The Great Grid Upgrade

Sea Link

Sea Link

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SEA LINK
ADDITIONAL SURVEY WORKS

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DEFINITIONS AND ABBREVIATIONS

Acronym	Description	Acronym	Description
A5.23	Infralittoral fine sand	HSG	Herring Spawning Ground
A5.231	Infralittoral Mobile Clean Sand with Sparse Fauna	JNCC	Joint Nature Conservation Committee
A5.25	Circalittoral fine sand	LAT	Lowest Astronomical Tide
A5.252	*Abra prismatica, Bathyporeia elegans* and Polychaetes in Circalittoral Fine Sand	LED	Light-emitting Diode
A5.43	Infralittoral Mixed Sediment	MAG	Magnetometer
A5.44	Circalittoral mixed sediments	MBES	Multi Beam Echo Sounder
BDC	Biodiversity Committee	MCZ	Marine Conservation Zone
BGS	British Geological Survey	MESH	Mapping European Seabed Habitats
BSL	Benthic Solutions Limited	NEXT	Next Geosolutions
CBD	Conservation of Biological Diversity	NGET	National Grid Electricity Transmission Plc
Cefas	Centre for Environment, Fisheries and Aquaculture.	NMMP	National Marine Monitoring Programme
CTD	Conductivity Temperature Depth	NMBAQC	National Marine Biological Association Quality Control scheme
DVV	Double Van Veen Sampler	N/S	No Sample
EBS	Environmental Baseline Survey	OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
EC	European Commission	PCA	Principle Component Analyses
EMODnet	European Marine Observation and Data Network	PC	Physio-chemistry
ETRS	European Terrestrial Reference System	PSA	Particle Size Analysis
EU	European Union	PSD	Particle Size Distribution
EUBS	European Union Biodiversity Strategy	SAC	Special Area of Conservation
EUNIS	European University Information Systems organisation	SBP	Sub-bottom Profiler
F1 and F2	Fauna grab samples 1 and 2	SCI	Site of Community Importance
FOCI	Features of Conservation Interest	SSS	Side Scan Sonar
GIS	Geographic Information System	UK	United Kingdom
HAP	Habitat Action Plan	UK BAP	United Kingdom Biodiversity Action Plan
HAS	Habitat Assessment Survey	UKCS	United Kingdom Continental Shelf
HD	High Definition	UTC	Universal Time Coordinated
HG	Hamon Grab	UTM 31	Universal Transverse Mercator – Zone 31
HVDC	High Voltage Direct Current		

Where abbreviations used in this document are not included in this list, it may be assumed that they are either equipment brand names or company names.

EXECUTIVE SUMMARY

The England and Wales Transmission Owner, National Grid Electricity Transmission Plc (NGET) are developing a High Voltage Direct Current (HVDC) electricity transmission link in the east coast of England from Richborough in Kent to Friston in Suffolk. A comprehensive survey of the main route has already been completed by MMT (2022). However, upon analysing the data, an additional five areas have been identified where the route could potentially avoid hazards or challenging seabed conditions whilst optimising the overall route length.

Next Geosolutions conducted a geophysical survey, acquiring multibeam echosounder data, side scan sonar, sub-bottom profiler and magnetometer aboard the *Shore Presence* between the 6th of November 2023 to the 6th of March 2024. The environmental survey, conducted with the support of Benthic Solutions Limited aboard the *Ievoli Grey* between the 22nd of August and the 2nd of September 2024, aimed to characterise the marine habitats and gather information on the physico-chemical and biological environment, including identifying any EC Habitats Directive Annex I habitats within the five additional survey areas.

The depths across the surveyed areas ranged between 7.3m to 27.4m below LAT. Sediment across the survey site was heterogeneous with most stations in Areas 2, 4 and 5 showing dominance of sand or gravels, stations in Areas 2 and 3 showed mixed sediments and one instance of dominant fines in Area. Sediment characteristics were found to be in line with findings within the previous MMT (2022) survey. The samples collected across the survey areas were represented by three Folk classifications, 'Muddy Sandy Gravel', 'Gravelly Sand', and 'Slightly Gravelly Sandy Mud'.

Total organic carbon (TOC) levels were fairly consistent across stations. Total organic matter (TOM) was slightly more varied. TOC and TOM levels recorded during the MMT (2022) survey were slightly lower on average than those found during the current survey.

Total hydrocarbon content (THC) of sediments was variable across stations, with higher levels observed in Area 2. This pattern corresponds to the higher proportion of fine sediments in that area and aligns with findings from the previous MMT survey report. A similar pattern was noted for total n-alkanes with the higher concentrations recorded in Area 2 in line with the previous survey report. All GC traces showed typical signatures of background contamination found in the North Sea. Total polycyclic aromatic hydrocarbons (PAHs) were variable across stations with levels below the NOAA ERL and ERM thresholds.

Concentrations of several metals, including arsenic, chromium, and nickel, exceeded environmental thresholds at certain stations in the survey area, with arsenic levels notably surpassing both OSPAR ERL and Cefas cAL 1 thresholds at multiple locations. Elevated arsenic concentrations are linked to natural geological inputs, industrial activities, and riverine discharge, consistent with findings from previous studies. Despite these exceedances, most metals remained below critical thresholds, indicating minimal risk to marine life and no significant environmental impact overall.

A total of 6,897 infaunal individuals (including solitary epifauna) were recorded across the survey area, with Annelida and solitary epifauna collectively accounting for 76% of the total individuals. Multivariate analysis identified three significantly distinct macrofaunal groupings which were influenced by the sediment composition of the site. Key differentiating factors in taxa were attributed to the abundance of the keel worm (*Spirobranchus lamarcki*), sea anemones (Actiniaria) and the two-toothed Montagu shell (*Kurtiella bidentata*).

CTD water profiles indicated a well-mixed water mass with no evidence of a thermocline or halocline.

The survey route consisted of four level four EUNIS (2012) habitats, 'Circalittoral Mixed Sediment' (A5.44), '*Abra prismatica, Bathyporeia elegans* and Polychaetes in Circalittoral Fine Sand' (A5.252), 'Infralittoral Mixed Sediment' (A5.43) and 'Infralittoral Mobile Clean Sand with Sparse Fauna' (A5.231). These habitats featured epifauna such as brittlestars (Ophiuroidea), hermit crabs (*Pagurus* sp.) and common sea stars (*Asterias rubens*).

An assessment of Annex I Geogenic Stony Reef was conducted across six transects in Areas 3 and 4 using HD video data, focusing on cobble and boulder coverage, elevation, epifaunal diversity, and patch extent. Results showed low-elevation cobble and boulder coverage, with only the Area 4 transects exhibiting more extensive patches. Although classified as "Low Reef," the limited species diversity—mainly tube worms, faunal turf, and sponges—and the lack of key reef-building species indicated the absence of any Annex I habitat.

The presence of *Sabellaria spinulosa* was analysed to evaluate its potential for forming Annex I Biogenic Reef habitats across four transects in Area 2, focusing on coverage, tube elevation, and patch extent from HD video stills. The results indicated that the area does not qualify as a reef due to insufficient elevation of *S. spinulosa* aggregations. While a few stills were classified as "Low Reef," they were only marginally distinguishable from surrounding "Not a Reef" areas, leading to the site's classification as "Not a Reef.

An assessment of Annex I blue mussel (*Mytilus edulis*) beds was conducted due to observations in Area 5. Using the SACFOR scale adapted from Roberts *et al.* (2012), results showed that coverage at A5_OPB_Add_01 was too sparse and patchy to qualify as an Annex I habitat, with no areas meeting Grade 1 criteria. In contrast, A5_OPB_05_HAS exhibited significant blue mussel coverage, with most stills classified as Grade 1 and forming three large patches, suggesting the presence of a potential Annex I habitat.

The survey route is located in areas designated as lesser sandeel (*Ammodytes marinus*) nursery and low-intensity spawning grounds. PSA data, assessed using methods from Greenstreet *et al.* (2010) and Latto *et al.* (2013), revealed that most stations were classified as 'Unsuitable,' with two stations identified as 'Preferred' due to their predominance of 'Gravelly Sand'. Additionally, the survey route intersects areas designated as high and low-intensity nursery grounds for Atlantic herring (*Clupea harengus*). Using methods outlined in Reach *et al.* (2013), it was found that most habitats were 'Unsuitable' because of excessive fine content (>5%) or insufficient gravel (<10%). No adult ocean quahogs (*Arctica islandica*) were identified during field operations (shell diameter >5cm), nor were siphons observed in the HD video review. No juvenile (<1cm shell diameter) or adult (>1cm shell diameter) specimens were recorded during taxonomic data analysis.

1 INTRODUCTION

1.1 Project Information and Survey Area

Client:	National Grid Electricity Transmission PLC (NGET)
Project:	Sea Link Next Geo NGET
Main Contractor:	Next GeoSolutions Europe S.p.A. (NEXT)
Main Contractor Reference:	P2097-010-REP-005
Subcontractor:	Benthic Solutions Limited
Survey Areas:	East of Shipwash, North of the Sunk, Grid Link Crossing and Outer Pegwell Bay (UK).
Survey Type:	Environmental Baseline Survey (EBS) and Habitat Assessment (HAS)
Survey Period:	22/08/2024 – 03/09/2024
Survey Equipment:	BSL Double Van Veen Grab, BSL Mini Hamon Grab, MOD4.1 Camera System, MOD4.5 Camera System, BSL Freshwater Lens, Valeport MIDAS 606 CTD.
Main Contractor Project Manager:	Lucy Cotton (l.cotton@nextgeosolutions.com)
Subcontractor Manager:	Cinda Houldsworth (cinda.houldsworth@benthicsolutions.com)

The England and Wales Transmission Owner, National Grid Electricity Transmission Plc (NGET), are developing a High Voltage Direct Current (HVDC) electricity transmission link in the east coast of England from Richborough in Kent to Friston in Suffolk (Figure 1-1). The overall route of the marine cable is 120km with the additional areas to be surveyed adding up to approximately 35km in length. NGET has awarded these additional marine surveys to Next GeoSolutions, supported by Benthic Solutions Limited (BSL), to execute the geophysical, habitat assessment (HAS) and environmental baseline survey (EBS), analysis, interpretation and reporting services for the programme.

This report is focussed on the habitat assessment, sediment particle size analysis (PSA), physico-chemistry (PC), benthic macrofaunal analysis and seawater profiling for the survey areas two to five along the Sea Link cable route, located in UKCS Blocks 56 and 52. The analysis and results of the vibrocore samples collected in Areas and 4 and 5 along the Sea Link cable route is provided separately in Appendix T –CORE ADDENDUM.

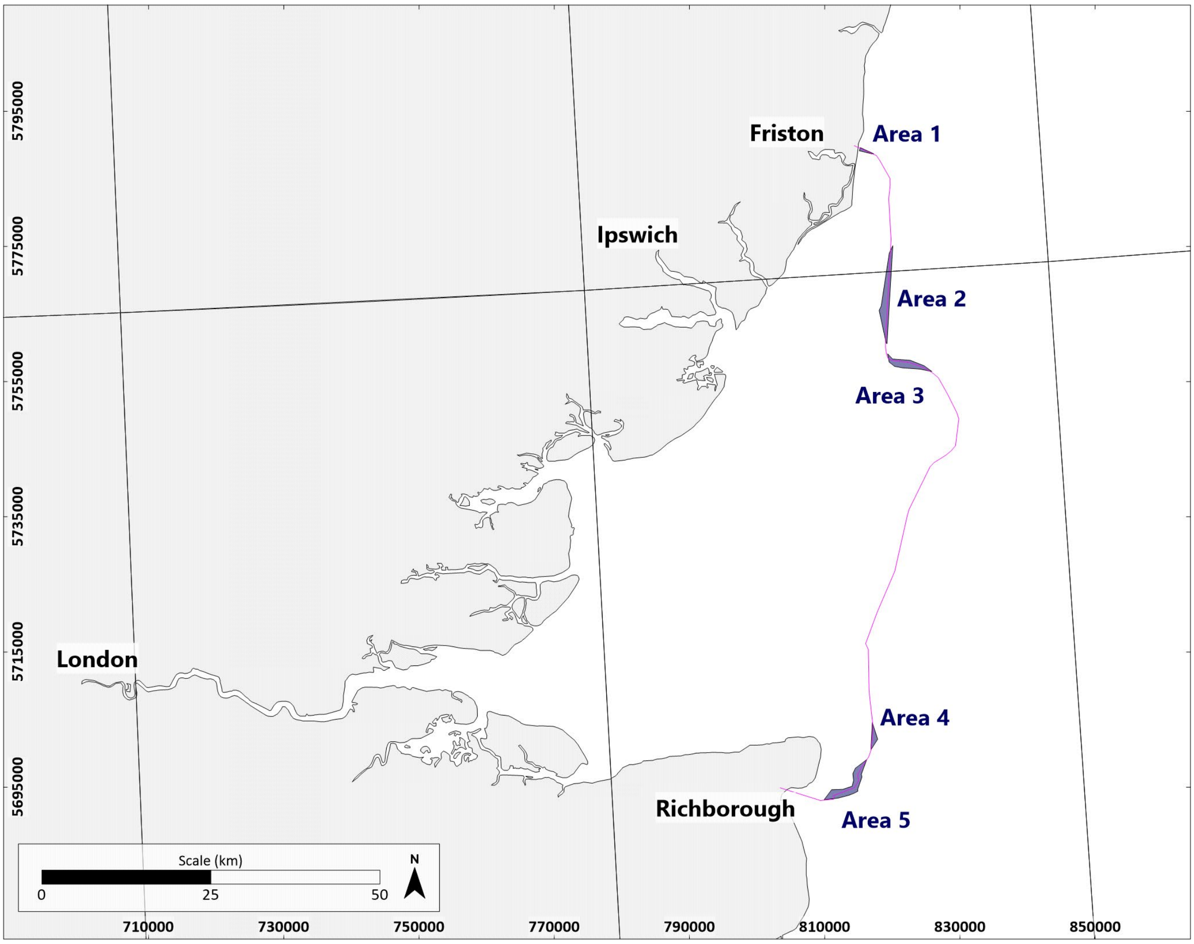


Figure 1-1 Sea Link Route : East of Shipwash to Outer Pegwell Bay

1.2 Survey Information

The objective of the environmental survey was to acquire all appropriate data for the confirmation of the preferred route for the high voltage direct current (HVDC) cable.

The environmental survey comprised grab sampling for faunal and sediment analyses and seabed imagery. This report covers the entire suite of sample analysis and habitat assessment with an exception of MMO Vibrocore samples reported separately (Appendix T –CORE ADDENDUM).

1.3 Scope of Work

1.3.1 Environmental Survey Objectives

The survey included characterisation of the benthos and investigation of the sediment and water column physico-chemistry (PC) and sediment benthic macrofauna to provide an understanding of baseline conditions at each survey area along the route. The specific objectives of the benthic survey are:

- Undertake a review of the acquired geophysical data within the survey area to preliminarily identify all habitats for further investigation and characterisation;
- Follow a benthic sampling plan and methodology agreed with the Client; to support consenting and environmental impact assessment (EIA) requirements.
- Acquire baseline data of PC and sediment biological characteristics across the survey area as well as water profiles from each location.
- Characterise the benthic environment across the sites to assign habitat types to biological level according to JNCC/EUNIS habitat classification systems;
- Identify habitats and species of potential conservation interest, defined as those listed in Annex I of the EC Habitats Directive, the OSPAR List of Threatened and/or Declining Species and Habitats, the UK Post-2010 Biodiversity Framework (formerly the UK Biodiversity Action Plan Priority Habitat descriptions).

1.4 Reference documents

The following reports will be provided by BSL, relating to the habitat assessment and environmental baseline surveys conducted at the Sea Link survey areas two to five for the potential cable route installation:

- **P2097-010-REP-008:** Benthic Field Report
- **P2097-010-REP-009:** Preliminary Geophysical Technical Note
- **P2097-010-REP-007:** Interim Benthic Report
- **P2097-010-REP-005:** Benthic and Environmental Survey Results Report **(This Report)**
  - **P2097-010-REP-005b:** Sea Link Core Addendum

2 SURVEY PARAMETERS

2.1 Geodetic Datum and Grid Coordinate System

2.1.1 Projection Parameters

The horizontal datum was referenced to the ETRS89 Datum, UTM 31N projection. The geodetic parameters used are provided below in Table 2-1.

Table 2-1 Projection parameters

Required Datum	
GPS Datum	ETRS1989
Projection Parameters	
Projection	UTM 31N
Central Meridian	03° 00′ 00.0″ E
Latitude of Natural Origin	00° 00′ 00.0″ E
False Easting	500 000 m
False Northing	0 m
Scale Factor at Origin	0.9996 at CM

2.1.2 Vertical Datum

The vertical datum for the marine survey operations is the LAT (Lowest Astronomical Tide). Height data was acquired in relation to the ellipsoid and translated to the project vertical datum (LAT) as defined by the United Kingdom Office Vertical Offshore Reference Frame (VORF) geoid model at the project location.

3 SURVEY PERFORMANCE

3.1 Survey Tasks

The environmental work scope was completed by BSL aboard the *Ievoli Grey* on a 24-hour operational basis. The vessel was provided by NEXT and was mobilised in Aberdeen, Scotland on the 23rd of August 2024 and demobilised in Great Yarmouth on the 3rd of September 2024. A summary of the survey operations is given in Table 3-1.

Table 3-1 Environmental Survey Tasks

Date	Activity	Details of Activity
22/08/2024	Travel/Standby	Travel to Aberdeen. Standby for vessel transfer.
23/08/2024	Standby/Transfer	Transfer to vessel at Aberdeen port.
24/08/2024	Transit/Operations	USBL calibrations offshore. Transit to Great Yarmouth.
25/08/2024	Transit	Transit to Great Yarmouth.
26/08/2024	Arrival/Standby	Vessel arrives at Great Yarmouth.
27/08/2024	Standby	Kick-off and HIRA meetings.
28/08/2024	Mobilisation	Benthic mobilisation.
29/08/2024	Operations	Camera ops: A2_ES_01 to A3_NS_01.
30/08/2024	Operations	Camera & grab ops: A2_ES_01 to A5_OPB_01. Weather standby.
31/08/2024	Standby (Weather)	Waiting on weather.
01/09/2024	Operations	Camera & grab ops: A4_GLC_01 to A5_OPB_04. Winch issues.
02/09/2024	Operations/Transit	Camera ops: A5_OPB_Add_01, A2_ES_Add_01, transit to Great Yarmouth.
03/09/2024	Demobilisation	Benthic demobilisation. Samples sent to BSL office.

3.1.1 Mobilisation

The initial Mobilisation commenced on the 28th of August 2024 in Great Yarmouth, UK, and was completed on the 2nd of September, 2024. For further details, please refer to the Benthic Field Report (Document ref.: P2097-010-REP-008).

3.1.2 Environmental Survey Operations

Out of the 11 proposed grab stations, 8 were successfully sampled with two stations removed from the scope, and one station's sampling attempt was unsuccessful. 14 of the original 18 proposed water profiling locations were acquired, with an additional three taken at camera transects, totalling 17 acquired water column profiles. Finally, 14 of the 18 planned camera transects were carried out with three removed from the scope and one required a re-run. Please refer to Appendix G – SAMPLE LOG SHEETS for sample positions for grabs and camera transects.

3.1.3 Demobilisation

The personnel conducting the environmental survey for Sea Link completed demobilisation in Great Yarmouth, UK on the 3rd September 2024.

3.2 Survey Vessel

The Environmental survey operations were conducted by the survey vessel *Ievoli Grey*, vessel specifications are detailed within Table 3-2. A complete list of survey equipment is provided in Table 3-3.

Table 3-2 Survey Vessel Details

Parameter	Detail	Parameter	Detail
Name	*Ievoli Grey*	Helideck (yes/no)	No
Flag	Italian	Gross Ton (T)	2995
Built (year)	2013	Endurance (days)	28
Length OA (m)	72m	Main Engine (-)	Main Engine Wartsila 12V M26 2 x 4000Kw at 1000 rpm
Breadth OA (m)	17m	Bow thrusters (-)	2 Tunnel Bow Thruster 2 x 900Kw / 1200Bhp - 1 Tunnel Stern Thruster 1 x 900Kw / 1200Bhp
Draft (m)	6.35m	Accommodation. (No.)	40
DP capacity (yes/no)	Yes		

Table 3-3 Vessel Equipment

Function	Type
Primary grab sampler	BSL Double Van Veen Grab (DVV)
Secondary grab sampler (in coarse sediments)	Mini Hamon Grab
Processing of fauna samples	*Wilson* Auto-siever
Primary camera system	MOD 4.1 Camera System with FWL
Secondary camera system	MOD 4.5 Camera System (Compatible with FWL)
CTD Profiler	Valeport MIDAS 606 CTD

3.3 Deviations from the Work Scope

Due to the shallow depth in Area 5, two grab locations (A5_OPB_02 and A5_OPB_03) were removed from the Scope of Work as per discussions with the Client (Document ref.: ECF_001, Reference No: 2353) (Appendix R – ENVIRONMENTAL CONCESSION FORMS.

One grab location (A4_GLC_02) was unsuccessful after attempting sampling with the DVV and Mini Hamon grab, as well as moving location 50m from the original position.

Three transects in Area 5 were removed from the Scope of Work as per discussion with the Client due to shallow depths in these areas (Document ref.: ECF_001, Reference No: 2353) (Appendix R – ENVIRONMENTAL CONCESSION FORMS. The shallowest station (A5_OPB_03), was attempted during high tide when operations could commence safely, however, camera and grab operations were unable to be accomplished due to vessel working limits and shallow depth. One transect (A4_GLC_03_A) was rerun to improve video quality

Three additional transects selected in the field were acquired to investigate the presence of the sensitive species *Sabellaria spinulosa* (A2_ES_ADD_01 and A2_ES_ADD_02), as well as the presence of blue mussel (*Mytilus edulis*) beds (A5_OPB_ADD_01).

4 METHODOLOGY

The benthic survey was performed using grab samplers and a video and still camera system. Sample sites were selected using the information provided from the geophysical survey data and in accordance with the requirements of the Client.

4.1 Field Methods

4.1.1 Survey Design

Prior to sampling operations, sidescan sonar (SSS) and multibeam echosounder (MBES) data were collected in the five additional areas of the Sea Link route. This data was reviewed to inform the survey strategy by BSL with input from NEXT. All sampling stations were approved by the Client prior to the environmental survey commencing.

A total of 11 environmental sampling stations were proposed across the five additional survey areas, targeting seabed features and varying sediment types, all with corresponding 50-150m camera transects. An additional seven camera transects were proposed to provide an enhanced regional understanding of different habitats encountered.

4.1.2 Photo and Video Sampling

Seabed video footage was the BSL MOD 4.1 camera system within the BSL freshwater lens fitted with a 5cm laser scale, to ground-truth all grab locations, and additional transects were performed to increase coverage of the site and target features observed within the geophysical data. Once at the seabed, the camera system was towed along the transect line as close to the seabed as possible to acquire high-quality imagery at a speed of approximately 0.3 - 0.5 knots, at an elevation of between 0.3-1.0m above the seafloor. Best efforts were made to minimise the contact with the seabed throughout the transects. Live video footage, overlaid with the date, time, position and site details were viewed in real-time, and were recorded by BSL personnel. High-definition stills images were taken at regular intervals along the transects. Upon recovery of the camera, data was backed onto a second storage medium to prevent inadvertent loss of information.

4.1.3 CTD

CTD profiles were acquired using the Valeport MIDAS CTD at 14 water locations across the Sea Link survey area, with a further three CTD profiles taken at additional camera transects, totalling 17 complete CTD water profiles.

4.1.4 Particle Size Analysis and Chemical Sampling

Sediment was sampled for PSA and chemical analyses at each benthic grab sample site. The sediment was sampled using a Double Van Veen (DVV) in softer sediments and a Mini Hamon Grab (HG) in areas of coarser material. From these grabs, a PSA sample was taken as well as a physico-chemical (PC) sample to undergo analysis of heavy-metals and hydrocarbon analysis.

Sub-sampling of physico-chemical parameters was undertaken from the grab samples with the following material retrieved from the surface sediments for later analysis:

- Hydrocarbons (stored in a pre-washed glass jar)
- Heavy & trace metals and Total Organic Carbon & Total Organic Matter (stored in doubled lined ziplock plastic bag)
- Particle size distribution (PSA; stored in doubled lined ziplock plastic bag)

4.1.5 Faunal Grab Sampling and Sample Preservation

All fauna samples were sieved using the *Wilson* Auto-siever (WAS) over a 5mm and a 0.5mm mesh sieve. These specific sieve sizes were used to replicate the sampling method applied by MMT (2022; Document ref: 103748-NAT-MMT-SUR-REP-ENVSURRE). The inner grab buckets were cleaned before deployment for any new station to avoid contamination. Samples were subject to quality control on recovery and were flagged if they did not meet the following requirements:

- Water above sample was undisturbed
- Bucket closure complete (no sediment washout)
- Sampler was retrieved perfectly upright
- Inspection/access doors had closed properly
- Sample size was at least 40% of the sampler's capacity
- No hagfish (*Myxine glutinosa*) and/or mucus coagulants

Key observations from samples included colour, sediment classification, layering, smell (including the presence of H_2S), obvious fauna, evidence of bioturbation and anthropogenic debris, including artefacts of archaeological importance.

The preservation of materials was undertaken using standard techniques. All physico-chemical samples were stored in appropriate containers (i.e. glass for hydrocarbons and plastics for metals and PSA) and immediately frozen and stored (<-18°C) for later transportation (frozen) to the laboratory upon demobilisation. Macrofaunal samples were fixed in 5-10% buffered formalin. This material will be later transferred to Industrial Methylated Spirit (IMS). All biological samples were double-labelled with internal and external tags.

4.2 Laboratory Methods

4.2.1 Particle Size Analysis

The samples recovered from each site were analysed by BSL which is accredited under the National Marine Biological Association Quality Control scheme (NMBAQC) for PSA analysis.

The sample was homogenised and split into a small sub-sample for laser diffraction and the remaining material was sieved through stainless steel sieves with mesh apertures from 63mm down to 1mm. In most cases almost the entire sample would pass through the sieve stack, but any material retained on the sieve, such as small shells, shell fragments and stones were removed and the weight was recorded.

The smaller sub-sample was wet screened through a 1000µm sieve and determined using a Malvern Mastersizer 3000 particle sizer according to Standard Operating Procedures (SOP). The results obtained by a laser sizer have been previously validated by comparison with independent assessment by wet sieving (Hart, 1996). The range of sieve sizes, together with their Wentworth classifications (Appendix F – DATA PRESENTATION, LABORATORY AND STATISTICAL ANALYSES. For additional quality control, all datasets were run through the Mastersizer in triplicate and the variations in sediment distributions assessed to be within the 95% percentile.

The separate assessments of the fractions above and below 1000µm were combined using a computer programme. This followed a manual input of the sieve results for fractions >63mm, 63mm-45mm, 45mm-31.5mm, 31.5mm-22.4mm, 22.4mm-16mm, 16mm-11.2mm, 11.2mm-8mm, 8mm-5.6mm, 5.6mm-4mm, 4mm-2.8mm, 2.8mm-2mm, 2mm-1.4mm and 1.4mm-1mm fractions and the electronic data captured by the Mastersizer below 1000µm.

This method defines the particle size distributions in terms of Phi mean, median, fraction percentages (i.e. coarse sediments, sands and fines), sorting (mixture of sediment sizes) and skewness (weighting of sediment fractions above and below the mean sediment size; Folk 1954). For more information on laboratory analyses please refer to Appendix F – DATA PRESENTATION, LABORATORY AND STATISTICAL ANALYSES.

4.2.2 Chemical Analysis

The different compounds that were analysed along with detection limits are stated in Table 4-1 to Table 4-3. The analyses included concentration analysis of metals, hydrocarbons (THC and PAH) and organics (organic matter and TOC).

Table 4-1 Metal Analysis and Minimum Limits of Detection

Metals	Detection Limits	Unit	Method of Analysis	Accreditation
Hg	0.01	mg/Kg (Dry Weight)	ICPMSS	MMO
Cd	0.04	mg/Kg (Dry Weight)	ICPMSS	MMO
Be	0.2	mg/Kg (Dry Weight)	ICPOES-MWSED	N
As, Cr, Cu, Pb	0.5	mg/Kg (Dry Weight)	ICPMSS	MMO
Ni	0.5	%	ICPMSS	MMO
Cr, Mn, V	1	mg/Kg (Dry Weight)	ICPMS-MWSED	UKAS
Zn	2	%M/M	ICPMSS	MMO
Ba	7.2	mg/Kg (Dry Weight)	ICPOES-MWSED	UKAS
Sr	10	mg/Kg (Dry Weight)	ICPOES-MWSED	UKAS
P	75	mg/Kg (Dry Weight)	ICPOES-MWSED	UKAS
Fe	860	mg/Kg (Dry Weight)	ICPOES-MWSED	UKAS
Al	1750	mg/Kg (Dry Weight)	ICPOES-MWSED	UKAS

Analysis of total hydrocarbons and aliphatics was performed by using an Agilent 6890 with an FID detector. Appropriate column and GC conditions were used to provide sufficient chromatographic separation of all analytes and the required sensitivity. PAH Dti and EPA are accredited by the United Kingdom Accreditation Service (UKAS).

Table 4-2 Hydrocarbon Analysis and Minimum Limits of Detection

Hydrocarbons	Detection Limits	Unit	Method of Analysis	Accreditation
THC	100	µg/Kg (Dry Weight)	ASC/SOP/303/306	N
PAH	1	µg/Kg (Dry Weight)	ASC/SOP/303/304	UKAS

TOC was analysed using an Eltra combustion method. This method is used for total carbon analysis of dried, crushed rock powder and environmental soil samples. The samples are previously treated with 10% HCl to remove inorganic carbon (Carbonates) before washing to remove residual acids and further dried. The Carbon Analyser heats the sample in a flow of oxygen and any carbon present is converted to carbon dioxide which is measured by infra-red absorption. The percentage carbon is then calculated with respect to the original sample weight. The range for the method is 0.01%-100%.

Table 4-3 Organics Analyses and Minimum Limits and Detection

Organics	Detection Limits	Unit	Method of Analysis	Accreditation
Total Organic Matter (TOM)	0.2	%	LOI(%MM)	N
Total Organic Carbon (TOC)	0.02	%M/M	WSLM59	UKAS

4.2.3 Macrofaunal Analysis

All macrofaunal determination was carried by BSL or BSL contracted specialist taxonomist with extensive experience in the identification of macrofaunal samples undertaken in shallow and deep-water environments and the survey region. Benthic sediment samples were thoroughly washed with freshwater on a 500µm sieve to remove traces of formalin, placed in gridded, white trays and then hand sorted by eye followed by binocular microscope, to remove all fauna. Sorted organisms were preserved in 70% IMS and 5% glycerol. Where possible, all organisms were identified to species level according to appropriate keys for the region.

The macrofauna are broadly split into two functional groups: 'infauna' are animals which live within the sediments and 'epifauna' are animals living on or attached to the seabed, stones or biota. Epifauna may be further divided into 'solitary epifauna' and 'colonial epifauna'. Solitary epifauna includes taxa which are epifaunal in nature but form distinct and countable units which can be attached to hard substrate. Colonial epifauna are inclusive of epifauna, which are counted on a presence and absence basis. Within the data analysis, solitary epifauna have been included within the infaunal species, however colonial epifauna have been omitted and this component of the macrobenthos is discussed separately in Section 5.3.3.

All taxa were distinguished by species but identified to at least family level where possible. Nomenclature for species names were allocated either when identity was confirmed, allocated as "cf." when apparently identifying to a known species but confirmation was not possible (for example, incomplete specimens or descriptions), or allocated as "aff." when close to but distinct from a described species. The terms "indet." refers to being unable to identify to a lower taxon and "juv" as a juvenile to that species, genus, or family.

Quality Assurance

BSL is committed to total quality control from the start of a project to its completion. All samples taken or received by the company were given a unique identification number. All analytical methods were carried out according to recognised standards for marine analyses. All taxonomic staff are fully qualified to post-doctorate level. Documentation is maintained that indicates the stage of analysis that each sample has reached. A full reference collection of all specimens has been retained for further clarification of putative species groups where/if required. BSL is a participant in the NMBAQC quality assurance scheme.

Digital datasets are kept for all sites in the form of excel spreadsheets (by sample and by station) on BSL's archive computer. This system is duplicated onto a second archive drive in case of electronic failure. These datasets will be stored in this way for a minimum of 3 years or transferred to storage disk.

Biological Data Standardisation and Analyses

In accordance with OSPAR Commission (2004) guidelines, all species falling into juvenile, colonial, planktonic or meiofaunal taxa are excluded from the full analyses within the dataset. This helps to reduce the variability of data undertaken during different periods within the year, or where minor changes may occur or where some groups may only be included in a non-quantitative fashion, such as presence/absence.

Certain taxa, such as the Nematoda, normally associated with meiofauna, were included where individuals greater than 10mm were recorded. Sub-sampling was performed for specific taxon (Mytilidae juv.) following NMBAQC guidelines at station A5_OPB_01. For more information, see Section 4.2.

4.3 Data Analyses

4.3.1 Visual Data Analysis

The stills were analysed to identify species including seabed substrate. The video recordings were used to aid in the assessment of features and extent of habitats. Particular attention was paid to the elevation of habitats above ambient seabed level, together with their spatial extent, percentage biogenic cover and patchiness, as these are key criteria for evaluating areas of conservation importance and reef structures (Gubbay, 2007; Irving, 2009 and Roberts, 2011).

4.3.2 Particle Size Analysis

Sediment particle size distribution statistics for each sample were calculated from the raw data by BSL's internal laboratory. The distribution curve compositions are present in Appendix I – PARTICLE SIZE DISTRIBUTION.

4.3.3 Chemical Analysis

A variety of reference values relating to regional background levels and threshold effect levels have been utilised in this report to aid in the interpretation of the environmental baseline survey results.

UKOOA 50th and 95th Percentiles for Background North Sea Sediments

In 2001, the UK Offshore Operators Association (herein known as UKOOA) published sediment quality guidelines for the UK North Sea (UKOOA, 2001). Using a database of survey data collected between 1975-95, the report sets out 'background' levels for a variety of parameters (e.g. organic carbon, hydrocarbon, and metals content) in sediments over 5km from an existing oil and gas platform. For the current Environmental Baseline Survey (EBS) the 50th and 95th percentile levels for uncontaminated background sediments are presented where available for the southern North Sea (SNS).

OSPAR Background Concentrations and Background Assessment Concentrations

To monitor progress towards 'background conditions' in the marine environment, OSPAR developed a range of background concentrations (BCs) and background assessment concentrations (BACs) for use as reference levels throughout the OSPAR marine area. BCs are concentrations of contaminants derived from analysis of core samples to reflect pre-industrial, pristine, background levels for the OSPAR area (Webster *et al.*, 2009). BACs have been statistically derived from BCs and represent the level above which concentrations can be considered to be significantly higher than the relevant BC, with concentrations said to be near background if they are below their corresponding BAC (OSPAR, 2008). In the current report, reference to BCs and BACs has been made after normalisation of metals and PAHs using the method described in detail in the corresponding results section.

OSPAR Effect Range Low (ERL) and Effect Range Median (ERM) Concentrations

In order to assign a level of context for toxicity, an approach used by Long *et al*., (1995) to characterise contamination in sediments will be used in this report. 'Effect range low' (ERL) levels were defined as concentration of metals at which adverse effects were reported in 10% of the data reviewed, whilst 'effect range median' (ERM) levels were defined as the concentrations at which 50% of studies reported harmful effects. The ERLs and ERMs have been used to evaluate the ecological significance of heavy and trace metal concentrations within the survey area.

Cefas Chemical Action Levels 1 and 2

Action levels for the disposal of dredged material are not statutory concentrations for dredged material but are used as part of a weight of evidence approach to decision making on the disposal of dredged material to sea (MMO, 2015 and Marine Scotland, 2017). While the action levels are strictly intended for consideration of dredging applications, they are often used to evaluate sediment physico-chemistry for non-dredging projects.

- Contaminant levels in dredged material below chemical action level (cAL) 1 are of no concern and are unlikely to influence the licencing decision.
- Dredged material with contaminant levels between cAL1 and cAL2 requires further consideration and testing before a decision can be made.
- Contaminant levels in dredged material above cAL2 are generally considered unsuitable for sea disposal.

The cAL1, due to the relatively low values, is the most effective of the European approaches at filtering out potentially toxic samples. i.e. potentially most protective of the environment. Whereas cAL2 values are among the least conservative of the OSPAR countries, and so have the potential to fail to prevent disposal at sea for sub-lethally or acutely toxic sediments.

4.3.4 Univariate Statistical Analysis

The following primary and univariate parameters were calculated for each all data by stations and sample (Table 4-4).

Table 4-4 Primary and Univariate Parameter Calculations

Variable	Parameter	Formula	Description
Total Species	S	Number of species recorded	Species richness
Total Individuals	N	Number of individuals recorded	Sample abundance
Shannon-Wiener Index	H(s)	$H(s) = -\sum_{i=1}^{s} (Pi)(\log_2 Pi)$ where s = number of species & Pi = proportion of total sample belonging to *i*th species.	Diversity: using both richness and equitability, recorded in log 2.
Simpsons Diversity	1-Lambda	$Lambda = \sum \left(\frac{ni(ni-1)}{N(N-1)} \right)$ where ni = number of individuals in the *i*th species & N = total number of individuals	Evenness, related to dominance of most common species (Simpson, 1949)
Pielou's Equitability	J	$J = \frac{H(s)}{(\log S)}$ where s = number of species & H(s) = Shannon-Wiener diversity index.	Evenness or distribution between species (Pielou, 1969)
Margalef's Richness	D_{Mg}	$D_{Mg} = \frac{(S-1)}{(\log N)}$ where s = number of species & N = number of individuals.	Richness derived from number of species and total number of individuals (Clifford and Stevenson, 1975)

In addition to univariate methods of analysis, data for both sample replicates and stations were analysed using multivariate techniques. These serve to reduce complex species-site data to a form that is visually interpretable. A multivariate analysis was based on transformed data (square root) to detect any improved relationships when effects of dominance were reduced. The basis for multivariate analyses was based upon the software PRIMER (Plymouth Routines In Multivariate Ecological Research).

4.3.5 Multivariate Statistical Analysis

Multivariate analysis of samples was undertaken using the PRIMER 7 software (Clarke *et al.*, 2014).

Similarity Matrices and Hierarchical Agglomerative Clustering (CLUSTER)

A similarity matrix is used to compare every individual sample station with each other. The coefficient used in this process is based upon Euclidean distance considered to be the most suitable for environmental data. These are subsequently assigned into groups according to their level of similarity and clustered together based upon a Group Average Method into a dendrogram of similarity.

Non-Metric Multi-dimensional Scaling (nMDS)

nMDS is currently widely used in the analysis of spatial and temporal change in benthic communities (e.g. Warwick and Clarke, 1991). The recorded observations from data were exposed to computation of triangular matrices of similarities between all pairs of samples. The similarity of every pair of sites was computed using the Bray-Curtis index on transformed data. Clustering was by a hierarchical agglomerative method using group average sorting, and the results are presented as a dendrogram and as a two-dimensional ordination plot. The degree of distortion involved in producing an ordination gives an indication of the adequacy of the nMDS representation and is recorded as a stress value.

Similarity Profiling (SIMPROF)

Analyses data for significant clusters that show evidence of a multivariate pattern in data that are a priori unstructured, i.e. single samples from each site. The test works by comparing samples which have been ranked and ordered by resemblance against an expected profile which is obtained by permuting random variables across the set of samples, a mean of 1000 permutations is taken to produce an expected result for null structure with rare and common species displaying the same pattern. If the actual data deviates outside the 95% limits of the expected profile, then there is evidence for significant structure and vice versa. The 'significant structure' is well represented on a dendrogram which will also show the clusters containing that lack significant differentiation (null structure), (Clarke & Gorley, 2006).

Principle Component Analyses (PCA)

This analysis is used to reduce the number of variables of larger data sets to smaller ones while still preserving as much information as possible. The PCA looks for patterns in the data and detects similarities or correlations between variables and brings out the strongest pattern in the data set which can then be further explored.

Similarity Percentages Analysis (SIMPER)

The nMDS clustering program is used to analyse differences between sites. SIMPER enables those species responsible for differences to be identified by examining the contribution of individual species to the similarity measure.

4.4 Habitat Classification

Habitat descriptions have been interpreted from the side scan sonar (SSS) and bathymetric data acquired during the current survey. Global Mapper V20 GIS software was used to review the SSS mosaic (Geotiff) and multibeam bathymetry data (Geotiff and xyz) and to delineate areas of different seabed habitats. In addition, information on seabed sediment types and faunal communities from seabed photography and grab sampling, and the predicted seabed habitat map produced by EMODnet was utilised in the habitat investigation across the Sea Link survey area.

4.5 Protected Habitat and Species Assessments

4.5.1 EMODnet Predicted Habitat Distributions

To further aid interpretation, comparison has been made with the predicted seabed habitat distribution data produced by the European marine observation and data network (EMODnet). EMODnet is a long-term marine data initiative developed through a stepwise approach to collect data and build on existing databases to provide access to European marine data across seven discipline-based themes: bathymetry, geology, seabed habitats, chemistry, biology, physics, and human activities (EMODnet, 2021). The broad-scale seabed habitat map is a predictive delineation of habitats within all European seas to the EUNIS classification system (EMODnet, 2022). Formulated through international (OSPAR) and national monitoring programmes in collaboration with European projects such as MESH or Mesh Atlantic the predicted seabed habitat map can be a useful resource in confidently assigning biotopes within a given survey area (Figure 4-1).

4.5.2 Legislative Background

4.5.2.1 UK Post-2010 Biodiversity Framework

The 'UK Post-2010 Biodiversity Framework' was released in July 2012 as a replacement for the UK Biodiversity Action Plan (UKBAP) and 'Conserving Biodiversity – the UK Approach'. It reflects a shift in strategic direction prompted by the publication of the CBDs 'Strategic Plan for Biodiversity 2011-2010' and the introduction of the EU Biodiversity Strategy (EUBS) in May 2011.

The UKBAP (2008) outlines priority species and habitats earmarked for protection, including 22 marine and coastal habitats of particular importance. Key habitats relevant to the survey area include:

- Subtidal Chalk
- Fragile Sponge and Anthozoan Communities on Subtidal Rocky Habitat
- *Sabellaria spinulosa* Reefs
- Subtidal Sands and Gravels
- Horse Mussel Beds
- File Shell Beds
- Maerl Beds
- Serpulid Reefs
- Geogenic Reefs
- Blue Mussel Beds on Sediment

4.5.2.2 OSPAR Commission

At its Biodiversity Committee (BDC) meeting in 2003, OSPAR agreed to proceed with a programme to collate existing data on the distribution of fourteen key habitats, as part of a wider programme to develop measures for their protection and conservation. The UK agreed to compile the relevant data for its marine waters and submit these for collation into composite maps on the distribution of each habitat type across the whole OSPAR area. The work is being coordinated by the Joint Nature Conservation Committee (JNCC). Key OSPAR habitats that may occur in coastal/open water marine environment include: "*Sabellaria spinulosa* Reefs", "*Modiolus modiolus* Beds", and "*Arctica islandica*" (OSPAR, 2008).

4.5.2.3 European Habitats Directive

The United Kingdom, a signatory of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention, 1979), adopted the European Community Habitats Directive in 1992 to fulfil its obligations under the convention. This Directive mandates member states to undertake various measures including, protecting species listed in Annexes, monitoring habitats and species, and submitting reports every six years on Directive Implementation.

The Directive lists 189 habitats in Annex I and 788 species in Annex II, which Member States must protect through a network of sites. Each Member State must propose a national list of sites for evaluation, leading to the establishment of a European network of Sites of Community Importance (SCIs). Eventually, these sites will be designated as Special Areas of Conservation (SACs) and, together with Special Protection Areas (SPAs) under the EC Birds Directive (2009), form the Natura 2000 protected area network. The Directive underwent amendments in 1997 and 2003.

Implementation of the Habitats Directive in offshore waters began in 2000, identifying potential habitats for SAC selection in UK offshore waters. Relevant habitats for this region include Sub-tidal reefs and Submarine structures formed by leaking gases. The Directive applies the precautionary principle to protect sensitive areas, allowing projects only if they do not adversely affect site integrity.

Following the UK's exit from the European Union (EU), new regulations have transposed the land and marine aspects of the Habitats Directive and Wild Birds Directive. The Conservation of Habitats and Species (EU exit) Regulations 2019, effective from January 1, 2021, amended the 2017 regulations to ensure their continued functionality post-EU exit. These amendments primarily transferred functions from the European Commission to authorities in England, Wales and Scotland, while retaining existing processes and terms (GOV.UK, 2022).

4.5.2.4 The UK Marine Monitoring Programme

The UK National Marine Monitoring Programme (NMMP) was established in response to the 1986 House of Lords select committee on marine science and technology, who recommended that a common approach to marine monitoring should be established to comply with the international and national commitments (OSPAR Convention and EC Directives). The NMMP focuses on stable depositional sites and records data on sediment chemistry, biological communities, the bioaccumulation of heavy metals (cadmium, mercury and lead) and their ecological effects (Bordin *et al.*, 1992; McLeese *et al.*, 1987).

A National Marine Biology Analytical Quality Control Scheme (NMBAQC) was established in 1992 to establish quality assurance standards for the biological aspects of the NMMP. Similar schemes were set up for chemical (NMCAQC) and ecotoxicological monitoring (NMEAQC) (Davies *et al.*, 2001). The NMCAQC scheme was subsequently renamed the National Marine Chemistry Advisory Group (NMCAG) and the terms of reference for this group were updated in 2007.

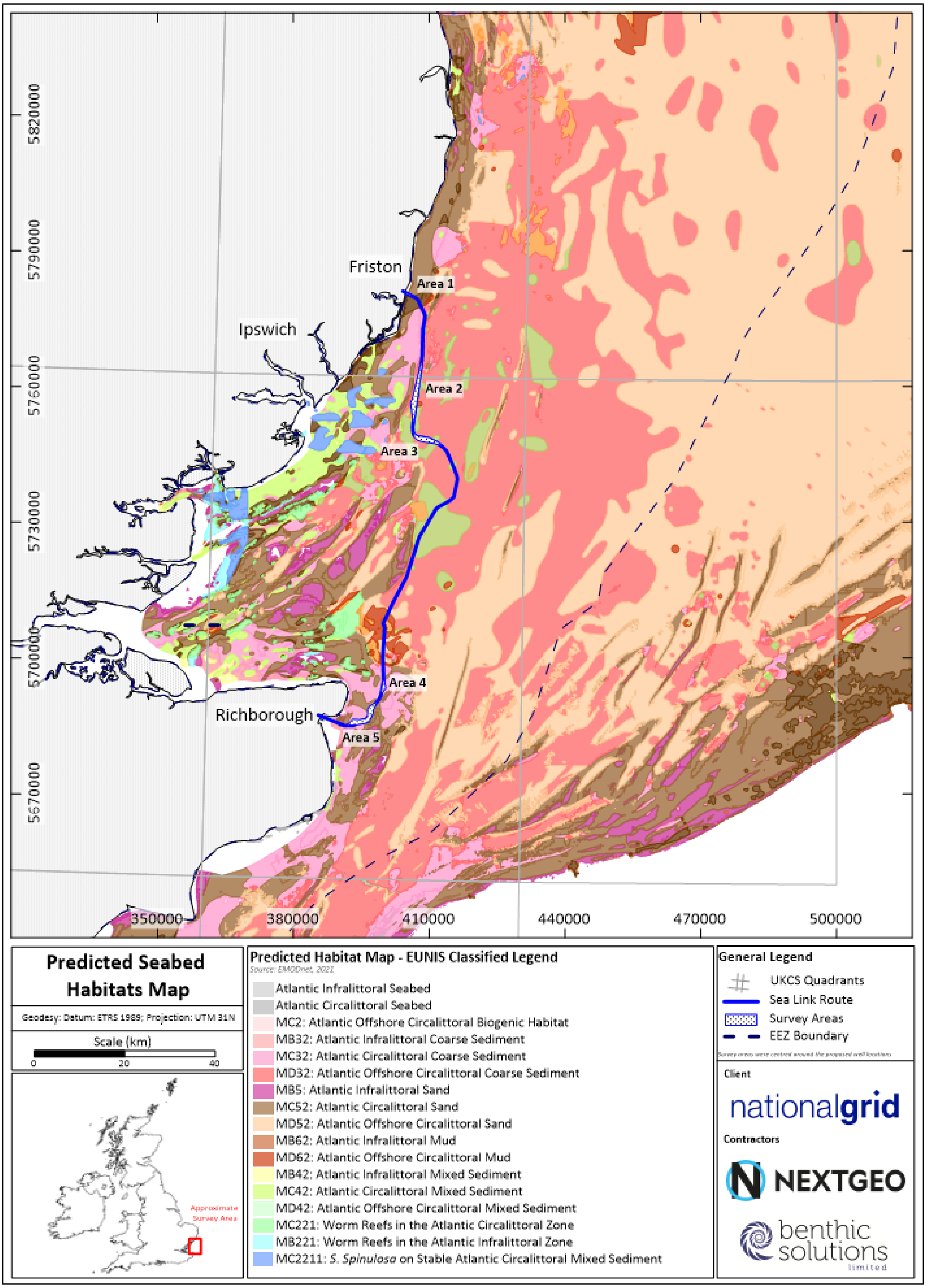


Figure 4-1 EMODnet Predicted Seabed Habitats Map in Relation to Survey Area

5 RESULTS

A total of 8 grab sampling stations were completed with a full suite of sediment PSA/PC/Fauna samples retained, as well as 17 camera transects were acquired, paired with 17 acquired CTD profiles.

See Table 5-1 for the number of sample stations, Table 5-2 for summary of completed grabs and Table 5-3 for summary of acquired camera transects.

Table 5-1 Number of Sample Stations

Number of Sample Sites	Camera Transects	Grab Sample Stations	PSA/PC Sample Stations	CTD Profiles
	17	8	8	17

Table 5-2 Summary of Completed Grab Stations

Geodetics; ETRS89, UTM 31N				
Station	Easting (m)	Northing (m)	Grab Sampling	
			PC	Fauna
A2_ES_01	407 815	5 762 429	✓	✓
A2_ES_02	407 344	5 759 565	✓	✓
A2_ES_03	406 826	5 756 145	✓	✓
A2_ES_04	406 419	5 752 338	✓	✓
A3_NS_01	408 455	5 748 522	✓	✓
A4_GLC_01	399 550	5 693 348	✓	✓*
A4_GLC_02	399 794	5 694 996	N/S	N/S
A4_GLC_03	399 278	5 691 871	✓	✓*
A5_OPB_01	396 886	5 687 396	✓	✓

<u>Notes:</u>
"PC" = Physico-chemistry (Particle Size Analysis, Total Organic Carbon and Matter, Hydrocarbons, Heavy and Trace Metals)
""= Small sample (<40% retention) however, sample collected as alternate*
"N/S" = No sample acquired

Table 5-3 Summary of Completed Camera Transects

Geodetics; ETRS89, UTM 31N								
Transect		Date	Time (UTC)	Easting (m)	Northing (m)	Video footage (mm: ss)	HD Video Quality	SD Video Quality
A2_ES_01	SOL	29/08/2024	13:08:58	407 799	5 762 436	11:17	✓	✓
	EOL		13:20:15	407 898	5 762 412			
A2_ES_02	SOL	29/08/2024	14:54:20	407 302	5 759 548	12:35	✓	✓
	EOL		15:06:55	407 408	5 759 583			
A2_ES_03*	SOL	29/08/2024	16:52:30	406 867	5 756 096	19:30	✓	✓
	EOL		17:11:50	406 754	5 756 210			
A2_ES_04	SOL	29/08/2024	20:14:00	406 412	5 752 292	11:30	✓	✓
	EOL		20:25:30	406 430	5 752 403			

Geodetics; ETRS89, UTM 31N								
Transect		**Date**	**Time (UTC)**	**Easting (m)**	**Northing (m)**	**Video footage (mm: ss)**	**HD Video Quality**	**SD Video Quality**
A2_ES_05_HAS	SOL	29/08/2024	18:42:35	406 509	5 754 562	16:52	✓	✓
	EOL		18:59:27	406 451	5 754 701			
A2_ES_ADD_01	SOL	02/09/2024	22:43:52	406 513	5 754 735	10:18	✓	✓
	EOL		22:54:10	406 496	5 754 649			
A2_ES_ADD_02_A	SOL	02/09/2024	21:57:58	406 493	5 754 602	11:32	✓	✓
	EOL		22:09:30	406 547	5 754 652			
A3_NS_01	SOL	29/08/2024	22:27:12	408 394	5 748 504	10:48	✓	✓
	EOL		22:38:00	408 499	5 748 537			
A3_NS_02_HAS*	SOL	30/08/2024	00:05:30	411 282	5 747 288	09:30	✓	✓
	EOL		00:15:00	411 374	5 747 305			
A3_NS_03_HAS	SOL	30/08/2024	00:34:00	411 454	5 747 317	12:45	✓	✓
	EOL		00:46:45	411 563	5 747 370			
A4_GLC_01*	SOL	01/09/2024	09:03:20	399 546	5 693 322	06:50	✓	✓
	EOL		09:10:10	399 556	5 693 389			
A4_GLC_02*	SOL	01/09/2024	02:30:00	399 773	5 695 092	14:00	✓	✓
	EOL		02:44:00	399 805	5 694 967			
A4_GLC_03_A*	SOL	01/09/2024	13:27:00	399 310	5 691 952	20:00	✓	✓
	EOL		13:47:00	399 266	5 691 838			
A5_OPB_01*	SOL	30/08/2024	21:37:00	396 900	5 687 404	12:00	✓	✓
	EOL		21:48:58	396 869	5 687 369			
A5_OPB_02	SOL	-	-	407 305	5 759 552	-	-	-
	EOL			407 401	5 759 584			
A5_OPB_03	SOL	01/09/2024	-	-	-	-	-	-
	EOL		-	-	-			
A5_OPB_04_HAS*	SOL	01/09/2024	18:09:04	397 284	5 688 336	13:00	✓	✓
	EOL		18:22:00	397 253	5 688 423			
A5_OPB_05_HAS	SOL	30/08/2024	20:19:00	396 556	5 686 646	16:00	✓	✓
	EOL		20:35:00	396 500	5 686 781			
A5_OPB_ADD_01*	SOL	02/09/2024	00:51:00	396 438	5 686 901	21:00	✓	✓
	EOL		01:12:00	396 320	5 686 745			
A5_OPB_06_HAS	SOL	-	-	395 520	5 686 312	-	-	-
	EOL			395 554	5 686 192			
A5_OPB_07_HAS	SOL	-	-	394 361	5 685 625	-	-	-
	EOL			394 260	5 685 636			

Notes:
The suffix "_A" denotes where camera transect was re-run.
"✓" Data acceptable for habitat assessment.
"-" Unable to obtain data after attempt.
"" Poor visibility due to high turbidity.*
"Greyed" are stations abandoned as per Client agreement.

5.1 Particle Size Analysis

5.1.1 Univariate Analysis of Sediment

The results of particle size analyses indicated a heterogeneous sediment type across the Sea Link route (Table 5-4). The seabed sediments across the route were primarily dominated by either sand (mean 45.1%±25.7SD) or gravel (mean 32.8%±24.0SD). The heterogeneity of the sediment was demonstrated by a high coefficient of variation for the proportion of sands (56.9%), gravel (73.3%) and fines (87.6%).

Proportions of sand ranged from 16.7% at station A2_ES_01 to 86.8% at station A5_OPB_01 (Figure 5-1). Stations with the highest proportions of sand (A5_OPB_01 and A2_ES_04) aligned with the defined area of Infralittoral Fine Sand (A5.23) in the northern extent of Area 5 as well as Circalittoral Fine Sand (A5.25) seen in the southern extent of Area 2. This was also reflected in the mean sand per survey area within the previous MMT report (MMT, 2022), which observes highest mean sands within Area 5 and Area 2 Table 5-4). No significant Spearman's correlation was apparent between the proportion of sands and water depth ($p>0.05$) (Appendix Q – SPEARMAN'S CORRELATION).

Gravel content ranged from 1.4% at station A2_ES_02 to 67.8% at station A2_ES_01 (Figure 5-1). While Area 2 exhibited both the highest and lowest gravel content amongst the stations, analysis of the average gravel percentages per area, shows a different pattern. Both this study and the previous MMT study identified Area 4 as having the lowest mean gravel content and Area 5 as the highest, highlighting heterogeneity across the surveyed areas. Fines content also varied, with the lowest proportion (3.0%) noted in the southern extent at A5_OPB_01, while the maximum (63.2%) was noted within Area 2 at station A2_ES_02. The variation was consistent with the mean fines data per area, where both the current and historical MMT reports had Area 2 as having the highest average fines. No significant Spearman's correlation was apparent between the proportion of gravel or fines and water depth ($p>0.05$).

The Folk (1954) and Wentworth (1922) classifications for each station are listed in Table 5-4. The Wentworth classification assigns a single sediment class based on the mean particle size and is appropriate for well sorted modal sediments, dominated by a narrow range of sediment particle sizes. The Folk classification provides a more representative description for poorly sorted sediments, encompassing a range of particle sizes as it takes into account the relative proportions of mud (<63µm), sand (63µm-2mm) and gravel (>2mm) fractions. For the purposes of this study, we have used the modified Folk classification produced by the British Geological Survey (Long, 2006).

The samples collected in the survey area were represented by three Folk classifications with the majority of stations assigned as the 'Muddy Sandy Gravel' classification. The remaining stations were allocated as either 'Gravelly Sand' or Slightly Gravelly Sandy Mud', reflecting the variation in seabed sediment types across the overall survey area (Table 5-4).

The Wentworth classification scale identified five different sediment classifications, with more than one station assigned as either 'Coarse Sand', 'Medium Sand' or 'Granule' whilst the 'Very Coarse Sand' and 'Medium Silt' were each assigned to just one station. All stations were classified as either Poorly Sorted, Very Poorly Sorted or Extremely Poorly Sorted, suggesting a natural variation in sediment composition throughout the four areas.

Table 5-4 Summary of Surface Particle Characteristics

Station	Depth (m)	Mean Sediment Size (mm)	Mean Sediment Size (Phi)	Wentworth Classification	Sorting Coefficient	Sorting Classification	Fines (%)	Sands (%)	Gravel (%)	Modified Folk Scale
A2_ES_01	17.7	3.68	-1.88	Granule	4.37	Extremely Poorly Sorted	15.5	16.7	67.8	Muddy Sandy Gravel
A2_ES_02	22.9	0.03	5.19	Medium Silt	2.55	Very Poorly Sorted	63.2	35.4	1.4	Slightly Gravelly Sandy Mud
A2_ES_03	24.7	0.26	1.95	Medium Sand	4.08	Extremely Poorly Sorted	30.4	36.2	33.4	Muddy Sandy Gravel
A2_ES_04	21.6	0.52	0.94	Coarse Sand	1.70	Poorly Sorted	7.1	82.8	10.1	Gravelly Sand
A3_NS_01	22.8	0.28	1.85	Medium Sand	4.37	Extremely Poorly Sorted	31.0	33.8	35.2	Muddy Sandy Gravel
A4_GLC_01	13.5	1.53	-0.62	V. Coarse Sand	3.67	Very Poorly Sorted	11.0	42.2	46.7	Muddy Sandy Gravel
A4_GLC_03	11.5	2.16	-1.11	Granule	4.14	Extremely Poorly Sorted	15.9	26.9	57.2	Muddy Sandy Gravel
A5_OPB_01	11.8	0.76	0.40	Coarse Sand	1.15	Poorly Sorted	3.0	86.8	10.2	Gravelly Sand
Route Mean		**1.15**	**0.84**	-	**3.25**	-	**22.1**	**45.1**	**32.8**	
SD		**1.25**	**2.23**	-	**1.28**	-	**19.4**	**25.7**	**24.0**	
CV (%)		**108.5**	**265**	-	**39.25**	-	**87.6**	**56.9**	**73.3**	
Minimum		**0.03**	**-1.88**	-	**1.15**	-	**3.0**	**16.7**	**1.4**	
Maximum		**3.68**	**5.19**	-	**4.37**	-	**63.2**	**86.8**	**67.8**	
Area Mean										
Area 2		**1.12**	**1.55**		**3.17**	-	**29.0**	**42.8**	**28.2**	
Area 3		**0.28**	**1.85**		**4.37**	-	**31.0**	**33.8**	**35.2**	
Area 4		**1.85**	**-0.86**		**3.90**	-	**13.5**	**34.5**	**52.0**	
Area 5		**0.76**	**0.40**		**1.15**	-	**3.0**	**86.8**	**10.2**	
Historical Data (MMT, 2022)										
MMT Route Mean		-	-	-	-	-	**18.4**	**66.5**	**15.1**	
Area 2		-	-	-	-	-	**18.4**	**59.2**	**22.4**	
Area 4		-	-	-	-	-	**9.0**	**45.0**	**46.0**	
Area 5		-	-	-	-	-	**14.2**	**79.9**	**5.9**	

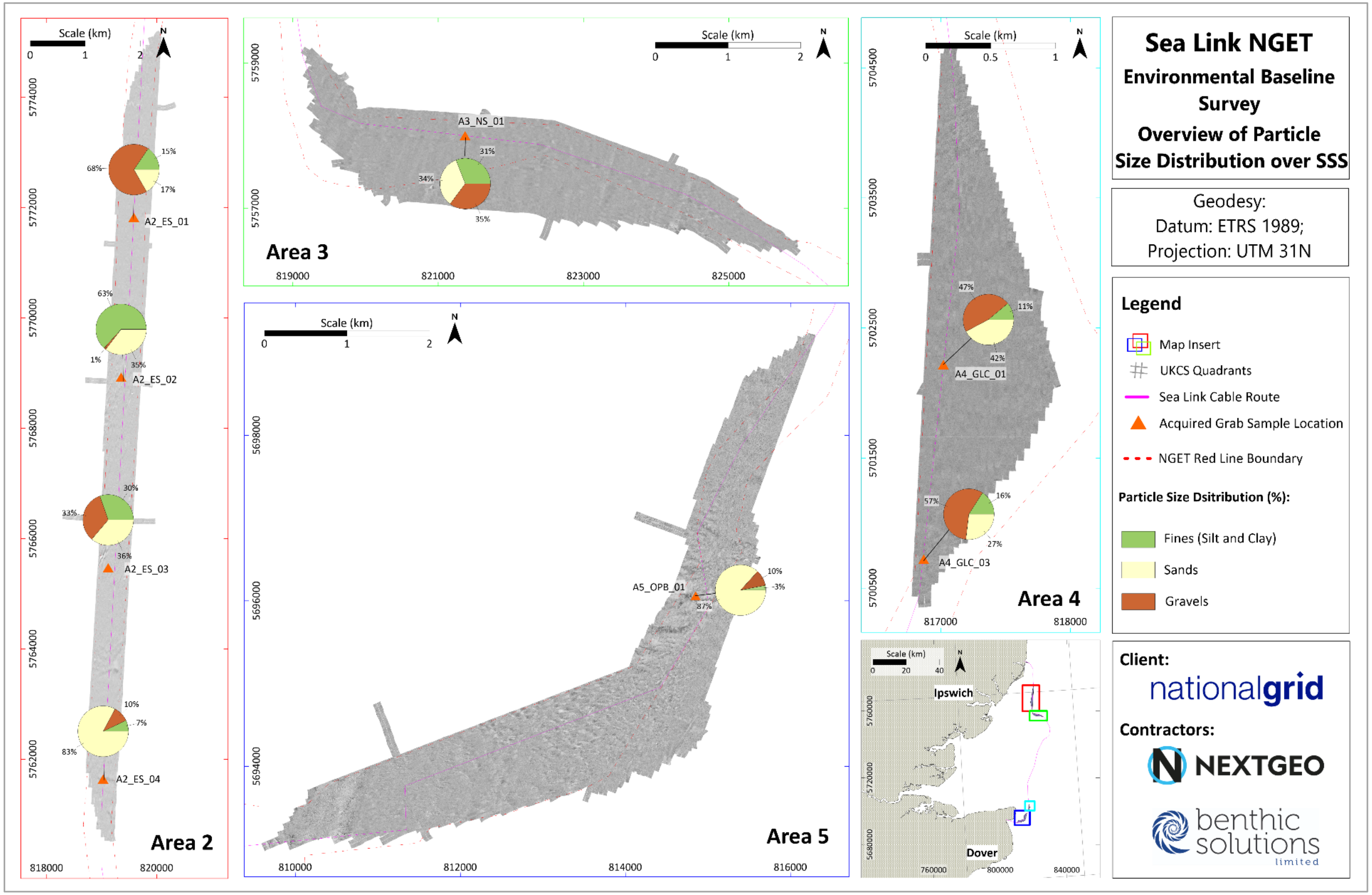


Figure 5-1 Overview of Particle Size Distribution

5.1.2 Multivariate Analysis of Sediment

The particle size distribution of sediments across the survey area were subjected to further detailed investigation by multivariate analysis using the Plymouth Routines in Multivariate Ecological Research software (PRIMER 7.0.17; Clarke *et al.*, 2014) to elucidate any spatial trends within the data.

A similarity dendrogram was generated by hierarchical agglomerative clustering (CLUSTER) using particle size data (phi) to illustrate similarities/differences between stations using the Euclidean distance dissimilarity measure. The dendrogram produced by cluster analysis is shown in and also sat within muddy sandy gravel and sandy gravel seabed feature. With red lines denoting statistically similar stations and black lines revealing significant differences. Similarity profiling analysis (SIMPROF) indicated the presence of five significantly different ($p<0.05$) clusters (Figure 5-2) as follows:

- Cluster 'a': This cluster was made up of two stations A2_ES_04 and A5_OPB_01 which both noted high proportion of sands (>80%) and are situated in an area defined seabed features of Sandy Gravel/ Silty Sand. The cluster was assigned the Modified Folk Classification of 'Gravelly Sand'.
- Cluster 'b': This cluster was formed by a single station; A2_ES_01 which noted the highest gravels (68%) across the survey areas. And assigned the 'Muddy Sandy Gravel' Modified Folk Classification.
- Cluster 'c': This cluster was formed of two Area 4 stations, A4_GLC_01 and A4_GLC_03, defined by seabed features as gravelly sand/sandy gravel. This cluster differentiated due to higher gravel content (>45%) compared to the majority of the route, increased influence of sands (>25%) and low proportions of fines were also noted (<15%). Similar to Cluster 'b' it was assigned the 'Muddy Sandy Gravel' Modified Folk Classification.
- Cluster 'd': This cluster was comprised of one station; A2_ES_02 which noted the highest fines content (63%) of the survey areas and was defined as 'Slightly Gravelly Sandy Mud' by the Modified Folk Classification.
- Cluster 'e': This final cluster comprised of two stations: A2_ES_03 and A3_NS_01, with mixed sediments. The cluster was defined as 'Muddy Sandy Gravel' by the Modified Folk Classification and was also situated within Muddy Sandy Gravel and Sandy Gravel seabed features.

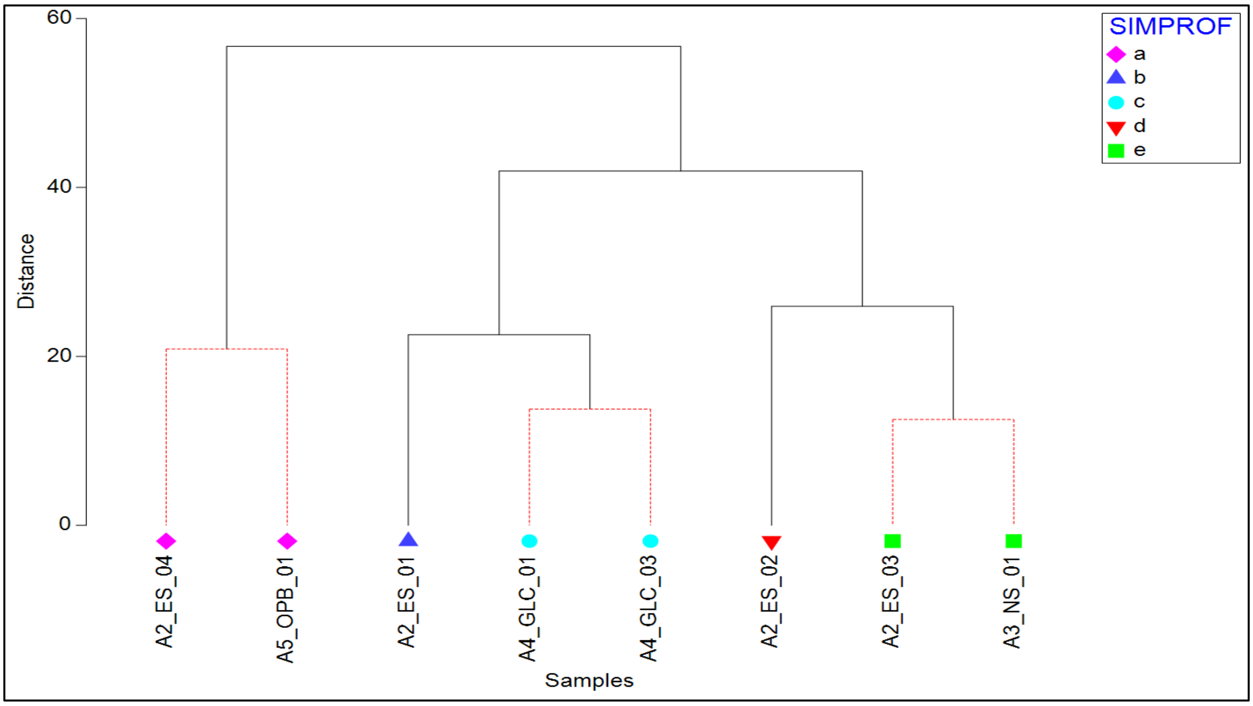


Figure 5-2 Particle Size Analysis Similarity Dendrogram

Similarities between the stations were also displayed as a 2-dimensional non-metric multi-dimensional scaling (nMDS) ordination (Figure 5-3) at a low stress level of 0.01. This plot shows the significant inter-cluster variation between cluster 'a' and the remaining clusters, of which were ordinated central and to the left of the plot, suggesting they were more closely related to each other than they were to cluster 'a'.

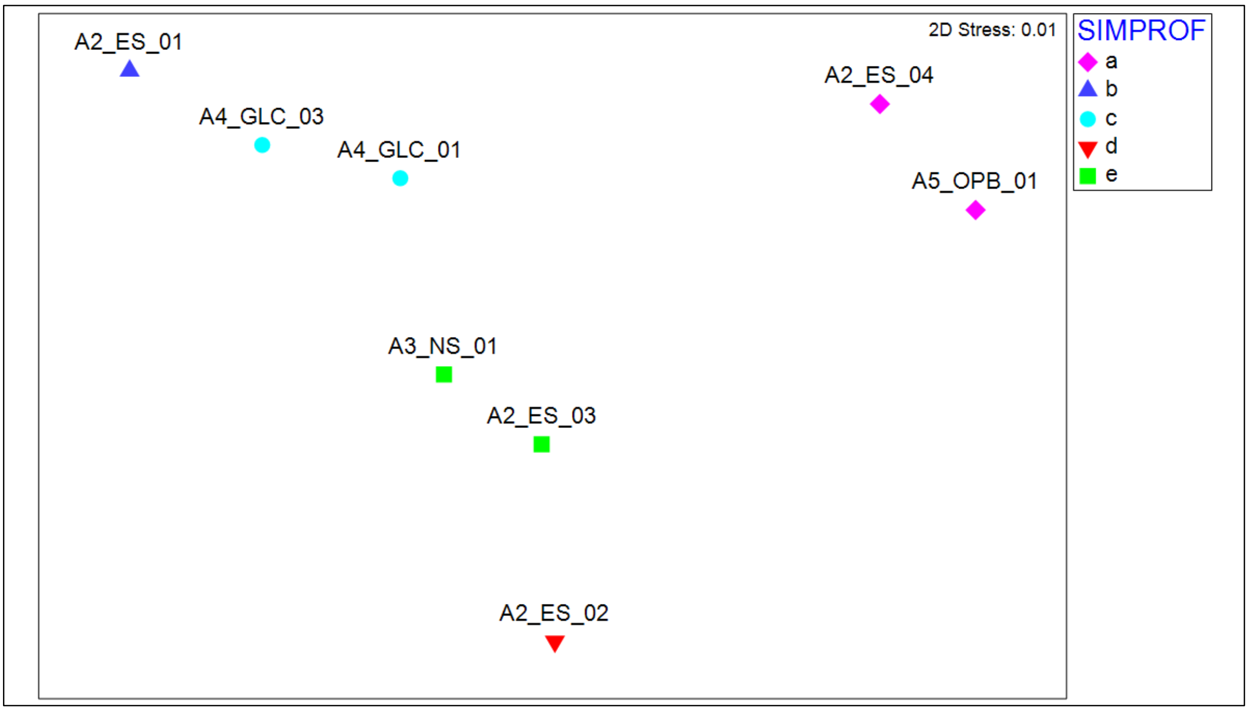


Figure 5-3 Particle Size Distribution nMDS Plot

A principal component analysis (PCA) was carried out on the proportional whole phi sieve fraction data for each survey station (Figure 5-4). The resultant PCA plot shows the distribution of each station along axes formed by the two principal components (PC1 and PC2) which together describe the largest proportion of overall variability in the particle size fraction dataset. The plot indicated that the varying proportions of phi fractions 1 to 2 (coarse to fine sand), as well as the proportion of phi fraction -3 (medium pebbles), were principally responsible for the differences in sediment composition across the Sea Link survey areas. Differentiation of cluster 'a' appeared to be largely due to the higher proportions of coarse to fine sand (phi 1 to 2), whilst clusters 'b' and 'c' were driven by proportions of medium pebble (phi -3). Clusters 'd' and 'e' were notably separated due to the negative relationship with the phi -3 fraction, where Cluster 'e' suggests an increased influence from higher phi fractions of fine sand to clay (phi >4).

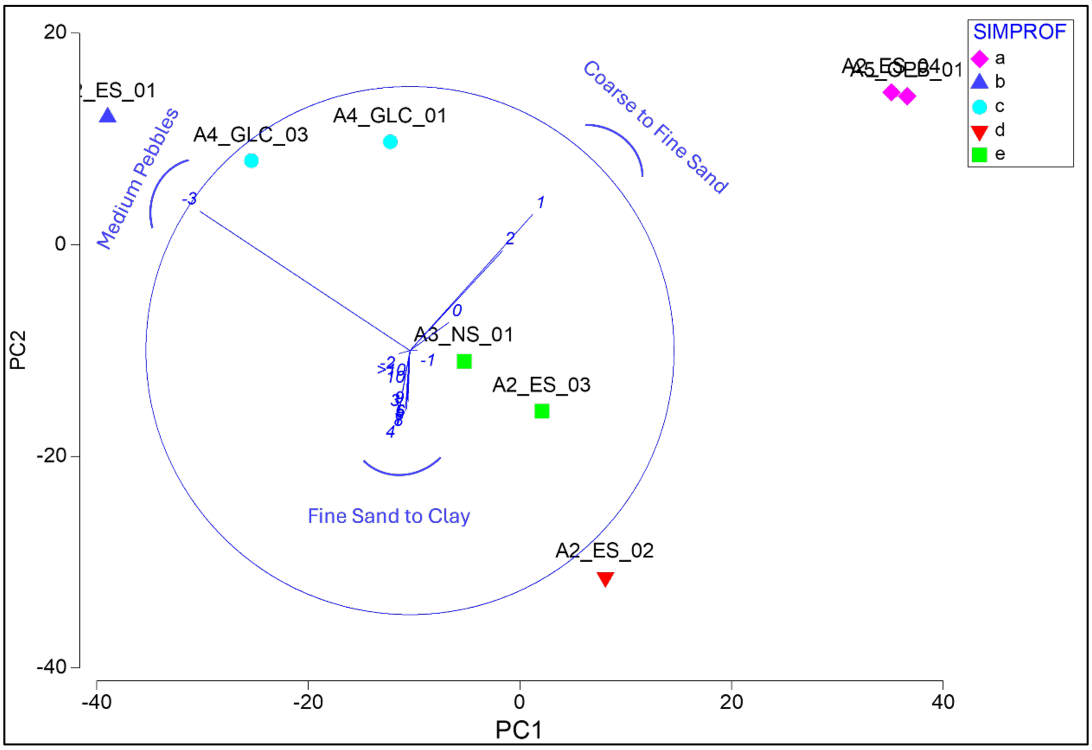


Figure 5-4 Particle Size Analysis Principal Components Analysis (PCA)

A comparison of the full particle size distribution dataset using Wentworth (1922) size categories split into the five clusters described above is shown in Figure 5-5, along with example sieve and grab sample photographs. The plot illustrates the general heterogeneity of the seabed sampled, with Cluster 'a' showing a unimodal distribution with a peak in the coarse to fine sand fraction (phi fraction 1 to 2). Cluster 'c' also noted a peak of coarse to fine sand, with a notable increase in the medium pebble fraction (phi -3). Cluster 'b' additionally showed a peak in the pebble fraction (phi -3) in comparison to Cluster 'e' which was notably more mixed and was defined by influence from the very coarse sand fraction (phi -1), the fine sand (phi 3) and the very fine silt fraction (phi 8). Cluster 'd' showed a similar distribution to Cluster 'e', however small peaks were only noted within the fine to very fine sand (phi 3 to 4) and very fine silt (phi 8) fractions. The geographical distribution of clusters is displayed over SSS in Figure 5-6.

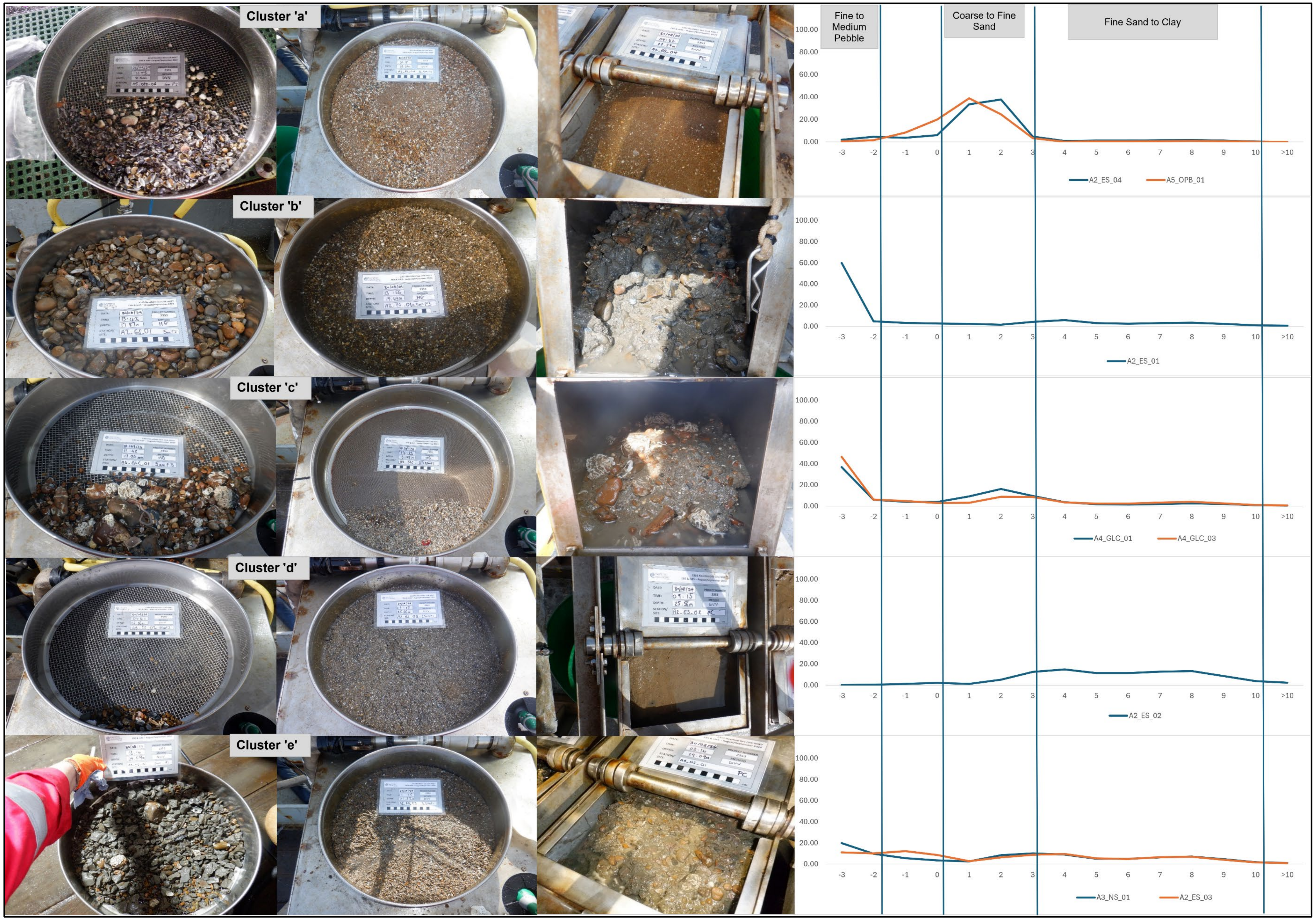


Figure 5-5 Particle Size Distribution for Clusters 'a' to 'e', with Example Grab Photographs of Samples Over 5mm (left) and 0.5mm (centre)

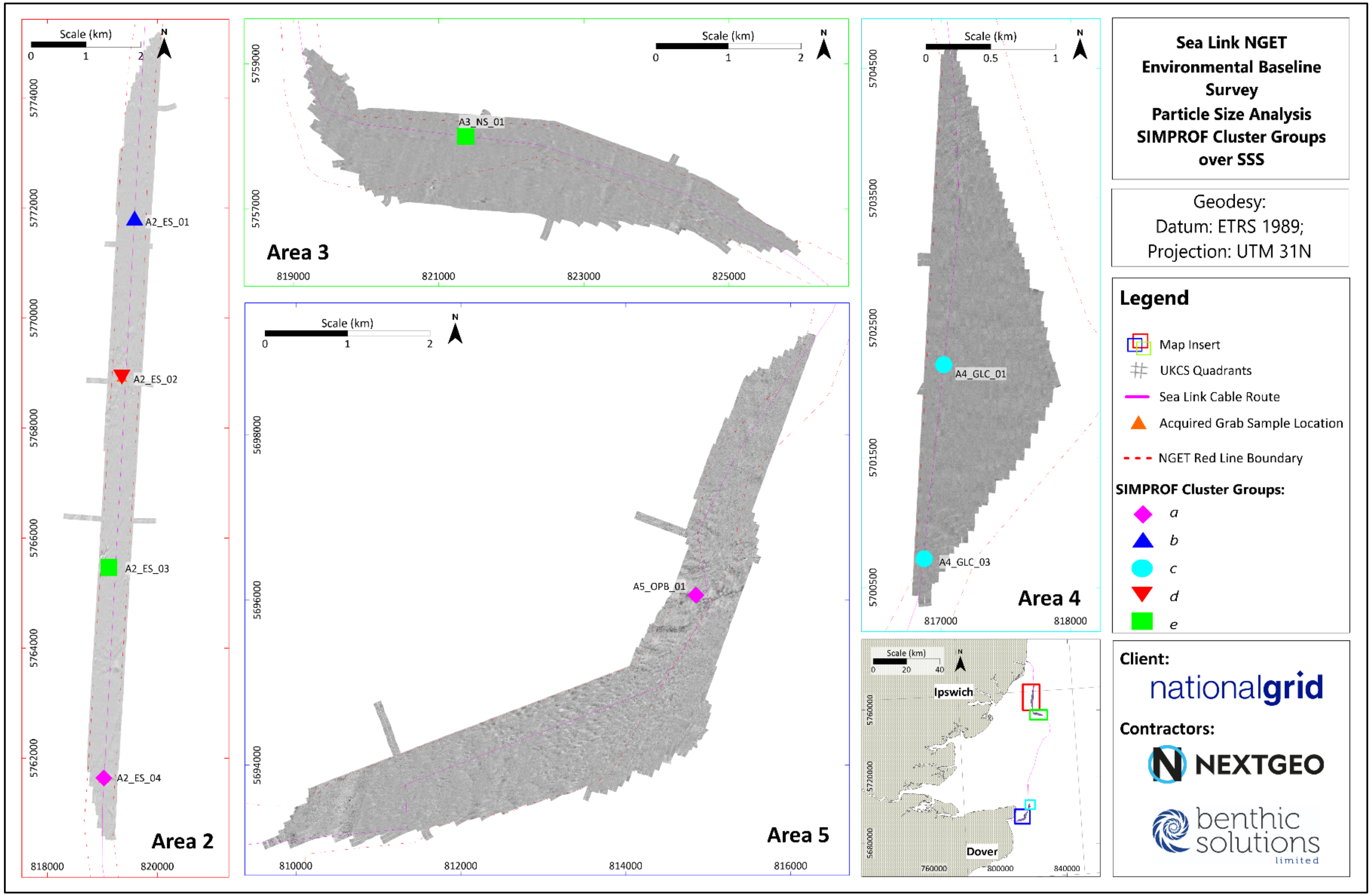


Figure 5-6 Particle Size Analysis SIMPROF Cluster Groups over SSS

5.2 Chemical Analysis

5.2.1 Organics

The sediments were analysed for total organic matter (TOM), total organic carbon (TOC) and moisture content, the results of which are presented in Table 5-5 with TOC additionally illustrated in Figure 5-7. TOC represents the proportion of biological material and organic detritus within the substrates. This method is less susceptible to the interference sometimes recorded using crude combustion techniques, such as analysing total organic matter by loss on ignition (LOI).

TOM levels were variable (mean 2.8%±1.4SD) and had a positive correlation with percentage of fines ($p<0.01$). Four of the stations were above the UKOOA (2001) SNS 50th percentile for TOM (1.12%), and the remaining four station exceeded the UKOOA (2001) SNS 95th percentile (2.30%).

TOC levels were fairly consistent across stations (mean 0.35%±0.17SD) and was found to have a positive Spearman’s correlation with the percentage of fines in the sediment ($p<0.01$, Appendix Q – SPEARMAN’S CORRELATION). TOC in surface sediments is an important source of food for benthic fauna (Snelgrove & Butman, 1994). However, an overabundance may lead to species richness and abundance reductions due to oxygen depletion. Increasing TOC may also reflect increases in physical factors (i.e., fines) and common co-varying environmental factors through greater sorption on increased sediment surface areas (Thompson and Lowe, 2004).

Moisture content at the stations had a mean of 25.0%±5.6SD.

TOC and TOM levels recorded during the MMT (2022) survey were slightly lower on average than those found during the BSL survey.

Table 5-5 Total Organic Carbon/Matter and Moisture Content

Station	Water Depth (m)	Total Organic Matter (%M/M)	Total Organic Carbon (% M/M)	Moisture Content (%)
A2_ES_01	18	2.5	0.36	23.4
A2_ES_02	23	5.0	0.64	34.8
A2_ES_03	25	2.5	0.35	25.3
A2_ES_04	22	1.6	0.19	24.3
A3_NS_01	23	4.9	0.54	27.7
A4_GLC_01	13	2.2	0.23	27.6
A4_GLC_03	12	2.1	0.37	21.6
A5_OPB_01	12	1.4	0.15	15.4
Mean		**2.8**	**0.35**	**25.0**
Standard Deviation		**1.4**	**0.17**	**5.6**
Variance (%)		**50.4**	**47.85**	**22.3**
Minimum		**1.4**	**0.15**	**15.4**
Maximum		**5.0**	**0.64**	**34.8**
Historical Information				
MMT Route Mean		**1.07**	**0.28**	**-**
Area 2 Mean		**0.65**	**0.25**	**-**
Area 4 Mean		**2.60**	**0.14**	**-**
Area 5 Mean		**1.20**	**0.22**	**-**
Reference Values				
UKOOA (2001) SNS 50th %ile		1.12	-	-
UKOOA (2001) SNS 95th %ile		2.30	-	-

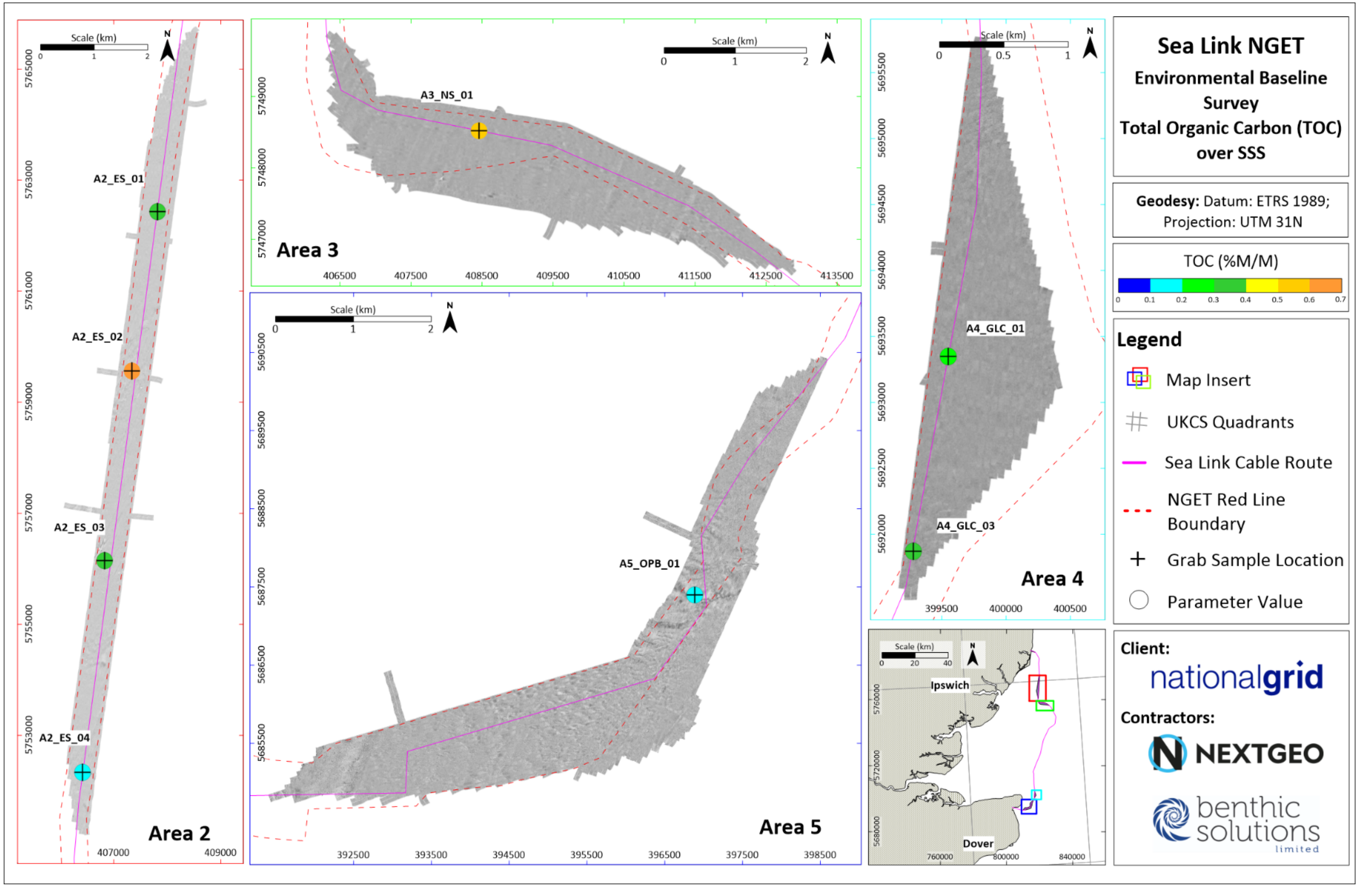


Figure 5-7 Total Organic Carbon

5.2.2 THC and PAH

Results for hydrocarbon analyses are summarised and tabulated as total hydrocarbon content (THC), total n-alkane and homologue ratios, total polycyclic aromatic hydrocarbons (PAH) in Table 5-6 and illustrated in Figure 5-8, Figure 5-10, and Figure 5-12. Individual alkanes (nC_{10}-nC_{37}) are listed in Appendix L – POLYCYLIC AROMATIC HYDROCARBON CONCENTRATIONS (µg.kg-1). An example of a gas chromatogram can be seen in Figure 5-9 (with the remainder presented in Appendix K – GC FID TRACES (SATURATES)) showing the aliphatic hydrocarbon traces for the station A2_ES_02.

5.2.2.1 Total Hydrocarbon Content

The total hydrocarbon content (THC) of the sediments, measured by integrating all non-polarised components within the GC trace, was variable across the stations, ranging from 0.66mg.kg^{-1} at A5_OPB_01 to 17.65mg.kg^{-1} at A2_ES_02 (Figure 5-8). This is likely influenced by the low percentage of fines (3.0%) of A5_OPB_01 and higher percentage of fines (63.2%) at A2_ES_02. There was a significant positive Spearman's correlation (p<0.05) between THC and fines reflecting the trend of higher THC levels being recorded at stations with a higher sedimentary fines content.

Five of the stations exceeded the UKOOA (2001) SNS 50th percentile for THC (3.20mg.kg^{-1}), and one station (A2_ES_02) exceeded the UKOOA (2001) SNS 95th percentile (11.40mg.kg^{-1}). The higher THC levels in Area 2 were consistent with the average THC content reported for the same area in the previous MMT report (11.40mg.kg^{-1}).

Table 5-6 Summary of Hydrocarbon Concentrations

Station	THC (mg.kg^{-1})	Total n-alkanes (mg.kg^{-1})	Carbon Preference Index	Petrogenic / Biogenic Ratio	Pristane / Phytane Ratio	Proportion of Alkanes (%)	Total PAHs (mg.kg^{-1})	NPD (mg.kg^{-1})	NPD (%)
A2_ES_01	8.81	0.347	2.11	0.48	3.09	3.93	0.407	0.16	38.99
A2_ES_02	17.65	0.742	2.35	0.50	3.64	4.20	0.904	0.37	40.88
A2_ES_03	10.09	0.356	2.42	0.56	2.24	3.52	0.373	0.13	34.64
A2_ES_04	1.35	0.017	4.05	0.21	NC	1.23	0.012	0.01	89.38
A3_NS_01	5.34	0.186	2.38	0.29	1.85	3.48	0.144	0.05	36.73
A4_GLC_01	3.61	0.070	2.01	0.31	NC	1.95	0.074	0.03	41.97
A4_GLC_03	6.90	0.138	2.43	0.26	NC	2.00	0.103	0.03	33.07
A5_OPB_01	0.66	0.007	3.46	0.00	NC	1.07	0.022	0.00	0.00
Mean	**6.80**	**0.230**	**2.65**	**0.33**	**2.70**	**2.67**	**0.26**	**0.10**	**39.46**
Standard Deviation	**5.51**	**0.246**	**0.72**	**0.18**	**0.81**	**1.25**	**0.302**	**0.12**	**24.29**
Variance (%)	**81.0**	**105.6**	**27.0**	**56.0**	**30.0**	**46.8**	**118.5**	**125.36**	**61.6**
Minimum	**0.66**	**0.007**	**2.01**	**0.00**	**1.85**	**1.07**	**0.012**	**0.00**	**0.00**
Maximum	**17.65**	**0.742**	**4.05**	**0.56**	**3.64**	**4.20**	**0.904**	**0.37**	**89.38**
Historical Information									
MMT Route Mean	**8.87**	**0.533**	**2.90**	**-**	**1.98**	**-**	**-**	**-**	**-**
Area 2 Mean	**11.40**	**0.378**	**2.04**	**-**	**1.91**	**-**	**-**	**-**	**-**
Area 4 Mean	**3.02**	**0.038**	**1.95**	**-**	**-**	**-**	**-**	**-**	**-**
Area 5 Mean	**6.16**	**0.788**	**3.62**	**-**	**1.92**	**-**	**-**	**-**	**-**
Reference Values									
UKOOA (2001) SNS 50th %ile	3.20	0.19	1.32	-	-	5.94	0.006	-	-
UKOOA (2001) SNS 95th %ile	11.40	0.78	2.12	-	-	6.84	0.366	-	-
Cefas (2015) cAL1	-	-	-	-	-	-	0.100	-	-
NOAA (2008) ERL	-	-	-	-	-	-	4.022	-	-
NOAA (2008) ERM	-	-	-	-	-	-	16.77	-	-

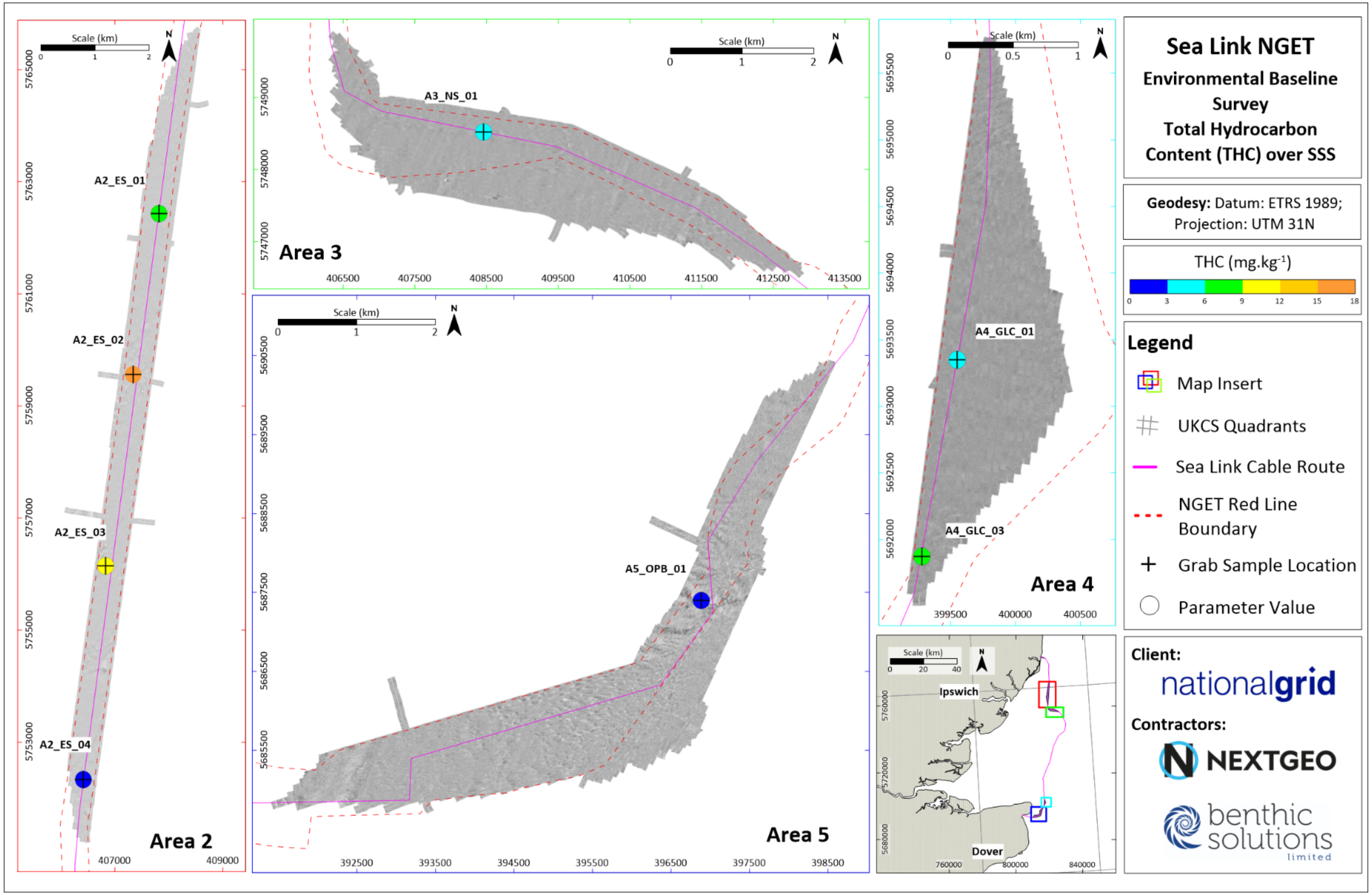


Figure 5-8 Total Hydrocarbon Concentration

5.2.2.2 Saturate/Aliphatic Hydrocarbons

All the sampling stations were analysed for n-alkanes using gas chromatography with flame ionisation detection (GC-FID). The results are summarised in Table 5-6 and are individually listed in Appendix K – GC FID TRACES (SATURATES) which gives a breakdown of consecutive n-alkane content from nC_{10} through to nC_{37}, together with the isoprenoid hydrocarbons Pristane (Pr) and Phytane (Ph). The total saturate alkane concentrations are illustrated in Figure 5-10 and an example of gas chromatograms is given in Figure 5-9.

Similar to THC, total n-alkane concentration was variable across the survey area, ranging from 0.007mg.kg^{-1} at A5_OPB_01 to 0.742mg.kg^{-1} at A2_ES_02 (Figure 5-10), where station A2_ES_02 also had the highest THC concentration. The relationship between THC and n-alkanes is supported by a positive Spearman's correlation (p<0.001). Three stations in Area 2 had n-alkane concentrations above the UKOOA (2001) SNS 50th percentile (0.19mg.kg^{-1}), but the values were consistent to the average n-alkanes concentration reported for the same area in the previous MMT report (0.533mg.kg^{-1}).

Inspection of the individual gas chromatograms showed hydrocarbon signatures indicative of those typically seen for background sediments in the North Sea (Figure 5-9; Appendix K – GC FID TRACES (SATURATES)). Traces of an unresolved complex mixture (UCM) spanning the majority of the trace (nC_{10} to nC_{37}) but peaking in the range nC_{24} to nC_{37} (light green highlight in Figure 5-9), superimposed by a series of odd-carbon dominated n-alkanes in the same range. UCM is composed of a complex mixture of hydrocarbons which remain after substantial weathering and biodegradation (McDougall, 2000). Hydrocarbons in the weight range of nC_{24} to nC_{37} commonly originate from terrestrial plant sources (Harborne, 1999), or alternatively they may represent the residue of highly weathered and biodegraded petrogenic material, including natural seeps, shipping discharges, or oil and gas exploration and extraction (McDougall, 2000; Bouloubassi *et al.,* 2001). Most stations showed variation of the typical background sediments, but the most pronounced traces occurred at station A2_ES_02.

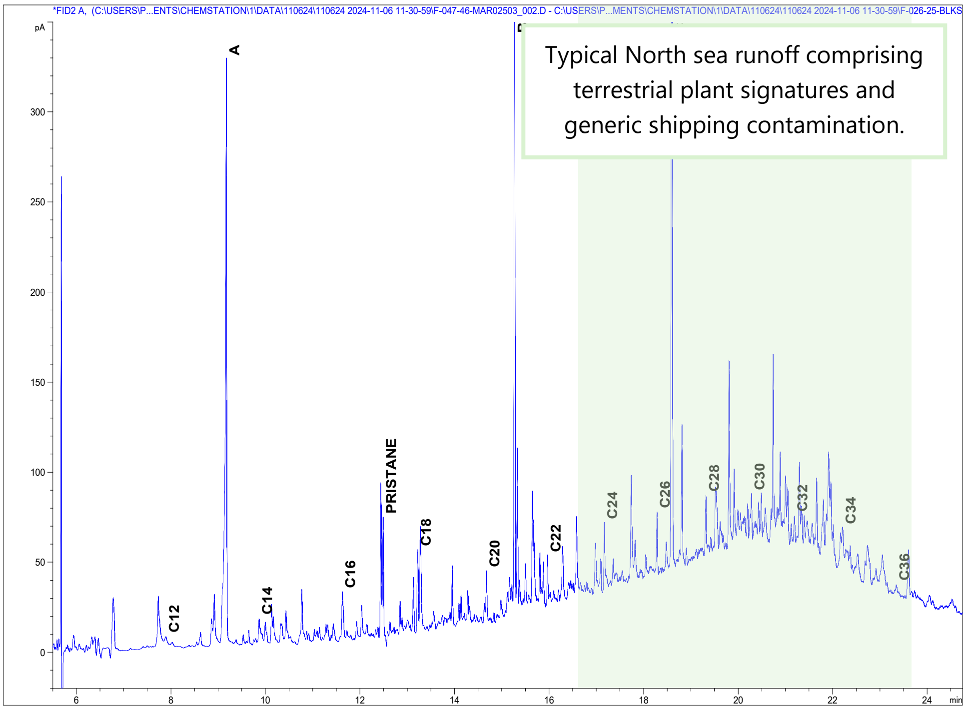


Figure 5-9 Example Gas Chromatogram for Saturate Hydrocarbon Analysis (A2_ES_02)

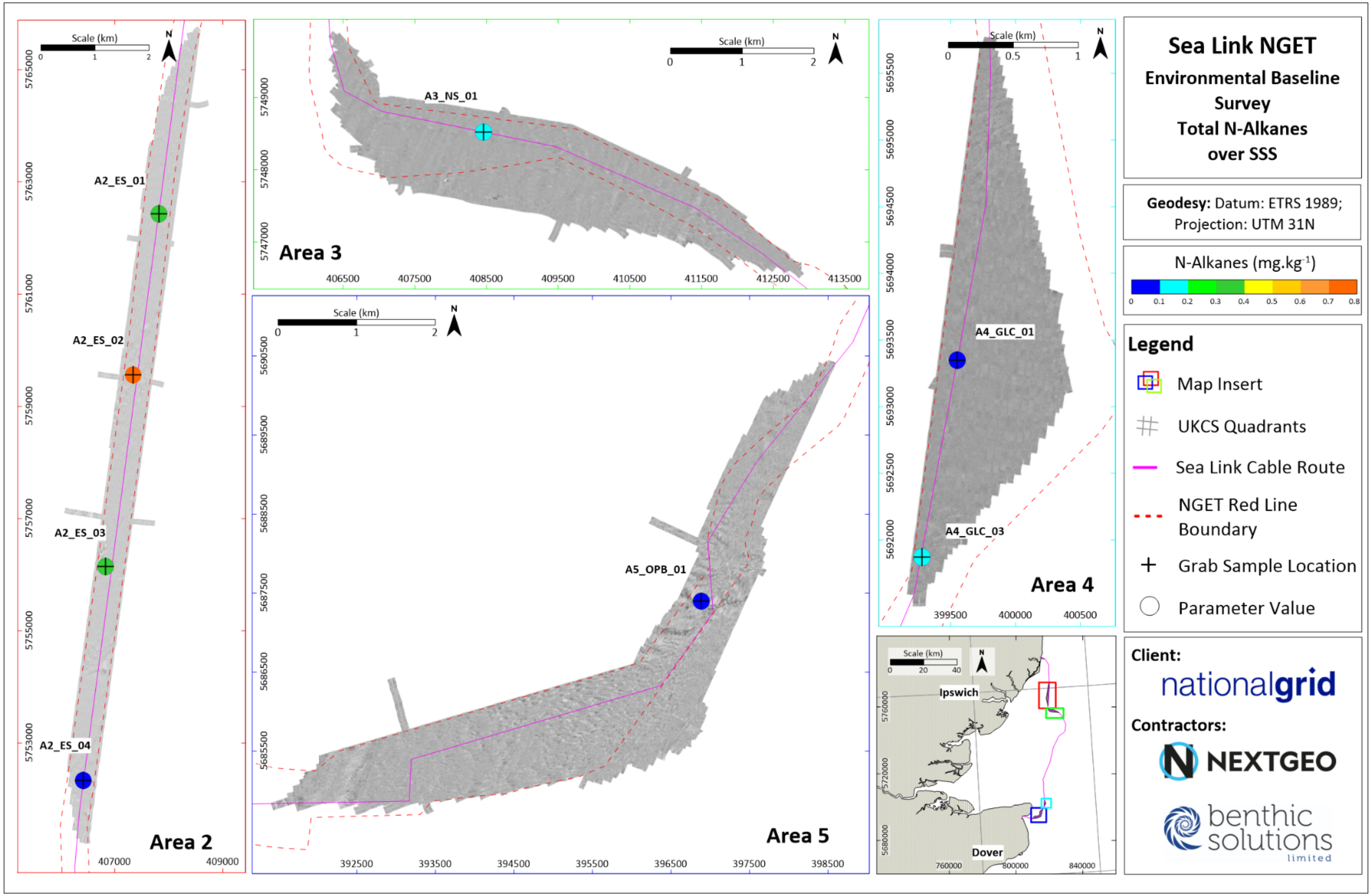


Figure 5-10 Total N-Alkanes

A closer review of the different proportions of n-alkanes recorded can sometimes identify trends within the data or the source from which the other organic components derive. Whilst this is particularly useful for stations that contain a moderate to high level of saturates, low concentrations can often skew such indices, so they appear unrepresentative; the following ratios were further reviewed below.

Carbon Preference Index

The Carbon Preference Index (CPI) is associated with the preference for biogenic n-alkanes (i.e. that of a preference for odd-carbon numbered homologues, particularly around nC_{27-33} (Sleeter *et al.,* 1980), derived from fatty acids, alcohols, esters and land plant waxes.

The CPI across the survey area varied from 2.01 (A4_GLC_01) to 4.05 (A2_ES_04). The results indicated a dominance of biogenic, odd-carbon numbered alkanes with all stations recording a CPI over 2. The majority of stations in the MMT (2022) survey also had a CPI of over 2.

Petrogenic/Biogenic (P/B) Ratio

The P/B ratio compares the lighter, more petrogenic aliphatics (nC_{10}-nC_{20}) with the heavier, biogenic aliphatics (nC_{21}-nC_{37}). Results were calculated for all stations and ranged from 0.00 at A5_OPB_01 to 0.56 at A2_ES_03. The stations were influenced by biogenic aliphatic compounds, with all samples recording a P/B ratio below 1.

Pristane/Phytane (Pr/Ph) Ratio

Pristane (Pr) and phytane (Ph) are both isoprenoid alkanes commonly found as constituents within crude oils (Berthou and Friocourt, 1981). However, in biogenic environments, only pristane is frequently found in the marine environment as it is naturally biosynthesised and a product of phytol, a moiety of chlorophyll. Phytane is generally absent or only present at low levels in uncontaminated natural systems (Blumer and Snyder, 1965). This ratio can be taken as an indication of a depositional environment (Peters *et al.,* 2005). The presence of both isoprenoids at similar levels is typically taken as an indication of petroleum contamination.

Pristane/phytane ratios were incalculable at four stations due to phytane levels being below the detection limit (<1$\mu g.kg^{-1}$). The ratios at remaining stations ranged from 1.85 (A3_NS_01) to 3.64 (A2_ES-02). The MMT (2022) survey reported a slightly lower average Pr/Ph ratio (1.98 MMT route mean) than the BSL survey (2.70 BSL survey mean; Table 5-6).

It should be noted that the pristane/phytane ratio can often be difficult to interpret due to its erratic nature and should be used mainly to substantiate other interpretations. The use of the ratio in interpretative discourse is open to criticism, mainly owing to the natural occurrence of phytane in some older sediments and the confusing variation of sedimentary pristane induced by the variability of phytoplankton numbers (Blumer and Snyder, 1965).

5.2.2.3 Polycyclic Aromatic Hydrocarbons

Non-Normalised Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAH) were analysed at each station using gas chromatography-mass spectrometry (GC-MS). Results of the single ion current (SIC) analyses are summarised in Table 5-6 and detailed in Appendix L – POLYCYLIC AROMATIC HYDROCARBON CONCENTRATIONS and Appendix M – POLYCYCLIC AROMTIC HYDROCARBON CONCENTRATIONS: EPA 19 (µg.kg-1), showing concentrations for both parent compounds and their alkyl derivatives.

PAHs and their alkyl derivatives have been recorded in a wide range of marine sediments (Laflamme and Hites, 1978), with many compounds produced from what is thought to be pyrolytic sources. These include the combustion of organic material such as forest fires (Youngblood and Blumer, 1975), the burning of fossil fuels and, in the case of offshore oil fields, flare stacks. The resulting PAHs, rich in the heavier weight 4-6 ring aromatics, are normally transported to the sediments via atmospheric fallout or river runoff (Neff, 1979). Another PAH source is petroleum hydrocarbon, often associated with localised drilling activities. These are rich in the lighter, more volatile 2 and 3 ring PAHs (NPD; naphthalene (128), phenanthrene, anthracene (178) and dibenzothiophene (DBT)) with their alkyl derivatives.

Total PAH (2-6 compound) ranged from 0.012mg.kg^{-1} (A2_ES_04) to 0.904mg.kg^{-1} (A2_ES_02). Three of eight stations exceeded the UKOOA (2001) SNS 50th percentile (0.006mg.kg^{-1}), two exceeded the Cefas (2015) cAL1 (0.100mg.kg^{-1}), whilst the remaining three stations exceeded the UKOOA (2001) SNS 95th percentile (0.366mg.kg^{-1}; Figure 5-12). No stations across the survey area resulted in values close to the NOAA (2008) ERL and ERM reference values (4.022mg.kg^{-1} and 16.77mg.kg^{-1} respectively). The petrogenic NPD fraction (2 and 3 ring aromatics) ranged from 0.00mg.kg^{-1} at A5_OPB_01 to 0.37mg.kg^{-1} at A2_ES_02.

Further information on the source(s) of PAH in the sediment may be obtained from a study of their alkyl homologue distributions (i.e. the degree of methyl, ethyl, and substitution of the parent compounds). Pyrolytically derived PAHs are predominantly unalkylated, whereas PAHs derived from petrogenic sources are formed at relatively low temperatures (<150°C) and contain mainly alkylated species. The distribution of parent 2-6 ring PAH compounds also reflects whether the source is petrogenic or pyrolytic. This trend is represented graphically in Figure 5-11, which shows three-dimensional plots of the parent compound distribution and the alkyl homologue distribution of the aromatic material in each sediment analysed. As illustrated, most stations sampled across the survey area were of mixed petrogenic and pyrolytic origin. One station (A5_OPB_01) aligned more with a petrogenic origin, and one station (A2_ES_04) had a more pyrolytic origin. These two results are likely attributable to the overall low levels of PAHs at these stations, which may exaggerate the perceived differences in source significance.

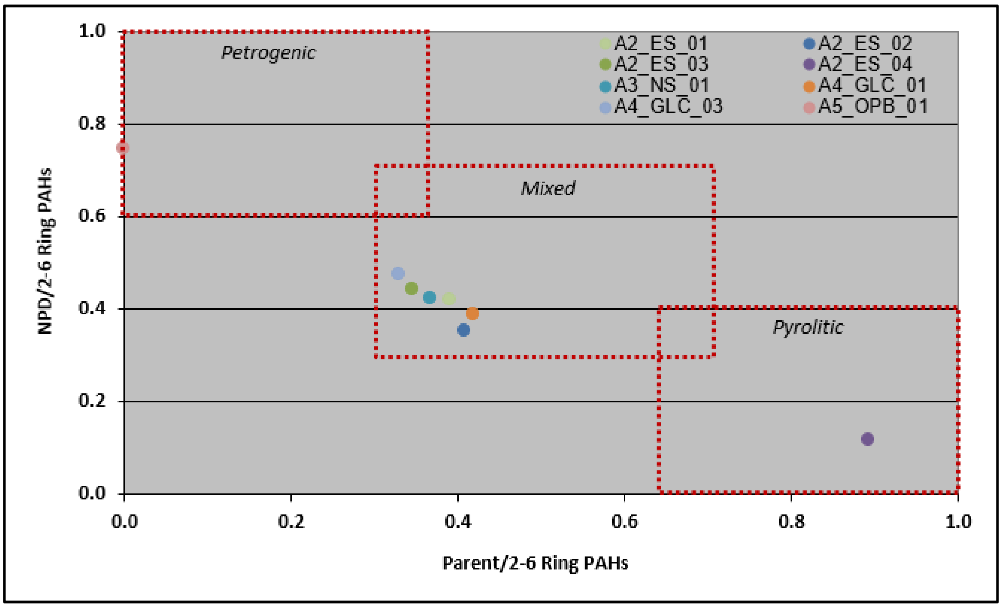


Figure 5-11 PAH Source Assignment

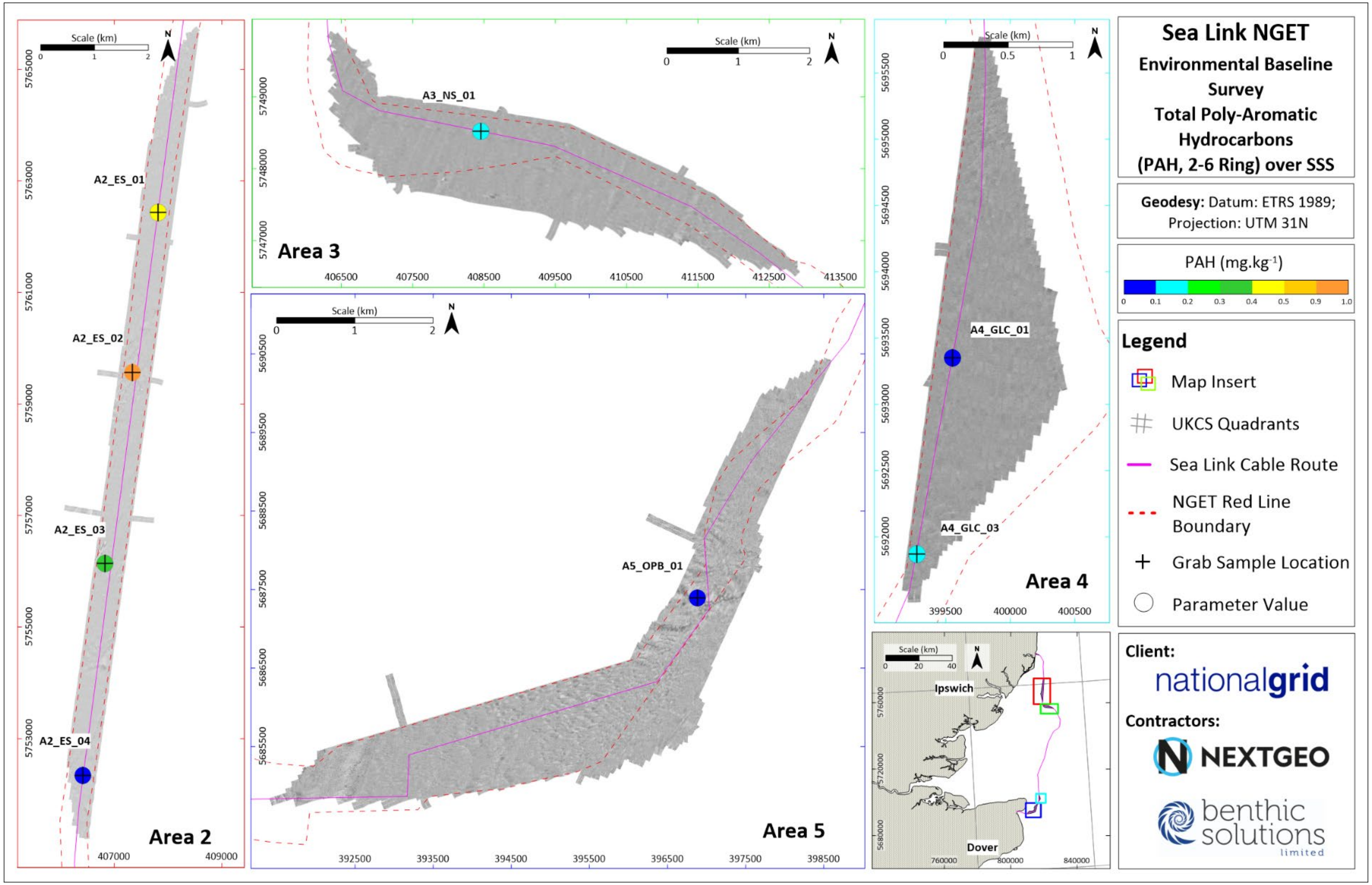


Figure 5-12 Total Polycyclic Aromatic Hydrocarbons (2-6 Ring)

Normalised Polycyclic Aromatic Hydrocarbons

Normalised total PAH concentrations were calculated to provide estimates of the proportion of bioavailable contaminants and to enable standardisation comparisons between samples, minimising the influence of organic content and sediment composition. Contaminants tend to show a much higher affinity to fine particulate matter due to the increased adsorption capacity of organic matter and clay minerals (OSPAR, 2009a). All total PAH concentrations (based on the 19 PAH components outlined in OSPAR, 2014) were normalised to the 2.5% total organic carbon content of the sediment at each station, with the results displayed in Table 5-7 along with OSPAR background concentrations (BCs) and background assessment concentrations (BACs). BCs are concentrations of contaminants derived from the analysis of core samples to reflect pre-industrial background levels for the OSPAR area. BACs have been statistically derived from BCs and represent the level above which concentrations can be considered to be significantly higher than the relevant BC (OSPAR, 2008).

Elevated levels of PAHs (naphthalene, dibenzothiophene, anthracene, pyrene, benzo[a]anthracene, and chrysene) exceeding either the BC or BAC thresholds were observed at every station. BC or BAC thresholds were exceeded at every station except A2_ES_04 for fluoranthene and benzo[a]pyrene, and every station except A5_OPB_01 for phenanthrene. Acenaphthene exceeded the OSPAR Effects Range Low (ERL) at A5_OPB_01, and the fluorene OSPAR ERL was exceeded at stations A2_ES_01 and A2_ES_02.

Table 5-7 Normalised Total Polycyclic Aromatic Hydrocarbons (µg.kg-1)

Station	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Dibenzothiophene	Anthracene	Fluoranthene	Pyrene	Benzo[a]anthracene	Chrysene	Benzo[b]fluoranthene	Benzo[k]fluoranthene	Benzo[e]pyrene	Benzo[a]pyrene	Perylene	Indeno[123,cd]pyrene	Dibenzo[a,h]anthracene	Benzo[ghi]perylene
A2_ES_01	54.38	12.56	6.94	19.83	147.51	10.90	17.19	171.93	148.13	59.87	87.06	92.18	77.61	70.89	78.87	33.95	68.34	12.57	82.57
A2_ES_02	67.97	8.85	9.78	22.66	111.29	10.36	22.06	144.59	130.08	72.03	93.43	111.77	92.25	85.24	93.21	42.04	86.19	16.86	101.86
A2_ES_03	41.00	7.14	7.14	16.34	116.72	7.14	22.44	163.41	140.23	73.85	93.25	96.21	86.71	73.09	92.21	36.27	79.52	15.48	83.90
A2_ES_04	13.16	13.16	13.16	13.16	18.98	13.16	13.16	13.16	13.16	13.16	13.16	13.16	13.16	13.16	13.16	13.16	13.16	13.16	13.16
A3_NS_01	13.36	4.63	4.63	4.63	30.77	4.63	4.63	39.52	35.21	16.27	22.72	26.41	22.36	19.26	21.29	9.10	16.44	4.63	19.81
A4_GLC_01	20.48	10.87	10.87	10.87	30.89	10.87	10.87	43.26	41.22	16.06	22.70	23.37	27.40	21.14	19.21	10.87	19.72	10.87	22.82
A4_GLC_03	19.11	6.76	6.76	6.76	24.49	6.76	6.76	47.11	44.19	18.09	25.05	27.79	29.29	22.55	25.83	13.35	22.31	6.76	24.99
A5_OPB_01	16.67	16.67	16.67	16.67	16.67	16.67	16.67	51.72	60.54	29.53	36.86	28.58	21.71	21.42	28.53	16.67	16.67	16.67	16.67
Historical Information																			
MMT Route Mean	14.47	3.09	3.81	4.98	23.37	4.79	6.11	30.37	28.05	15.99	20.58	19.37	11.88	20.14	19.12	10.52	16.84	5.52	20.89
Area 2 Mean	7.00	1.65	2.55	2.60	18.74	3.20	6.47	39.88	35.66	21.68	27.15	25.15	14.23	24.75	24.90	10.98	15.93	4.30	18.15
Area 4 Mean	<1	<1	<1	<1	<1	<1	<1	1.50	1.50	<1	<1	1.20	<1	1.20	<1	<1	<1	<1	<1
Area 5 Mean	20.87	4.25	3.70	5.03	35.93	5.20	6.97	41.80	40.67	19.27	28.73	29.10	13.33	29.67	22.63	14.17	19.47	3.73	26.47
Reference Values																			
OSPAR (2014) BC	5	-	-	-	17	0.6	3	20	13	9	11	-	-	-	15	-	50	-	45
OSPAR (2014) BAC	8	-	-	-	32	-	5	39	24	16	20	-	-	-	30	-	103	-	80

5.2.3 Heavy and Trace Metal Concentrations

5.2.3.1 Non-normalised Heavy Metals

Concentrations of several metals (barium, copper, iron, lead, mercury, nickel, vanadium and zinc) exceeded the UKOOA (2001) SNS 50th percentile at all stations, and Chromium exceed its 50th percentile value at all except one station (A5_OPB_01). Whilst, all the aforementioned metals with the exception of copper, exceeded their respective UKOOA 95th values at least one station (Table 5-8).

The OSPAR ERL threshold for arsenic (8.2mg.kg^{-1}) was exceeded at every station, ranging from 12.8mg.kg^{-1} at A2_ES_02 to 41.4mg.kg^{-1} at A3_NS_01 (Figure 5-13). In addition to exceeding the OSPAR ERL value, the arsenic concentration at station A2_NS_01, A2_ES_02 and A3_NS_01 also exceeded the Cefas cAL 1 (20mg.kg^{-1}). Elevated arsenic levels in marine sediments in the SNS are attributed to a combination of natural geological inputs, significant anthropogenic activities, and riverine discharge. Industrial processes such as mining, smelting, and chemical manufacturing, along with agricultural runoff and contributions from major rivers like the Rhine, Meuse, Humber estuary, and Scheldt, are major sources of arsenic pollution in this region (Emeis *et al.,* 2020; NOAA, 2020). In addition, similar higher levels of arsenic were identified within the MMT (2022) survey, suggesting these concentrations to be at background levels.

The nickel concentration of 24.2mg.kg^{-1} at A3_NS_01 exceeds the Cefas cAL 1 (20mg.kg^{-1}) which can be attributed to natural variation of metal concentration within sediments, whilst no trace metals within the survey area exceeded the Cefas cAL 2 reference values (Table 5-8).

The concentrations of almost all metals, with the exception of arsenic, are below Cefas cALs and OSPAR ERL levels for all stations, indicating there is minimal risk to marine life and no significant environmental impact at these locations.

Table 5-8 Non-Normalised Metal Concentrations (mg.kg-1)

Station	Aluminium (Al)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Nickel (Ni)	Phosphorus (P)	Strontium (Sr)	Vanadium (V)	Zinc (Zn)
A2_ES_01	13,900	14.2	158	0.2	0.06	11.9	5.4	17,700	6.6	188	0.02	10.2	5,390	337	48	21.4
A2_ES_02	32,100	12.8	344	0.5	0.17	21.4	9.6	22,500	16	317	0.05	16.3	731	265	66.7	44.2
A2_ES_03	13,200	25.1	193	<0.2*	0.06	13.2	5.9	19,600	8.3	213	0.02	11.6	1,410	251	51.2	26.3
A2_ES_04	7,070	37	94.6	0.3	<0.04*	8.1	3.9	19,900	10.1	393	0.02	9.2	780	421	58.5	26.8
A3_NS_01	15,000	41.4	287	<0.2*	0.17	10.6	6.5	34,100	6.6	221	0.04	24.2	1,560	211	55.4	26.8
A4_GLC_01	9,020	26.4	102	<0.2*	<0.04*	7.9	3.5	17,700	8.3	196	0.03	8.6	759	322	42.2	28.8
A4_GLC_03	9,110	16.4	130	<0.2*	<0.04*	6.9	3.4	11,600	7.1	156	0.02	6.6	737	311	29.9	19.6
A5_OPB_01	5,960	41.2	90.1	<0.2*	0.05	5	2.2	21,900	7.9	386	0.02	8.3	670	509	38.1	26.5
Mean	**13,170**	**27**	**175**	**0**	**0**	**11**	**5**	**20,625**	**9**	**259**	**0**	**12**	**1,505**	**328**	**49**	**28**
Standard Deviation	**8,325**	**11.9**	**94.7**	**0.2**	**0.1**	**5.1**	**2.3**	**6,401.5**	**3.1**	**93.1**	**0**	**5.8**	**1,606.8**	**96.7**	**11.8**	**7.4**
Variance (%)	**63**	**44.4**	**54.2**	**45.8**	**61**	**48.2**	**46.3**	**31**	**35**	**36**	**42.4**	**48.6**	**106.8**	**29.4**	**24.3**	**26.9**
Minimum	**5,960**	**12.8**	**90.1**	**0.2**	**0.1**	**5**	**2.2**	**11600**	**6.6**	**156**	**0**	**6.6**	**670**	**211**	**29.9**	**19.6**
Maximum	**32,100**	**41.4**	**344.0**	**0.5**	**0.2**	**21.4**	**9.6**	**34100**	**16**	**393**	**0.1**	**24.2**	**5390**	**509**	**66.7**	**44.2**
Historical Information																
MMT Route Mean	**15,469**	**19**	**162.9**	**0.5**	**0.11**	**19.5**	**8.1**	**17,124**	**11.1**	**-**	**0.05**	**9.2**	**2,048**	**240**	**35.5**	**34.2**
Area 2 Mean	**11,912**	**21.4**	**137.7**	**0.5**	**0.12**	**17.8**	**6.5**	**18,430**	**7.5**	**-**	**0.05**	**7.8**	**2,403**	**294**	**37.9**	**24.5**
Area 4 Mean	**5,380**	**22.5**	**65.9**	**0.3**	**0.06**	**8.9**	**4.5**	**14,100**	**5.2**	**-**	**0.05**	**4.8**	**606**	**252**	**27.7**	**23.3**
Area 5 Mean	**14,587**	**16**	**157.4**	**0.5**	**0.08**	**16.6**	**8.9**	**17,690**	**13.7**	**-**	**0.05**	**6.5**	**321**	**160**	**28**	**40.8**
Reference Values																
UKOOA (2001) SNS 50th %ile	-	-	26	-	0.03	6.51	2.04	5,128.50	6	-	0.02	3.97	-	-	14.7	12.2
UKOOA (2001) SNS 95th %ile	-	-	272.4	-	0.72	44.77	13.86	18,555	21.03	-	0.05	21.45	-	-	35.76	35.8
OSPAR (2014) ERL	-	8.2	-	-	1.2	81	34	-	46.7	-	0.15	20.9	-	-	-	150
Cefas (2015) cAL1	-	20	-	-	0.4	40	40	-	50	-	0.3	20	-	-	-	130
Cefas (2015) cAL2	-	50	-	-	2	400	400	-	50	-	3	200	-	-	-	800

*Not included in statistical analysis of mean, SD, min, max, and median.

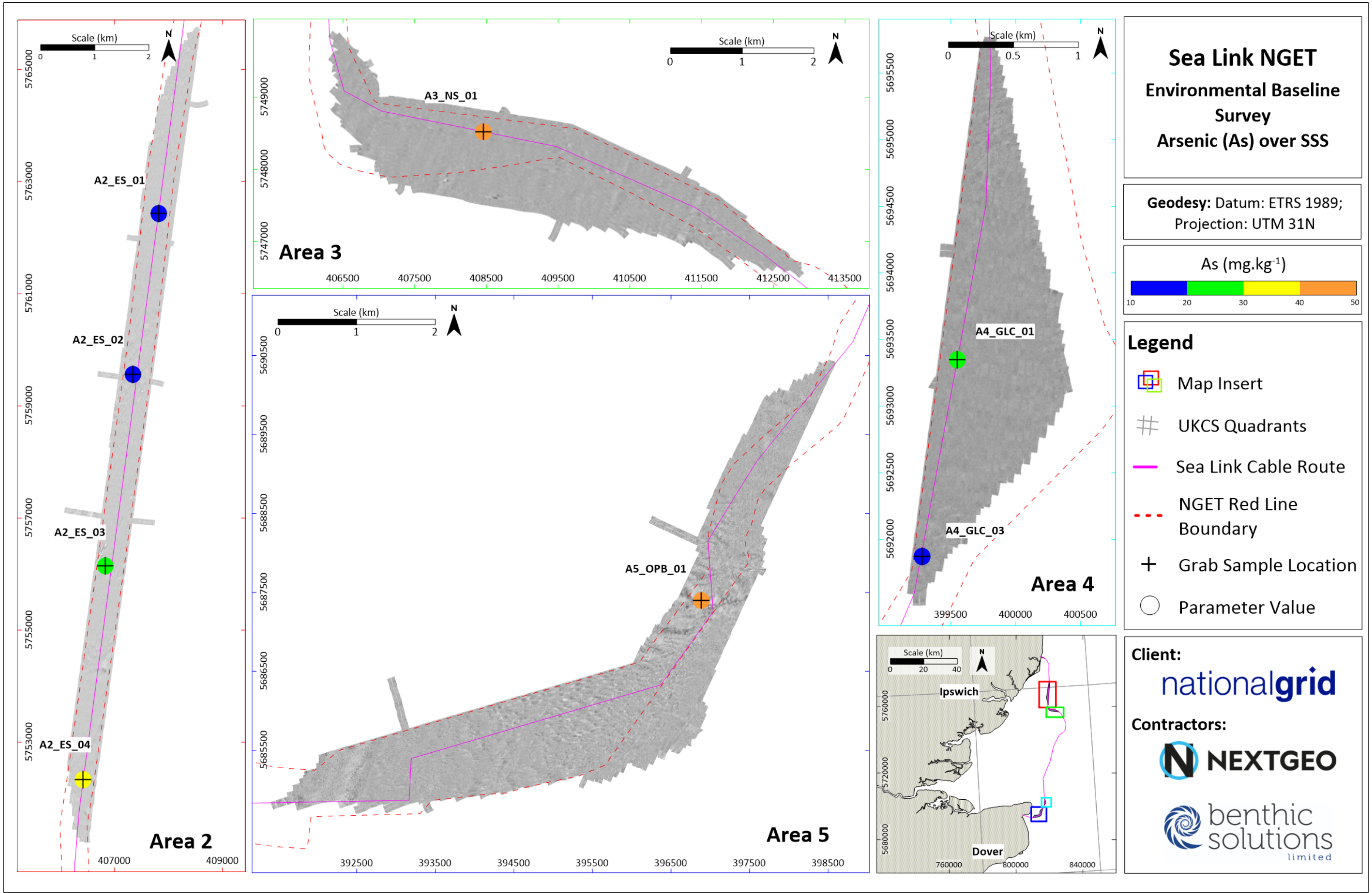


Figure 5-13 Concentration of Arsenic (As)

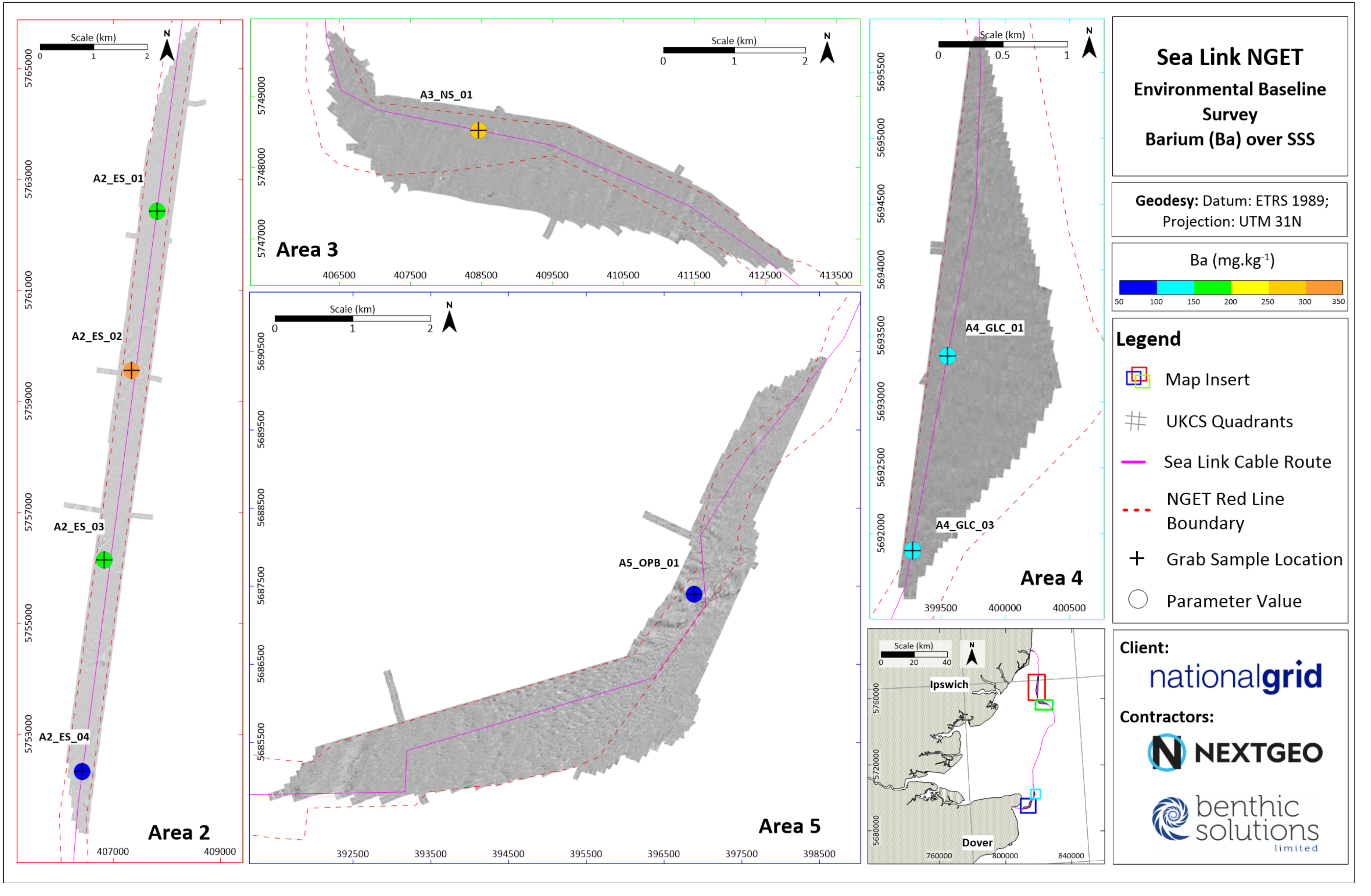


Figure 5-14 Concentration of Barium (Ba)

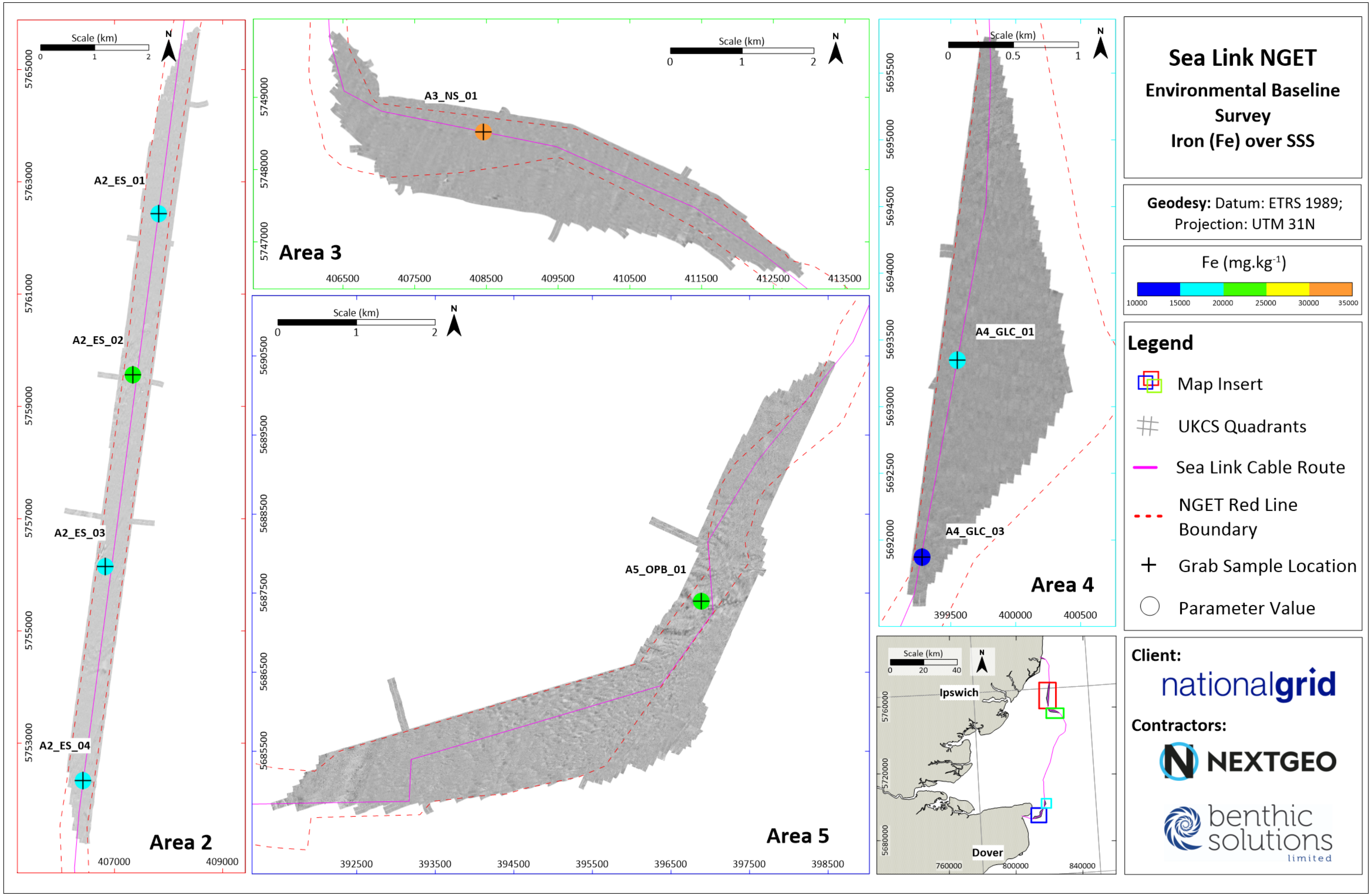


Figure 5-15 Concentration of Iron (Fe)

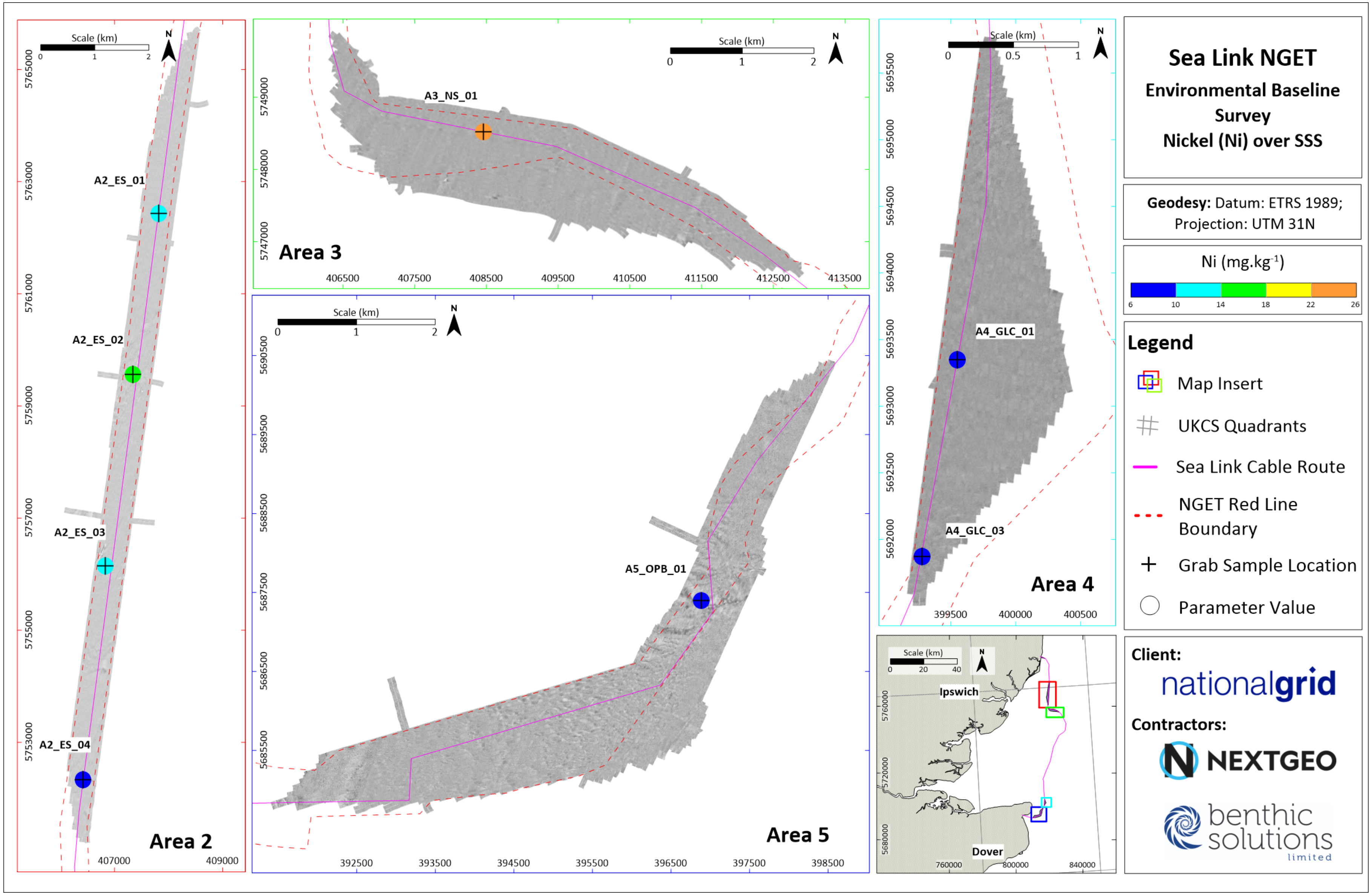


Figure 5-16 Concentration of Nickel (Ni)

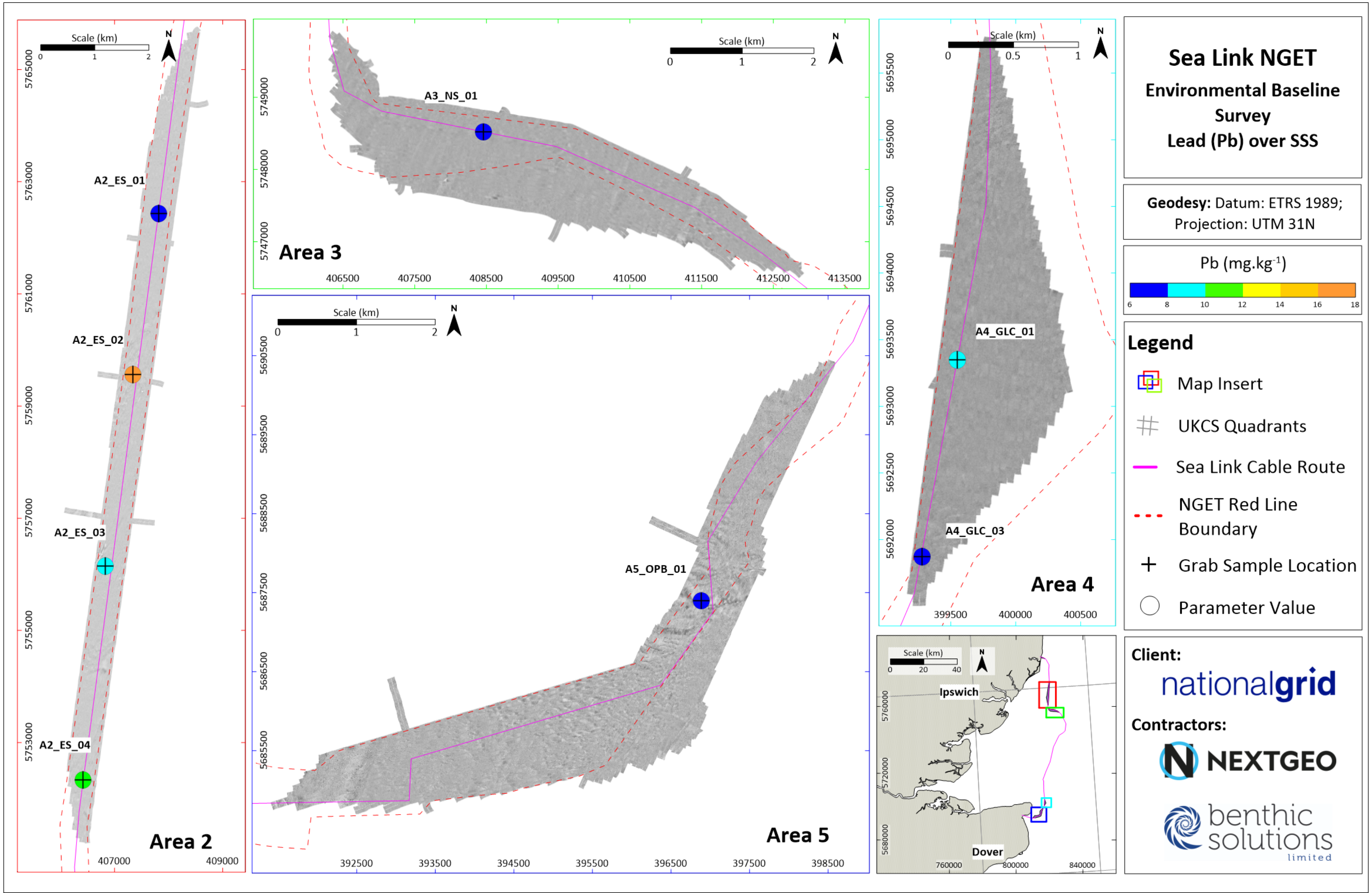


Figure 5-17 Concentration of Lead (Pb)

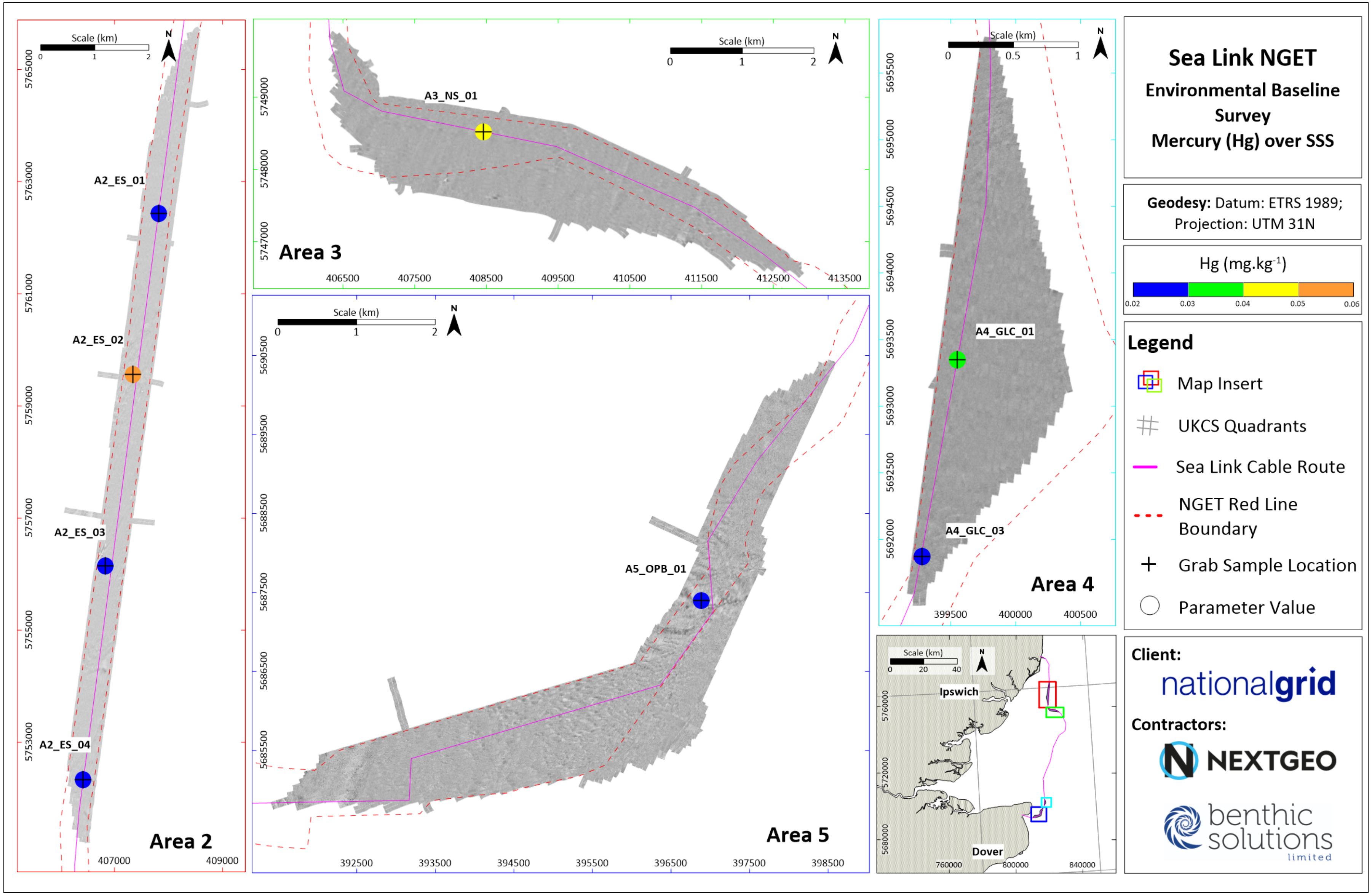


Figure 5-18 Concentration of Mercury (Hg)

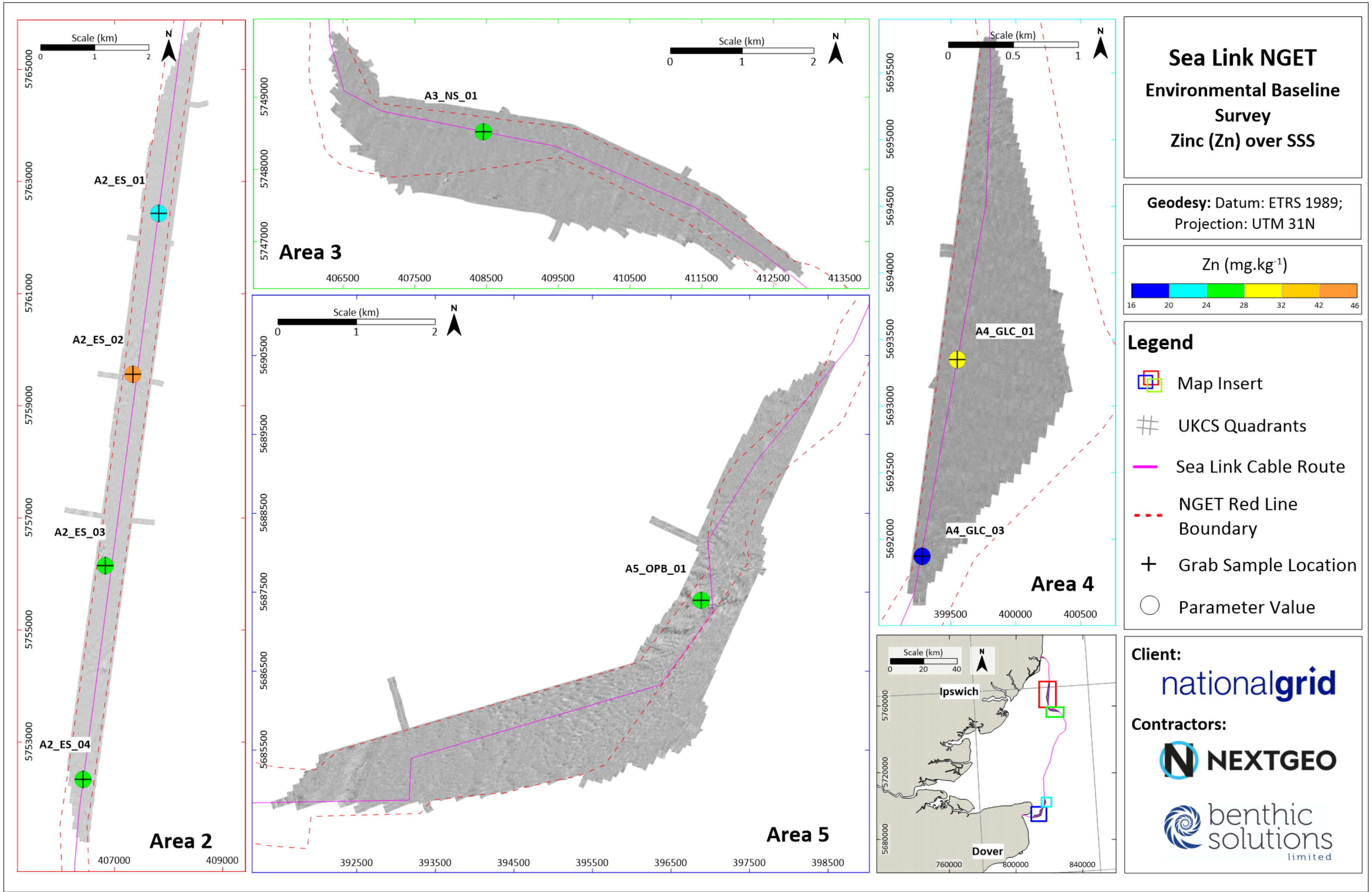


Figure 5-19 Concentration of Zinc (Zn)

5.2.3.2 Normalised Heavy Metals

Normalised heavy and trace metal values were calculated to provide estimates of the proportion of bioavailable contaminants and to enable standardised comparisons between samples, minimising the influence of organic matter and sediment composition. Normalisation for metals was undertaken using the current Coordinated Environmental Monitoring Programme (CEMP) normalisation procedure to 58,000mg.kg^{-1} aluminium, involving the use of pivot values (OSPAR, 2008). Some metals were environmentally inadmissible as the concentration of the normaliser contaminant was less than the normaliser pivot values and, as such, have been represented by '-' in Table 5-9. Any normalised results returning a negative or any values higher than the possible maximum concentrations are regarded as environmentally inadmissible by OSPAR CEMP guidance and, as such, are excluded. Every station except A2_ES_02 had metals that could not be normalised due to levels being below the pivot values. Cadmium could not be normalised at every station as the concentration was below the detection limit (<0.04mg.kg^{-1}) at three stations.

Five of the eight stations had one or more metals exceed the OSPAR BCs and BACs. Normalised concentrations at A3_NS_01 were elevated, exceeding the OSPAR BACs for six metals. Every metal exceeded thresholds at one or more stations.

Table 5-9 Normalised Metal Concentrations (mg.kg^{-1})

Station	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Nickel (Ni)	Zinc (Zn)
A2_ES_01	-	-	497	-	1065	-	-	-
A2_ES_02	24	0.4	33.4	19.0	26	0.1	33.9	88.8
A2_ES_03	-	-	2	-	47.5	-	-	-
A2_ES_04	-	NC	44.1	-	2	-	-	-
A3_NS_01	1607	6.2	-	157	-	1.8	892.8	620.2
A4_GLC_01	-	NC	58.1	-	15.2	-	-	-
A4_GLC_03	-	NC	67.9	-	26.1	-	-	-
A5_OPB_01	-	-	56.8	7.4	15	-	-	-
OSPAR (2014) BC	15	0.2	60	20	25	0.05	30	90
OSPAR (2014) BAC	25	0.31	81	27	38	0.07	36	122
'-' = Environmentally inadmissible results as per OSPAR CEMP (2008)								

5.3 Macrofaunal Analysis

Subsequent macrofaunal taxonomy of all recovered fauna (infauna and solitary epifauna) identified a total of 6,897 individuals (from the 23 samples analysed (Table 5-10). Faunal data for each sample are listed in Appendix N – MACROFAUNAL SPECIES LISTS.

Table 5-10 Phyletic Composition from Grab Samples

Phylum	Number of Taxa	Abundance (Total No. of Individuals)
Solitary Epifauna	8	2,381
Annelida	99	2,382
Crustacea	43	1,166
Mollusca	33	573
Echinodermata	8	77
Other	5	318
Total (Including Solitary Epifauna)	**221**	**6,897**
Total (Excluding Solitary Epifauna)	**196**	**4,516**

The as sampled species accumulation curve (Figure 5-20) shows a stepwise increase in fauna as the number of sample effort increases, this was reflective of the varying sediment composition the survey area. This analysis estimated the maximum species accumulation (Chao expected curve) for the survey corridor to be 334 species, compared to the actual 196 infaunal species recorded during the survey. The number of species recorded did not exceed the representative proportion of the population (67% or 224 species), possibly due to the low number of samples as this survey was carried out as a supplement to the previous survey of the Sea Link route conducted by MMT (2022). The interpretation of the macrofaunal community should therefore not be taken as a standalone, but rather used alongside the MMT (2022) macrofauna analysis.

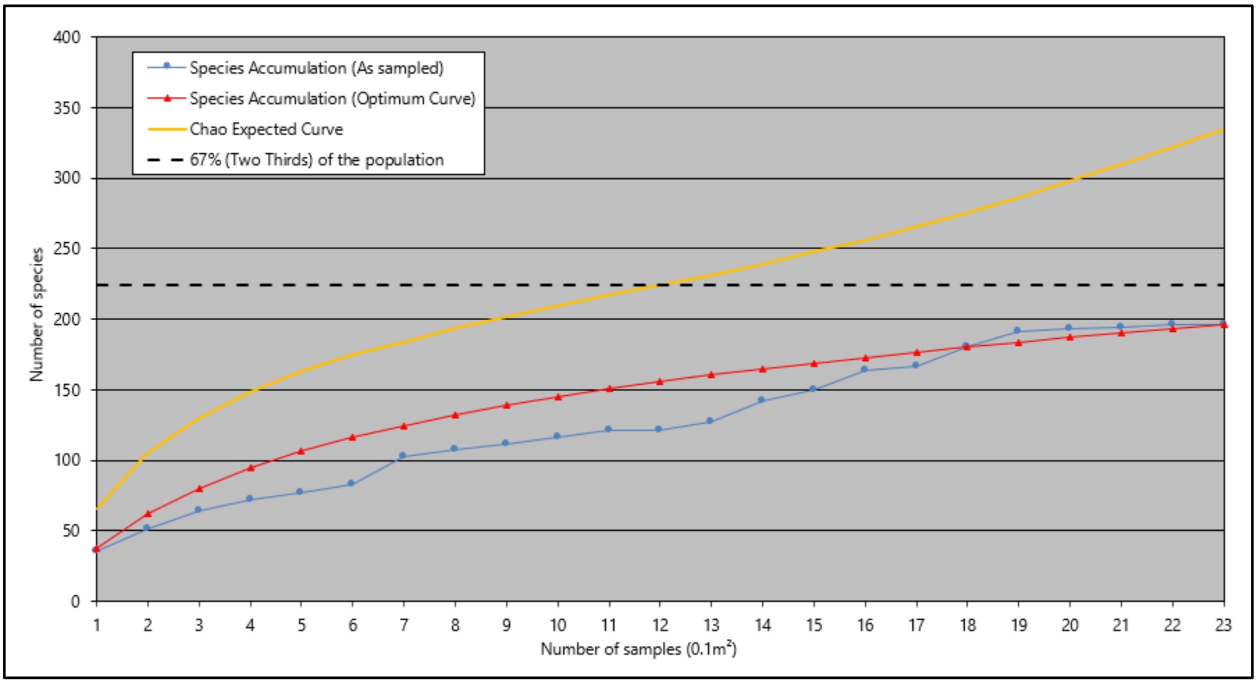


Figure 5-20 Species Accumulation Curve of the Sea Link Survey Areas

The total number of taxa recorded to genus level or lower reached 95.4% with the inclusion of colonial epifauna and 96.9% when colonial epifauna were excluded. It was not possible to ascribe juvenile/egg specimens to a species at this stage in their lifecycle, and as such have been grouped to class level. Juveniles are often excluded from community analyses due to their high mortality prior to reaching maturity and difficulties in distinguishing species of the same genus. Consequently, they tend to induce a recruitment spike at certain times of the year due to rapid settlement and colonisation but are essentially an ephemeral part of the population masking the underlying trends within the mature adults. These specimens have therefore been excluded from univariate and multivariate analyses but have been listed separately in Appendix N – MACROFAUNAL SPECIES LISTS.

5.3.1 Primary and Univariate Parameters

The primary and univariate parameters for all replicates and stations are listed in Table 5-11 and Table 5-12 and represented by Figure 5-21 to Figure 5-25.

Three sample replicates were obtained at each station with the exception of A4_GLC_03 where only two faunal replicates were achieved due to the coarse sediments impacting sample acquisition. Univariate results per station have been averaged across replicates as opposed to summed, to allow direct comparison of primary and univariate parameters between all stations (Table 5-12).

The number of individuals per $0.1m^2$ at replicate level was variable, ranging from 23 at A5_OPB_0_F3 to 778 at A3_NS_01_F3 , these minimum and maximum values were also reflected at station level (24 at A5_OPB_01 to 707 at A3_NS_01). The number of species across replicates varied from 8 at A5_OPB_01_F3 to 75 at A3_NS_01_F2 , again mirrored at station level (10 at A5_OPB_01 to 66 at A3_NS_01) (Table 5-11 and Table 5-12). Both species richness and abundance correlated with the sorting coefficient of the sediment ($p<0.05$, Appendix Q – SPEARMAN'S CORRELATION).

Margalef's Index, a measure of species richness, indicated a relatively diverse community in replicate level ranging from 2.23 at A5_OPB_01_F3 to 11.51 at A3_NS_01_F2, whilst station level data ranged from 2.82 at station A5_OPB_01 to 9.93 at stations A3_NS_01 (Table 5-12). Pielou's equitability was lowest at replicate sample A4_GLC_01_F2 (0.520) and highest at A5_OPB_01_F1 (0.929), whilst station A4_GLC_01 retained the lowest station level average of 0.540, and A2_ES_01 recorded the highest average at 0.861. Diversity values represented by Shannon's H'(log^2) ranged from 'Moderate' (2.39 at A5_OPB_01_F2) to 'High' (5.02 at A3_NS_01_F2) at replicate level, and 'Moderate' (2.64 at A2_ES_04) to 'High' (4.68 at A3_NS_01) diversity at station level following the threshold values outlined in Dauvin *et al* (2012). Whereby values >4.00 indicate high diversity; values between 3.00 and 4.00 indicate good diversity, values between 2.00 and 3.00 indicate moderate diversity and values between 1.00 and 2.00 indicate bad diversity, whilst values <1.00 indicate poor diversity (Table 5-12). Simpsons diversity indices varied from 0.669 at station A4_GLC_01 to 0.957 at station A2_ES_01 (Figure 5-23).

The Infaunal Quality Index (IQI) is a multi-metric index composed of three individual components, the AZTI Marine Biotic Index (AMBI), the Simpson's Dominance (1- λ) and the number of taxa (S), which together describe the ecological health of the biological quality element of the macrofauna. Each individual metric is normalised to a reference value, which is the expected value for that metric in the habitat type that is being assessed when there is minimal or no disturbance due to human activities. All replicate level and station level values were considered to range from "Moderate/Poor" (0.44-0.63) to "High/Good" (≥ 0.74) ecological status by IQI analysis (Table 5-11 and Table 5-12; WFD-UKTAG, 2014).

Overall, the following results show a moderate to high diversity community across all stations, with minimal variation in spatial patterns relating to natural variation across the different areas.

Table 5-11 Univariate Faunal Parameters by Replicate (per 0.1m²)

Station Replicate	Number of Species (S)	Number of Individuals (N)	Richness (Margalef)	Evenness (Pielou's)	Shannon Wiener Diversity H'(log²)	Simpson's Diversity (1-Lambda')	IQI	Ecological Status (v4)
A2_ES_01_F1	35	212	6.35	0.824	4.23	0.925	0.73	GOOD
A2_ES_01_F2	43	164	8.24	0.892	4.84	0.960	0.76	HIGH
A2_ES_01_F3	50	280	8.70	0.846	4.78	0.952	0.81	HIGH
A2_ES_02_F1	21	38	5.50	0.900	3.95	0.936	0.67	GOOD
A2_ES_02_F2	17	54	4.01	0.797	3.26	0.867	0.62	MODERATE
A2_ES_02_F3	20	138	3.86	0.705	3.05	0.813	0.61	MODERATE
A2_ES_03_F1	49	416	7.96	0.667	3.74	0.823	0.66	GOOD
A2_ES_03_F2	39	272	6.78	0.749	3.96	0.882	0.67	GOOD
A2_ES_03_F3	38	260	6.65	0.723	3.8	0.876	0.67	GOOD
A2_ES_04_F1	13	26	3.68	0.782	2.89	0.791	0.67	GOOD
A2_ES_04_F2	12	61	2.68	0.709	2.54	0.732	0.68	GOOD
A2_ES_04_F3	9	28	2.40	0.786	2.49	0.765	0.67	GOOD
A3_NS_01_F1	58	722	8.66	0.760	4.46	0.930	0.72	GOOD
A3_NS_01_F2	75	621	11.51	0.806	5.02	0.9520	0.72	GOOD
A3_NS_01_F3	65	778	9.61	0.758	4.56	0.931	0.72	GOOD
A4_GLC_01_F1	59	466	9.44	0.567	3.33	0.681	0.70	GOOD
A4_GLC_01_F2	56	702	8.39	0.520	3.02	0.644	0.69	GOOD
A4_GLC_01_F3	68	569	10.56	0.538	3.27	0.685	0.72	GOOD
A4_GLC_03_F1	59	557	9.17	0.620	3.65	0.789	0.74	GOOD
A4_GLC_03_F2	46	460	7.34	0.549	3.03	0.674	0.70	GOOD
A5_OPB_01_F1	13	24	3.78	0.929	3.44	0.931	0.60	MODERATE
A5_OPB_01_F2	9	26	2.46	0.754	2.39	0.735	0.64	MODERATE
A5_OPB_01_F3	8	23	2.23	0.900	2.7	0.858	0.64	MODERATE
Route Mean	**34**	**300**	**6.52**	**0.743**	**3.58**	**0.832**	**0.69**	-
SD	**22**	**261**	**2.87**	**0.120**	**0.79**	**0.103**	**0.05**	-
CV (%)	**63.9**	**86.9**	**44.1**	**16.2**	**22.0**	**12.4**	**7.2**	-
Minimum	**8**	**23**	**2.23**	**0.520**	**2.39**	**0.644**	**0.60**	-
Maximum	**75**	**778**	**11.51**	**0.929**	**5.02**	**0.960**	**0.81**	-
IQI Score:								
≥0.75 = High / Good; 0.64 - 0.74 = Good / Moderate; 0.45 - 0.63 = Moderate / Poor; ≤ 0.44= Poor / Bad								

Table 5-12 Univariate Faunal Parameters Averaged by Station (per 0.1m²)

Station	Number of Species (S)	Number of Individuals (N)	Richness (Margalef)	Evenness (Pielou's)	Shannon Wiener Diversity H'(log²)	Simpson's Diversity (1-Lambda')	IQI	Ecological Status (v4)
A2_ES_01	43	219	7.76	0.850	4.61	0.946	0.76	HIGH
A2_ES_02	19	77	4.46	0.800	3.42	0.872	0.63	MODERATE
A2_ES_03	42	316	7.13	0.710	3.83	0.860	0.67	GOOD
A2_ES_04	11	38	2.92	0.760	2.64	0.763	0.67	GOOD
A3_NS_01	66	707	9.93	0.770	4.68	0.938	0.72	GOOD
A4_GLC_01	61	579	9.46	0.540	3.21	0.670	0.70	GOOD
A4_GLC_03*	53	509	8.26	0.580	3.34	0.732	0.72	GOOD
A5_OPB_01	10	24	2.82	0.861	2.84	0.841	0.63	MODERATE
Route Mean	**38**	**309**	**6.59**	**0.736**	**3.57**	**0.828**	**0.69**	-
SD	**22**	**264**	**2.83**	**0.118**	**0.75**	**0.098**	**0.05**	-
CV (%)	**57.9**	**85.5**	**42.9**	**16.0**	**21.1**	**11.9**	**6.9**	-
Minimum	**10**	**24**	**2.82**	**0.540**	**2.64**	**0.670**	**0.63**	-
Maximum	**66**	**707**	**9.93**	**0.861**	**4.68**	**0.946**	**0.76**	-
**Duplicate replicate (F1, F2)*								
IQI Score:								
≥0.75 = High / Good; 0.64 - 0.74 = Good / Moderate; 0.45 - 0.63 = Moderate / Poor; ≤ 0.44= Poor / Bad								

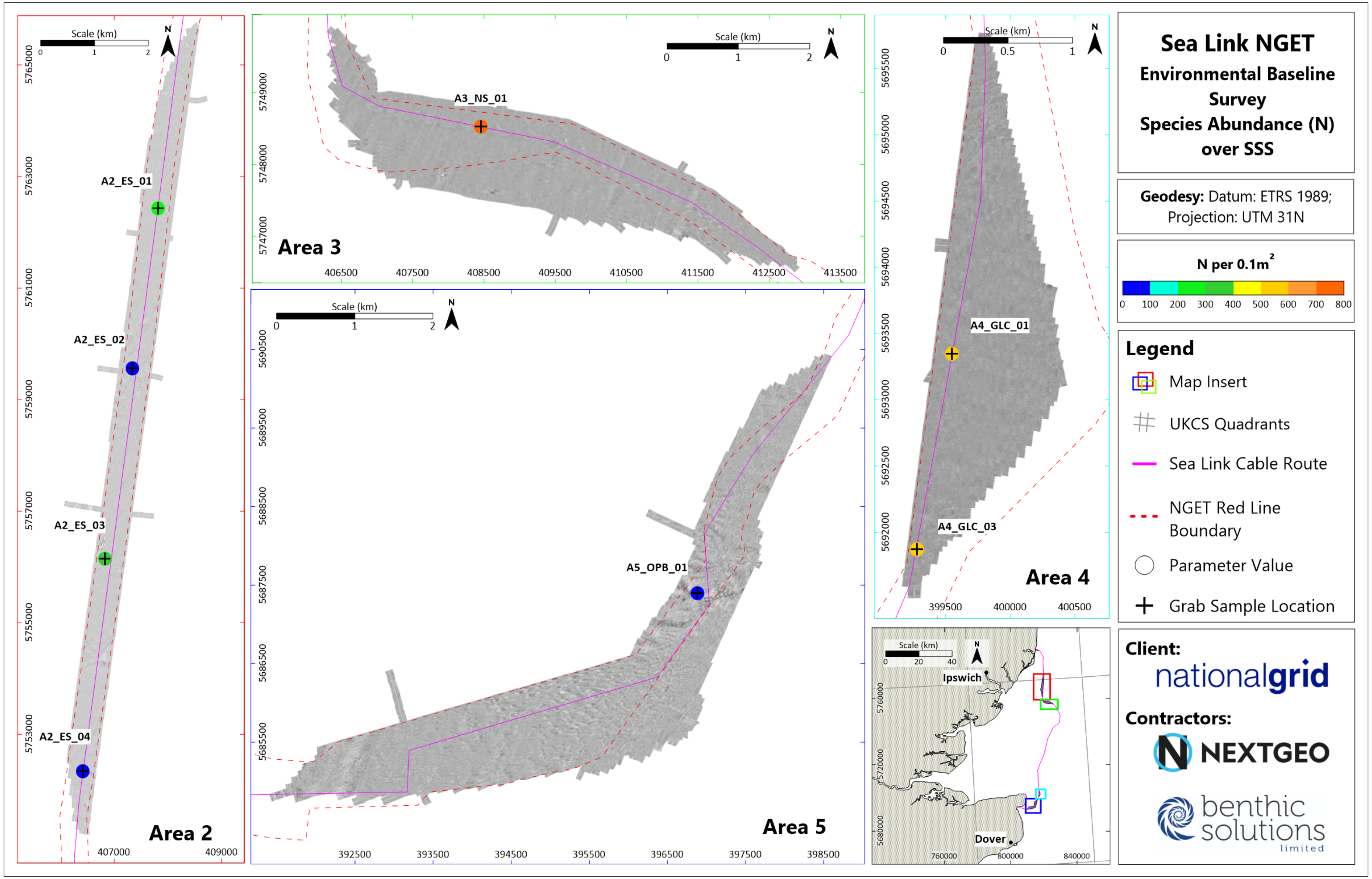


Figure 5-21 Species Abundance (N) per 0.1m²

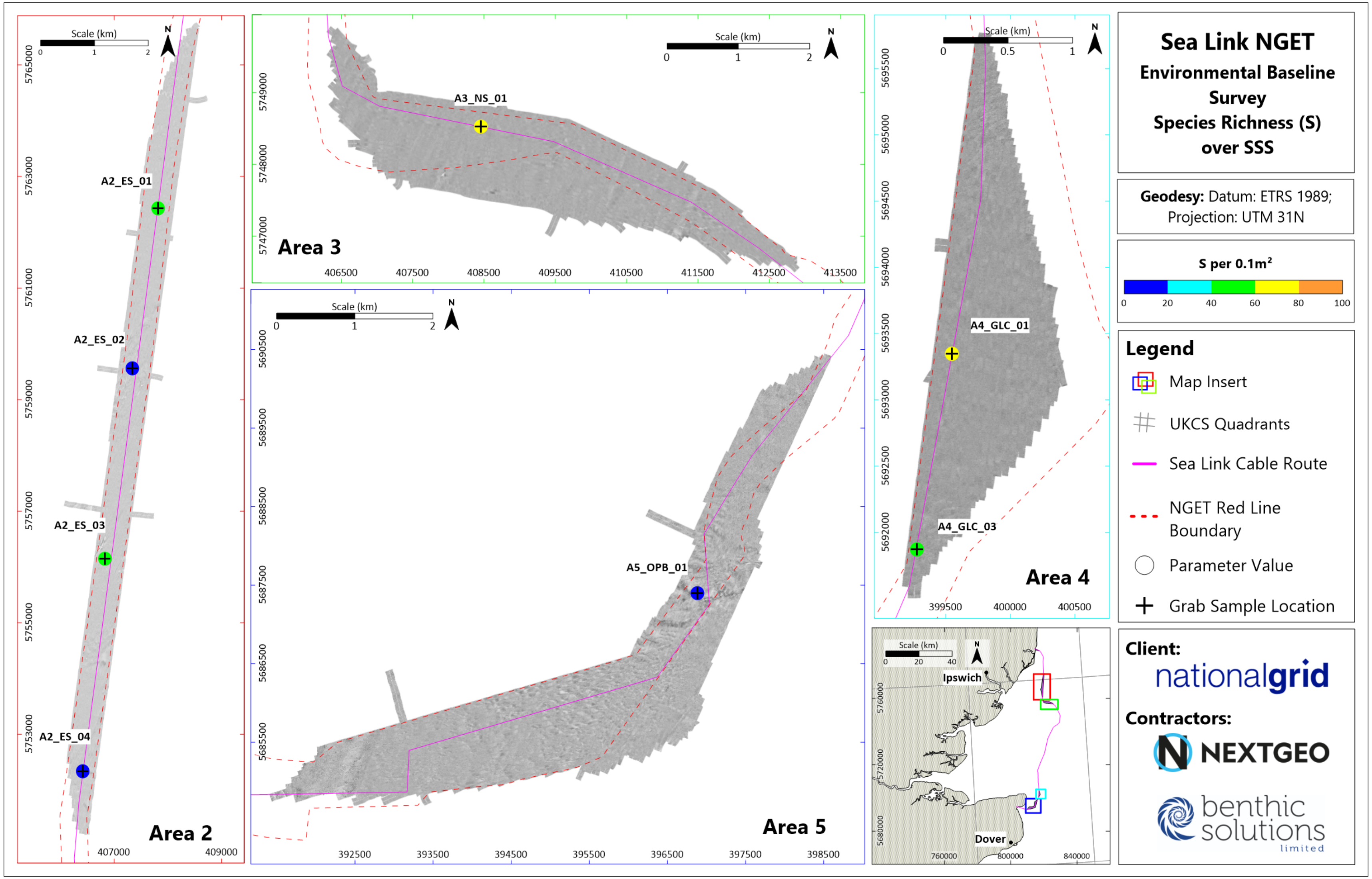


Figure 5-22 Species Richness (S) per 0.1m²

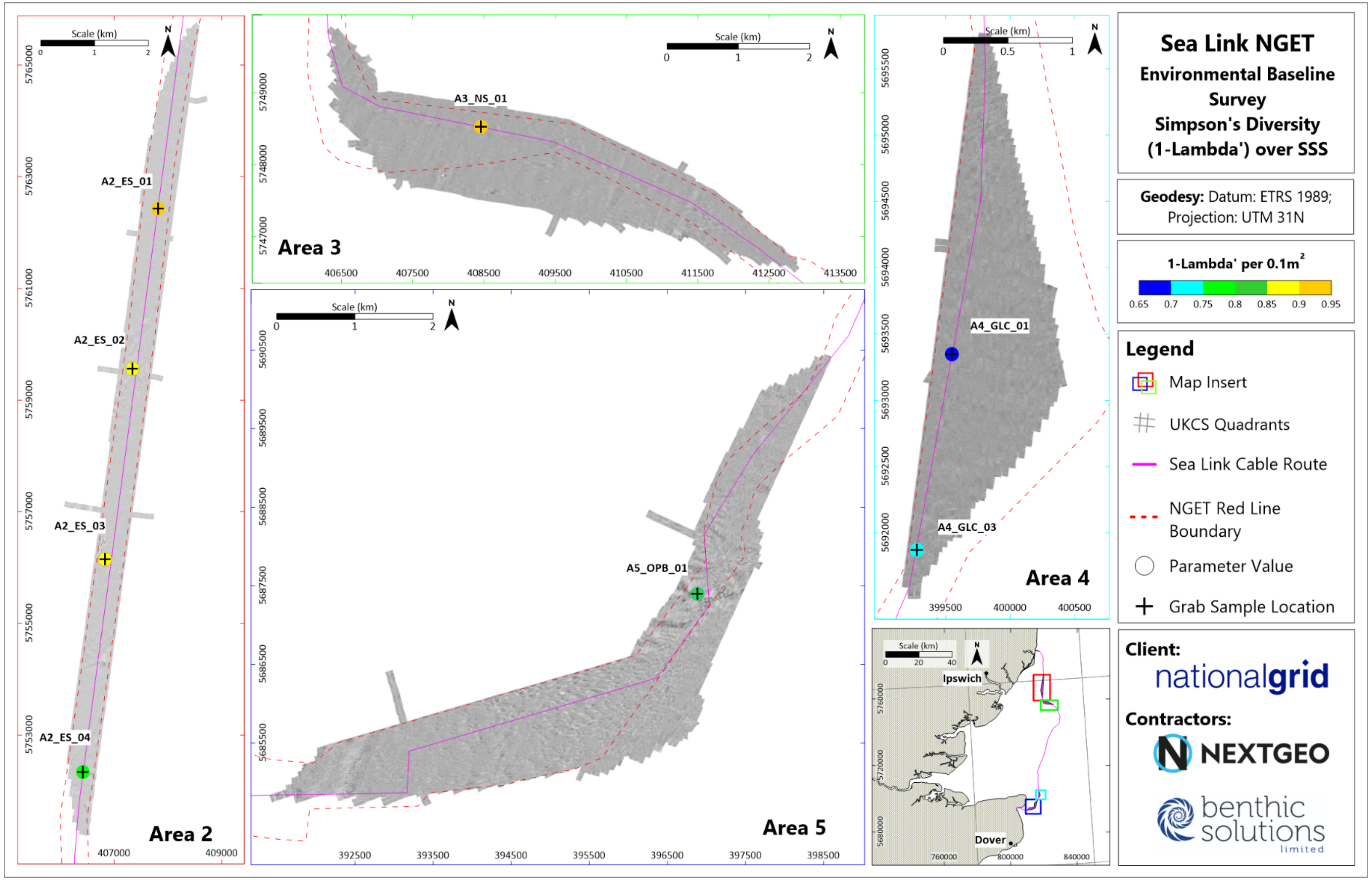


Figure 5-23 Simpson's Diversity (1-Lambda') per 0.1m²

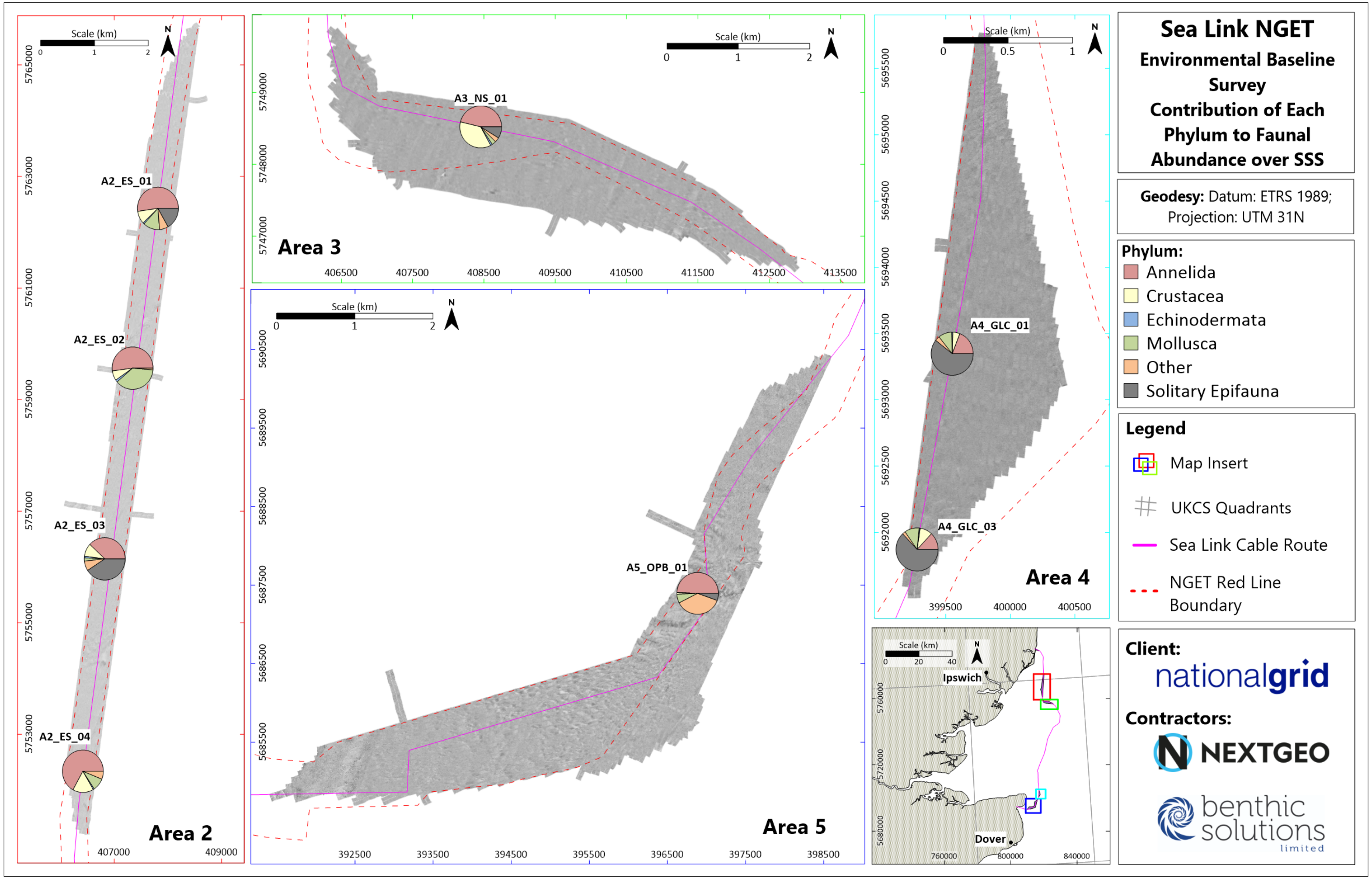


Figure 5-24 Average Contribution of Each Phylum to Total Faunal Abundance for Each Station (per 0.1m²)

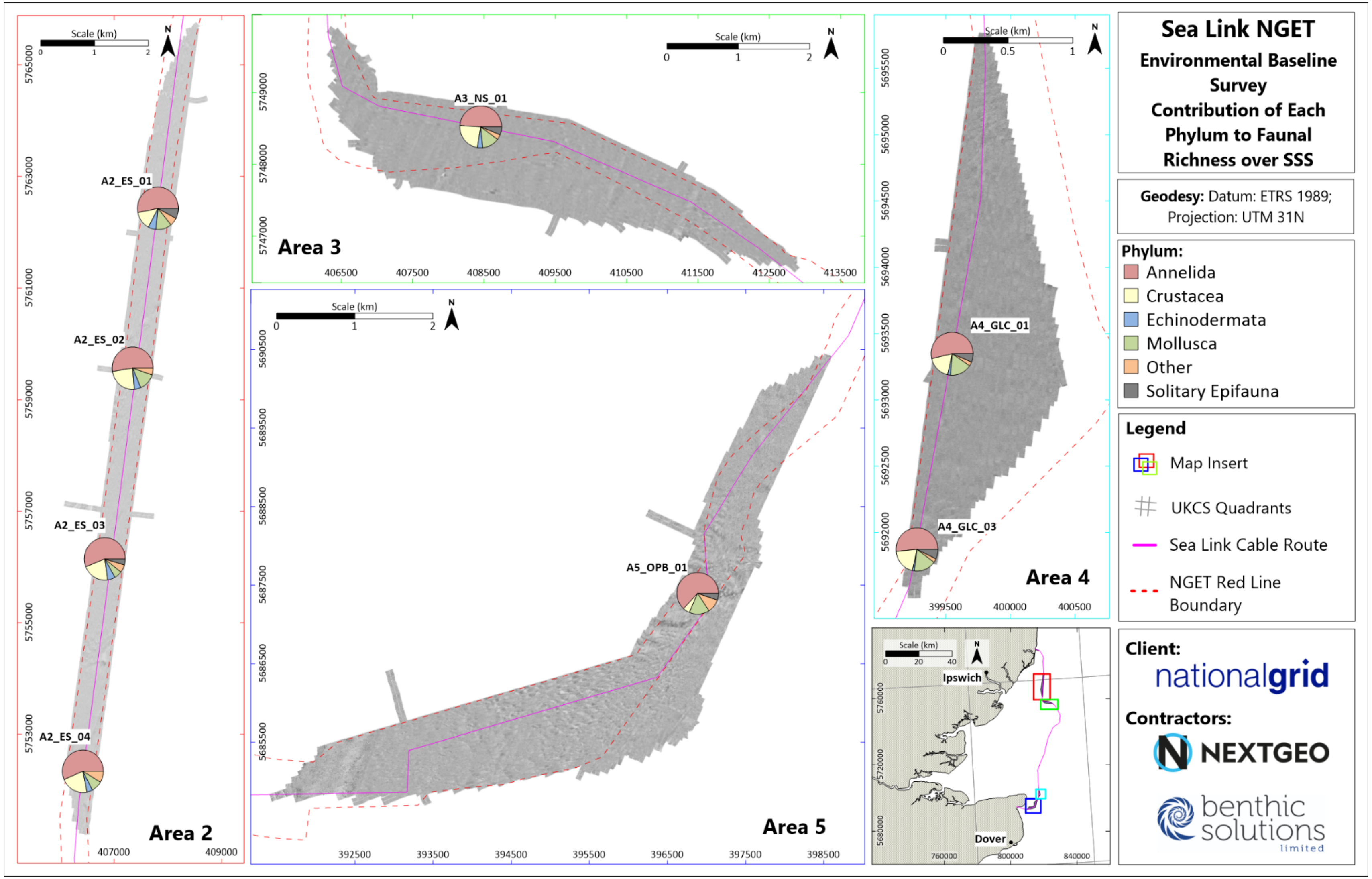


Figure 5-25 Average Contribution of Each Phylum to Total Faunal Richness for Each Station (per 0.1m^2)

5.3.2 Multivariate analysis

Consistent with the MMT (2022) report, all replicate and station data underwent square-root transformation prior to multivariate PRIMER analysis (PRIMER 7.0.17; Clarke *et al.*, 2014) to down-weight the influence of any dominant species between sample similarities/dissimilarities.

5.3.2.1 Hierarchical Agglomerative Clustering – Group Average Method

Similarity dendrograms were created using group average hierarchical agglomerative clustering (CLUSTER) and is presented for all replicates in Figure 5-26. SIMPROF analysis highlighted the presence of seven significantly different (p<0.05) clusters comprising of one or more sample replicate which were differentiated by black branches on the dendrogram. Replicates displayed Bray Curtis similarities between 10% to 80%. Most replicates from the same station grouped together, showing close intraspecific relationships.

The macrofauna dataset was summed to station level which enables an accurate characterisation of the broad-scale spatial variation in species assemblages within the survey area. A further similarity dendrogram was produced following agglomerative clustering (Figure 5-27). At station level the SIMPROF test revealed three significantly different structured groupings at a Bray Curtis similarity of 10% to 55%. For station A4_GLC_03, where only two replicates (per 0.2m²) were obtained, the species data was excluded from the multivariate analysis to avoid bias related to the reduced number of individuals and species, when compared to the summed stations. It has been inferred that the summed station A4_GLC_03 would be assigned to the station level (per 0.3m²) cluster 'a' due to the significant similarity observed at the replicate level (Table 5-13).

Table 5-13 SIMPROF Station Groupings

SIMPROF Group	Similarity (%)	Stations	Interpretation
a	47.85	A2_ES_01, A2_ES_03, A3_NS_01, A4_GLC_01, A4_GLC_03*	This cluster comprised of five stations, each classified as 'Muddy Sandy Gravel' under the Modified Folk Classification. These stations had the highest levels of species richness and faunal abundance, with the macrofaunal community dominated by the keelworm (*Spirobranchus lamarcki*), the annelid *Ampharete lindstroemi* and Actinaria. *A4_GLC_03 has been included within this cluster based on the significant similarities of macrofaunal abundances and similar replicate clustering observed at ~40% (Figure 5-26).
b	<2 samples	A2_ES_02	This cluster consisted of a singular station, with a significant difference in sediment composition compared to other stations, supported by its unique cluster within Section 5.1.2. A higher proportion of fines characterised this station, defining it as 'Slightly Gravelly Sandy Mud'. Demonstrating a moderate species richness, the macrofaunal community was dominated the mollusc *Kurtiella bidentata* and polychaete *Spiophanes bombyx*.
c	37.55	A2_ES_04, A5_OPB_01	This final cluster included two stations which were both classified as 'Gravelly Sand', each noted by the high sands content. This cluster is dominated by the macrofaunal community of Nemertea and the annelid *Microphthalmus*.

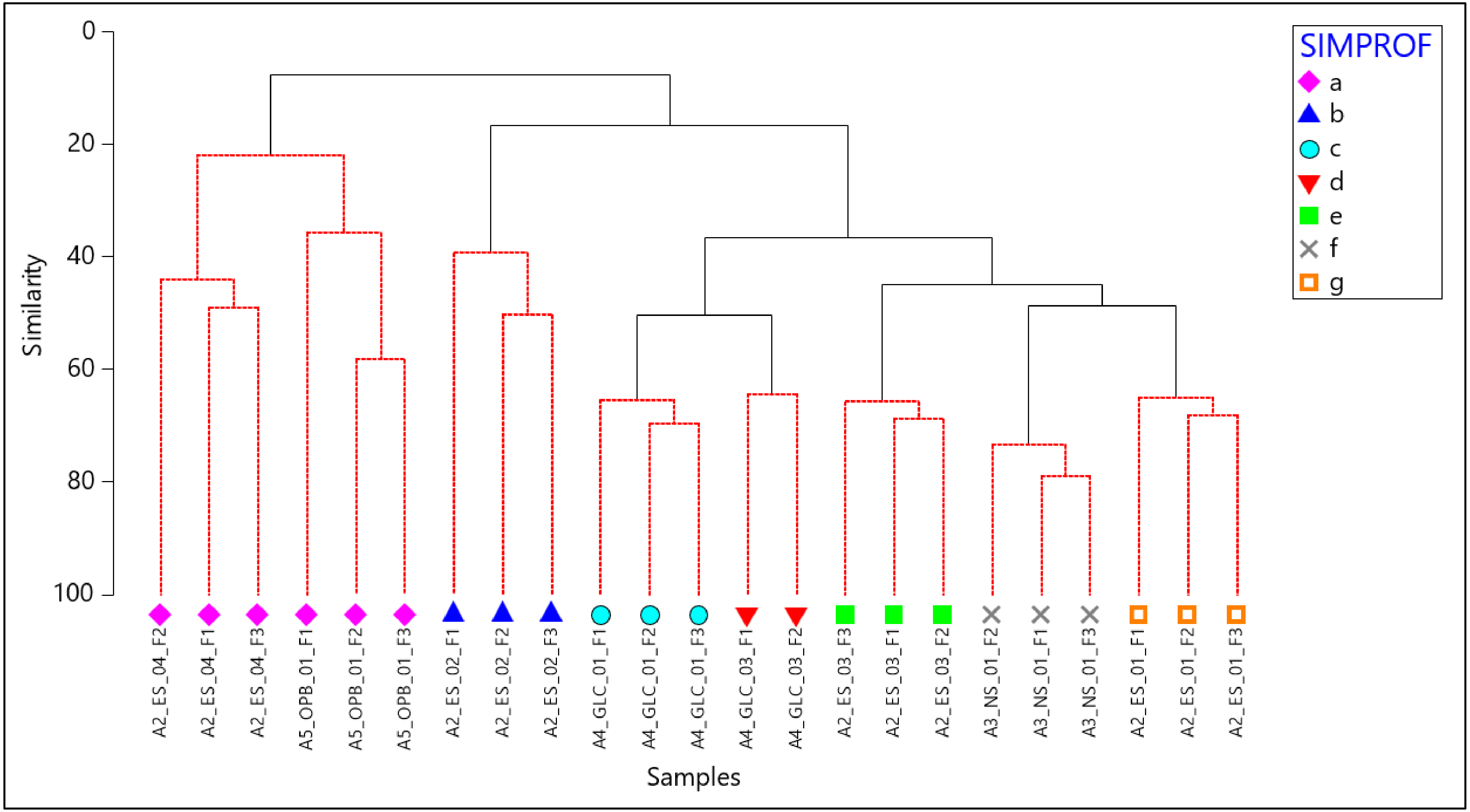


Figure 5-26 Dendrogram of Macrofaunal Replicates (per 0.1m^2)

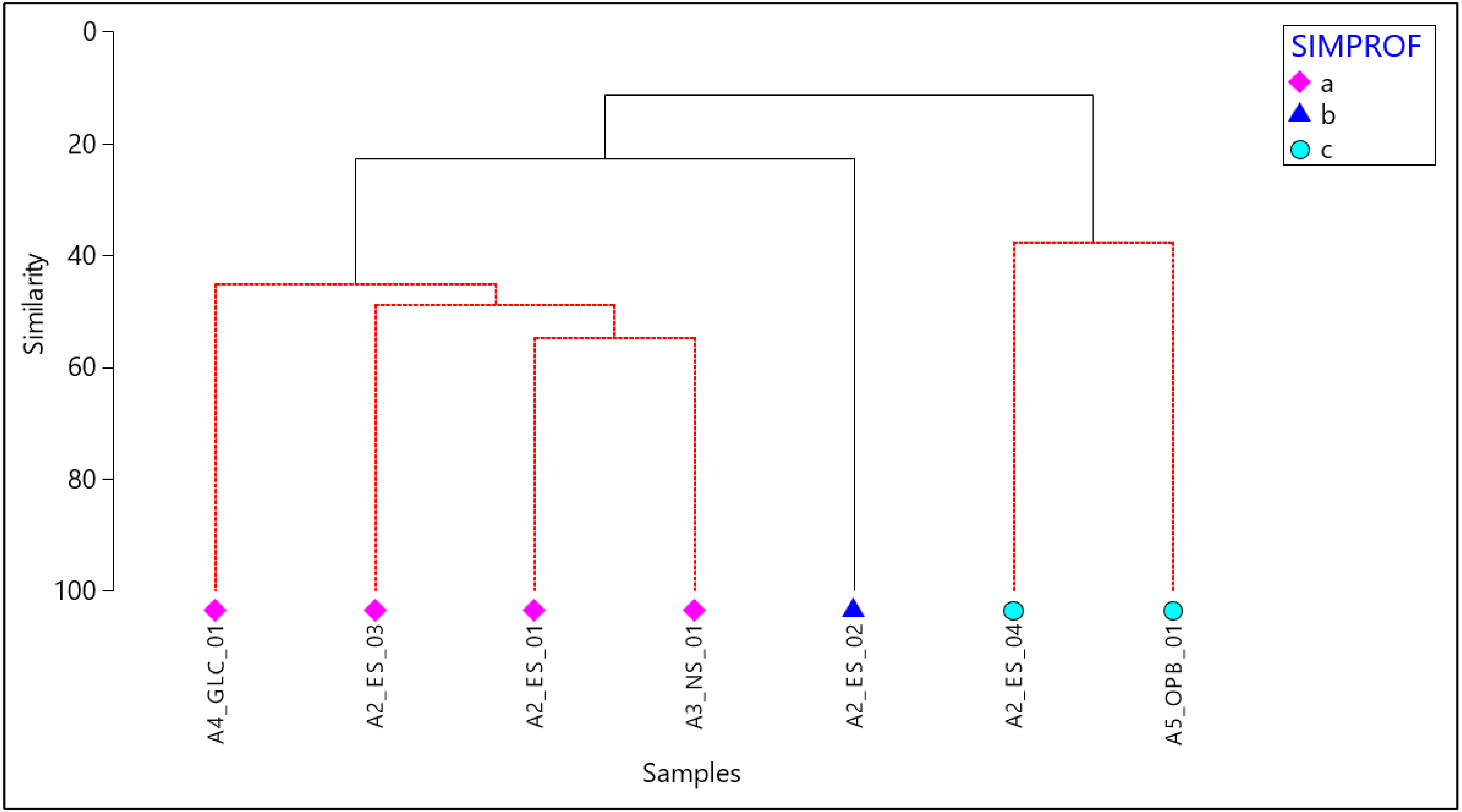


Figure 5-27 Dendrogram Of Macrofaunal Stations (per 0.3m^2)

5.3.2.2 Non-Metric Multi-Dimensional (nMDS) Ordination

Similarities in the macrofaunal communities recorded across the survey area are presented in Figure 5-28 by replicates and Figure 5-29 by station as a 2-dimensional non-metric multi-dimensional scaling (nMDS) ordination. The nMDS plot in Figure 5-28 presents the 23 replicates from the survey area, revealing a moderate ordination of the data with a low stress level of 0.07. The plotted replicates aligned consistently with the clusters identified in the dendrogram. The primary macrofaunal assemblage of the Sea Link survey area plotted in the bottom right side of the plot, whilst stations with differing sediment compositions ordinated further afield to the far left and top of the plot (Figure 5-29).

At station level, the nMDS plot ordinated three SIMPROF groupings with an excellent stress level of 0 (Figure 5-29), revealing an accurate representation of the data. Cluster 'a', representing a majority of the surveyed stations, ordinated centrally to the bottom of the plot, with no intra-cluster variation – indicating a consistent macrofaunal community and abundance across the included stations for the survey area.

Cluster 'b' ordinated to the right of the plot due to its relatively unique macrofaunal community, whilst cluster 'c' demonstrates significant intra-cluster variation between stations based on its similar species richness but differing contributions of individuals. The difference between clusters is likely based on natural variability in macrofaunal assemblage which is also driven by differing sediment composition across the survey area.

The geographical distribution of the multivariate clusters is provided in Figure 5-30.

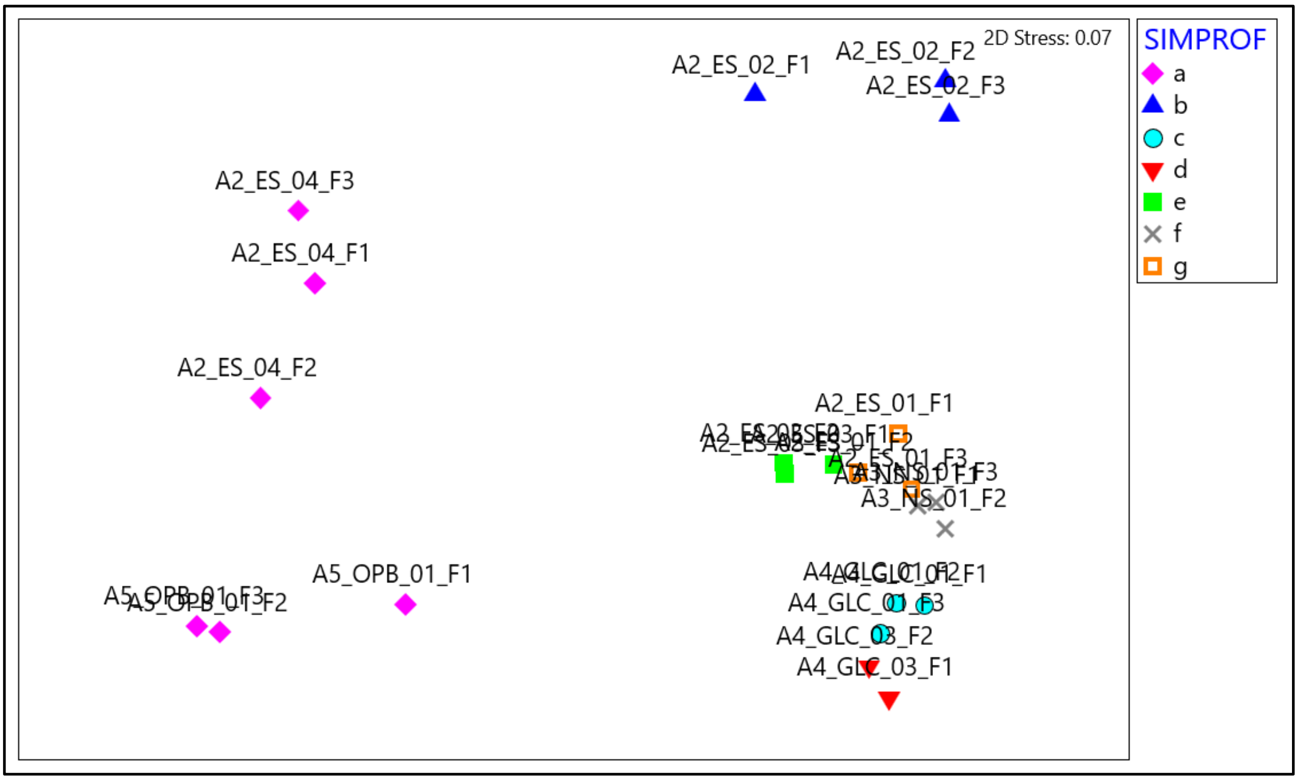


Figure 5-28 nMDS Ordination Plot of Macrofaunal Replicates (per 0.1m²)

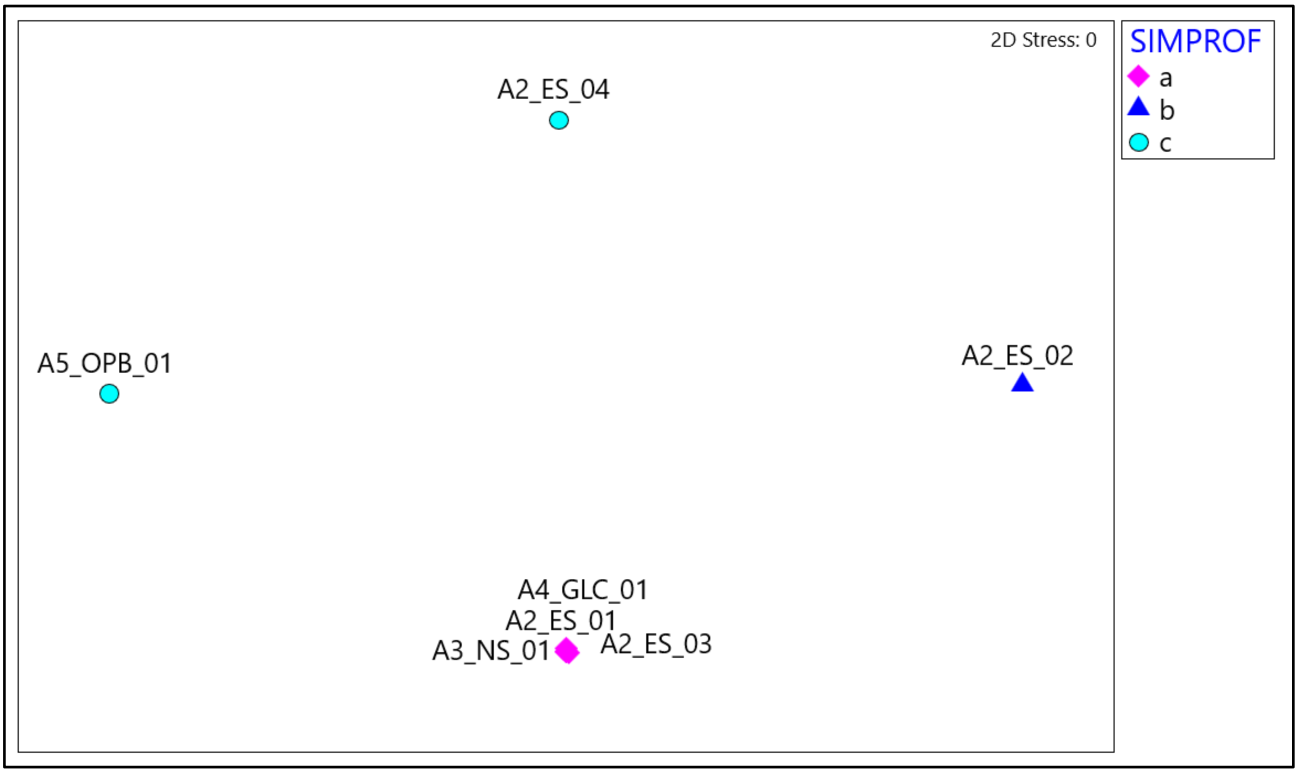


Figure 5-29 nMDS Ordination Plot of Macrofaunal Stations (per 0.3m²)

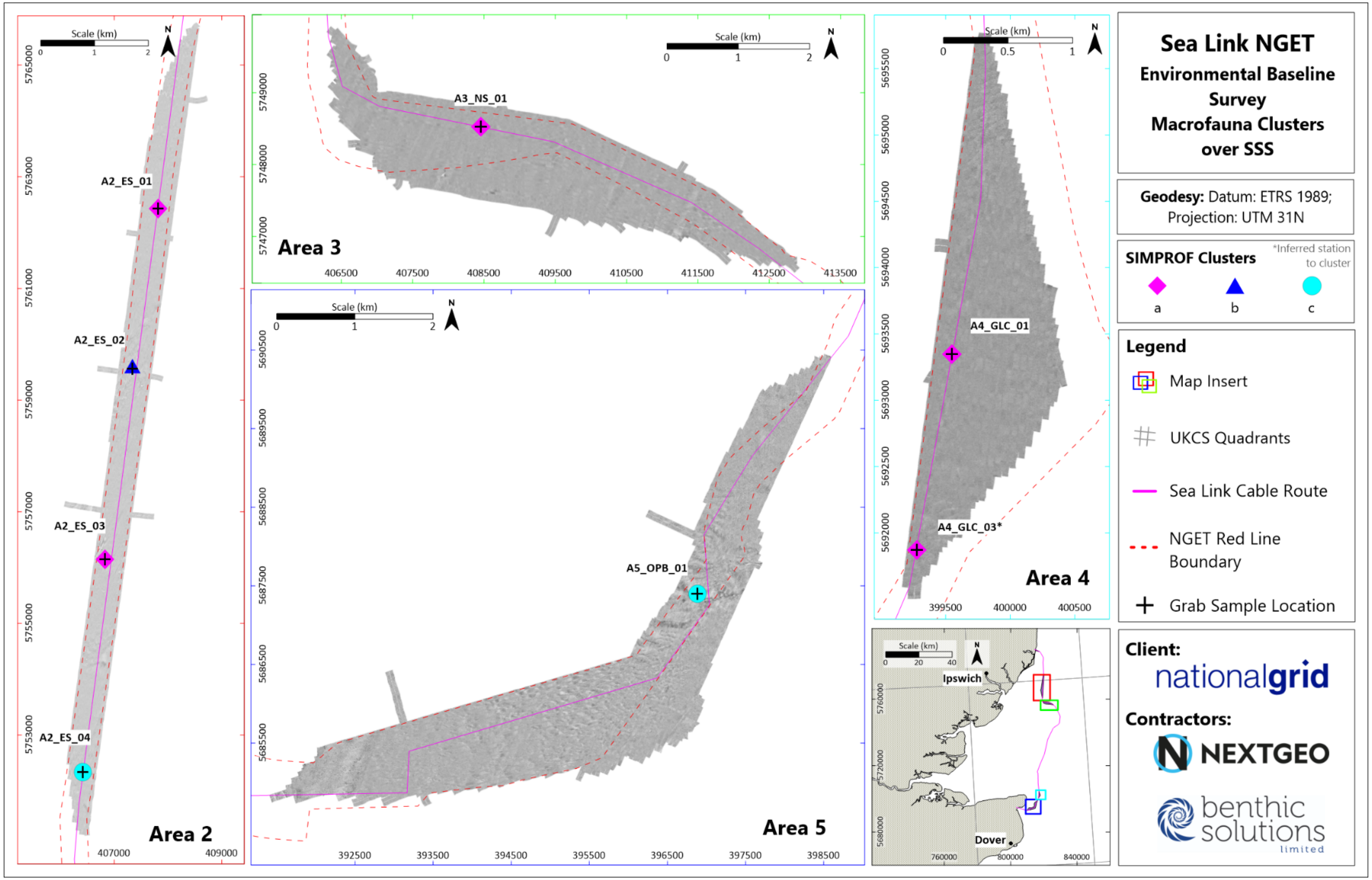


Figure 5-30 Macrofauna SIMPROF Clusters

5.3.2.3 Correlation with Environmental Variables

To assess whether the observed differences in community composition were related to the sediment composition of the survey area, a RELATE test (correlation test) followed by a BEST test was performed, mirroring that of the previous MMT survey (2022).

The results revealed a significant correlation between sediment characteristics and the macrofaunal assemblages ($\varrho=0.703$, $p<0.01$), where phi classes 1 (medium sand) and -3 (pebbles) together constituted the variables that best explained the observed pattern of spatial distribution for fauna. To visualise this relationship, a PCA was carried out on the phi data overlain with the clusters identified from the macrofaunal dataset (Figure 5-31). The plot shows that the macrofaunal community within cluster 'a' had notable intra-cluster variation spanning from pebbles (phi -3) to very coarse sand (phi -1), suggesting that macrofaunal assemblages found within this cluster are common across varying sediment compositions. Macrofaunal communities in cluster 'b' were characterised by fine sand to clay (phi 3 to >10) with elements of medium to coarse sand (phi 1). Whilst cluster 'c' had a sediment composition of coarse to fine sand (phi 0 to 2), suggesting macrofaunal species present here had an affinity to well sorted sands.

Further RELATE and BEST tests were performed between macrofauna and organics (TOC/TOM), hydrocarbons, and heavy metals, however no significant correlations were noted ($p>0.05$).

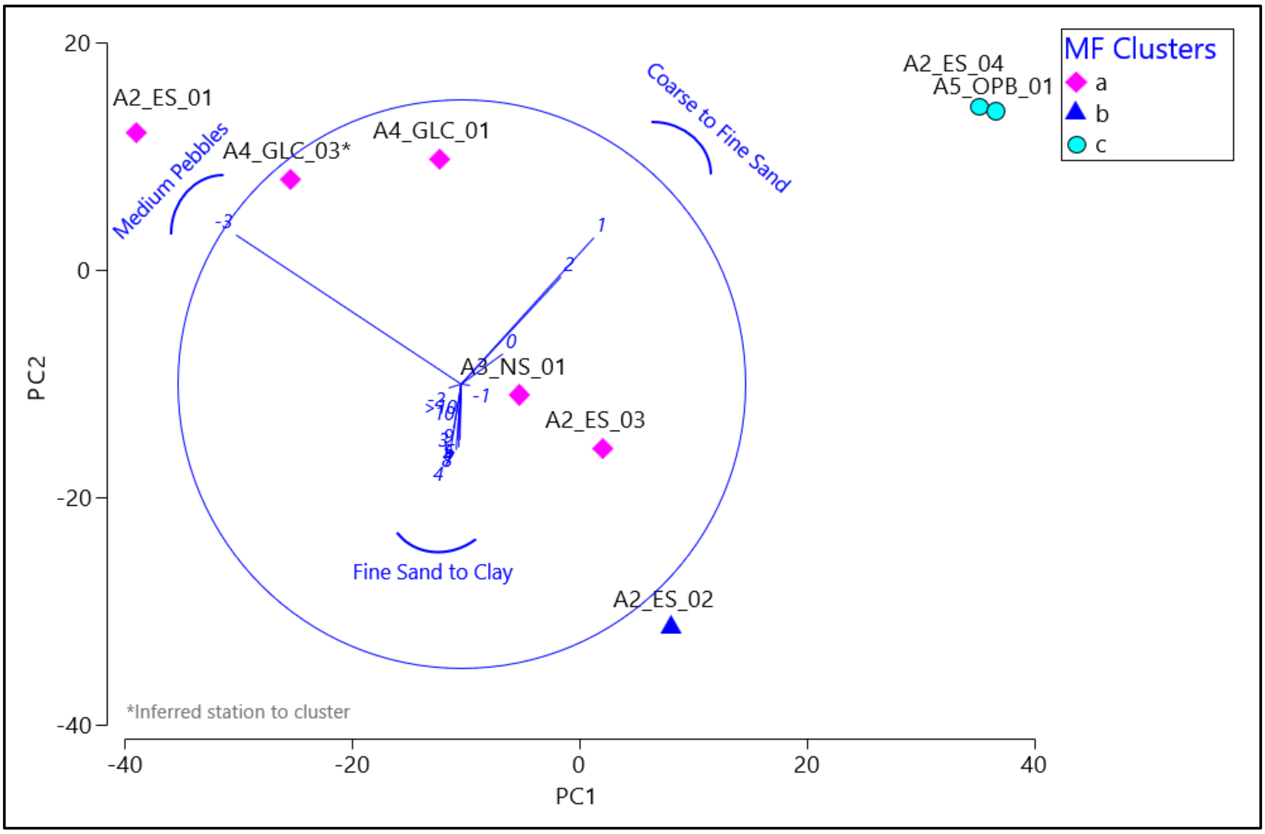


Figure 5-31 Macrofaunal Clusters Plotted Over PSA PCA Plot

5.3.2.4 Inter-Cluster Variation in Community Composition

To investigate the differing macrofaunal communities described by the identified multivariate clusters, the ranges of primary and derived univariate diversity indices for stations grouped within each cluster were calculated and are summarised in Table 5-14, including the inferred station (A4_GLC_03) into cluster 'a'.

Table 5-14 Overview of the Univariate Parameters per SIMPROF Clusters

SIMPROF Cluster	Number of Species (S)		Number of Individuals (N)		Richness (Margalef)		Evenness (Pielou's)		Shannon Wiener Diversity		Simpson's Diversity (1-Lambda')	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
a	42	66	219	707	7.13	9.93	3.208	0.854	3.21	4.68	0.670	0.946
b	-	19	-	77	-	4.46	-	0.801	-	3.42	-	0.872
c	10	11	24	38	2.82	2.92	0.759	0.861	2.64	2.84	0.763	0.841

Differences in the relative phyletic composition of macrofaunal communities were explored by plotting the average percentage contribution of major phyla to the overall number of individuals and number of species within each cluster (Figure 5-32 and Figure 5-33). The results showed that clusters 'b' and 'c' were characterised by Annelida, which contributed between 52.2% and 60.1% of the total individuals respectively. Mollusca abundance was highest in cluster 'b' at a contribution of 37.4% of individuals. Cluster 'a' had the highest Crustacea abundance, with the phylum accounting for 17.4% of individuals. There were few individuals in the Echinodermata phylum present in all clusters, contributing from 0.5% to 1.7%. Other species (Nemetoda, Nemertea, Phoronida, Cnidaria) showed varied contributions, ranging from 1.3% at cluster b to 18.1% at cluster 'c'.

Cluster 'a' was characterised mainly by solitary epifauna, which contributed to 36.7% of individuals, closely followed by its Annelida contribution (33.2%). This notable solitary epifaunal presence is primarily attributed to the keel worm, *Spirobranchus lamarcki*. Although classified as solitary epifauna, this species is an annelid, aligning with the trend observed in other clusters where Annelida constitutes a significant proportion of individuals. Unlike other annelids that typically inhabit sediment, *S. lamarcki* resides on hard substrates, firmly attached to the surface rather than burrowing. Therefore, it is categorised as solitary epifauna which is also visible within sample photographs, attached to large pebbles.

In terms of contribution of phyla to the number of species, the clusters had similar proportions of species richness with minimal variation in dominating phyla. Annelida remained the most dominant phylum across all three clusters, ranging from 48.8% at cluster 'a' to 54.8% at cluster 'c'. The number of Crustacea was relatively similar across the clusters, ranging from 19.4% in cluster 'c' to 23.7% in cluster 'b'. Similarly, Mollusca had minimal variation from 12.9% to 16.3% as well as Echinoderms ranging from 3.2% to 5.3%. Other species varied from 2.9% in cluster 'a' to 6.5% in cluster 'c'. Solitary epifauna was entirely absent from cluster 'b', with an increase of presence at cluster 'c' (3.2%) and cluster 'a' (4.7%).

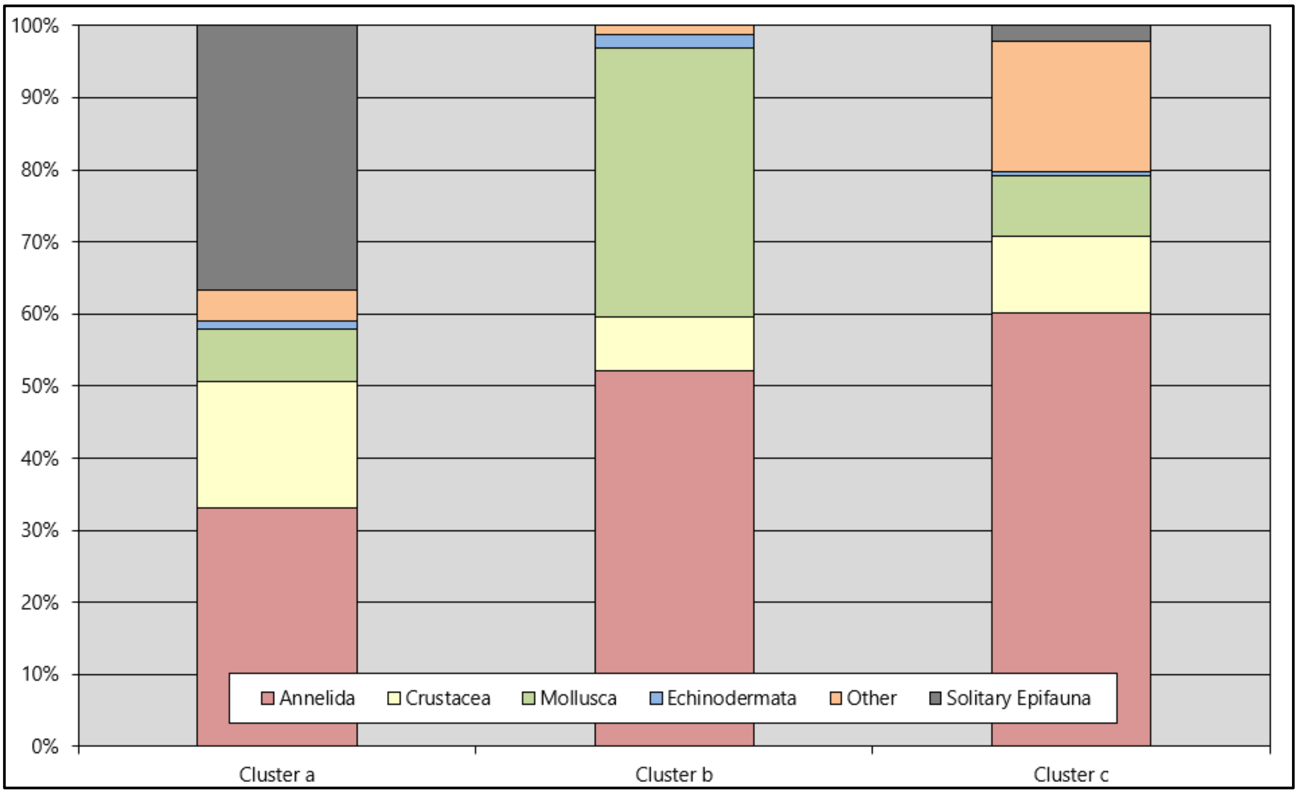


Figure 5-32 Average Contribution of Each Phylum to Total Faunal Abundance for Each Cluster

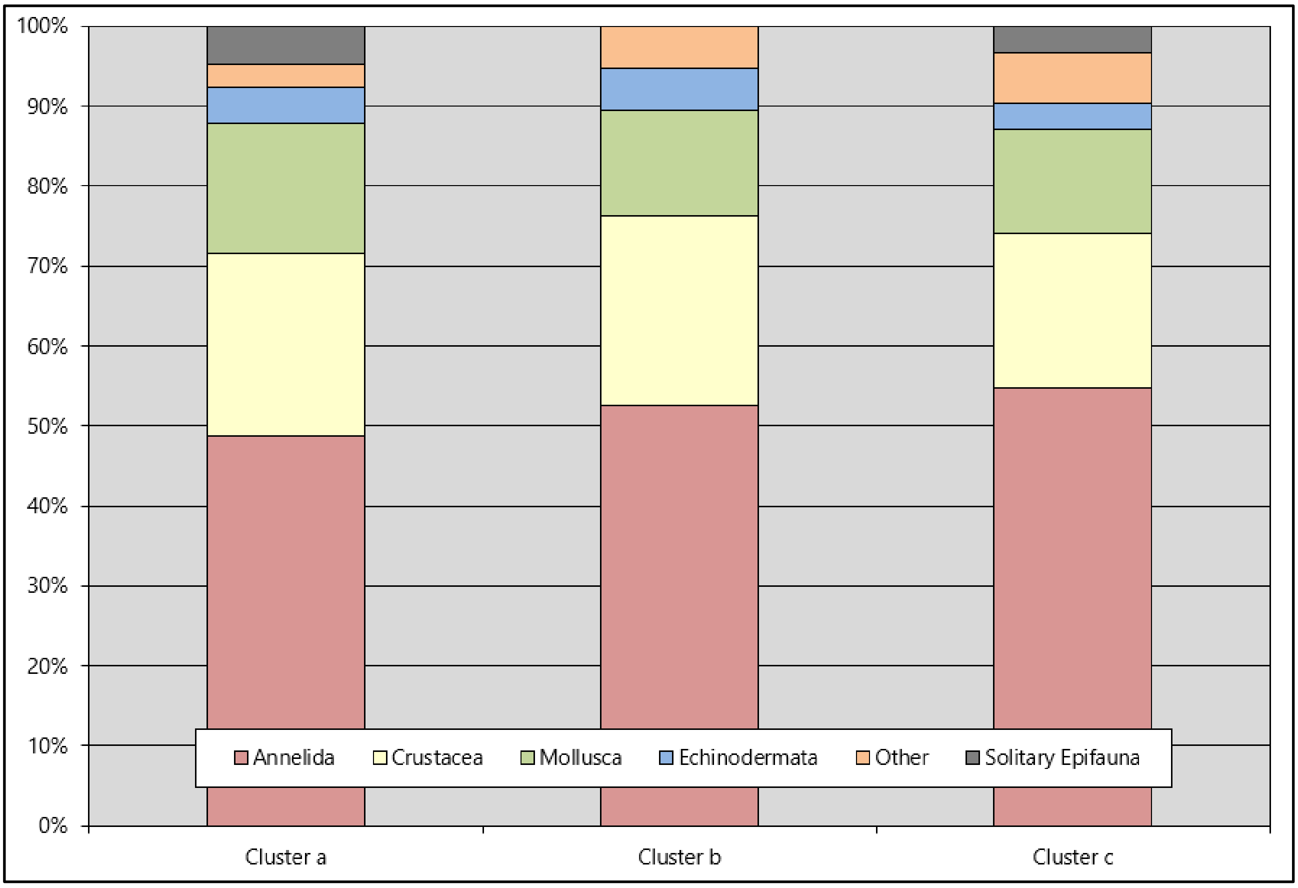


Figure 5-33 Average Contribution of Each Phylum to Total Number of Species for Each Cluster

Table 5-15 provides additional details on the ecological parameters influencing the separation of macrofaunal clusters across the survey areas. The contribution of different ecological groups (EG) was assessed using the AMBI method developed by Borja *et al.* (2000). AMBI scores were calculated as a percentage for each cluster by summing the values for each EG across all stations (including A4_GLC_03), then aggregating all EGs, and expressing each individual value as a percentage of the total. The results for each cluster are illustrated in Figure 5-34.

This revealed that disturbance sensitive species (EG I) were present in every cluster and most dominant in cluster 'c', where it accounted for 38.3% of species, whilst cluster 'a' had 25.7% followed by cluster 'b' 10.2% for EG I species. Disturbance indifferent taxa (EG II) were also present in every cluster, though they were particularly dominant in cluster 'a', accounting for 50.0% of taxa, attributed to abundances of *Lumbrineris cingulata* and *S. lamarcki*. Disturbance tolerant species (EG III) were once again found in all clusters, and was the highest AMBI group in cluster 'b', accounting for 61.5% of taxa which can be attributed to the bivalve *Kurtiella bidentata*. Second-order opportunistic species (EG IV) appeared in low numbers in all clusters, ranging from 3.5% (cluster 'c') to 13.3% (cluster 'b'). First-order opportunistic taxa (EG V) was not detected at cluster level across the survey area.

Furthermore, the AMBI Biotic Coefficient Index (BCI) was developed to determine the impacts and the quality status in soft-bottom marine benthic communities but is now broadly used along European coastlines to aid in determining the level of pollution within an environment (WFD-UKTAG, 2014). The system operates between 0 and 7, with lower numbers corresponding to higher or good ecological status (WFD-UKTAG, 2014). All clusters scored <2.6 indicative of "Good"-"High" ecological status. A "High" ecological status indicates all the disturbance-sensitive taxa associated with undisturbed conditions are present whilst "Good" ecological status indicates that most of the sensitive taxa of the type-specific communities are present (WFD-UKTAG, 2014). Subsequently, the conformance of the ecological status across all clusters indicates that the differentiation of the macrofaunal clusters is likely to reflect natural sediment variation in the distribution of benthic macrofauna with no influence of localised pollution evident.

Table 5-15 AMBI Ecological Groups I-V Percentage Contribution per SIMPROF Clusters

SIMPROF Cluster	EG I (%)		EG II (%)		EG III (%)		EG IV (%)		EG V (%)		AMBI BCI	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
a	14.5	47.9	26.3	70.4	5.4	35.1	4.3	13.9	0.0	0.1	1.2	2.2
b	-	10.2	-	15.0	-	61.5	-	13.3	-	0.0	-	2.6
c	15.7	60.9	24.3	38.6	12.2	41.4	2.6	4.3	0.0	0.0	0.9	2.0

AMBI Group	Feeding Method
Group I	Disturbance sensitive species
Group II	Disturbance indifferent species
Group III	Disturbance tolerant species
Group IV	Second order opportunistic species
Group V	First order opportunistic taxa

AMBI BCI:
0.0 ≤ 1.2 = High status
1.2 ≤ 3.3 = Good status
3.3 ≤ 4.3 = Moderate status
4.3 ≤ 5.5 = Poor status
5.5 ≤ 7.0 = Bad status

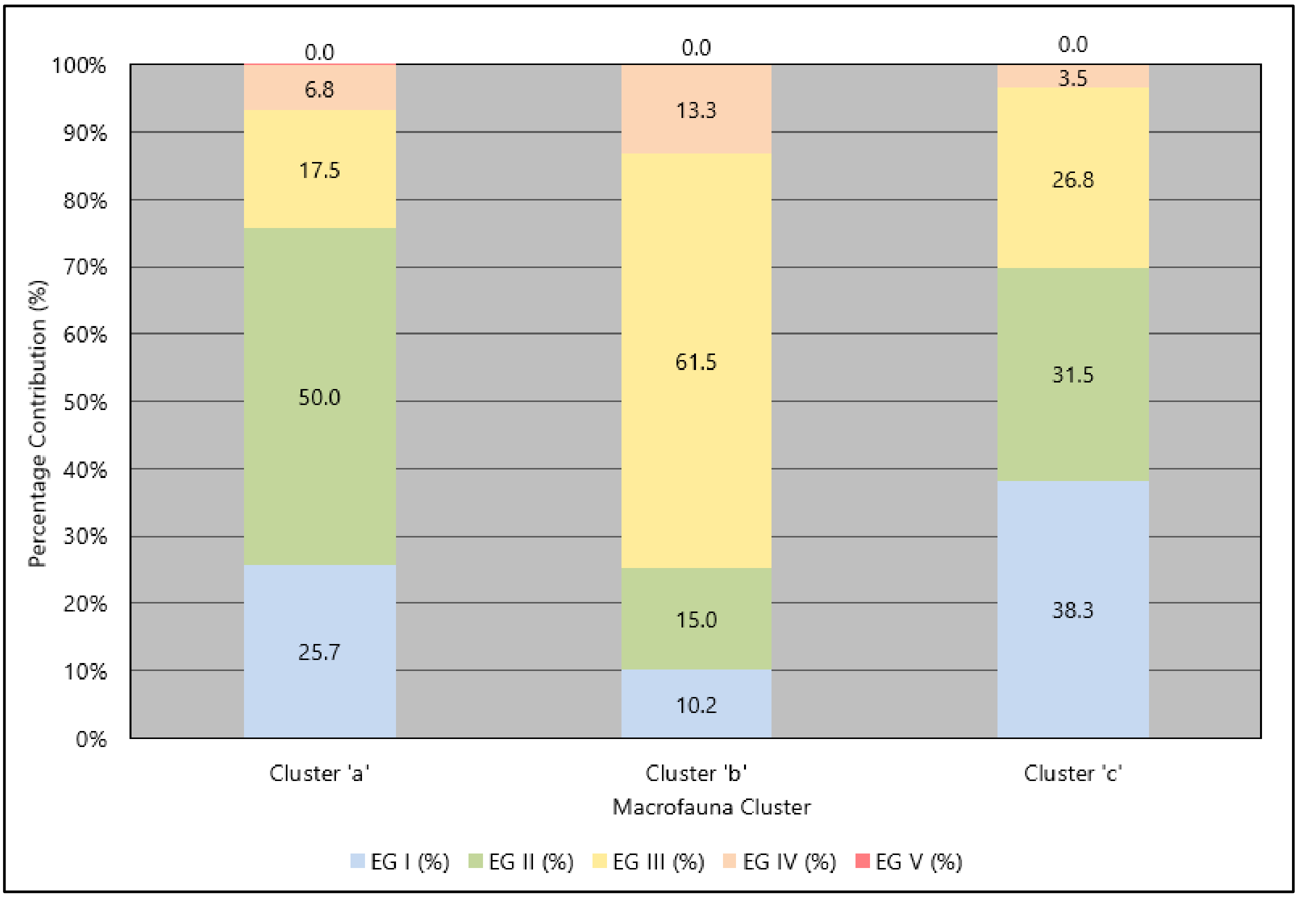


Figure 5-34 AMBI Ecological Groups I-V Percentage Contribution per SIMPROF Clusters

To determine the species driving the differences between the three clusters identified, Table 5-16 presents the top ten characterising taxa in each cluster together with their percentage contribution to the overall similarity within the cluster. Table 5-17 shows the top five species responsible for differences between clusters.

Clusters were typically characterised by their proportion of annelids and differing molluscs and arthropods, both clusters 'b' and 'c' shared characterising taxa with cluster 'a', however cluster 'b' and 'c' did not share any of the same top ten characterising taxa between one another. Cluster 'b' had the highest number of unique taxa, with eight species not appearing in the top ten most abundant species of other clusters, followed by cluster 'c' with seven unique taxa, and cluster 'a' having five unique taxa.

Cluster 'a' had a high species richness with a lower species abundance, suggesting an ambient macrofaunal assemblage across the variable sediment proportions. Cluster 'b's top contributing species (*Kurtiella bidentata, Spiophanes bombyx, Lagis koreni* and *Abra alba)* are characteristic of circalittoral muddy sands which directly relates to the singular station's Phi proportions (phi 3 to 10, very fine sand to clay respectively). Whilst cluster 'c's top taxa (Nemertea, *Microphthalmus* and *Caulleriella*) are typically found within coarser sediments such as coarse to fine sands (phi 0 to 3), again relating macrofaunal communities to sediment composition.

A review of the taxa most responsible for differentiating the clusters (Table 5-17) identified that the greatest dissimilarity was found between clusters 'b' and 'c' (88.82%). The largest species contributing to this dissimilarity is *Kurtiella bidentata*, which is only found in clusters 'a' and 'b', though it is significantly more abundant in cluster 'b'. The taxa *Spirobranchus lamarcki,* Actinaria and *Ampharete lindstroemi* were the top contributors causing a high dissimilarity between clusters 'a' and 'b' as well as 'a' and 'c', this is due to cluster 'a' having an equal species richness in top contributing taxa in comparison to remaining clusters. Actiniaria was also a large contributor to dissimilarity between clusters, due to its increased abundance within cluster 'a' and absence across clusters 'b' and 'c'. Both *S. lamarcki* and Actinaria are increasingly abundant in clusters with a higher percentage of gravel content where they can attach themselves to the hard substrate.

Table 5-16 Top 10 Species Abundances for Clusters 'a' to 'c'

Top 10 Species	Cluster a			Cluster b			Cluster c		
	Average similarity: 47.85%			Less than 2 samples in group			Average similarity: 37.55%		
	Species	Av. Abundance	Contribution (%)	Species	Av. Abundance	Contribution (%)	Species	Av. Abundance	Contribution (%)
1	*Ampharete lindstroemi*	9.0	5.9	*Kurtiella bidentata*	53.0	23.0	Nemertea	3.7	18.0
2	Actiniaria	9.3	5.6	*Spiophanes bombyx*	46.0	20.0	*Microphthalmus*	2.4	12.7
3	*Lumbrineris cingulata*	7.1	4.8	*Lagis koreni*	26.0	11.3	*Caulleriella*	1.4	10.4
4	Nemertea	5.5	4.2	*Abra alba*	26.0	11.3	Nematoda	1.4	7.4
5	*Ampelisca spinipes*	7.1	4.0	*Nephtys hombergii*	18.0	7.8	*Glycera lapidum*	1.2	7.4
6	*Spirobranchus lamarcki*	12.3	3.5	*Photis reinhardi*	6.0	2.6	*Hesionura elongata*	1.9	7.4
7	Nematoda	4.5	3.5	*Ampharete lindstroemi*	4.0	1.7	*Pholoe inornata*	1.0	7.4
8	*Photis longicaudata*	7.4	3.4	*Notomastus*	4.0	1.7	*Streptosyllis campoyi*	1.0	7.4
9	*Pholoe inornata*	4.9	3.4	*Nucula nitidosa*	4.0	1.7	*Macrochaeta*	1.5	7.4
10	*Kurtiella bidentata*	4.7	3.1	*Microprotopus maculatus*	3.0	1.3	*Ophelia borealis*	4.2	7.4
Pink: taxa shared across two clusters.									

Table 5-17 Dissimilarity Percentages For SIMPROF Clusters

	Cluster b		Cluster c	
Cluster a	**Average dissimilarity = 77.31%**		**Average dissimilarity = 88.65%**	
	Spirobranchus lamarcki	3.88	*Spirobranchus lamarcki*	4.39
	Actiniaria	3.42	Actiniaria	3.54
	Photis longicaudata	2.28	*Ampharete lindstroemi*	3.36
	Ampelisca spinipes	2.25	*Photis longicaudata*	2.58
	Ampharete lindstroemi	2.25	*Lumbrineris cingulata*	2.46
Cluster b			**Average dissimilarity = 88.82%**	
			Kurtiella bidentata	6.76
			Spiophanes bombyx	6.30
			Lagis koreni	4.74
			Abra alba	4.74
			Nephtys hombergii	3.94

5.3.3 Epifaunal and Other Biological Groups

All eight of the stations acquired in the survey recorded the presence of colonial epifauna that were not statistically assessed within the infauna data analysis, as they were tabulated on presence/absence basis. Due to the presence/absence scale to which epifaunal species were identified, for the purpose of this chart and to highlight the epifaunal richness; where epifaunal species were recorded as present this was given the numerical value of "1" to represent the colony. The distribution of epifaunal assemblages across the survey areas between stations is represented inFigure 5-35. Infaunal and epifaunal species are listed separately in Appendix N – MACROFAUNAL SPECIES LISTS.

The analysis indicated that infauna was dominant across every station, with colonial epifauna typically exceeding presence of solitary epifauna. Epifaunal taxa belonging to the phyla Annelida, Arthropoda, Bryozoa, Chordata, Cnidaria, Entoprocta, Mollusca, and Porifera were present. Station A4_GLC_03 had the highest richness of colonial epifauna at 16 species, while stations A2_ES_02, A2_ES_04, and A5_OPB_01 had the lowest richness at 4 species each. The stations where the highest species of colonial epifaunal taxa were found had the highest percentage of gravels in the sediment (>35%), meaning they had the hard substrate required for colonial epifauna to affix to.

Grab sampling often fails to recover coarse material, especially larger pebbles, cobbles, and boulders colonised by epifauna; therefore, it is important to not only assess epifauna through physical samples, but also to analyse video footage (Section 5.4).

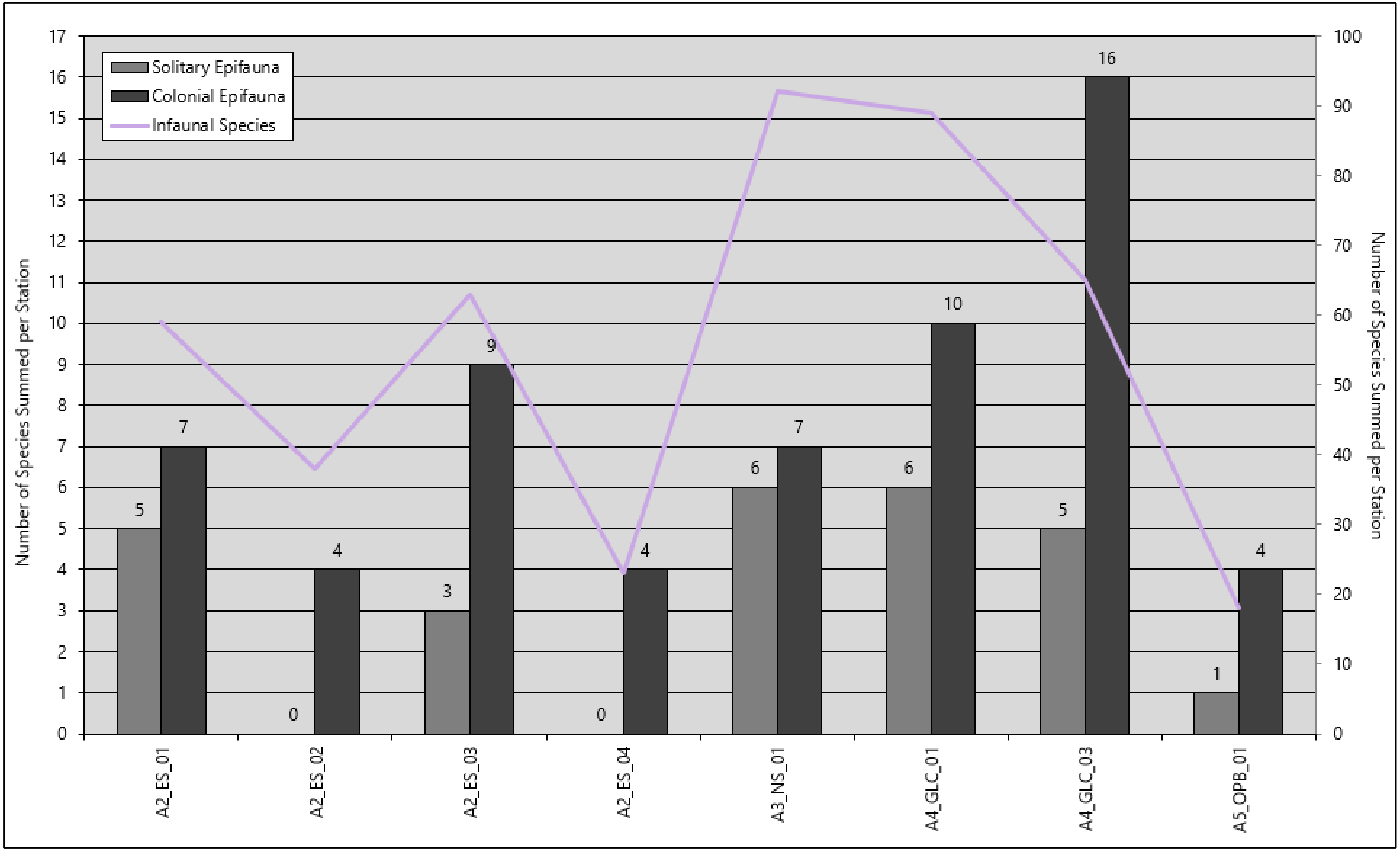


Figure 5-35 Epifaunal versus Infaunal Stations

5.3.4 Notable Taxa

5.3.4.1 Non-Native Taxa

The non-native slipper limpet (*Crepidula fornicata*) was identified a total of 3 times across grab sample sites A2_ES_01 and A4_GLC_01, whilst also being previously identified as non-native during the 2022 MMT survey. The species originates from the east coast of North America, with its first recorded appearance in Britain dating back to 1872 in Liverpool Bay. Although this population has since become extinct, the species was reintroduced to Essex in the late 1880s. It is now firmly established, occurring along much of the English coastline and in other regions surrounding the North Sea (Eno, Clark, & Sanderson, 1997).

5.3.4.2 Rare Taxa

No infauna or epifauna taxa observed in the survey area are listed on the global IUCN Red List or the Great Britain Rarity Status list.

5.4 CTD

CTD profiles measuring conductivity, temperature and depth were acquired at 17 stations across the survey area. Two water profiles are displayed below (Figure 5-36) and represent the variability across the survey area with depth. Station A5_OPB_04_HAS represents the shallowest water depth (12.3m LAT) recorded across the route, while station A3_NS_03_HAS represents the deepest water depth (28.4m LAT) recorded.

Station A4_GLC_01 had a minimum temperature of 18.9°C and A2_ES_02 peaking at 19.7°C. Whilst A2_ES_ADD_01 had the lowest salinity at 34.5‰ and A4_GLC_01 the highest at 35‰. The profiles revealed the absence of both a thermocline and halocline across the Sea Link survey area indicating the presence of a well-mixed water mass.

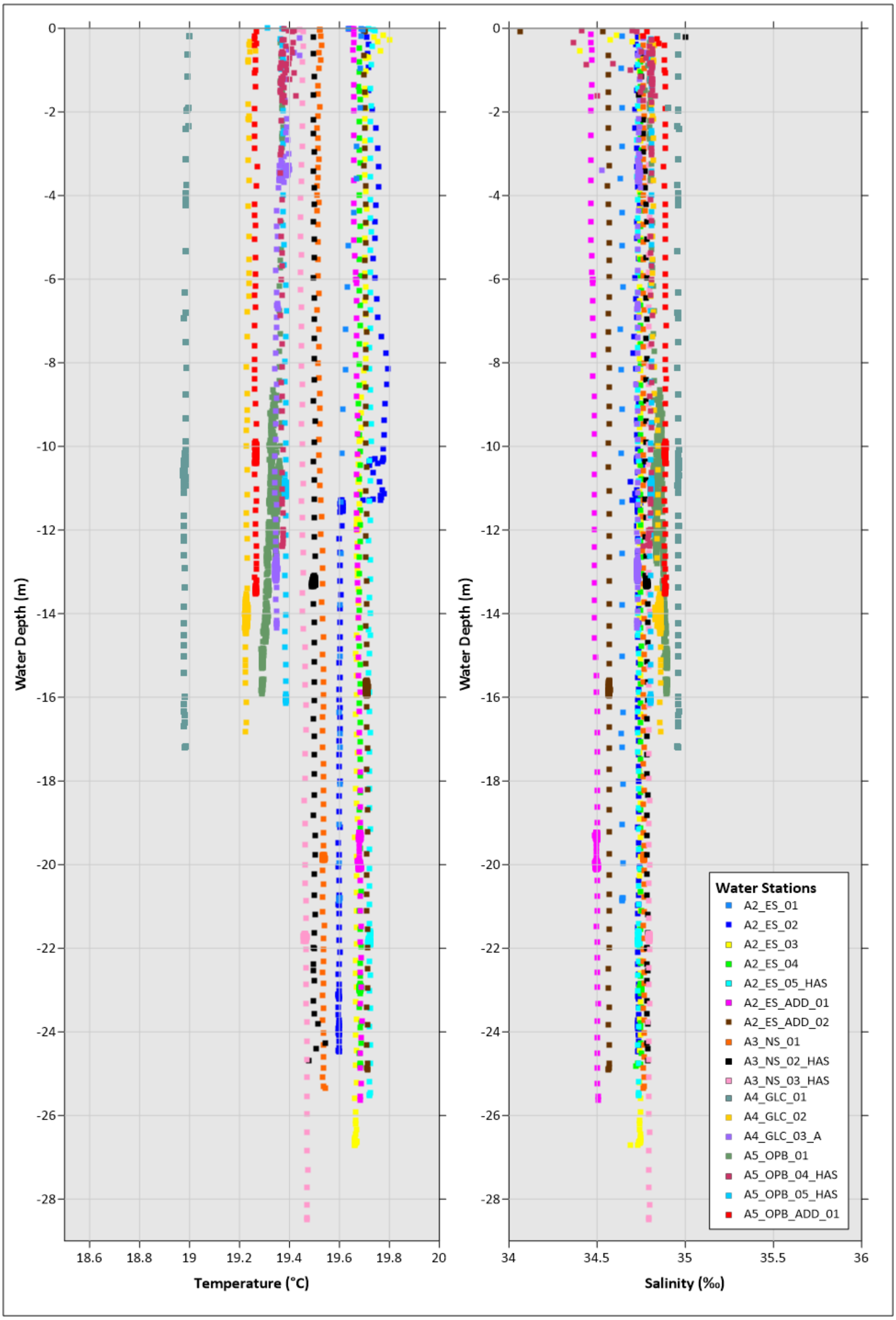


Figure 5-36 CTD Profiles for Sea Link Survey Route

5.5 Summary of Identified Habitats

Habitats were identified using a combination of field observations, detailed review of the SSS, bathymetry, video footage and stills images. Based on the ground-truthing data obtained from the Sea Link survey route, a total of four EUNIS habitats are indicated to be present within the additional areas (Area 2 – Area 5).

See Table 5-18 below which translates BGS Modified Folk Classification and seabed features to its respective EUNIS classification, and Figure 5-37 representing the identified EUNIS classifications across the survey area.

Table 5-18 Summarised Habitat Classifications

BGS Modified Folk Classification of Particle Size Analysis	Seabed Features	2012 EUNIS Classification
Muddy sandy gravel, Gravelly sand,	Gravelly Sand to Sandy Gravel, Gravelly Sand, Sandy Gravel, Muddy Sandy Gravel, Chalk	A5.44 Circalittoral mixed sediments
Gravelly sand	Silty Sand, Sand, Clayey Sand, Gravelly Sand, Sandy Silt	A5.252 *Abra prismatica, Bathyporeia elegans* and Polychaetes in Circalittoral Fine Sand
Gravelly sand	Sand to Silty Sand	A5.231 Infralittoral Mobile Clean Sand with Sparse Fauna
No grab sample acquired.	Sandy Gravel	A5.43 Infralittoral Mixed Sediment

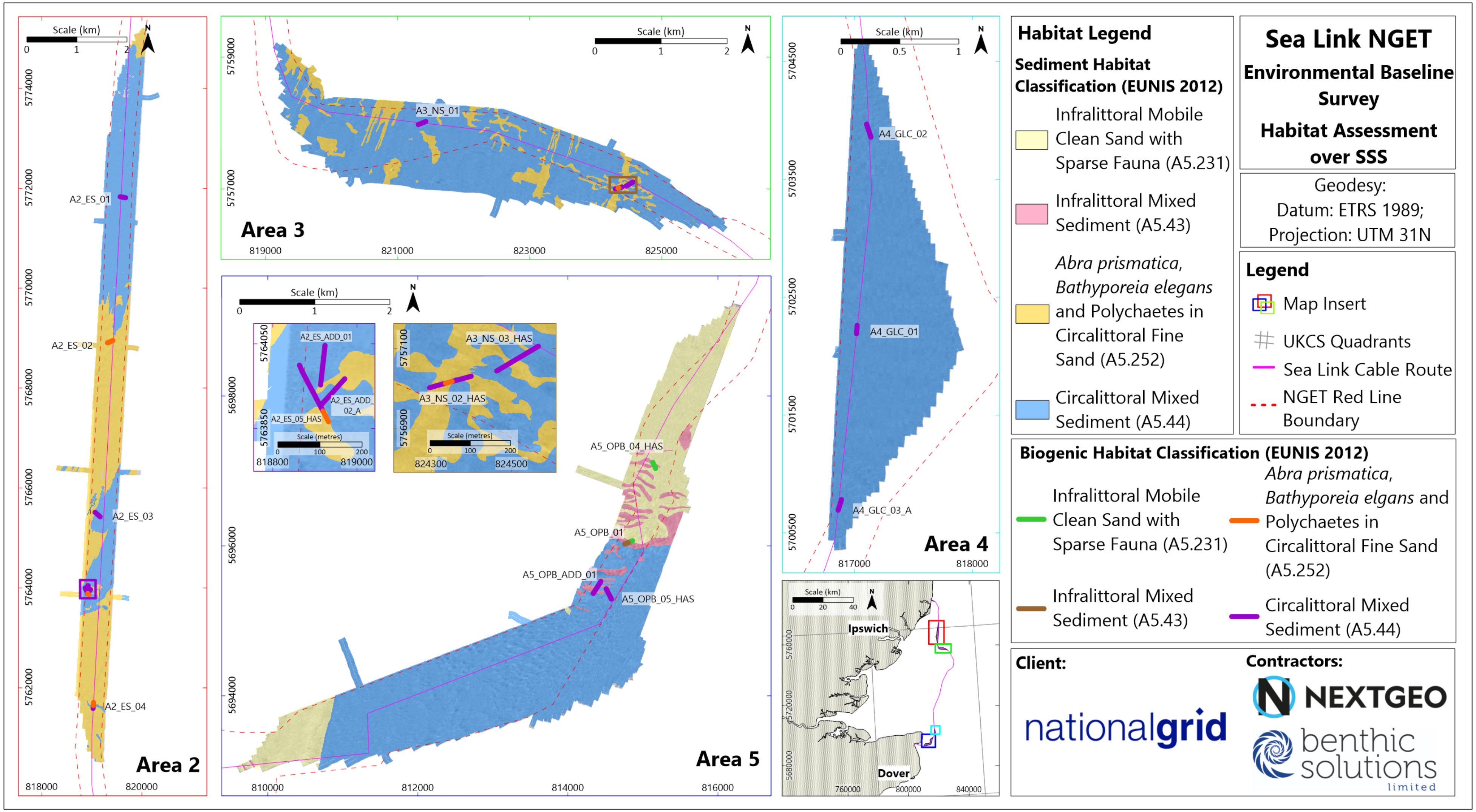


Figure 5-37 Habitat Distribution over SSS Data for the Sea Link Survey Area

5.6 Detailed Area Descriptions

5.6.1 Route Overview

'*Abra prismatica, Bathyporeia elegans* and Polychaetes in Circalittoral Fine Sand' (A5.252) made up the northern end of the route (Area 2 and 3) alongside 'Circalittoral Mixed Sediment' (A5.44) (Figure 5-37). The southern region of the route (Area 4 and 5) mostly consisted of 'Circalittoral Mixed Sediment' (A5.44) with Area 5 comprising of 'Infralittoral Mobile Clean Sand with Sparse Fauna' (A5.231) and 'Infralittoral Mixed Sediment' (A5.43) in more shallow regions (Figure 5-37).

5.6.1.1 Infralittoral Fine Sand (A5.23)

Habitats consisting mainly of rippled fine sand with some coarser elements were observed in Area 5 in a depth range of 10-12m in the transects A5_OPB_01 and A5_OPB_04_HAS. This habitat possessed some coarser elements with gravel and shell but was predominantly sand based. Described by EUNIS as "*Clean sands which occur in shallow water, either on the open coast or in tide-swept channels of marine inlets. The habitat typically lacks a significant seaweed component and is characterised by robust fauna, particularly amphipods (Bathyporeia) and robust polychaetes including Nephtys cirrosa and Lanice conchilega*".

Infralittoral Mobile Clean Sand with Sparse Fauna (A5.231)

A further refined EUNIS habitat 'Infralittoral Mobile Clean Sand with Sparse Fauna' (A5.231) was identified based on the minimal observed fauna within the video data as well as results from taxonomical analysis where few polychaetes such as *Hesionura elongata* and *Protodriloides* dominated the macrofaunal community. This limited diversity of epifauna and minimal abundance of polychaetes further supports this refined EUNIS classification due to no observation of any characterising species. The previous MMT report identified this habitat in a similar region within Area 5 and denoted it as '*Nephtys cirrosa* and *Bathyporeia* spp. in Infralittoral Sand' due to the characterising infaunal data obtained from grab stations in the area.

Example images are given in Figure 5-38 and the expected extent of the habitat 'Infralittoral Mobile Clean Sand with Sparse Fauna' (A5.231) is mapped in Figure 5-37.

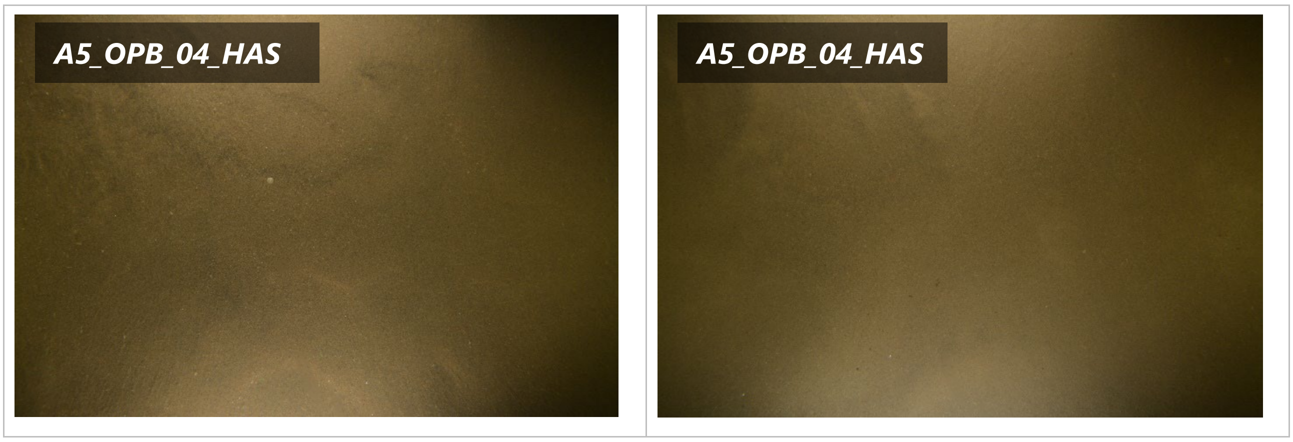


Figure 5-38 Example Images of Infralittoral Mobile Clean Sand with Sparse Fauna Habitats

5.6.1.2 Infralittoral Mixed Sediment (A5.43)

Within Area 5, bathymetry data and HD video footage indicated ribbons of shallow areas of mixed sediment with noticeable fines, sand and gravel. This habitat is described by EUNIS as "*Shallow mixed (heterogeneous) sediments in fully marine or near fully marine conditions, supporting various animal-dominated communities, with relatively low proportions of seaweeds. This habitat may include well mixed muddy gravelly sands or very poorly sorted mosaics of shell, cobbles and pebbles embedded in mud, sand or gravel.*" This habitat was observed across A5_OPB_01 where a shallow (<10m) area occurred, also showing intermixed areas of "Circalittoral Mixed Sediment", both were observed in areas of "Sandy Gravel" across the survey route.

There are several level 5 habitats associated with 'Infralittoral Mixed Sediment', although these cannot be accurately assigned due to limited epifaunal presence in the video data and minimal macrofauna abundance within acquired grabs. Therefore the classification of this habitat remains at a level 4 classification. This habitat was featured in the MMT (2022) report but in southern areas closer to the shore along the survey route.

Example images are provided in Figure 5-39 and the spatial extent of the 'Infralittoral Mixed Sediment' (A5.43) habitat is mapped in Figure 5-37.

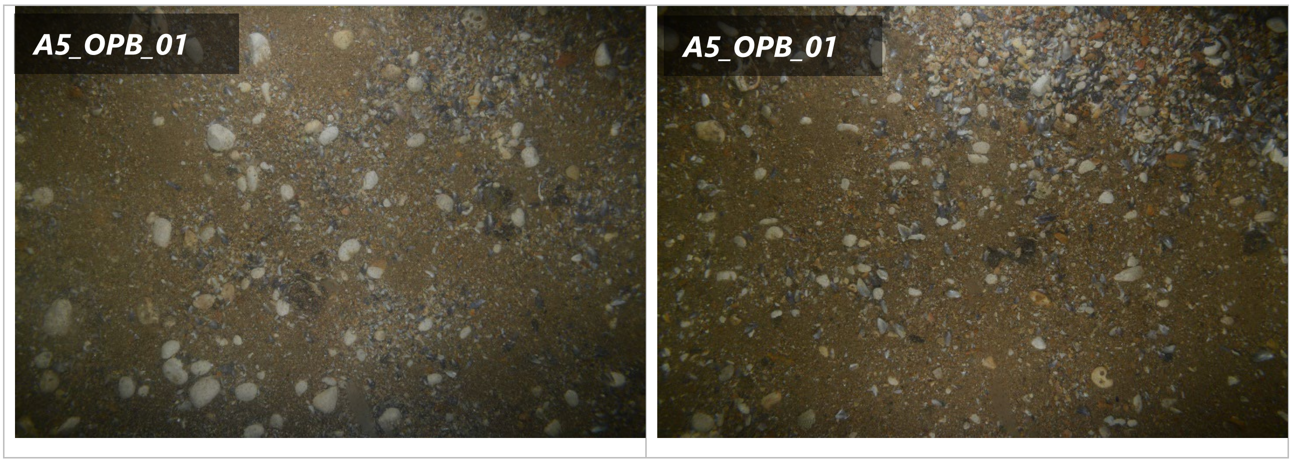


Figure 5-39 Example Images of Infralittoral Mixed Sediment Habitats

5.6.1.3 Circalittoral Fine Sand (A5.25)

This habitat occurred in several areas across Area 2 and 3, generally possessing fine sand in the deeper regions of the survey area presenting as areas of lower reflectivity on SSS imagery. This habitat is described by EUNIS as "*Clean fine sands with less than 5% silt/clay in deeper water, either on the open coast or in tide-swept channels of marine inlets in depths of over 15-20 m. The habitat may also extend offshore and is characterised by a wide range of echinoderms (in some areas including the pea urchin Echinocyamus pusillus), polychaetes and bivalves. This habitat is generally more stable than shallower, infralittoral sands and consequently supports a more diverse community.*" This habitat was found to associate with the seabed features silty sand, sand, clayey sand, gravelly sand and sandy silt within the survey route. This habitat was found within the MMT report alongside the EUNIS habitat 'Circalittoral Muddy Sand' in similar areas, in updated habitat classifications, these two habitats are combined due to their similarity.

Abra prismatica, Bathyporeia elegans and Polychaetes in Circalittoral Fine Sand (A5.252)

Epifauna observed were commonly seen throughout the route, such as brittle stars (Ophiuroidea), common sea stars (*Asterias rubens*) and hermit crabs (*Pagurus* sp.). This variation in conjunction with taxonomical analysis corresponds to the further refined EUNIS description of the A5.252 habitat; '*Abra prismatica, Bathyporeia elegans* and Polychaetes in Circalittoral Fine Sand'. This has been assigned based on the polychaete-rich community (*Spiophanes bombyx* and *Lagis koreni*) and high density of bivalves (*Kurtiella bidentata* and *Abra alba*) observed within grab samples across the A5.25 habitat.

Example images are provided in Figure 5-40 and the spatial extent of the '*Abra prismatica, Bathyporeia elegans* and Polychaetes in Circalittoral Fine Sand' (A5.252) habitat is mapped in mapped in Figure 5-37.

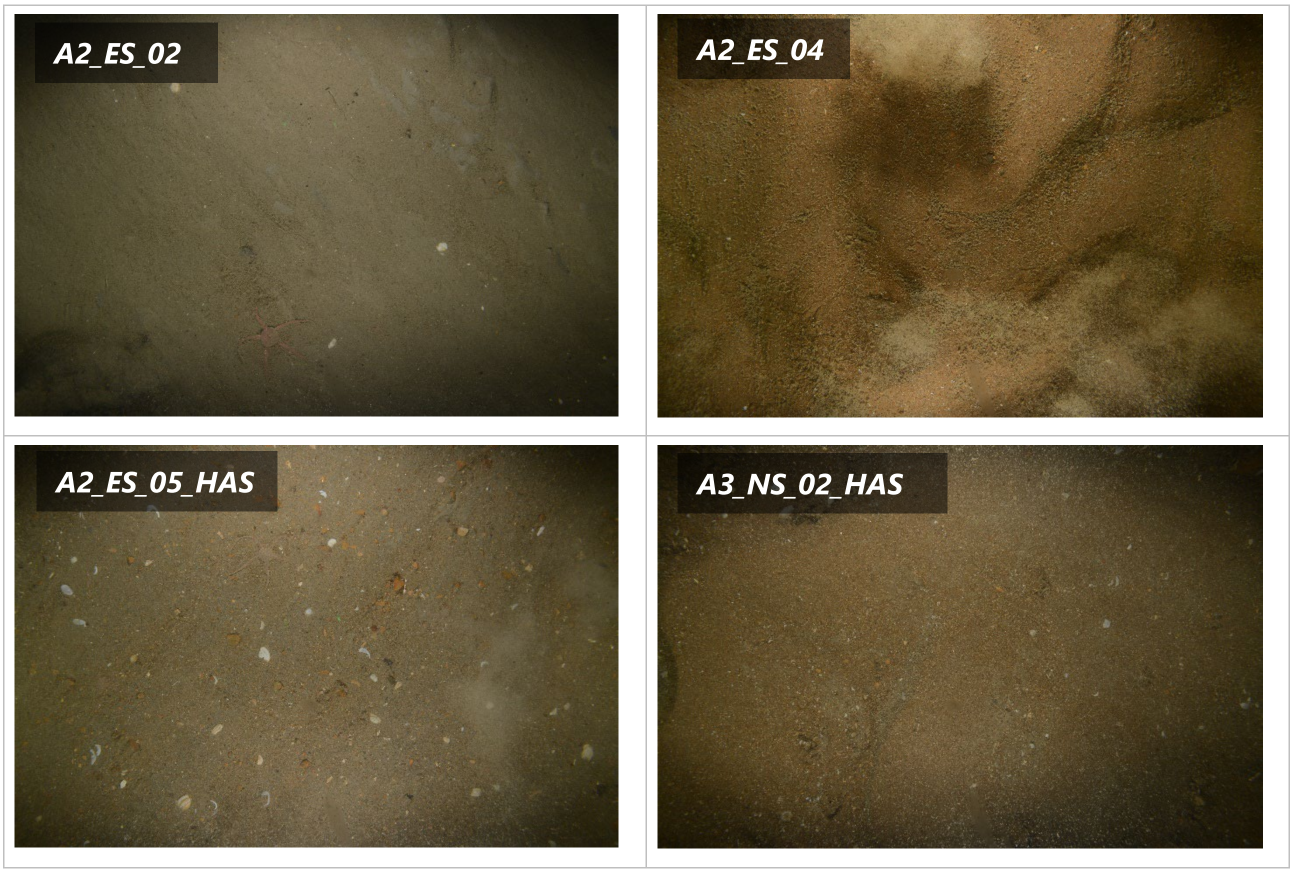


Figure 5-40 Example Images of *Abra prismatica, Bathyporeia elegans* and Polychaetes in Circalittoral Fine Sand Habitats

5.6.1.4 Circalittoral Mixed Sediments (A5.44)

Areas dominated by pebbles, cobbles and gravel overlying a sandy sediment with noticeable fines was observed across all four areas. This habitat is described by EUNIS as "*Mixed (heterogeneous) sediment habitats in the circalittoral zone (generally below 15-20 m) including well mixed muddy gravelly sands or very poorly sorted mosaics of shell, cobbles and pebbles embedded in or lying upon mud, sand or gravel.*"

Faunal diversity observed within this habitat was increased in comparison to other habitats. The increase in hard substrate (cobbles and gravel) lead to a noticeable proportion of Serpulidae, bryozoan/hydrozoan turf, dead man's fingers (*Alcyonium digitatum*) and anemone species (Actinaria). Along two transects (A5_OPB_05_HAS and A5_OPB_Add_01) in Area 5, there was a noticeable population of blue mussels (*Mytilus edulis*) creating an encrusting layer of which will undergo further assessment to determine potential sensitive habitat presence. This diversity was also present alongside species found in other biotopes such as brittlestars (Ophiuroidea), hermit crabs (*Pagurus* sp.) and common sea stars (*Asterias rubens*).

There are several level 5 habitat classifications associated with 'Circalittoral Mixed Sediment' which can be determined using epifaunal data from video footage and taxonomic data. The presence of the Ross worm (*Sabellaria spinulosa*) was noted across various transects consisting of mixed sediment potentially indicating the presence of the level 5 Sublittoral sediment habitat '*Sabellaria spinulosa* on Stable Circalittoral Mixed Sediment' (A5.611), requiring an assessment to determine whether this is a reef forming population (see Section 5.7.2). Due to the infrequent appearance of this habitat and minimal characterising macrofauna identified, this habitat has been left at the level 4 'Circalittoral Mixed Sediment' (A5.44). This habitat also possessed epifauna covered cobbles frequent enough to warrant a stony reef assessment on transects in Area 3 and 4. This would determine whether an Annex I habitat would occur within the survey area.

Example images are given in Figure 5-41 and the expected extent of the habitat 'Circalittoral Mixed Sediment' (A5.44) is mapped in Figure 5-37.

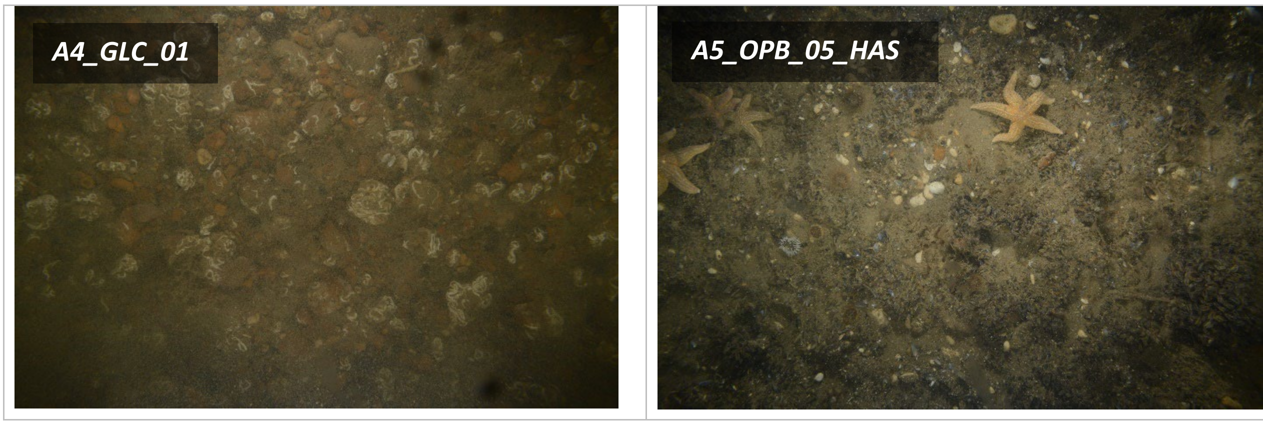


Figure 5-41 Example Images of Circalittoral Mixed Sediment Habitats

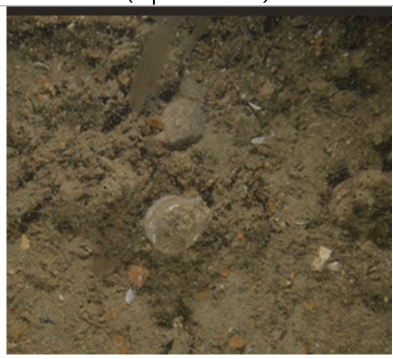
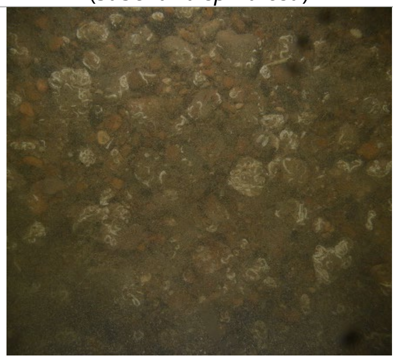
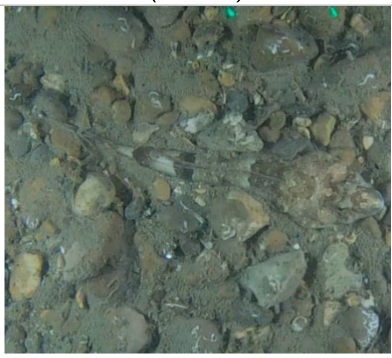
5.7 Potential Areas and Species of Conservation Value

Variable diversity was present throughout the Sea Link survey area with example images shown below in Table 5-19, with brittle stars (Ophiuroidea), hermit crabs (*Pagurus* sp.) and common sea stars (*Asterias rubens*) found across a majority of the transects analysed. Areas 3 and 4 had increased cobbles/hard substrate which fauna can attach to, such as calcareous tube worms (Serpulidae), dead man's finger (*Alcyonium digitatum*) and anemones (Actinaria).

Chordata species were observed across the survey area with various fish (Actinopterygii) observed, including the common dragonet (*Callionymus lyra*) and solenette (*Buglossidium luteum*) observed. Brachyura species were observed in the survey area with occasional observations of the velvet swimming crab (*Necora puber*), harbour crab (*Polybius* sp.), and leeches spider crab (*Inachus phalangium).* Ross worm (*Sabellaria spinulosa)* aggregations were observed across the survey areas in variable abundances. In contrast, bivalves were present in fewer areas along the survey route. The queens scallop (*Aequipecten opercularis*) was observed only along a singular transect, while blue mussels (*Mytilus edulis*) were more widespread, forming crusts that covered parts of the seabed, particularly at A5_OPB_05_HAS and, to a lesser extent, A5_OPB_Add_01. Both *S. spinulosa* and *M. edulis* have been further evaluated to assess the potential sensitivities of the habitats (see Sections 5.7.2 and 5.7.3).

Whilst no sandeel (Ammodytidae) were identified on the HD footage, the route enters an area marked as a low intensity spawning ground and nursery ground, also requiring further assessment to determine the potential occurrence of a sandeel spawning ground (see Section 5.7.4). Herring (Clupeidae) were observed at A3_NS_03_HAS, with several points along the survey route overlapping with areas designated as high and low intensity nursery grounds. This warranted a further investigation to determine whether areas in the survey route could be designated as a potential herring spawning ground (see Section 5.7.5).

Table 5-19 Example Images of Conspicuous Fauna

Examples of Conspicuous Fauna		
 Spiny Dogfish (*Squalus acanthias*)	 Urchin (Echinodermata)	 Brittlestar (Ophiuroidea*)*
 Blue Mussel bed (*Mytulis edulis)*	 Sea Chevril *(Alcyonidium diaphanum)*	 Ross Worm (*Sabellaria spinulosa*)
 Fish (Actinopterygii)	 Sponge (Porifera*)*	 Calcareous Worm Serpulidae
 Common Sea Star (*Asterias rubens*)	 Pogge (*Agonus cataphractus*)	 Leeches Spider Crab *(Inachus phalangium)*

Hermit Crab
(*Pagurus* sp.)

Velvet Swimming Crab
(*Necora puber*)

Solenette
(*Buglossidium luteum*)

5.7.1 Annex I Stony Reef formed from boulders and cobbles

Noticeable coverage of cobbles were record across six transects (A3_NS_01, A3_NS_02_HAS, A3_NS_03_HAS, A4_GLC_01, A4_GLC_02, A4_GLC_03_A) within Area 3 and Area 4. These transects comprised of mainly mixed sediment including cobbles and underwent further assessment to determine whether an Annex I Stony Reef habitat occurs.

The underwater video footage was assessed for potential stony reefs using the criteria proposed by Irving (2009). This breaks down the assessment criteria measures of 'quality' or 'reefiness' as outlined in Table 5-20. This is based on a minimum cobble size of 64mm being present and indicating relief above the natural seabed where >10% of the matrix are cobble related and a minimum area of ~25m² is recorded. The stony reef assessment was based on acquired underwater stills taken every 20 seconds along the camera transect. When underwater stills were out of focus due to environmental conditions (boat movement, seabed slope, turbidity etc.), additional screengrabs were taken in the office (using HD video footage). These screengrabs were taken as close to the 20 second interval as possible but may have varied by a few seconds to enable a clear focus. Each still and screengrab was assessed for changes in density, height and cover of cobbles and boulders. Each section of the transects where cobbles or boulders were detected was then analysed and categorised according to its composition, elevation and extent.

Table 5-20 Summary of resemblance to a stony reef as summarised in Irving (2009)

Measure of 'Reefiness'	Not a Reef	Low[(c)]	Medium	High
Composition[(a)]	<10%	10-40%	40-95%	>95%
Elevation[(b)]	Flat seabed	<64mm	64mm-5m	>5m
Extent (m²)	<25m²	>25m²	>25m²	>25m²
Biota	Dominated by infauna			>80% of species are epifauna

(a) *Diameter of cobbles / boulders being greater than 64mm. Percentage cover relates to a minimum area of 25m². This 'composition' characteristic also includes 'patchiness'.*
(b) *Minimum height (64mm) relates to minimum size of constituent cobbles. This characteristic could also include 'distinctness' from the surrounding seabed.*
(c) When determining if the seabed is considered as Annex I stony reef, a 'low' scored in any category, would require a strong justification for this area to be considered as contributing to the Marine Natura site network of qualifying reefs in terms of the EC Habitats Directive.

The Irving (2009) stony reef protocol was split into separate assessments of reef 'structure' and 'overall reefiness' using a method developed by BSL staff (Table 5-21, Table 5-22 and Table 5-23). This provided a reef structure value that could then be assessed against extent, where applicable, to provide a measure of overall reefiness, as illustrated in Table 5-23. As separate thresholds for 'Low', 'Medium' and 'High' stony reef extent were not given in Irving (2009), the overall reefiness is determined by reef structure provided that the extent of the stony reef covers a minimum of 25m². Reefiness parameters are colour coded to aid visual assessment of the data.

Table 5-21 Stony Reef Structure Matrix (after Irving, 2009)

Reef Structure Matrix			**Elevation**			
			Flat	<64mm	64mm-5m	>5m
			Not a Reef	Low	Medium	High
Composition	<10%	Not a Reef	Not a Reef	Not a Reef	Not a Reef	Not a Reef
	10-40%	Low	Not a Reef	Low	Low	Low
	40-95%	Medium	Not a Reef	Low	Medium	Medium
	>95%	High	Not a Reef	Low	Medium	High

Table 5-22 Stony Reef Structure Matrix (Structure vs Biota)

Reef Structure Matrix			**Structure**			
			Not a Reef	Low	Medium	High
Epifaunal Coverage	<10%	Not a Reef	Not a Reef	Not a Reef	Not a Reef	Not a Reef
	10-40%	Low	Not a Reef	Low	Low	Low
	40-80%	Medium	Not a Reef	Low	Medium	Medium
	>80%	High	Not a Reef	Low	Medium	High

Table 5-23 Overall Stony Reefiness Matrix (Structure vs Extent)

Overall Reefiness Matrix			**Reef Structure (incl. Composition and Elevation)**			
			Not a Reef	Low	Medium	High
Extent (m^2)	<25	Not a Reef	Not a Reef	Not a Reef	Not a Reef	Not a Reef
	>25	Low - High	Not a Reef	Low	Medium	High

The stills taken during the survey and additional screengrabs from the video footage analysed for stony reef assessment indicated intermittent distribution of cobbles and boulders across the offshore transects (a complete log of the assessment per still is provided in Appendix O – REEF AND MUSSEL BED ASSESSMENT LOGSHEET).

For example, out of the 183 images from transects reviewed for stony reef presence, 5 (2.7%) were classified as 'No Reef' with no cobbles present and 60 (32.8%) were unclear images due to poor visibility (Table 5-24). A total of 30 (16.4%) images classed as 'Not a Reef', 30 (16.4%) as 'Low Reef' and 58 (31.7%) as 'Medium Reef' and no stills were classified as 'High Reef' in terms of stony reef composition or percentage cover (Table 5-24). In terms of elevation, 5 stills (2.7%) were classified as 'Not a Reef' and 118 (64.5%) were classified as 'Low Reef'. When both composition and elevation were taken into account, by examining reef structure, there was a noticeable proportion of reefiness with 30 (16.4%) classed as 'Not a Reef' and 88 (48.1%) as 'Low Reef' with no stills being classed as 'Medium Reef' or 'High Reef' (Table 5-24). This is consistent of the video footage as transects in Area 4 show a noticeable proportion of cobbles present across the entire transect, whereas Area 3 showed a larger variation (Figure 5-42).

Table 5-24 Summary of stony reef image analysis (Composition vs Elevation)

'Reefiness' of Video Screengrabs	Unclear Footage		No Stony Reef		Not a Reef		Low		Medium		High	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Composition (% cover)	60	32.8	5	2.7	30	16.4	30	16.4	58	31.7	0	0
Elevation					16	8.7	102	55.7	0	0	0	0
Reef Structure					30	16.9	88	48.1	0	0	0	0

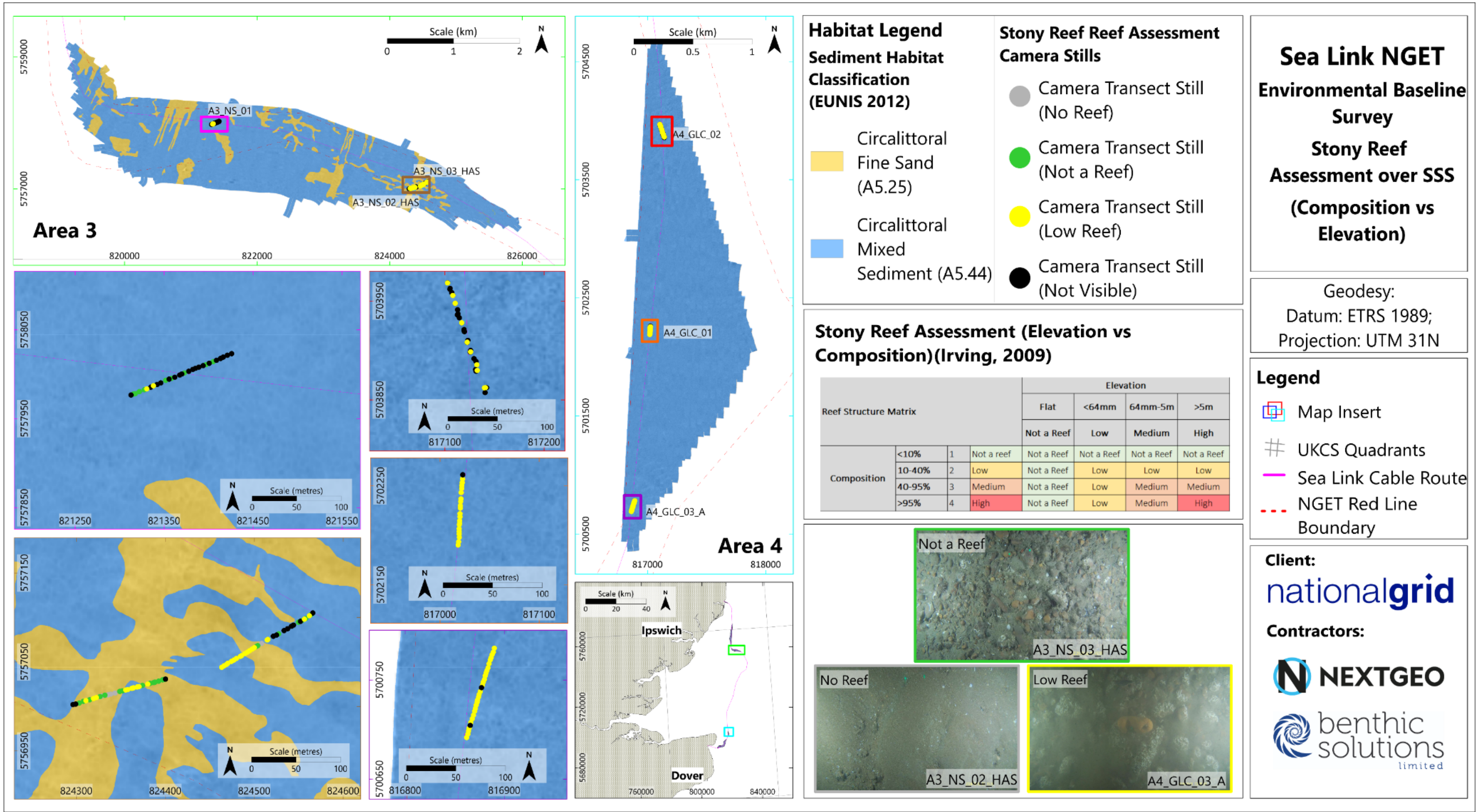
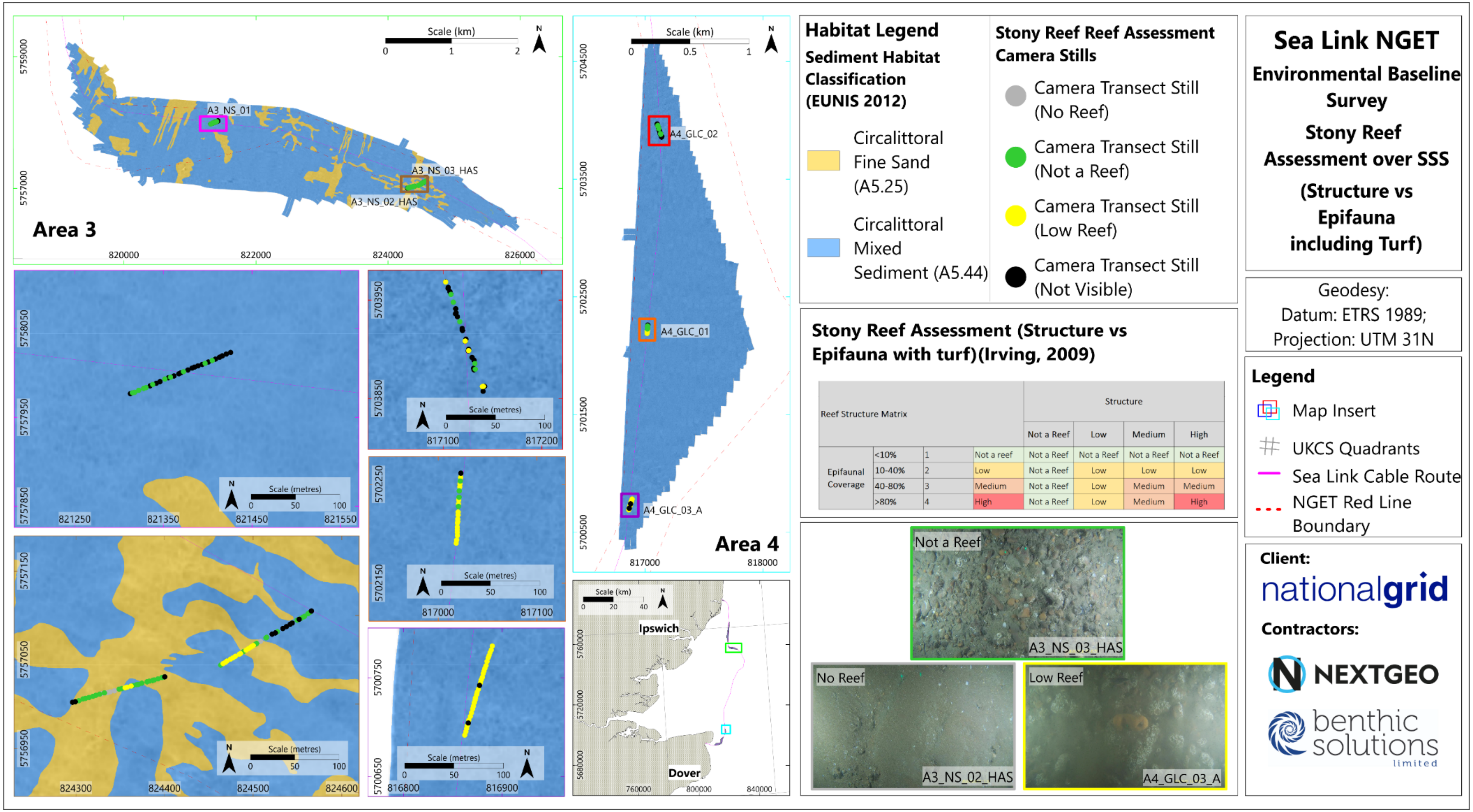


Figure 5-42 Stony Reef Assessment (Composition vs Elevation)

Another aspect of the stony reef assessment is to take into account the coverage of epifauna (erect and turf forming species such as Bryozoans or Hydrozoans) on the cobbles present which indicates whether this elevation is reef forming. Of the 118 stills which showed a potential stony reef (i.e. 'Not a Reef', 'Low Reef', 'Medium Reef', 'High Reef'), 19 stills (16.1%) were classified as 'Not a Reef', 72 stills (61%) were classified as 'Low Reef', 27 stills (22.9%) were classified as 'Medium Reef', and none were 'High Reef' (Table 5-25). Considering epifaunal coverage in relation to composition and elevation can further inform reef structure. When epifaunal coverage was applied to structure, 54 stills (45.8%) were classified as 'Not a Reef' and 64 stills (54.2%) were classified as 'Low Reef' with no stills classified as 'Medium Reef' or 'High Reef' (Table 5-25; Figure 5-43).

Table 5-25 Summary of stony reef image analysis (Structure vs Biota)

'Reefiness' of Video Screengrabs	Not a Reef		Low		Medium		High	
	No.	%	No.	%	No.	%	No.	%
Epifaunal Coverage (%)	19	16.1	72	61.0	27	22.9	0	0
Reef Structure	54	45.8	64	54.2	0	0	0	0



Reef Structure Matrix				Structure			
				Not a Reef	Low	Medium	High
Epifaunal Coverage	<10%	1	Not a reef	Not a Reef	Not a Reef	Not a Reef	Not a Reef
	10-40%	2	Low	Not a Reef	Low	Low	Low
	40-80%	3	Medium	Not a Reef	Low	Medium	Medium
	>80%	4	High	Not a Reef	Low	Medium	High

Figure 5-43 Stony Reef Assessment (Structure vs Epifauna including turf)

In order to determine whether reefiness was associated with any seabed features or sediment types, a Chi-squared frequency test was performed. The test revealed that there was no statistically significant association with the seabed features 'Muddy Sandy Gravel' (x^2= 2.1, p>0.05), 'Chalk' (x^2= 2.06, p>0.05), 'Sandy Gravel' (x^2= 2.55, p>0.05) and 'Gravelly Sand' (x^2= 3.1, p>0.05). There was a significant statistical association with 'Silty Sand' (x^2=16.39, p<0.01) however the test reveals this was due to an association between reef stills being outside of 'Silty Sand' areas.

As there was no strong correlation between sediment type and reefiness, a precautionary approach was taken to estimate the extent of the reef formations. Approximations were based on the measured length of continuous reef along the transect, assuming that reefs occupied circular areas of seabed (i.e. the straight-line distance between known locations of reef stills equates to the diameter of a circle, the area of which is calculated using πr^2). Utilising the Irving (2009) guidance, areas of seabed classified as 'Not a Reef', based on reef structure (composition vs. elevation vs. epifaunal coverage) would still be 'Not a Reef' regardless of whether the extent was <25m^2 or >25m^2 (Table 5-23).

The results, mapped in Figure 5-44, revealed 3 patches of poor visibility, 1 patch of 'No Reef', 10 patches of 'Not a Reef' and 7 patches considered 'Low Reef'. The patches of 'Low Reef' all occurred in Areas 3 and 4. Details of the full assessment are provided in Appendix O – REEF AND MUSSEL BED ASSESSMENT LOGSHEET.

Table 5-26 Overview of Stony Reef Extent Patches

Structure vs Extent	Total Patches	Not Visible	No Reef	Not a Reef	Low Reef
Patch Number	21	3	1	11	6

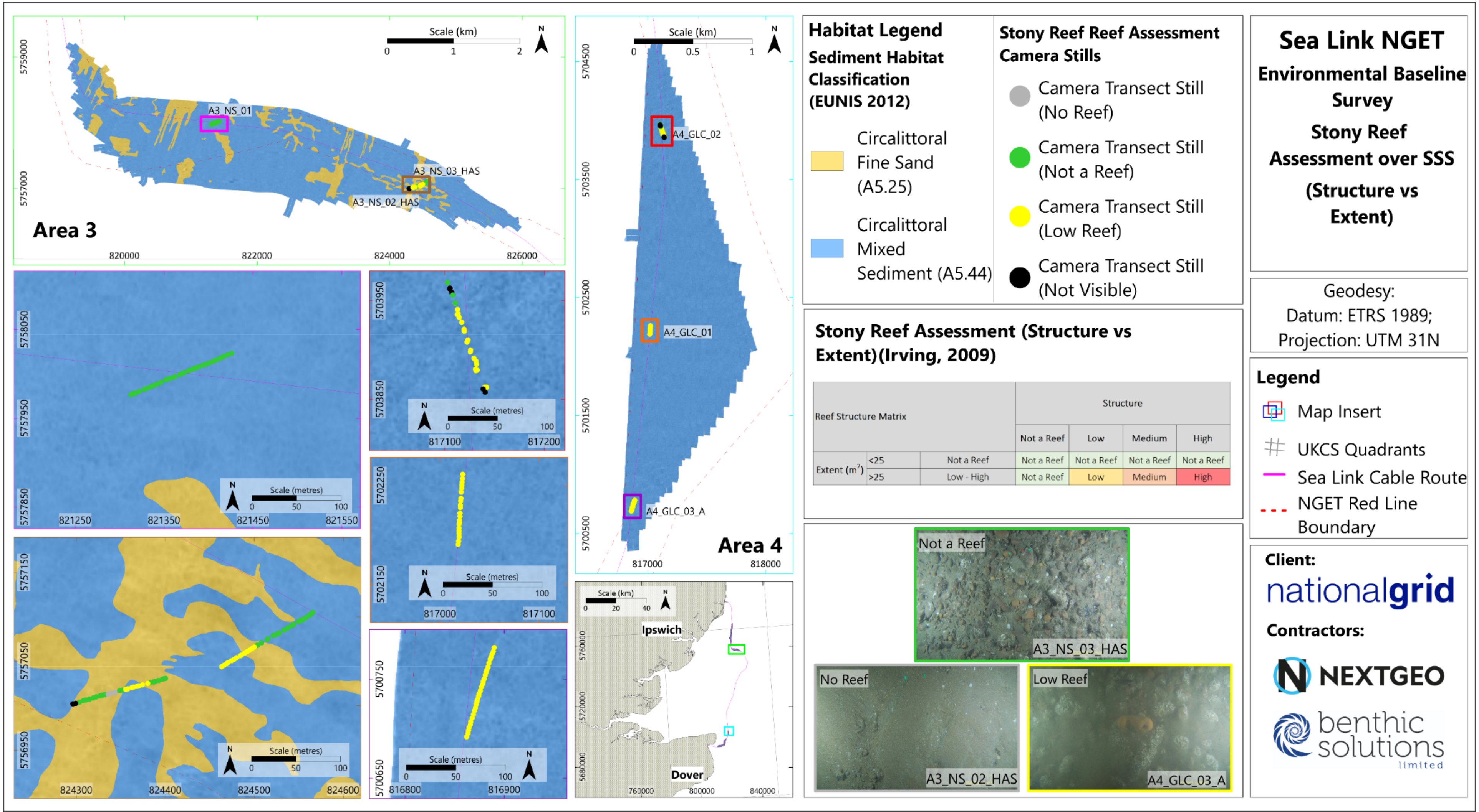


Figure 5-44 Stony Reef Assessment (Strcuture vs Extent)

Table 5-27 Summary of Stony Reef Assessment (After Irving, 2009)

Geodetics: ETRS89, UTM 31N									
				Stony Reefiness (After Irving, 2009)					
Station	**Easting (m)**	**Northing (m)**	**Sediment Type**	**Mean Composition (% Cover of Cobbles/ Boulders)**	**Mean Elevation (of Cobbles/ Boulders in mm)**	**Mean Epifaunal Coverage (% of epifaunal coverage on Cobbles / Boulders)**	**Mean Reefiness (Structure)**	**>25m²**	**Overall Mean Reefiness (Structure vs Extent)**
A3_NS_01	408 394	5 748 504	Muddy Sand with gravel	7.7	15.0	12.3	Not a Reef	>25m²	Not a Reef
	408 419	5 748 512							
	408 424	5 748 513	Muddy Sand with gravel	6.2	9.0	5.2	Not a Reef	>25m²	Not a Reef
	408 510	5 748 541							
A3_NS_02_HAS	411 283	5 747 288	Not Visible	N/A	N/A	N/A	N/A	<25m²	N/A
	411 286	5 747 289							
	411 290	5 747 289	Muddy Sand with gravel	8.2	9.3	7.8	Not a Reef	>25m²	Not a Reef
	411 320	5 747 296							
	411 323	5 747 296	Rippled fine sand with gravel in troughs	0.0	0.0	0.0	No Reef	>25m²	No Reef
	411 331	5 747 297							
	411 337	5 747 299	Muddy Sand with gravel	5.5	20.0	0	Not a Reef	<25m²	Not a Reef
	411 340	5 747 299							
	411 344	5 747 300	Muddy Sand with gravel	29.8	18.8	15.0	Low Reef	>25m²	Low Reef
	411 369	5 747 304							
	411 371	5 747 305	Muddy Sand with gravel	6.5	12.5	10	Not a Reef	>25m²	Not a Reef
	411 389	5 747 308							

Geodetics: ETRS89, UTM 31N									
Station	Easting (m)	Northing (m)	Sediment Type	Stony Reefiness (After Irving, 2009)					
				Mean Composition (% Cover of Cobbles/ Boulders)	Mean Elevation (of Cobbles/ Boulders in mm)	Mean Epifaunal Coverage (% of epifaunal coverage on Cobbles / Boulders)	Mean Reefiness (Structure)	$>25m^2$	Overall Mean Reefiness (Structure vs Extent)
A3_NS_03_HAS	411 453	5 747 316	Muddy Sand with gravel	45.0	22.1	39.3	Low Reef	$>25m^2$	Low Reef
	411 491	5 747 335							
	411 494	5 747 336	Muddy Sand with gravel	4.7	5.0	6.7	Not a Reef	$>25m^2$	Not a Reef
	411 500	5 747 339							
	411 506	5 747 343	Muddy Sand with gravel	15.0	15.0	9	Not a Reef	$<25m^2$	Not a Reef
	411 507	5 747 343							
	411 514	5 747 346	Muddy Sand with gravel	6.5	7.5	2.5	Not a Reef	$>25m^2$	Not a Reef
	411 545	5 747 360							
	411 547	5 747 361	Muddy Sand with gravel	8.2	5.2	12	Not a Reef	$>25m^2$	Not a Reef
	411 560	5 747 369							
A4_GLC_01	399 545	5 693 321	Muddy Sand with gravel	43.5	20.8	22	Low Reef	$>25m^2$	Low Reef
	399 556	5 693 391							
A4_GLC_02	399 775	5 695 084	Muddy Sand with gravel	40.0	50.0	40	Low Reef	$<25m^2$	Not a Reef
	399 775	5 695 084							
	399 777	5 695 078	Not Visible	N/A	N/A	N/A	N/A	$>25m^2$	N/A
	399 779	5 695 071							
	399 779	5 695 071	Muddy Sand with gravel	35.0	10.0	2.5	Not a Reef	$>25m^2$	Not a Reef
	399 781	5 695 063							
	399 781	5 695 063	Muddy Sand with gravel	26.0	21.0	20	Low Reef	$>25m^2$	Low Reef
	399 805	5 694 975							
	399 828	5 694 999	Muddy Sand with gravel	25.0	10.0	35	Low Reef	$>25m^2$	Low Reef
	399 803	5 694 975							
	399 802	5 694 974	Not Visible	N/A	N/A	N/A	N/A	$<25m^2$	N/A
	399 803	5 694 970							

Geodetics: ETRS89, UTM 31N									
Station	Easting (m)	Northing (m)	Sediment Type	Stony Reefiness (After Irving, 2009)					
				Mean Composition (% Cover of Cobbles/ Boulders)	Mean Elevation (of Cobbles/ Boulders in mm)	Mean Epifaunal Coverage (% of epifaunal coverage on Cobbles / Boulders)	Mean Reefiness (Structure)	>25m^2	Overall Mean Reefiness (Structure vs Extent)
A4_GLC_03_A	399 303	5 691 929	Muddy Sand with gravel	61.6	21.3	36.8	Low Reef	>25m^2	Low Reef
	399 268	5 691 842							

One of the key principles to be considered for an area when assessing its 'resemblance' to Annex I stony reef is stability; areas of consolidated and patchy hard substrate may not fulfil the composition requirements of the Annex I stony reef criteria by Irving (i.e. not having the required percentage of cobbles and boulders), but stability allows a diverse and 'reef-like' epifaunal community to develop (Golding *et al.,* 2020).

The transects where an initial Annex I stony reef assessment were conducted and exhibited overall 'Low Reef' (structure vs epifaunal coverage vs extent) were further investigated to establish whether hard substrate areas still corresponded to reef-like structures based on the epifauna present. This involved the assignment of 'reef biotopes', the identification of key species and the richness of 'reef species' according to the criteria outlined in Golding *et al.,* 2020 (Table 5-28).

Table 5-28 Biota Criteria for Defining 'Low Resemblance' Stony Reef (Golding *et al.,* 2020)

Reef	Stage 1	Stage 2	Stage 3
	Reef Biotopes	**Key Reef Species Count**	**Reef Species Count**
Reef	Reef biotope	≥3	>20
Possible reef	Possible reef biotope	>1 and <3	>5 and <20
Not reef	Non-reef biotope	0	<5

The majority of the transects occurred in the habitat 'Circalittoral Mixed Sediment' a possible reef biotope (Golding *et al.,* 2020). Throughout the 'Low Reef' stills of the assessment, the number of species present was very low. A majority of the stills only possessed tube worms (Serpulidae) on the cobbles, these tube worms are considered a desirable species rather than a key reef species. This indicates that these stills were 'Not a Reef' due to the low epifaunal diversity. Alongside these tube worms there were occasions where faunal turf or sponge would occur, however this would still bring the reef species to <5. Therefore these patches were likely to consist of 'Low Reef' with insufficient evidence to justify Annex I protection for these formations.

Overall due to the low species diversity and generally low elevation of many of the habitats present it is unlikely that an Annex I Stony Reef habitat occurs along the survey route.

5.7.2 Annex I Biogenic reefs formed by *Sabellaria spinulosa*

Sabellaria spinulosa is a tube-building polychaete worm and can occur as isolated individuals, small aggregations, thin crust-like veneers, or when in large numbers can form hard reef-like structures which can act to stabilise the surrounding seabed (Gibb *et al.*, 2014). As their tubes are built of sand, a high suspended sediment content is essential for growth of reeflike structures and the mobile sandy seabed within the survey corridor may provide this.

The presence of *S. spinulosa* was noted along four transects in Area 2 of the survey route. These transects were therefore investigated further to assess whether any areas have the potential to be classified as Annex I Biogenic reefs. An assessment of reefiness as described by Gubbay (2007) (Table 5-29) was performed to describe the habitat, focusing on transects where *S. spinulosa* was recorded during review of video footage and stills photographs. Changes in coverage and density of the *S. spinulosa* tubes were noted during the videos in order to accurately estimate the area covered by *S. spinulosa*.

Table 5-29 An Overview of *Sabellaria spinulosa* Reef Classification (after Gubbay, 2007)

Measure of 'Reefiness'	Not a Reef	Low	Medium	High
Elevation (average tube height, cm)	<2	2-5	5-10	>10
Area (m^2)	<25	25-10,000	10,000–1,000,000	>1,000,000
Patchiness (%Cover)	<10	10-20	20-30	>30

To apply the Gubbay (2007) protocol to the acquired data, it was further separated into reef 'structure' and overall 'reefiness' (Table 5-30 and Table 5-31). The advantage of this method is that the reef structure value derived from the patchiness (i.e. percent coverage) and tube elevation reefiness, can be assessed against the extent to produce a measure of overall reefiness. This method was initially devised by BSL staff and later approved by the JNCC in 2010 (see Jenkins *et al.* (2015) for an example of application by JNCC and Cefas).

Stills were created at 20 second intervals to ensure appropriate coverage of the transects where *S. spinulosa* was present. Each still was assessed for *S. spinulosa* patchiness and tube elevation, which were then combined to assess reef structure. Areas of similar reefiness were grouped together to create patches and underwent a chi squared test to see whether areas of reefiness are associated with certain seabed features.

Assessment was more challenging for *S. spinulosa* encrusted cobbles and boulders as it was difficult to estimate the size of the underlying cobble/boulder, therefore tube elevation levels were estimated by the reviewer, focussing on differentiating between tube elevation size classes of relevance to 'reefiness' assessment. For example, *S. spinulosa* aggregations <64mm were estimated to have a tube elevation of 2 to 5cm (Low Reefiness), while aggregation of 64 to 256mm would be estimated to have a tube elevation of 5 to 10cm (Medium Reefiness) and aggregations >256mm would be estimated as >10cm tube elevation (High Reefiness).

Table 5-30 *Sabellaria spinulosa* Reef Assessment Composition vs Elevation

Reef Structure Matrix			**Elevation (cm)**			
			<2	**2 to 5**	**5 to 10**	**>10**
			Not a Reef	**Low**	**Medium**	**High**
Patchiness	<10%	Not a Reef	Not a Reef	Not a Reef	Not a Reef	Not a Reef
	10-20%	Low	Not a Reef	Low	Low	Low
	20-30%	Medium	Not a Reef	Low	Medium	Medium
	>30%	High	Not a Reef	Low	Medium	High

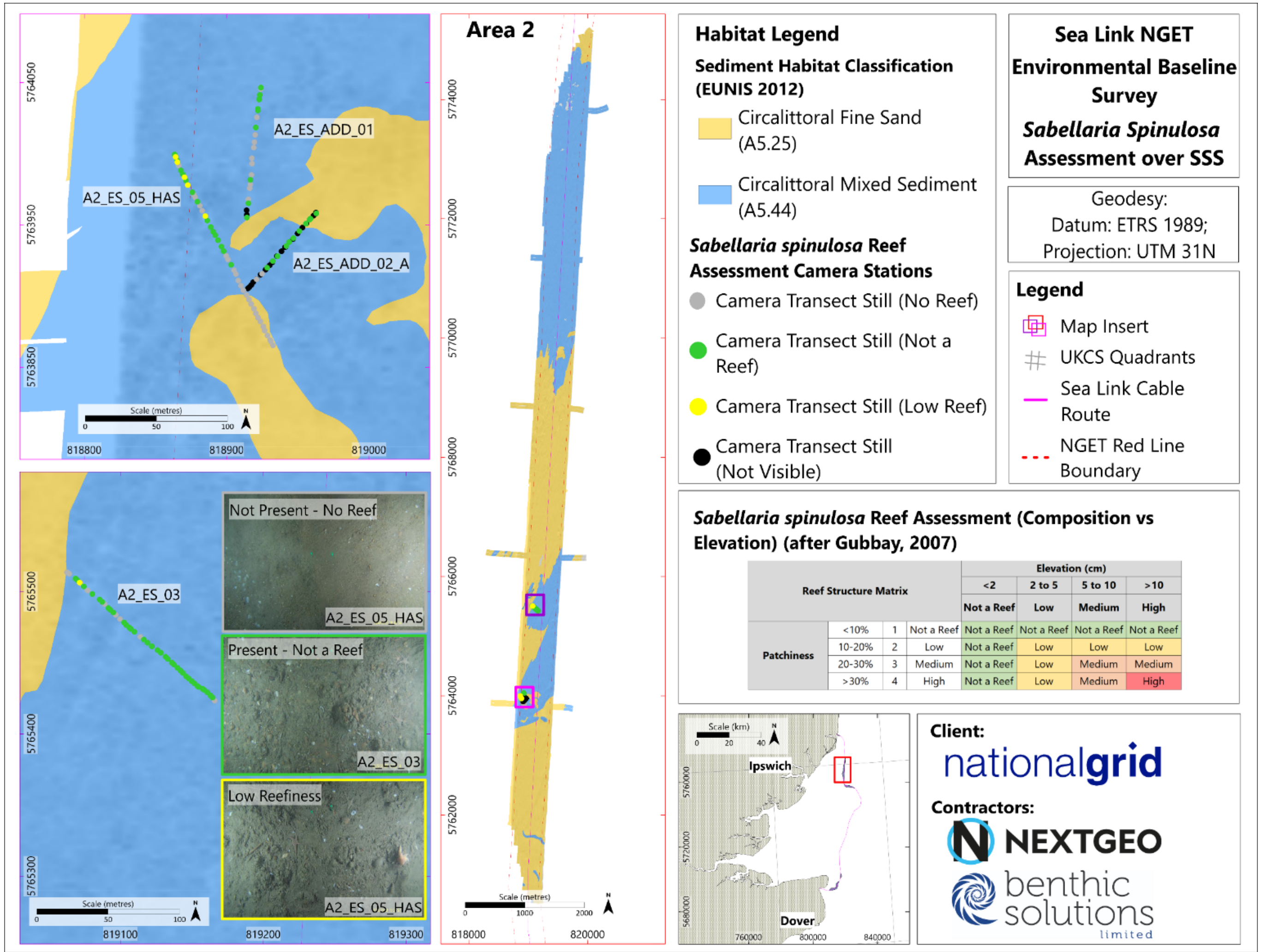
Table 5-31 *Sabellaria spinulosa* Reef Assessment Structure vs Extent

Reef Structure vs Area			**Area (m²)**			
			<25	**25-10,000**	**10,000-1,000,000**	**>1,000,000**
			Not a Reef	**Low**	**Medium**	**High**
Reef Structure (incl. Patchiness and Elevation)	<10%	Not a Reef	Not a Reef	Not a Reef	Not a Reef	Not a Reef
	10-20%	Low	Not a Reef	Low	Low	Low
	20-30%	Medium	Not a Reef	Low	Medium	Medium
	>30%	High	Not a Reef	Medium	High	High

The UW stills indicated a low density of *S. spinulosa* across the survey area with transects mainly comprising of low elevation elements of *S. spinulosa* on top of mixed sediment. Of the 151 total images assessed, 19 (12.6%) were unclear for analysis, with 52 (34.4%) were classified as 'No Reef. In terms of percentage cover 32 stills (21.2%) were considered 'Not a Reef', 21 stills (13.9%) were considered 'Low Reef', 13 (8.6%) were considered 'Medium Reef' and 14 stills (9.3%) were considered 'High Reef'. In terms of elevation the data indicated less reefiness with 64 stills (27.2%) being classified as 'Not a Reef' and 16 stills (10.6%) were considered 'Low Reef' with no stills considered 'Medium Reef' or 'High Reef' (Table 5-32). When both patchiness and elevation were taken into account to look at overall reef structure, 74 images (49%) were considered 'Not a Reef' and 6 stills (3.4%) were considered 'Low Reef'. The low elevation of the *S. spinulosa* structures was the main reasoning for reef structure being 'Not a Reef' overall. The distribution of the stills and their reef structure is illustrated in Figure 5-45.

Table 5-32 *Sabellaria spinulosa* Reef Assessment (Composition vs Elevation)

'Reefiness' of Video Screengrabs	**Unclear UW Still**		**No *Sabellaria***		**Not a Reef**		**Low**		**Medium**		**High**	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Patchiness (% cover)	19	12.6	52	34.4	32	21.2	21	13.9	13	8.6	14	9.3
Elevation (Tube height)					64	27.2	16	10.6	0	0	0	0
Reef Structure					74	49	6	3.4	0	0	0	0



Reef Structure Matrix				Elevation (cm) <2	2 to 5	5 to 10	>10
				Not a Reef	Low	Medium	High
Patchiness	<10%	1	Not a Reef	Not a Reef	Not a Reef	Not a Reef	Not a Reef
	10-20%	2	Low	Not a Reef	Low	Low	Low
	20-30%	3	Medium	Not a Reef	Low	Medium	Medium
	>30%	4	High	Not a Reef	Low	Medium	High

Figure 5-45 *Sabellaria spinulosa* Reef Assessment (Composition vs Elevation)

The second stage of the *Sabellaria* reefiness investigation was to assess the average reef structure for each delineated patch of *S. spinulosa* against the delineated patch area to assess the overall patch 'reefiness' (Table 5-32). In such circumstances, an approximation of the aerial extent of each *S. spinulosa* patch can be made from the transect length, by assuming that reefs occupied circular areas of seabed (i.e. reef extent or distance equates to the diameter of a circle, whose area is calculated using πr^2).

There were 12 areas delineated as 'Not a Reef' with no patches considered 'Low Reef', 'Medium Reef' or 'High Reef' (Table 5-33; Figure 5-46.). Details of the full assessment are provided in Appendix O – REEF AND MUSSEL BED ASSESSMENT LOGSHEET. Overall the results indicate that an Annex I habitat did not occur in the survey route with any *Sabellaria spinulosa* aggregations being low elevation and non-reef forming.

Table 5-33 Overview of *Sabellaria spinulosa* Reef Assessment Patches

Structure vs Extent	Total	Not Visible	No Reef	Not a Reef	Medium Reef	High Reef
Patches	14	1	2	12	0	0

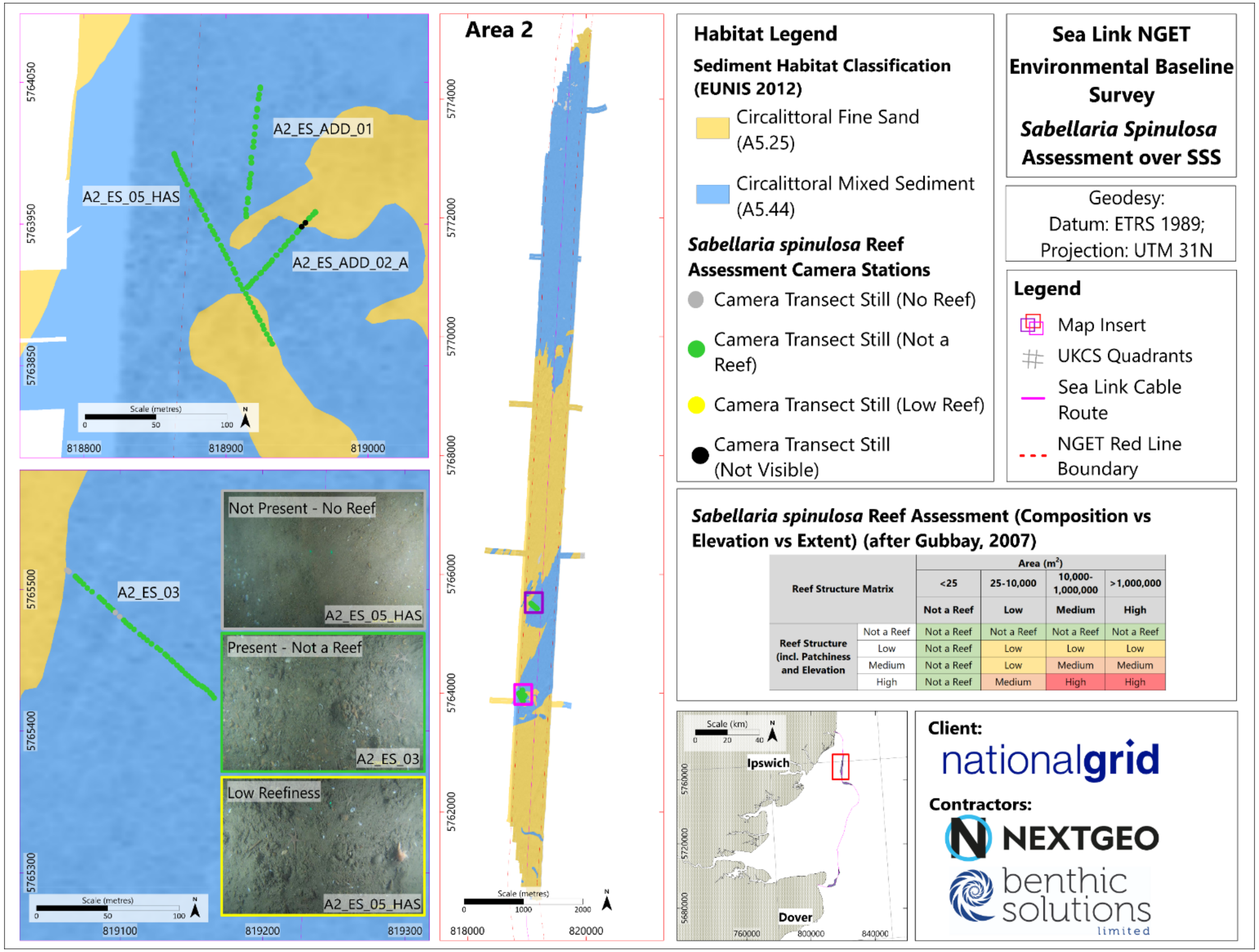


Figure 5-46 *Sabellaria spinulosa* Reef Assessment (Structure vs Extent)

5.7.3 Annex I Blue Mussel (*Mytilus edulis*) Beds

During video assessment, two transects (A5_OPB_05_HAS and A5_OPB_Add_01) were observed to have a high density of blue mussels (*Mytilus edulis*). Blue mussel beds are a UKBAP priority habitat with blue mussels having a role in coastal sediment dynamics, acting as a food source and providing enhanced biodiversity (JNCC, 2008). This habitat is threatened by commercial fisheries with the targeted removal of mussels as well as fishing causing physical damage to the beds, due to their feeding habits *Mytilus edulis* accumulate pollutants which can lead to sublethal or lethal responses and coastal development causing physical damage.

To assess the presence of mussels in these transects, a method was adopted incorporating the SACFOR scale alongside a grading system outlined in Roberts *et al.*, (2011). Stills were captured at 20 second intervals to evaluate total mussel coverage. Initially it was determined whether the still represented a crust/meadow (single layer of mussels on sediment) or a massive/turf (several layers of mussel on a large scale) as this classification would inform the application of the SACFOR scale based on coverage (Table 5-34). Each still was then assigned a SACFOR scale rating according to mussel coverage, which was used to inform the grading of the mussel habitat, to provide a quantitative assessment.

Table 5-34 Overview of Mussel (*Mytilus edulis*) Bed Assessment Categories

Coverage	Crust/Meadow SACFOR	BSL Grading adapted from Roberts *et al*, 2011	Massive/Turf	BSL Grading adapted from Roberts *et al*, 2011
>80%	Superabundant	1	Superabundant	1
40-79%	Abundant		Superabundant	
20-39%	Common		Abundant	
10-19%	Frequent	2	Common	
5-9%	Occasional		Frequent	2
1-5%	Rare	3	Occasional	
<1%	Less than Rare		Rare	3
0%	Absent	4	Absent	4

The stills taken during the survey and additional screengrabs from the video footage analysed displayed crust/meadow rather than a massive/turf environment form was present (a complete log of the assessment per still is provided in Appendix O – REEF AND MUSSEL BED ASSESSMENT LOGSHEET).

Of the 99 images from transects, 6 (6.1%) were unclear images due to poor visibility (Table 5-35). Five stills (5.1%) were classified as 'Superabundant', 14 (14.1%) were classified as 'Abundant', 15 (15.2%) were classified as 'Common', 14 (14.1%) were classified as 'Frequent', 16 (16.2%) as 'Occasional', 10 (10.1%) as 'Rare' and 19 (19.2%) as 'Absent' (Table 5-35.)

Table 5-35 Overview of SACFOR Results for Blue Mussel Bed Assessment

SACFOR Scale	Stills	
	No.	%
Super abundant	5	5.1
Abundant	14	14.1
Common	15	15.2
Frequent	14	14.1
Occasional	16	16.2
Rare	10	10.1
Less than rare	0	0.0
Absent	19	19.2
Not visible	6	6.1

When this SACFOR scale was converted into the grading system by Roberts *et al* (2011) it revealed that most images were considered Grade 1 and 2. A total of 34 stills (34.3%) were considered Grade 1, 30 (30.3%) were categorised as Grade 2, 10 (10.1%) were classed as Grade 3, 19 (19.2%) were classified as Grade 4. These findings can be summarised in Table 5-36 and illustrated in Figure 5-47 showing the spatial distribution.

Table 5-36 Overview of BSL Grading of Blue Mussel Bed Assessment

Roberts *et al* (2011) Adapted BSL Grading	Unclear UW Still		Grade 4		Grade 3		Grade 2		Grade 1	
	No.	%	No.	%	No.	%	No.	%	No.	%
Stills	6	6.1%	19	19.2	10	10.1	30	30.3	34	34.3

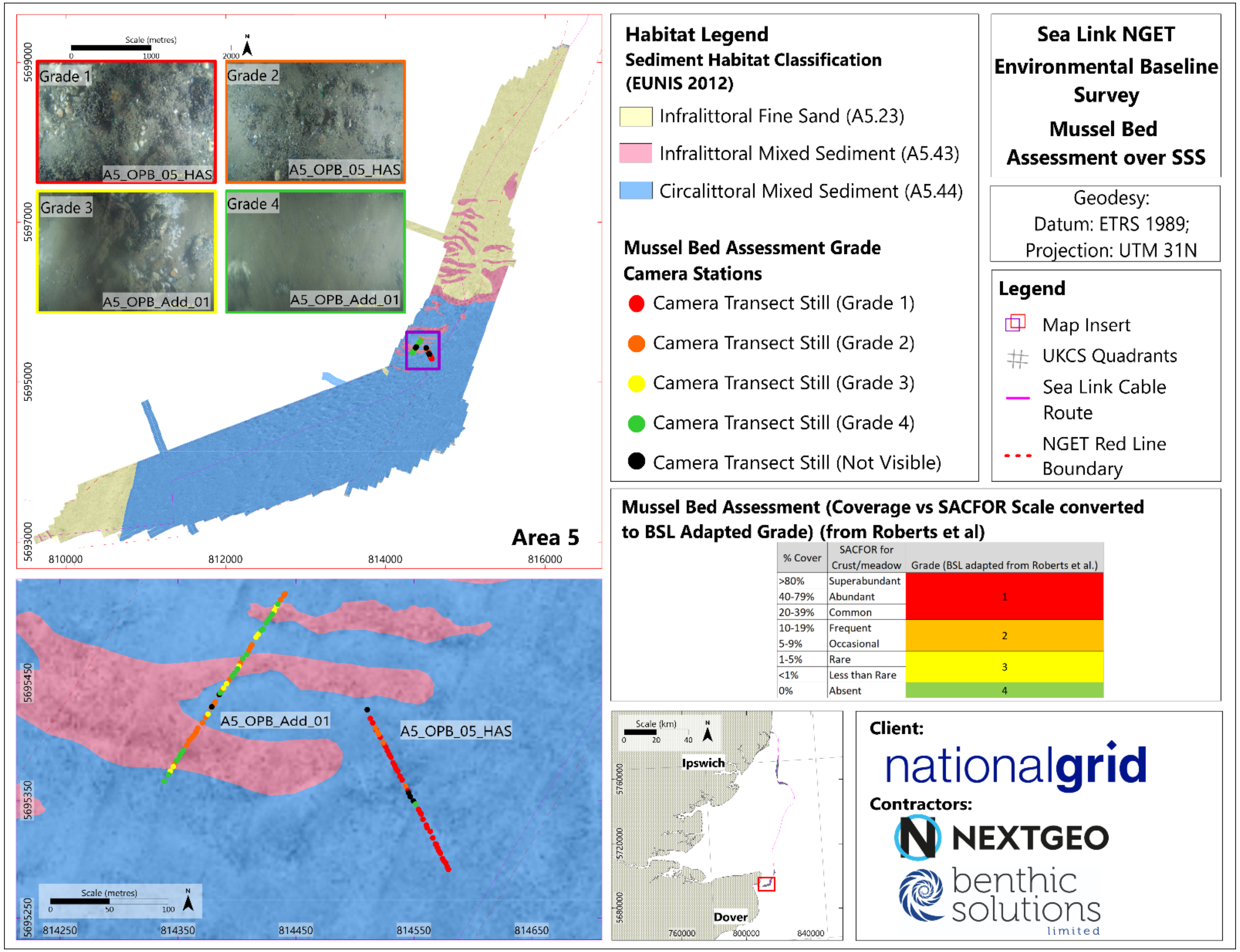


Figure 5-47 Blue Mussel (*Mytilus edulis*) Bed Assessment (BSL Grading)

This assessment reveals that all of the Grade 1 stills were found along transects A5_OPB_05_HAS with A5_OPB_Add_01 showing more patchy and less dense aggregations. To calculate the estimated area of the Mussel beds, an approximation of the aerial extent of each *M. edulis* patch was made from the transect length, by assuming that reefs occupied circular areas of seabed (i.e. reef extent or distance equates to the diameter of a circle, whose area is calculated using πr^2).

Overall there were 18 patches in the survey area with a single non-visible patch. Of the remaining patches, 3 were classed as Grade 1, 5 being classed as Grade 2, 4 being classed as Grade 3 and 5 being classed as Grade 4. OSPAR definitions define a mussel bed as at least a 20% cover of subtidal sediments over an area of at least 25m^2 to qualify as a bed (OSPAR, 2010), using this definition patches can be estimated and those with an area of greater than 25m^2 and considered Grade 1 could be potential mussel beds. This revealed that all three grade 1 patches found could be a potential mussel bed under this definition with an overview of these patches is summarised in Table 5-37.

Table 5-37 Blue Mussel Assessment Patches Extent Overview

Grading vs Extent	Total	Grade 1	Grade 2	Grade 3	Grade 4	Not Visible
Patches	18	3	5	4	5	1

5.7.4 Lesser Sandeel (*Ammodytes marinus*) Spawning and Nursery Grounds

Sandeels are small, thin eel-like fish that form large shoals and live most of their life buried in the seabed. They are considered an important component of marine food webs providing food for marine predators such as seabirds, mammals, and other fish (Furness, 1990; 2002). Of the five species of sandeels occurring in the North Sea, the lesser sandeel (*A. marinus*) is the most abundant and comprises over 90% of sandeel fishery catches (Fisheries Management Guidance, 2014). Sandbanks and other sandy areas are known to be important habitat for sandeel, which prefer habitats in water depths between 30m and 70m but are known to occur at depths of 15 m and 120 m (Holland *et al.,* 2005). These small fish burrow into the sediment, sand and use interstitial water to ventilate their gills (Holland *et al.,* 2005). They do not create a permanent opening when burrowed. Fine sediment has the potential to clog their gills and therefore, sandeel have a very specific habitat requirement, resulting in an often highly patchy distribution (Holland *et al.,* 2005; Jensen *et al.,* 2011).

Preferred sandeel habitat is a substrate which contains a high percentage of medium to coarse sand (particle size of 0.25 mm to 2 mm), with a mud content of less than 10% (particles <63 µm) (Wright *et al.,* 1998; Holland *et al.,* 2005). Sediments with a gravel component are also considered to be suitable for sandeel habitat. The inclusion of gravel means that using Folk classifications (Folk, 1954) to assess the habitat can overstate the suitability of habitat for sandeels. To determine areas of potential available habitat for sandeel grounds, the PSA results for the grab stations were compared to the parameters specified by Latto *et al.* (2013), as shown in Table 5-38 with these groupings overlaid on a Folk Triangle scale in Figure 5-48.

Table 5-38 Sandeel Ground Assessment Categories Specified by Latto *et al.* (2013)

Folk Categories	Habitat Preference
Sand	Preferred
Gravelly Sand	Preferred
Slightly Gravelly Sand	Preferred
Sandy Gravel	Marginal
Other	Unsuitable

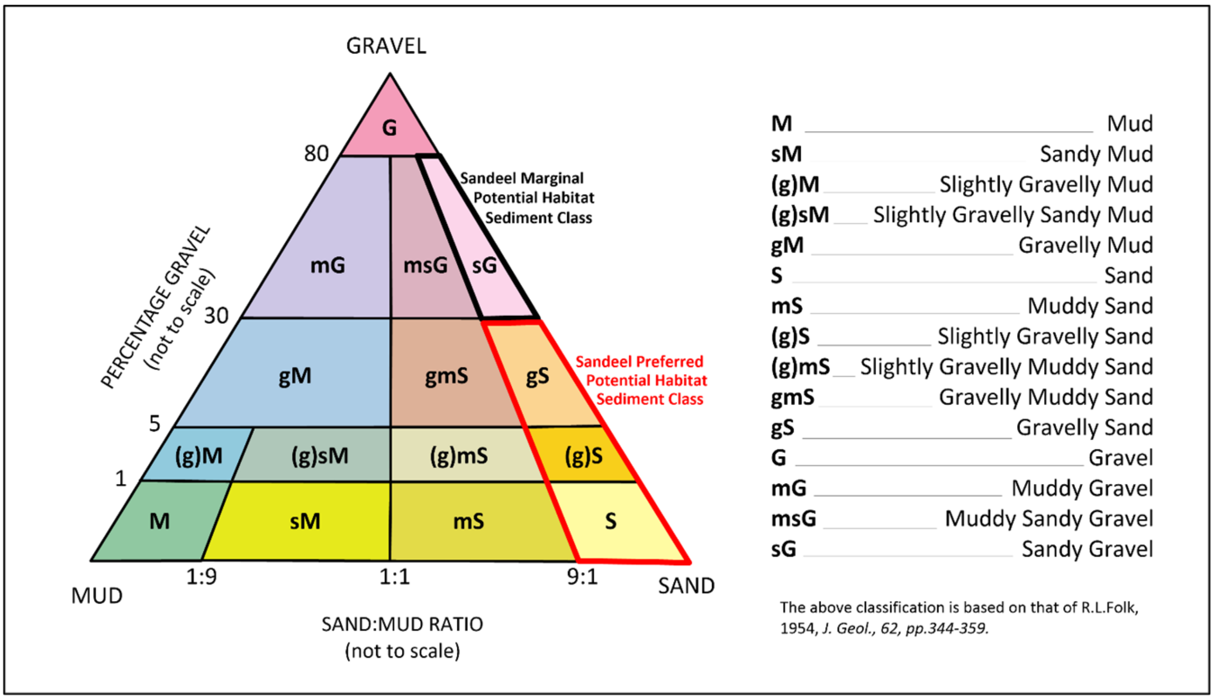


Figure 5-48 Folk Sediment Triangle with Sandeel Preferred and Marginal Habitat Sediment Classes (Based on Latto *et al.*, 2011; adapted from Greenlink 2019)

Results from analysis of PSA and assigned Folk scale data, using the method outlined in Latto *et al.* (2013) are outlined in Table 5-39. 'Preferred' sediments for sandeel grounds were identified at two stations (A2_ES_04 and A5_OPB_01) located Area 2 and Area 5 of the survey area with the folk scale 'Gravelly Sand' (Table 5-39). A2_ES_04 was located in 'Circalittoral Mixed Sediment', however this small area was surrounded by a large area of 'Circalittoral Fine Sand' with A5_OPB_01 located in an area of 'Infralittoral Fine Sand'. Both grab locations were situated in areas with ripples and wave features. The remaining stations were classed as 'Unsuitable' for sandeel habitat as the stations showed bimodal sediment distributions, containing fine and coarse material, and were therefore assigned to Folk classifications of 'Muddy Sandy Gravel' and 'Slightly Gravelly Sandy Mud' (Table 5-39).

Table 5-39 Sandeel ground assessment results using Latto *et al.* (2013)

Station	Depth (m)	Modified Folk Scale	Habitat Preference
A2_ES_01	17.7	Muddy Sandy Gravel	Unsuitable
A2_ES_02	22.9	Slightly Gravelly Sandy Mud	Unsuitable
A2_ES_03	24.7	Muddy Sandy Gravel	Unsuitable
A2_ES_04	21.6	Gravelly Sand	Preferred
A3_NS_01	22.8	Muddy Sandy Gravel	Unsuitable
A4_GLC_01	13.5	Muddy Sandy Gravel	Unsuitable
A4_GLC_03	11.5	Muddy Sandy Gravel	Unsuitable
A5_OPB_01	11.8	Gravelly Sand	Preferred

More specific definitions of sandeel preferred grounds using sediment particle size were provided by Greenstreet *et al.* (2010). This method utilises the percentage composition of the sediment by weight, which is split into two distinct fractions; silt and fine sand (particles >0.25mm), and medium to coarse sand (particles 0.25-2.0mm). The coarse >2mm fraction, which can often overstate sandeel habitat suitability, is not considered by this method. The sediment fraction data are then used to assess sandeel sediment preference for each station from Figure 5-49.

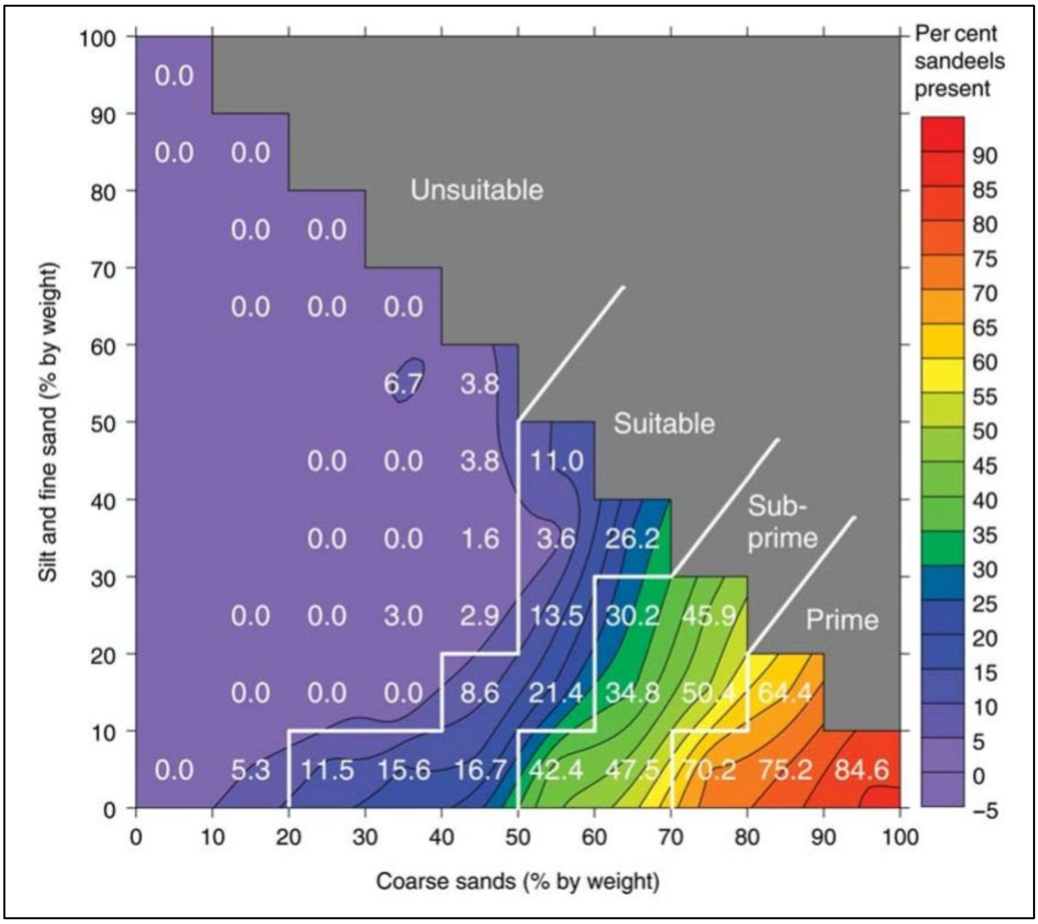


Figure 5-49 Sandeel sediment preference categories as per Greenstreet *et al.* (2010) (silt and fine sand refer to particle sizes >0.25mm, whilst medium to coarse sand refer to particle sizes 0.25 to 2.0mm)

The results using the method outlined in Greenstreet *et al.* (2010) indicated less habitat suitability than with the Latto *et al.,* (2013) method, with stations that were 'Unsuitable' in Latto *et al.,* (2013) method still being 'Unsuitable'. A5_OPB_01 was classed as 'Prime' with this method however A2_ES_04 became classed as 'Sub-Prime' due to the higher proportion of 'Silt and Fine Sands' (Table 5-40 and Figure 5-50). There were no sandeels recovered in the grab samples. The Sea Link survey route falls within sandeels low intensity spawning and nursing grounds; however, it should be noted that even optimal habitats may not be occupied by sandeels if populations are below the area's carrying capacity (Holland *et al.,* 2005).

Table 5-40 Sandeel ground assessment results using Greenstreet *et al.* (2010)

Station	Water Depth (m)	Silt and Fine Sands (% by weight)	Medium to Coarse Sands (% by weight)	Habitat Preference
A2_ES_01	17.7	25.5	6.7	Unsuitable
A2_ES_02	22.9	90.3	8.3	Unsuitable
A2_ES_03	24.7	48.8	17.8	Unsuitable
A2_ES_04	21.6	12.6	77.3	Sub-Prime
A3_NS_01	22.8	50.3	14.5	Unsuitable
A4_GLC_01	13.5	24.2	29.1	Unsuitable
A4_GLC_03	11.5	28.0	14.8	Unsuitable
A5_OPB_01	11.8	6.5	83.3	Prime

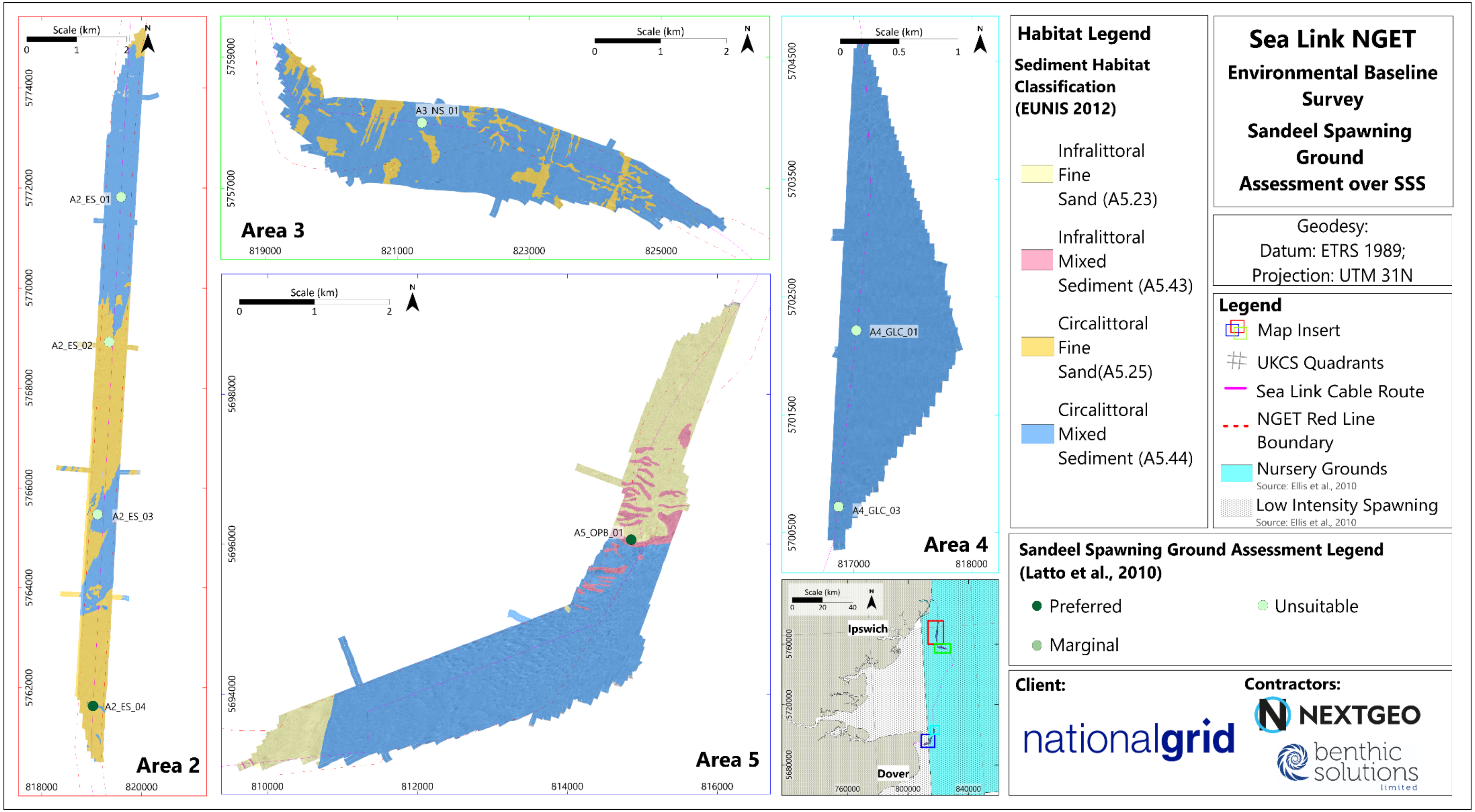


Figure 5-50 Sandeel Spawning and Nursing Grounds (Latto *et al.*,2013)

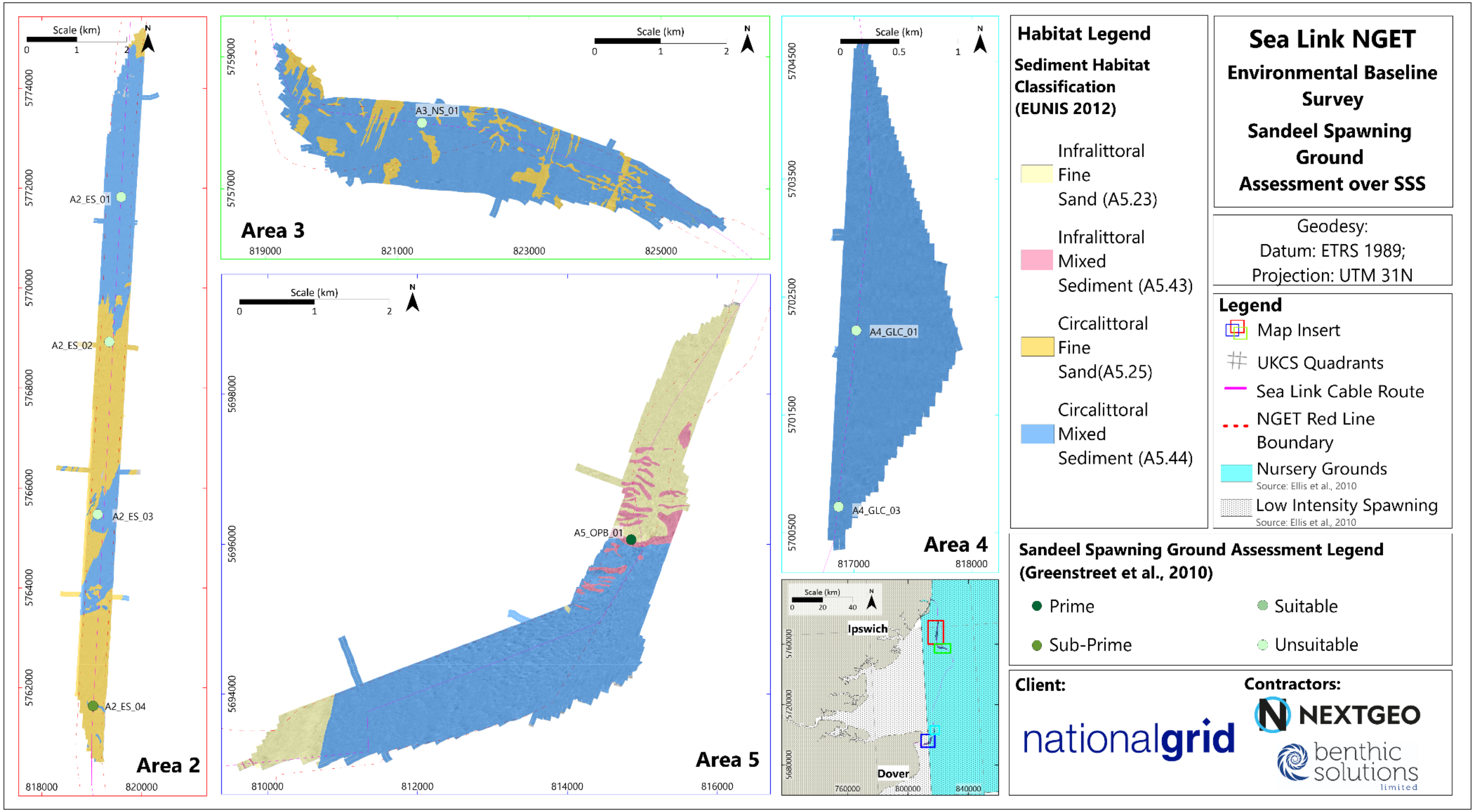


Figure 5-51 Sandeel Spawning and Nursing Grounds (Greenstreet *et al.*,2010)

5.7.5 Herring Spawning and Nursery Grounds

Herring spawning grounds (HSGs) and nursery grounds have been delineated by Cefas for UK waters. The Sea Link survey route lies within both a low intensity and high intensity nursery ground (Figure 5-52). Spawning occurs during August to October and suitable HSGs include sediments that are well oxygenated, allowing their sticky eggs to gestate for around three weeks before they hatch (Rogers & Stocks, 2001). Such sediments are limited to unimodal, unmixed very coarse sands and gravels with a low proportion of fines (Ellis *et al.,* 2012). Overexploitation and poor recruitment led to a decline in the North Sea herring spawning stock in the 1970s, forcing closure of the fishery in 1977. Due to the unique sedimentary requirement for HSGs and the stock's vulnerability to overfishing (Rogers & Stocks 2001), HSGs may be subject to protection if found. To determine whether any potential habitat for herring spawning exists within the Sea Link survey route, the PSA results from the grab sampling stations were assigned to the categories specified by Reach *et al.* (2013), as shown in Table 5-41.

Table 5-41 Herring Spawning Ground Assessment Categories Specified by Reach *et al.* (2013)

Percent Contribution of Mud & Gravel	Habitat Sediment Preference	Habitat Sediment Classification
<5% mud, >50% gravel	Prime	Preferred
<5% mud, >25% gravel	Sub-prime	Preferred
<5% mud, >10% gravel	Suitable	Marginal
>5% mud or <10% gravel	Unsuitable	Unsuitable

Results from particle size distribution of the survey area indicated that most stations were classified as 'Unsuitable' for herring spawning grounds due to the fines content being above 5%. The only exception was A5_OPB_01 which had a lower fines content of 3.0% however gravel content was at 10.2% which whilst considered 'Suitable' in terms of preference only allowed it to be classified as 'Marginal'. This station was found in an area with the modified folk classification of 'Gravelly Sand' and classified as 'Infralittoral Fine Sand' from the habitat assessment (Table 5-42 and Figure 5-52). Assessments for HSG have only been carried out for grab stations in which ground truthing PSA data is available and not across the entire transects. Although video data can provide a view into the overall transects potential classification, the significant influencing factors have not been quantified and therefore cannot be used to define the preference and classification of HSG.

Table 5-42 Herring Spawning Ground Assessment Results Using Reach *et al.* (2013)

Station	Water Depth (m)	Fines (%)	Sands (%)	Gravel (%)	Habitat Sediment Preference	Habitat Sediment Classification
A2_ES_01	17.7	15.5	16.7	67.8	Unsuitable	Unsuitable
A2_ES_02	22.9	63.2	35.4	1.4	Unsuitable	Unsuitable
A2_ES_03	24.7	30.4	36.2	33.4	Unsuitable	Unsuitable
A2_ES_04	21.6	7.1	82.8	10.1	Unsuitable	Unsuitable
A3_NS_01	22.8	31.0	33.8	35.2	Unsuitable	Unsuitable
A4_GLC_01	13.5	11.0	42.2	46.7	Unsuitable	Unsuitable
A4_GLC_03	11.5	15.9	26.9	57.2	Unsuitable	Unsuitable
A5_OPB_01	11.8	3.0	86.8	10.2	Suitable	Marginal

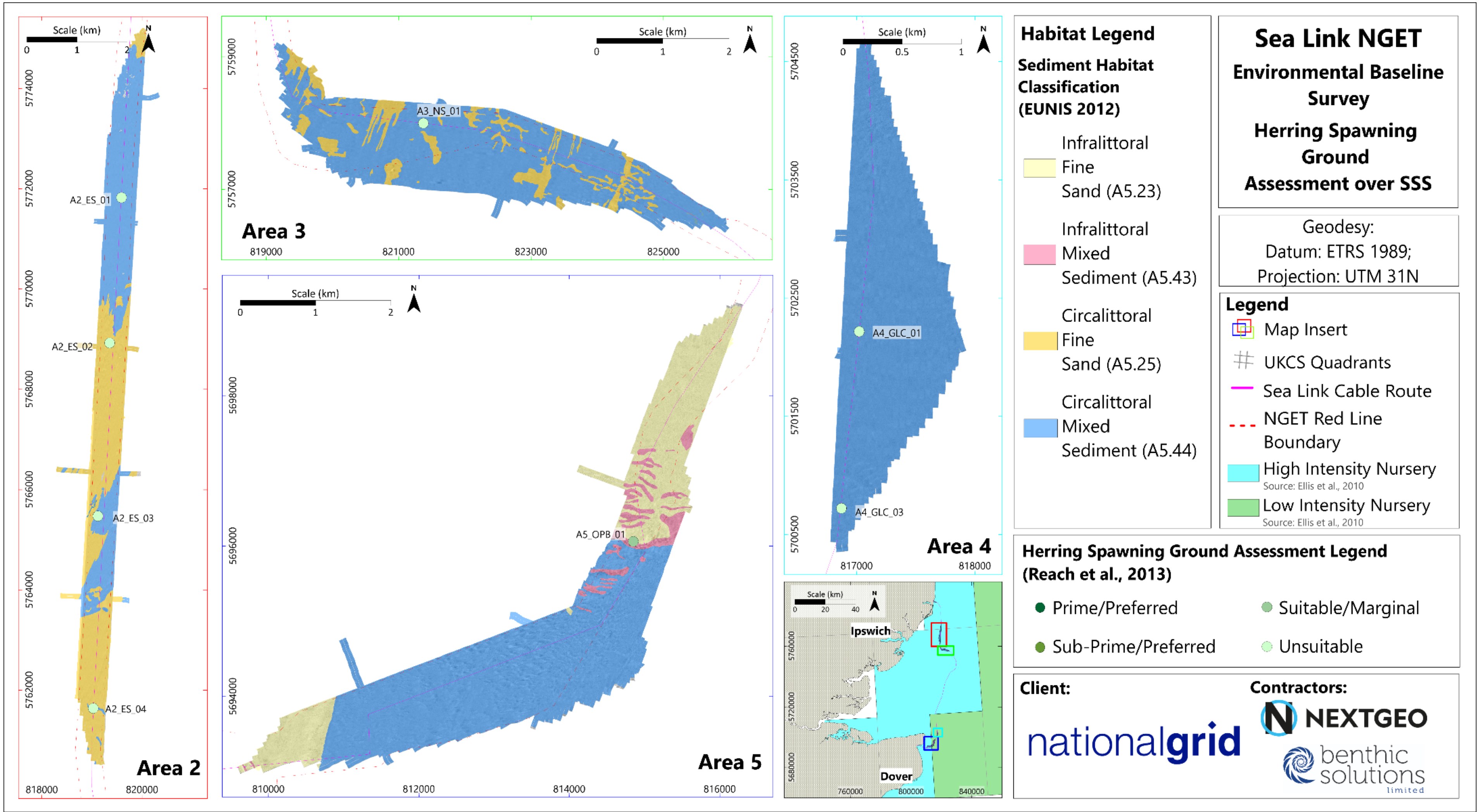


Figure 5-52 Herring Spawning and Nursing Grounds (Reach *et al.*, 2013)

5.7.6 Ocean Quahog (*Arctica islandica*)

The ocean quahog (*Arctica islandica*) bivalve species is afforded protected status under the OSPAR Commission due to its inclusion on the OSPAR list of threatened and/or declining species in the Greater North Sea area as a priority species (OSPAR, 2008; 2009b). This species is also listed as an MCZ FOCI for both inshore and offshore protection (JNCC and Natural England, 2016). Ocean quahog grow very slowly, and are at particular risk from bottom fishing gear, and, like other slow-growing animals, once their numbers have been reduced their populations can take a long time to recover.

Field assessment of *Arctica islandica* can be challenging for specimens with shell sizes below 5 cm due to their morphological similarities to other species such as *Dosinia*. To ensure accurate identification during field processing, *Arctica* specimens with a shell diameter above 5 cm—approximately half the typical adult size of 10-13 cm (Begum *et al.,* 2009)—are classified as adults. These specimens are measured, logged, and returned to the sea. Specimens with a shell diameter below 5 cm are retained within the grab sample for further taxonomic review. During this review, individuals with a shell size above 1 cm are logged as adults, while those below 1 cm are categorised as juveniles, following the NMBAQC guidance (August 2023).

No living adult specimens were identified during field operations (>5cm shell diameter) and no siphons were observed during the HD video review or stills. No juvenile (<1cm shell diameter) or adult (>1cm shell diameter) specimens were recorded during taxonomic data analysis.

5.8 Designated Sites

The Sea Link survey areas two and three are situated within the large Southern North Sea Special Area of Conservation (SAC), which stretches from the central North Sea (north of Dogger Bank) to the Straits of Dover in the south. A mix of habitats which are afforded Annex I protection, such as sandbanks and gravel beds, are present within the SAC but are designated as individual SACs and Marine Conservation Zones (MCZs). No Sea Link survey areas are not situated within a MCZ but is located near to two MCZs; Orford Inshore and Kentish Knock East (Table 5-43). There is also a Special Protection Area (SPA) near the cable route; the Outer Thames Estuary, which is split into three sections and all Sea Link survey areas are under 10km away at the nearest point. The MCZs, SACs and SPAs found near to the Sea Link survey area and the primary features for which they were designated are summarised below in Table 5-43.

Table 5-43 Key aspects of nearby protected areas

Protected Area Type	Designated Site	Site Area	Closest Distance to Survey Site	Key Aspects
MCZ	Orford Inshore	72km^2	9.27km North West of area 2	The site protects the Subtidal mixed sediments habitats, which is important nursery and spawning grounds for many fish species, including Dover sole (*Solea solea*), lemon sole (*Microstomus kitt*) and sandeels. Important shark species are also found within the site, including the small-spotted catshark (*Scyliorhinus canicula*).
	Kentish Knock East	96.4 km^2	16.5kmSouth West of area 3	The site protects examples of different Subtidal sediments, supporting a wide variety of infaunal species and the small spotted cat shark (*Scyliorhinus canicula*) and flatfish species.
SAC	Southern North Sea	36,951km^2	Areas 2 and 3 are Situated within and 5.94km West of Area 4 and 8.35km West of Area 5	Important area for Annex II harbour porpoise (*Phocoena phocoena*).
SPA	Outer Thames Estuary	3, 924km^2 made up of three inshore and offshore areas	Area 2 is partly situated within, 6.35km South West of Area 3 , 7.12km West of Area 4, and 7.55km North West of Area 5	Protects the wintering red-throated diver, breeding little terns and breeding common terns. The area also contains sandbanks (Annex I)

6 CONCLUSION

The depths in the surveyed areas of the Sea Link ranged from 7.3m to 27.4m below LAT. Sediment composition across the site was varied, with Areas 2, 4, and 5 predominantly consisting of sand and gravel, while Areas 2 and 3 exhibited mixed sediments. There was also one instance of dominant fines in Area 3. These sediment characteristics align with the results from the previous MMT (2022) survey.

Particle size analysis revealed a relatively heterogeneous seabed. Stations in the southern part of Area 2 and in Area 5 were dominated by sand, while stations in Area 4 and the northern part of Area 2 were primarily composed of gravel. Other stations in Areas 3 and the central part of Area 2 exhibited more mixed sediments. One station (A2_ES_02) in the central region of Area 2 was notably dominated by fines. No significant correlation was found between sediment characteristics and depth ($p > 0.05$). The samples collected represented three Folk classifications: the majority were classified as 'Muddy Sandy Gravel', while the remaining samples were categorised as either 'Gravelly Sand' or 'Slightly Gravelly Sandy Mud'. The mean particle size for each area aligned with the findings from the previous MMT (2022) survey.

Total organic carbon (TOC) levels were relatively low, ranging from 0.15% at A5_OPB_01 to 0.64% at A2_ES_02. Total organic matter (TOM) ranged from 1.4% at A5_OPB_01 to 5.0% at A2_ES_02. Both parameters were found to have a positive Spearman's correlation with percentage of fines in the sediment ($p < 0.01$). TOC and TOM levels recorded during the MMT (2022) survey were slightly lower on average than those found during the current survey.

Total hydrocarbon content (THC) concentrations ranged from 0.66mg.kg^{-1} at A5_OPB_01 to 17.65mg.kg^{-1} at A2_ES_02. The higher THC levels in Area 2 were consistent with the average THC content reported for the same area in the previous MMT report (11.40mg.kg^{-1}). Similar to THC, total n-alkane concentration was variable across the survey area, ranging from 0.007mg.kg^{-1} at A5_OPB_01 to 0.742mg.kg^{-1} at A2_ES_02. Three stations in Area 2 had n-alkane concentrations above the UKOOA (2001) SNS 50th percentile (0.19mg.kg^{-1}), but the values were consistent to the average n-alkanes concentration reported for the same area in the previous MMT report (0.533mg.kg^{-1}). GC traces showed hydrocarbon signatures typically seen for background sediments in the North Sea. Total PAH levels were variable, ranging from 0.012mg.kg^{-1} at A2_ES_04 to 0.904mg.kg^{-1} at A2_ES_02. No stations across the survey area resulted in values close to the NOAA (2008) ERL and ERM reference values.

Concentrations of several metals (barium, copper, iron, lead, mercury, nickel, vanadium, and zinc) exceeded the UKOOA (2001) SNS 50th percentile at all stations, with chromium exceeding this threshold at all but one station (A5_OPB_01), while all these metals, except copper, surpassed their UKOOA 95th percentile values at least one station. Arsenic levels exceeded the OSPAR ERL threshold (8.2mg.kg^{-1}) at all stations, ranging from 12.8mg.kg^{-1} at A2_ES_02 to 41.4mg.kg^{-1} at A3_NS_01, with concentrations at A2_NS_01, A2_ES_02, and A3_NS_01 also surpassing the Cefas cAL 1 (20mg.kg^{-1}). Elevated arsenic levels are attributed to natural geological inputs, anthropogenic activities, and riverine discharge, including contributions from rivers such as the Rhine, Meuse, Humber estuary, and Scheldt, as well as industrial processes and agricultural runoff. Similar findings in the MMT (2022) survey suggest these concentrations are background levels. Nickel at A3_NS_01 (24.2mg.kg^{-1}) exceeded Cefas cAL 1, likely due to natural sediment variation, but no metals exceeded Cefas cAL 2. Overall, except for arsenic, metal concentrations were below Cefas cALs and OSPAR ERL levels, posing minimal risk to marine life and no significant environmental impact.

Macrofaunal analysis revealed a total of 6,897 infaunal individuals (including solitary epifauna). Annelida and solitary epifauna were the most abundant groups, collectively accounting for 76% of the total individuals across the survey area. Multivariate statistical analysis identified three significantly different macrofaunal groupings within the area. Differences in macrofaunal composition were significantly related to sediment composition. Cluster groups were typically differentiated by variations in the abundance of the keel worm (*Spirobranchus lamarcki*), and sea anemones (Actiniaria), which were more prevalent at stations with higher gravel content. Additionally, the mollusc *Kurtiella bidentata* was notably more abundant in areas characterised by muddy sands.

CTD water profiles resulted in a lack of both a thermocline and halocline across the survey area, indicating a well-mixed water mass.

The seabed within the survey area was classified into four EUNIS level four habitats. In the northern part of the survey route (Areas 2 and 3), the habitats identified were 'Circalittoral Mixed Sediment' (A5.44) and '*Abra prismatica, Bathyporeia elegans* and Polychaetes in Circalittoral Fine Sand' (A5.252). The 'Circalittoral Mixed Sediment' was characterised by a higher gravel content within muddy sand, while '*Abra prismatica, Bathyporeia elegans* and Polychaetes in Circalittoral Fine Sand' consisted predominantly of fine sand with occasional gravel patches. In the southern section (Areas 4 and 5), the habitats included both 'Circalittoral Mixed Sediment' and two additional types: 'Infralittoral Mixed Sediment' (A5.43) and 'Infralittoral Mobile Clean Sand with Sparse Fauna' (A5.231). The 'Infralittoral Mixed Sediment' was similar to its circalittoral counterpart, featuring a gravel component within muddy sand, and was observed in shallow ribbons, particularly in Area 5. 'Infralittoral Mobile Clean Sand with Sparse Fauna', found in the shallower parts of Area 5, was primarily composed of fine sand with occasional gravel patches.

Various potential sensitive habitats and species were identified from the HD video data. These included Annex I Geogenic stony reefs (EC Habitats Directive Annex I habitat), biogenic reef (EC Habitats Directive Annex I, Habitat FOCI, OSPAR Threatened and/or Declining Habitat, UKBAP Priority Habitat), lesser sandeel (*Ammodytes marinus*) (Species FOCI, UKBAP Priority Species), herring (*Clupea harengus*) spawning grounds, ocean quahog (*Arctica islandica*) (Species FOCI, OSPAR Threatened and/or Declining Species) and blue mussel (*Mytilus edulis*) beds (EC Habitats Directive Annex I habitat, UKBAP Priority Habitat).

An assessment for Annex I Geogenic Stony Reef was conducted across six transects in Areas 3 and 4, using HD video data. The evaluation focused on cobble and boulder coverage, elevation, epifaunal diversity, and patch extent. The results indicated low-elevation cobble and boulder coverage, with only the Area 4 transects (A4_GLC_01, A4_GLC_02, A4_GLC_03_A) displaying more extensive patches. Although classified as "Low Reef," the low species diversity—primarily consisting of tube worms, faunal turf, and sponges—and the absence of key reef-building species indicated no Annex I habitat present.

The presence of *Sabellaria spinulosa* was analysed to assess its potential to form Annex I Biogenic Reef habitats. Observed across four transects in Area 2, the analysis focused on coverage, tube elevation, and patch extent using still images from HD video. The results concluded that the area as a whole does not qualify as a reef, with *S. spinulosa* aggregations lacking sufficient elevation. Only a few stills were classified as "Low Reef," but these were marginally distinguishable from the surrounding "Not a Reef" areas. Consequently, the site is categorised as "Not a Reef."

An assessment of Annex I blue mussel (*Mytilus edulis*) beds was carried out due to high-density observations at A5_OPB_05_HAS and less frequent occurrences at A5_OPB_Add_01. Using the SACFOR scale and a grading system adapted from Roberts *et al.* (2012), results indicated that *M. edulis* coverage at A5_OPB_Add_01 was too sparse and patchy to qualify as an Annex I habitat, with no areas meeting the Grade 1 criteria. In contrast, A5_OPB_05_HAS showed blue mussel coverage, with most stills classified as Grade 1, forming three large patches. These findings suggest the presence of a potential Annex I habitat at A5_OPB_05_HAS.

The survey route is situated in areas considered lesser sandeel (*Ammodytes marinus*) nursery grounds as well as low intensity spawning grounds. The PSA data was therefore assessed using methods outline in Greenstreet *et al* (2010) and Latto *et al* (2013) to determine habitat suitability for lesser sandeel spawning grounds. Using the method outlined in Latto *et al* (2013) it was found that most stations were deemed 'Unsuitable' with two stations (A2_ES_04 and A5_OPB_01) deemed 'Preferred' with these stations consisting mainly of 'Gravelly Sand'. The Greenstreet *et al* (2010) method showed similar results with most stations being 'Unsuitable' with A2_ES_04 considered 'Sub-Prime' due to a higher silt content compared to A5_OPB_01 which was considered 'Prime'.

The survey route is also present in areas designated as high and low intensity nursery grounds for Atlantic Herring (*Clupea harengus*). PSA was used to determine the suitability of the habitat for herring spawning grounds using methods outlined in Reach *et al* (2013). It was found that most habitats were 'Unsuitable' due to possessing too much fine content (>5%) or too little gravel (<10%), the only exception was A5_OPB_01 which was considered 'Suitable' but as it only just possesses enough gravel content (10.2%) and subsequently classed as 'Marginal'.

Ocean quahog (*Arctica islandica*) are a bivalve species afforded protected status under the OSPAR Commission and declining population in the Greater North Sea. No adult specimens were identified during field operations (shell diameter >5cm) and no siphons were observed during HD video review. No juvenile (<1cm shell diameter) or adult (>1cm shell diameter) specimens were recorded during taxonomic data analysis.

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APPENDIX A – BSL DOUBLE GRAB

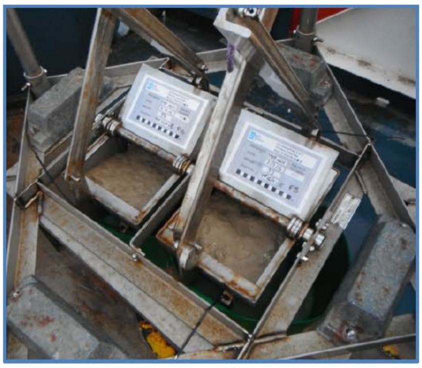
benthic solutions limited

BSL DOUBLE GRAB

- **General Specifications**
  - 2 x 0.1m² Sample Area
  - Total Stainless Steel Construction
  - Adjustable weight
  - Proven performance in 2000m depth
  - Flat Pack for Air Freighting

- **Services**

The BSL Double Grab was designed and built by BSL in 2007 to carry out more efficient grab sampling operations in very deep waters. It is also routinely used for projects where multiple replicates are required or where both chemical and biological analysis are needed from the same deployment. This multi-purpose sampling tool is ideal for shallow water and deep water operations alike, halving the ship-time required to acquire sample replicates in moderate water depths.



Recovery

Grab stand and sample trays

Made of stainless steel, the grab can be ballasted with additional lead weights, for operations in deeper waters, strong currents or compacted sediments. The two pairs of extended stainless steel arms increase the leverage on closure to the buckets, but these can be fouled by coarser gravels.

Both buckets have hinged doors fully enclosing the samples on recovery but allowing the scientist access to the undisturbed sample prior to emptying the sampler. Each bucket has the capacity to collect samples of approximately 15L.

Deployment

Direct access to sample

Shipping weight	200kg
Shipping dimension	0.4*to 1.2 x 1 x 0.2m
Specifications	920 x 920 x 1000mm

**if sampler is dismantled for freighting*

Benthic Solutions, Unit A, Greengates Way, Hoveton, NR12 8ED, United Kingdom
Tel : +44 (0) 1603 784726 Mail: info@benthicsolutions.com www.benthicsolutions.com

APPENDIX B – BSL MINI HAMMON GRAB

benthic solutions limited

Mini-HAMON GRAB

- <u>General Specifications</u>

- 0.1m² Sample Area
- Stainless Steel Bucket Construction
- Proven performance in both deep and shallow waters
- Excellent for coarse sediments
- Inspection hatch for direct sub-sampling

- <u>Services</u>

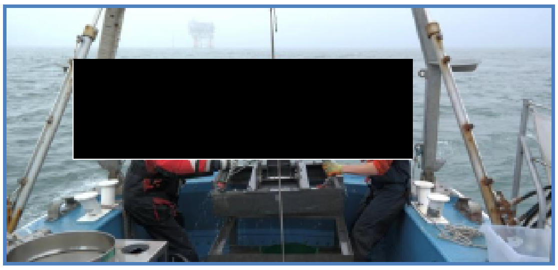
Benthic Solutions Limited owns and operates several 0.1m² Mini-Hamon grabs, which are ideal for obtaining bulk samples in mixed sands and gravels, as well as for sampling benthic macrofauna (approved by CEFAS). This relative small grab was modified from the larger 0.2m² unit used in the aggregate industry for use during inshore environmental assessments in mixed sediments.

The Hamon Grab comprises of a stainless steel box shaped sampling scoop mounted in a triangular frame. Upon contact with the seabed tensioned wires are released which causes the sampling bucket to pivot through 90° pushing seabed sediment into the bucket in a single direction. On completion of its travel the open end of the bucket comes against a rubber sealed steel plate which stops the sediment escaping during recovery. The surface area of seabed covered during the travel of this bucket is approximately 1000cm² and achieves a penetration of typically 15-20cm.

On recovery the grab is landed onto a rectangular base from where access can be gained to the inside of the bucket via an inspection hatch added to the back of the sampler. Whilst in the stand, the grab sample can easily be emptied into a sampling container located under the frame.

Shipping weight	120-200kg
Shipping dimension	1 x 1 x 1.5m
Sample area	0.1m²

These grabs are used for the collection of samples from coarse (diamicton sands and gravel) where glacial deposits are common or in areas of high energy environments. Note that there is some minor disturbance to the structure of the sample (particularly in granular sediments) so it is not the preferred sampling tool for detailed physico-chemical sub-sampling where the in situ structure needs to be maintained. The sampler is regularly used for macro-invertebrate and particle size analysis.



ISO 9001 REGISTERED FIRM
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APPENDIX C – WILSON AUTO-SIEVER

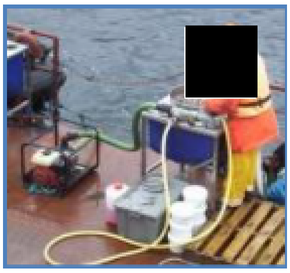
benthic solutions limited

WILSON AUTOSIEVER

***Best practice** for benthic samples**

- **General Specifications**

The *Wilson* Autosiever is a semi-automated sieving table for reducing benthic sediment samples offshore in a routine and controlled manner.



- Reduces time consuming and laborious sample handling in the field
- Reduces personnel numbers required for benthic processing
- Reduces damage to biological material during processing
- Well proven field performance on benthic surveys worldwide
- Standardises sample processing
- Robust stainless-steel construction that dismantles for storage or freighting
- New design with adjustable height

- **Services**

The *Wilson* Autosiever (WAS) was initially designed in the late 1980s by Ian Wilson (BSL Director), but was implemented from the early 1990s as the preferred benthic processing tool for all sampling operations by a major UK based environmental survey contractor. The system was subsequently commercialised and made available for purchase to other operators and users following the success of the trial at an NMBAQC workshop in 1997*.

The WAS system was designed to standardise all sieving operations between surveys and personnel, increasing the efficiency of the sample handling and processing without compromising the quality of the biology recovered.

Its simple yet unique and revolutionary design enables its employment from small vessels and large ships alike and in a variety of different sediment conditions, ranging from coarse heterogenic substrates down to soft clays and silts.

Cited as *best practice* for biological processing*, the WAS system has become the preferred tool for a large number of organisations that routinely carry out benthic surveys. Systems are currently being employed around the world (including UK, Ireland, Norway, Netherlands, Germany, France, Australia, Africa and South America) by a multitude of different users including survey companies, fish farms, government institutes and agencies, laboratories, universities and environmental consultancies.

* Proudfoot, R.K., Elliott, M., Dyer, M.F., Barnett, B.E., Allen, J.H., Proctor, N.L., Cutts, N.D., Nikitik, C., Turner, G. Breen, J. Hemmingway, K.L. and Mackie, T., 1997. Collection and Processing of macrobenthic samples from soft sediments; a best practice review. Proceedings of the Humber Benthic Field Methods Workshop, Hull University.

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APPENDIX D – BSL UNDERWATER CAMERA – MOD4

benthic solutions limited

UNDERWATER CAMERA – MOD4
Seabed Monitoring & Underwater Real-time Footage

- General Specifications
  - Flexible deployment scenarios
  - Depth rated to 3500m
  - Superior stills and streaming video quality
  - Near zero-delay shutter release
  - Unattended time lapse photography
  - Solutions for very low visibility environments

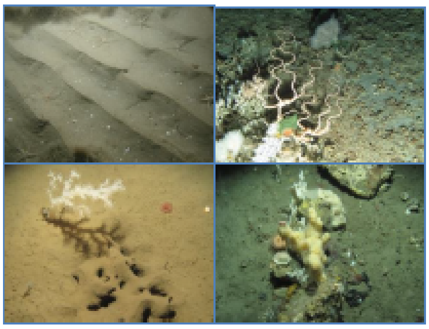
- 4 Camera Configurations
  1. Deepwater real time
  2. Shallow water real time
  3. Ultra deepwater timelapse
  4. Remote timelapse

- 4 Deployment Configurations
  1. Towed system (deep to shallow)
  2. Bed-hop ultra deep water
  3. Remote mooring timelapse
  4. Poor visibility freshwater lens

- Services

Benthic Solutions Ltd have an array of underwater cameras for various deployment scenarious. Our latest development (MOD4) is the most flexible camera to date. For water depths of less than 400m it is capable of communicating with the surface via a multicore umbilical cable, which provides a very high quality live view of the seabed. Zero-delay still images of 24 megapixels can be captured and transmitted to the surface for instant review.

For deeper waters the camera can be controlled via an armoured coax cable, of the type commonly used for towing sidescan sonar. A theoretical maximum cable length of 12km can be used. In this setup, the live feed quality is slightly reduced. To compensate for this an additional 1080p 30fps camera can be added if very high quality seabed video footage is desired.



High output lighting has been developed using the latest LED technology. 2x 2200 lumen lamps provide flood lighting ahead of the camera for video streaming, whilst a multi-head strobe system (up to three heads) can be utilised in TTL configuration to give perfectly exposed under water still images.

Benthic Solutions can also provide different camera frames suitable for seabed towing or 'drop down' use. These can be small and lightweight, or larger with increased ballast for deep water scenarios.

Shipping weight	200kg *
Shipping dimension	2 x 1 x 0.2m *
Specifications	2 x 1 x 1m *

*as multiple configurations are available, values shown indicate the maximum

www.benthicsolutions.com

APPENDIX E – FIELD OPERATIONS AND SURVEY METHODS

Appendix A to D presents a summary of the different equipment and methods employed during the survey field operations. For additional information, please refer to the Environmental Field Report (BSL 2024).

Seabed Photography and Video

Seabed video footage was acquired at 14 locations across the Sea Link Route to provide ground-truthing of sediments indicated in the acoustic data. The 14 camera transects were carried out using MOD4.1 and MOD4.5 camera systems mounted within a BSL freshwater lens equipped with a separate strobe, and LED lamps.

Once at the seabed, the camera was moved along the length of the transect at a speed of 0.3 to 0.5 knots. Still photographs were captured remotely using a surface control unit via a soft towed umbilical to the camera system. The stills were uploaded in real-time and saved to the camera and a laptop via specialist software. Live video footage, overlaid with the date, time, position and site details were viewed in real-time. The live video stream was used to assist with targeting of the stills camera. HD footage was saved internally by the video camera; data was downloaded at the end of each day of camera operations and backed-up onto a hard drive

Grab Sampling

A BSL double grab (dual Van Veen) acquiring 2 x 0.1m^2 samples per deployment was used at 4 sampling locations. Where samples were not acquired due to coarse sediment the Mini-Hammon Grab was used. This occurred at four stations across the site. When using the BSL double grab, two successful deployments were required at each location. Three consecutive 'no sample' deployments were agreed to be the maximum number of attempts at any location before moving on.

Pre-deployment procedures included the cleaning of the inner stainless grab buckets, cable and shackles so that they were generally grease free. Samples were subject to quality control upon recovery and were flagged if they did not meet the following requirements:

- Water above sample is undisturbed;
- Bucket closure complete allowing no sediment washout;
- Sampler access doors had closed properly enclosing the sample;
- No disruption of the sample through striking the side of the vessel;
- Sample was taken within the acceptable target range <10m;
- Sample represented greater than 5L capacity (ca. 40% of the sampler's capacity);
- No hagfish (*Myxine glutinosa*) and/or other mucus coagulants were found in the sample;
- No obvious contamination from equipment or the vessel;
- The sample was acceptable to the principal scientist.

Upon recovery, each sample was inspected, described and photographed prior to processing. Key observations from samples included colour, sediment classification, layering, smell (including the presence of H_2S), obvious fauna, evidence of bioturbation and evidence of anthropogenic debris. Four successful 0.1m^2 replicates were required per station to acquire enough material for three macrofauna replicates and sub-sampling of physico-chemistry from the remaining sample, achieved through two deployments of the double grab and four deployments of the Hamon Grab. The macrofaunal replicates were processed on-board over a 1 over a 5mm and a 0.5mm aperture mesh by BSL scientists using a *Wilson* Auto-siever.

Sample Processing

Field processing was conducted on board by BSL scientists after they had been subjected to the afore mentioned quality control and proclaimed acceptable. Sub-sampling of physico-chemical parameters was undertaken from the grab samples with the following material retrieved from the surface sediments (0-2cm) for later analysis:

1. Hydrocarbons (stored in a pre-washed foil capped glass jar);
2. Heavy & trace metals and Total Organic Carbon & Matter (stored in doubled lined Ziplock plastic bag);
3. Particle size distribution (PSA; stored in doubled lined Ziplock plastic bag).

The preservation of materials was undertaken using standard techniques. All physico-chemical samples were stored in appropriate containers (i.e., glass for hydrocarbons, and plastics for metals and PSA) and immediately frozen and stored (<-18°C) for later transportation (frozen) to the laboratory upon demobilisation. Macrofaunal samples were fixed and stained in 5-10% buffered formalin for storage and transportation. This material will be later transferred to Industrial Methylated Spirit (IMS). All biological samples were double labelled with internal tags.

APPENDIX F – DATA PRESENTATION, LABORATORY AND STATISTICAL ANALYSES

PARTICLE SIZE DISTRIBUTION

Formulae and classifications for particle calculations made are given below:

- **Graphic Mean (M)** - a very valuable measure of average particle size in Phi units (Folk and Ward, 1957).

$$M = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

Where *M = The graphic mean particle size in Phi*
ø = the Phi size of the 16th, 50th and 84th percentile of the sample

Phi and Sieve Apertures with Wentworth Classifications

Microns (µm)		Phi (φ)		Sediment Description	
Aperture	**Sediment Retained**	**Aperture**	**Sediment Retained**		
63000	≥ 63000	-6	<-6	Cobbles & Boulders	Gravel
45000	45000 < 63000	-5.5	-5.5 < -6	Very Coarse Pebble	
31500	31500 < 45000	-5	-5 < -5.5		
22400	22400 < 31500	-4.5	-4.5 < -5	Coarse Pebble	
16000	16000 < 22400	-4	-4 < -4.5		
11200	11200 < 16000	-3.5	-3.5 < -4	Medium Pebble	
8000	8000 < 11200	-3	-3 < -3.5		
5600	5600 < 8000	-2.5	-2.5 < -3	Fine Pebble	
4000	4000 < 5600	-2	-2 < -2.5		
2800	2800 < 4000	-1.5	-1.5 < -2	Very Fine Pebble	
2000	2000 < 2800	-1	-1 < -1.5		
1400	1400 < 2000	-0.5	-0.5 < -1	Very Coarse Sand	Sands
1000	1000 < 1400	0	0 < -0.5		
710	710 < 1000	0.5	0.5 < 0	Coarse Sand	
500	500 < 710	1	1 < 0.5		
355	355 < 500	1.5	1.5 < 1	Medium Sand	
250	250 < 355	2	2 < 1.5		
180	180 < 250	2.5	2.5 < 2	Fine Sand	
125	125 < 180	3	3 < 2.5		
90	90 < 125	3.5	3.5 < 3	Very Fine Sand	
63	63 < 90	4	4 < 3.5		
44	44 < 63	4.5	4.5 < 4	Coarse Silt	Fines (Silts)
31.5	31.5 < 44	5	5 < 4.5		
22	22 < 31.5	5.5	5.5 < 5	Medium Silt	
15.6	15.6 < 22	6	6 < 5.5		
11	11 < 15.6	6.5	6.5 < 6	Fine Silt	
7.8	7.8 < 11	7	7 < 6.5		
5.5	5.5 < 7.8	7.5	7.5 < 7	Very Fine Silt	
3.9	3.9 < 5.5	8	8 < 7.5		
2.8	2.8 < 3.9	8.5	8.5 < 8	Clay	Fines (Clays)
2	2 < 2.8	9	9 < 8.5		
1.4	1.4 < 2	9.5	9.5 < 9		
1	1 < 1.4	10	10 < 9.5		
<1	<1	10.5	≥ 10.5		

- **Sorting (D)** – the inclusive graphic standard deviation of the sample is a measure of the degree of sorting (Table II.II).

$$D = \frac{\varnothing 84 + \varnothing 16}{4} + \frac{\varnothing 95 + \varnothing 5}{6.6}$$

where *D = the inclusive graphic standard deviation*
ø = the Phi size of the 84th, 16th, 95th and 5th percentile of the sample

Sorting Classifications

Sorting Coefficient (Graphical Standard Deviation)	Sorting Classifications
0 < 0.35	Very well sorted
0.35 < 0.50	Well sorted
0.50 < 0.71	Moderately well sorted
0.71 < 1	Moderately sorted
1 < 2	Poorly sorted
2 < 4	Very poorly sorted
4 +	Extremely poorly sorted

- **Skewness (S)** – the degree of asymmetry of a frequency or cumulative curve (Table II.III).

$$S = \frac{\varnothing 84 + \varnothing 16 - (\varnothing 50)}{2(\varnothing 84 - \varnothing 16)} + \frac{\varnothing 95 + \varnothing 5 - 2(\varnothing 50)}{2(\varnothing 95 - \varnothing 5)}$$

where *S = the skewness of the sample*
ø = the Phi size of the 84th, 16th, 50th, 95th and 5th percentile of the sample

Skewness Classifications

Skewness Coefficient	Mathematical Skewness	Graphical Skewness
+1 > +0.30	Strongly positive	Strongly coarse skewed
+0.30 > +0.10	Positive	Coarse skewed
+0.10 > -0.10	Near symmetrical	Symmetrical
-0.10 > -0.30	Negative	Fine skewed
-0.30 > -1	Strongly negative	Strongly fine skewed

- **Graphic Kurtosis (K) –** The degree of peakedness or departure from the 'normal' frequency or cumulative curve.

$$K = \frac{\varnothing 95 - \varnothing 5}{2.44(\varnothing 75 - \varnothing 25)}$$

Where *K = Kurtosis*
ø = the Phi size of the 95th, 5th, 75th and 25th percentile of the sample

Kurtosis Classifications

Kurtosis Coefficient	Kurtosis Classification	Graphical meaning
0.41 < 0.67	Very Platykurtic	Flat-peaked; the ends are better sorted than the centre
0.67 < 0.90	Platykurtic	
0.90 < 1.10	Mesokurtic	Normal; bell shaped curve
1.11 < 1.50	Leptokurtic	Curves are excessively peaked; the centre is better sorted than the ends.
1.50 < 3	Very Leptokurtic	
3 +	Extremely Leptokurtic	

APPENDIX G – SAMPLE LOG SHEETS

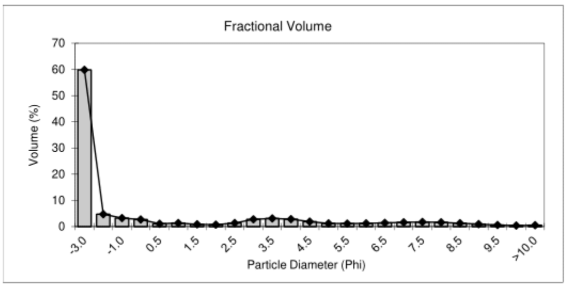
Appendix G -
Sample Log Sheet.xl

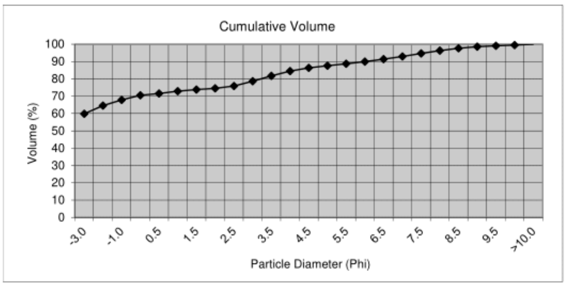
APPENDIX H -CAMERA TRANSECT LOG SHEETS

Appendix H -
Camera Transect Loç

APPENDIX I – PARTICLE SIZE DISTRIBUTION

Sample No.:	A2_ES_01	**Operator**	MilliGasser
Source Data:	2353 Sealink	**Date & Time:**	09/09/2024 11:45





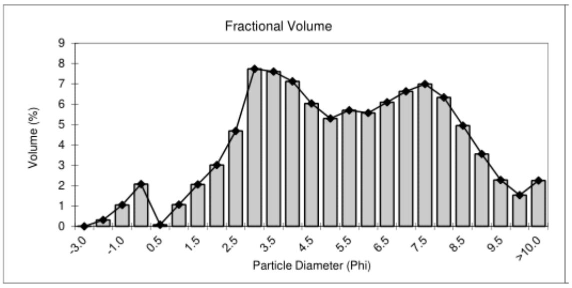
Aperture (mm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.0000	-3.0	59.86	59.86	Pebble
4.0000	-2.0	4.73	64.59	
2.0000	-1.0	3.24	67.83	Granule
1.0000	0.0	2.72	70.55	V.Coarse Sand
0.7100	0.5	1.04	71.59	Coarse Sand
0.5000	1.0	1.32	72.92	
0.3550	1.5	0.89	73.81	Medium Sand
0.2500	2.0	0.71	74.52	
0.1800	2.5	1.33	75.85	Fine Sand
0.1250	3.0	2.76	78.60	
0.0900	3.5	3.07	81.68	V.Fine Sand
0.0630	4.0	2.83	84.51	
0.0440	4.5	1.87	86.37	Coarse Silt
0.0315	5.0	1.18	87.56	
0.0220	5.5	1.17	88.73	Medium Silt
0.0156	6.0	1.23	89.96	
0.0110	6.5	1.42	91.38	Fine silt
0.0078	7.0	1.60	92.97	
0.0055	7.5	1.74	94.71	V.Fine Silt
0.0039	8.0	1.62	96.33	
0.0028	8.5	1.29	97.62	
0.0020	9.0	0.92	98.54	Coarse Clay
0.0014	9.5	0.57	99.10	
0.0010	10.0	0.37	99.48	Medium Clay
<0.001	>10.0	0.53	100.00	Fine Clay

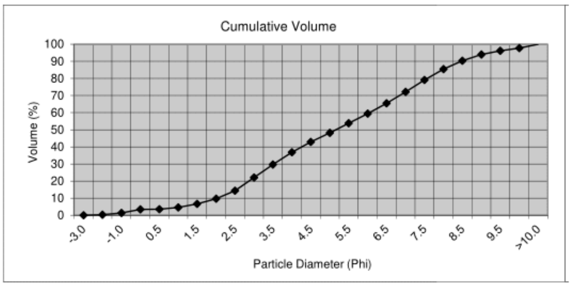
Graphical	mm	StDev (mm)	Phi
Mean (MZ)	3.683	23.887	-1.881
Median	16.335		-4.030
Wentworth Classification		Granule	

Sorting	Value	Inference
Coefficient	4.37	Extremely Poorly Sorted
Skewness	0.71	Very Positive (Coarse)
Kurtosis	0.74	Platykurtic
Fines (%)	15.50%	
Sands (%)	16.68%	
Gravel (%)	67.83%	

BGS Mod. Folk Classification	Muddy Sandy Gravel
Mod. Folk for Habitat Classification	Mixed Sediments

Sample No.:	A2_ES_02	**Operator**	MilliGasser
Source Data:	2353 Sealink	**Date & Time:**	09/09/2024 12:16





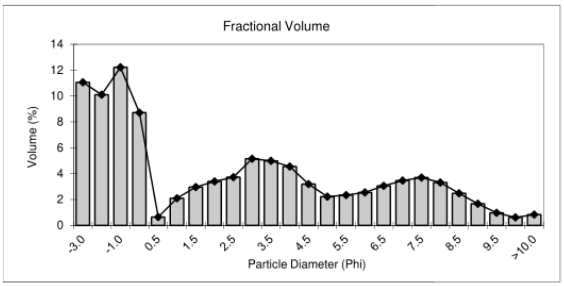
Aperture (mm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.0000	-3.0	0.00	0.00	Pebble
4.0000	-2.0	0.32	0.32	
2.0000	-1.0	1.05	1.37	Granule
1.0000	0.0	2.08	3.45	V.Coarse Sand
0.7100	0.5	0.07	3.52	Coarse Sand
0.5000	1.0	1.07	4.59	
0.3550	1.5	2.06	6.65	Medium Sand
0.2500	2.0	3.01	9.66	
0.1800	2.5	4.69	14.35	Fine Sand
0.1250	3.0	7.73	22.08	
0.0900	3.5	7.60	29.68	V.Fine Sand
0.0630	4.0	7.12	36.80	
0.0440	4.5	6.03	42.83	Coarse Silt
0.0315	5.0	5.30	48.13	
0.0220	5.5	5.70	53.83	Medium Silt
0.0156	6.0	5.57	59.40	
0.0110	6.5	6.10	65.49	Fine silt
0.0078	7.0	6.63	72.12	
0.0055	7.5	6.99	79.11	V.Fine Silt
0.0039	8.0	6.33	85.44	
0.0028	8.5	4.95	90.39	
0.0020	9.0	3.56	93.95	Coarse Clay
0.0014	9.5	2.27	96.22	
0.0010	10.0	1.53	97.75	Medium Clay
<0.001	>10.0	2.25	100.00	Fine Clay

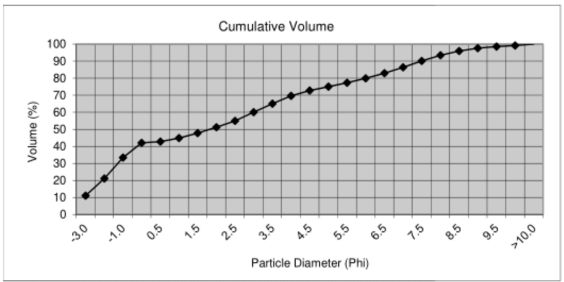
Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.027	0.159	5.195
Median	0.028		5.139
Wentworth Classification		Medium Silt	

Sorting	Value	Inference
Coefficient	2.55	Very Poorly Sorted
Skewness	0.02	Symmetrical
Kurtosis	0.82	Platykurtic
Fines (%)	63.20%	
Sands (%)	35.43%	
Gravel (%)	1.37%	

BGS Mod. Folk Classification	Slightly Gravelly Sandy Mud
Mod. Folk for Habitat Classification	Mud and Sandy Mud

Sample No.:	A2_ES_03	Operator	MilliGasser
Source Data:	2353 Sealink	Date & Time:	09/09/2024 12:36





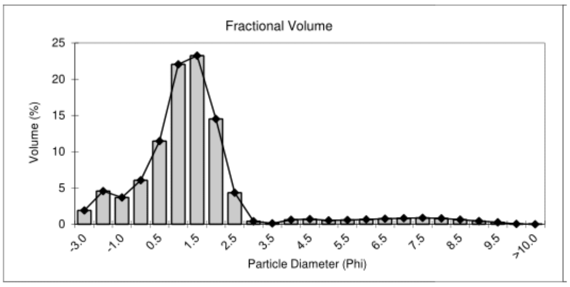
Aperture (mm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.0000	-3.0	11.05	11.05	Pebble
4.0000	-2.0	10.10	21.15	
2.0000	-1.0	12.22	33.37	Granule
1.0000	0.0	8.72	42.09	V.Coarse Sand
0.7100	0.5	0.65	42.73	Coarse Sand
0.5000	1.0	2.10	44.83	
0.3550	1.5	2.96	47.79	Medium Sand
0.2500	2.0	3.39	51.18	
0.1800	2.5	3.73	54.92	Fine Sand
0.1250	3.0	5.15	60.06	
0.0900	3.5	4.99	65.05	V.Fine Sand
0.0630	4.0	4.55	69.61	
0.0440	4.5	3.19	72.80	Coarse Silt
0.0315	5.0	2.22	75.02	
0.0220	5.5	2.34	77.36	Medium Silt
0.0156	6.0	2.55	79.91	
0.0110	6.5	3.05	82.96	Fine silt
0.0078	7.0	3.47	86.43	
0.0055	7.5	3.70	90.13	V.Fine Silt
0.0039	8.0	3.31	93.44	
0.0028	8.5	2.48	95.92	
0.0020	9.0	1.66	97.59	Coarse Clay
0.0014	9.5	0.97	98.55	
0.0010	10.0	0.61	99.17	Medium Clay
<0.001	>10.0	0.84	100.00	Fine Clay

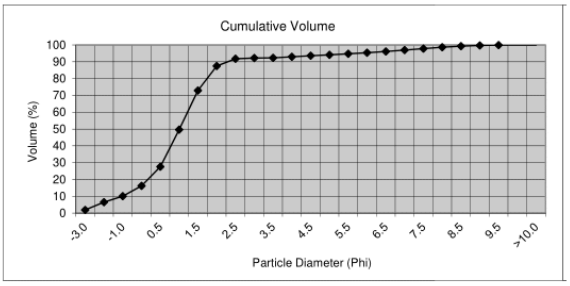
Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.259	4.126	1.949
Median	0.287		1.803
Wentworth Classification	Medium Sand		

Sorting	Value	Inference
Coefficient	4.08	Extremely Poorly Sorted
Skewness	0.08	Symmetrical
Kurtosis	0.71	Platykurtic
Fines (%)	30.39%	
Sands (%)	36.24%	
Gravel (%)	33.37%	

BGS Mod. Folk Classification	Muddy Sandy Gravel
Mod. Folk for Habitat Classification	Mixed Sediments

Sample No.:	A2_ES_04	Operator	MilliGasser
Source Data:	2353 Sealink	Date & Time:	09/09/2024 12:53





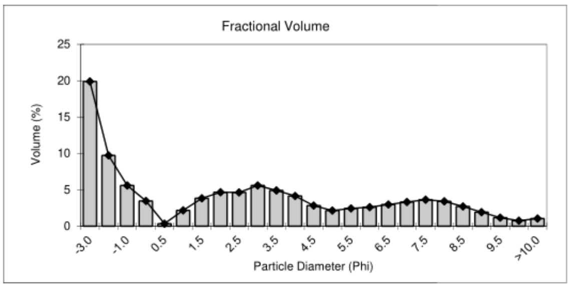
Aperture (mm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.0000	-3.0	1.91	1.91	Pebble
4.0000	-2.0	4.55	6.47	
2.0000	-1.0	3.67	10.14	Granule
1.0000	0.0	6.05	16.19	V.Coarse Sand
0.7100	0.5	11.45	27.64	Coarse Sand
0.5000	1.0	22.04	49.68	
0.3550	1.5	23.23	72.92	Medium Sand
0.2500	2.0	14.52	87.44	
0.1800	2.5	4.35	91.79	Fine Sand
0.1250	3.0	0.40	92.19	
0.0900	3.5	0.13	92.32	V.Fine Sand
0.0630	4.0	0.61	92.93	
0.0440	4.5	0.69	93.62	Coarse Silt
0.0315	5.0	0.54	94.15	
0.0220	5.5	0.58	94.74	Medium Silt
0.0156	6.0	0.65	95.39	
0.0110	6.5	0.75	96.14	Fine silt
0.0078	7.0	0.82	96.95	
0.0055	7.5	0.87	97.82	V.Fine Silt
0.0039	8.0	0.80	98.63	
0.0028	8.5	0.64	99.26	
0.0020	9.0	0.45	99.71	Coarse Clay
0.0014	9.5	0.25	99.96	
0.0010	10.0	0.04	100.00	Medium Clay
<0.001	>10.0	0.00	100.00	Fine Clay

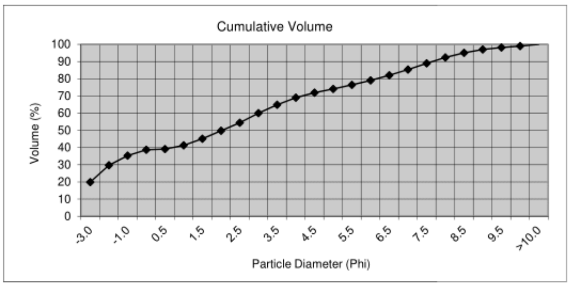
Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.521	1.663	0.941
Median	0.498		1.006
Wentworth Classification	Coarse Sand		

Sorting	Value	Inference
Coefficient	1.70	Poorly Sorted
Skewness	0.03	Symmetrical
Kurtosis	2.78	Very Leptokurtic
Fines (%)	7.08%	
Sands (%)	82.79%	
Gravel (%)	10.14%	

BGS Mod. Folk Classification	Gravelly Sand
Mod. Folk for Habitat Classification	Coarse Sediments

Sample No.:	A3_NS_01	Operator	MilliGasser
Source Data:	2353 Sealink	Date & Time:	09/09/2024 14:45





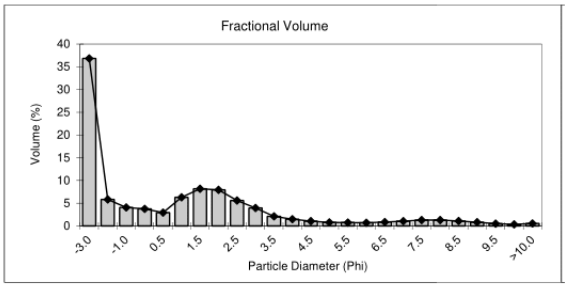
Aperture (mm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.0000	-3.0	19.90	19.90	Pebble
4.0000	-2.0	9.73	29.63	
2.0000	-1.0	5.60	35.23	Granule
1.0000	0.0	3.47	38.71	V.Coarse Sand
0.7100	0.5	0.35	39.06	Coarse Sand
0.5000	1.0	2.18	41.24	
0.3550	1.5	3.83	45.07	Medium Sand
0.2500	2.0	4.66	49.73	
0.1800	2.5	4.64	54.38	Fine Sand
0.1250	3.0	5.59	59.96	
0.0900	3.5	4.90	64.87	V.Fine Sand
0.0630	4.0	4.16	69.02	
0.0440	4.5	2.84	71.87	Coarse Silt
0.0315	5.0	2.15	74.01	
0.0220	5.5	2.43	76.44	Medium Silt
0.0156	6.0	2.60	79.04	
0.0110	6.5	2.98	82.02	Fine silt
0.0078	7.0	3.32	85.34	
0.0055	7.5	3.63	88.97	V.Fine Silt
0.0039	8.0	3.41	92.38	
0.0028	8.5	2.72	95.10	
0.0020	9.0	1.93	97.03	Coarse Clay
0.0014	9.5	1.18	98.21	
0.0010	10.0	0.75	98.96	Medium Clay
<0.001	>10.0	1.05	100.00	Fine Clay

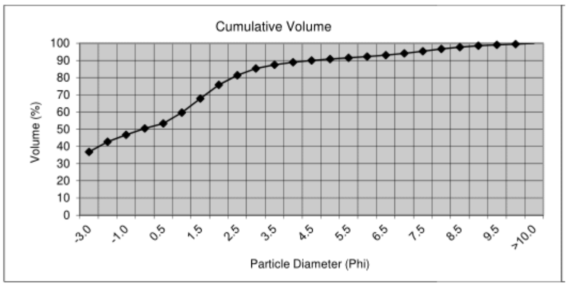
Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.278	5.877	1.847
Median	0.246		2.023
Wentworth Classification	Medium Sand		

Sorting	Value	Inference
Coefficient	4.37	Extremely Poorly Sorted
Skewness	0.00	Symmetrical
Kurtosis	0.65	Very Platykurtic
Fines (%)	30.98%	
Sands (%)	33.79%	
Gravel (%)	35.23%	

BGS Mod. Folk Classification	Muddy Sandy Gravel
Mod. Folk for Habitat Classification	Mixed Sediments

Sample No.:	A4_GLC_01	Operator	MilliGasser
Source Data:	2353 Sealink	Date & Time:	09/09/2024 15:19





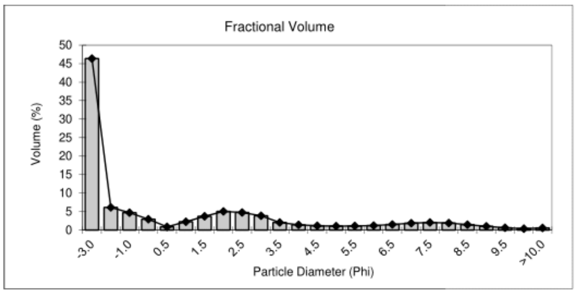
Aperture (mm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.0000	-3.0	36.84	36.84	Pebble
4.0000	-2.0	5.82	42.66	
2.0000	-1.0	4.05	46.71	Granule
1.0000	0.0	3.75	50.46	V.Coarse Sand
0.7100	0.5	2.94	53.40	Coarse Sand
0.5000	1.0	6.28	59.69	
0.3550	1.5	8.18	67.87	Medium Sand
0.2500	2.0	7.94	75.80	
0.1800	2.5	5.59	81.39	Fine Sand
0.1250	3.0	3.95	85.35	
0.0900	3.5	2.11	87.46	V.Fine Sand
0.0630	4.0	1.49	88.95	
0.0440	4.5	1.06	90.02	Coarse Silt
0.0315	5.0	0.77	90.79	
0.0220	5.5	0.73	91.52	Medium Silt
0.0156	6.0	0.71	92.23	
0.0110	6.5	0.85	93.08	Fine silt
0.0078	7.0	1.05	94.13	
0.0055	7.5	1.27	95.40	V.Fine Silt
0.0039	8.0	1.29	96.69	
0.0028	8.5	1.10	97.79	
0.0020	9.0	0.82	98.61	Coarse Clay
0.0014	9.5	0.52	99.13	
0.0010	10.0	0.34	99.47	Medium Clay
<0.001	>10.0	0.53	100.00	Fine Clay

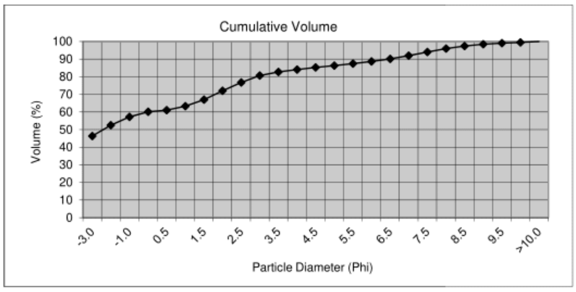
Graphical	mm	StDev (mm)	Phi
Mean (MZ)	1.533	12.848	-0.617
Median	1.123		-0.167
Wentworth Classification	V. Coarse Sand		

Sorting	Value	Inference
Coefficient	3.67	Very Poorly Sorted
Skewness	0.02	Symmetrical
Kurtosis	0.84	Platykurtic
Fines (%)	11.05%	
Sands (%)	42.24%	
Gravel (%)	46.71%	

BGS Mod. Folk Classification	Muddy Sandy Gravel
Mod. Folk for Habitat Classification	Mixed Sediments

Sample No.:	A4_GLC_03	Operator	MilliGasser
Source Data:	2353 Sealink	Date & Time:	09/09/2024 15:39





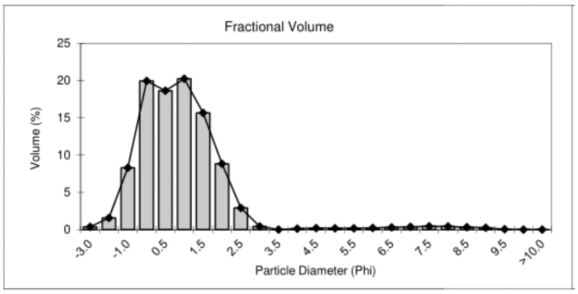
Aperture (mm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.0000	-3.0	46.36	46.36	Pebble
4.0000	-2.0	6.14	52.50	
2.0000	-1.0	4.72	57.22	Granule
1.0000	0.0	2.91	60.14	V.Coarse Sand
0.7100	0.5	0.86	60.99	Coarse Sand
0.5000	1.0	2.27	63.26	
0.3550	1.5	3.73	66.99	Medium Sand
0.2500	2.0	5.04	72.03	
0.1800	2.5	4.73	76.76	Fine Sand
0.1250	3.0	3.89	80.65	
0.0900	3.5	2.03	82.69	V.Fine Sand
0.0630	4.0	1.39	84.08	
0.0440	4.5	1.17	85.25	Coarse Silt
0.0315	5.0	1.06	86.31	
0.0220	5.5	1.14	87.44	Medium Silt
0.0156	6.0	1.20	88.65	
0.0110	6.5	1.51	90.15	Fine silt
0.0078	7.0	1.83	91.99	
0.0055	7.5	2.06	94.04	V.Fine Silt
0.0039	8.0	1.90	95.95	
0.0028	8.5	1.46	97.41	
0.0020	9.0	1.01	98.42	Coarse Clay
0.0014	9.5	0.61	99.02	
0.0010	10.0	0.40	99.43	Medium Clay
<0.001	>10.0	0.58	100.00	Fine Clay

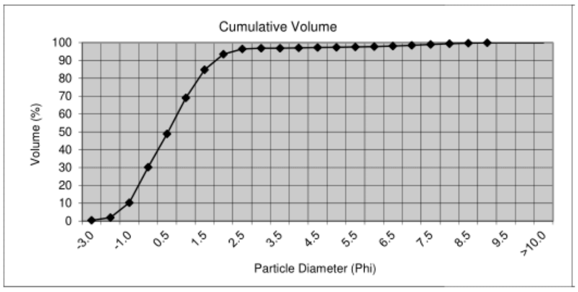
Graphical	mm	StDev (mm)	Phi
Mean (MZ)	2.161	15.208	-1.111
Median	5.630		-2.493
Wentworth Classification	Granule		

Sorting	Value	Inference
Coefficient	4.14	Extremely Poorly Sorted
Skewness	0.53	Very Positive (Coarse)
Kurtosis	0.78	Platykurtic
Fines (%)	15.93%	
Sands (%)	26.85%	
Gravel (%)	57.22%	

BGS Mod. Folk Classification	Muddy Sandy Gravel
Mod. Folk for Habitat Classification	Mixed Sediments

Sample No.:	A5_OPB_01	Operator	MilliGasser
Source Data:	2353 Sealink	Date & Time:	09/09/2024 15:58





Aperture (mm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.0000	-3.0	0.38	0.38	Pebble
4.0000	-2.0	1.57	1.96	
2.0000	-1.0	8.29	10.24	Granule
1.0000	0.0	19.94	30.18	V.Coarse Sand
0.7100	0.5	18.64	48.83	Coarse Sand
0.5000	1.0	20.24	69.07	
0.3550	1.5	15.66	84.73	Medium Sand
0.2500	2.0	8.82	93.55	
0.1800	2.5	2.92	96.47	Fine Sand
0.1250	3.0	0.41	96.88	
0.0900	3.5	0.00	96.88	V.Fine Sand
0.0630	4.0	0.13	97.01	
0.0440	4.5	0.21	97.22	Coarse Silt
0.0315	5.0	0.17	97.39	
0.0220	5.5	0.19	97.57	Medium Silt
0.0156	6.0	0.23	97.80	
0.0110	6.5	0.31	98.11	Fine silt
0.0078	7.0	0.38	98.49	
0.0055	7.5	0.44	98.94	V.Fine Silt
0.0039	8.0	0.42	99.36	
0.0028	8.5	0.34	99.70	
0.0020	9.0	0.25	99.94	Coarse Clay
0.0014	9.5	0.06	100.00	
0.0010	10.0	0.00	100.00	Medium Clay
<0.001	>10.0	0.00	100.00	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.756	1.034	0.404
Median	0.698		0.519
Wentworth Classification	Coarse Sand		

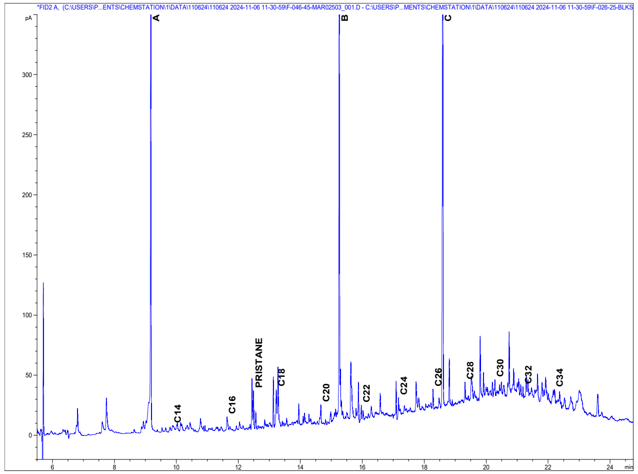
Sorting	Value	Inference
Coefficient	1.15	Poorly Sorted
Skewness	-0.14	Negative (Fine)
Kurtosis	1.07	Mesokurtic
Fines (%)	2.99%	
Sands (%)	86.77%	
Gravel (%)	10.24%	

BGS Mod. Folk Classification	Gravelly Sand
Mod. Folk for Habitat Classification	Coarse Sediments

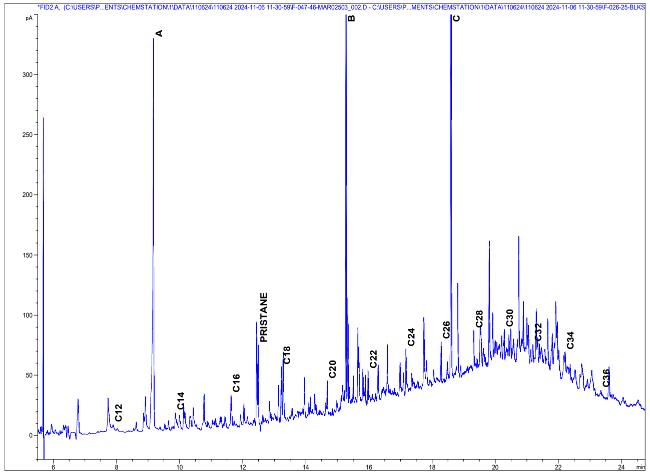
APPENDIX J – TOTAL ALIPHATIC CONCENTRATIONS BY STATION (µG.KG^{-1})

Station	A2_ES_01	A2_ES_02	A2_ES_03	A2_ES_04	A3_NS_01	A4_GLC_01	A4_GLC_03	A5_OPB_01
nC10	<1	<1	<1	<1	<1	<1	<1	<1
nC11	<1	<1	<1	<1	<1	<1	<1	<1
nC12	<1	<1	<1	<1	<1	<1	<1	<1
nC13	5.24	19.9	8.11	<1	<1	<1	<1	<1
nC14	3.49	16.3	4.60	<1	<1	<1	<1	<1
nC15	8.96	25.5	23.6	<1	<1	<1	<1	<1
nC16	9.47	26.9	12.1	<1	<1	<1	2.10	<1
nC17	35.7	93.3	46.3	2.92	20.5	9.19	16.2	<1
Pristane	26.9	78.5	24.9	1.82	10.3	4.58	22.9	<1
nC18	19.8	25.9	14.6	<1	8.72	3.61	2.65	<1
Phytane	8.70	21.6	11.1	<1	5.60	<1	<1	<1
nC19	16.7	23.9	12.7	<1	7.10	2.25	5.72	<1
nC20	12.7	16.5	6.15	<1	5.26	1.58	2.16	<1
nC21	16.2	15.0	6.96	<1	1.90	<1	<1	<1
nC22	7.41	18.1	5.67	<1	3.19	2.21	2.05	<1
nC23	13.0	26.1	9.57	1.63	4.25	2.24	3.82	<1
nC24	12.5	26.7	13.3	<1	4.71	2.43	3.48	<1
nC25	25.2	56.5	20.4	1.60	12.8	4.27	10.8	<1
nC26	12.9	29.6	15.0	1.45	9.41	5.02	4.40	<1
nC27	26.4	58.9	29.0	7.14	18.1	8.86	17.7	<1
nC28	15.3	29.0	12.8	<1	4.48	2.67	4.98	<1
nC29	42.7	89.4	41.6	<1	35.9	15.9	27.0	3.03
nC30	9.22	16.6	10.9	1.83	11.6	3.89	12.3	1.58
nC31	30.4	71.3	38.7	<1	20.5	4.24	7.62	2.45
nC32	6.71	6.58	3.75	<1	2.83	<1	2.07	<1
nC33	12.3	29.9	10.3	<1	8.06	<1	7.70	<1
nC34	2.02	7.41	2.79	<1	1.80	<1	1.86	<1
nC35	2.17	4.18	4.30	<1	1.72	<1	1.33	<1
nC36	<1	1.65	2.14	<1	3.01	1.94	2.27	<1
nC37	<1	6.62	<1	<1	<1	<1	<1	<1
THC	**8812**	**17648**	**10088**	**1350**	**5338**	**3612**	**6898**	**661**
Total n-alkanes	**347**	**742**	**356**	**16.6**	**186**	**70.3**	**138**	**7.06**

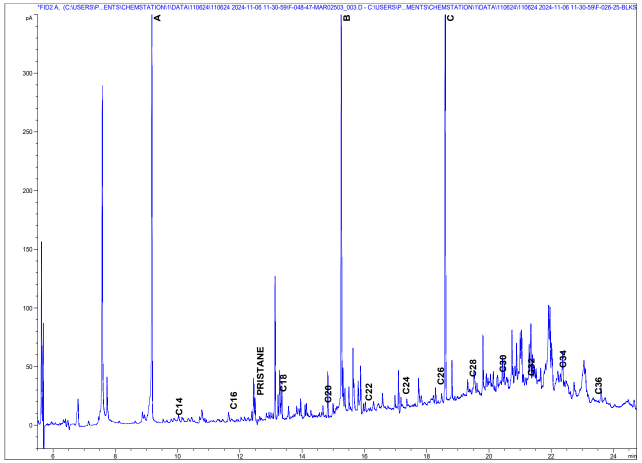
APPENDIX K – GC FID TRACES (SATURATES)



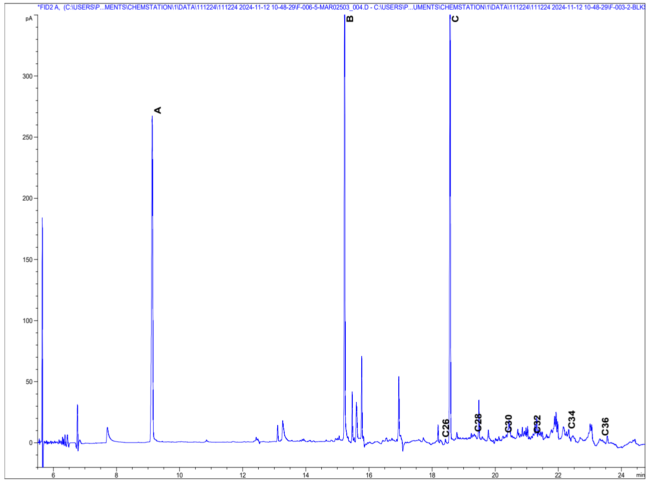
A2_ES_01



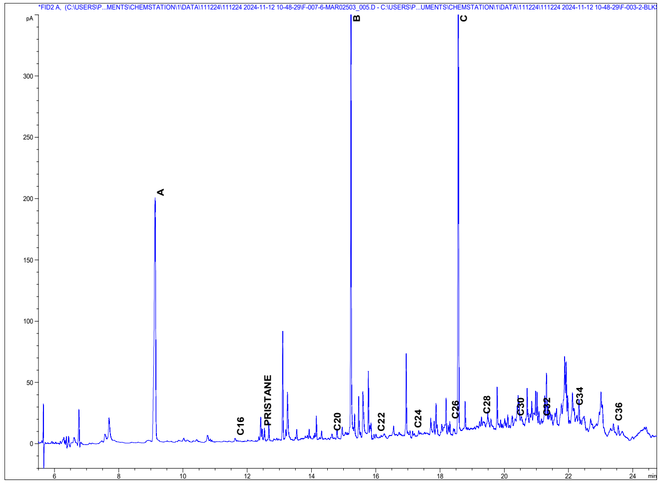
A2_ES_02



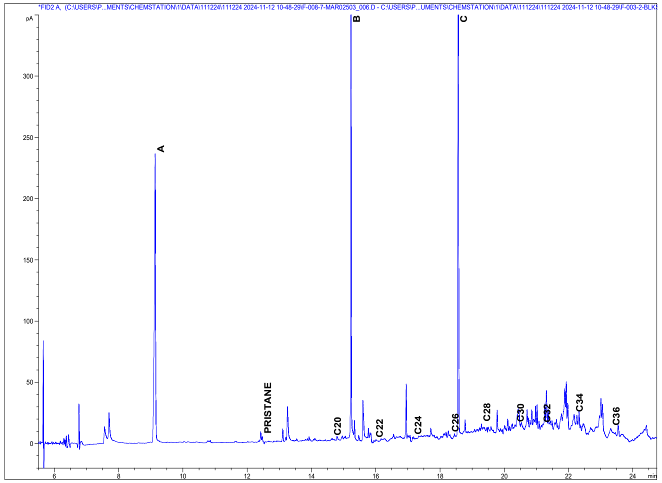
A2_ES_03



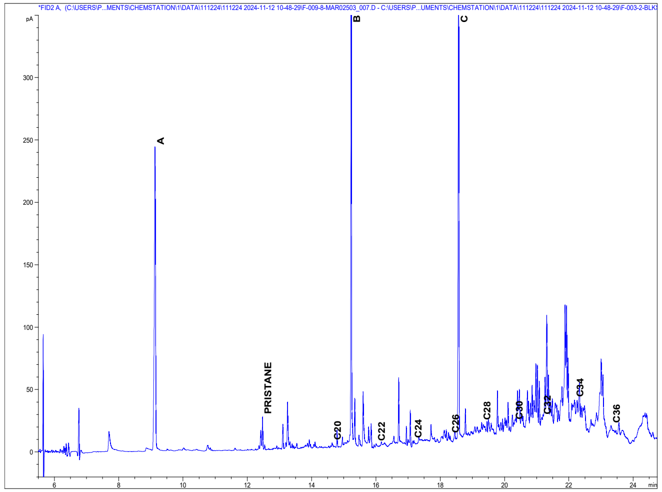
A2_ES_04



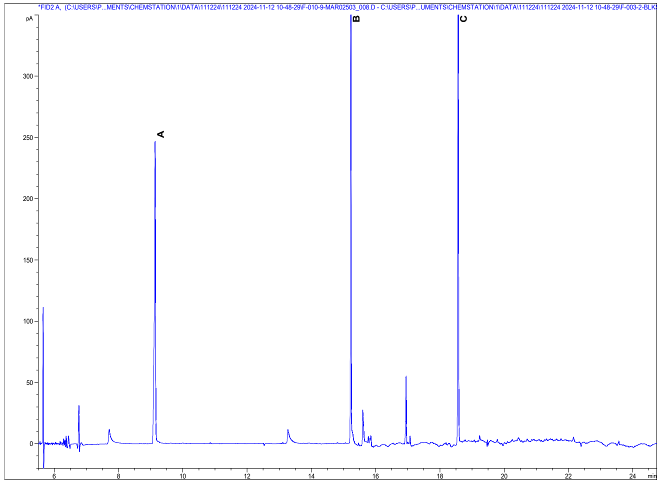
A3_NS_01



A4_GLC_01



A4_GLC_03



A5_OPB_01

APPENDIX L – POLYCYLIC AROMATIC HYDROCARBON CONCENTRATIONS (µG.KG^{-1})

Station	A2_ES_01	A2_ES_02	A2_ES_03	A2_ES_04	A3_NS_01	A4_GLC_01	A4_GLC_03	A5_OPB_01
Naphthalene	7.8	17.4	5.7	<1	2.9	1.9	2.8	<1
C1 Naphthalenes	25.0	57.6	19.8	2.3	7.9	5.1	3.9	<1
C2 Naphthalenes	24.4	57.3	18.8	2.3	9.2	5.5	6.9	<1
C3 Naphthalenes	21.3	55.6	17.3	2.2	8.1	4.4	4.2	<1
C4 Naphthalenes	9.5	26.4	7.5	<1	3.1	2.3	1.9	<1
Sum Naphthalenes	88.0	214.4	69.2	6.8	31.3	19.1	19.7	0.0
Phenanthrene / Anthracene	23.7	34.1	19.5	1.4	6.6	2.8	3.6	0.0
C1 178	16.1	38.2	14.9	1.5	6.8	3.7	5.3	<1
C2 178	13.6	39.7	11.9	1.4	5.3	3.3	3.4	<1
C3 178	9.0	23.7	7.6	<1	3.1	2.0	2.2	<1
Sum 178	62.3	135.7	53.9	4.4	21.8	11.8	14.4	0.0
Dibenzothiophene	1.6	2.7	<1	<1	<1	<1	<1	<1
C1 Dibenzothiophenes	2.3	5.1	2.0	<1	<1	<1	<1	<1
C2 Dibenzothiophenes	2.7	7.0	2.3	<1	<1	<1	<1	<1
C3 Dibenzothiophenes	1.8	4.9	1.6	<1	<1	<1	<1	<1
Sum Dibenzothiophenes	8.3	19.7	6.0	0.0	0.0	0.0	0.0	0.0
Fluoranthene / Pyrene	46.1	70.3	42.5	0.0	16.1	7.8	13.5	6.7
C1 202	17.0	42.1	17.5	1.3	6.5	3.2	4.4	2.4
C2 202	17.3	42.1	15.1	<1	6.4	3.2	4.3	<1
C3 202	14.3	27.3	9.4	<1	4.1	2.5	2.7	<1
Sum 202	94.7	181.7	84.5	1.3	33.2	16.7	25.0	9.1
Benzanthracene / Chrysene	21.2	42.4	23.4	0.0	8.4	3.6	6.4	4.0
C1 228	12.8	27.1	10.9	<1	4.5	2.1	3.0	1.4
C2 228	10.4	23.5	9.3	<1	4.1	2.0	2.4	<1
Sum 228	44.4	92.9	43.6	0.0	17.1	7.7	11.8	5.4
Benzofluoranthenes / Benzopyrenes	46.0	97.9	48.8	0.0	19.3	8.4	15.6	6.0
C1 252	17.9	44.3	19.7	<1	7.2	3.6	5.2	1.9
C2 252	12.0	41.1	12.5	<1	4.0	2.4	3.1	<1
Sum 252	75.9	183.3	80.9	0.0	30.5	14.4	23.8	8.0

Station	A2_ES_01	A2_ES_02	A2_ES_03	A2_ES_04	A3_NS_01	A4_GLC_01	A4_GLC_03	A5_OPB_01
Aranthanthrenes / Indenopyrene / Benzoperylene	23.5	52.5	25.0	0.0	7.8	3.9	7.0	0.0
C1 276	4.4	10.7	4.8	<1	1.5	<1	<1	<1
C2 276	5.2	13.6	4.8	<1	1.5	<1	1.5	<1
Sum 276	33.2	76.7	34.6	0.0	10.7	3.9	8.5	0.0
Sum of all PAHs	**406.8**	**904.4**	**372.7**	**12.5**	**144.5**	**73.6**	**103.4**	**22.5**
Sum of NPD fraction	**158.6**	**369.7**	**129.1**	**11.1**	**53.1**	**30.9**	**34.2**	**0.0**

APPENDIX M – POLYCYCLIC AROMTIC HYDROCARBON CONCENTRATIONS: EPA 19 (µG.KG^{-1})

Station	A2_ES_01	A2_ES_02	A2_ES_03	A2_ES_04	A3_NS_01	A4_GLC_01	A4_GLC_03	A5_OPB_01
Naphthalene	7.83	17.40	5.74	<1	2.89	1.88	2.83	<1
Acenaphthylene	1.81	2.27	<1	<1	<1	<1	<1	<1
Acenaphthene	<1	2.50	<1	<1	<1	<1	<1	<1
Fluorene	2.86	5.80	2.29	<1	<1	<1	<1	<1
Phenanthrene	21.24	28.49	16.34	1.44	6.65	2.84	3.62	<1
Dibenzothiophene	1.57	2.65	<1	<1	<1	<1	<1	<1
Anthracene	2.48	5.65	3.14	<1	<1	<1	<1	<1
Fluoranthene	24.76	37.01	22.88	<1	8.54	3.98	6.97	3.10
Pyrene	21.33	33.30	19.63	<1	7.61	3.79	6.54	3.63
Benzo[a]anthracene	8.62	18.44	10.34	<1	3.51	1.48	2.68	1.77
Chrysene	12.54	23.92	13.06	<1	4.91	2.09	3.71	2.21
Benzo[b]fluoranthene	13.27	28.61	13.47	<1	5.70	2.15	4.11	1.71
Benzo[k]fluoranthene	11.18	23.62	12.14	<1	4.83	2.52	4.33	1.30
Benzo[e]pyrene	10.21	21.82	10.23	<1	4.16	1.95	3.34	1.29
Benzo[a]pyrene	11.36	23.86	12.91	<1	4.60	1.77	3.82	1.71
Perylene	4.89	10.76	5.08	<1	1.96	<1	1.98	<1
Indeno[123,cd]pyrene	9.84	22.07	11.13	<1	3.55	1.81	3.30	<1
Dibenzo[a,h]anthracene	1.81	4.32	2.17	<1	<1	<1	<1	<1
Benzo[ghi]perylene	11.89	26.08	11.75	<1	4.28	2.10	3.70	<1

APPENDIX N – MACROFAUNAL SPECIES LISTS

Infauna

Appendix N -
Infauna.xlsx

Epifauna and Miscellaneous

Appendix N -
Epifauna and Misc.x

APPENDIX O – REEF AND MUSSEL BED ASSESSMENT LOGSHEET

Geogenic Reef

Appendix O -
Geogenic Reef Asse:

Sabellaria spinulosa Biogenic Reef

Appendix O -
Biogenic Sabellaria :

Mytilus edulis Biogenic Reef

Appendix O -
Mytilus edulis Reef /

APPENDIX P – SAMPLE AND SEABED PHOTOGRAPHS

Appendix P -
Sample and Seabed

APPENDIX Q – SPEARMAN'S CORRELATION

PDF

Appendix Q -
Spearman's Correlat

APPENDIX R – ENVIRONMENTAL CONCESSION FORMS

Appendix R -
Environmental Conc

APPENDIX S – MANAGEMENT OF CHANGE

Appendix S -
Management of Cha

APPENDIX T – CORE ADDENDUM

P2097-010-REP-005
- Core Addendum R

APPENDIX U – SERVICE WARRANTY

This report, with its associated works and services, has been designed solely to meet the requirements of the contract agreed with you, our client. If used in other circumstances, some or all the results may not be valid, and we can accept no liability for such use. Such circumstances include different or changed objectives, use by third parties, or changes to, for example, site conditions or legislation occurring after completion of the work. In case of doubt, please consult Benthic Solutions Limited. Please note that all charts, where applicable should not be used for navigational purposes.

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