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White Cross Offshore Windfarm Environmental Statement

Chapter 8: Marine and Coastal Processes

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Glossary of Acronyms

Acronym	Definition
BERR	Department for Business, Enterprise and Regulatory Reform
CCMA	Coastal Change Management Area
CEA	Cumulative Effect Assessment
Cefas	Centre for the Environment and Fisheries and Aquaculture Science
CPA	Coast Protection Act
DESNZ	Department for Energy Security and Net Zero
EEA	European Economic Area
EIA	Environmental Impact Assessment
ES	Environmental Statement
ETG	Expert Topic Group
FEPA	Food and Environmental Protection Act
HRA	Habitats Regulation Assessment
IPCC	Intergovernmental Panel on Climate Change
IGS	Institute of Geological Sciences
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
Km^2	Square kilometre
m	Metre
MCZ	Marine Conservation Zone
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MMO	Marine Management Organisation
MPS	Marine Policy Statement
MW	Megawatts
NDC	North Devon Council
NPPF	National Planning Policy Framework
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
WCOWL	White Cross Offshore Windfarm Limited
PDE	Project Design Envelope
RCP	Representative Concentration Pathways
SAC	Special Area of Conservation
SMP	Shoreline Management Plan
SPA	Special Protection Area

Acronym	Definition
SSSI	Site of Special Scientific Interest
UK	United Kingdom
UKCP18	United Kingdom Climate Projections 2018

Glossary of Terminology

Defined Term	Description
Applicant	White Cross Offshore Windfarm Limited.
Cumulative effects	The effect of the Project taken together with similar effects from a number of different projects, on the same single receptor/resource. Cumulative Effects are those that result from changes caused by other past, present or reasonably foreseeable actions together with the Project.
Environmental Impact Assessment (EIA)	Assessment of the potential impact of the proposed Project on the physical, biological and human environment during construction, operation and decommissioning.
Export Cable Corridor	The area in which the export cables will be laid, either from the Offshore Substation or the inter-array cable junction box (if no offshore substation), to the NG Onshore Substation comprising both the Offshore Export Cable Corridor and Onshore Export Cable Corridor.
Landfall (to MLWS)	Where the offshore export cables come ashore.
Mean high water spring	The average tidal height throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest.
Mean low water spring	The average tidal height throughout a year of two successive low waters during those periods of 24 hours when the range of the tide is at its greatest.
Mitigation	Mitigation measures have been proposed where the assessment identifies that an aspect of the development is likely to give rise to significant environmental effects, and discussed with the relevant authorities and stakeholders in order to avoid, prevent or reduce impacts to acceptable levels. For the purposes of the EIA, two types of mitigation are defined: • Embedded mitigation: consisting of mitigation measures that are identified and adopted as part of the evolution of the project design, and form part of the project design that is assessed in the EIA • Additional mitigation: consisting of mitigation measures that are identified during the EIA process specifically to reduce or eliminate any predicted significant effects. Additional mitigation is therefore subsequently adopted by Offshore Wind Ltd (OWL) as the EIA process progresses.
National Grid Onshore Substation	Part of an electrical transmission and distribution system. Substations transform voltage from high to low, or the reverse by means of the electrical transformers.
Onshore Development Area	The onshore area landward of MLWS including the underground onshore export cables connecting to the White Cross Onshore Substation and onward to the NG grid connection point at East Yelland. The onshore development area will form part of a separate Planning application to the

Defined Term	Description
	Local Planning Authority (LPA) under the Town and Country Planning Act 1990.
Onshore Export Cables	The cables which bring electricity from MLWS at the Landfall to the White Cross Onshore Substation and onward to the NG grid connection point at East Yelland.
Onshore Export Cable Corridor	The proposed onshore area in which the export cables will be laid, from MLWS at the Landfall to the White Cross Onshore Substation and onward to the NG grid connection point at East Yelland.
Onshore Infrastructure	The combined name for all infrastructure associated with the Project from MLWS at the Landfall to the NG grid connection point at East Yelland. The onshore infrastructure will form part of a separate Planning application to the Local Planning Authority (LPA) under the Town and Country Planning Act 1990.
Onshore Transmission Assets	The aspects of the project related to the transmission of electricity from MLWS at the Landfall to the NG grid connection point at East Yelland including the Onshore Export Cable, the White Cross Onshore Substation and onward connection to the NG grid connection point at East Yelland.
the Onshore Project	The Onshore Project for the onshore TCPA application includes all elements onshore of MLWS. This includes the infrastructure associated with the offshore export cable (from MLWS), landfall, onshore export cable and associated infrastructure and new onshore substation (if required).
White Cross Offshore Windfarm Ltd	White Cross Offshore Windfarm Ltd (WCOWL) is a joint venture between Cobra Instalaciones Servicios, S.A., and Flotation Energy Ltd.
the Project	the Project is a proposed floating offshore windfarm called White Cross located in the Celtic Sea with a capacity of up to 100MW. It encompasses the project as a whole, i.e. all onshore and offshore infrastructure and activities associated with the Project.
Project Design Envelope	A description of the range of possible elements that make up the Project design options under consideration. The Project Design Envelope, or 'Rochdale Envelope' is used to define the Project for Environmental Impact Assessment (EIA) purposes when the exact parameters are not yet known but a bounded range of parameters are known for each key project aspect.
White Cross Onshore Substation	A new substation built specifically for the White Cross project. It is required to ensure electrical power produced by the offshore windfarm is compliant with NG electrical requirements at the grid connection point at East Yelland.
Works completion date	Date at which construction works are deemed to be complete and the windfarm is handed to the operations team. In reality, this may take place over a period of time.

8. Marine and Coastal Processes

8.1 Introduction

1. This chapter of the Environmental Statement (ES) presents the potential impacts of the White Cross Offshore Windfarm Project (the Onshore Project) on marine and coastal processes. Specifically, it considers impacts landward of Mean Low Water Spring (MLWS) Tides during its construction, operation and maintenance, and decommissioning phases.

2. The ES has been finalised with due consideration of pre-application consultation to date (see **Chapter 7: Consultation**) and the ES will accompany the application to North Devon Council (NDC) for planning permission under the Town and Country Planning Act 1990.

3. The components of the White Cross Offshore Windfarm Project seaward of Mean High Water Spring (MHWS) ('the Offshore Project') are subject to a separate application for consent under Section 36 of the Electricity Act 1989, and for Marine Licences under the Marine and Coastal Access Act 2009. These applications are supported by a separate ES covering all potential impacts seaward of MHWS.

4. This assessment has been undertaken with specific reference to the relevant policy, legislation and guidance, which are summarised in **Section 8.2** of this chapter. Further information on the international, national and local planning policy and legislation relevant to the Onshore Project is provided in **Chapter 3: Policy and Legislative Context**.

5. Details of the methodology used for the Environmental Impact Assessment (EIA) and Cumulative Effect Assessment (CEA), are presented in **Section 8.3** of this chapter and **Chapter 6: EIA Methodology**.

6. The impacts assessed in this chapter inform the following linked ES chapters:

   - **Chapter 9: Marine Water and Sediment Quality**
   - **Chapter 10: Benthic and Intertidal Ecology**
   - **Chapter 17: Onshore Archaeology and Cultural Heritage**.

7. Inter-relationships with these chapters are further described in **Section 8.10**.

8. This ES chapter:

   - Presents the existing environmental baseline established from desk studies, and consultation

- Presents the potential environmental effects on marine and coastal processes arising from the Onshore Project, based on the information gathered and the analysis and assessments undertaken
- Identifies any assumptions and limitations encountered in compiling the environmental information
- Highlights any necessary monitoring and/or mitigation measures which could prevent, minimise, reduce or offset the possible environmental effects identified in the EIA process.

8.2 Policy, Legislation and Guidance

9. **Chapter 3: Policy and Legislative Context** describes the wider policy and legislative context for the Onshore Project. The principal policy and legislation used to inform the assessment of potential impacts on marine and coastal processes for the Onshore Project are outlined in this section.

8.2.1 National Planning Policy Framework

10. The National Planning Policy Framework (NPPF) (Ministry of Housing, Communities and Local Government, updated July 2021) is the primary source of national planning guidance in England. Sections relevant to this aspect of the ES are summarised below in **Table 8.1**.

Table 8.1 Summary of NPPF Policy relevant to marine and coastal processes

Summary	How and where this is considered in the ES
170. In coastal areas, planning policies and decisions should take account of the UK Marine Policy Statement and marine plans. Integrated Coastal Zone Management should be pursued across local authority and land/sea boundaries, to ensure effective alignment of the terrestrial and marine planning regimes.	Consideration of the UK Marine Policy Statement and marine plans in provided **Section 8.2.2**. The Onshore Project is in line with Integrated Coastal Zone Management and will not affect policies presented in the Shoreline Management Plan (SMP). Embedded mitigation to minimise potential impacts at the coast of cable installation and operation are described in **Section 8.3.5**.
171. Plans should reduce risk from coastal change by avoiding inappropriate development in vulnerable areas and not exacerbating the impacts of physical changes to the coast. They should identify as a Coastal Change Management Area any area likely to be affected by physical changes to the coast, and: be clear as to what development will be appropriate in such areas and in what circumstances; and	Currently there is no defined Coastal Change Management Area (CCMA) that overlaps the Onshore Project. However, a research project was completed in 2021 to develop best practice on establishing a CCMA (through the Local Plan), which would include Saunton Sands, Braunton Burrows and the Taw-Torridge Estuary. Embedded mitigation to minimise potential impacts at the coast of cable installation and operation are described in **Section 8.3.5**.

Summary	How and where this is considered in the ES
make provision for development and infrastructure that needs to be relocated away from Coastal Change Management Areas.	
172. Development in a Coastal Change Management Area will be appropriate only where it is demonstrated that: • it will be safe over its planned lifetime and not have an unacceptable impact on coastal change • the character of the coast including designations is not compromised • the development provides wider sustainability benefits; and • the development does not hinder the creation and maintenance of a continuous signed and managed route around the coast.	As above.
173. Local planning authorities should limit the planned lifetime of development in a Coastal Change Management Area through temporary permission and restoration conditions, where this is necessary to reduce a potentially unacceptable level of future risk to people and the development.	As above.

8.2.2 Marine Policy Statement and Marine Plans

11. The Marine Policy Statement (MPS, HM Government, 2011) provides the high-level approach to marine planning and general principles for decision making that contribute to achieving this vision. It also sets out the framework for environmental, social and economic factors that need to be considered in marine planning. Regarding the topics covered by this chapter the key reference is in Section 2.6.8.6 of the MPS which states: "…*Marine plan authorities should not consider development which may affect areas at high risk and probability of coastal change unless the impacts upon it can be managed. Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement.*"

12. The MPS is also the framework for preparing individual Marine Plans and taking decisions affecting the marine environment. The Marine Plan relevant to the Onshore Project is the South West Inshore and the South West Offshore Marine

Plan (HM Government, 2021) which includes policy relating to marine and coastal processes. These policies are summarised in **Table 8.2**.

Table 8.2 The South West Inshore and South West Offshore Marine Plan policies relating to marine and coastal processes

Policy Code	Summary	Policy Aim
SW-CC-1	Proposals that conserve, restore or enhance habitats that provide flood defence or carbon sequestration will be supported. Proposals that may have significant adverse impacts on habitats that provide a flood defence or carbon sequestration ecosystem service must demonstrate that they will, in order of preference: a) avoid; b) minimise; c) mitigate - adverse impacts so they are no longer significant; d) compensate for significant adverse impacts that cannot be mitigated.	Habitats that provide flood defence and carbon sequestration contribute to natural resilience for coastal communities that are vulnerable to coastal erosion and change. SW-CC-1 requires proposals to manage impacts, enabling these important habitats to continue to provide this valuable service. Proposals that cannot avoid, minimise, and mitigate or, or as a last resort, compensate for significant adverse impacts, will not be supported.
SW-CC-2	Proposals in the south west marine plan areas should demonstrate for the lifetime of the project that they are resilient to the impacts of climate change and coastal change.	The effects of climate change are wide-ranging and can include sea-level rise, coastal flooding and rising sea temperatures. SW-CC-2 adds provision to enable enhanced resilience of developments, activities and ecosystems within the south west marine plan areas to the effects of climate change and coastal change.
SW-CC-3	Proposals in the south west marine plan areas, and adjacent marine plan areas, that are likely to have significant adverse impacts on coastal change, or on climate change adaptation measures inside and outside of the proposed project areas, should only be supported if they can demonstrate that they will, in order of preference: a) avoid; b) minimise; c) mitigate - adverse impacts so they are no longer significant.	Large areas of the south west inshore marine plan area coast are subject to or vulnerable to change. SW-CC-3 ensures proposals do not exacerbate coastal change, enabling communities to be more resilient and better able to adapt to coastal erosion and flood risk. SW-CC-3 also supports proposals that do not compromise existing adaptation measures, which will enable an improvement in the resilience of coastal communities to coastal erosion and flood risk. Proposals that cannot avoid, minimise and mitigate significant adverse impacts will not be supported.

8.2.3 National Policy Statement

13. The assessment of potential impacts on marine and coastal processes has been made with specific reference to the relevant National Policy Statement (NPS). NPSs are statutory documents which set out the Government's policy on specific types of Nationally Significant Infrastructure Projects (NSIPs) and are published in accordance with the Planning Act 2008.

14. Although the Offshore Project is not an NSIP, it is recognised that due to its size of up to 100MW and its location in English waters, certain NPS are considered relevant to the Offshore Project. Therefore, to align with the approach to the assessment of the Offshore Project, certain NPS are also considered as part of the Onshore Project.

15. The NPSs relevant to marine and coastal processes are the overarching NPS for Energy (EN-1), NPS for Renewable Energy Infrastructure (EN-3) and NPS for Electricity Networks Infrastructure (EN-5) (Department for Energy Security and Net Zero 2023a, 2023b and 2023c respectively), which are summarised in **Table 8.3**.

Table 8.3 Summary of NPS EN-1, EN-3 and EN-5 provisions relevant to marine and coastal processes

Summary	How and where this is considered in the ES
NPS for Energy (EN-1)	
"Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures." – **EN-1, paragraph 5.6.11**	The approach adopted in this ES for all impacts is conceptual and evidence based. This was agreed in general terms through the Marine Geology Expert Topic Group (ETG).

Summary	How and where this is considered in the ES
"The ES should include an assessment of the effects on the coast. In particular, applicants should assess: • The impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast • The implications of the proposed project on strategies for managing the coast as set out in Shoreline Management Plans (SMPs) (which provide a large-scale assessment of the physical risks associated with coastal processes and present a long term policy framework to reduce these risks to people and the developed, historic and natural environment in a sustainable manner), any relevant Marine Plans, River Basin Management Plans, and capital programmes for maintaining flood and coastal defences and Coastal Change Management Areas • The effects of the proposed project on marine ecology, biodiversity, protected sites and heritage assets • How coastal change could affect flood risk management infrastructure, drainage and flood risk • The effects of the proposed project on maintaining coastal recreation sites and features • The vulnerability of the proposed development to coastal change, taking account of climate change, during the Project's operational life and any decommissioning period". **EN-1, paragraph 5.6.12**	The assessment of potential construction and operational impacts are described in **Section 8.5** and **Section 8.6**, respectively. The Onshore Project will not affect the policies presented in SMP. Embedded mitigation to minimise potential impacts at the coast of cable installation and operation are described in **Section 8.3.5**. Effects on marine ecology biodiversity and protected sites are assessed in **Chapter 10: Benthic and Intertidal Ecology** and **Chapter 11: Marine Mammal and Marine Turtle Ecology**. Effects on recreation are assessed in **Chapter 21: Socioeconomics (including Tourism and Recreation)**. As described above the Onshore Project has been designed so that it is not vulnerable to coastal change or climate change.
"The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Protected Areas (MPAs). These could include MCZs, HRA Sites including Special Areas of Conservation and Special Protection Areas with marine features, Ramsar Sites, Sites of Community Importance, and SSSIs with marine features. Applicants should also identity	The potential receptor to morphological change is the Devon coast. The potential to affect its integrity is assessed with respect to impacts on the form and function of the coast landward of MLWS, and suspended sediment concentrations, due to cable installation

Summary	How and where this is considered in the ES
any effects on the special character of Heritage Coasts". – **EN-1, paragraph 5.6.14**	(**Section 8.5.1** and **Section 8.5.2**, respectively).
NPS for Renewable Energy Infrastructure (EN-3)	
"Applicant assessment of the effects of installing cable across the intertidal zone should demonstrate compliance with mitigation measures identified by The Crown Estate in any plan-level HRA produced as part of its leasing round and include information, where relevant, about: • Any alternative landfall sites that have been considered by the applicant during the design phase and an explanation of the final choice • Any alternative cable installation methods that have been considered by the applicant during the design phase and an explanation of the final choice • Potential loss of habitat • Disturbance during cable installation, maintenance/repairs and removal (decommissioning) • Increased suspended sediment loads in the intertidal zone during installation and maintenance/repairs • Predicted rates at which the intertidal zone might recover from temporary effects based on existing monitoring data • Protected sites". **EN-3, paragraph 3.8.138**	Landfall to MLWS Site Selection and Assessment of Alternatives are provided in **Chapter 4: Site Selection and Assessment of Alternatives**. A range of cable installation methods may be required, and these are detailed in **Chapter 5: Project Description**. The worst-case scenario for marine and coastal processes is provided in **Section 8.3.3**. Potential habitat loss in the intertidal zone is covered in **Chapter 10: Benthic and Intertidal Ecology**. Assessment of the potential disturbance and increased suspended sediment concentrations in the intertidal zone due to cable installation is provided in **Section 8.5.2**. The recoverability of the coastal receptor (Saunton Sands) is assessed for morphological and sediment transport effects due to trenching and backfilling at the coast (**Section 8.5.1**).
NPS for Electricity Networks Infrastructure (EN-5)	
"As climate change is likely to increase risks to the resilience of some of this infrastructure, from flooding for example, or in situations where it is located near the coast or an estuary or is underground, applicants should in particular set out to what extent the proposed development is expected to be vulnerable, and, as appropriate, how it has been designed to be resilient to: • Flooding, particularly for substations that are vital to the network; and especially in light of changes to groundwater levels resulting from climate change; • The effects of wind and storms on overhead lines	The Onshore Project is designed so it is not vulnerable to coastal change or climate change. Potential flood risk impacts are considered in **Chapter 14: Water Resources and Flood Risk**.

Summary	How and where this is considered in the ES
• Higher average temperatures leading to increased transmission losses • Earth movement of subsidence caused by flooding or drought (for underground cables) • Coastal erosion - for the landfall of offshore transmission cables and their associated substations in the inshore and coastal locations respectively." **EN-5, paragraph 2.3.2**	

8.2.4 Guidance

16. In demonstrating adherence to industry good practice, this chapter has been compiled in accordance with the following relevant standards and guidance:

- Offshore Windfarms: Guidance Note for Environmental Impact Assessment in respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) requirements: Version 2 (Cefas, 2004)
- Review of Cabling Techniques and Environmental Effects applicable to the Offshore Windfarm Industry (BERR, 2008)
- Coastal Process Modelling for Offshore Windfarm Environmental Impact Assessment (Lambkin et al., 2009)
- Guidelines for Data Acquisition to support Marine Environmental Assessments of Offshore Renewable Energy Projects (Cefas, 2011)
- IEMA. (2016) Environmental Impact Assessment. Guide to Delivering Quality Development.

8.3 Assessment Methodology

8.3.1 Study Area

17. Details of the location of the Onshore Project and the onshore components are set out within **Chapter 5: Project Description**.

18. The marine and coastal processes study area is defined by the distance over which impacts from all the Onshore Project (i.e. landfall to MLWS, onshore export cable corridor, compounds, access routes and onshore substation) may occur and by the location of any receptors that may be affected by those potential impacts.

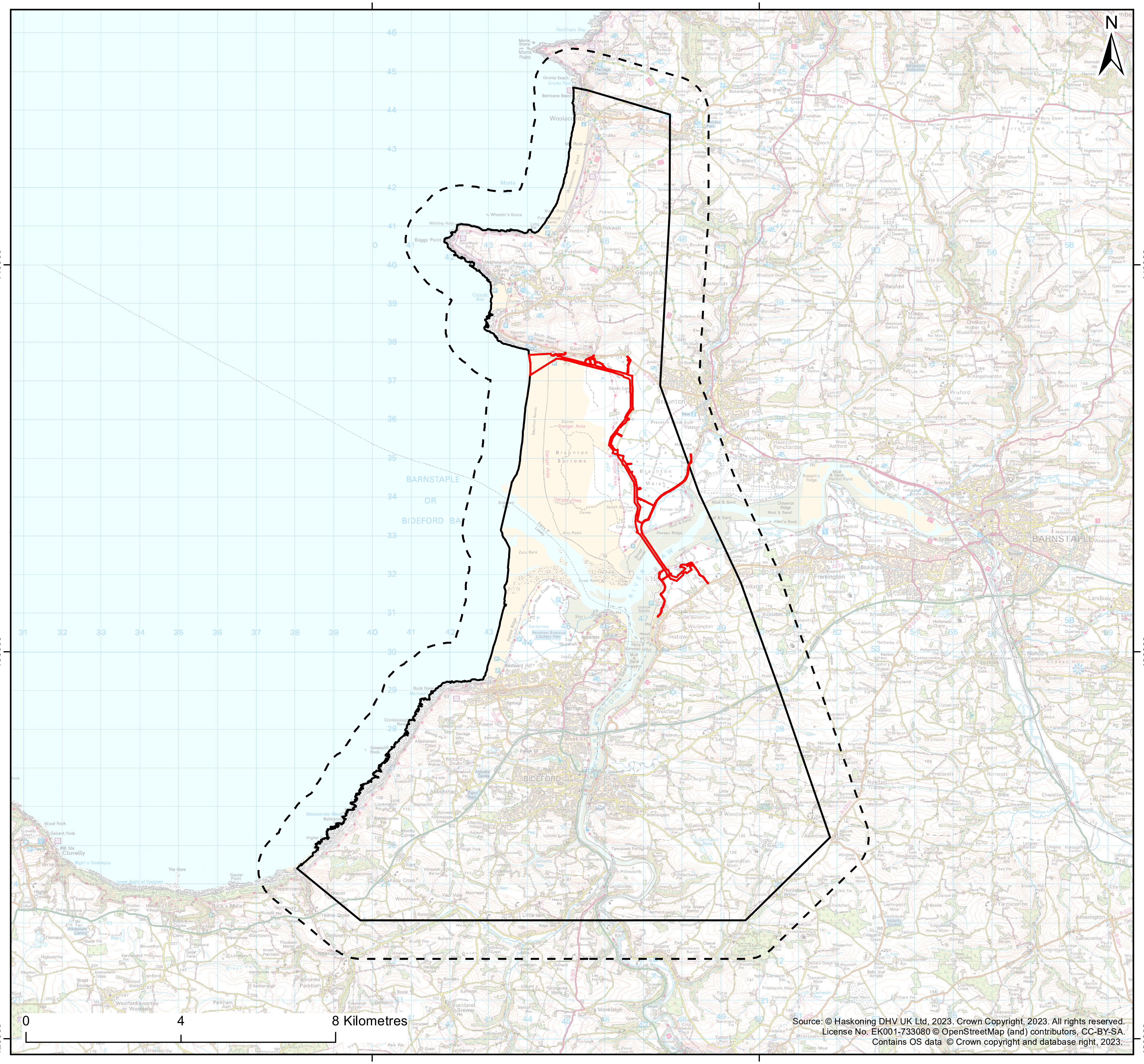
19. The study area for marine and coastal processes comprises the coast landward of MLWS between Combesgate Beach in Woolacombe and Peppercombe Beach, south of Westward Ho!, including Saunton Sands, Braunton Burrows and the Taw-Torridge

Estuary (**Figure 8.1**). This study area accounts for the potential local and regional effects on physical and sedimentary processes due the construction and operation of the Onshore Project.

8.3.2 Approach to Assessment

20. **Chapter 6: EIA Methodology** provides a summary of the general impact assessment methodology applied to the Onshore Project. The following sections outline the methodology used to assess the potential effects on marine and coastal processes.

21. The assessment of effects on marine and coastal processes are predicated on a Source-Pathway-Receptor (S-P-R) conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor impacted by the effect, and the receptor is the receiving entity. An example of the S-P-R conceptual model is provided by cable installation which disturbs sediment in the nearshore and intertidal areas (source). This sediment could then be transported by waves until it is deposited (pathway), which could change the composition and elevation of the substrate (receptor).



Legend:

- Marine and Coastal Processes Study Area
- Onshore Area of Search
- Onshore Development Area

Client: Offshore Wind Ltd.	Project: White Cross Offshore Windfarm

Title: Marine and Coastal Processes Study Area

Figure:	8.1	Drawing No:	PC2978-RHD-ZZ-XX-DR-Z-0694

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22. For each impact, the assessment identifies receptors sensitive to that impact and implements a systematic approach to understanding the impact pathways and the level of effect on given receptors. The following key terms have been used in this assessment:

- Impact - used to describe a change via the Onshore Project
- Receptor - used to define the environment being exposed to the Impact
- Effect - the consequence of an Impact combining with a Receptor, defined in terms of Significance (exact significance dependant on magnitude of impact and the sensitivity of the receptor)
- Adverse effect - an alteration of the existing environment with negative implications for the affected receptor
- Beneficial effect - an alteration of the existing environment with positive implications for the affected receptor
- Mitigation - measures incorporated as part of the project design in order to either avoid or reduce adverse effects, or to enhance beneficial effects
- Residual effect - the effects remaining once all mitigation measures have been taken into consideration.

23. For the effects on marine and coastal processes, several discrete direct receptors can be identified. These include certain morphological features with ascribed inherent values, such as MCZ features, beaches, and dunes at the coast. The impact assessment incorporates a combination of the sensitivity of the receptor, its value (if applicable) and the magnitude of the change to determine a significance of impact. The significance of the impact is based on an assessment of the sensitivity of the receptor and magnitude of effect by means of an impact significance matrix.

8.3.2.1 Definitions of magnitude of impact

24. For each of the impacts assessed in this Environmental Statement, a magnitude has been assigned. In doing so the spatial extent, duration, frequency and reversibility of the impact from the construction, operation and maintenance, or decommissioning phase of the Onshore Project have been considered, where applicable.

25. The terms used to define magnitude of impact are outlined in **Table 8.4**.

26. Where the assessment identifies that there is no loss or alteration of characteristics, features or elements, or no observable impact in either direction upon a given receptor or group of receptors from an Impact, for example due to implication of embedded mitigation or through an assessment of the potential pathway, then the assessment for that Impact upon those receptor(s) will be **No Change**.

Table 8.4 Definition of terms relating to magnitude of an impact

Magnitude	Definition
High	Fundamental, permanent/irreversible changes, over the whole receptor, and/or fundamental alteration to key characteristics or features of the receptor's character or distinctiveness.
Medium	Considerable, permanent/irreversible changes, over most of the receptor, and/or discernible alteration to key characteristics or features of the receptor's character or distinctiveness.
Low	Discernible, short term/temporary (events over part of the project duration) change, over a minority of the receptor, and/or limited but discernible alteration to key characteristics or features of the receptor's character or distinctiveness.
Negligible	Discernible, short term/temporary (events over part of the project duration) change, or barely discernible change for any length of time, over a small area of the receptor, and/or slight alteration to key characteristics or features of the receptor's character or distinctiveness.

27. Impacts assessed as **No Change** have no potential for a significance of effect and therefore are not assessed further.

8.3.2.2 Definitions of receptor sensitivity/value

28. The sensitivity level of marine and coastal processes to each impact is justified within the assessment and is dependent on the following factors:

- Adaptability - The degree to which a receptor can avoid or adapt to an effect
- Tolerance - The ability of a receptor to accommodate temporary or permanent change without a significant adverse effect
- Recoverability - The temporal scale over and extent to which a receptor will recover
- Value - A measure of the receptor importance and rarity.

29. The terms used to define sensitivity/value are outlined in **Table 8.5**.

Table 8.5 Definition of terms relating to receptor sensitivity/value

Sensitivity	Definition
High	Individual receptor has very limited or no capacity to avoid, adapt to, accommodate, or recover from the anticipated impact.
Medium	Individual receptor has limited capacity to avoid, adapt to, accommodate, or recover from the anticipated impact.
Low	Individual receptor has some tolerance to accommodate, adapt or recover from the anticipated impact.
Negligible	Individual receptor is generally tolerant to and can accommodate or recover from the anticipated impact.

8.3.2.3 Significance of effect

30. The potential significance of effect for a given impact, is a function of the sensitivity of the receptor and the magnitude of the impact (see **Chapter 6: EIA Methodology** for further details). A matrix is used (**Table 8.6**) as a framework to determine the significance of an effect. Definitions of each level of significance are provided in **Table 8.7**. Impacts and effects may be deemed as being either positive (beneficial) or negative (adverse).

31. In all cases, the evaluation of receptor sensitivity, impact magnitude and significance of effect has been informed by professional judgement and is underpinned by narrative to explain the conclusions reached.

Table 8.6 Significance of an effect resulting from each combination of receptor sensitivity and the magnitude of the impact on it

		Negative Magnitude				**Beneficial Magnitude**			
		High	Medium	Low	Negligible	Negligible	Low	Medium	High
Sensitivity	High	Major	Major	Moderate	Minor	Minor	Moderate	Major	Major
	Medium	Major	Moderate	Minor	Minor	Minor	Minor	Moderate	Major
	Low	Moderate	Minor	Minor	Negligible	Negligible	Minor	Minor	Moderate
	Negligible	Minor	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Minor

Table 8.7 Example definitions of effect significance

Magnitude	Definition
High	A significant, very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a national or population level because they contribute to achieving national, objectives or could result in exceedance of statutory objectives and/or breaches of legislation.
Medium	A noticeable and significant change in receptor condition, which are likely to be important considerations at a regional level.
Low	Small change in receptor condition, which may be raised as localised issues but are unlikely to be important in the decision-making process.
Negligible	No discernible change in receptor condition.
No change	No impact, therefore, no change in receptor condition.

32. Potential effects are described, followed by a statement of whether the effect is significant in terms of the EIA regulations. Potential effects identified within the assessment as major or moderate are regarded as significant in terms of the EIA regulations. Whilst minor effects (or below) are not significant in EIA terms, it is

important to distinguish these, as they may contribute to significant effects cumulatively or through interactions.

33. Following initial assessment, if the effect does not require additional mitigation (or none is possible), the residual effect will remain the same. If, however, additional mitigation is proposed, there will be an assessment of the post-mitigation residual effect.

8.3.3 Worst-case Scenario

34. In accordance with the assessment approach to the 'Rochdale Envelope' set out in **Chapter 6: EIA Methodology**, the impact assessment for marine and coastal processes has been undertaken based on a realistic worst-case scenario of predicted impacts. The Project Design Envelope for the Onshore Project is detailed in **Chapter 5: Project Description**.

35. Using the project design envelope approach means that receptor-specific potential effects draw on the options from within the wider envelope that represent the most realistic worst-case-scenario. It is also worth noting that under this approach the combination of project options constituting the realistic worst-case scenario may differ from one receptor to another and from one effect to another.

36. **Table 8.8** presents the realistic worst-case scenario considered for the assessment of marine and coastal processes.

Table 8.8 Definition of realistic worst-case scenario details relevant to the assessment of impacts in relation to marine and coastal processes

Impact	Realistic worst-case scenario	Rationale
Construction		
Impact 1: Impacts on the form and function of the coast landward of MLWS due to cable installation	Two export cables would be buried in a trench across the northern end of Saunton Sands and into the subtidal. The trench dimensions across the beach would be 0.5m wide and 700m long, = 700m^2 (total plan area for two cables). The cable trench would be at least 1.2m deep, = 840m^3 (volume for two cables).	The worst-case scenario represents the greatest potential for morphological change landward of MLWS because of changes to sedimentary processes.
Impact 2: Impacts on suspended sediment concentrations due to cable installation	As Construction Impact 1.	The worst-case scenario represents the greatest potential for increased suspended sediment concentrations because of

Impact	Realistic worst-case scenario	Rationale
		changes to sedimentary processes.
Operation		
None	None	There are no operational impacts identified because the cable is buried landward of MLWS.
Decommissioning		
To be determined	The decommissioning policy for the Onshore Project infrastructure is not yet defined however it is anticipated that some infrastructure would be removed, reused or recycled; other infrastructure could be left in situ. The following infrastructure is likely be removed, reused, or recycled where practicable: • Onshore substation • Export Cables. The following infrastructure is likely to be decommissioned and could be left in situ depending on available information at the time of decommissioning: • Transition joint bays • Cable joint bays Cable ducting.	The detail and scope of the decommissioning works will be determined by the relevant legislation and guidance at the time. Decommissioning arrangements will be detailed in a Decommissioning Plan, which will be drawn up and agreed with the relevant consenting body/stakeholder prior to decommissioning. For the purposes of the worst-case scenario, it is anticipated that the impacts will be comparable to those identified for the construction phase.

8.3.4 Impact Receptors

37. The principal receptors with respect to marine and coastal processes are those features of the Devon coast with an inherent geological or geomorphological value or function which may potentially be affected by the Onshore Project. The specific features of the Devon coast defined within these receptors as requiring further assessment at the EIA stage for the Onshore Project are listed in **Table 8.9**.

8.3.5 Summary of Mitigation

38. This section outlines the mitigation relevant to the marine and coastal processes assessment, which has been incorporated into the design of the Onshore Project. Further information is detailed in **Chapter 5: Project Description**.

Table 8.9 Marine and coastal processes receptors along the Devon coast relevant to the Onshore Project

Receptor	Extent of coverage	Description of relevant features	Distance from the Onshore Project
Bideford to Foreland Point MCZ	Bideford to Foreland Point	Protects a wide range of habitats, from beaches of intertidal sand to subtidal sediment and rock habitats, which are permanently submerged. This site is important for creating connectivity between sites along the north coast of Devon and Cornwall.	0km. Overlaps with Landfall to MLWS and Onshore Export Cable Corridor
Braunton Burrows SAC	Braunton Burrows	Annex I Shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes') Annex I Fixed dunes with herbaceous vegetation ('grey dunes') Annex I Dunes with Salix repens ssp. argentea (*Salicion arenariae*) Annex I Humid dune slacks Annex I Mudflats and sandflats not covered by seawater at low tide	0km. Overlaps with Landfall to MLWS and Onshore Export Cable Corridor
Braunton Burrows SSSI		Braunton Burrows is a key site for coastal geomorphology. It is one of the largest dune systems in Britain, about 5km long north-south and 1.5km wide, with lime-rich dunes up to 30m high, and an extensive system of variably flooded slacks, grassland, and scrub, inland of a wide sandy foreshore, rich in lime from broken seashells, with some intertidal shingle grading to silt in the Taw-Torridge Estuary	0km. Overlaps with Landfall to MLWS and Onshore Export Cable Corridor
Taw-Torridge Estuary SSSI	Taw-Torridge Estuary	The Taw-Torridge Estuary's wide tidal range is reflected by the very large areas of mudflats and sandbanks together with beaches and saltmarshes. Habitats include low energy intertidal rock, intertidal coarse sediment, intertidal sand and muddy sand, coastal saltmarsh and saline reedbed, subtidal sand, and subtidal mud	0km. Overlaps with Landfall to MLWS and Onshore Export Cable Corridor
Northam Burrows SSSI Westward Ho! Cliffs SSSI	Northam Burrows to Westward Ho!	Northam Burrows is of interest for its wide range of coastal habitats including dunes, intertidal sand, and a cobble ridge. The cobble ridge is a classic coastal feature noted for the large size of the sediments present. Few spits in Britain are formed of large cobbles at the back of an extensive sandy intertidal zone. Part of the site is listed in the Geological Conservation Review	Approximately 1.9km from Landfall to MLWS and Onshore Export Cable Corridor

8.3.5.1 Embedded Mitigation

39. The embedded mitigation measures are those defined in the IEMA guidance as either primary or tertiary mitigation. Those measures relevant to the marine and coastal processes assessment are summarised in **Table 8.10**.

Table 8.10 Embedded mitigation measures relevant to the marine and coastal processes assessment

Component/Activity/Impact	Mitigation embedded into the design of the Onshore Project
Landfall cable corridor	Either open trenching or trenchless technique will be used to install the cables at the landfall (landward of MLWS). Cables will be buried at sufficient depth to have no effect on coastal processes. Sediment transport would continue as a natural phenomenon driven by waves, which would not be affected by the Onshore Project.
Cable corridor crossing of the Taw-Torridge Estuary SSSI	Trenchless techniques will be used to install the cables underneath the Taw-Torridge Estuary SSSI. Cables will be buried at sufficient depth to have no effect on estuary processes. Sediment transport would continue as a natural phenomenon driven by waves and tidal currents, which would not be affected by the Onshore Project.

40. As these measures have been embedded the assessment of effects is undertaken on the basis that these forms of mitigation will be delivered. Therefore, any effects that might have arisen without these forms of mitigation do not need to be identified as ‘potential effects’, as there should be no potential for them to arise.

8.3.6 Baseline Data Sources

8.3.6.1 Desktop Study

41. A desk study was undertaken to obtain information on marine and coastal processes. Data were acquired within the onshore study area through a detailed desktop review of existing studies and datasets. Agreement was reached with all consultees that the data collected, and the sources used to define the baseline characterisation for marine and coastal processes are fit for the purpose of the EIA (agreed at the Marine Geology ETG held on 26th May 2022).

42. The sources of information presented in **Table 8.11** were used to inform the marine and coastal processes assessment.

Table 8.11 Data sources used to inform the marine and coastal processes assessment

Source	Summary
Admiralty Tide Tables (2022) and Environment Agency (2018)	Coastal water levels
UK Climate Projections (UKCP18) user interface for the model grid cell that covers the Landfall	Climate change and sea-level rise
Institute of Geological Sciences (1983) 1:250,000 seabed sediment mapping and Wood (2022) geophysical survey	Nearshore seabed type and sediment distribution
Environment Agency Lidar elevation data captured in 2006/07, 2011/12, 2016/17 and 2020/21	Topographic changes to Saunton Sands over the past 14 years
Benthic Characterisation Report (**Appendix 8.A**)	Nearshore seabed type

8.3.7 Data Limitations

43. There are no data limitations with the baseline data and their ability to materially influence the outcome of the EIA.

8.3.8 Scope

44. Considering the baseline environment, the project description outlined in **Chapter 5: Project Description**, and consultation with key stakeholders (see **Section 8.3.9**), potential impacts on marine and coastal processes have been scoped in or out. Only three potential impact are identified, and these are scoped in (**Table 8.12**).

Table 8.12 Summary of impacts scoped in relating to marine and coastal processes

Potential Impact	Justification
Construction impacts on the form and function of the coast landward of MLWS due to cable installation	The presence of a trench (or trenchless technology infrastructure) at the landfall (landward of MLWS) could cause temporary changes in longshore beach sediment transport, and potentially trap sediment.
Construction impacts on suspended sediment concentrations due to cable installation	Disturbance of the intertidal zone (landward of MLWS) due to the installation activities for the cables could potentially release sediment resulting in temporarily increased suspended sediment concentrations.
Operational impacts on waves at the coast due to the physical presence of the infrastructure	The physical presence of offshore infrastructure and substructure above the seabed could result in changes to waves at the coast due to physical blockage effects.

8.3.9 Consultation

45. Consultation has been a key part of the development of the Onshore Project. Consultation regarding marine and coastal processes has been conducted throughout the development of the EIA. An overview of the project consultation process is presented within **Chapter 7: Consultation**.

46. A summary of the key issues raised during consultation specific to marine and coastal processes is outlined below in **Table 8.13**, together with how these issues have been considered in the production of this ES.

Table 8.13 Consultation responses

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
Marine Management Organisation (MMO)	Scoping Opinion	Study area and assessment. The MMO notes that the Scoping Study Area is very large to account for uncertainty surrounding the exact routes of onshore elements of the Proposed Development. The ES should ensure that it is clear where the ongoing assessment work has refined the options and addressed potentially significant effects through design.	The study area is discussed in **Section 8.3.1**.
MMO	Scoping Opinion	Para 194-195 and Table 2.4. Designated Sites. The ES should therefore identify the location of any other relevant statutory or non-statutory sites protected for their geological interest as part of the baseline studies and assess any likely significant effects on all sites identified.	The potential onshore receptor to morphological change is the Devon coast. The potential to affect its integrity is assessed with respect to impacts on the form and function of the coast landward of MLWS, and suspended sediment concentrations, due to cable installation (**Section 8.5.1** and **Section 8.5.2**, respectively).

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
MMO	Scoping Opinion	Coastal change and flood risk. Coastal change should be considered with respect to any works in this proposed area (specifically for the siting of the cable landfall, cable route and associated infrastructure). The assessment should include geomorphological uncertainties about the future evolution of the coastline and estuary, as well as any development or future development of intertidal habitats and flood defences, with consideration of the Shoreline Management Plan.	Baseline coastal processes at the landfall (landward of MLWS) including historic morphological changes to the beach are considered in **Section 8.4.1**. Potential construction impacts at the landfall (landward of MLWS) are considered in **Section 8.5.1** and **Section 8.5.2**. Potential flood risk impacts are considered in **Chapter 14: Water Resources and Flood Risk**.
MMO	Scoping Opinion	Cable landfall and coastal processes. There is need to consider the potential for cable landfall (and the associated engineering works) to interfere with long-shore and near-shore coastal processes and we recommend that an assessment is made of the potential to temporarily, or potentially permanently, disrupt sediment movements and hydrodynamics during the works.	Potential construction impacts at the landfall (landward of MLWS) are considered in **Section 8.5.1** and **Section 8.5.2**.

8.4 Existing Environment

47. This section describes the existing environment in relation to marine and coastal processes associated with the White Cross onshore study area.

8.4.1 Current Baseline

8.4.1.1 Water Levels

48. The Landfall (landward of MLWS) is in an area subject to a macrotidal regime, with a mean spring tidal range of about 8.3m at Ilfracombe (the nearest point of analysis to the Landfall).

49. The onshore study area can be susceptible to storm surges, and water levels across could become elevated several metres by these meteorological effects. Environment Agency (2018) calculated one in one-year water levels of 5.43m at Ilfracombe, about 0.9m above MHWS. The 1 in 50-year water levels are predicted to be 5.85m, about 1.3m above MHWS.

8.4.1.2 Climate Change and Sea-level Rise

50. Historical data show that the global temperature has risen significantly due to anthropogenic influences since the beginning of the 20th Century, and predictions are for an accelerated rise, the magnitude of which is dependent on the magnitude of future emissions of greenhouse gases and aerosols.

51. According to UKCP18 which draws on the Intergovernmental Panel on Climate Change (IPCCs) Fifth Assessment of Climate Change (Church *et al.*, 2013), it is likely (IPCC terminology meaning greater than 66% probability) that the rate of global sea-level rise has increased since the early 20th Century. It is very likely (IPCC terminology meaning greater than 90% probability) that the global mean rate was 1.7mm/year (1.5 to 1.9mm/year) between 1901 and 2010 for a total sea-level rise of 0.19m (0.17 to 0.21m). The average long-term trend for the UK is estimated as 1.4mm/year which is slightly lower than the global 1.7mm/year. Between 1993 and 2010, the rate was very likely (IPCC terminology) higher at 3.2 mm/year (2.8 to 3.6mm/year), and this is the historic rate used in this analysis.

52. The rate of global mean sea-level rise during the 21st Century is likely to exceed the rate observed between 1993 and 2010. Church *et al.* (2013) developed projections of global sea-level rise for four emissions scenarios of future climate change, called the Representative Concentration Pathways (RCP). In this analysis, the median projection of the worst-case emissions scenario (RCP8.5) is used. For RCP8.5, the rise by 2100 is 0.74m (range 0.52 to 0.98m) with a predicted sea-level rise rate during 2081–2100 of 8 to 16mm/year.

53. One of the most important long-term implications of climate change is the physical response of the coast to future sea-level rise. Predicting coastal erosion rates is critical to forecasting future problem areas. It is likely that the future erosion rate of the coast at the Landfall (landward of MLWS) will be affected by the higher rates of sea-level rise than historically. Higher baseline water levels would result in a greater occurrence of waves impacting the dunes of Braunton Burrows, increasing their susceptibility to erosion.

8.4.1.1 Nearshore Seabed Sediment Distribution

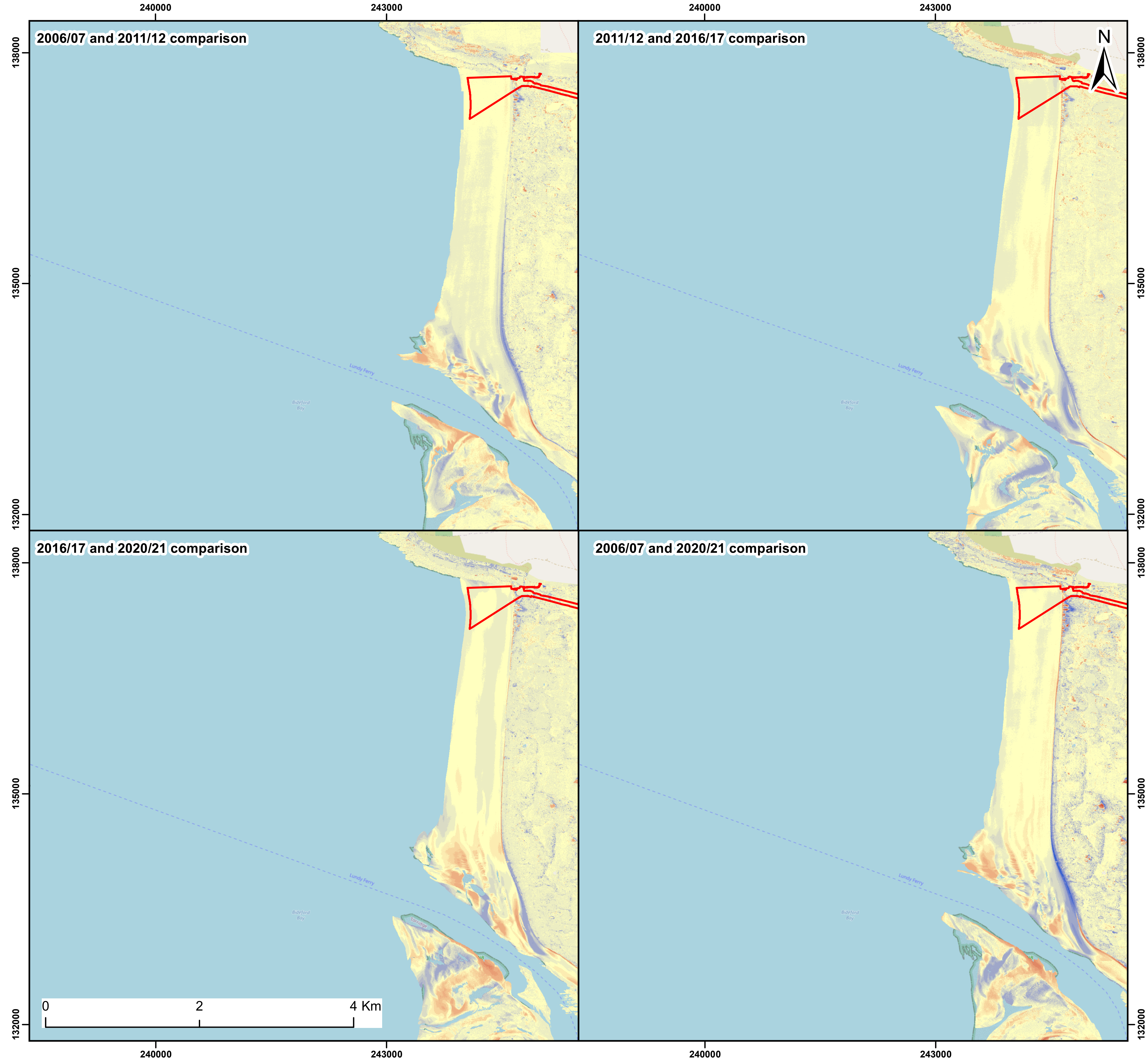
54. Mapping of nearshore sediment types was completed by Institute of Geological Sciences (1983) and Ocean Ecology (2023). The data shows that across the nearshore parts of the Offshore Export Cable Corridor, seabed sediments are predominantly gravelly sand and sand. Wood (2022) described the nearshore seabed as flat and featureless and composed of sand.

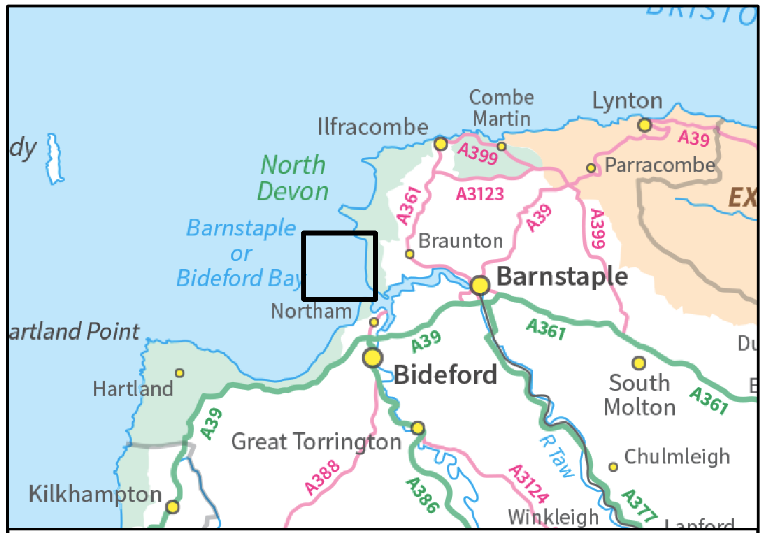
8.4.1.2 Coastal Processes at the Landfall (landward of MLWS)

55. The export cable will make Landfall at the northern end of Saunton Sands fronting the car park where the coast is dominated by a wide sand beach and the extensive dune system of Braunton Burrows. The beach-dune system extends southwards approximately 5km from the resistant cliff headland of Saunton Down (immediately north of Landfall to MLWS) into the mouth of the Taw-Torridge Estuary.

56. Lidar elevation data captured in 2006/07, 2011/12, 2016/17 and 2020/21 provides a time series that is analysed here for historic changes to Saunton Sands over the past 14 years. Comparisons of the 2006/07 and 2011/12 data, 2011/12 and 2016/17 data, 2016/17 and 2020/21 data, and 2006/07 and 2020/21 data are presented in **Figure 8.2**. Comparisons of the same data at the Landfall (landward of MLWS) are presented in **Figure 8.3**.

57. Between 2006/07 and 2011/12, Saunton Sands has varied between erosion (up to 0.25m over the five-year period) and accretion (up to 0.25m over the five-year period), with a higher rate of erosion (up to 0.5m) at the top of the beach at Landfall to MLWS (**Figure 8.2** and **Figure 8.3)**. Similarly, between 2011/12 and 2016/17, the beach was both erosional and accretional, up to 0.25m (with up to 0.5m of accretion at the top of the beach at Landfall to MLWS). A mix of accretion and erosion also took place between 2016/17 and 2020/21. Overall, between 2006/07 and 2020/21, Saunton Sands, including most of the Landfall (landward of MLWS) has eroded by up to 0.25m over the 14-year period (0-18mm/year). The top of the beach at landfall to MLWS has accreted by up to 0.25m over the 2006/07 to 2020/21 period (0-18mm/year).





Legend:

Onshore Development Area

LiDAR comparison - Change in elevation (m)

Gain	> 6
	5.01 - 6
	4.01 - 5
	3.01 - 4
	2.01 - 3
	1.01 - 2
	0.76 - 1
	0.51 - 0.75
	0.26 - 0.5
	0.01 - 0.25
Loss	-0.24 - 0
	-0.49 - -0.25
	-0.74 - -0.5
	-0.99 - -0.75
	-1.99 - -1
	-2.99 - -2
	-3.99 - -3
	-4.99 - -4
	-5.99 - -5
	-6.99 - -6
	< -7

Client: Offshore Wind Ltd.

Project: White Cross Offshore Windfarm

Title: Historic changes to Saunton Sands between 2006/07, 2011/12, 2016/17 and 2020/21

Figure: 8.2

Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0695

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P01	02/08/2023	ND	DB	A3	1:50,000

Co-ordinate system: British National Grid

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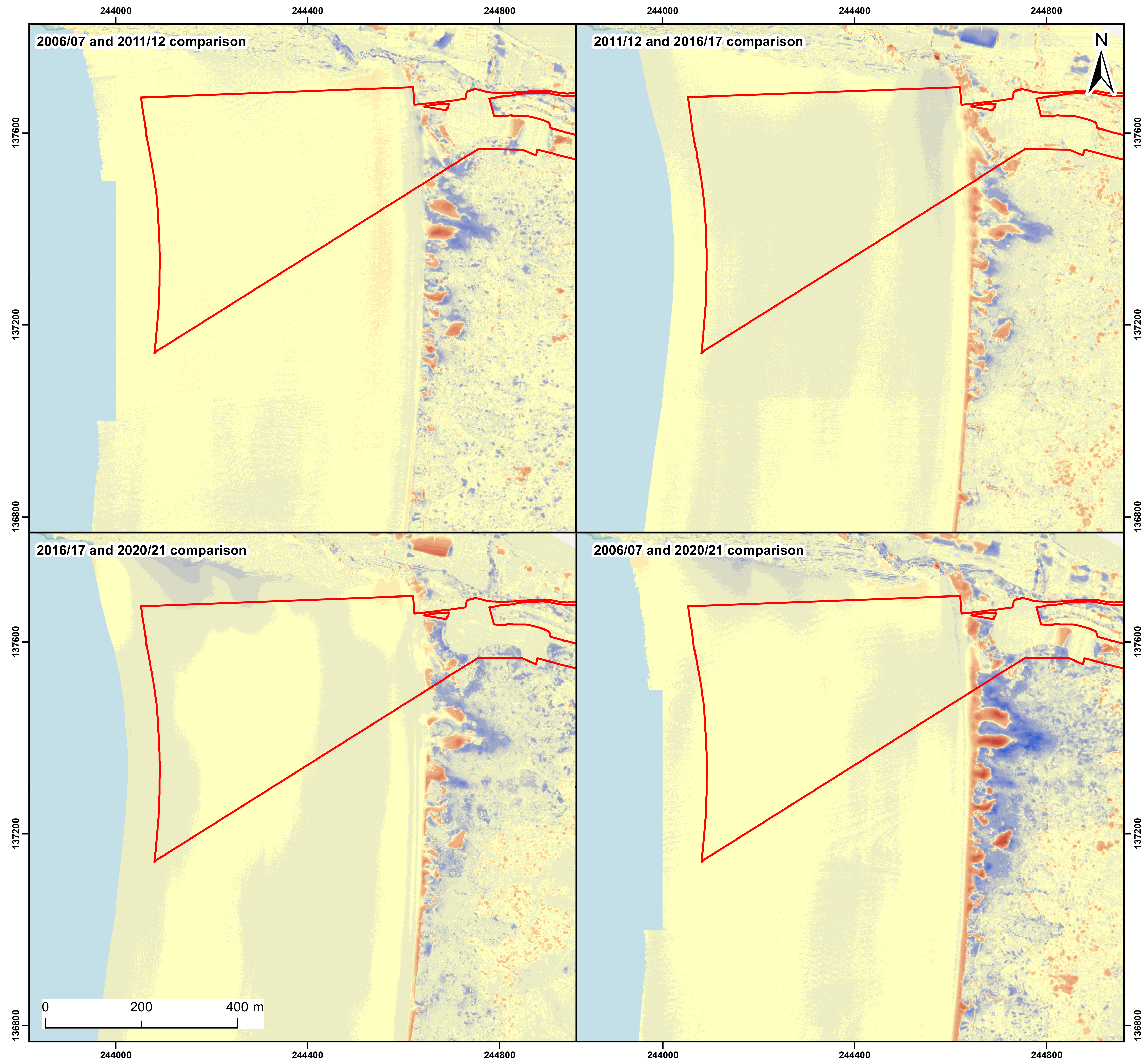

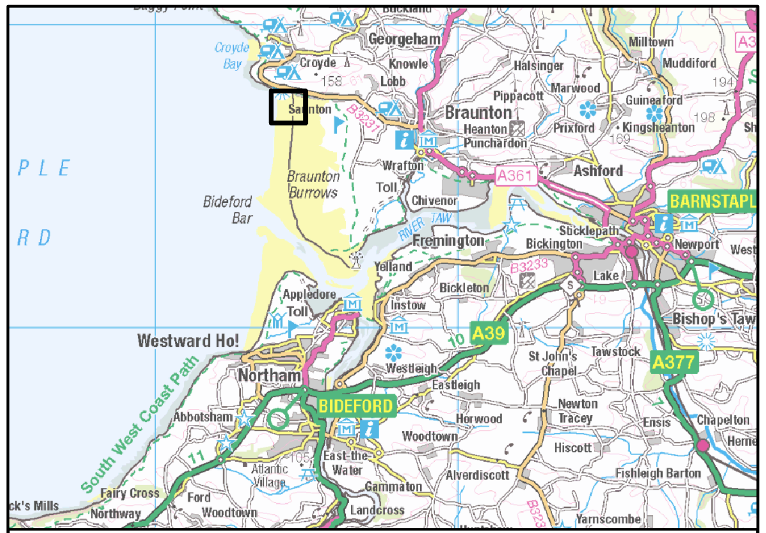

Legend:

Onshore Development Area

LiDAR comparison - Change in elevation (m)

Gain
- > 6
- 5.01 - 6
- 4.01 - 5
- 3.01 - 4
- 2.01 - 3
- 1.01 - 2
- 0.76 - 1
- 0.51 - 0.75
- 0.26 - 0.5
- 0.01 - 0.25

Loss
- -0.24 - 0
- -0.49 - -0.25
- -0.74 - -0.5
- -0.99 - -0.75
- -1.99 - -1
- -2.99 - -2
- -3.99 - -3
- -4.99 - -4
- -5.99 - -5
- -6.99 - -6
- < -7

Client: Offshore Wind Ltd.

Project: White Cross Offshore Windfarm

Title:

Historic changes of the beach at the Landfall between 2006/07, 2011/12, 2016/17 and 2020/21

Figure: 8.3 | Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0696

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P01	02/08/2023	ND	DB	A3	1:8,000

Co-ordinate system: British National Grid

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8.4.2 Do Nothing Scenario

58. The Town and Country Planning (Environmental Impact Assessment) Regulations 2017 require that "an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge" is included within the ES (EIA Regulations, Schedule 4, paragraph 3). From the point of assessment, over the course of the development and operational lifetime of the Onshore Project (operational lifetime anticipated to be 50 years), long-term trends mean that the condition of the baseline environment is expected to evolve. This section provides a qualitative description of the evolution of the baseline environment, on the assumption that the Onshore Project is not constructed, using available information and scientific knowledge of marine and coastal processes.

59. The baseline conditions for marine and coastal processes will continue to be controlled by waves driving changes in sediment transport and nearshore and coastal morphology. However, the long-term established performance of these drivers may be affected by environmental changes including climate change driven sea-level rise (see Climate Change and Sea-level Rise section). This will have the greatest effect at the coast where more waves will impinge on the beach and dunes, potentially increasing their rate of erosion.

8.5 Potential impacts during construction

60. The potential impacts during construction of the Onshore Project have been assessed for marine and coastal processes. A description of the potential effect on marine and coastal processes caused by each identified impact is given in this section.

8.5.1 Impact 1: Impacts on the form and function of the coast landward of MLWS due to cable installation

61. As part of the export cable installation process at Landfall (landward of MLWS), the worst-case scenario is open trenching to bury two cables across the entire width of Saunton Sands. The indicative length and width of the trench across the beach would be 700m and 0.5m, respectively (plan area for two cables of 700m^2). The trench would be excavated to a depth of 1.2m (volume of 840m^3 for two cables) with a mechanical digger over an indicative period of up to five days. This excavated sediment would be backfilled into the trench by mechanical means to re-instate the beach to its original morphology. The landfall activities would cause a temporary

short-term cessation of longshore beach sediment transport, due to the presence of the trench and its potential to trap sediment.

62. Assuming the worst-case scenario, a trench would be cut across the beach providing an almost continuous barrier to sediment transport for a period of up to five days. The rate of net annual longshore transport specifically at the Landfall (landward of MLWS) has not been established. However, given its location in the immediate lee of Saunton Down and the absence of any distinct longshore transport driven morphological features, indicates that actual longshore sediment transport rates are low in this area, and so the presence of the trench for such a short period of time would have little effect on beach morphology.

63. One of the main uncertainties in the landfall construction methodology is the depth to which the cables should be buried across the beach. At the landfall (landward of MLWS), the beach sand overlies bedrock, but the depth to the bedrock is not known. It is important to define the depth of burial, so that over the design lifetime of the cables (50 years), the risk of exposure is reduced if beach levels lower (potentially because of sea-level rise) into the future. A Cable Burial Risk Assessment will be completed to accurately define the preferred burial depth to mitigate future exposure.

64. The route of the onshore export cable corridor will also coincide with the Taw-Torridge Estuary. The worst-case scenario is to install the cables underneath the estuary. Hence, the installation of the cables will be at sufficient depth below the estuary bed to have no effect on estuary processes. Sediment transport would continue as a natural phenomenon driven by waves and tidal currents, which would not be affected by construction.

8.5.1.1 Sensitivity, magnitude of impact and significance of the effect

65. Due to the short-term nature of the construction programme and the long-term (14 years) low rates of vertical change of the beach at the Landfall (landward of MLWS) (0-18mm/year) means that changes to the beach would be low and temporary. After installation of the cables, the trench would be backfilled, returning the beach to its original morphology. The magnitude of impact is therefore considered **negligible**.

66. Importantly, the Devon coast overlaps the route for the Onshore Export Cable Corridor and the Landfall. The sensitivity and value of this receptor is presented in **Table 8.14**.

Table 8.14 Sensitivity and value assessment of the Devon coast

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Devon coast	Negligible	Negligible	Negligible	High	Negligible

67. The return of the beach to its pre-construction morphology means that short-term changes in the form and function of the coast arising from cable installation would not be significant. Hence, the overall significance of the effect under a worst-case scenario on the identified morphological receptor is deemed **negligible adverse**. This effect reduces to **no significant effect** upon cessation of the works and the restoration of the beach to its former profile. There is **no significant effect** on the Taw-Torridge Estuary SSSI because the cable will be installed using trenchless techniques.

8.5.2 Impact 2: Impacts on suspended sediment concentrations due to cable installation

68. The processes of mechanical excavation and backfilling using a land-based digger (at low tide) could release fine sediment to the beach surface that was previously buried. This sediment could then be released into the water column on the subsequent high tide as the beach becomes submerged, resulting in a temporary and short-term increase in suspended sediment concentrations.

69. The worst-case scenario of trenching across Saunton Sands would displace a volume of 840m^3 of sediment assuming 0.5m-wide, 1.2m-deep excavations. The installation of the cables would be mainly through sand (or coarser) because the energy levels at the beach are too high for significant deposition of finer sediment, both at the present day and historically. Hence, the volume of fine sediment excavated to create the trench, that could be suspended, would be very small. Most of the sediment disturbed by the excavation and remaining on the beach would be bedload and temporarily form part of the natural sediment transport processes.

70. Also, any increases in suspended sediment concentrations would be short in duration (lasting a maximum duration of five days) and, over time, the suspended sediment would be widely dispersed by tidal and wave action.

8.5.2.1 Sensitivity, magnitude of impact and significance of the effect

71. The magnitude of impact is considered **negligible**. The disturbance effects along the cable are likely to persist in the water column for hours to a few days before being dispersed to ambient concentrations.

72. Importantly, the Devon coast overlaps the route for the Onshore Export Cable Corridor and Landfall (to MLWS). The sensitivity and value of this receptor is presented in **Table 8.15**.

Table 8.15 Sensitivity and value assessment of the Devon coast

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Devon coast	Negligible	Negligible	Negligible	High	Negligible

73. Based on the conceptual evidence-based assessment of suspended sediment generated from cable installation indicates that the changes would be very small. This means that the effects on the identified morphological receptor would be **not significant**. Hence, the overall significance of the effect under a worst-case scenario on the identified morphological receptor is deemed **negligible adverse**.

8.6 Potential impacts during Operation and Maintenance

74. The potential impacts during operation and maintenance have been assessed for marine and coastal processes. A description of the potential effect on marine and coastal processes caused by each identified impact is given in this section. The only potential impact is the impact on coastal waves due to the physical presence of the offshore infrastructure.

75. There are no other potential impacts on marine and coastal processes of the operation and maintenance of the Onshore Project. This is because the cable will be buried beneath the beach of Saunton Sands, the dunes of Braunton Burrows and the Taw-Torridge Estuary. Hence, coastal processes (wave-driven sediment transport), and coastal geomorphological change (erosion and accretion) will continue uninterrupted by any infrastructure related to the cable.

8.6.1 Impact 3: Impacts on waves due to the physical presence of the infrastructure

76. Potential impacts on waves at the coast during operation could occur due to the physical presence of offshore infrastructure, which may result in localised changes to waves due to physical blockage effects. The infrastructure would present only small obstacles to the passage of waves locally, causing a small modification to the wave heights and/or directions as they pass.

77. Bespoke modelling of swell waves was completed to predict changes in nearshore wave climate due to the presence of the infrastructure, using a conservative representation of the eight floating substructures and a jacket structure. **Figure 8.4** and **Figure 8.5** show the difference in significant wave height between the baseline condition and the infrastructure layouts for surfing swell from the west for mean high water spring tides and mean low water spring tides respectively.

78. The presence of the infrastructure is predicted to result in a slight reduction in significant wave height, up to 0.015m (15mm) local to each substructure element. With distance towards the coast, the effect gradually reduces until there is no impact on the coastal wave conditions (significant wave height, peak period and mean wave direction) along the North Devon coast, and at each of the seven coastal locations analysed.

8.6.1.1 Magnitude of impact and significance of the effect

79. The operational infrastructure is a small obstacle to wave passage. The Devon coast is remote from the zone of potential influence on the wave regime. Due to this, no pathway exists between the source and the coast, and so in terms of effects at the coast the effect is deemed **no effect**.

8.7 Potential Impacts during Decommissioning

80. No decision has been made regarding the final decommissioning policy for the Onshore Project as it is recognised that industry best practice, rules and legislation change over time.

81. The anticipated decommissioning activities are outlined in **Section 8.3.3**. The potential impacts of the decommissioning of the Onshore Project have been assessed for marine and coastal processes on the assumption that decommissioning methods will be similar or of a lesser scale than those deployed for construction. The types of impact would be comparable to those identified for the construction phase:

- Impact 4: Impacts on the form and function of the coast landward of MLWS due to cable decommissioning
- Impact 5: Impacts on suspended sediment concentrations due to cable decommissioning.

Figure 8.4 Differences in significant wave height for surfing swell from the west at mean high water spring tides

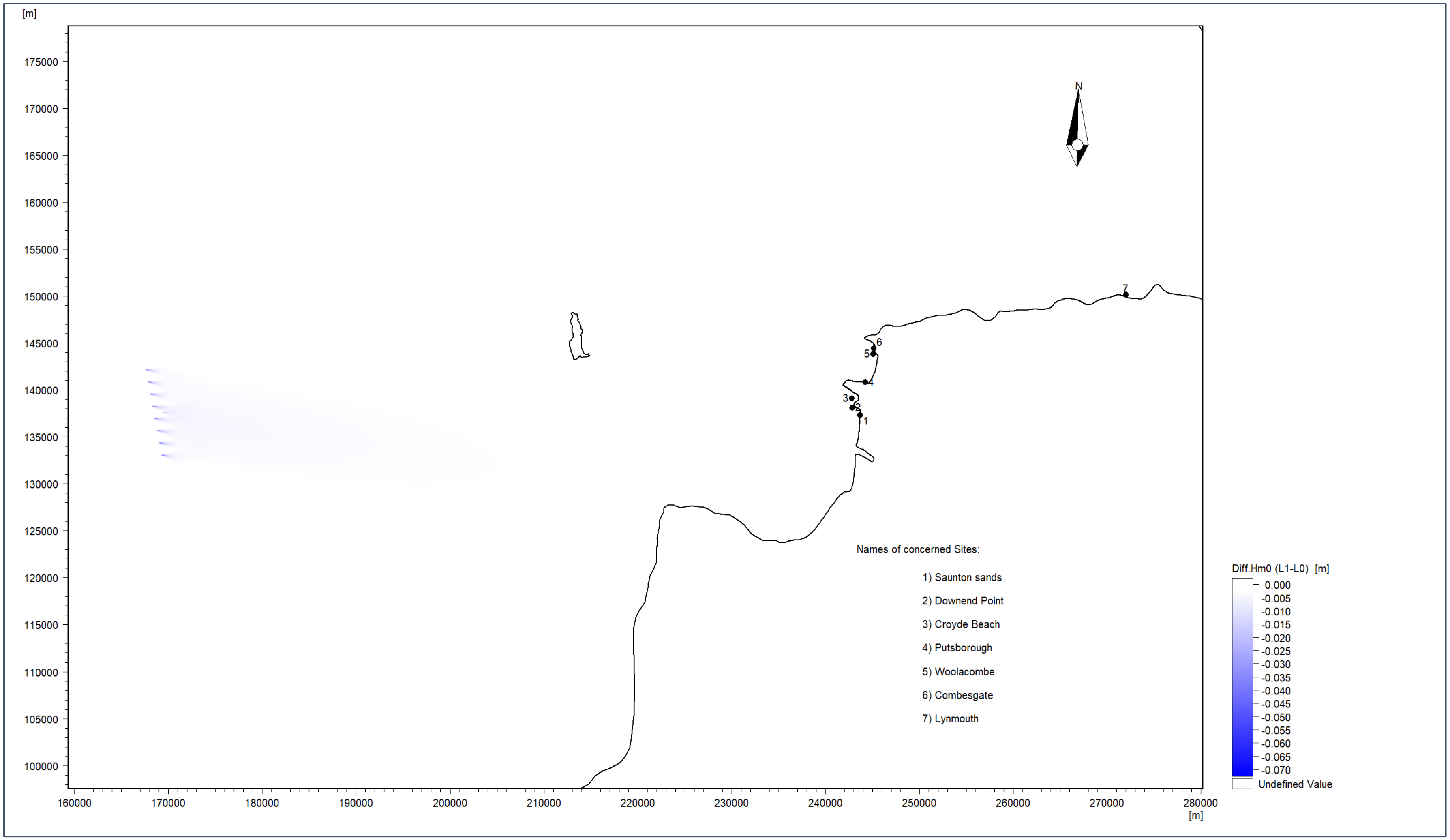
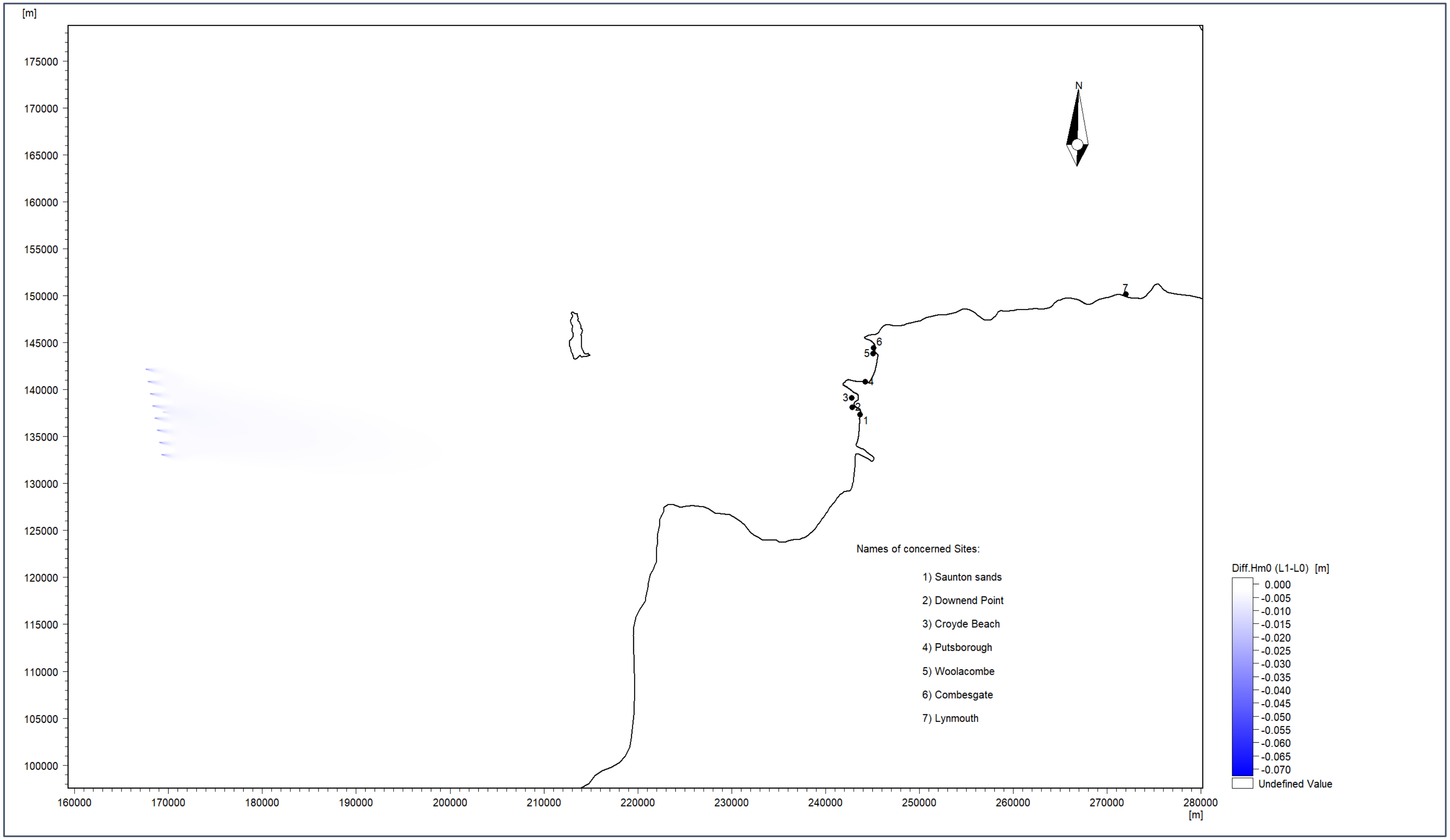


Figure 8.5 Differences in significant wave height for surfing swell from the west at mean low water spring tides



82. The magnitude of impacts would be comparable to or less than those identified for the construction phase. The construction phase assessments concluded "no significant effect" or "negligible adverse effect" for marine and coastal processes receptors. Hence, it is anticipated that the same would be valid for the decommissioning phase regardless of the final decommissioning methodologies.

8.8 Potential cumulative effects

83. The approach to CEA is set out in **Chapter 6: EIA Methodology**. Only projects which are reasonably well described and sufficiently advanced to provide information on which to base a meaningful and robust assessment have been included in the CEA. Projects which are sufficiently implemented during the site characterisation for the Onshore Project have been considered as part of the baseline for the EIA. Where possible the Applicant has sought to agree with stakeholders the use of as-built project parameter information (if available) as opposed to consented parameters to reduce over-precaution in the cumulative assessment. The scope of the CEA was therefore be established on a topic-by-topic basis with the relevant consultees.

84. The cumulative effect assessment for marine and coastal processes was undertaken in two stages. The first stage was to consider the potential for the effects assessed as part of the project to lead to cumulative effects in conjunction with other projects. The first stage of the assessment is detailed in **Table 8.16**.

Table 8.16 Potential cumulative impacts considered for marine and coastal processes

Impact	Potential for cumulative effect	Rationale
Construction Impact 1: Impacts on the form and function of the coast landward of MLWS due to cable installation	Yes	There is potential for temporal overlap of offshore export cable construction
Construction Impact 2: Impacts on suspended sediment concentrations due to cable installation	Yes	There is potential for temporal overlap of offshore export cable construction
Decommissioning Impact 4: Impacts on the form and function of the coast landward of MLWS due to cable decommissioning	Yes	There is potential for temporal overlap of offshore export cable decommissioning
Decommissioning Impact 5: Impacts on suspended sediment concentrations due to cable decommissioning	Yes	There is potential for temporal overlap of offshore export cable decommissioning

85. Only potential impacts assessed in **Section 8.4.2, Section 8.6** and **Section 8.7** as negligible or above are included in the CEA (i.e. those assessed as 'no impact' are not taken forward as there is no potential for them to contribute to a cumulative impact).

86. The second stage of the CEA is to evaluate the projects considered for the CEA to determine whether a cumulative effect is likely to arise. The list of considered projects (identified in **Chapter 6: EIA Methodology**) and their anticipated potential for cumulative effects are summarised in **Table 8.17**.

Table 8.17 Projects considered in the cumulative effect assessment on marine and coastal processes

Project	Status	Distance from Onshore Development Area (km)	Included in the CEA?	Rationale
White Cross Offshore Project	Consent application submitted	0	Yes	Potential for temporal overlap of export cable installation activities close to and at the coast

87. It is noted that the first project listed is the Section 36 consent application for the offshore components of the White Cross OWF which are a separate element to the onshore Town and Country Planning Application for which this ES is prepared. The specific combined project components are assessed cumulatively first and then cumulatively with all other projects.

88. The action plan developed in the SMP recommends all the different policies (Hold the Line, No Active Intervention, Managed Realignment) for various stretches of coast from Saunton Sands to the Taw-Torridge Estuary and Northam Burrows. However, there are no specific activities related to these policies that can be translated into the CEA. The policy at landfall to MLWS and adjacent areas is No Active Intervention, and so there are no cumulative impacts as there are no activities proposed.

8.8.1 Impact 6: White Cross Offshore Project

89. There is potential for temporal overlap of the offshore and onshore installation of the export cables across the landfall to MLWS zone of northern Saunton Sands.

8.8.1.1 Magnitude of impact and significance of the effect

90. Based on an assumption that the installation of the landfall to MLWS cables across Saunton Sands would take place over a period of up to five days, a temporal overlap in cable construction activities is unlikely. The installation of the export cable in the subtidal zone and the installation of the onshore cable landwards would have no interaction. The magnitude of impact is therefore considered **negligible** to **no impact**. The overall significance of the effect under a worst-case scenario on the identified morphological receptors is deemed **negligible adverse**. This effect reduces to **no effect** upon cessation of the works. Also, if the installation uses trenchless techniques then there would be no interaction.

8.8.1.2 Further Mitigation

91. No further mitigation is required.

8.9 Potential transboundary impacts

92. The Scoping Report identified that there was no potential for significant transboundary effects regarding marine and coastal processes from the Onshore Project upon the interests of other European Economic Area (EEA) States. This is because the nearest EEA is at a distance from the Onshore Project such that impacts would not extend that far. Hence, potential transboundary effects are not discussed further.

8.10 Inter-relationships

93. Inter-relationship impacts are covered as part of the assessment and consider impacts from the construction, operation or decommissioning of the Onshore Project on the same receptor (or group). A description of the process to identify and assess these effects is presented in **Chapter 6: EIA Methodology**. The potential inter-relationship effects that could arise in relation to marine and coastal processes include both:

- **Project lifetime effects:** Effects arising throughout more than one phase of the Onshore Project (construction, operation, and decommissioning) to interact to potentially create a more significant effect on a receptor than if just one phase were assessed in isolation
- **Receptor led effects:** Assessment of the scope for all relevant effects to interact, spatially and temporally, to create inter-related effects on a receptor (or group). Receptor-led effects might be short term, temporary or transient effects, or incorporate longer term effects.

94. **Table 8.18** serves as a signposting for inter-relationships.

Table 8.18 Marine and coastal processes Inter-relationships

Topic and description	Related chapter	Where addressed in this Chapter	Rationale
Construction Impact 1: Impacts on the form and function of the coast landward of MLWS due to cable installation	**Chapter 9: Marine Water and Sediment Quality** **Chapter 10 Benthic and Intertidal Ecology** **Chapter 17 Onshore Archaeology and Cultural Heritage**	**Section 8.5.1**	Disruption to coastal morphology could affect these receptors by altering the existing sedimentary environment. However, this is unlikely to be to levels which are significant.
Construction Impact 2: Impacts on suspended sediment concentrations due to cable installation	**Chapter 9 Marine Water and Sediment Quality** **Chapter 10 Benthic and Intertidal Ecology**	**Section 8.5.2**	Suspended sediment could be contaminated and could cause disturbance to fish and benthic species through smothering.
Decommissioning	Inter-relationships for impacts during the decommissioning phase will be the same as those outlined above for the construction phase.		

8.11 Interactions

95. The impacts identified and assessed in this chapter have the potential to interact with each other, which could give rise to synergistic impacts because of that interaction. The areas of interaction between impacts are presented in **Table 8.19** and **Table 8.20**, along with an indication as to whether the interaction may give rise to synergistic impacts. This provides a screening tool for which impacts have the potential to interact.

96. **Table 8.21** then provides an assessment for each receptor (or receptor group) related to these impacts in two ways. Firstly, the impacts are considered within a development phase (i.e. construction, operation, maintenance or decommissioning) to see if, for example, multiple construction impacts could combine. Secondly, a lifetime assessment is undertaken which considers the potential for impacts to affect receptors across development phases. The significance of each individual impact is determined by the sensitivity of the receptor and the magnitude of effect; the sensitivity is constant whereas the magnitude may differ. Therefore, when considering the potential for impacts to be additive it is the magnitude of effect which is important – the magnitudes of the different effects are combined upon the

same sensitivity receptor.

Table 8.19 Interaction between impacts during construction

Construction	Impact 1: Impacts on the form and function of the coast landward of MLWS due to cable installation	Impact 2: Impacts on suspended sediment concentrations due to cable installation
Impact 1: Impacts on the form and function of the coast landward of MLWS due to cable installation		Yes
Impact 2: Impacts on suspended sediment concentrations due to cable installation	Yes	

Table 8.20 Interaction between impacts during decommissioning

Decommissioning	Impact 3: Impacts on the form and function of the coast landward of MLWS due to cable decommissioning	Impact 4: Impacts on suspended sediment concentrations due to cable decommissioning
Impact 3: Impacts on the form and function of the coast landward of MLWS due to cable decommissioning		Yes
Impact 4: Impacts on suspended sediment concentrations due to cable decommissioning	Yes	

Table 8.21 Potential interactions between impacts on marine and coastal processes

Highest level significance					
Receptor	Construction	Operation and Maintenance	Decommissioning	Phase Assessment	Lifetime Assessment
Devon coast	Negligible Adverse	No effect	Negligible Adverse	No greater than individually assessed effect. The effects are no effect to negligible adverse effect on the receptor. Given that each effect will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater effect than assessed individually	No greater than individually assessed effect.

8.12 Summary

97. This chapter has investigated the potential effects on marine and coastal processes receptors arising from the Onshore Project. The range of potential impacts and associated effects considered has been informed by the Scoping Opinion, consultation, and agreed through ETG Meetings, as well as reference to existing policy and guidance. The impacts considered include those brought about directly as well as indirectly.

98. The effects on the identified receptor during construction, operation and decommissioning phases of the Onshore Project are considered **negligible adverse** or **no effect**. **Table 8.22** presents a summary of the impacts assessed within this ES chapter, any commitments made, and mitigation required and the residual effects. The assessment of cumulative effects from the Onshore Project and other developments and activities concluded that only one has the potential for interaction: the White Cross Offshore Project. However, the effects would be of no greater than negligible adverse significance.

99. The screening of transboundary impacts identified that there was no potential for significant transboundary impacts regarding marine and coastal processes from the Onshore Project.

Table 8.22 Summary of potential impacts for marine and coastal processes during construction, operation, maintenance and decommissioning of the Onshore Project

Potential impact	Receptor	Sensitivity	Magnitude	Significance	Potential mitigation measure	Residual impact
Construction and Operation						
Impact 1: Impacts on the form and function of the coast landward of MLWS due to cable installation	Devon coast	N/A	Negligible	Negligible Adverse	N/A	No effect
Impact 2: Impacts on suspended sediment concentrations due to cable installation	Devon coast	N/A	Negligible	Negligible Adverse	N/A	No effect
Impact 3: Impacts on waves due to the physical presence of the infrastructure	Devon coast	N/A	No impact	No effect	N/A	No effect
Decommissioning						
Impact 4: Impacts on the form and function of the coast landward of MLWS due to cable decommissioning	Devon coast	N/A	Negligible	Negligible Adverse	N/A	No effect
Impact 5: Impacts on suspended sediment concentrations due to cable decommissioning	Devon coast	N/A	Negligible	Negligible Adverse	N/A	No effect
Cumulative						
Impact 6: White Cross Offshore Project	Devon coast	N/A	Negligible	Negligible Adverse	N/A	No effect

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White Cross Offshore Windfarm Environmental Statement

Appendix 8.A: Benthic Characterisation Report

Ocean Ecology

Marine Surveys, Analysis & Consultancy

White Cross Offshore Windfarm Benthic Characterisation Survey: Technical Report

REF: OEL_NSEWHI10222_TCR

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Details

Version	Date	Description	Author(s)	Reviewed By
V01	04/10/2022	Draft	Clare Hill, Ellie Arthur-Morgan, Samuel Holmes, Elena Cappelli, Emily Sparkes, Lucy Martin	Ross Griffin
V02	06/03/2023	Final	Samuel Holmes	Ross Griffin

Updates

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List of Abbreviations

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

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

1. Introduction

1.1. Project Overview

White Cross is an approximately 100MW Test and Demonstration floating windfarm located in the Celtic Sea. The project is being developed by Offshore Wind Ltd (OWL). OWL is a joint venture partnership between Cobra Instalaciones y Servicios, S.A. and Floatation Energy plc.

The project array area is located 52.5 km off the Cornish coast in England and covers an area of 142 km^2. The proposed cable landfall will be located at Saunton Sands in Bideford Bay on the North coast of Devon, southwest England. Water depths in the array area range between 65 – 75 m which gradually decrease along the Export Cable Corridor (ECC) to the proposed landfall location (Figure 1). The project has a maximum capacity of 100MW with a baseline layout consisting of 8 x 12MW wind turbines, each mounted on top of a floating foundation with an offshore substation located within the windfarm area.

1.2. Project Background

N-Sea (the lead survey contractor) contracted Ocean Ecology Limited (OEL) to undertake a benthic characterisation survey to provide a description of the biological and physio-chemical nature of the seabed across the project area. The project area is defined as the Windfarm Order Limits including the array, ECC, and landfall areas. This report presents the combined results of the initial preliminary phase of the benthic characterisation survey ('Phase I' herein) and results of the secondary phase (Phase II herein) for a full benthic characterisation of the site.

1.3. Aims and Objectives

Provision of accurate ground truthing for geophysical data collected in June and July 2022 using a combination of Drop-Down Camera (DDC) images and sediment grab sampling was the key focus of the benthic characterisation survey. Information collected will be used to inform the Environmental Impact Assessment (EIA) for the project and will form part of the baseline dataset against which any future changes to the sediment characteristics, macrobenthic communities, and seabed physico-chemical properties will be monitored.

The main aims of the benthic characterisation survey were to:

- Describe benthic communities present within and adjacent to the project area, including biotopes, biodiversity, function, abundance, extent, species richness, representativeness, rarity, and sensitivity. This was to cover the range of water depths across the site and include both infaunal and epifaunal communities.
- Identify and assess the status of species and habitats of conservation importance, including Annex I protected species and habitats (such as *Sabellaria spinulosa* biogenic

reef or stony reef), and Annex V species[1] of the Habitats Regulations, species listed under Schedule 5 of the Wildlife & Countryside Act[2], OSPAR species and habitats[3] and designated features of the MPA network (e.g., SAC and MCZ features); and

- Confirm the presence/absence of any invasive non-native species (INNS), species non-native to UK waters, and species non-native to the local habitat types (e.g., hard-substrate specialists in a wider sedimentary habitat).

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

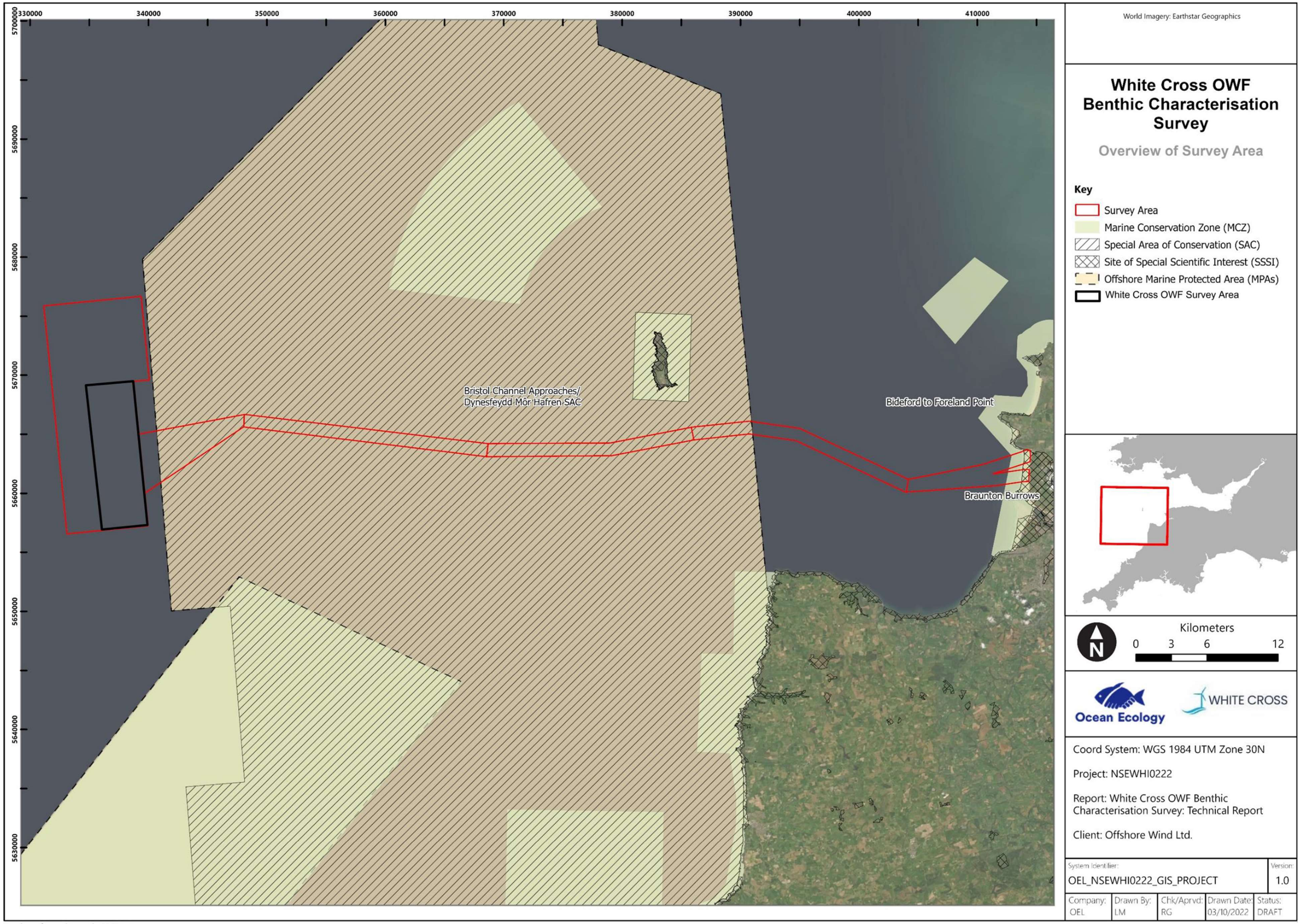

Figure 1 Overview of survey area with sites of conservation interest.

2. Designated Sites

The nearshore extent of the ECC intersects the Bideford to Foreland Point Marine Conservation Zone (MCZ) which extends to the upper shore of Saunton Sands where it overlaps with the onshore Braunton Burrows Special Area of Conservation (SAC) (Figure 1). The offshore extent of the ECC intersects the Bristol Channel Approaches SAC (Figure 1).

2.1. Bideford to Foreland Point Marine Conservation Zone (MCZ)

Bideford to Foreland Point was designated as a MCZ in 2016 to protect a number of key species including pink sea-fan (*Eunicella verrucosa*) and spiny lobster (*Palinurus elephas*) as well as the following habitats:

- Low energy intertidal rock
- Moderate energy intertidal rock
- High energy intertidal rock
- Intertidal coarse sediment
- Intertidal mixed sediment
- Intertidal sand and muddy sand
- Intertidal under boulder communities
- Littoral Chalk communities
- Low energy infralittoral rock
- Moderate energy infralittoral rock
- High energy infralittoral rock
- Moderate energy circalittoral rock
- High energy circalittoral rock
- Subtidal coarse sediment
- Subtidal mixed sediments
- Subtidal sand
- Fragile sponge and anthozoan communities on subtidal rocky habitats
- Honeycomb worm (*Sabellaria alveolata*) reefs,

2.2. Braunton Burrows Special Area of Conservation (SAC) and Site of Special Scientific Interest (SSSI)

Braunton Burrows was designated as a SAC due the following Annex I habitats which are a primary reason for the selection of this site:

- Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)
- Fixed coastal dunes with herbaceous vegetation (grey dunes)
- Dunes with *Salix repens* ssp. argentea (*Salicion arenariae*)
- Humid dune slacks

As well as due to the presence of Annex I habitat 'mudflats and sandflats not covered by seawater at low tide' which is a qualifying feature of this SAC but not a primary reason for designation.

2.3. Bristol Channel Approaches SAC

The Bristol Channel Approaches SAC spans the Bristol Channel between the northern coast of Cornwall into Carmarthen Bay in Wales. The site has been identified for the protection of harbour porpoise and is within the Celtic and Irish Seas Management Unit.

3. Existing Habitat Mapping

3.1. EMODnet Habitat Mapping

Existing habitat mapping available on the European Marine Observation and Data Network (EMODnet) Seabed Habitats portal[4] indicates that the survey area comprises a number of sediment habitats including European Nature Information System (EUNIS) biotope complexes A5.27 'Deep circalittoral sand', A5.15' 'Deep circalittoral coarse sediment', A5.14 'Circalittoral coarse sediment', A5.25/A5.26 'Circalittoral fine sand or Circalittoral muddy sand', and A5.23/A5.24 'Infralittoral fine sand or infralittoral muddy sand' (Figure 2).

3.2. Geophysical Data

Geophysical data (MBES, SSS and backscatter) was collected throughout the survey area by N-Sea between June and August 2022. The seabed throughout the proposed area was broadly interpreted from the bathymetry as typical shallow ~ 7 – 94 m and gently sloping, gradually deepening from the northeast to the southwest. Nearshore, the seabed was broadly interpreted as a gently sloping (from east to west) homogenous sediment seabed with several long, sinuous sand waves oriented northwest to southeast. Throughout the mid-section of the ECC, harder seabed features indicative of bedrock were evident, extending west *c.*15 km. Offshore, the seabed within the fan and array areas was broadly interpreted as shallow, homogenous rippled seabed shallowing to the northeast and deepening to the southwest.

[4] https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/

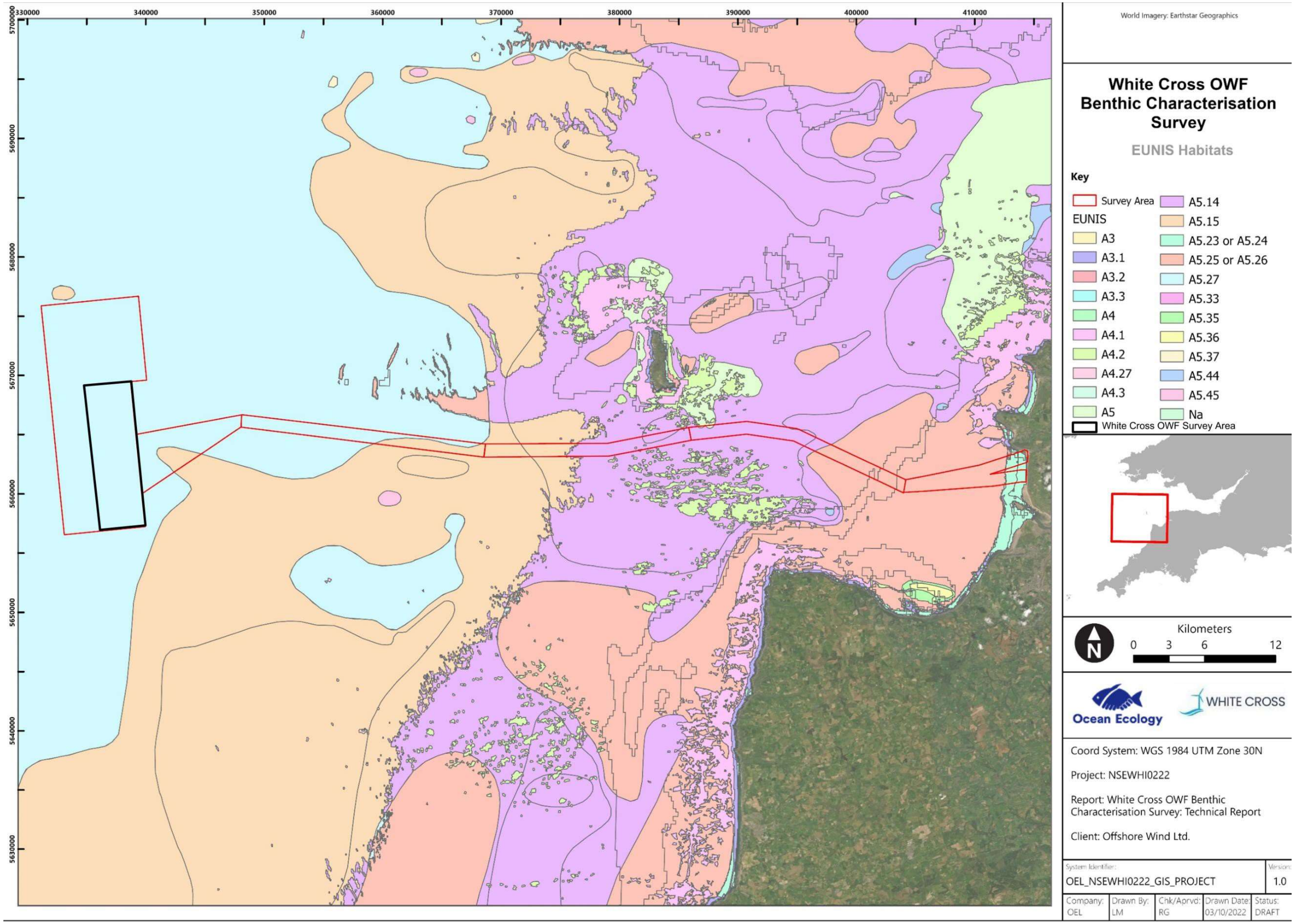

Figure 2 Known EUNIS habitat mapping across the White Cross survey area.

4. Survey Design

4.1. Overview

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

- Adequate spatial coverage of the array and ECR areas
- Representative sampling of all main sediment types
- Representative examples of all potential features of conservation interest (e.g., Annex I reefs) were adequately ground-truthed.

4.2. Rationale

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

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

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

4.3. Sampling Design

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

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

MBES and SSS was reviewed simultaneously to micro site samples around a stratified grid which was initially overlain on the project area. SSS and MBES was reviewed manually to identify areas of differing sediment type and seabed elevation. Sediment / substrate type was inferred from SSS based on the reflectivity (coarser sediments providing showing greater reflectivity) and seabed elevation was determined by review of MBES which presents water depth. A representative number of stations was attributed to each of the main Broadscale Habitats (BSH) to ensure coverage of the array area was proportional to the dominant BSH present whilst also considering adequate spatial coverage. Sample locations were further micro sited to consider contaminant sampling which targeted at sampling stations thought to be characterised by fine sediment. The 10 DDC transects were positioned to ground-truth and delineate potential rocky reef features and confirm the presence/absence of key features of conservation interest (e.g. pink sea fan colonies and fragile sponge and anthozoan communities).

The proposed sampling plan is presented visually in Figure 3 and Table 1 and further rationale for each sample location in Appendix I.

Table 1 Numbers of sampling stations per survey block for Phase II sampling. * shallower than 10 m LAT. ** wider corridor at the approach to the array area.

Block	No. of DDC/Grab Stations	No of DDC Transects
Nearshore*	16	-
Area 3	16	3
Area 2	16	7
Area 1	17	-
Fan**	16	-
OWF	34	-
Total	**115**	**10**

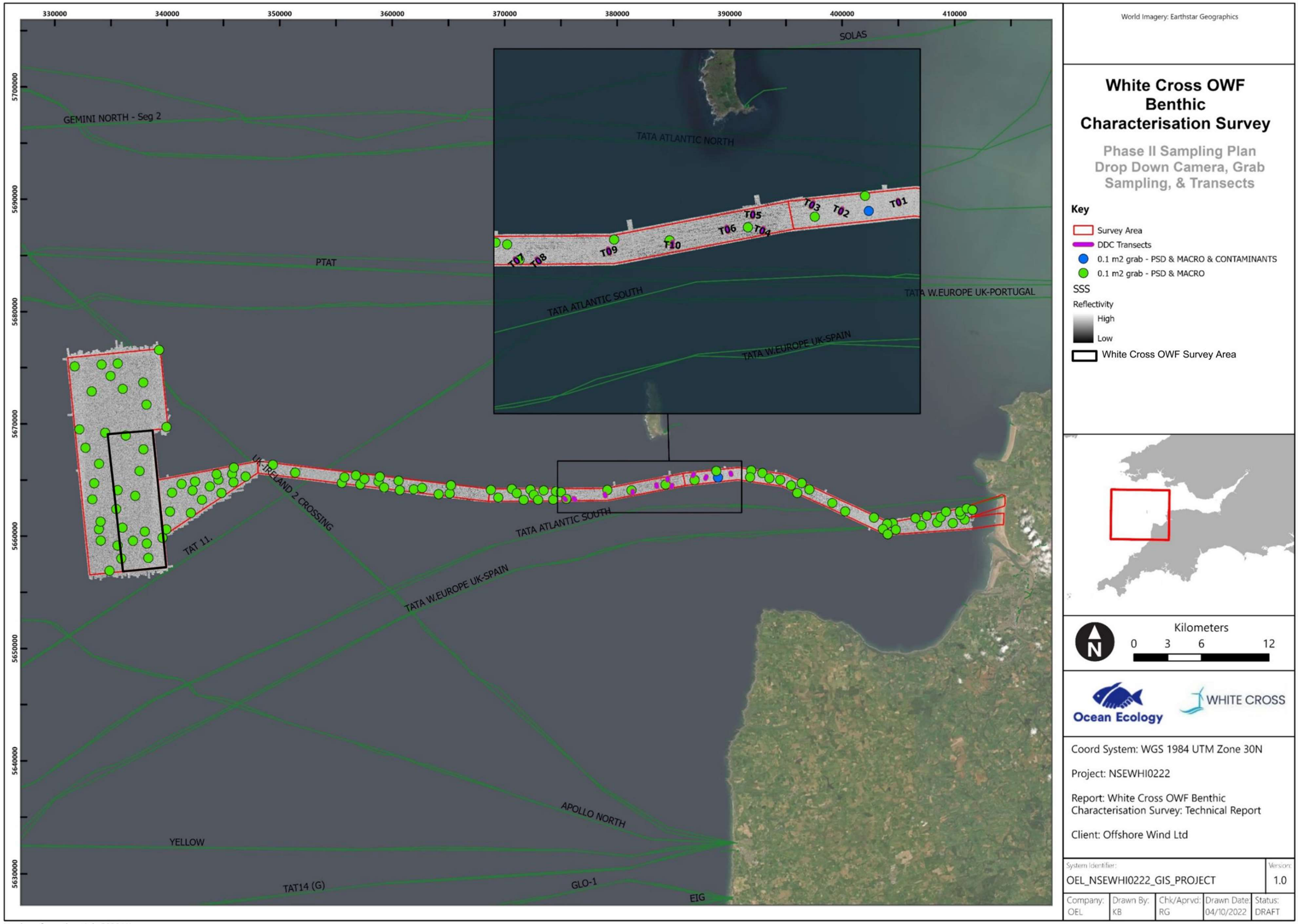

Figure 3 Locations of sampling stations across the White Cross survey area.

5. Field Methods

5.1. Survey Vessels

Phase I was conducted aboard Marine and Coastal Agency (MCA) Category 2, 11.7 m dedicated survey vessel '*Argyll Explorer*' (Plate 1), mobilising out of Padstow and operating from Ilfracombe and Clovelly. The vessel was equipped with a Hemisphere V104s Global Positioning System (GPS) compass system. The Hemisphere V104s's internal GPS receiver automatically searches for and uses a minimum of 4 GPS satellites and manages the navigation information required for position to within 3 m (95% accuracy). Since there is some error in the GPS data calculations, the V104s also automatically tracks a Satellite-Based Augmentation System (SBAS) differential correction to improve its position accuracy to better than 1.0 m 95%. The V104s has an integrated gyro and two tilt sensors to provide an accurate heading for the navigation software.

Phase II was conducted aboard the 34.5m dedicated survey vessel *Geo Focus* (Plate 1). The vessel was equipped with Class 1 Dynamic Positioning (DP). The 40m^2 back deck provided ample space for several items of survey equipment.

Plate 1 Top: Phase I survey vessel, OEL's Argyll Explorer. Bottom: Phase II survey vessel Geo Focus.

5.2. Project Parameters

5.2.1. Horizontal Datum

A summary of geodetic and projection parameters used during the project are provided in Table 2 and Table 3 below.

Table 2 Datum parameters.

Parameter	Details
Name	World Geodetic System 1984 (WGS84)
Ellipsoid	WGS 84
Semi-Major Axis (a)	6378137.000 m
Semi-Minor Axis (b)	6356752.314 m
Inverse Flattening	298.257 223 563
Geodetic parameters EPSG Code	4326

Table 3 Projection parameters.

Projection	Universal Transverse Mercator (UTM)
Zone	30 North
Central Meridian	3° West
Latitude of Origin	0°
False Easting	500 000.00 m
False Northing	0.00 m
Scale Factor at Central Meridian	0.9996
Projected coordinate system EPSG code	32630
Units	metres

5.2.2. Unit Format and Conversions

The following units were used throughout this project and are expressed using the following conventions.

Table 4 Project unit format and convention details.

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

5.3. Subsea Positioning

Subsea positioning of the sampling equipment during both phases of the survey was achieved using USBL positioning systems. EIVA NaviPac V4.2 software was employed for all DDC and grab sampling operations to ensure the accurate positioning of the vessel and survey equipment via the USBL system. A navigation screen, displaying EIVA Helmsman Display was provided at the helm position of the vessel for the Officer on Watch as well as for the ecologist/surveyor in the wheelhouse.

5.4. Survey Equipment

5.4.1. Phase I

Sampling equipment utilised during Phase I of the survey is included in Table 5.

Table 5 Equipment utilised onboard the *Argyll Explorer*.

Equipment	Model
Subsea Positioning	Easytrak Nexus 2 Lite Ultra-Short Baseline
Camera System (Primary)	OEL freshwater housing with HD video and high-resolution stills camera (SubC Imaging Rayin BPE)
Camera System (Redundancy)	OEL freshwater housing with HD video and high-resolution stills camera (RovTech Solutions)
Grab Sampler	0.2m^2 Dual Van Veen grab sampler
Equipment Dampener	A-frame fitted equipment dampener system
dGPS	Hemisphere V200s GPS Compass
Gyro Compass	Hemisphere V200s GPS Compass
Navigation Software	EIVA NaviPac V4.5

For Phase I seabed imagery was collected using OEL's freshwater housing camera system to collect high definition (HD) video and high-resolution (up to 24 megapixels (MP)) still images at each targeted station. The camera system consisted of a SubC Rayfin camera, freshwater housing frame, two RovTech LED strip lights with two 5kW green dot lasers (set to 10cm distance for scale), a 300m umbilical and topside computer. The camera was powered with the use of an Uninterruptable Power Supply (UPS) to ensure no damage was caused should the vessel have lost power or caused a power surge. The freshwater housing is height and angle adjustable providing a variety of options for view, lighting, and focal length to maximise data quality with respect to prevailing conditions (e.g., high turbidity). Following a review of seabed imagery during the survey, adjustments to the lighting angle were made to improve illumination within the centre of images.

For Phase I the grab was deployed from the hydraulic A-frame on the aft deck of Argyll Explorer and lowered to the seabed. An 'equipment dampener' mobilised on the A-frame allowed for grab operations to continue in a wider weather window (Plate 2). Sampling was conducted using a 0.2 m^2 Dual Van Veen (DVV) grab (Plate 2).

The DVV is favourable for medium to fine sediments and is ideal for the collection of chemical samples as it enabled to collect samples with undisturbed surface sediments. The DVV was employed for 22 of the 25 stations.

A 0.1m^2 mini-Hamon Grab mobilised as a back-up system was employed for 3 stations due to the presence of medium to coarse sediment.

Plate 2 Left: 0.2 m^2 DVV Grab. Right: Equipment dampener mobilised on A-Frame.

5.4.2. Phase II

Sampling equipment utilised during Phase II of the survey is included in Table 6.

Table 6 Equipment list mobilised onboard the *Geo Focus*.

Equipment	Model
Camera System (Primary)	OEL freshwater housing with High Definition (HD) video and high-resolution stills camera (SubC Rayfin Powerline Ethernet (PLE))
Camera System (Redundancy)	OEL freshwater housing with HD video and high-resolution stills camera (SubC Rayfin PLE)
Grab Sampler	0.1m^2 Day grab sampler
Grab Sampler	0.1m^2 mini-Hamon grab sampler
Survey Software	SubC Rayfin Control
Subsea Positioning	HiPAP Kongsberg transducer

Seabed imagery taken during Phase II was collected using the same frame as that utilised during Phase I as outlined in section 5.2.2, but equipped with a SubC Rayfin Camera system including, LED lamps and swathe lasers (Plate 3). This provided 4K video and high-resolution (up to 21 megapixels (MP)) still images.

Using Phase I as a reference point, sampling was initially conducted using a 0.1m^2 mini-Hamon grab at stations in Area 2. The mini-Hamon grab was used for 58 macrofaunal / PSD stations.

At stations consisting of medium to fine sediment, a 0.1m^2 Day grab was employed, including at the single station where chemical sampling was required. The Day grab was used for 52 macrofaunal / PSD stations and one chemical station.

Plate 3 DDC and Hamon Grab mobilised on aft deck of the '*Geo Focus*'.

5.5. Seabed Imagery Collection

Seabed imagery was collected at DDC stations (co-located with grab sample locations for prior investigation) and along DDC transects in consideration of the Joint Nature Conservation Committee (JNCC) epibiota remote monitoring operational guidelines[5].

[5] Hitchin, R., Turner, & Verling. (2015). *Epibiota Remote Monitoring from Digital Imagery: Operational Guidelines*.

At each DDC station, a minimum of two minutes of video footage and five seabed still images were obtained. The vessel was moved within a 20 m radius of the target location to adequately characterise the target area. Along the transects, a 'bed hoping' approach was employed to ensure representative imagery was collected along the full transects with still images taken every 5-10 m along with continuous video recording. All video footage was reviewed *in situ* by OEL's environmental scientists.

5.6. Grab Sampling

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

- The sample was less than 5L. i.e., the sample represented less than half the 10L 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).

Where a suitable sample could not be collected after three attempts within a 20 m radius of the target location, the sample location was moved by up to 50 m away. Where samples of less than 5L were continually achieved, these samples were assessed on site to establish if the sample volume was acceptable to allow subsequent analysis. No pooling of samples took place. Where a suitable sample was not collected after four attempts, the sample location was abandoned.

5.6.1. Grab Sample Processing (PSD and Macrobenthic Samples)

Initial grab sample processing was undertaken aboard the vessels in line with the following methodology:

- Initial visual assessment of sample size and acceptability made.
- Photograph of the unprocessed sample in sample hopper with station details and scale bar taken.
- Sub-sample removed for PSD analysis and transferred to a labelled tray.
- Remaining sample emptied onto 1.0 mm sieve net laid over 4.0 mm sieve table and washed through using gentle rinsing with seawater hose.
- Photograph of the sieved sample on 1.0 mm sieve net taken.
- Remaining sample for faunal sorting and identification backwashed into a suitable sized sample container and diluted 10 % formalin solution added to fix the sample prior to laboratory analysis.
- Sample containers clearly labelled internally and externally with date, sample ID and project name.

5.6.2. Grab Sample Processing (Chemical Contaminants)

A separate sediment sample was collected for subsequent chemical contaminant analysis at a subset of 15 sampling stations. From each of these samples two subsamples (primary A rep and back up b rep) were retained. Initial sample processing onboard aligned to the following methodology:

- Inspection cover lifted and general assessment of sample size and acceptability made ensuring sediment surface was undisturbed and no obvious sign of contamination. Checks to ensure no grease, oils or lubes entered the sample once the inspection cover was open were also undertaken.
- pH / Redox probe placed into sediment sample and allowed to settle for 2 minutes before taking readings in field logs.
- Sediment samples were sub-sampled and decanted into the recommended sample containers provided by SOCOTEC, the contaminant laboratory specialists, to undertake the MMO suite analysis for disposal at sea along with additional analyses, as summarised below:
- Total Organic Matter by Loss on Ignition (LOI)
- Moisture content
- 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) - Acenaphthene, Acenaphthylene, Anthracene, Benzo[a]anthracene, Benzo[a]pyrene, Benzo[b]fluoranthene, Benzo[ghi]perylene, Benzo[e]pyrene, Benzo[k]fluoranthene, Chrysene, Dibenzo[a,h]anthracene, Fluoranthene, Fluorene, Indeno[123,cd]pyrene, Naphthalene, Perylene, Phenanthrene, Pyrene
- Total Hydrocarbon Content (THC);
- Polychlorinated biphenyls (PCBs 25 including the ICES 7)

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

6. Laboratory and Analytical Methods

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

6.1. Particle Size Distribution (PSD) Analysis

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

6.1.1. Sample Preparation

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

6.1.2. Dry Sieving

The > 1 mm fraction was then returned to a drying oven and dried at 80 °C for at least 24 hours prior to dry sieving. Once dry, the sediment sample was run through a series of Endecott BS 410 test sieves (nested at 0.5 φ intervals) using a Retsch AS200 sieve shaker to fractionate the samples into particle size classes. The dry sieve mesh apertures used are given in Table 7.

Table 7 Sieve series employed for Particle Size Distribution (PSD) analysis by dry sieving (mesh size in mm).

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

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

6.1.3. Laser Diffraction

The fine fraction residue (< 1mm sediments) was transferred to a suitable container and allowed to settle for 24 hours before excess water syphoned from above the sediment surface until a paste texture was achieved.

The fine fraction was then analysed by laser diffraction using a Beckman Coulter LS13 320. For silty sediments, ultrasound was used to agitate particles and prevent aggregation of fines.

6.1.4. Data Merging

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

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

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

Wentworth Scale	Phi Units (φ)	Sediment Types
>64000 µm	<-6	Cobble and boulders
32000 – 64000 µm	-5 to -6	Pebble
16000 – 32000 µm	-4 to -5	Pebble
8000 – 16000 µm	-3 to -4	Pebble
4000 - 8000 µm	-3 to -2	Pebble
2000 - 4000 µm	-2 to -1	Granule
1000 - 2000 µm	-1 to 0	Very coarse sand
500 - 1000 µm	0 - 1	Coarse sand
250 - 500 µm	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. Sediment Chemical Analysis

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

6.2.1. Hydrocarbons

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

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

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

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

- Pristane / Phytane ratio: values close to one indicate hydrocarbons of petrogenic origin, values higher than one indicate biogenic origin of alkanes, while ratios below one indicates pyrogenic origin. Pristane is typically found in marine organisms while phytane is a component of oil (Guerra-García et al. 2003) hence the use of this ratio to assess source origin of hydrocarbons

6.2.2. Heavy and Trace Metals

A total of 8 main heavy and trace metals were analysed from sediments taken at each of the 14 stations sampled. These were Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn).

Where available, mean metal concentrations were compared to the OSPAR Background Assessment Concentration (BAC) (OSPAR et al. 2009), the USA Environmental Protection Agency (EPA) Effect Range Low (ERL) (NJDEP 2009), (DEFRA 2003) Action Level (AL) 1 and AL 2, and the Canadian sediment quality guideline (CSQG) Threshold Effect Level (TEL) and Probable Effect Level (PEL) (CCME 2001). To note that ERL, TEL and PEL are based on field research programmes based on North American data that have demonstrated associations between chemicals and biological effects by establishing cause and effect relationships in particular organisms (CCME 2001). This means they provide a measure of environmental toxicity compared to the other reference levels which instead provide information on the degree of contamination of the sediments. At levels above the TEL, adverse effects may occasionally occur, whilst at levels above the PEL, adverse effects may occur frequently; concentrations below the ERL rarely cause adverse effects in marine organisms. Additionally, the TEL has been adopted as the International Sediment Quality Guideline (ISQG) (CCME 2001), while ERL has been adopted by OSPAR to assess the ecological significance of contaminant concentrations in sediments, where concentrations below the ERL rarely cause adverse effects in marine organisms. For these reasons ERL, TEL and PEL are presented here as reference values despite being based on North American data.

BACs were developed to assess the status of contaminant concentrations in sediment within the OSPAR framework with concentrations significantly below the BAC considered to be near background levels for the North-East Atlantic. Cefas ALs are used as part of a 'weight of evidence' approach to assessing dredged material and its suitability for disposal to sea (DEFRA 2003). Contaminant levels in dredged material which fall below AL1 are of no concern and are unlikely to influence decision-making, while contaminant levels above AL2 are generally considered unsuitable for at-sea disposal.

6.3. Macrobenthic Analysis

All elutriation, extraction, identification, and enumeration of the grab samples was undertaken at OEL's NMBAQC scheme participating laboratory in line with the NMBAQC Processing Requirement Protocol (PRP) (Worsfold & Hall 2010). All processing information and macrobenthic records were recorded using OEL's cloud-based data management application 'ABACUS' that employs MEDIN[6] validated controlled vocabularies ensuring all sample information, nomenclature, qualifiers, and metadata are recorded in line with international data standards.

For each macrobenthic sample, the excess formalin was drained off into a labelled container over a 1 mm mesh sieve in a well-ventilated area. The samples were then re-sieved over a 1 mm mesh sieve to remove all remaining fine sediment and fixative. The low-density fauna was then separated by elutriation with fresh water, poured over a 1 mm mesh sieve, transferred into a Nalgene and preserved in 70 % Industrial Denatured Alcohol (IDA). The remaining sediment from each sample was subsequently separated into 1 mm, 2 mm and 4 mm fractions and sorted under a stereomicroscope to extract any remaining fauna (e.g., high-density bivalves not 'floated' off during elutriation). All macrobenthos present was identified to species level, where possible, and enumerated by trained benthic taxonomists using the most up to date taxonomic literature and checks against existing reference collections. Nomenclature utilised the live link within ABACUS to the WoRMS[7] REST webservice (World Register of Marine Species), to ensure the most up to date taxonomic classifications were recorded. Colonial fauna (e.g., hydroids and bryozoans) were recorded as present (P). For the purposes of subsequent data analysis, taxa recorded as P were given the numerical value of 1.

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

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

[6] Marine Environmental Data and Information Network
[7] http://www.marinespecies.org

6.4. Macrobenthic Data Analysis

6.4.1. Data Truncation and Standardisation

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

6.4.2. Pre-Analysis Data Treatment

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

In accordance with the OSPAR Commission guidelines (OSPAR 2004) records of colonial, meiofaunal, parasitic, egg and pelagic taxa (e.g. epitokes and larvae) were recorded, but were excluded when calculating diversity indices and conducting multivariate analysis of community structure. Newly settled juveniles of macrobenthic species may at times dominate the macrobenthos, however the OSPAR (2004) guidelines suggest they should be considered an ephemeral component due to heavy post-settlement mortality and not therefore representative of prevailing bottom conditions (OSPAR 2004). OSPAR (2004) further states that "Should juveniles appear among the ten most dominant organisms in the data set, then statistical analyses should be conducted both with and without these in order to evaluate their importance". As juveniles of Amphiuridae and Spatangoida appeared in the top ten most dominant taxa across White Cross, a 2STAGE analysis was conducted to compare the two data sets (with and without juveniles) which revealed a 92 % of similarity between the two and therefore juveniles were retained in the dataset for all further analyses and discussion.

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

6.4.3. Multivariate Statistics

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

The PRIMER v7 software package (Clarke & Gorley 2015) was utilised to undertake the multivariate statistical analysis on the biotic macrobenthic dataset.

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

6.4.4. Determining EUNIS Classifications

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

6.5. Seabed Imagery Analysis

All seabed imagery analysis was undertaken using the Bio-Image Indexing and Graphical Labelling Environment (BIIGLE) annotation platform (Langenkämper et al. 2017) and in line with JNCC epibiota remote monitoring interpretation guidelines (Turner et al. 2016) with consideration of the latest NMBAQC/JNCC Epibiota Quality Assurance Framework (QAF) guidance and identification protocols.

A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of Annex I reef habitats as detailed in Table 9 and Table 10. The annotation label tree, provided as Appendix VIII, 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. Any images that were designated as a low resemblance stony reef were further assessed in line with (Golding et al. 2020).

Table 9 Characteristics of stony reef (Irving 2009).

<table>
<tr><th rowspan="2">Characteristic</th><th colspan="4">'Reefiness'</th></tr>
<tr><th>Not a Reef</th><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td>Composition (proportion of boulders/cobbles (>64 mm))</td><td>< 10 %</td><td>10 - 40 % matrix supported</td><td>40 - 95 %</td><td>> 95 % clast-supported</td></tr>
<tr><td>Elevation</td><td>Flat seabed</td><td>< 64 mm</td><td>64 mm - 5 m</td><td>> 5 m</td></tr>
<tr><td>Extent</td><td>< 25 m²</td><td colspan="3">>25 m²</td></tr>
<tr><td>Biota</td><td>Dominated by infaunal species</td><td colspan="3">> 80 % of species present composed of epibiotal species</td></tr>
</table>

Table 10 Characteristics of *Sabellaria spinulosa* reef (Gubbay 2007).

Characteristic	'Reefiness'			
	Not a Reef	Low	Medium	High
Elevation (cm)	< 2	2 - 5	5 – 10	> 10
Extent (m^2)	< 25	25 – 10,000	10,000 – 1,000,000	> 1,000,000
Patchiness (% Cover)	< 10	10 - 20	20 – 30	> 30

6.5.1. Tier 1 Analysis

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

- Broadscale Habitat (BSH) type.
- EUNIS habitat classification.
- Substrate type (and percentage cover in 10% intervals).
- The presence of any Annex I habitats, Features of Conservation Importance (FOCI) or Habitats of Conservation Importance (HOCI).
- The presence of any visible impacts or other modifiers (such as discarded fishing gear or marine litter (as per the Marine Strategy Framework Directive (MSFD) categories), visible physical damage to the seabed, evidence of strong currents, non-native species, etc.).
- Image quality categories (including "Not Analysable" category).

Depending on the presence of reef, this also included:

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

The substratum observed in each still image was recorded as a percentage cover substratum type where possible (based on substrate types from NMBAQC/JNCC Quality Assurance Framework). Determination of sediment type (such as coarse, mixed, sand etc.) was facilitated using the adapted Folk sediment trigon (Long 2006) incorporated into a sediment category correlation table. Percentage cover of the different substrate types was used to determine and assign EUNIS codes and BSH.

6.5.2. Tier 2 Analysis

The second stage, "Tier 2", consisted of annotating biota within an image on a presence/absence basis using point annotations. This was achieved by using a customised OEL label tree (based on the Collaborative and Annotation Tools for Analysis of Marine Imagery (CATAMI)) (Althaus et al. 2015)).

6.6. Habitat/Biotope Assignment

All grab samples for which PSD and macrobenthic data were available were assigned a EUNIS habitat and/or biotope based on the latest JNCC guidance (Parry 2019). These were utilised alongside the imagery analysis to assess the various habitats and biotopes encountered across the survey area.

6.7. Habitat / Biotope Mapping

All mapping processes were conducted in ESRI ArcPro Version 3.0.0. All seabed imagery assigned a EUNIS habitat in BIIGLE was utilised alongside the acoustic information and ground-truthed data from the grab samples to manually delineate the boundaries (polygons) of the various habitats encountered across the survey area. Confidence scores were assigned to each polygon to give an indication of their accuracy. A value of 1 (low confidence) or 2 (high confidence) was assigned depending on the following:

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

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

7. Results

7.1. Particle Size Distribution Data

The composition of sediment data at each grab sampling stations throughout the survey area are mapped in Figure 5. Grab sampling logs and sample photos for 134 stations are provided in Appendices II and III respectively and full PSD data has been provided in Appendices IX and X.

7.1.1. Sediment Type

Sediment types at each grab sampling station as classified by the (Folk 1954) classification are summarised in Appendix X and illustrated in Figure 4. Despite some variation in sediment types between stations, the majority of stations were dominated by sand. Mud content was highest close to land at ST01 and also high at ST38. Gravel content was low overall but variable along the ECR with a few stations along the route found to contain > 50 % gravel composition (ST03, ST07, ST09, ST10, ST102, ST118, and ST123). The majority of samples were comprised of sand representing EUNIS BSH A5.2 (Sand and Muddy Sand). Some stations were classified as Sandy Gravel (sG) or Gravelly Sand (gS) representing EUNIS BSH A5.1 (Coarse Sediment); 7 stations were classified as Muddy Sandy Gravel (msG) and 4 stations as Gravelly Muddy Sand (gmS) representing EUNIS BSH A5.4 (Mixed Sediment) (Figure 5).

Most of the sediments recorded were classified as moderately sorted (40 %) and comprised almost entirely of sand. Remaining stations classified as moderately well sorted (11 %), poorly (30 %) to very poorly sorted (19 % of stations). This variation results from a mixed composition of different size fractions of all three principal sediment types (gravel, sand, and mud).

7.1.2. Sediment Composition

The percentage contribution of gravels (> 2 mm), sands (0.63 mm to 2 mm), and fines (< 63 µm) at each station are presented in Figure 6. Sand was the main sediment fraction present at most stations, comprising the largest percentage contribution across the survey area. The mean proportion (± Standard Error, SE) of sands across all stations was 85 % (± 1.5), the mean (±SE) mud, and gravel content across the survey area was 6 % (± 0.7) and 9 % (± 1.4) respectively. Sand content was greatest at station ST078 and lowest at ST09. The mean grain size at sampling stations ranged from 34.83 µm at station ST01 to 5,559 µm at station ST123 (Figure 7).

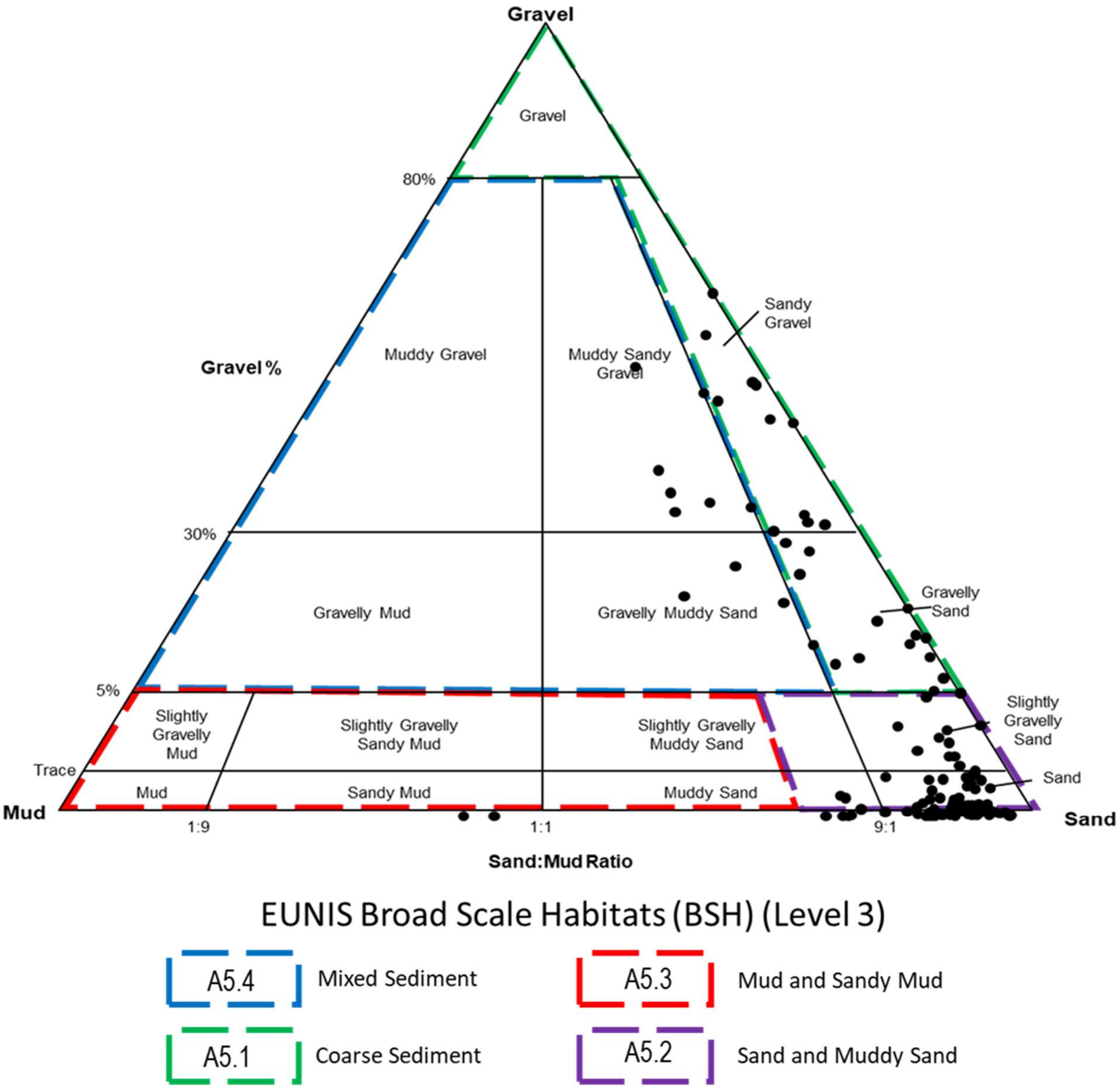

Figure 4 Folk (Folk 1954) triangle classifications of sediment gravel percentage and sand to mud ratio of samples collected across the survey area, overlain by the modified Folk triangle for determination of mobile sediment BSHs under the EUNIS habitat classification system (adapted from (Long 2006)).

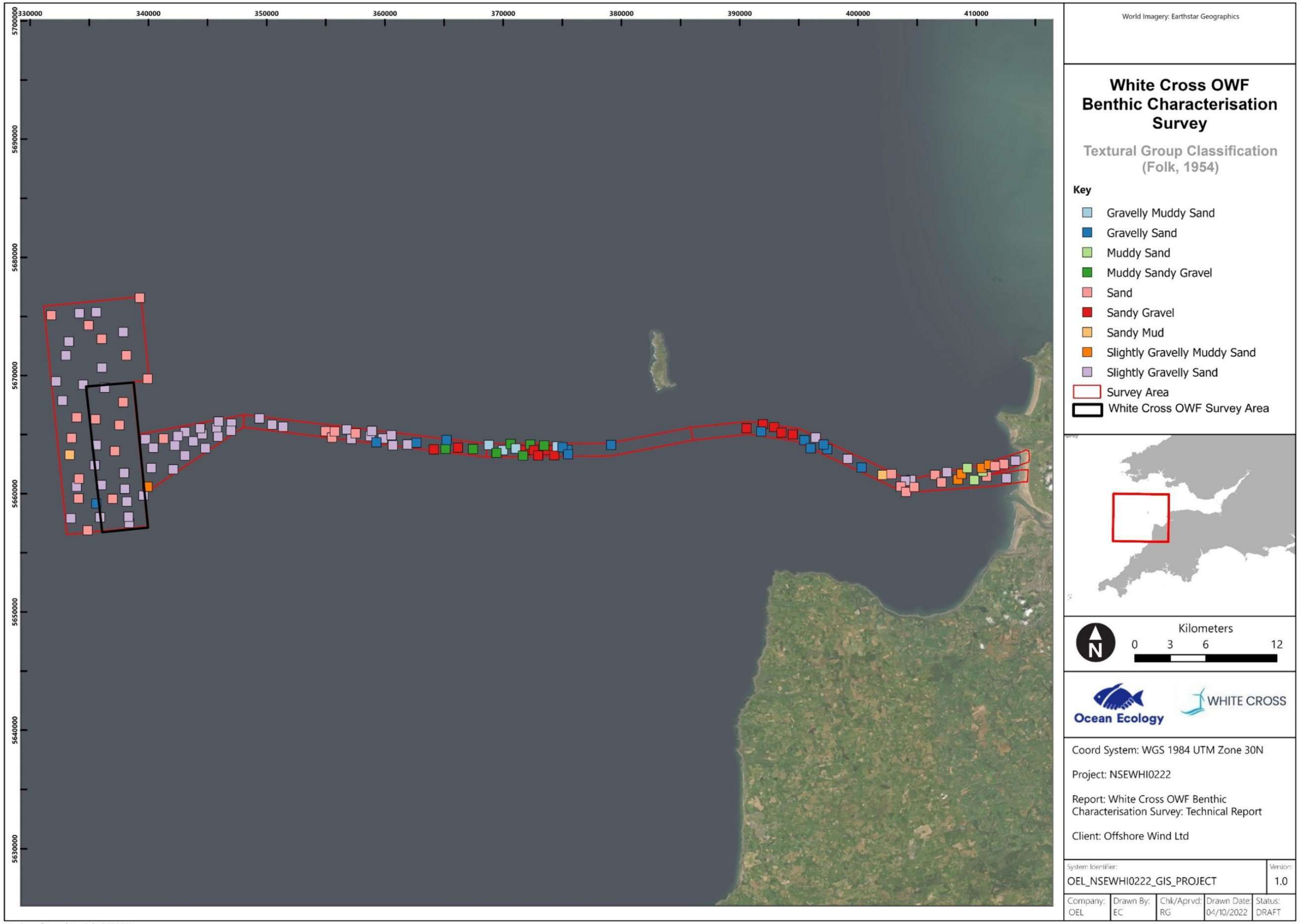

Figure 5 Textural group classification at each sampling station across the survey area.

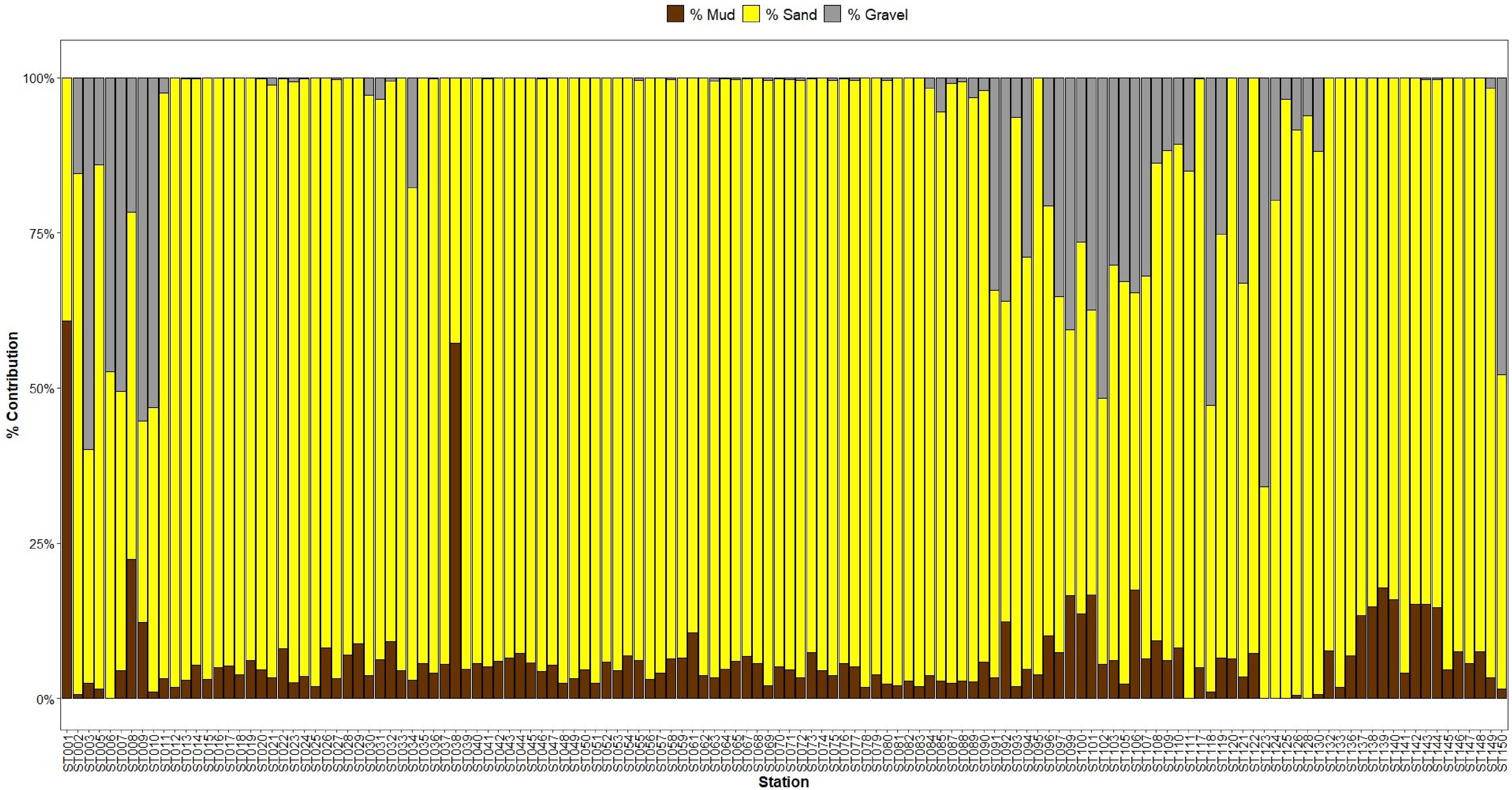

Figure 6 Percentage volume of gravel (G), sand (S), and mud (M) at each sampling station across the survey area.

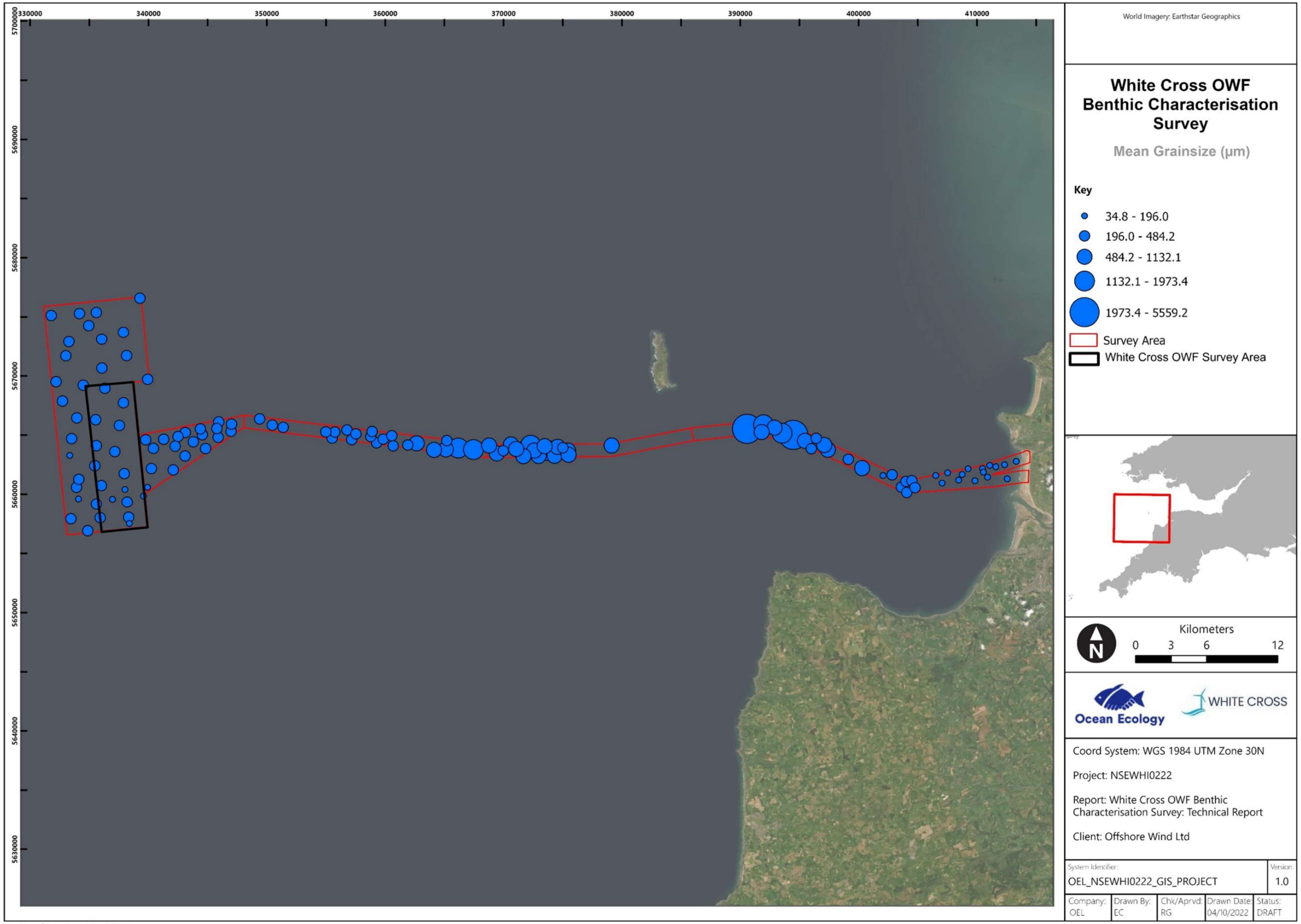

Figure 7 Mean grain size (µm) at each sampling station across the survey area.

7.2. Sediment Chemistry

Sediment samples for chemical contaminant analysis were collected from 15 stations sampled across the survey area. Grab samples taken for chemical analyses were analysed for Total Organic Carbon (TOC) and Total Organic Matter (TOM) (Section 7.2.1), heavy and trace metals (Section 7.2.2), Polycyclic Aromatic Hydrocarbon (PAH) and Total Hydrocarbon Content (THC) (Section 7.2.3), Organotins (Section 7.2.4), and Polychlorinated Biphenyls (PCBs) (Section 7.2.5). Raw sediment chemistry data are provided in Appendix XI (provided separately).

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

TOC concentrations ranged from < 0.02 % at ST01 to 1.16 % at ST09 with an average value (± SE) of 0.30 ± 0.07 % across the survey area (Figure 8). In general, relatively higher TOC values were recorded at stations located in the middle reaches of the survey area, compared to the stations located to the east and more offshore. No clear trend was observed between mud content in the sediment and percentage contribution of TOC.

TOM concentrations ranged from 1.2 % at stations ST013, ST018 and ST019 to 4.9 % at ST009 with an average value (± SE) of 1.912 ± 0.32 % across the survey area (Figure 9).In general, relatively lower TOM values were recorded at stations located to the east and more offshore compared to stations located in the middle reaches and towards the shore of the survey area. No clear trend was observed between mud content in the sediment and percentage contribution of TOM.

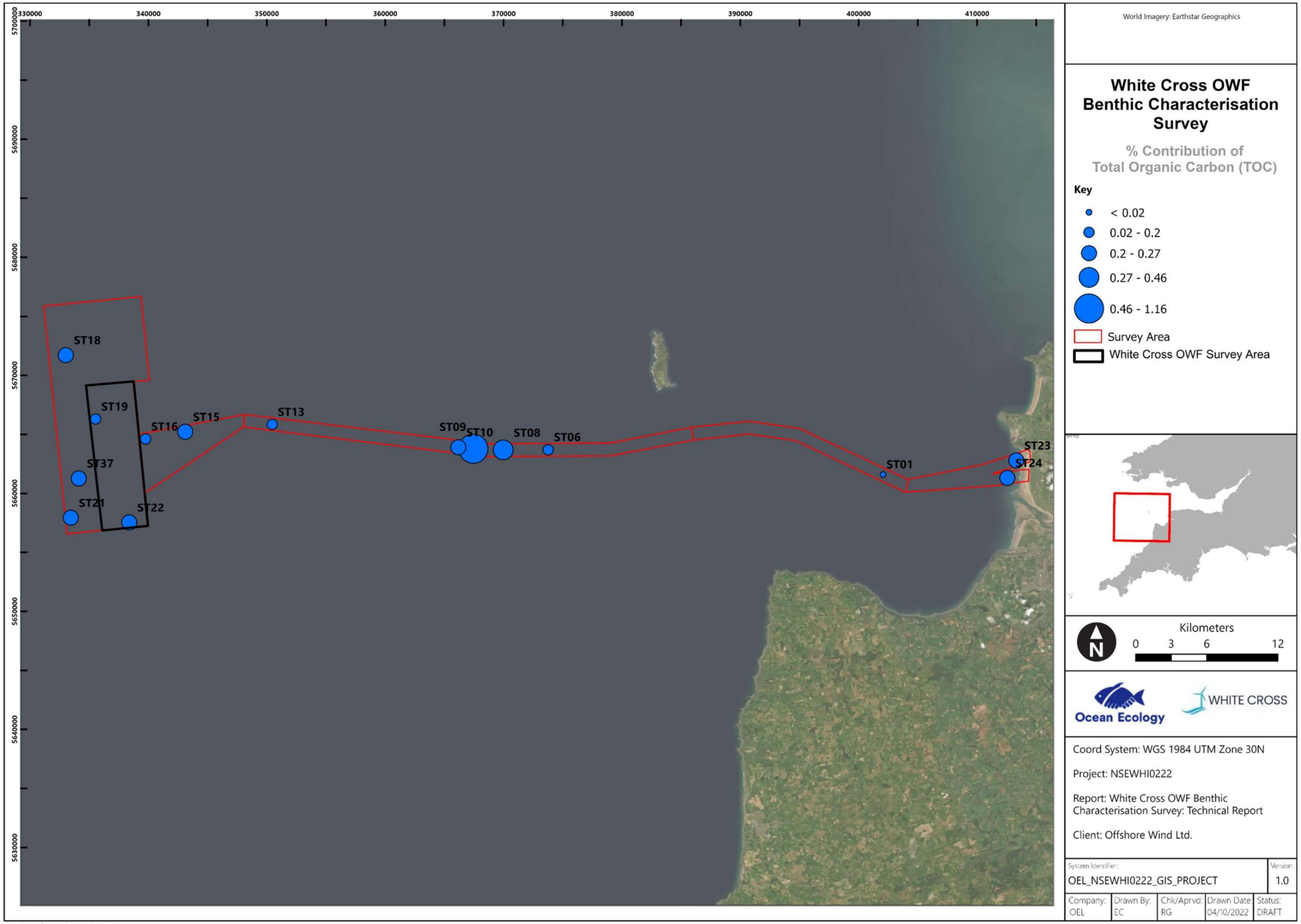

Figure 8 Percentage contribution of TOC across the survey area.

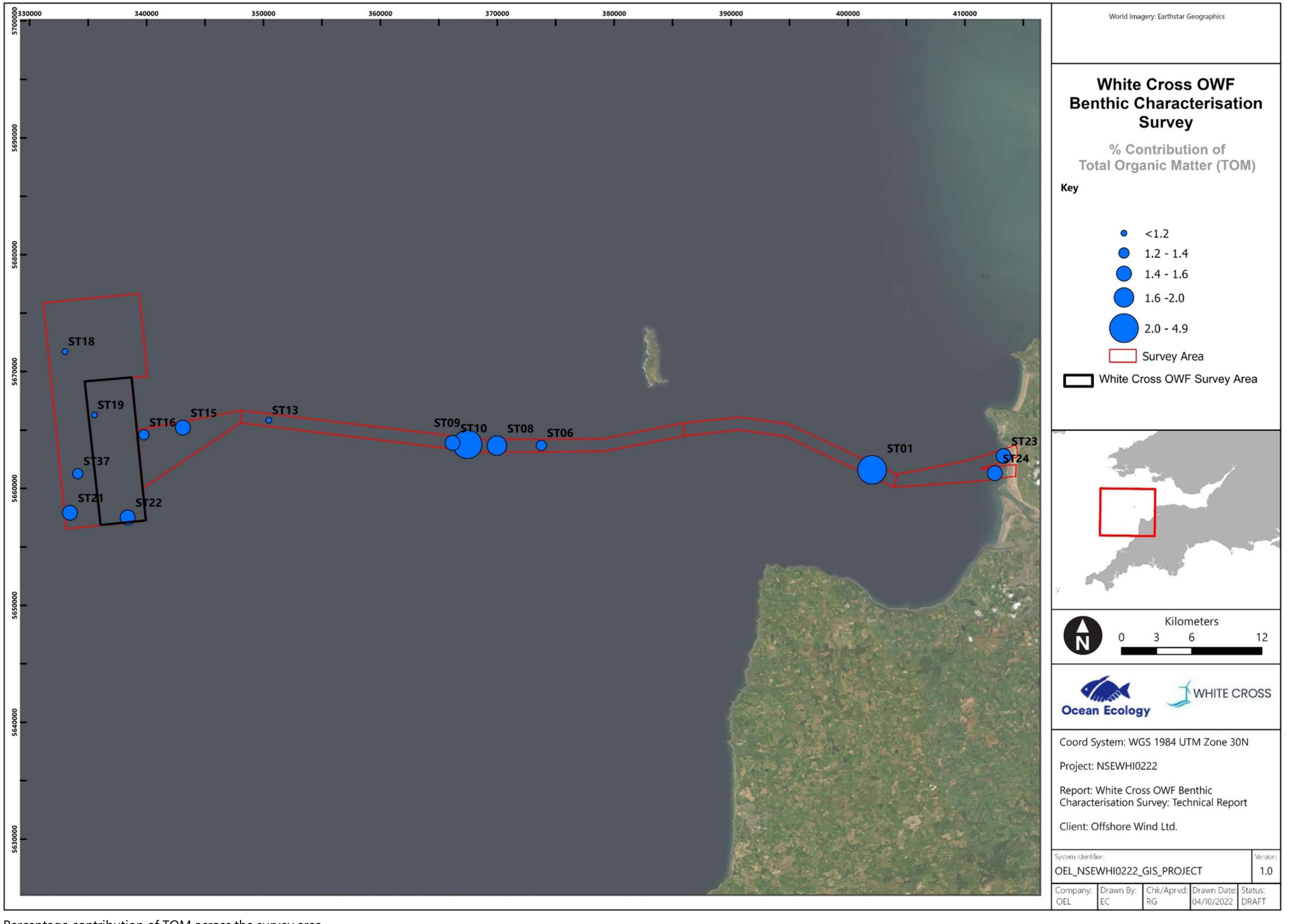

Figure 9 Percentage contribution of TOM across the survey area.

7.2.2. Heavy and Trace Metals

A total of eight main heavy and trace metals were analysed from sediments taken at each of the 15 sampling stations. These were: Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn).

Raw data for the eight main heavy and trace metals (dry-weight concentration, mg kg^{-1}) are shown in Table 11 together with available reference levels (see Section 6.2.2 for details on national and international reference levels). Two of the main heavy and trace metals exceeded Cefas AL 1, these were As (mean value ± SE across survey area of 21.4 ± 3.88 mg kg^{-1}) at four stations: ST06, ST08, ST09 and ST10 and Ni (mean value ± SE across survey area of 10.9 ± 1.24 mg kg^{-1}) at ST01. The mean value for As across the survey site was calculated to be above the Cefas AL 1 refence level. Levels of As also exceeded the PEL reference level at two survey stations. However, As and Ni concentrations were well below the Cefas AL 2 threshold level. Of notice, Cd was below detection limit (0.04 mg kg^{-1}) at seven of the 15 stations sampled.

The most abundant metal was Zn which ranged from 27.9 mg kg^{-1} at ST37 to 108 mg kg^{-1} at ST01, however, it was always recorded below any of the reference levels (Table 11). Also recorded in relatively high concentrations was As, ranging between 11.0 mg kg^{-1} at ST22 and 54.2 mg kg^{-1} at ST06. The third most abundant metal was Pb which varied from 9.20 mg kg^{-1} at ST19 and ST21 and 36.0 mg kg^{-1} at ST01, these Pb levels did not exceed reference levels. Similarly, Cr was detected at higher concentrations (mean value across survey area of 12.7 mg kg^{-1} ±1.25 mg kg^{-1}) but also did not exceed reference levels.

Figure 10 illustrates the spatial distribution of these four metals across the survey area. Typically, Zn, Pb, Cr, and As had lower concentrations at stations located more offshore with no obvious east-west concentration gradient.

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

Table 11 Main heavy and trace metals (mg kg^{-1}) in sediments. Shading indicates values above AL1.

Analyte	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
ST01	16.20	0.07	24.70	16.40	0.14	21.60	36.00	108.00
ST06	54.20	< 0.04	12.80	7.10	0.03	12.30	17.00	38.30
ST08	40.70	0.06	12.60	8.30	0.05	11.60	17.60	50.80
ST09	22.70	0.06	22.80	13.40	0.09	18.90	29.30	89.30
ST10	49.80	< 0.04	10.10	7.50	0.03	13.60	13.60	37.40
ST13	13.60	< 0.04	9.40	4.50	0.03	6.80	10.70	33.40
ST15	13.60	< 0.04	10.40	4.90	0.02	7.10	10.00	41.60
ST16	12.10	0.05	10.40	4.30	0.02	6.90	9.30	32.30
ST18	13.10	< 0.04	10.80	5.20	0.02	7.10	10.40	35.80
ST19	12.10	< 0.04	10.30	4.70	0.02	6.70	9.20	34.80
ST21	12.00	0.06	10.00	4.90	0.02	6.30	9.20	28.60
ST22	11.00	0.06	10.20	4.90	0.02	7.10	9.60	33.50
ST23	18.60	0.05	11.10	6.80	0.02	13.70	16.00	69.00
ST24	19.30	0.04	11.00	6.20	0.02	13.70	15.90	65.40
ST37	11.40	< 0.04	14.00	4.20	0.02	9.30	9.70	27.90
Min	11.00	0.04	9.40	4.20	0.02	6.30	9.20	27.90
Max	54.20	0.07	24.70	16.40	0.14	21.60	36.00	108.00
Mean	**21.36**	**0.06**	**12.71**	**6.89**	**0.04**	**10.85**	**14.90**	**48.41**
Standard Error	3.75	0.00	1.20	0.91	0.01	1.24	2.05	6.20
CEFAS AL1	20	0.4	40	40	0.3	20	50	130
CEFAS AL2	100	5	400	400	3	200	500	800
OSPAR BAC	25	0.31	81	27	0.07	36	38	122
ERL	8.2*	1.2	81	34	0.15	21*	47	150
TEL	7.24	0.7	52.3	18.7	0.1	-	30.2	124
PEL	41.6	4.2	160	108	0.7	-	112	271

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

Table 12 Number of stations across the White Cross survey area exhibiting elevated heavy and trace metals levels in comparison with OSPAR, CEFAS and Canadian/International Sediment Quality Guidelines.

Metal	OSPAR		CEFAS		Canadian SQG	
	BAC	ERL	AL1	AL2	TEL	PEL
As	3	15*	4	0	15	2
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	1	0
Hg	2	0	0	0	1	0
Ni	0	1*	1	0	-	-
Zn	0	0	0	0	0	0

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

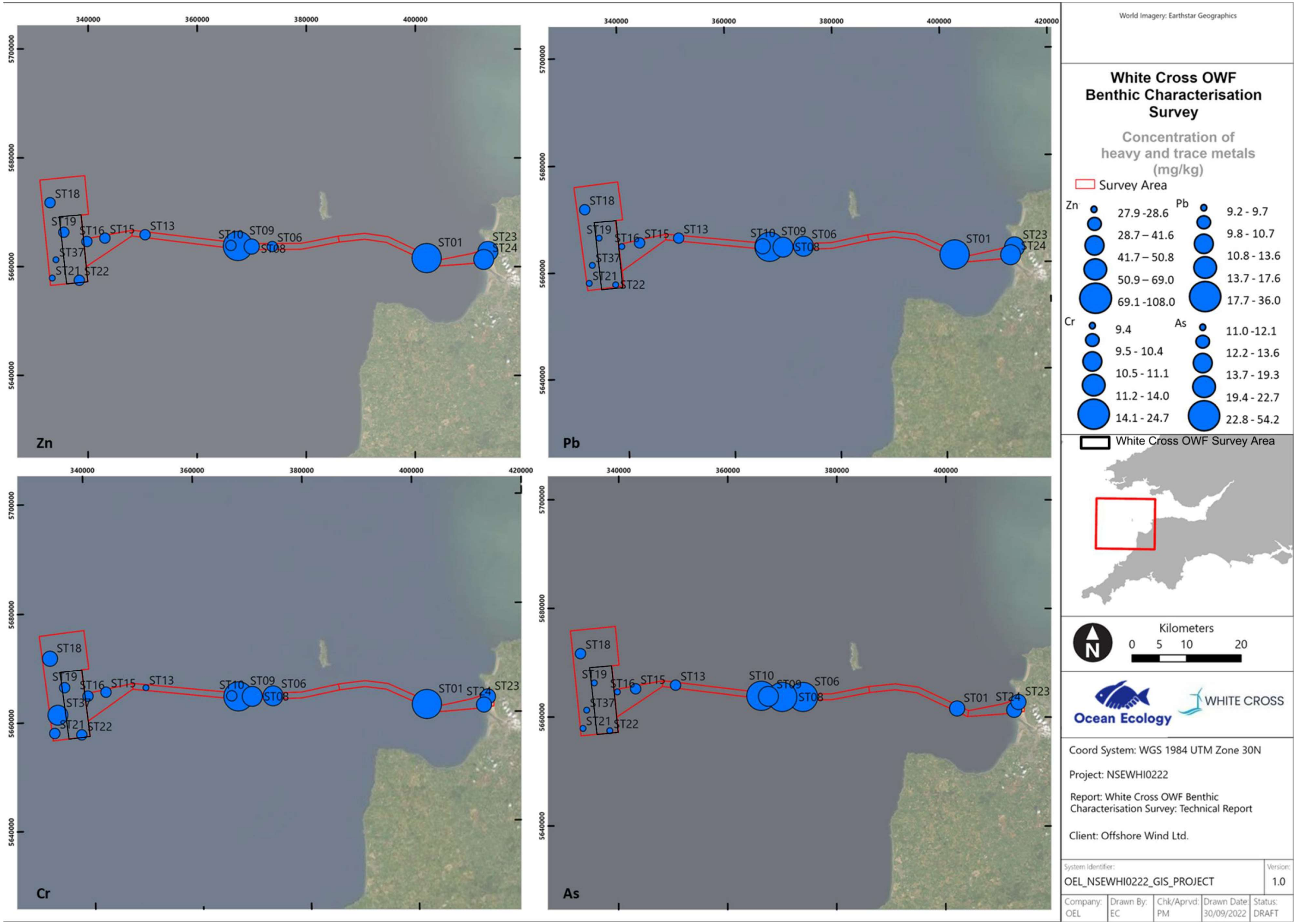

Figure 10 Concentration of the key heavy and trace metals sampled across the survey area. Note different scales for each chemical.

7.2.3. Polycyclic Aromatic Hydrocarbons (PAHs) and Total Hydrocarbons (THC)

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 15 contaminant sub-samples collected.

The results of the PAHs analysis undertaken are reported in Appendix XI. PAH concentrations were compared to Cefas AL1 (no Cefas AL2 available for PAHs), OSPAR BAC levels and ERLs, and TEL and PEL where possible (Table 13). The Cefas AL1 reference level was exceeded at ST09 for Fluoranthene. Both the BAC and TEL reference levels were exceeded at ST08 and ST09 for multiple PAHs including Naphthalene, Phenanthrene, Pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo[a]anthracene, Benzo[a]pyrene, Dibenzo[ah]anthracene, Fluoranthene, and Fluorene (Table 13 and Table 14). However, when averaged across the survey area, only Naphthalene concentrations (mean value across survey area of 8.19 $\mu g\ kg^{-1}$ ± 4.03 $\mu g\ kg^{-1}$) exceeded the BAC reference level.

The most abundant PAHs were: Fluoranthene with a mean concentration across the survey area of 16.61 $\mu g\ kg^{-1}$ ± 8.01 $\mu g\ kg^{-1}$ and a maximum concentration of 122.00 $\mu g\ kg^{-1}$ at ST09, Phenanthrene with a mean concentration across the survey area of 13.25 $\mu g\ kg^{-1}$ ± 6.25 $\mu g\ kg^{-1}$ and a maximum concentration of 98.00 $\mu g\ kg^{-1}$ at ST09 and Pyrene with a mean concentration across the survey area of 13.07 $\mu g\ kg^{-1}$ ± 6.23 $\mu g\ kg^{-1}$ and a maximum concentration of 95.00 $\mu g\ kg^{-1}$ at ST09.

PAHs with an elevated concentration above refence levels were only found at ST09 and ST08. All other stations saw PAHs with levels below all reference levels (Table 13 and Table 14). In general PAHs showed no obvious trend and no clear east-west gradient was observed. Higher concentrations of PAHs were observed as ST09 and ST08 which are located in the middle of the survey area cable route.

To determine the origin source of PAH compounds in sediments, the ratio between LMW and HMW PAHs was calculated. Based on this ratio all stations were characterised by PAHs of pyrogenic origin (LMW/HMW < 1). Similarly, the ratios of Phenanthrene / Anthracene (Ph/Ant) indicated a pyrogenic origin of PAHs as this ratio was below 10 at all stations. However, it should be noted that Anthracene concentrations were below detection limit at 6 of the 15 stations and therefore it was not possible to calculate Ph/Ant at these locations. Therefore, the Fluoranthene / Pyrene ratio (Fl/Py) was calculated to determine the origin of PAHs. At all stations the Fl/Py ratio was higher than one at all stations indicating a pyrogenic origin source of PAHs across the survey area (Figure 11).

Table 13 Summary of PAH concentrations (μg kg^{-1}) in sediments. Shading indicates values above reference levels.

Analyte	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene
Min	< 1	< 1	< 1	< 1	< 1	< 1
Max	***60***	***7.44***	***13.00***	***25.60***	***98.00***	***18.3***
Station of Max	ST09	ST09	ST09	ST09	ST09	ST09
Cefas AL1	**100**	**100**	**100**	**100**	**100**	**100**
Cefas AL2	-	-	-	-	-	-
BAC	**8**	-	-	-	**32**	**5**
ERL	**160**	-	-	-	**240**	**85**
TEL	**34.6**	**5.87**	**46.9**	**21.2**	**86.7**	**46.9**
PEL	**391**	**128**	**245**	**144**	**544**	**245**

Analyte	Fluoranthene	Pyrene	Benzo[a]anthracene	Chrysene (inc. Triphenylene)	Benzo[b]fluoranthene	Benzo[k]fluoranthene
Min	2.09	< 1	< 1	1.30	1.67	< 1
Max	***122.0***	***95.0***	***60.90***	***95.0***	***102.0***	***40.8***
Station of Max	ST09	ST09	ST09	ST09	ST09	ST09
Cefas AL1	**100**	**100**	**100**	**100**	-	-
Cefas AL2	-	-	-	-	-	-
BAC	**39**	**24**	**16**	**20**	-	-
ERL	**600**	**665**	**261**	**384**	-	-
TEL	**113**	**153**	**74.8**	**108**	-	-
PEL	**1494**	**1398**	**693**	**846**	-	-

Analyte	Benzo[e]pyrene	Benzo[a]pyrene	Perylene	Ideno[123,cd]pyrene	Dibenzo[a,h]anthracene	Benzo[ghi]perylene
Min	1.23	< 1	< 1	1.05	< 1	1.12
Max	***74***	***79.30***	***21.8***	***79.7***	***17.3***	***77.4***
Station of Max	ST09	ST09	ST09	ST09	ST09	ST09
Cefas AL1	-	**100**	-	**100**	**100**	**100**
Cefas AL2	-	-	-	-	-	-
BAC	-	**30**	-	**103**	-	**80**
ERL	-	**430**	-	-	-	-
TEL	-	**88.8**	-	-	**6.22**	-
PEL	-	**763**	-	-	**135**	-

Table 14 Number of stations across the survey area exhibiting elevated PAHs levels in comparison with OSPAR and Canadian Sediment Quality Guidelines (CSQG). Fluoranthene exceeded Cefas AL1.

Analyte	Cefas	OSPAR		CSQG	
	AL1	BAC	ERL	TEL	PEL
Acenaphthene	0	-	-	1	0
Acenaphthylene	0	-	-	1	0
Anthracene	0	2	0	0	0
Benzo[a]anthracene	0	2	0	0	0
Benzo[a]pyrene	0	1	0	0	0
Benzo[b]fluoranthene	-	-	-	-	-
Benzo[ghi]perylene	0	0	0	-	-
Benzo[e]pyrene	-	-	-	-	-
Benzo[k]fluoranthene	-	-	-	-	-
Chrysene	0	0	0	0	0
Dibenzo[ah]anthracene	0	-	-	1	0
Fluoranthene	1	2	0	1	0
Fluorene	0	-	-	1	0
Indeno[1,2,3-cd]pyrene	0	0	0	-	-
Naphthalene	0	2	0	1	0
Perylene	0	-	-	-	-
Phenanthrene	0	2	0	1	0
Pyrene	0	2	0	0	0

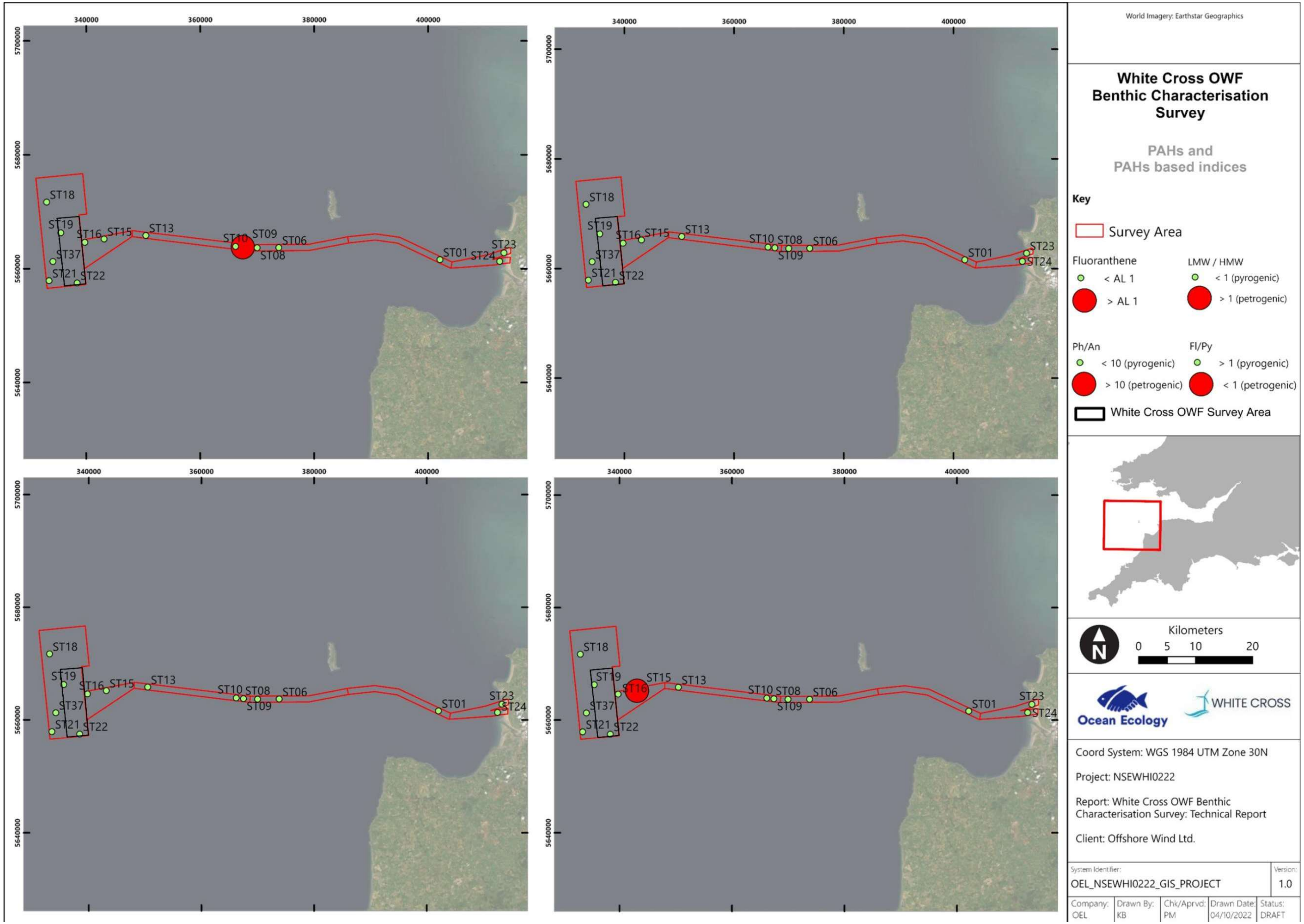

Figure 11 Concentration (µg kg^{-1}) of Fluoranthene against Cefas AL1 and PAHs based indices across the survey area. Note different scales for each chemical.

7.2.4. Organotins

The concentrations of two organotins (Dibutyltin (DBT) and Tributyltin (TBT)) were analysed from the sediment taken at each of the 15 station and reported in Appendix XI.

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}.

7.2.5. Polychlorinated Biphenyls (PCBs)

All 25 PCBs congeners were analysed from the sediments taken at each of the 15 stations and reported in Appendix XI.

No Cefas Action Levels exist for each individual PCBs, however most PCBs had concentrations below the detection limit of 0.00008 mg kg^{-1} across the survey area. Cefas Action Levels do exist for the sum of all 25 PCBs congeners (Σ25PCBs) and for the sum of the 7 ICES PCBs (ΣICES7) as reported in Table 15. The 7 ICES PCBs have been selected to cover the range of toxicological properties of the group. Both Σ25PCBs and ΣICES7 were above Cefas AL1 at station ST01, while only Σ25PCBs was above Cefas AL1 at ST10. At all stations both Σ25PCBs and ΣICES7 were below Cefas AL 2.

Table 15 PCBs (mg kg^{-1}) against Cefas AL1 and AL2. Shading indicates concentrations above AL1.

Station	Σ25PCBs	ΣICES7
ST01	0.039	0.014
ST06	0.000	0.000
ST08	0.004	0.002
ST09	0.012	0.004
ST10	0.023	0.008
ST13	0.010	0.003
ST15	0.000	0.000
ST16	0.000	0.000
ST18	0.000	0.000
ST19	0.000	0.000
ST21	0.000	0.000
ST22	0.000	0.000
ST23	0.000	0.000
ST24	0.015	0.004
ST37	0.002	0.001
CEFAS AL1	0.02	0.01
CEFAS AL2	0.2	-

7.3. Macrobenthos

7.3.1. Macrobenthic composition

A diverse macrobenthic assemblage was identified across the survey area from the 134 macrobenthic samples collected, with a total of 12,651 individuals and 487 taxa recorded. The mean (± SE) number of taxa per station was 27 ± 2, mean (± SE) abundance per station was 94 ± 11 and mean (± SE) biomass per station was 0.3945 ± 0.1205 gAFDW.

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

As shown in Figure 12, juvenile specimens of the brittle star family Amphiuridae were the most abundant taxon sampled accounting for 11.4 % of all individuals recorded. They were also the most frequently occurring taxon recorded in 72.4 % of samples and accounted for the greatest average density per sample. Other key taxa were the Ross worm *S. spinulosa*, which accounted for the maximum abundance per sample (Figure 12c), and the two-toothed Montagu shell *Kurtiella bidentata* which was second to the juveniles of Amphiuridae in contribution to abundance and average density per sample.

Figure 13 illustrates the relative contributions to total abundance, diversity, and biomass of the major taxonomic groups in the macrobenthic community sampled across the survey area. Annelida taxa contributed most to abundance as they accounted for approximately 37 % of all individuals recorded, followed by Echinodermata taxa accounting for the 25 %. Annelida taxa contributed the most to the overall diversity of the macrobenthic assemblages at 44 %, while Echinodermata taxa dominated the biomass and accounted for the 52% of the total biomass (Figure 13).

The sampling stations with the highest abundance were stations ST118, ST009 and ST006 all of which dominated by Annelida taxa (Figure 14). Sampling stations with the highest richness (number of taxa) were stations ST118, ST003 and ST106 with specimens belonging to 152, 105 and 104 different taxa, respectively (Figure 14). Biomass ranged between 0.0021 and 15.2515 gAFDW per sample, with the highest value found at station ST118 due to high Echinodermata biomass (Figure 14).

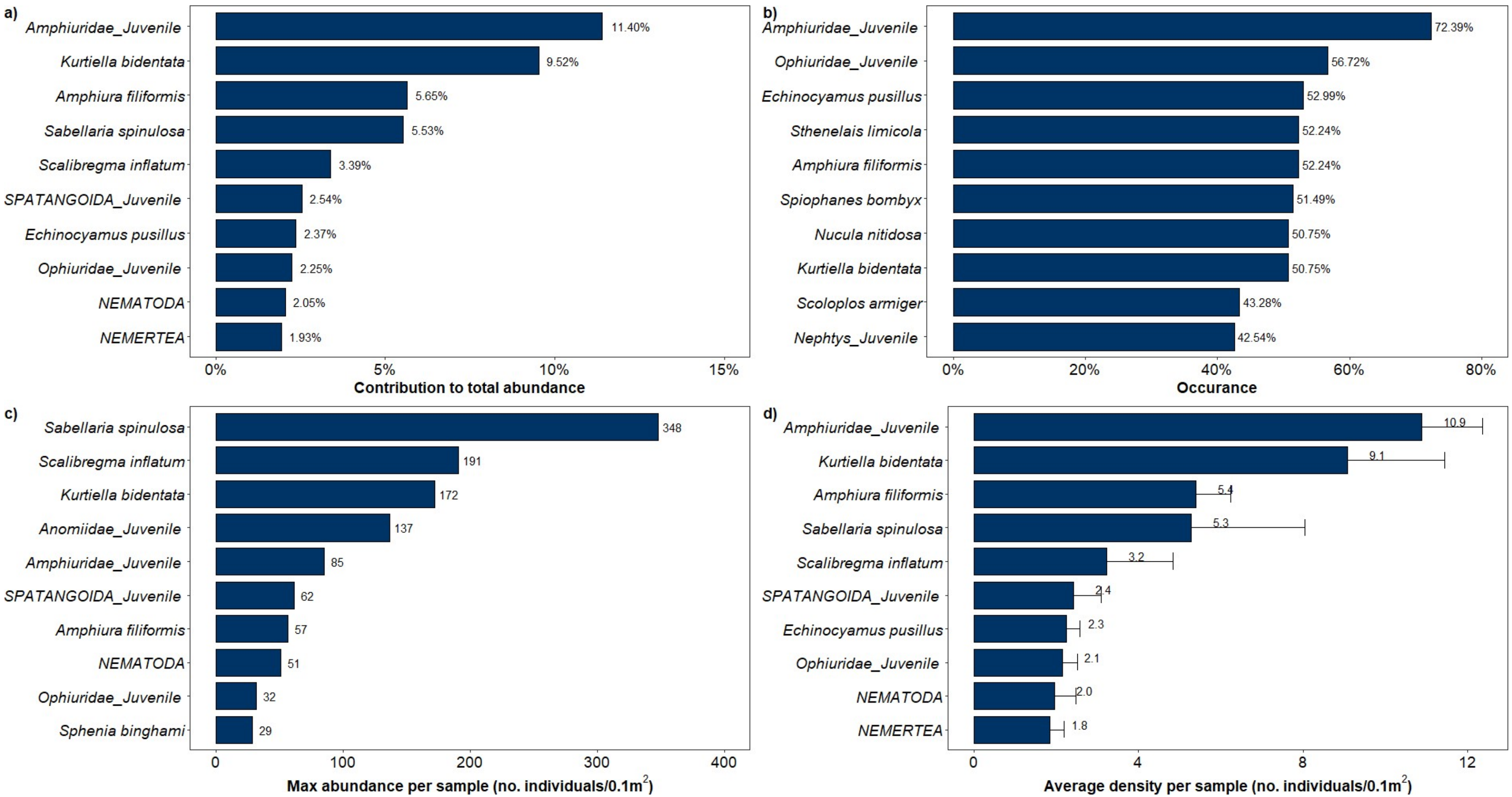

Figure 12 Percentage contributions of the top 10 macrobenthic taxa to total abundance (a) and occurrence (b) from samples collected across the survey area. Also shown are the maximum densities of the top 10 taxa per sample (c) and average densities of the top 10 taxa per sample (d).

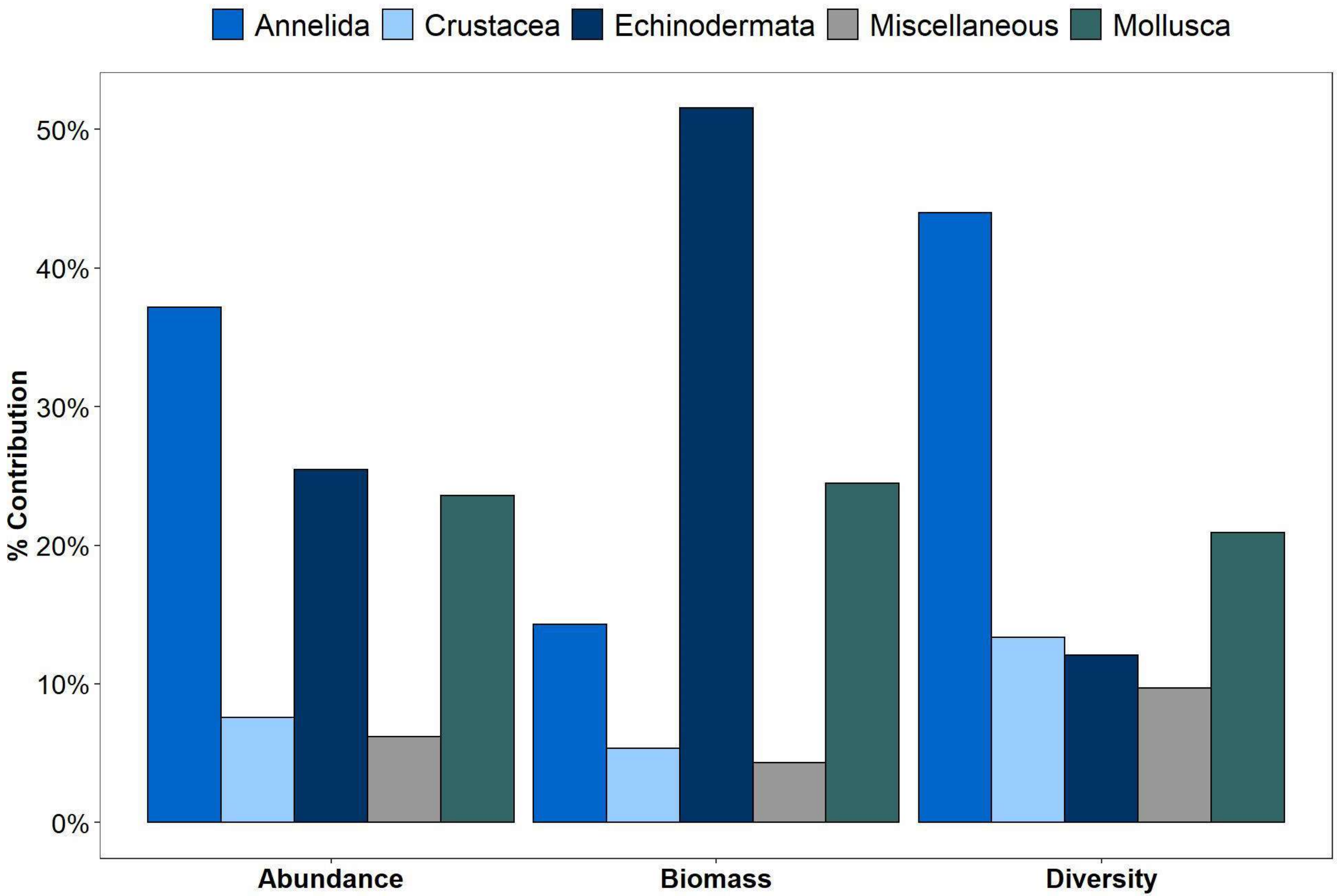

Figure 13 Relative contribution of the major taxonomic groups to the total abundance, diversity and biomass of the macrobenthos sampled across the survey area. Abundance counts exclude colonial taxa.

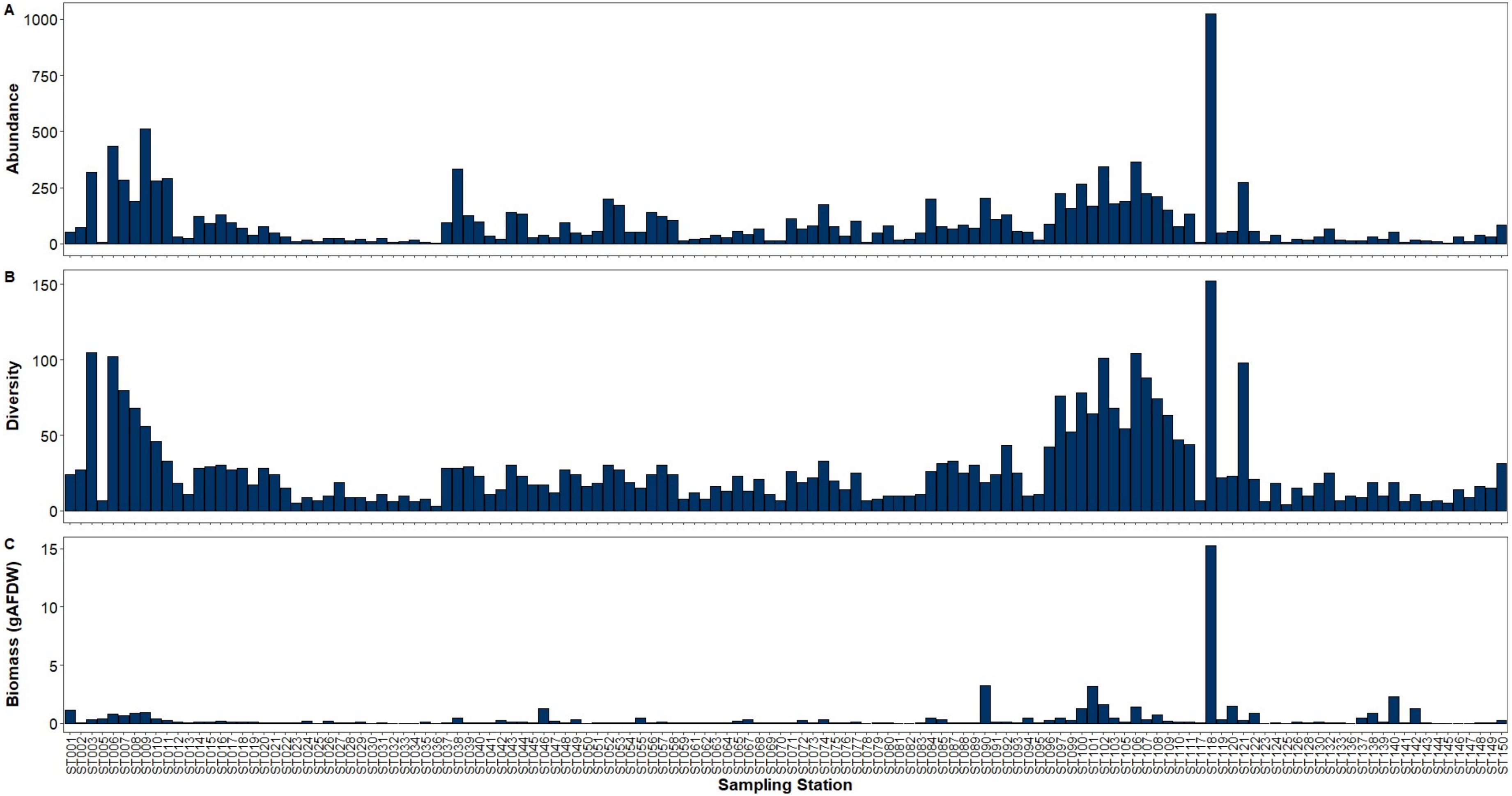

Figure 14 Abundance, diversity and biomass (gAFDW) per station across the White Cross survey area.

7.4. Macrobenthic Groupings

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

Cluster analysis of the macrobenthic data was performed on a Bray-Curtis similarity matrix to analyse the spatial similarities in macrobenthic communities recorded across all sampled stations. The dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF (similarity profile routine) permutation test of all nodes within the dendrogram, identified 22 statistically significantly similar groups ($p > 0.05$) and 6 outlier stations that did not belong to any group. A dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF permutation test are provided in Appendix XIV. To enable a broad interpretation of the community present across the survey area, a similarity slice at 31 % was used to amalgamate the 28 SIMPROF groups which yielded to 15 broader macrobenthic groups and 14 outlier stations remaining on their own; 7 of the 15 macrobenthic groups were made of only two or three stations each.

To visualise the relationships between the sampled macrobenthic assemblages, a non-metric multi-dimensional scaling (nMDS) plot was generated on the community abundance data (Figure 15). The nMDS represents the relationships between the communities sampled, based on the distance between sample (station) points. The stress value of the nMDS ordination plot (0.22) indicates that the two-dimensional plot provides a reasonable representation of the similarity between stations, however caution needs to be used when interpreting patterns between and within groups. This relatively high stress value is most likely due to the presence of several groups (clusters) made only of a few stations owning the high diversity in the macrobenthic community observed across the survey area. In general, the degree of clustering of intra-group sample points demonstrates the level of within group similarity (e.g., points within Macrobenthic Group H shows distinct clustering), whilst the degree of overlap of inter-group sample points is indicative of the level of similarity between different Macrobenthic Groups (e.g., Macrobenthic Groups L and K).

SIMPER (similarity percentage analysis) was used to identify the key taxa contributing to the within group similarity of each of the 15 macrobenthic groups; the full SIMPER results are provided in Appendix XV.

Macrobenthic Group A (2 stations) - Characterising taxa present at the two stations (ST024 and ST025) belonging to this group were the hermit crab *Diogenes pugilator* and the amphipod *Bathyporeia elegans*. Average similarity of this group was 35.13 %.

Macrobenthic Group B (2 stations) - The taxa contributing most to similarities between the two sampling stations (ST130 and ST150) within this group (average similarity: 34.57%) were Nemertea, the polychaete *Spiophanes bombyx*, the pea urchin *E. pusillus* and the bivalve *Goodallia triangularis*.

Macrobenthic Group C (2 stations) – Dominant taxa contributing within this group were the tellin *Asbjornsenia pygmaea*, the cumacean *Bodotria scorpioides*, the pea urchin *E. pusillus* and the bivalve *G. triangularis* all together contributing to over 55% of t the within group average similarity of 42.09%.

Macrobenthic Group D (2 stations) – Characterising taxa present at the two stations (ST002 and ST111) belonging to this group (average similarity 40.86 %) were the bivalves *A. pygmea* and *Spisula elliptica*, the pea urchin *E. pusillus* and the polychaete *Glycera lapidum*.

Macrobenthic Group E (3 stations) – Key taxa contributing to the within group average similarity of 39.79 % were the Ross worm *S. spinulosa*, the pea urchin *E. pusillus*, the polychaete *Lumbrineris cingulata* and the brittle star *Amphipholis squamata*. Stations ST003, ST118 ST121 belonged to this group.

Macrobenthic Group F (15 stations) – Characterising taxa present at the stations belonging to this group were the polychaetes *Mediomastus fragilis*, *G. lapidum*, *Syllis garciai* and *Lumbrineris*, venerid bivalves such as *Spisula* sp. and *Diplodonta rotundata*, the pea urchin *Echinocyamus pusillus* along with amphipods such as *Ampelisca spinipes*. Average similarity of this group was 40.11 %.

Macrobenthic Group G (4 stations) – The taxa contributing most to similarities between the four sampling stations within this group (average similarity: 38.15%) were juvenile specimens of Ophiuridae, the bivalve *Nucula nitidosa* and the pea urchin *E. pusillus*.

Macrobenthic Group H (13 stations) – Key taxa contributing to the within group average similarity of 36.22% were the bean-like tellin *Fabulina fabula*, the polychaete *Magelona johnstoni* and juveniles of the venerid bivalve *Spisula*.

Macrobenthic Group I (2 stations) – Only two stations (ST012 and ST128) belonged to this group with the pea urchin *E. pusillus* and juveniles of the heart urchin Spatangoida and of the polychaete *Nephtys* contributing to over 80 % of the within group average similarity of 35.42 %

Macrobenthic Group J (4 stations) –The key taxa contributing to the average similarity of 45.44% were the amphipod *Bathyporeia elegans* and juveniles of the polychaete *Nephtys*.

Macrobenthic Group K (7 stations) – Key taxa characterising this group were the bivalves *Kurtiella bidentata* and *N. nitidosa*, and echinoderms such as juveniles of Amphiuridae and Ophiuridae. Average similarity of this group was 41.79 %.

Macrobenthic Group L (6 stations) – Key taxa contributing to the within group average similarity of 36.22% were the brittle star *Amphiura filiformis* and the polychaetes *Lumbrineris cingulata* and *Scoloplos armiger*.

Macrobenthic Group M (56 stations) – This was the largest of the macrobenthic groups and was characterised by the following key taxa contributing to the within group average similarity of 39.91%: the brittle star *A. filiformis*, the bivalves *K. bidentata, N. nitidosa* and *Abra prismatica*, the polychaetes *Spiophanes bombyx* and *S. armiger* and the pea urchin *E. pusillus*.

Macrobenthic Group N (2 stations) – Only two stations (ST141 and ST144) belonged to this group with the transparent razor shell *Phaxas pellucidus* and the basket shell *Varicorbula gibba* contributing to the within group average similarity of 32.94 %

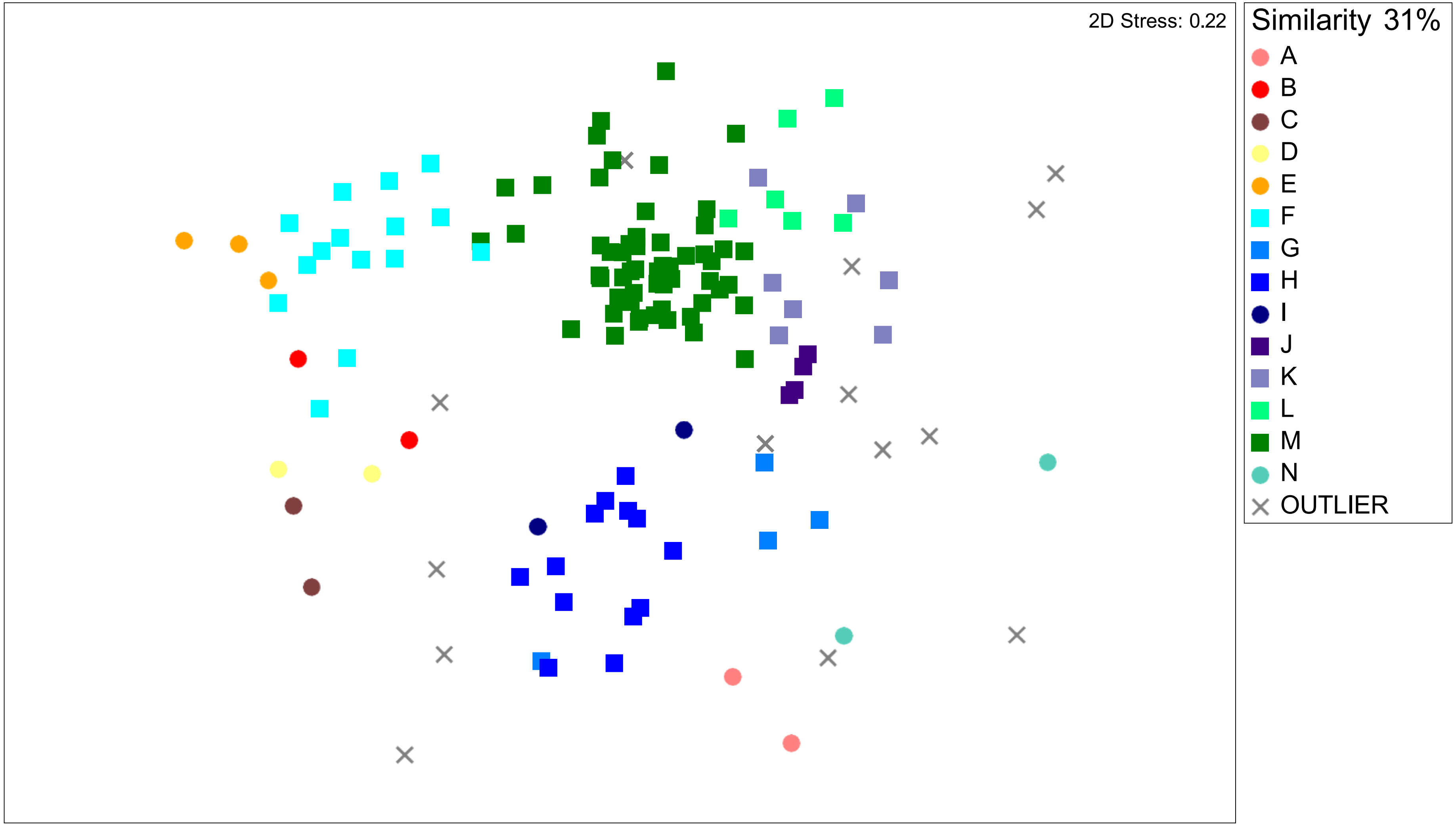

Figure 15 Two-dimensional nMDS ordination of macrobenthic communities sampled across the survey area, based on square root transformed and Bray-Curtis similarity abundance data. Samples symbolised based on similarity slice at 31 %. Circles indicate groups made up of three or less stations, squares indicate groups made up of more than three stations; crosses indicate outliers.

7.4.1. Biotope Assignment

For each of the Macrobenthic Groups determined using cluster analysis and a 31 % similarity slice, biotopes and habitats were assigned in line with JNCC guidance based upon their faunal and physical characteristics (Parry 2019). The spatial distribution of the habitat and biotopes encountered across the survey area is mapped in Figure 16.

All outlier stations were assigned to their corresponding BSH based on sediment analysis as the macrobenthic multivariate analysis did not show any pattern in the community composition that could be used to assign a biotope.

Similarly, most of the macrobenthic groups which were made up of only a handful of stations were assigned to level 4 EUNIS classifications as their macrobenthic assemblages were not dominated by any key taxa typically associated to a biotope. Therefore, macrobenthic groups B, C and D most closely aligned with EUNIS level 4 habitat “A5.14 Circalittoral coarse sediment”, macrobenthic group A was classified as EUNIS “A5.25 Circalittoral fine sand”, while macrobenthic groups G, K and L best aligned with EUNIS level 4 habitat “A5.26 Circalittoral muddy sand”.

Despite only comprising three stations, the community observed in Macrobenthic Group E was very distinctive and most closely aligned with the biotope “A5.142 *Mediomastus fragilis, Lumbrineris spp*. and venerid bivalves in circalittoral coarse sand or gravel”. This biotope is described as typical of circalittoral gravels and/or coarse to medium sands which is consistent with the sediment found at the stations falling into this group. Additionally key characterising taxa of A5.142 such as *M. fragilis, L. cingulata, G. lapidum, E. pusillus,* Nemertea*, S. bombyx, A. squamata, Timoclea ovata* and *Hydroides norvegicus* were all driving community average similarity within macrobenthic group E.

Two biotopes aligned with the community observed within Macrobenthic Group F: “A5.142 *Mediomastus fragilis, Lumbrineris spp.* and venerid bivalves in circalittoral coarse sand or gravel” and “A5.451 Polychaete-rich deep *Venus* community in offshore mixed sediments”. As Macrobenthic Group F was made up of a mixture of stations classified as either “A5.1 coarse sediment” or “A5.4 Mixed sediment” based on PSA data alone, it is not surprising that a mosaic biotope was identified at these locations which reflects local heterogeneities in the seabed. Characterising taxa of this mosaic biotope included *M. fragilis, G. lapidum, E. pusillus,* Nemertea, *Ampelisca spinipes, L. cingulata,* syllid species and venerid bivalves such as *Spisula* and *Diplodonta*.

The biotope that most closely aligned with the community observed in Macrobenthic Group H was “A5.242 *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand”. This biotope is typical of infralittoral stable fine sands and slightly muddy sands which is consistent with the PSA results however stations belonging to this group were mostly located in the main array not in the infralittoral zone (Figure 16). Characterising taxa of this biotope include *F. fabula, Magelona* spp. as well as *S. bombyx* and *Spisula* sp. all of which drove community average similarity within macrobenthic group H.

The biotope that most closely aligned with the community observed in Macrobenthic Group J was "A5.233 - *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand". This is consistent with the PSA results which classified the stations falling into this group as sand and muddy sand. This biotope occurs in sediment subject to physical disturbance as the result of wave action in shallow waters (< 30 m). Once again, stations belonging to this group were not located in the infralittoral zone but more offshore in the "fan" section of the survey area and main array (Figure 16).

Two biotopes aligned with the community observed in Macrobenthic Group M: "A5.252 -*Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand" and "A5.351 - *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud". Macrobenthic Group M included 56 of the 134 stations analysed of which 47 were classified as BSH A5.2 while the remaining were a mix of BSHs A5.1, A5.3 and A5.4. Considering that this group covered a large portion of the survey area with slight variations in sediment type and composition, it is not surprising that a mosaic biotope was identified at these locations. Characterising taxa of this mosaic biotope included *A. filiformis, K. bidentata, N. nitidosa, E. pusillus, A. prismatica* and *S. bombyx*.

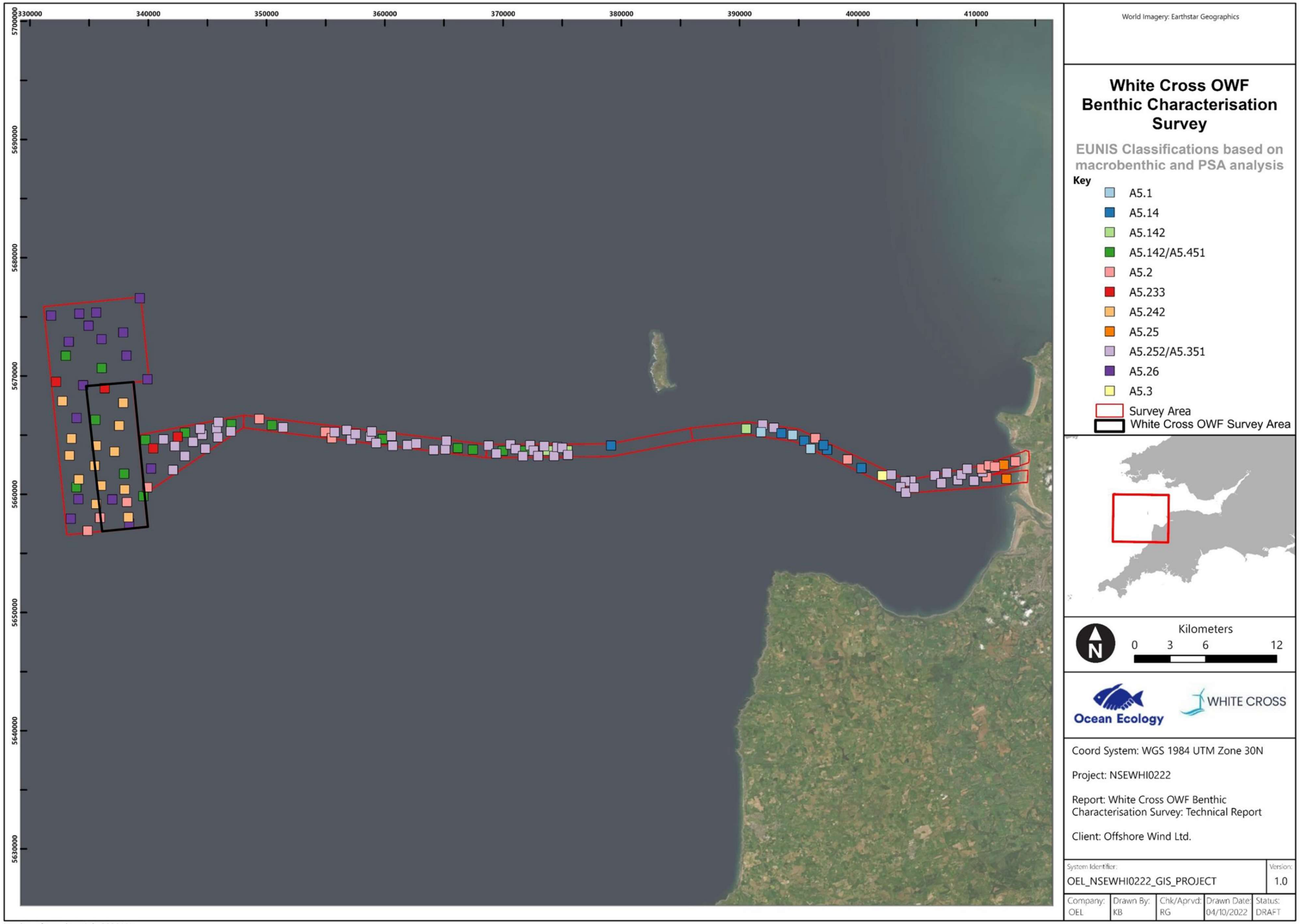

Figure 16 Spatial distribution of habitat and biotopes identified across the survey area based on macrobenthic and sediment analysis.

7.5. Notable Taxa

Five taxa of interest were identified from the 134 grab samples collected across the survey area (Table 16).

The polychaete *Goniadella gracilis* is an invasive non-native species (INNS) and occurred only at 9 stations where a total of 34 individuals were identified. This species is native of Southern Africa and North-eastern USA with the first record in UK water dating back to 1970 in Liverpool Bay[8].

Another INNS observed across the survey area was the Slipper limpet *Crepidula fornicata* which only occurred at station ST121 where one individual was identified. This species is native of the Atlantic coast of the USA and was imported to England in the late 1800s together with American oysters.

The Ross worm *S. spinulosa* is a protected species when occurring in reef form under the OSPAR list of threatened and/or declining species and habitats (2008) and as an Annex I species under the EU Habitat Directive. The latter directive has been transposed into UK law under the Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended)[9]. A total of 708 specimens of *S. spinulosa* were identified across the survey area based on grab samples with 348 individuals counted at station ST118 and the reminder occurring between 17 other stations. Nevertheless, the seabed imagery analysis showed no sign of reef forming structures at these locations (Section 7.6.1).

Two Mollusca taxa identified across the survey area are designated as economically important species, these were the queen scallop *Aequipecten opercularis* and clams of the family Veneridae. A total of 6 queen scallop specimens were counted across three stations while 11 Veneridae clams were found across 6 stations.

Table 16 Notable taxa found across the White Cross survey area.

Taxon	Major Group	Designation	N of individuals
Aequipecten opercularis	Mollusca	Economically Important Species	6
Crepidula fornicata		Invasive & Non-Native	1
Goniadella gracilis	Annelida	Invasive & Non-Native	34
Sabellaria spinulosa	Annelida	OSPAR threatened and/or declining	708
Veneridae	Mollusca	Economically Important Species	11

[8] GB non-native species secretariat

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

7.6. Seabed Imagery

A total of 140 DDC stations and 10 transects were sampled resulting in the collection of 1,031 high-resolution still images. Full image analysis proforma are presented in Appendices XVIII and XIX.

A total of 10 EUNIS classifications were encountered across the survey area (Table 17, Figure 17). A5.26 was the most frequently encountered classification, assigned to 479 out of 1,031 of the analysed images (46.5 % of analysed images). This was followed by 196 images assigned to A4.13 (19.0 % of analysed images) and 192 images assigned to A5.44 (18.6 % of analysed images). Example images of the key EUNIS classifications are included in Plate 4.

Table 17 EUNIS classifications (both 2012 and 2022 codes) identified across the survey area.

EUNIS BSH (2012)	EUNIS Level 4 (2012)	EUNIS Description	EUNIS Code (2022)
A4.1- High Energy Circalittoral Rock	A4.1	Atlantic and Mediterranean high energy circalittoral rock.	MC12
	A4.13	Mixed faunal turf communities on circalittoral rock.	MC121
	A4.131	Bryozoan turf and erect sponges on tide-swept circalittoral rock.	MC1213
A5.1 - Subtidal Coarse Sediment	A5.14	Circalittoral coarse sediment	MC32
	A5.141	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	MC3211
A5.2 - Subtidal Sand	A5.23	Infralittoral fine sand	MB52
	A5.25	Circalittoral fine sand	MC52
	A5.26	Circalittoral muddy sand	MC52
A5.3 - Subtidal Mud	A5.35	Circalittoral sandy mud	MC62
A5.4 - Subtidal Mixed Sediment	A5.44	Circalittoral mixed sediments	MC42

Plate 4 Example imagery collected across the survey area, including EUNIS habitat classification, station number, and image log number.

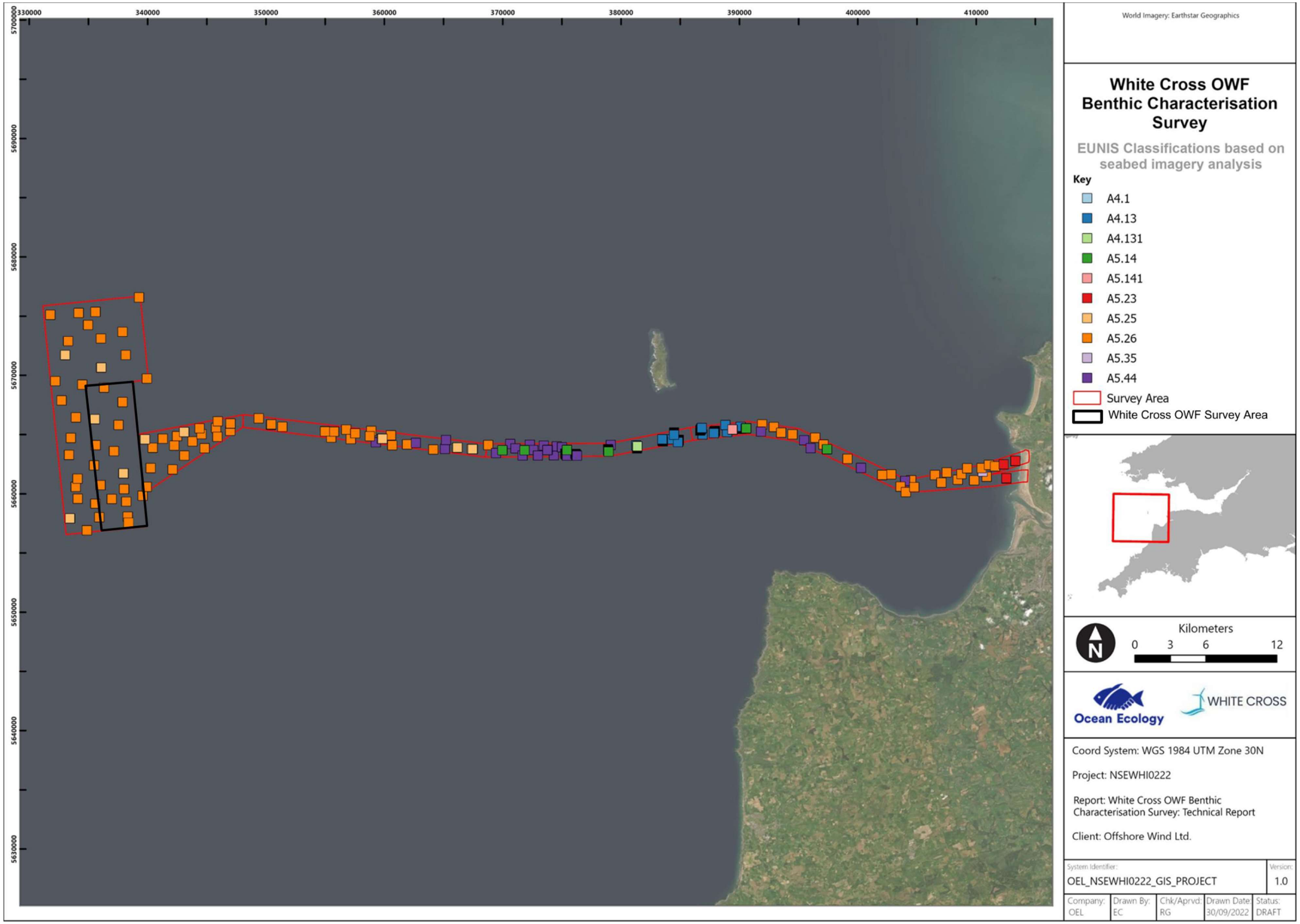

Figure 17 EUNIS classifications identified across the survey area based on seabed imagery.

7.6.1. Annex I Reefs

A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of Annex I reef habitats as detailed in Table 9 and Table 10. The full Annex I reef assessment for each image is presented in Appendix XVI and XVII. A summary of this Annex I reef assessment is presented in Table 18. Of the areas meeting the criteria of Annex I reef, 50 % consisted of Bedrock, 35 % of Low Stony, 10 % of Bedrock & Low Stony, 4 % of Low Stony and Bedrock and 1 % of Medium Stony (Figure 18). In the instances where bedrock and stony reefs co-occurred, video transects were further analysed to assess whether the two features could be identified. Based on the assessment of both video footage and the still images, the overall biological community observed and the fact that cobbles were visible in a large number of images where bedrock was recorded, it is highly likely that there was continuous bedrock present under the stony reef veneer, but the height of stony cover was such that it was not possible to observe the bedrock underneath.

No biogenic reef habitat was observed across the survey area despite individuals of *S. spinulosa* being found in the grab samples. The tube aggregations observed at these stations were not deemed to meet the reef qualifying criteria set out in Table 10 (See sections 6.5 and 7.5).

Table 18 Summary of Annex I reef assessment for each station/transect at which potential reef was observed (number of pictures per station/transect).

Station/Transect	Annex I Reef Assessment					
	Not a Reef	Low	Medium	Bedrock	Bedrock & Low Stony	Low Stony & Bedrock
ST112	0	2	0	3	1	0
ST113	0	2	0	0	3	0
ST114	0	5	0	0	0	0
ST115	0	3	0	0	0	3
ST116	0	4	0	0	0	1
T01	6	8	0	10	0	0
T02	0	9	1	8	3	1
T03	1	14	1	9	1	1
T04	0	6	0	12	2	1
T05	0	7	0	13	4	0
T06	0	6	0	16	1	0
T07	19	1	0	6	0	0
T08	16	0	0	13	1	0
T09	20	4	0	4	0	0
T10	2	3	0	10	5	1

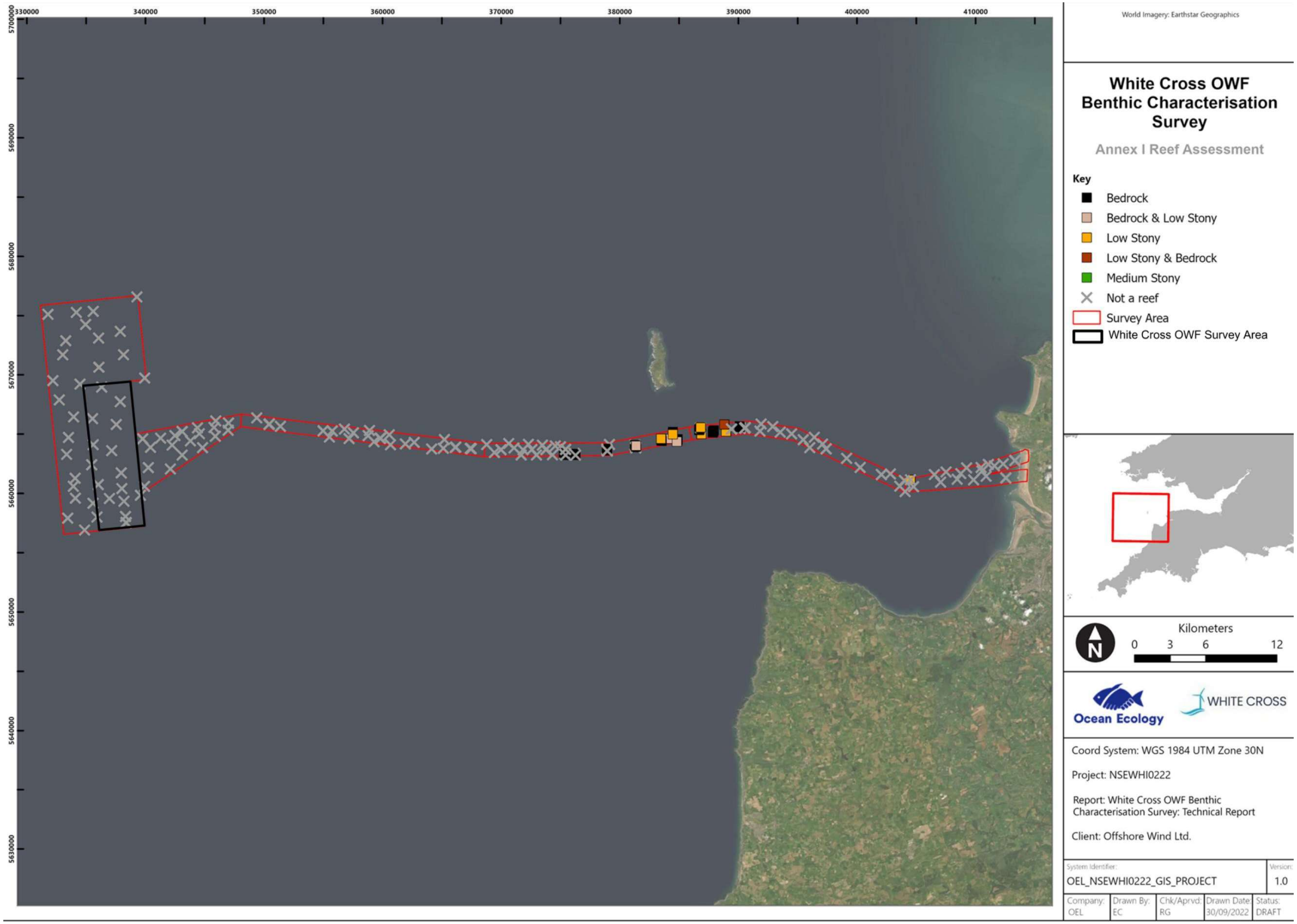

Figure 18 Annex I reef habitats identified across the survey area based on imagery analysis.

7.7. Habitat/Biotope Mapping

Seabed imagery and site characterisation sampling were undertaken to identify the principal habitats that occurred across the survey area. Acoustic data was additionally interrogated to identify the boundaries of the biotopes and habitats inferred from seabed imagery and grab samples analyses as mapped by station/transect in Figure 19 and listed in Table 19.

The main complexes identified across the survey area were the mosaic habitat made up of EUNIS level 5 habitat "A5.252 *Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand" and "A5.351 *Amphiura filiformis, Mysella bidentata* and *Abra nitida* in circalittoral sandy mud" observed at 56 of the 134 grab sampling stations and EUNIS level 4 habitat "A5.26 circalittoral muddy sand" which was assigned to 479 out of 1,031 seabed images analysed.

In general, habitat dominated by sand characterised the more offshore part of the survey area, as well as the portion of the survey area closer to land; conversely habitat dominated by mixed and coarse sediments were more common in the central part of the ECR, where Annex I reef habitats were also observed based on the imagery analysis (Figure 19). Of the sand dominated habitats, the most offshore supported macrobenthos such as *F. fabula, Magelona johnstoni, A. filiformis, A. alba, N. nitidosa* and venerid bivalves, while the more inshore were characterised by *E. pusillus* and various polychaetes. Coarse and mixed sediment habitats supported a rich community dominated by polychaetes such as *M. fragilis* and *Lumbrineris* spp. as well as venerid bivalves like *T. ovata* and *Spisula* spp..

Table 19 EUNIS classifications identified within the survey area.

EUNIS BSH (2012)	Method	EUNIS Level 4 (2012)	EUNIS Description	EUNIS Code (2022)
A4.1- High Energy Circalittoral Rock	Seabed imagery	A4.1	Atlantic and Mediterranean high energy circalittoral rock.	MC12
		A4.13	Mixed faunal turf communities on circalittoral rock.	MC121
		A4.131	Bryozoan turf and erect sponges on tide-swept circalittoral rock.	MC1213
A5.1 - Subtidal Coarse Sediment	Imagery & Grab	A5.14	Circalittoral coarse sediment	MC32
	Seabed imagery	A5.141	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	MC3211
	Grab	A5.142	*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel	MC3212
A5.2 - Subtidal Sand	Seabed imagery	A5.23	Infralittoral fine sand	MB52
	Grab	A5.233	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	MB5233
	Grab	A5.242	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand	MB5236
	Imagery & Grab	A5.25	Circalittoral fine sand	MC52
	Grab	A5.252	*Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand	MC5212
	Imagery & Grab	A5.26	Circalittoral muddy sand	MC52
A5.3 - Subtidal Mud	Seabed imagery	A5.35	Circalittoral sandy mud	MC62
	Grab	A5.351	*Amphiura filiformis, Mysella bidentata* and *Abra nitida* in circalittoral sandy mud	MC6211
A5.4 - Subtidal Mixed Sediment	Seabed imagery	A5.44	Circalittoral mixed sediments	MC42
	Grab	A5.451	Polychaete-rich deep Venus community in offshore mixed sediments	MD4211

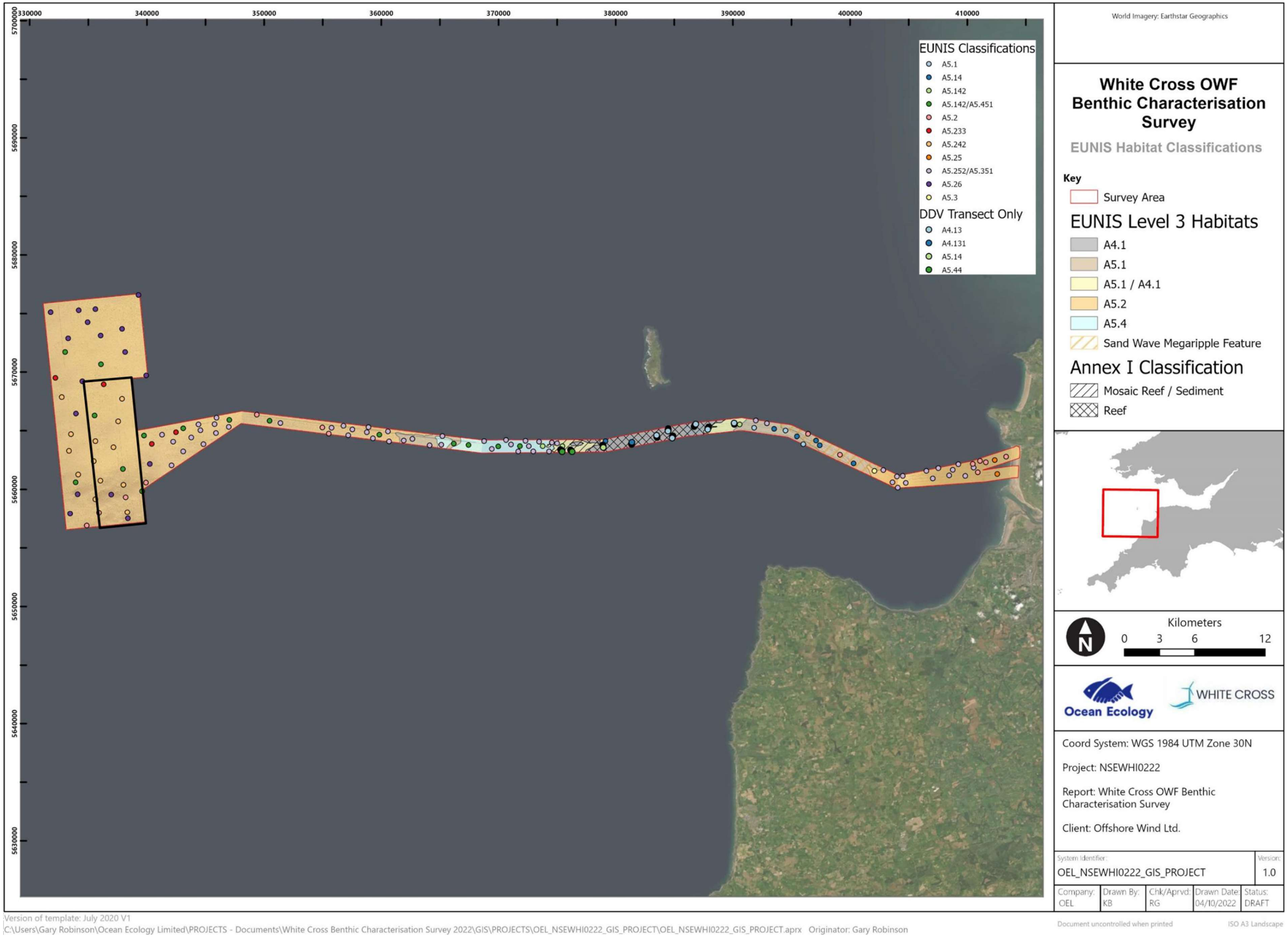

Figure 19 EUNIS classifications assigned across the survey area overlain on MBES data.

8. Discussion

This report presents the results and interpretation of the seabed imagery, macrobenthic and sediment analysis with the aim to set out the environmental baseline conditions across the proposed White Cross OWF. The findings will be used to inform final engineering design and the installation process of the proposed windfarm as well as providing a robust dataset for future comparison if required.

8.1. Sediments

Despite some variation in sediment types between stations, the majority of stations were dominated by sand. Mud content was highest close to land at ST01, mud content was also high at ST38. Gravel content was overall low but variable along the cable route with a few stations along the route found to contain > 50 % gravel composition. The majority of samples were comprised of sand representing EUNIS BSH A5.2 (Sand and Muddy Sand). Some stations were classified as Sandy Gravel (sG) or Gravelly Sand (gS) representing EUNIS BSH A5.1 (coarse sediment); seven station were classified as Muddy Sandy Gravel (msG) and four stations as Gravelly Muddy Sand (gmS) representing EUNIS BSH A5.4 (Mixed Sediment).

These sublittoral sediment types could represent 'subtidal sands and gravels' and 'subtidal mixed muddy sediments' listed as habitats of principal importance under Section 41 of the Natural Environment and Rural Communities Act 2006. To note that these habitats are among the most common habitats found below the mean low water springs (MLWS) around the coast of the UK.

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

Sand was the main sediment fraction present at most stations, comprising the largest percentage contribution across the survey area. Sand content was greatest at station ST078 and lowest at ST09. The mean grain size at sampling stations ranged from 34.83 µm at station ST01 to 5,559 µm at station ST123.

No pattern was observed between stations with relatively high mud (> 5 %) and TOC content despite many studies based on the coastal ocean and marine environment having found a positive relationship between organic carbon content and proportions of finer sediment grain size (Winterwerp & van Kesteren 2004, McBreen et al. 2008, Hunt et al. 2020). Average TOC compares well with global sediment average TOC content for the deep ocean (0.5 %) (Seiter et al. 2004).

8.2. Sediment Chemistry

Several guidelines exist to assess the degree of contamination and likely ecological impacts of contaminants in marine sediments. These regulations defined the levels below which effects are of no concern and/or rarely occur (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, As, Hg, Pb and Ni were the only metals with concentrations above reference levels at one or more stations. Specifically, As was above Cefas AL1 at 4 stations, while Ni was higher than AL1 at one station. Hg and Pb both occurred in concentrations above the TEL at stations ST01. Hg and Pb concentrations exceeding the TEL has possibly to do with the TEL being based on North American data and as such it may not be representative of UK conditions (Section 6.2.2) (MMO 2015, Mason et al. 2020). In comparison OSPAR BAC and Cefas ALs are based on UK data and therefore are more suitable for the current assessment. No obvious pattern emerged when comparing stations with elevated As and Ni concentrations with mud content, however elevated TOC and metals concentrations were observed in the middle section of the ECC which could be related to transportation and deposition across the survey area. Elevated metal sediment concentrations do not necessarily imply toxicity to benthic communities (Rees et al. 2007) as the bioavailability of these metals is more important than simply concentration levels. Despite the elevated As levels at four stations, no macrobenthic anomalies were identified at these locations to suggest any adverse effects were present. No stations had metals concentrations above AL2, overall 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. Most of the measured PAHs exceeded the BAC at stations ST08 and ST09. Additionally, Fluoranthene was above Cefas AL1 at station ST09. Stations with elevated PAHs concentrations also had relatively high TOC, and metals concentrations which could be related to transportation and deposition across the survey area; however, no macrobenthic anomalies were identified at these locations to suggest any adverse effects were present.

When assessing the origin source of PAH compounds in sediments, the ratio between LMW and HMW PAHs was found to be lower than 1 at all stations indicating a pyrogenic origin, similarly the Fl/Py ratio was higher than 1 at all stations also indicating a pyrogenic source of PAHs). PAHs of pyrogenic origin can derive from various activities which ultimately involve the combustion of organic substances at high temperatures under low oxygen conditions. These may include incomplete combustion of motor fuels, or products derived from the foundry and steel industries. All organotins measured were below the detection limit of 0.001 mg kg^{-1}.

8.3. Macrobenthos

A diverse macrobenthic assemblage was identified across the survey area from 134 macrobenthic samples collected, with a total of 12,651 individuals and 487 taxa recorded. The most abundant and frequent taxon sampled with the greatest average density per sample was juveniles of the brittle star *Amphiuridae*. Other key taxa included the Ross worm *S. spinulosa* which accounted for the maximum abundance per sample and the two-toothed Montagu shell *K. bidentata* which was second to juveniles of *Amphiuridae* for abundance and density per sample. Annelida taxa contributed the most to abundance and overall diversity of the macrobenthic assemblages, whilst Echinodermata taxa dominated by biomass, accounting for over 50 % of the total biomass.

Macrobenthic communities can be highly heterogenous as they are heavily influenced by ambient environmental conditions such as sediment composition (Cooper et al. 2011), hydrodynamic forces and physical disturbance (Hall 1994), depth (Ellingsen 2002), and salinity (Thorson 1966). Multivariate analysis on macrobenthic data identified 15 macrobenthic groups (31 % similarity slice) and 14 outlier stations across the White Cross survey area owing the high diversity in the macrobenthic community and the associated difficulties in determining a few key dominant species within each group. Nevertheless, a clear distinction was observed between stations located in the middle of the ECR and all other stations. Sediment composition was a key factor in determining the macrobenthic community structure at these locations (Hall 1994, Cooper et al. 2011) and was clearly reflected in Macrobenthic Groups B, C, D and E indicating an affinity for coarser substrates compared to the other macrobenthic groups typical of sandy substrates with variable mud content. Coarser sediment supported a community characterised by *M. fragilis* and *Lumbrineris* and venerid bivalves, while finer sediments were characterised by high abundances of *E. pusillus*, *A. filiformis*, *K. bidentata* and *N. nitidosa*.

Five notable taxa were identified across the survey area. These included OSPAR threatened and/or declining species Ross worm (*S. spinulosa*) (however there were no sign of reef forming structures observed), INNS polychaete *Goniadella gracilis* and INNS slipper limpet *C. fornicata*, and two Economically Important Species: the queen scallop *A. opercularis* and clams of Veneridae family.

8.4. Seabed Imagery

A total of 10 EUNIS habitat types were encountered across the survey area. A5.26 (Circalittoral muddy sand) was the most frequently encountered EUNIS habitat, assigned to 479 out of 1,031 of the analysed images (46.5 % of analysed images). This was followed by 196 images assigned to A4.13 (Mixed faunal turf communities on circalittoral rock) (19.0 % of analysed images) and 192 images assigned to A5.44 (Circalittoral mixed sediments) (18.6 % of analysed images). (Example habitat images included in Plate 3).

8.4.1. Annex I Reefs

The White Cross survey area consisted almost entirely of muddy sand and mixed sediments, however areas of Annex I reef were identified in the middle section of the survey area along the ECR. These corresponded to seabed imagery that we assigned to the EUNIS classifications A4.1, A4.13 and A4.131. Annex I reefs identified consisted of Bedrock (50 %), Low Stony (35 %), Bedrock & Low Stony (10 %), Low Stony and Bedrock (4 %), and Medium Stony (1 %). Along most transects where reef was identified stony and bedrock reef co-occurred. Based on assessment of video footage, the overall biological community present within the images and the fact that cobbles were visible in a large number of images where bedrock was recorded, it is highly likely that there was continuous bedrock present under the stony reef, but the height of stony cover was such that it was not possible to see the bedrock underneath. Where bedrock and stony reef were observed to co-occur within the same images, the labels 'Bedrock & Low Stony' and 'Low Stony and Bedrock' were used depending on which type of reef was predominant. Additionally, large parts of these reef areas were interspersed with mixed and coarse sediments further pointing to the presence of mosaic habitats across the middle section of the ECR where most likely areas of bedrock were covered by stony reefs and/or a veneer of coarse and mixed sediments while in places bottom currents and sediment dynamics exposed the bedrock reef.

8.5. EUNIS Habitats/Biotopes

PSD data clearly indicated the dominance of sandy sediments across White Cross with areas of coarse (A5.1) and mixed (A5.4) sediments in the middle section of the ECR. This was corroborated by the imagery analysis which showed the dominance of EUNIS habitat "A5.26 Circalittoral muddy sand" across most of the survey area while the middle part of the ECR was characterised by Annex I reef habitats as well as coarse and mixed sediments. On the other hand, the macrobenthic data showed more complexity compared to sediment and seabed imagery as the macrobenthic community was extremely diverse with no obviously key species dominating the assemblage. This resulted in a high number of statistically significant groups based on multivariate analyses performed on macrobenthic abundance data and a relatively low confidence in the biotopes and habitat complexes identified based on this data as it was difficult to delineate clear boundaries between groups/habitats/biotopes.

This was further demonstrated by the presence of mosaic habitats across large portion of the survey area where sandy and muddy biotopes coexisted (A5.252/A5.351) as well as coarse and mixed sediment habitats (A5.142/A5.451). Acoustic data was then interrogated to aid in the definition of boundaries between the habitats and biotopes identified based on PSA, imagery and macrobenthic analysis. As most of the survey area was dominated by sands, the acoustic data did not show any anomalies that could be used to draw boundaries that would reflect the EUNIS complexes identified based on the macrobenthic analysis; conversely hard substrates such as Annex I reefs and coarse sediments were well represented in the acoustic data. For these reasons the habitat mapping in Figure 19 shows EUNIS level 3 classifications as polygons for which a combination of acoustic data, seabed imagery and PSD data was used to delineate their boundaries, while the higher-level classifications based on macrobenthic data were superimposed at station level to reflect the high diversity of the community observed across White Cross.

The main complexes identified across the survey area were the mosaic habitat made up of EUNIS level 5 habitat "A5.252 *Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand" and "A5.351 *Amphiura filiformis, Mysella bidentata* and *Abra nitida* in circalittoral sandy mud" observed at 56 of the 134 grab sampling stations. Annex I reef habitats were identified based on the imagery analysis at stations located south of Lundy along the cable route.

9. References

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