_05 was classified as a prime habitat as it was dominated by gravel. A breakdown of Folk sediment classification and herring habitat spawning preference per sampling station is provided in Appendix VIII.

Table 10 Herring spawning ground preference habitat according to sediment composition.

Station	% Gravel	% Sand	% Mud	Habitat Preference
NS_01	0%	98%	2%	Unsuitable
NS_02	0%	98%	2%	Unsuitable
NS_04	0%	98%	1%	Unsuitable
NS_05	85%	15%	0%	Prime
NS_06	8%	91%	1%	Unsuitable

7.2.2. Sandeel

Four of the five stations were deemed suitable for sandeel spawning grounds, with the exception of NS_05 (Table 11). which contained too much gravel. A breakdown of Folk sediment classification and sandeel habitat spawning preference per sampling station is provided in Appendix VIII. The classification of stations based on the Greenstreet classification framework are outlined in Table 12.

Table 11 Sandeel spawning ground preference habitat according to sediment composition.

Station	% Gravel	% Sand	% Mud	Habitat Preference
NS_01	0%	98%	2%	Preferref
NS_02	0%	98%	2%	Preferred
NS_04	0%	98%	1%	Preferred
NS_05	85%	15%	0%	Unsuitable
NS_06	8%	91%	1%	Preferred

However, when the classification by Greenstreet et al. (2010) is considered, only stations NS_01 and NS_06 are considered suitable habitats for sandeel spawning (Table 12). The difference between the two classifications stems from the majority of the sand present at stations NS_02 and NS_04 was very fine sand and did not contribute to the coarse sediment fraction which is key to the Greenstreet classification.

Table 12 Sandeel spawning ground habitat preference based on the Greenstreet et al. 2010 methodology.

Habitat Preference	N of Stations	Stations
Prime	0	-
Sub-prime	1	NS_06
Suitable	1	NS_01
Unsuitable	3	NS_02, NS_04, NS_05

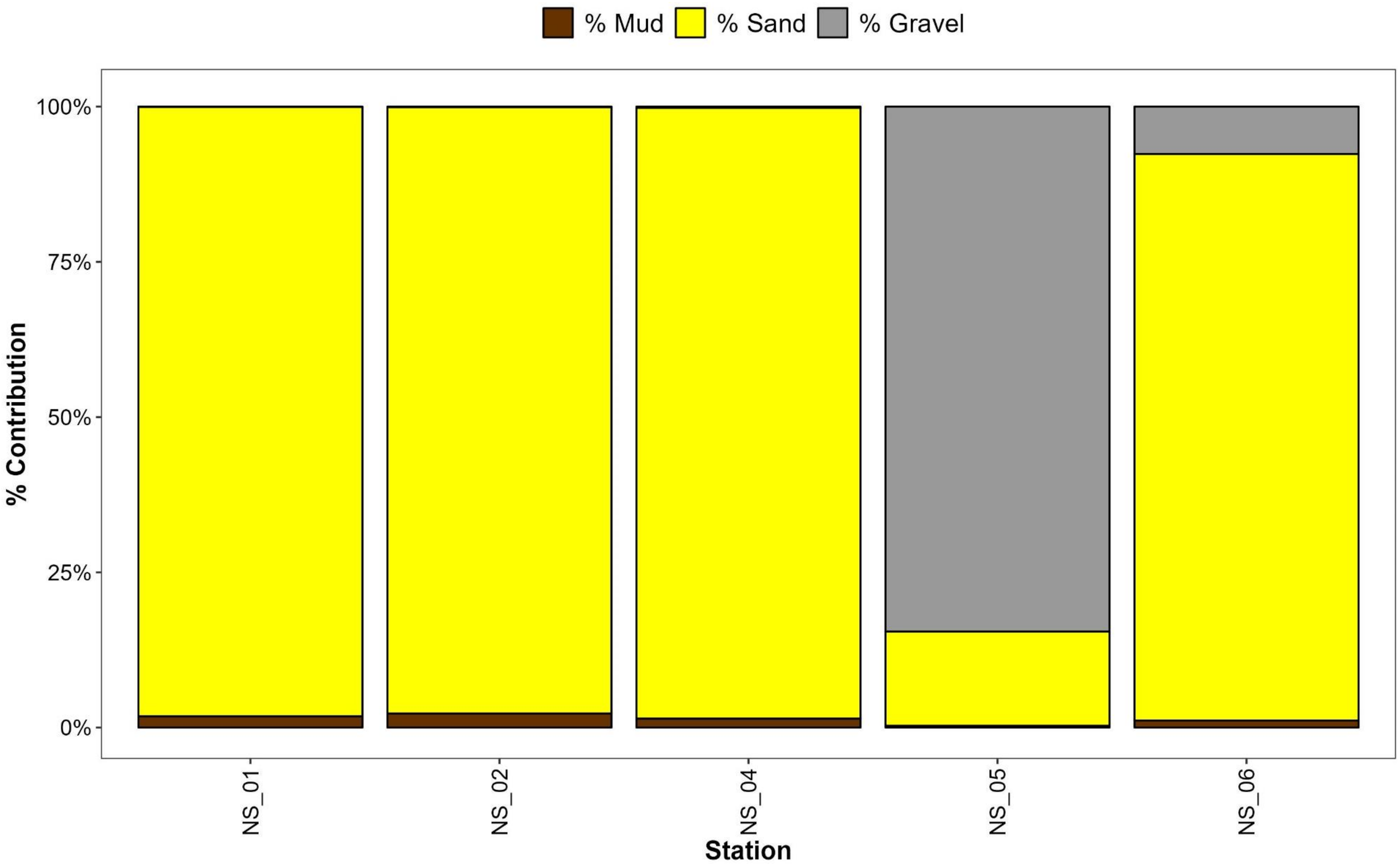

Figure 9 Percentage volume of gravel (G), sand (S), and mud (M) at each sampling station across the survey area.

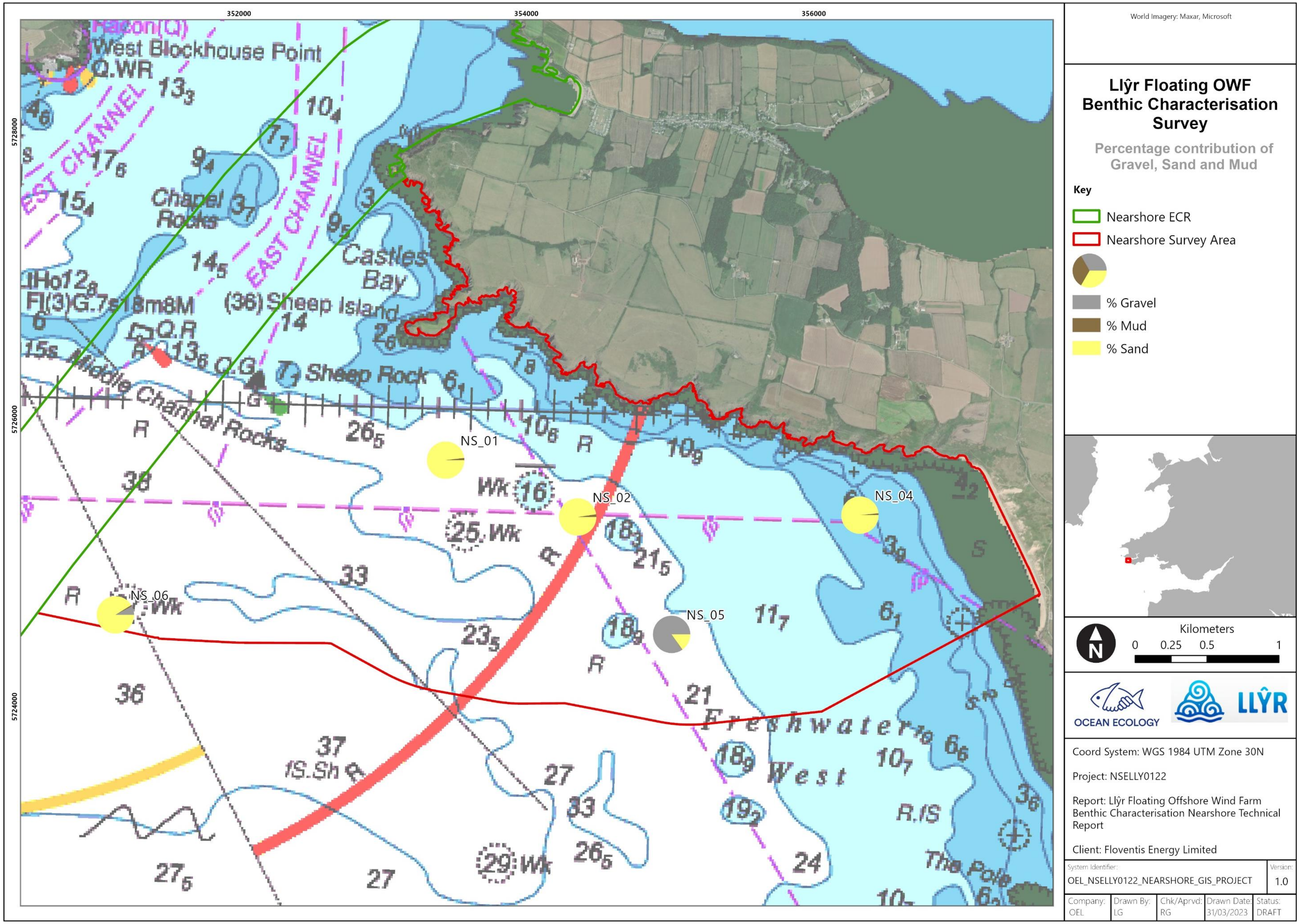

Figure 10 Percentage contribution of sand, gravel and mud at each station across the survey area.

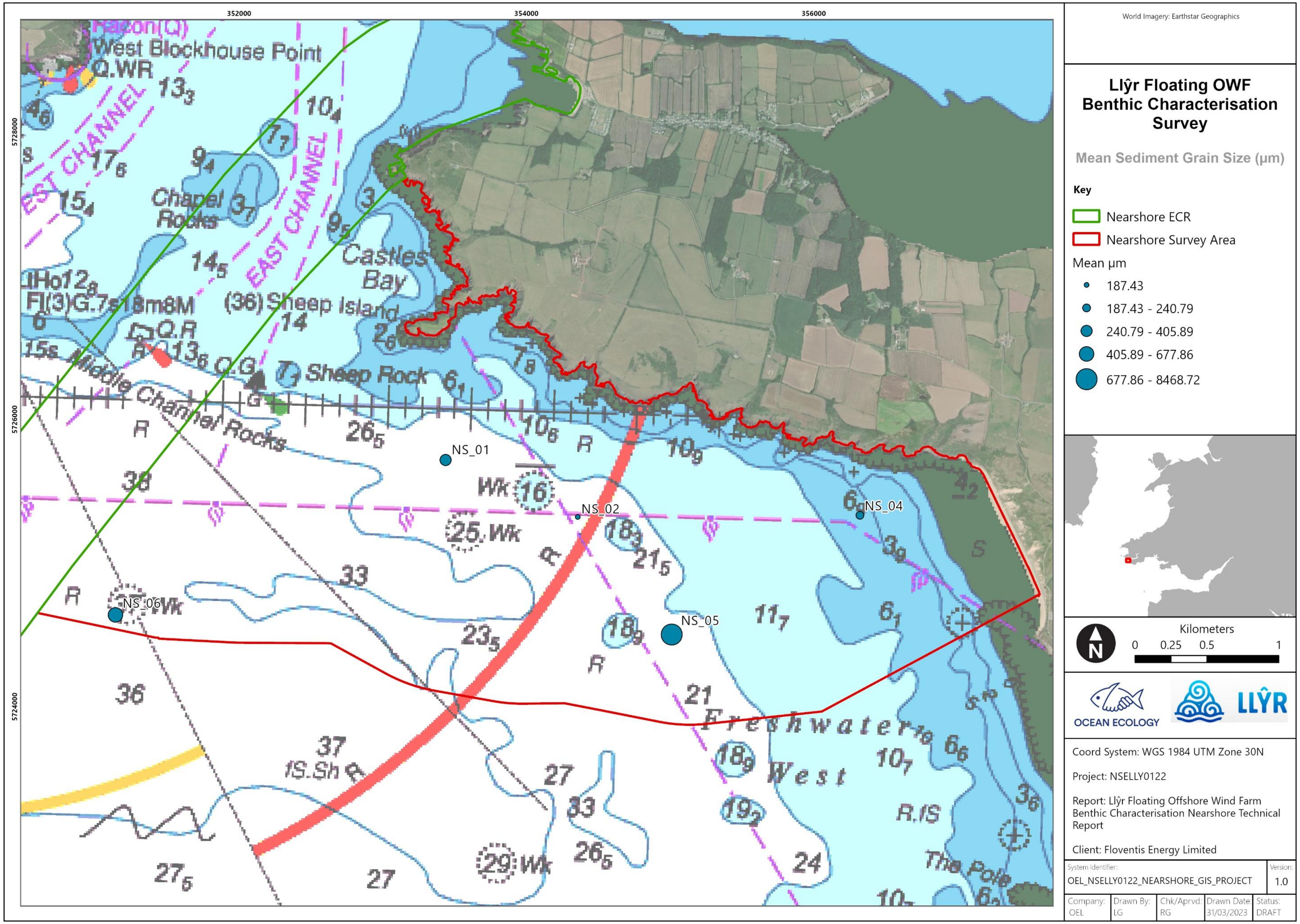

Figure 11 Mean grain size (µm) at each sampling station across the survey area.

7.3. Sediment Chemistry

Three samples were assessed for chemical contaminants.

7.3.1. Total Organic Carbon

TOC was measured for all five stations and ranged between 0.14 % at station NS_02 to 0.4 % at station NS_01 with an average value (± SE) of 0.25 ± 0.05 % across all stations.

Total Organic Matter (TOM) ranged between 1.1 % at stations NS_02 and NS_05 and 1.9 % at station NS_01 with an average value (± SE) for the survey area of 1.4 ± 0.17 %.

In general, no clear trend was observed between TOC, TOM, and mud content.

7.3.2. Heavy and Trace Metals

Raw data for the 8 main heavy and trace metals (dry-weight concentration, mg kg^{-1}) are shown in Table 13 together with available reference levels. None of the main heavy and trace metals exceeded reference levels with the exception of As which was above the ERL and TEL reference levels at two stations: NS_01 and NS_04. However, As concentrations were below the CEFAS AL 1 reference level at all stations and had an average concentration across the survey area of 8.17 mg kg^{-1}.

The most abundant metal was Zn which ranged from 17.8 mg kg^{-1} at NS_04 to 31.7 mg kg^{-1} at NS_01, however, it was always recorded well below any of the reference levels (Table 13). As was the second most abundant metal but was recorded in relatively low concentrations, ranging between 6.6 mg kg^{-1} at NS_02 and 9.1 mg kg^{-1} at NS_01, exceeding TEL and ERL reference levels at two stations as noted above. The spatial distribution of the four most abundant metals is presented within Figure 12.

A positive trend was observed between the concentration of Chromium and the amount of mud in sediments but due to the small sample size it cannot be confidently concluded that there was a strong relationship between chromium and mud across the survey area.

Table 13 Main heavy and trace metals (mg kg^{-1}) in sediments. Shading indicates values above reference levels.

Station	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
NS_01	9.1	<0.04	7.3	5.6	10.5	<0.01	7.3	31.7
NS_02	6.6	<0.04	10.2	4.9	7.6	<0.01	6.8	22.3
NS_04	8.8	0.07	5.8	5.0	5.3	<0.01	5.4	17.8
Min	6.6	0.07	5.8	4.9	5.3	BDL	5.4	17.8
Max	9.1	0.07	10.2	5.6	10.5	BDL	7.3	31.7
Mean	8.17	0.07	7.77	5.17	7.80	BDL	6.50	23.93
SE	0.79	-	1.29	0.22	1.50	BDL	0.57	4.09
Cefas AL1	20	0.4	40	40	50	0.3	20	130
Cefas AL2	100	5	400	400	500	3	200	800
BAC	25	0.31	81	27	38	0.07	36	122
ERL	8.2*	1.2	81	34	47	0.15	21	150
TEL	7.24	0.7	52.3	18.7	30.2	0.13	-	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 only assessed against the BAC; BDL = Below Detection Limit

Table 14 Number of stations across the Llŷr nearshore 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	0	0	0	2	2	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
Zn	0	0	0	0	0	0

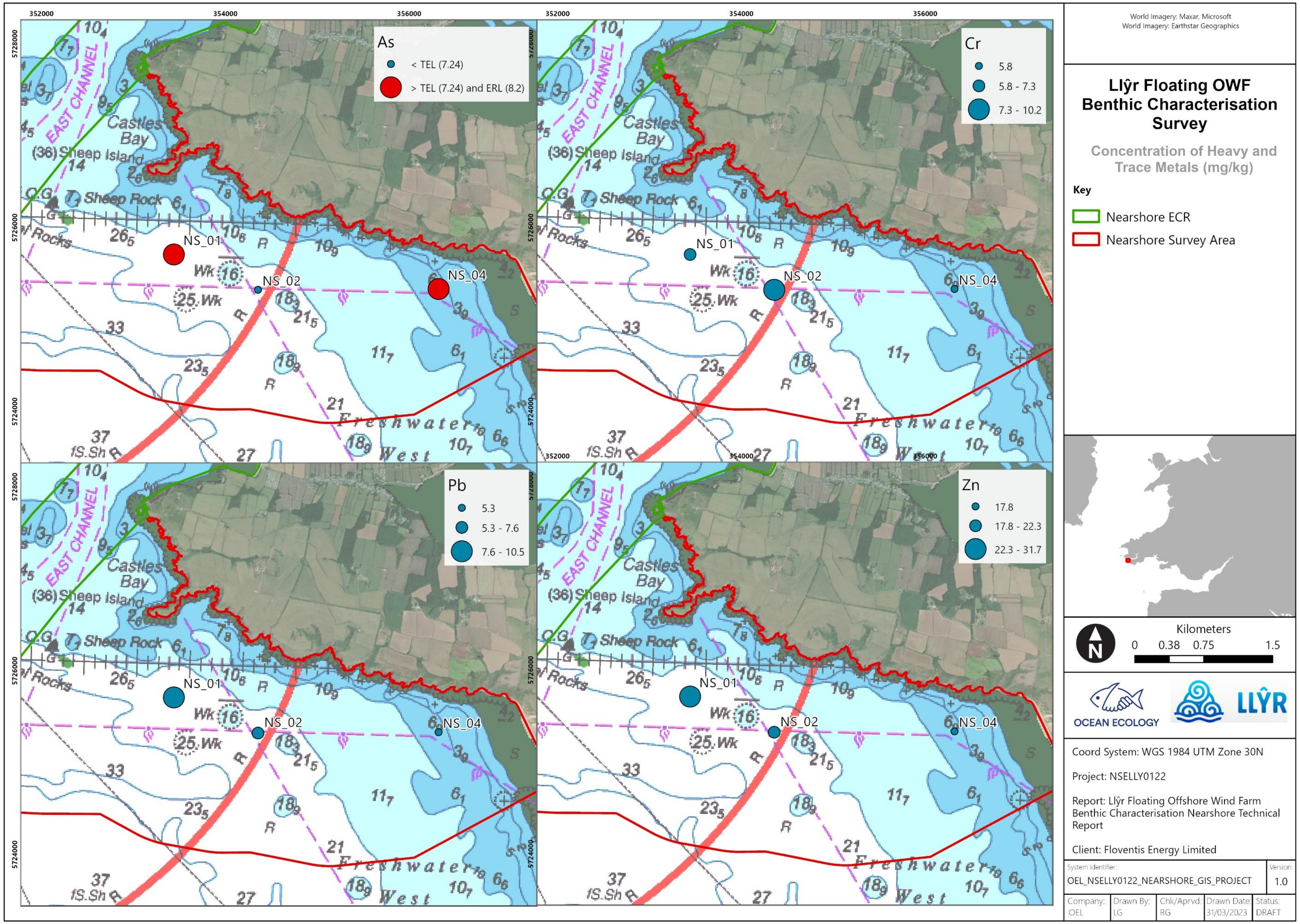

Figure 12 Concentration of the key heavy and trace metals sampled across the survey area. Note different scales for each chemical.

7.3.3. 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 three contaminant sub-samples collected.

PAH concentrations were compared to CEFAS AL1 (no CEFAS AL2 available for PAHs), OSPAR BAC levels and ERLs, and TEL and PEL where possible. None of the PAH concentrations exceeded any of the reference levels.

The most abundant PAHs were only measured at detectable limits at station NS_01 and were: Fluoranthene measured at a concentration of 1.62 $\mu g\ kg^{-1}$, Phenanthrene with a concentration of 11.0 $\mu g\ kg^{-1}$, Pyrene measured at 1.32 $\mu g\ kg^{-1}$ and Chrysene with a concentration of 9.16 $\mu g\ kg^{-1}$ at ENV003. None of these PAHs exceeded reference levels.

It was not possible to calculate the Phenanthrene / Anthracene (Ph / Ant) or Fluoranthene / Pyrene (Fl / Py) as levels of these PAHs were below the level of detection at two out of three stations. However, the LMW/HMW ratio was calculated at two stations NS_01 and NS_02 and determined a that PAHs at these stations were characterised by a pyrogenic origin (LMW / HMW <1).

The spatial distribution the most abundant PAHs across the three stations are presented within Figure 13.

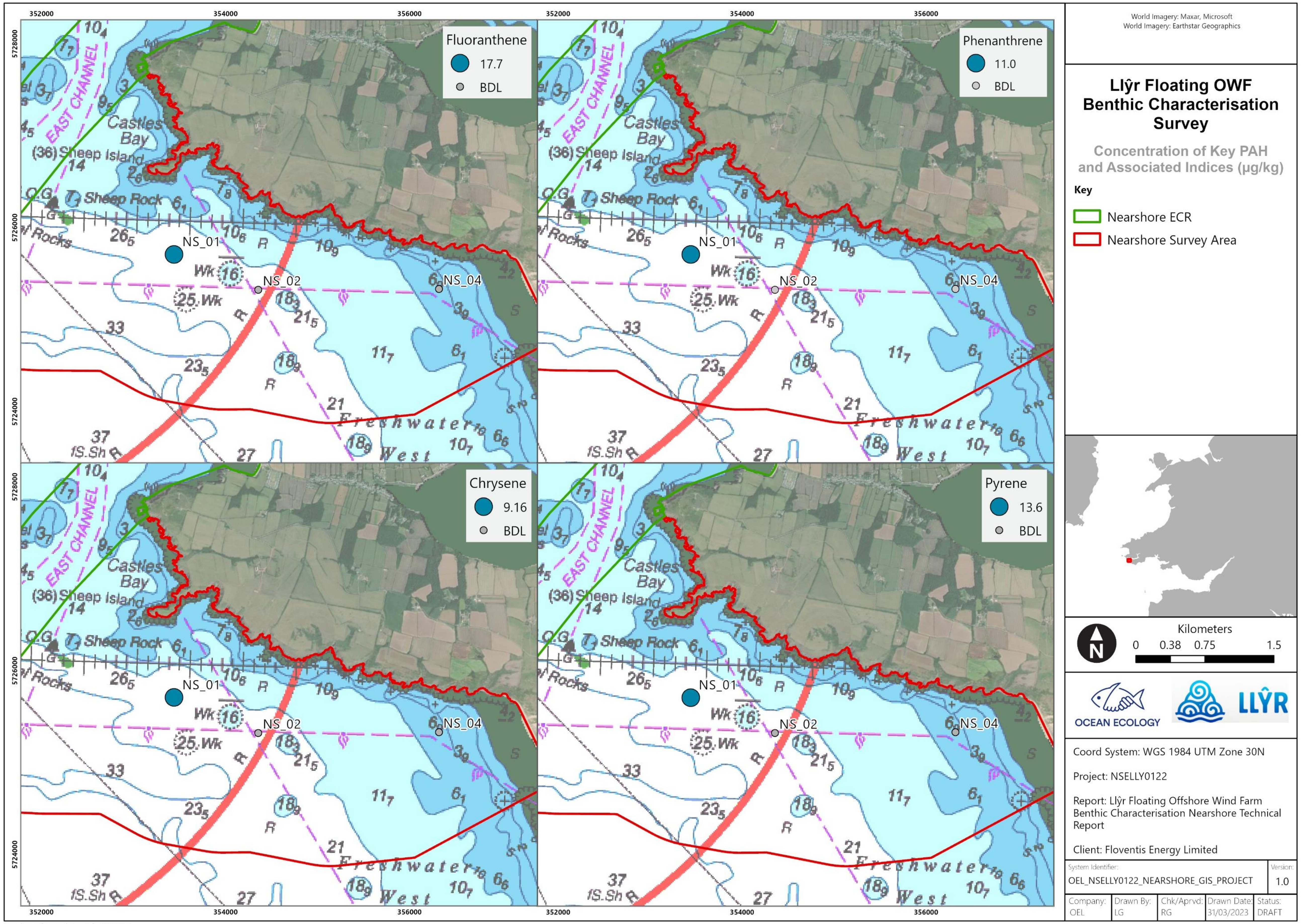

Figure 13 Sediment PAH concentrations (µg kg^{-1}) across the survey area.

7.3.4. Total Hydrocarbons (THC)

THC in sediment samples ranged from 683μg kg^{-1} at station NS_04 to 1,330 μg kg^{-1} at station NS_01 with an average value (± SE) for the survey area of 1,064 ± 196 μg kg^{-1}.

N-alkanes (saturates) in sediments had carbon chains length ranging between C17 and C35, with the dominant chains being C20 for the even numbered chains and C29 for the odd numbered chains. However, the overall concentration of total n-alkanes was recorded below the limit of detection (< 28) at all stations.

Pristane was the highest at station NS_02 being 1.46 μg kg^{-1}, and the lowest at station NS_04 where it was recorded as 1.03 μg kg^{-1}. 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 and CPI are presented in Figure 14.

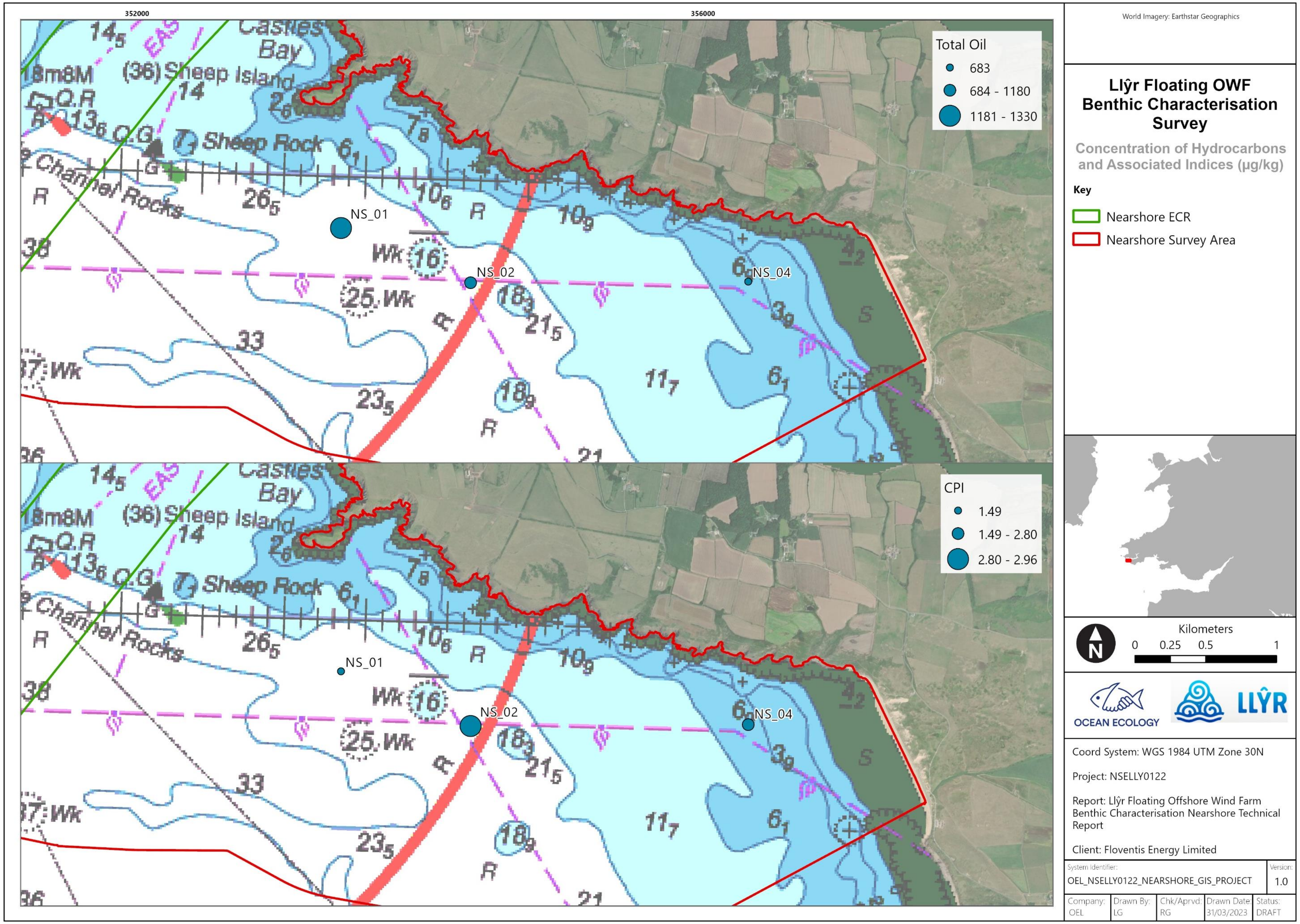

Figure 14 Concentrations of hydrocarbons and associated Carbon Preference index (CPI) for stations sampled across the survey area. Note different scales.

7.3.5. PCBs

The 7 International Council for the Exploration of the Sea (ICES) PCBs have been measured to cover the range of toxicological properties of the group. Raw data are presented in Appendix IX buy at all three stations, PCB levels were measured below the limit of detection.

7.3.6. Organotins

The concentrations of two organotins (Dibutyltin (DBT) and Tributyltin (TBT)) were analysed from the sediment taken at each of the three stations and reported in Appendix IX.

All stations had organotin concentrations below the detection limit of 0.001 mg kg^{-1}. To provide context, Cefas AL1 for organotins is 0.1 mg kg^{-1} and AL2 is 1 mg kg^{-1}.

7.4. Macrobenthos

7.4.1. Composition

The macrobenthic samples collected from the survey area indicated the presence of an impoverished community, with a total of 63 individuals and 29 taxa recorded. The mean (± SE) number of taxa per station was 7 ± 2, the mean (± SE) abundance per station was 17 ± 3, and the mean (± SE) biomass per station was 0.0483 ± 0.0475 gAFDW.

The complete abundance matrix can be found in Appendix X. The biomass (g AFDW) of each major taxonomic group (Annelida, Crustacea, Mollusca, Echinodermata, and Miscellaneous) for each sample collected is provided in Appendix XI.

The macrobenthic assemblage analysis across the survey area revealed that Miscellaneous was the most abundant major group (**Error! Reference source not found.**). Mollusca constituted the majority of the biomass, while other taxa exhibited minor biomass contributions. Annelida also displayed the highest diversity among the taxa.

In terms of sampling stations, NS_02 exhibited the highest abundance and richness, indicating a more diverse and abundant macrobenthic community at this location (**Error! Reference source not found.**). It is noteworthy that biomass was substantially low across all stations, except for NS_02, which demonstrated a markedly higher biomass in comparison.

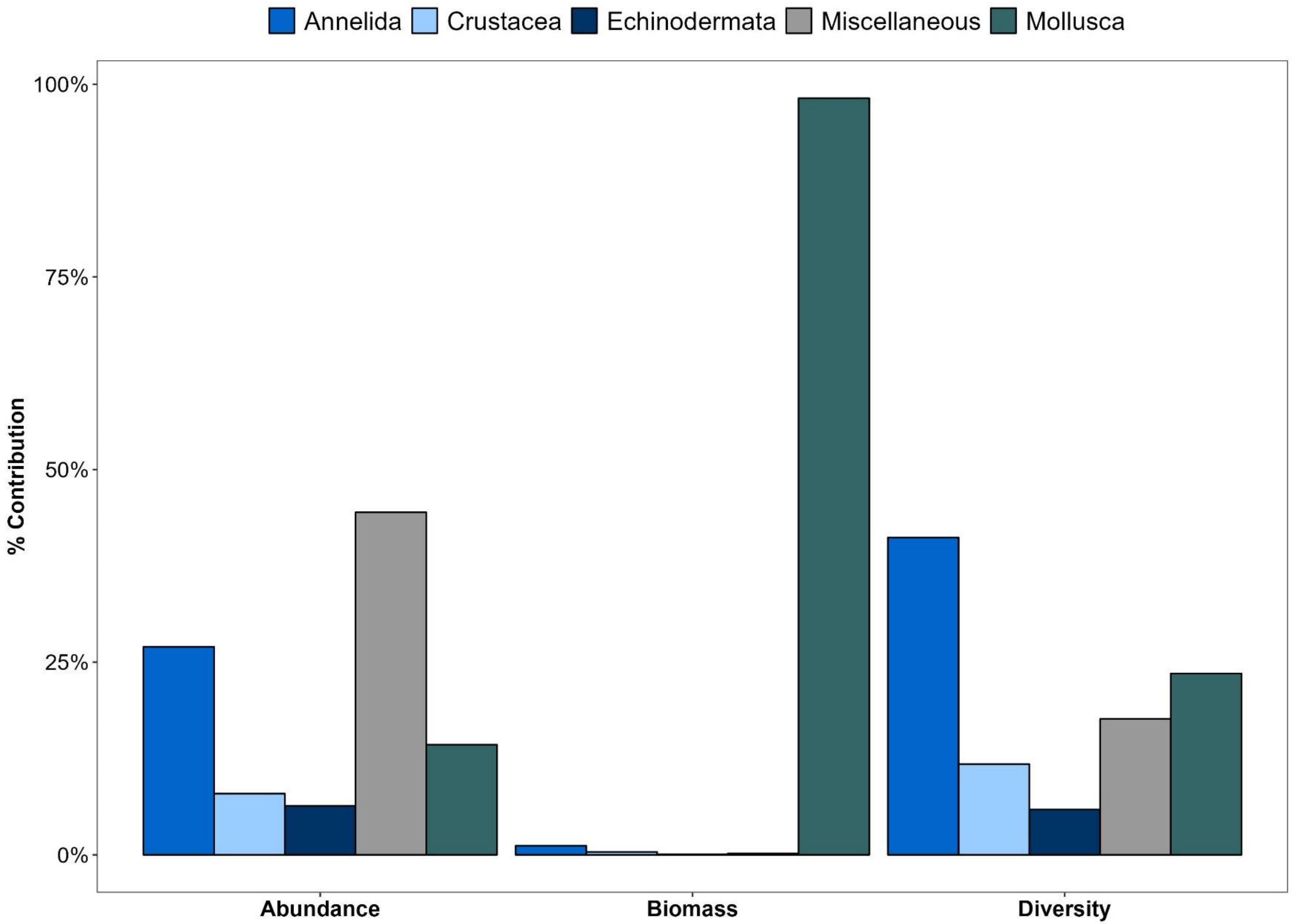

Figure 15 Relative contribution of the major taxonomic groups to the total abundance, diversity and biomass of the macrobenthos sampled across the survey area. Abundance counts exclude colonial taxa.

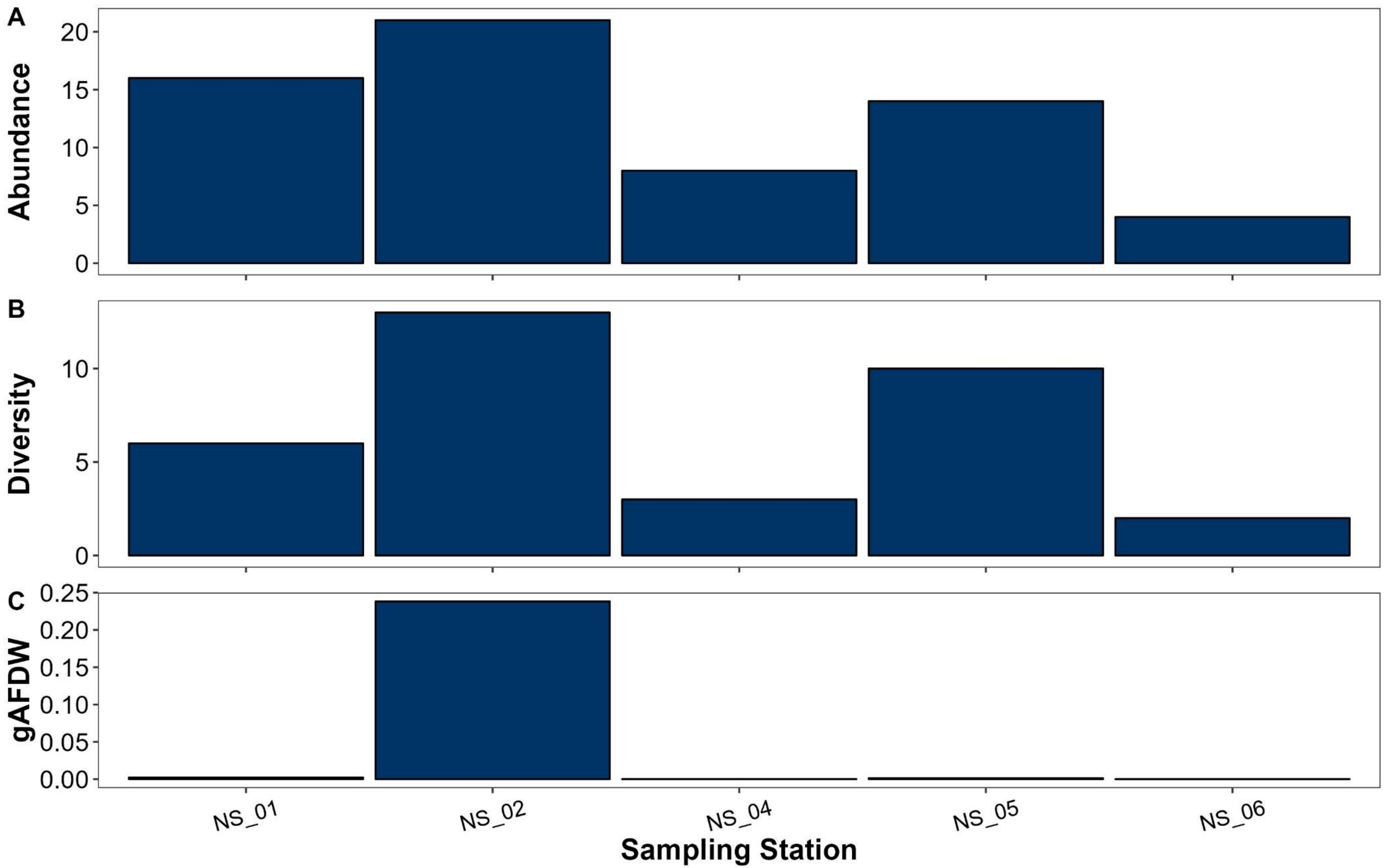

Figure 16 Abundance, diversity, and biomass (gAFDW) per station across the survey area.

7.4.2. Macrobenthic Groupings

Multivariate analysis was conducted on the square-root transformed macrobenthic abundance data to evaluate spatial distribution patterns of the macrobenthic assemblages across the survey area and identify the characterising taxa present.

Cluster analysis of the macrobenthic data was performed using a Bray-Curtis similarity matrix to assess the spatial similarities in macrobenthic communities recorded across all sampled stations. However, the dendrogram resulting from the cluster analysis, along with the associated Type 1 SIMPROF (similarity profile routine) permutation test, indicated no statistically significant differences between stations ($p > 0.05$). Consequently, all stations belonged to the same cluster and were characterised by the presence of Nematodes (see Appendix XVI).

SIMPER tests are commonly utilised as a post-hoc analysis when dissimilarities are discerned between samples or stations. In this instance, no significant differences were detected, but the SIMPER test was conducted regardless. Nevertheless, owing to the scarcity of taxa within the samples, the SIMPER analysis provided limited information. It was determined that nematodes were the sole major group significantly impacting community composition. Therefore, to determine biotope or habitat classification, the presence of specific species was evaluated for their relevance in EUNIS habitat classifications. Notably, the presence of *Abra prismatica*, *Bathyporeia elegans*, and polychaetes at one station (NS_02) was taken into account for habitat classification.

7.4.3. Habitat Classification

Considering the observed paucity of macrobenthic diversity and abundance across all sampling stations, it was not feasible to characterise biotopes utilising the EUNIS classification system accurately. Habitat mapping was therefore produced by integrating findings derived from geophysical data, imagery analysis and sedimentological examination.

7.5. Geophysical Data

The SSS and MBES data collected by N-Sea covered the entire nearshore survey area and the majority of the adjacent ECR, up to the coast. These data were initially utilised for the identification of subsea hazards and seabed features of interest when designing the sampling plan and were interpreted together with the seabed imagery to inform the seabed habitat assessment and mapping process.

The SSS data presented a varied reflectivity across the survey area, the signatures of which were indicative of a variety of sediment and rocky habitats. Areas to the east and west of the survey area displayed predominantly uniform high reflectivity, indicative of homogenous harder sediments characterised by regular small rippled bedforms. Strong reflective signatures indicative of harder substrates including potential Annex I bedrock and stony reef were identified throughout the survey area, and investigated by DDC transects.

A narrow band of distinctive linear features indicative of larger bedforms were identified to the east of the survey area visible as distinct changes in reflectivity. Features visible to the north spanned a distance of about 250 m orientated northwest to southeast. A narrow band of linear bedforms approximately 40-100 m long and 10 m wide orientated southwest to northeast spanned a distance of about 1.8 km northwest to southeast across the survey area.

The bathymetry presented as a gently sloping seabed shallowing to the northeast and deepening to the southwest transitioning from bedrock to sediment features. Bathymetric highs corresponded with topographic features identified from SSS as changes in reflectivity associated with harder seabed features.

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.

7.6. Seabed Imagery

All 6 proposed DDC stations, 10 high priority DDC transects (Figure 7) and one of the low priority DDC transects were successfully sampled, resulting in the collection of 176 still images 26 videos. The low priority transect NS_T011 was not sampled due to failing light levels, after discussion and confirmation with client. Full DDC video logs can be found in Appendix XII and stills logs in Appendix XIII.

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 15. Findings of the imagery analysis including BSH description and the EUNIS habitat description are presented in Appendix XIIII, with Annex I reef assessments in Appendix XV.

Six BSHs, two EUNIS Level 3 (biotope complexes), five EUNIS Level 4 and three EUNIS Level 5 were identified in the seabed imagery collected across the survey area (Table 15).

The most commonly encountered of these was A4.13 ‘Mixed faunal turf communities on circalittoral rock’ identified in 66 images and widely distributed across survey area. This was followed by A5.14 ‘Circalittoral coarse sediment’, identified in 38 images (Figure 17).

Concordance between seabed imagery and grab samples appeared restricted, particularly in the context of BSH A5.2 'Sublittoral Sand' and A5.1 'Subtidal Coarse Sand', which were discerned in both PSD data and seabed imagery studies. A4.1 'High Energy Circalittoral Rock' emerged as the predominant habitat in the majority of the seabed imagery. Also, notably, it is worth mentioning that of A3.2 'Moderate Energy Infralittoral Rock' and A4.2 'Moderate Energy Circalittoral Rock' samples were comparatively scarce, appearing only in a select few images.

Table 15 EUNIS BSH and biotope complexes identified in seabed imagery across the survey area.

BSH	EUNIS Code	EUNIS Description
A3.1	-	High energy infralittoral rock
	A3.116	Foliose red seaweeds on exposed lower infralittoral rock
A3.2	-	Moderate energy infralittoral rock
A4.1	A4.13	Mixed faunal turf communities on circalittoral rock
	A4.131	Bryozoan turf and erect sponges on tide-swept circalittoral rock
A4.2	A4.241	*Mytilus edulis* beds with hydroids and ascidians on tide-swept exposed to moderately wave-exposed circalittoral rock
A5.1	A5.13	Infralittoral coarse sediment
	A5.14	Circalittoral coarse sediment
	A5.141	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles
A5.2	A5.23	Infralittoral fine sand
	A5.25	Circalittoral fine sand

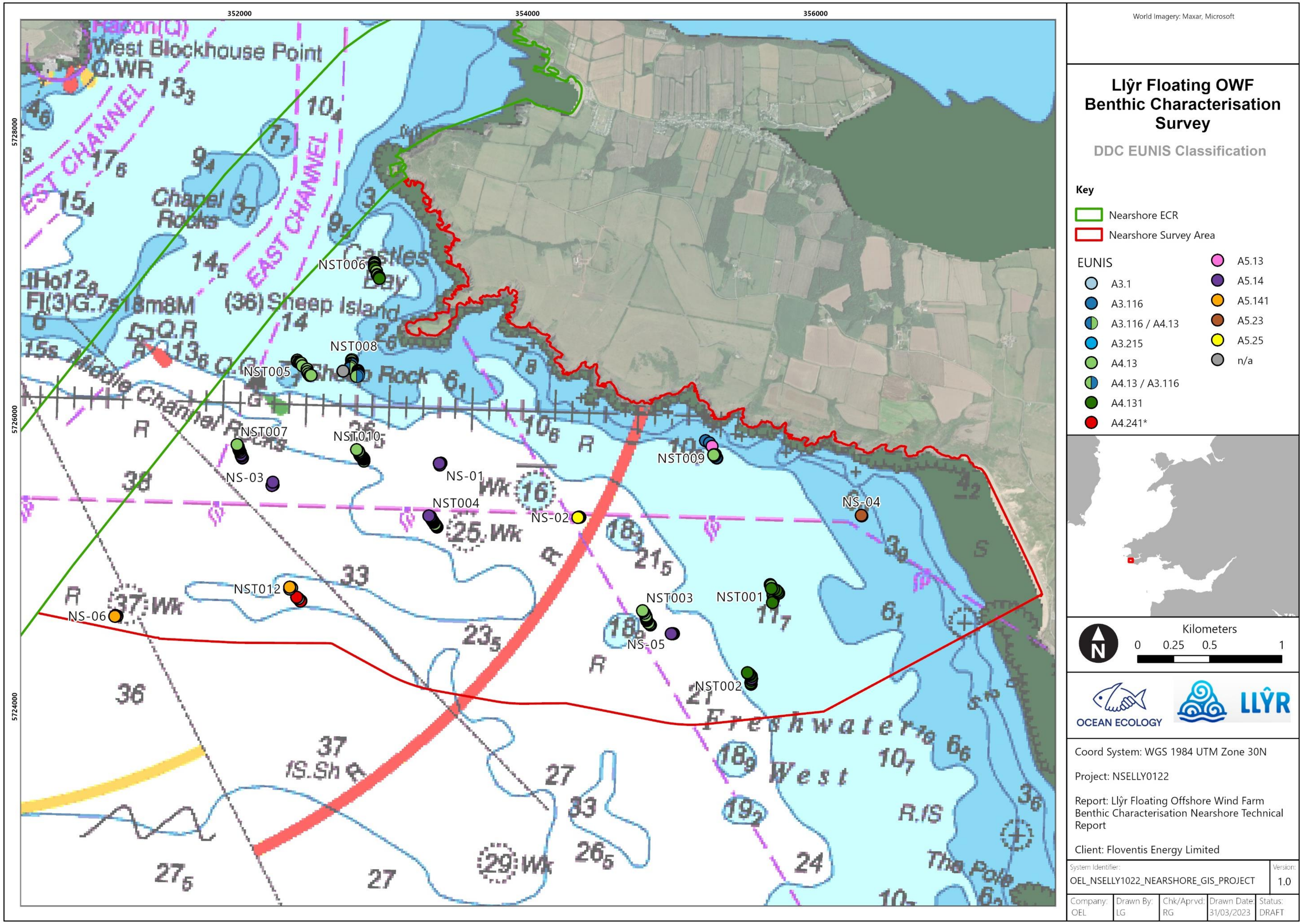

Figure 17 EUNIS codes assigned to DDC imagery collected across the survey area. * *M. edulis* beds.

7.6.1. Annex I Reef

Potential Annex I reef features were found in 113 images (68.5%) across the survey area (Of these:

- Bedrock was found in 87 images across transects NST001, NST002, NST003, NST004, NST005, NST006, NST008, NST009, NST012. Of these, 77 were determined as bedrock reef and 6 were determined as low stony and bedrock.
- Stony reef was found in 37 images across transects NST002, NST004, NST005, NST006, NST007, NST010, NST012. Of these, 13 were determined as areas of low stony reef habitat, 17 were determined as medium stony reef habitat and 6 were determined as low stony and bedrock.
- All Annex I reef assessments were undertaken in line with the criteria set out in Section 6.7.

Plate 3 Example DDC imagery of Annex I Reef.

7.6.3. Blue Mussel Beds

M. edulis beds with hydroids and ascidians on tide-swept exposed to moderately wave-exposed circalittoral rock (A4.241) were identified in three images along transect NST012 (Plate 4).

Plate 4 Example DDC imagery of HOCI *M. edulis* beds observed at transect NST012.

7.6.4. Conspicuous Taxa

Various faunal species were consistently observed in seabed video footage and still images, including *Cellaria* spp. Bryozoans, acorn barnacles, cup corals (*Caryophillia smithii*), encrusting (e.g., *Hemimycale columella*), branching (*Stelligera montagui*), and cushion sponges (e.g., *Dysidea fragilis*), as well as faunal turfs. No observations of epibenthic invasive non-native species (INNS) were recorded during the assessment. Likewise, no fish (e.g., *Ammodytes* spp.) were collected in the samples taken and no oyster beds or individuals were identified across the survey.

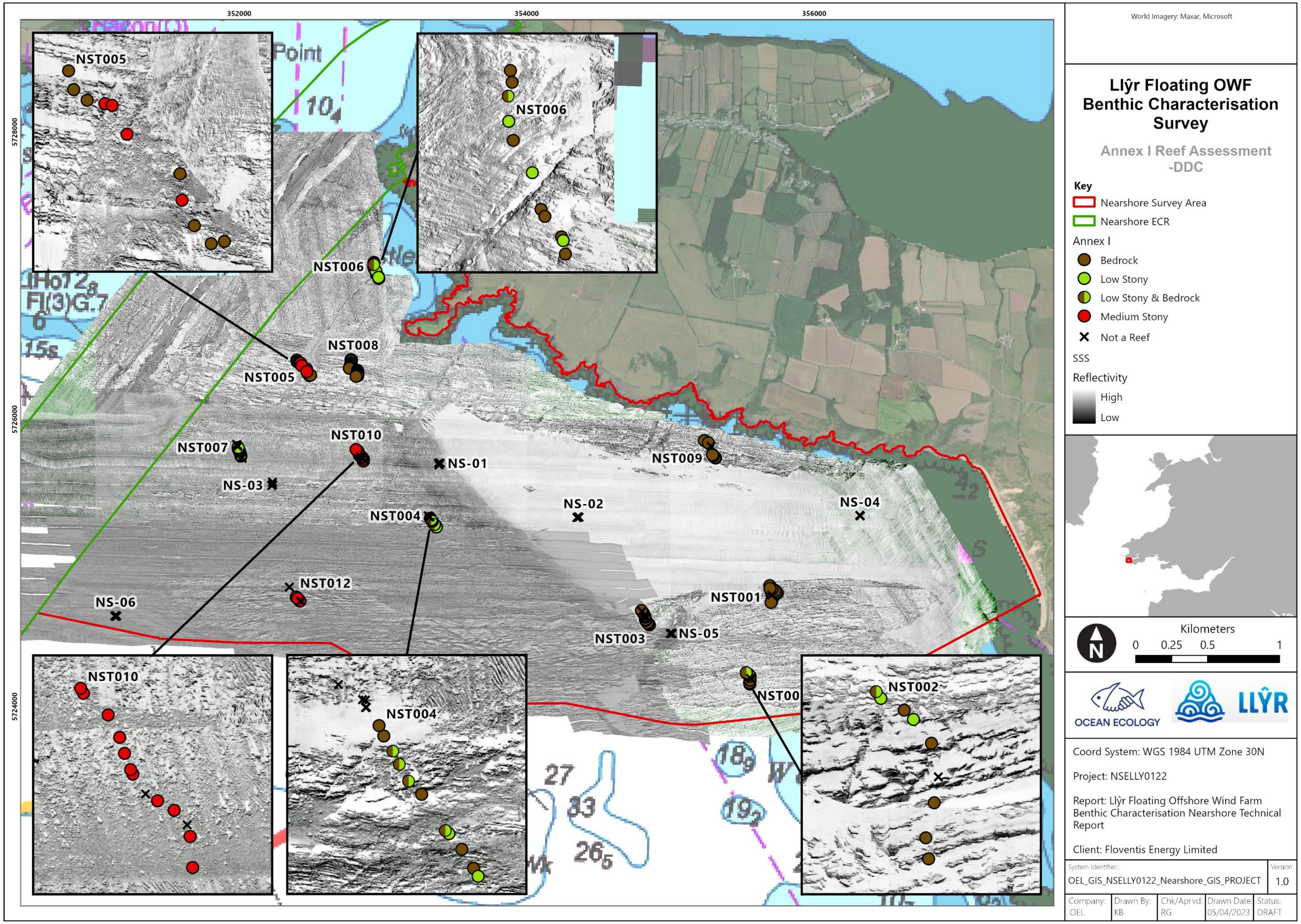

Figure 18 Annex I reef identified in DDC imagery across survey area.

7.7. Habitat Mapping

To map the principal habitats that occurred across the survey area, a full interrogation of available PSD and geophysical data, in combination with review of DDC imagery was undertaken. Given the paucity of macrobenthic diversity and subsequent uncertainty in high-level biotope assignment, habitats across the survey area were classified broadly, particularly where both ground-truth DDC imagery data and distinct acoustic boundaries were also absent.

The nearshore survey area and ECR were dominated by coarse sediments (A5.1), fine sands (A5.2) and bedrock features (A3.1/A4.1). High energy circalittoral rock (A4.1) dominated to the north and south, interspersed with channels of coarse sediments. Circalittoral coarse sediment (A5.14) dominating to southwest with a mosaic of the two (A4.1/5.14) dominating the centre of the survey area. Subtidal fine sands and muddy sands (A5.23, A5.25, and A5.2) dominated to the east of both the survey area and ECR. Sandy sediments in the survey area were fringed by a distinct sandbank bedform feature separating sands in the east from coarse sediments in the west.

A charted wreck classified as features of circalittoral rock (A4.7) was present within the circalittoral fine sands (A5.25) of the survey area.

The distribution and extent of the habitats/biotopes identified across the survey area, based on all the available data, are presented in Figure 19. Descriptions of each of these habitat/biotope types are presented in Table 16, along with the corresponding EUNIS classification assigned to each.

Habitat mapping and sampling GIS shapefiles are provided in Appendix XVII.

Table 16 EUNIS classifications (and MNCR 04/05 correlations) identified within the nearshore survey area.

EUNIS Level 3	EUNIS Level 4	EUNIS Level 5	MNCR Code	EUNIS Description
A3.1	-	-	IR.HIR	High energy infralittoral rock
	A3.11	A3.116	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock
A4.1	-	-	CR.HCR	High energy circalittoral rock
	A4.13	-	CR.HCR.XFa	Mixed faunal turf communities on circalittoral rock
A4.7	-	-	CR.FCR	Features of circalittoral rock
A5.1	-	-	SS.SCS	Sublittoral coarse sediment
	A5.13	-	SS.SCS.ICS	Infralittoral coarse sediment
	A5.14	-	SS.SCS.CCS	Circalittoral coarse sediment
A5.2	-	-	SS.SSa	Sublittoral sands and muddy sands
	A5.25	-	SS.SSa.CFiSa	Circalittoral fine sand
	A5.23	-	SS.SSa.IFiSa	Infralittoral fine sand

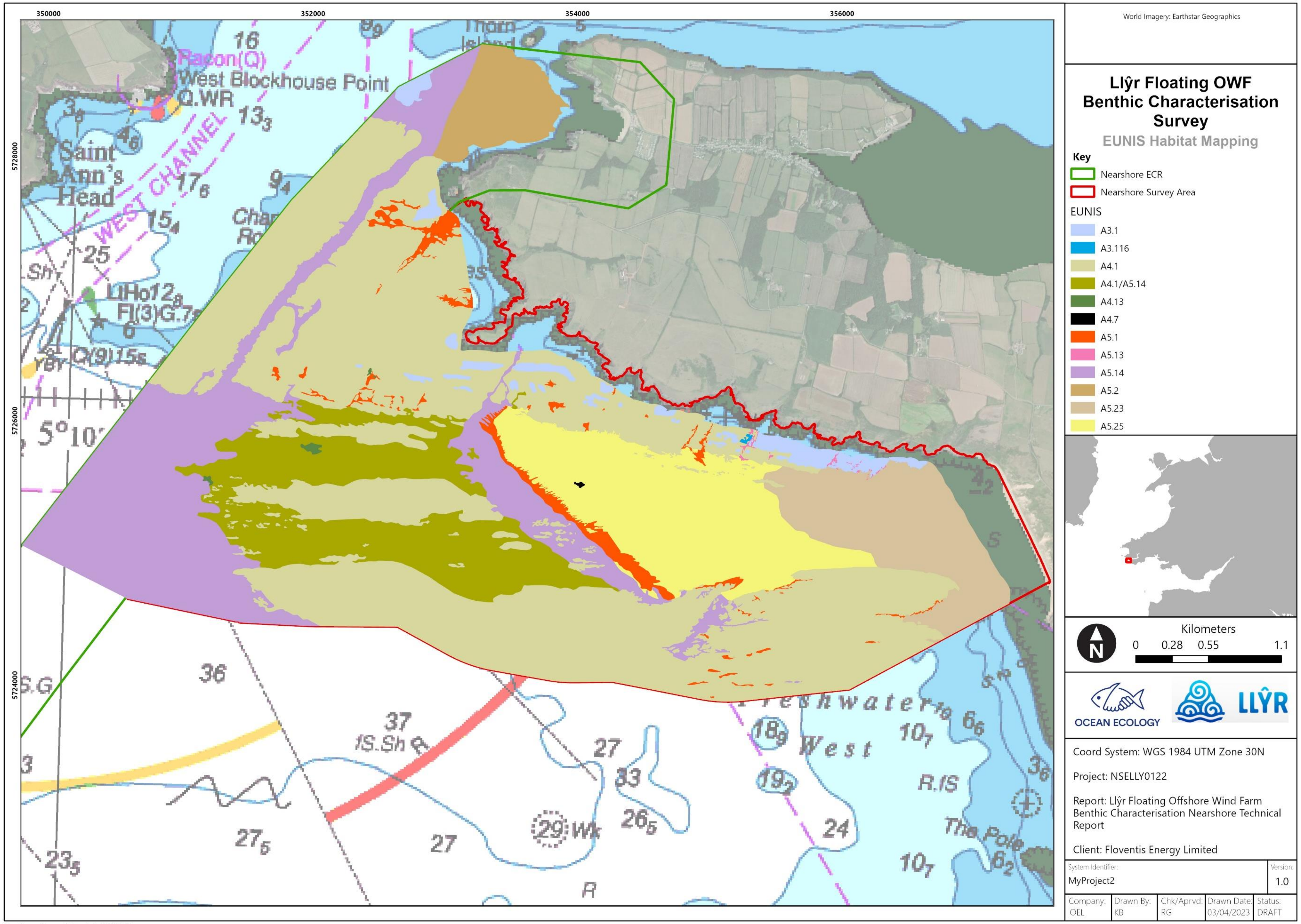

Figure 19 EUNIS classification mapping across the survey area.

7.7.1. Habitats of Conservation Importance

7.7.1.1. Blue Mussel Beds

M. edulis beds (A4.241) were observed in three DCC images across transect NST012, on areas of bedrock reef (Figure 20). However, the full extent and boundaries of this habitat could not be confidently delineated from the surrounding rocky habitat in order to identify whether these beds were extensive enough to be classified as Annex I biogenic reef.

7.7.1.2. Subtidal Mixed Muddy Sediment

Whilst subtidal mixed muddy sediment was historically recorded across the southwest of the survey area, this FOCI was not observed in seabed imagery collected in this survey or identified in the acoustic data.

7.7.1.3. Fragile Sponge and Anthozoan Communities

Whilst fragile sponge and anthozoan communities were across the north of the survey area and within the adjacent ECR, this FOCI was not observed in seabed imagery collected in this survey or identified in the acoustic data.

7.7.1.4. 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 8. To note that where stony and bedrock reefs were recorded along the same transects, they were deemed to form mosaic reef habitats.

Areas of Annex I stony reef were widely present across the survey area, located within and adjacent to the ECR (Figure 21). In total, seven transects showed evidence of Annex I stony reef (NST04, NST02, NST05 NST06, NST07, NST010 and NST012). Of these, four transects were deemed to contain areas 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 NST07 (Figure 21). Three transects were deemed to contain areas representative of medium resemblance stony reef, the boundaries of which were most confidently delineated at transect NST05 (Figure 21).

Annex I bedrock reef was also widely identified across the survey area, observed within transects NST01, NST02, NST03, NST04, NST06, NST08 and NST09. This habitat was most extensively mapped within the north of the ECR and across the north, west and southern extents of the survey area, corresponding with EUNIS classifications A4.1 and A3.1 (Figure 21). This included additional areas of bedrock mapped beyond the extent of ground-truth data, where strong reflective signatures, indicative of harder substrate bedrock reef, were present in the acoustic data. These additional areas were deemed to meet the bedrock reef qualifying criteria of an extent greater than 25 m^2 (Golding et al. 2020b), and as such, were classified as potential Annex I reef.

A large area to the west of the survey area was interpreted as a mosaic of two EUNIS habitats A4.1 and A5.14 due to the presence of coarse sediment, bedrock, and low/medium resemblance stony reef visible on the seabed imagery and acoustic data. The boundaries of which could not be discretely delineated. As such, this area was categorised more broadly as Annex I geogenic reef to represent the mosaic of stony and bedrock reef features present.

Areas classified as Annex I reef were assigned a 'High' confidence score where distinct topographic characteristics, ground-truth data, and an intersection with existing potential Annex I reef were present (Figure 21). 'Medium' and 'Low' confidence was assigned where two or one of these features were present respectively.

Annex I Biogenic Reef

No species or habitats were observed that were deemed to qualify as Annex I biogenic reef despite *M. edulis* beds being observed across transect NST012 as noted above.

7.7.1.5. Annex I Sandbanks

A distinct band of wave forms indicative of potential Annex I sandbank features were interpreted from the acoustic (MBES/SSS) data. A series of distinct reflective signatures indicative of linear bedforms spanning a distance of about 250 m was visible to the north, orientated northwest to southeast. Whilst a narrow band of linear bedforms orientated southwest to northeast was visible spanning a distance of about 1.8 km northwest to southeast across the survey area. These features were approximately 40-100 m long, and 10 m wide and interpreted from the combined acoustic data and seabed imagery as a sloping seabed of sandy sediments to the northeast deepening to coarser sediments to the southwest. Areas interpreted as potential Annex I sandbank features are displayed in Figure 22.

7.7.1.6. Annex I Estuaries and Large Shallow Inlets and Bays

The ECR intersects an area historically mapped as both Annex I Estuaries and Large Shallow Inlets and Bays. The boundaries of these Annex I habitat features in relation to the mapped area are displayed in Figure 23.

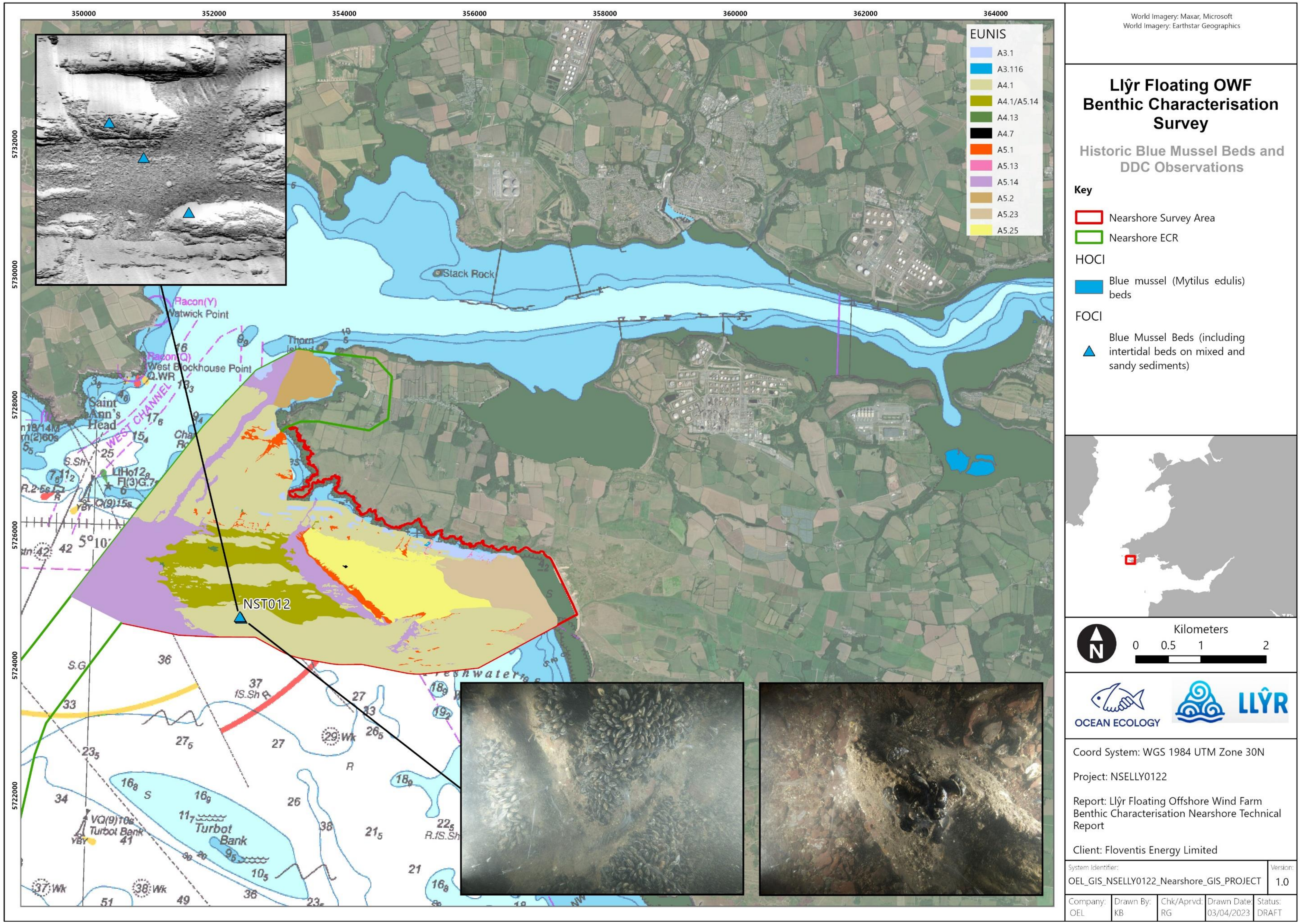

Figure 20 Historic records of HOCI *M. edulis* beds and DCC observations of this habitat across the survey area.

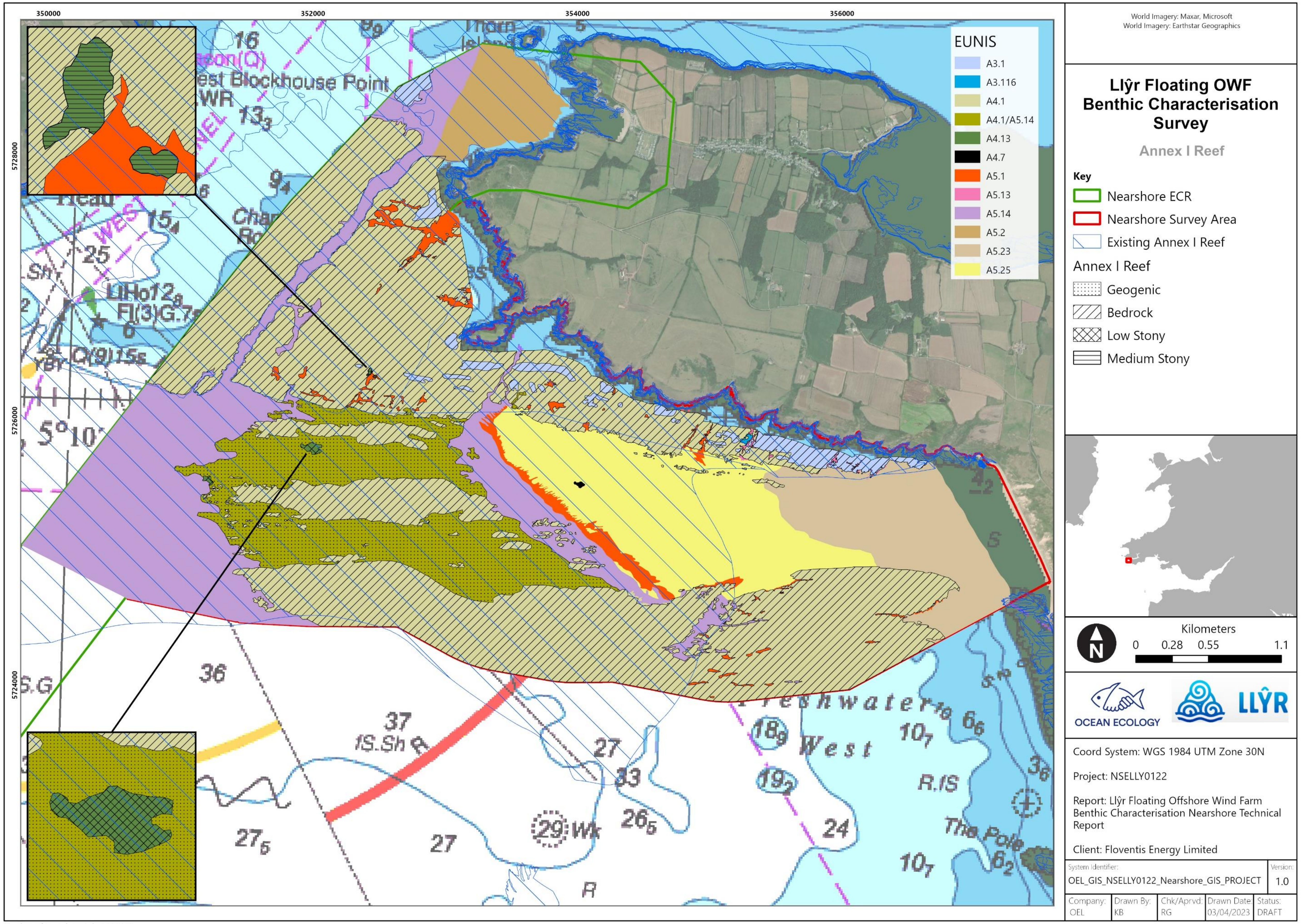

Figure 21 Areas of Annex I reef habitat mapped across the survey area.

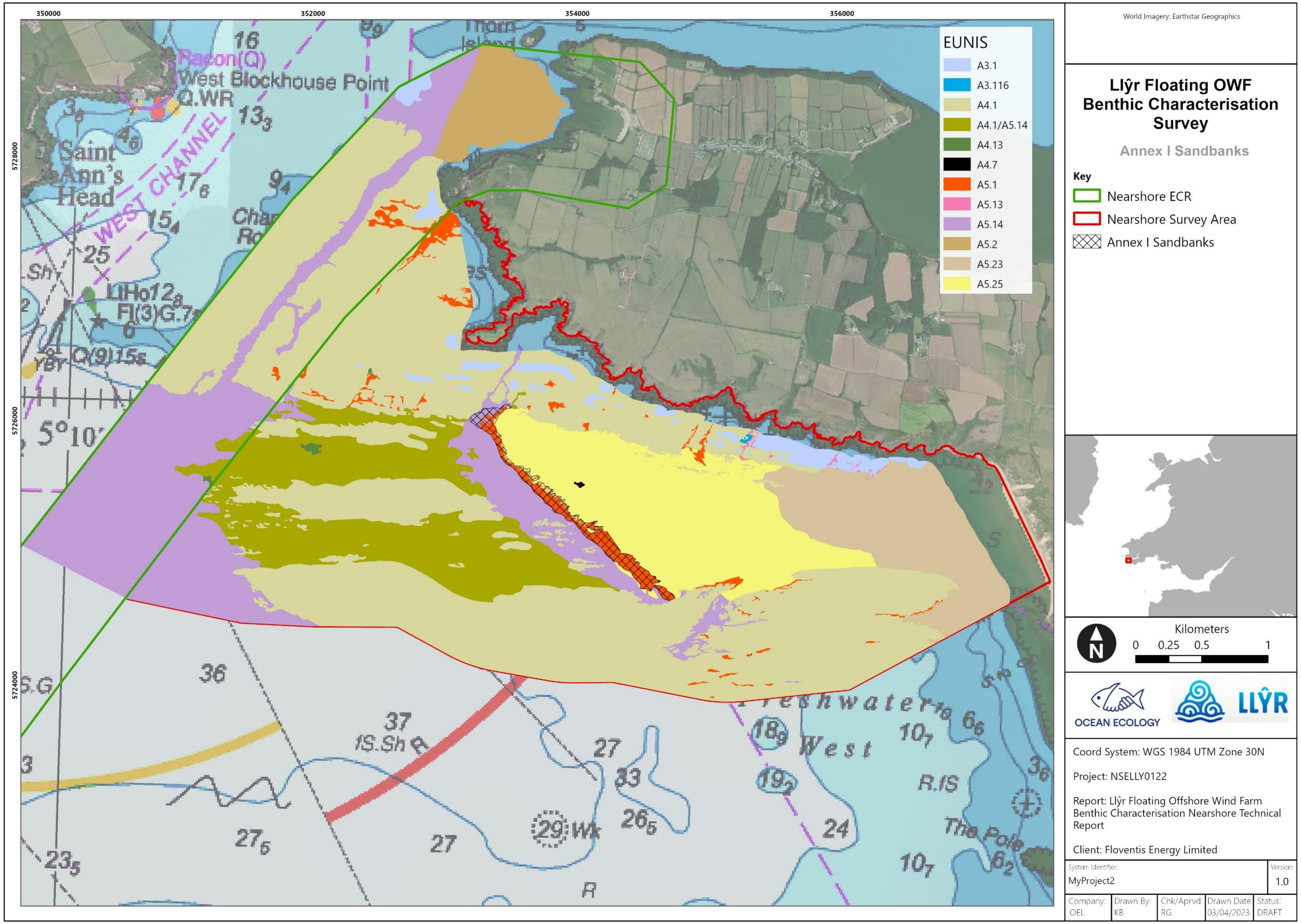

Figure 22 Areas of Annex I sandbank habitat mapped across the survey area.

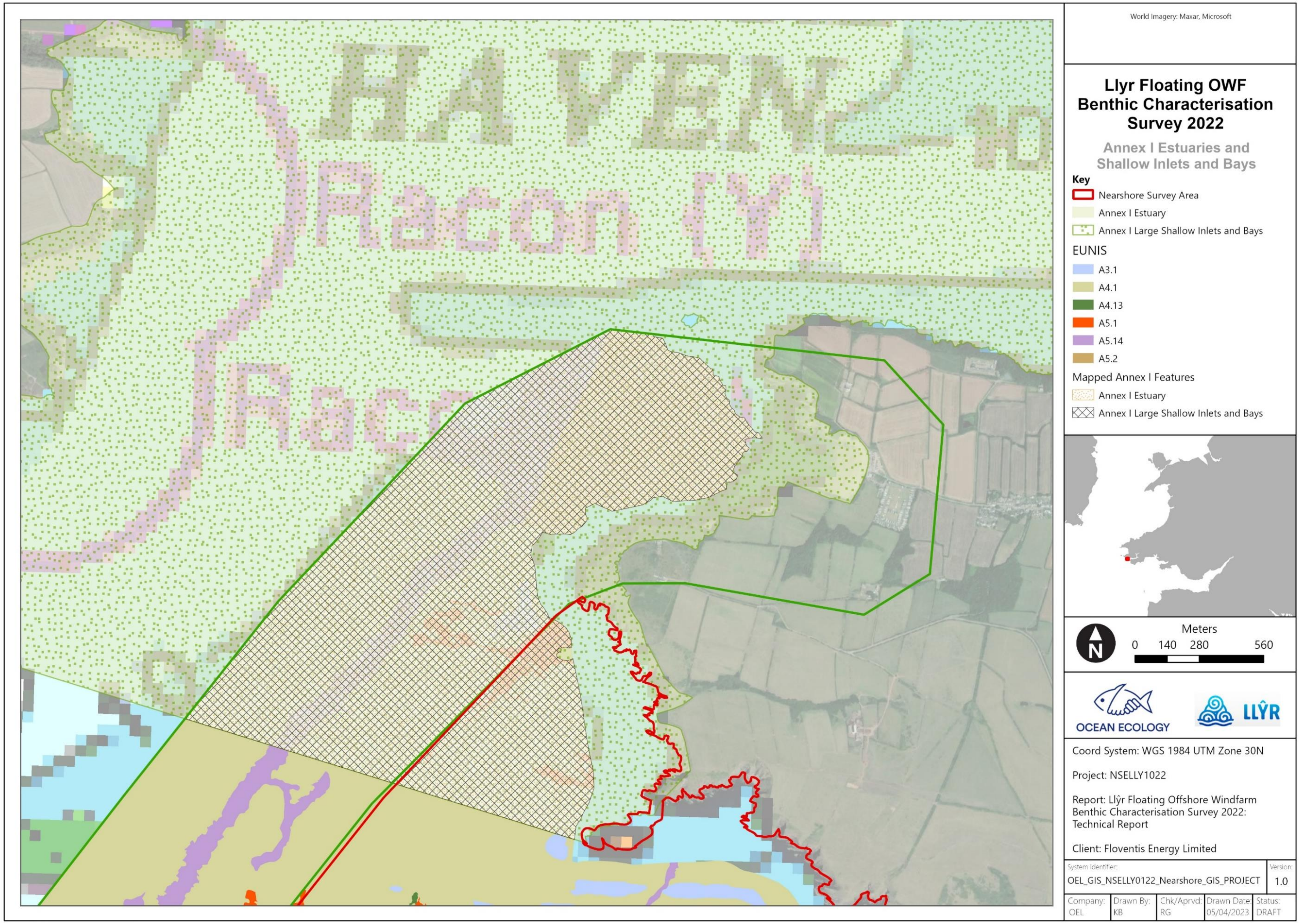

Figure 23 Areas of Annex I Estuaries and Shallow Inlets and Bays mapped across the survey area.

8. Discussion

8.1. Sediment

The sediment composition across the survey area displayed some variability, with most stations being characterised by sand. At station NS_05, gravel was the primary sediment type. Generally, the majority of stations was categorised as sand and muddy sand (BSH A5.2) under the EUNIS habitat classification system. Consequently, from a conservation perspective, the survey area is characterised by the "Subtidal sands and gravels" of Section 7 Priority Habitats under Environment (Wales) Act 2016. However, it is important to note that this classification is not exclusive to the area and represents a common habitat type along the coast of the British Isles.

Regarding the suitability of the sediment composition for fish spawning grounds (see (Reach et al. 2013), four of the five stations were deemed unsuitable for herring spawning, while station NS_05, was identified as a prime habitat for herring spawning. Conversely, four of the five stations were deemed suitable for sand eel spawning grounds, except for NS_05, which contained too much gravel.

8.2. Sediment Chemistry

TOC content was overall low across the survey area ranging from 0.14 % to 0.4 %, 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).

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 three stations, As was the only metal with concentrations above reference levels at two stations. Specifically, As was above OSPAR ERL and CSQG TEL reference levels at stations NS_01 and NS_04.

However, it should be noted that the TEL for As is lower than BAC and CEFAS Al1. This may be attributed to TEL being based on North American data and as such it may not be fully representative of UK conditions (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 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.

No obvious pattern emerged when comparing stations with elevated As concentrations with mud content. 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 imply concentration levels. Despite the elevated As levels at two of the three stations, no macrobenthic anomalies were identified at these locations to suggest and adverse effects were present.

THC was highest at station NS_01 with a biogenic source origin of hydrocarbons determined at all three stations 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-20 and C-29 being the most abundant alkanes across the survey area (Al-hejuje et al. 2015).

All measured PAHs, Organotins and PCBs were below the limit of detection.

8.3. Macrobenthos

The macrobenthic samples from the survey area indicated the presence of an impoverished community across the region, based on the 63 individuals and 29 taxa recorded from the five samples collected. The taxonomic diversity we observed varied across the survey area, with higher levels of diversity found in some locations (e.g., NS_02, with 13 identified taxa) and lower levels in others (e.g., NS_06, with only 2 identified taxa). The low diversity of taxa can be attributed to factors such as salinity variation and high sediment mobility, which favour opportunistic, stress-tolerant taxa like nematodes (Forster 1998). These taxa are adapted to survive in habitats where resources and suitable conditions for other organisms may be limited.

The diversity at each station was influenced by the predominant substrate type in line with existing literature (e.g., (Mackie et al. 1995, Van Dalfsen et al. 2000). Three out of five stations were dominated by clean, mobile sand, while the remaining two featured coarse sediment (gravel). The three sandy stations, characterised by low diversity, could be classified as EUNIS habitat types "Infralittoral mobile clean sand with sparse fauna" (A5.231) or "Infralittoral mobile sand in variable salinity" (estuaries) (A5.221) due to their proximity to an estuary.

These habitats typically exhibit low diversity because of high sediment mobility and variable salinity, which hinder the establishment of stable communities. Alternatively, the presence of few *A. prismatica*, *B. elegans*, and polychaetes, as well as the sample depths, suggest that "*Abra prismatica*, *Bathyporeia elegans*, and polychaetes in circalittoral fine sand" (A5.252) could be another possible classification.

The two gravelly stations also showed low diversity, potentially aligning with "Sparse fauna on highly mobile sublittoral shingle (cobbles and pebbles)" (A5.131), or with the broader classifications of circalittoral coarse sediment (A5.14) or infralittoral coarse sediment (A5.13). However, it is important to note that as the macrobenthic community observed across the survey area was overall impoverished no key species were identified that could help in assigning biotopes and refine the resolution of the habitat mapping based on geophysical data, imagery, and PSD analyses.

Similarly to the offshore area, 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

The resulting habitat map updates both the presence and extent of historically mapped Annex I habitats throughout the survey area. The geogenic reef areas (bedrock and stony) identified extend Annex I reef habitat features southeast of their previously recorded location. The boundaries of existing Annex I reef features have further been refined due to the fine-scale delineation of hard substrate boundaries, made possible due to the availability of ultra-high resolution acoustic data; therefore, identifying areas of sands and coarse sediments. Confidence was generally high (1-2) due to the quality of the acoustic data and the availability of ground-truthed imagery, lower confidence was assigned to larger areas with low ground-truthed coverage.

An area identified as a potential Annex I sandbank feature was interpreted and mapped, this extensive feature separates two distinctive sediment types interpreted as circalittoral fine sand (A5.25) to the east and circalittoral coarse sediment (A5.14) to the west. The feature spans the full extent of the sediment boundary, terminating at bedrock features to the northwest and southeast. No Annex I sandbank features have previously been mapped within the survey area or ECR however mapped areas do exist to the southwest. Confidence is medium (2) as this feature was delineated from acoustic data alone.

The ECR intersects an area historically mapped as both Annex I Estuaries and Large Shallow Inlets and Bays. These two Annex I habitats are described as habitat complexes and can therefore comprise of multiple features including other Annex I habitats such as reefs, sandbanks, mudflats, and saltmarshes. Six broadscale habitats were interpreted and mapped as cooccurring with these Annex I features including three habitats identified as Annex I reef (A3.1, A4.1 and A4.13). Confidence is low (1) as both features were delineated from historical data only. The criteria for assigning Annex I classifications to both features is dependent on a variety of environmental and physical factors, as such it was not possible to make a detailed delineation of these habitat features from the acoustic data alone.

Blue mussel beds classified as '*M. edulis* beds with hydroids and ascidians on tide-swept exposed to moderately wave-exposed circalittoral rock' (A4.241) were observed from ground-truthed imagery alone, with no delineation of this biotope possible from the acoustic data. Therefore, the extent of this biotope could not be mapped. However, the habitat required for *M. edulis* beds to occur, i.e. tide-swept exposed to moderately wave-exposed circalittoral rock (A4.1) was extensively mapped, therefore it is possible that this species and biotope is underrepresented here.

The ECR and survey area intersected several historically mapped areas or individual records of FOCI including subtidal mixed muddy sediments and fragile sponge and anthozoan communities. However, no evidence of these habitats was identified in seabed imagery, sediment analysis or within the acoustic data.

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