Improvement Programme for England's Natura 2000 Sites (IPENS) – Planning for the Future IPENS021

Drigg Coast SAC, Ravenglass Estuary Intertidal Survey

Drigg Coast Special Area of Conservation (SAC)

First published 16 July 2015

www.gov.uk/government/publications/improvement-programme-for-englands-natura-2000-sites-ipens

This project is part of the IPENS programme (LIFE11NAT/UK/000384IPENS) which is financially supported by LIFE, a financial instrument of the European Community'.

Foreword

The **Improvement Programme for England's Natura 2000 sites (IPENS)**, supported by European Union LIFE+ funding, is a new strategic approach to managing England's Natura 2000 sites. It is enabling Natural England, the Environment Agency, and other key partners to plan what, how, where and when they will target their efforts on Natura 2000 sites and areas surrounding them.

As part of the IPENS programme, we are identifying gaps in our knowledge and, where possible, addressing these through a range of evidence projects. The project findings are being used to help develop our Theme Plans and Site Improvement Plans. This report is one of the evidence project studies we commissioned.

An intertidal survey was commissioned for Drigg Coast Special Areas of Conservation (SAC) in order to gather data on the distribution, extent and range of communities in the intertidal mud and sand flats habitats within the site to provide evidence for assessing changes within the site and to be able to monitor future changes. Anthropogenic influences on the site's features were also recorded.

A total of 10 EUNIS biotopes were recorded across the intertidal area of the site. Sediment composition across the study area was dominated by sand fractions, whilst silt and gravel fractions were found in high proportions and a number of sample locations. A general pattern of distribution of sediment deposits across the site showed a higher proportion of silt furthest up in the estuary, with gravel fractions dominating mid estuary areas and the mouth of the estuary dominated by sand fractions. Infaunal benthic sampling identified a range of benthic invertebrates with a total of 78 taxa and 14,884 individuals identified. A contaminant analysis demonstrated that all levels of contaminants were below the Effects Range Low (ERL) and Environmental Assessment Criteria (EAC) thresholds prescribed by the OSPAR Commission Coordinated Environmental Monitoring Programme report.

The report notes that there was no evidence of significant anthropogenic impacts on the intertidal features, however, anthropogenic disturbance across the full extent of the site were recorded. This included disturbance from commercial and recreational boats moored on the foreshore around Ravenglass; littering of anthropogenic debris such as fishing nets and bottles; as well as the use of the foreshore/beaches for recreational purposes such as dog walking. Potential impacts from arable land adjacent to the estuary were noted where periods of heavy or prolonged rainfall may cause excess nutrients to be flushed into the estuary.

The key audience for this work, which is of a technical nature, is the staff within Natural England and land managers and should be used to inform current site condition and future management requirements.

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ISBN 978-1-78354-222-2

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REPORT WARRANTY

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DRIGG COAST SAC, RAVENGLASS ESTUARY INTERTIDAL SURVEY : FINAL REPORT

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Report Proofing:	Daniel Brutto		26/02/2014
Report Authorisation:	Daniel Brutto		26/02/2014
Report Status:	Final		
Issue Date:	26/02/2014		

STATEMENT

Marine Ecological Surveys Limited (MESL) was commissioned by Natural England to conduct an intertidal survey across the Drigg Coast Special Area of Conservation (SAC).

The Drigg Coast and Ravenglass estuary provides an important UK example of a small bar-built estuary complex, exposed to minimal anthropogenic pressures. The site, located in the west of Cumbria, adjoins the southern portion of the Cumbria Coast recommended Marine Conservation Zone (rMCZ) and is itself notified as a Site of Special Scientific Interest (SSSI) and designated as a SAC.

The survey undertaken by MESL in October 2013 involved Phase I biotope mapping of intertidal habitats, Phase II intertidal core sampling at 21 stations, and sediment surface scrapes for contaminant analysis at 4 locations. The purpose of the survey was to gather data on the presence and extent of important intertidal mud and sand flats habitats within the site and provide data to inform the condition monitoring of a number of the SSSI and SAC sub-features.

MESL have compiled this report to outline the methodology and results of the Drigg Coast and Ravenglass intertidal sediments survey, carried out between the 2nd and 10th of October 2013.

MESL is a member of the Institute of Environmental Management and Assessment (IEMA) and is a leading participant in the National Marine Biological Analytical Quality Control (NMBAQC) scheme.

iema
INSTITUTE OF ENVIRONMENTAL MANAGEMENT & ASSESSMENT

NMBAQC SCHEME

Marine Ecological Surveys Limited
26 February 2014

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NON-TECHNICAL SUMMARY

Marine Ecological Surveys Limited (MESL) conducted an intertidal survey of the intertidal mud and sand flats habitats across the Drigg Coast SAC between the 2nd and 10th of October 2013.

The objective of the survey was to identify and map the extent, distribution and characterising communities of intertidal mud and sand flats habitats, noting the presence of any nationally rare or specialised biotopes. Additional information on anthropogenic influences on the site's features was recorded.

The key findings of the report are as follows:

- During the Drigg Coast Special Areas of Conservation (SAC) survey of intertidal sediments a total of 10 EUNIS biotopes were recorded across the intertidal area of interest. The most frequently recorded biotopes across the area were; 'Polychaetes in littoral fine sand' (A2.231), 'Estuarine coarse sediment shores' (A2.12), and 'Polychaete/oligochaete-dominated upper estuarine mud shores' (A2.32). The habitat of conservation importance 'Peat exposure' was identified on the Drigg Coast portion of the site.

- A general pattern in the distribution of the sediment deposits across the Drigg Coast SAC, was that the stations furthest up the estuary had higher proportions of silt, stations found in the mid estuary were generally dominated by gravel fractions and the mouth of the estuary was almost entirely comprised of sand fractions.

- A range of benthic invertebrate species were recorded across the Drigg Coast SAC; a total of 78 taxa and 14884 individuals were identified. The mean number of taxa recorded per sample was 7.1 and the mean number of organisms per sample was 141.8.

- Taxa belonging to the Phylum Annelida were the most important in terms of both abundance and diversity, representing 38% of the total abundance and 41% of the taxa sampled.

- Mollusca represented 85% of the total sampled biomass of the site, of which 77% was contributed by the two bivalves *Mytilus edulis* and *Cerastoderma edule.*

- The most abundant taxon was the phylum Nematoda, which accounted for approximately 26% of all fauna sampled, *Corrophium volutator* was only slightly less abundant representing 24%. The top ten most abundant species accounted for over 92% of the total faunal abundance.

- *'Ceramium* sp. and piddocks on eulittoral fossilised peat', a habitat of conservation interest falling into the category of 'Nationally and more nationally important communities' was recorded across the Drigg Coast portion of site.

- There was no evidence of significant anthropogenic impact on intertidal features that were targeted during this study.

- The contaminants analysis demonstrated that all levels of contaminants were below the ERL and EAC thresholds prescribed by the OSPAR CEMP report.

A. INTRODUCTION

Natural England commissioned an intertidal survey of the Drigg Coast SAC, with the intent to gather data on the distribution, extent and range of communities in the intertidal mud and sand flats habitats across the area of interest.

The survey was designed to gather evidence to help inform the condition monitoring of a number of the Site of Special Scientific Interest (SSSI) units and Special Areas of Conservation (SAC) sub-features.

Figure 1 shows the Drigg Coast SAC, the area of interest for this project.

A.1. Background to the Study

The Drigg Coast and Ravenglass estuary provides an important UK example of a small bar-built estuary complex, exposed to minimal anthropogenic pressures. The site, located in the west of Cumbria, adjoins to the southern portion of the Cumbria Coast rMCZ and itself is notified as a Site of Special Scientific Interest (SSSI) and designated as a Special Area of Conservation (SAC).

The estuary is fed by three rivers (the Irt, Mite and Esk) that converge to the south west of Ravenglass and discharge through a narrowed mouth due to large sand and shingle spits. Historic surveys have shown that the sediment deposits of the Rivers Irt and Mite are largely dominated by mud/silt fractions whilst those of the Esk have higher proportions of sand fractions.

The SAC hosts a number of important Annex 1 habitats, of which the main coastal elements covered by this project are, Estuaries and Mudflats and Sandflats not covered by seawater at low tide.

Historic intertidal survey data of the Ravenglass estuary are limited to Covey & Davies[1] (1989) and Covey[2] (1998), representing NCC and MNCR survey reports respectively.

Reporting in 1989, Covey and Davies described the upper reaches of the Esk estuary as being composed of very fine sand (70%) and silt (30%), with an anoxic layer recorded near the surface. The infaunal communities were reported to be dominated by *Arenicola marina*, *Corophium volutator* and *Eurydice pulchra.*

The 1998 MNCR survey reported on the estuary that the mid and upper reaches of the Esk and the majority of the Mite and Irt estuaries were dominated by fine, sandy mud deposits inhabitated by *Hediste diversicolor* communities.

Most recently in 2013, a biotope map was produced for the adjoining Cumbria Coast rMCZ, which provides a 1km overlap of the Drigg Coast SAC. This showed that the outer reaches of the estuary were dominated by the biotope Polychaete/amphipod-dominated fine sand shores (A2.23).

[1] Covey, R., & Davies, J. (1989) Littoral survey of South Cumbria (Barrow-in-Furness to St Bees Head). Nature Conservancy Council, CSD Report, No. 985

[2] Covey, R. (1998). MNCR Sector 11. Liverpool Bay and the Solway Firth: Area Summaries. Peterborough, JNCC. (Coasts and Seas of the UK.MNCR Series)

A.2. Aims and Objectives

The survey of intertidal sediments within the Drigg Coast SAC had three distinct components with specific objectives:

1. **Broad scale Phase I biotope survey of intertidal sediments**
   To identify and map the extent and distribution of intertidal mud and sand flats habitats within the area of interest.

2. **Phase II Infaunal Sampling**
   To acquire standardised intertidal samples for infaunal and Particle Size Analysis (PSA) from stations dispersed across 7 transects throughout the SAC.

3. **Contaminant sediment surface scrapes**
   To obtain sediment surface scrapes for both heavy metals and organic contaminants analysis.

This report documents the above objectives and the results act as a preliminary baseline in order to facilitate future condition assessment. Information on the following is presented within this report:

- The composition and biomass of the benthic biological communities that occur across the survey area and the key characterising taxa which occur within each community type.

- The distribution of sediment types across the survey area and the relationship between sediments and benthic community composition.

- The levels of TBT, heavy metals and organic contaminants found across the site, with comparisons against OSPAR CEMP thresholds.

B. METHODOLOGY

MESL undertook the Drigg Coast SAC assessment in a single survey conducted between the 2nd and 10th of October, 2013.

The survey was undertaken on foot and access to the foreshore was ascertained via public rights of way. The survey team comprised two experienced MESL staff. The methods and techniques used were in accordance with the guidance outlined in the CSM Guidance[3], Marine Monitoring Handbook[4] and the CCW Handbook for Marine Intertidal Phase I Survey and Mapping[5] .

Due to the inherently dangerous and dynamic nature of the environment, risk assessments produced for the survey were provided to Natural England prior to the surveys being undertaken and surveyors were required to read this in full prior to the survey. Due to the potential for unforeseen problems, risk assessments were dynamic, with continual assessments of potential dangers and actions made where necessary by surveyors to reduce risk throughout the survey.

Additionally, a Project Plan[6] for the Drigg Coast and Ravenglass Estuary intertidal survey was prepared by MESL and approved by Natural England prior to the commencement of field operations.

[3] Joint Nature Conservation Commitee (JNCC). (2004) Common Standards Monitoring Guidance for Littoral Sedimens Habitats. 34pp.
[4] Joint Nature Conservation Commitee (JNCC). (2001) Marine Monitoring Handbook. 405pp.
[5] Wyn, G., Brazier, P., Birch, K., Bunker, A., Cooke, A., Jones, M., Lough, N., McMath, A., & Roberts, S. (2006) Handbook for Marine Intertidal Phase 1 Biotope Mapping Survey. Countryside Council for Wales. 122pp.
[6] MESL. (2013) Project Plan: Drigg Coast, Ravenglass Estuary intertidal survey Technical Report NEDCSAC0713 prepared for Natural England. 13pp + appendices.

B.1. Phase I Biotope Mapping

Prior to the start of the survey aerial imagery and OS mapping covering the entire site, were provided by the Environment Agency and Ordinance Survey respectively. These were subsequently digitised to produce basic wire maps of the littoral sediments. These maps were annotated in the field by the survey team, identifying biotopes, significant features of the site and any anthropogenic impacts. The maps were used in conjunction with a hand-held GPS (accuracy 3-5m) which was used to mark centre points or boundaries of biotopes, to assist in the production of the final mapping of the biotopes.

All biotopes assigned during the Phase I survey used the EUNIS classification to the highest possible level (minimum level 3), using a 0.5mm sieve in the field where necessary to verify the presence of characteristic fauna at the site. Sieves were taken where changes in sediment type were observed and in an ad hoc manner when covering large expanses of foreshore. Individual taxa were identified to the highest possible taxonomic level in the field, in order to characterise the area.

B.2. Phase II Sampling

B.2.1. Infaunal Benthic Sampling

Five intertidal sediment cores were successfully collected, from each of the 21 stations that were distributed throughout the Drigg Coast SAC in order to assess the composition of benthic communities present. The position of the final sample locations is presented in Figure 1 and Table 1.

At each target station, 5 x 0.01 m^2 core samples were taken within 1m of one another, to a depth of 15cm. These were photographed and placed in sealable plastic containers with internal labels. An additional sample was taken for sediment Particle Size Analysis (PSA) and stored in sealable plastic containers provided by the National Laboratory Service (NLS). The anoxic layer depth and depth of any changes in sediment were recorded for each sample, and wherever feasible, interstitial salinity was also recorded.

Station locations were recorded on a hand-held GPS unit (accuracy 3-5m) and recorded in the survey notebook along with the date and time of sampling and observed weather conditions. A photograph was taken of each sampling station in order to help visually characterise the sediments and a 'survey ruler' was used in each photograph as a label to identify each station and provide a scale. Any evidence of anthropogenic disturbance or damage at any of the stations was logged and photographed.

Each sample was labelled with the survey name and sample number on collection. Faunal samples were preserved in 4% buffered formalin and on arrival back to the MESL laboratory were subsequently sieved to 0.5mm and prepared to be dispatched to the third party contractor for faunal analysis.

All field notes were recorded in the pro-forma for benthic core samples (shown in Appendix B of the Project Plan).

B.2.2. Sediment Surface Scrapes

Sediment surface scrape samples were taken at 4 stations across the SAC, in order to assess both the heavy metals and organic contaminants within the study area.

At each station a total of 3 scrape samples were taken, one for organics and two for heavy metals. Sampling followed the protocol provided by Natural England, that the top 1cm of sediment would be removed using a clean plastic scoop for metals and a metal scoop for organics, avoiding any anoxic layers.

All samples were placed in sterile pots provided by the NLS.

The sediment scrape samples were taken at stations 5, 11, 14 and 17 as shown in Table 1 and Figure 1.

Table 1. Coordinates of the stations sampled throughout the Drigg Coast SAC (* stations where contaminant scrapes were taken). Coordinate system: WGS 1984.

Station	Longitude	Latitude
1	-3.4343	54.3443
2	-3.4372	54.3430
3	-3.4410	54.3413
4	-3.4235	54.3460
5*	-3.4221	54.3453
6	-3.4199	54.3444
7	-3.4206	54.3518
8	-3.4183	54.3525
9	-3.4156	54.3533
10	-3.4247	54.3590
11*	-3.4225	54.3578
12	-3.4202	54.3566
13	-3.4014	54.3353
14*	-3.4016	54.3363
15	-3.4018	54.3371
16	-3.4087	54.3601
17*	-3.4092	54.3604
18	-3.4098	54.3607
19	-3.4060	54.3468
20	-3.4074	54.3468
21	-3.4086	54.3468

B.3. Sample Analysis

B.3.1. Particle Size Analysis (PSA)

The PSA was undertaken by the National Laboratory Service (NLS). On receipt of the PSA data values were summarised into higher groupings of % silt (<0.063mm), % sand (0.063-2mm) and % gravel (>2mm), for ease of broad scale substrate assessment (shown in Appendix Table 3). These data were used for the description and classification of sediments.

B.3.2. Contaminants Analysis

Analysis of contaminants was undertaken by the NLS, to identify levels of TBT, heavy metals and organics in the area of interest.

B.3.3. Macrobenthic Analysis

The macrobenthic analysis was carried out by Fugro EMU Ltd. All samples were sieved over a 0.5mm mesh and preserved in formalin by MESL, before being sent for analysis.

B.3.4. Statistical Analysis of the Data

Univariate statistical analyses were carried out by MESL using Microsoft Excel (2007). The data were analysed in a number of ways in order to extract information regarding the abundance of fauna and the number of taxa present (species richness) at each station.

Multivariate analysis was carried out using the PRIMER V6 software package[7]. The following routines were employed on the data:

- Hierarchical Cluster Analysis
- Multidimensional Scaling (MDS) Ordination
- Similarity Percentage analysis (SIMPER)
- Analysis of Similarity (ANOSIM)
- Matching Two Multivariate Patterns (RELATE & BIO-ENV)

A method statement for each routine listed above is presented in Appendix Table 9.

[7] Clarke, K.A. & Warwick, R.M.2001. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation.* Second Edition. Primer-E Ltd, Plymouth, UK.

B.4. Data Interpretation and Mapping

On completion of the intertidal walk over survey, all the survey information was transferred to the MESL database and photographs and GPS data were downloaded for assessment.

Maps of the extent and distribution of the broad scale habitats of interest identified within the SAC were produced by systematically analysing the survey notes, photographs and GPS data.

All of the GIS maps used in within this report were generated using ArcGIS version 9.3.1 and 10. GIS and accompanying metadata have been produced to meet the MEDIN metadata discovery standards and habitats have been provided to the MESH translated habitat data exchange format where required.

A catalogue of the geo-referenced photographs taken during the survey can be found in Appendix Table 8.

B.5. Limitations

The broad-scale habitat mapping-based approach to intertidal site surveying produced an illustrated map that defines the presence and extent of the littoral sediment habitats of interest to the project. However, intertidal areas, particularly those that are susceptible to erosion, are dynamic systems and the maps produced represent a 'snap-shot in time'. Habitats may change naturally through physical and biological processes or through anthropogenic disturbance, such as the creation or removal of sea defence structures.

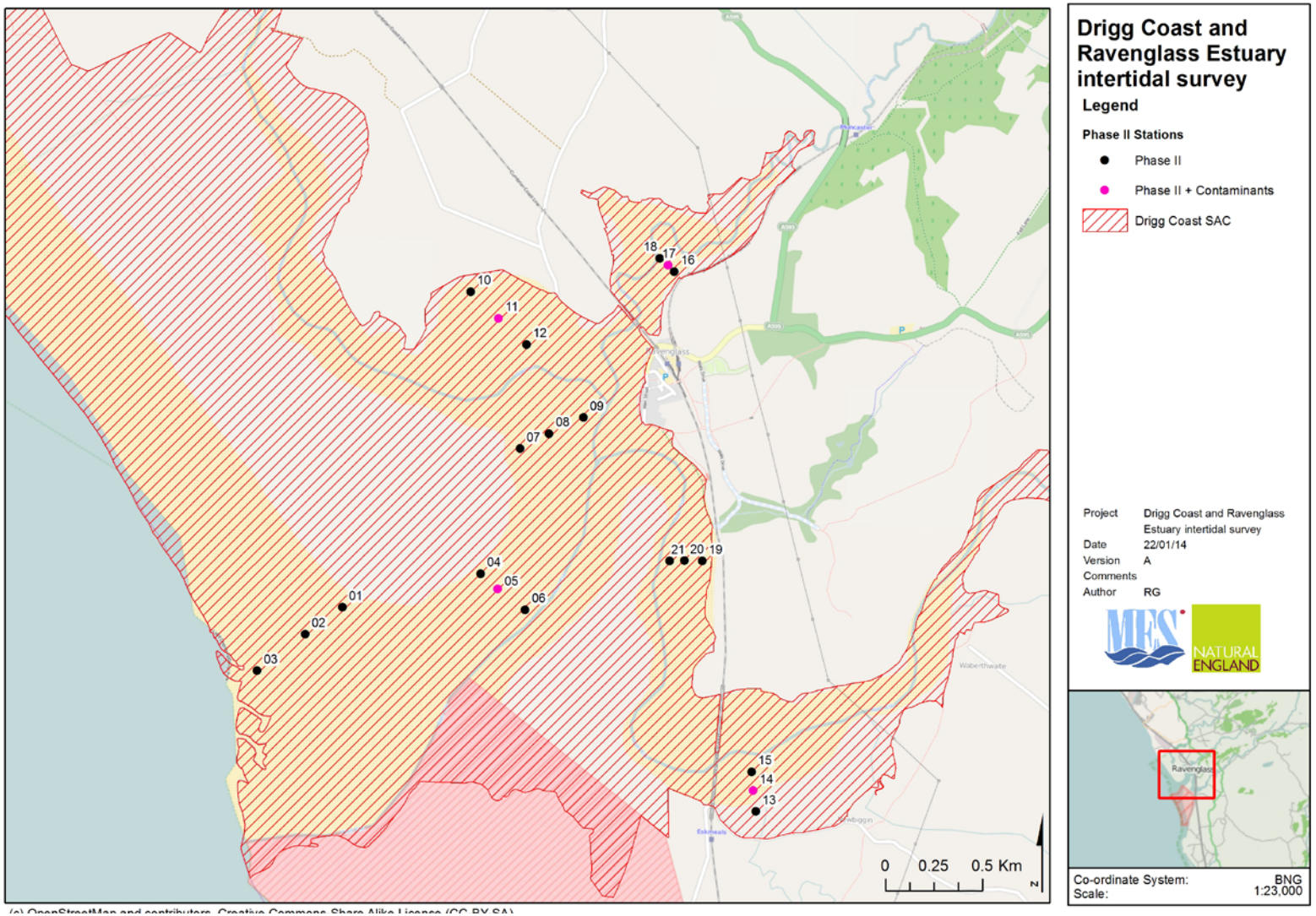

Figure 1. Location of stations sampled as part of the Drigg Coast SAC survey, October 2013. Black points represent stations where faunal and PSA samples were collected and pink points are locations where additional sediment surface scrape samples were obtained.

C. RESULTS

C.1. Site Descriptions and Habitat Maps

Due to the relative size of the Drigg Coast SAC, site descriptions have been split into 5 areas: River Mite, River Irt, The Ravenglass Estuary, River Esk and Drigg Coast.

These areas have individual site descriptions, to provide a more detailed characterisation of the site.

C.1.1. River Mite

The River Mite was almost entirely comprised of intertidal mudflats, of the biotope; 'Polychaete/oligochaete dominated upper estuarine mud shores' (A2.32). In situ sieves of the littoral mud across the river showed numerous *Corophium volutator.*

The River Mite also had a small section of fine sand, sieves at this location revealed a small number of polychaetes. Thus, these areas were classified as 'Polychaete/amphipod dominated fine sand shores' (A2.23).

Some high shore regions of the mudflats were colonised by glasswort (*Salicornia*) and the vast majority were backed by developed saltmarsh communities.

There was little evidence of impacts from anthropogenic sources for this part of the Estuary, with the exception of a few small boats moored on the high shore near the railway bridge.

Phase II samples were taken along a single transect on the south side of the river. There was little variation in salinity across the Phase II stations, values ranged from 28 to 30 PPT, with the highest salinity found at the mid shore. A contaminants scrape was taken from the mid shore.

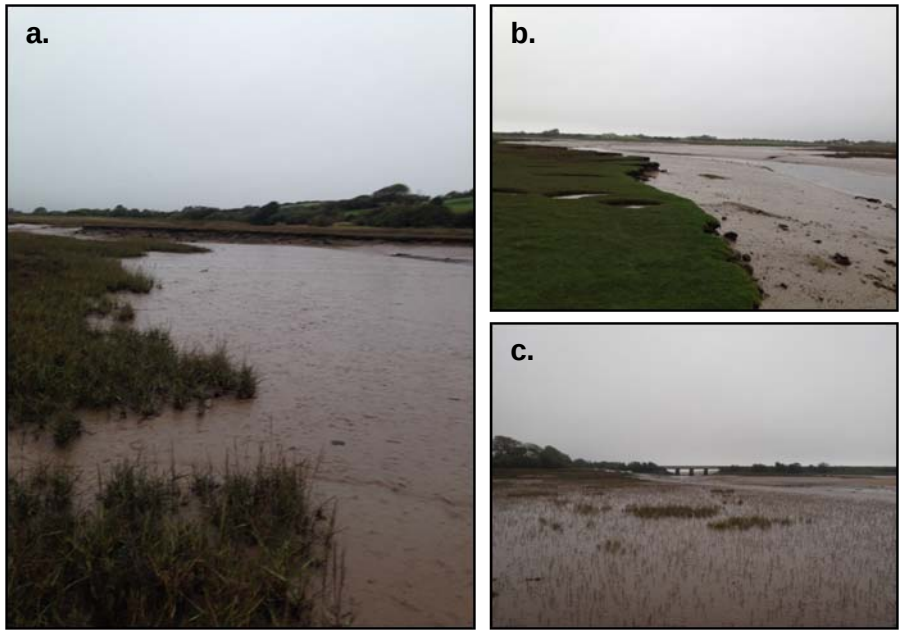

Plate 1: a.&b.) Upper estuarine mud flats of the River Mite backed by developed saltmarsh; **c.)** View south west across A2.32 noting sparse *Salicornia*.

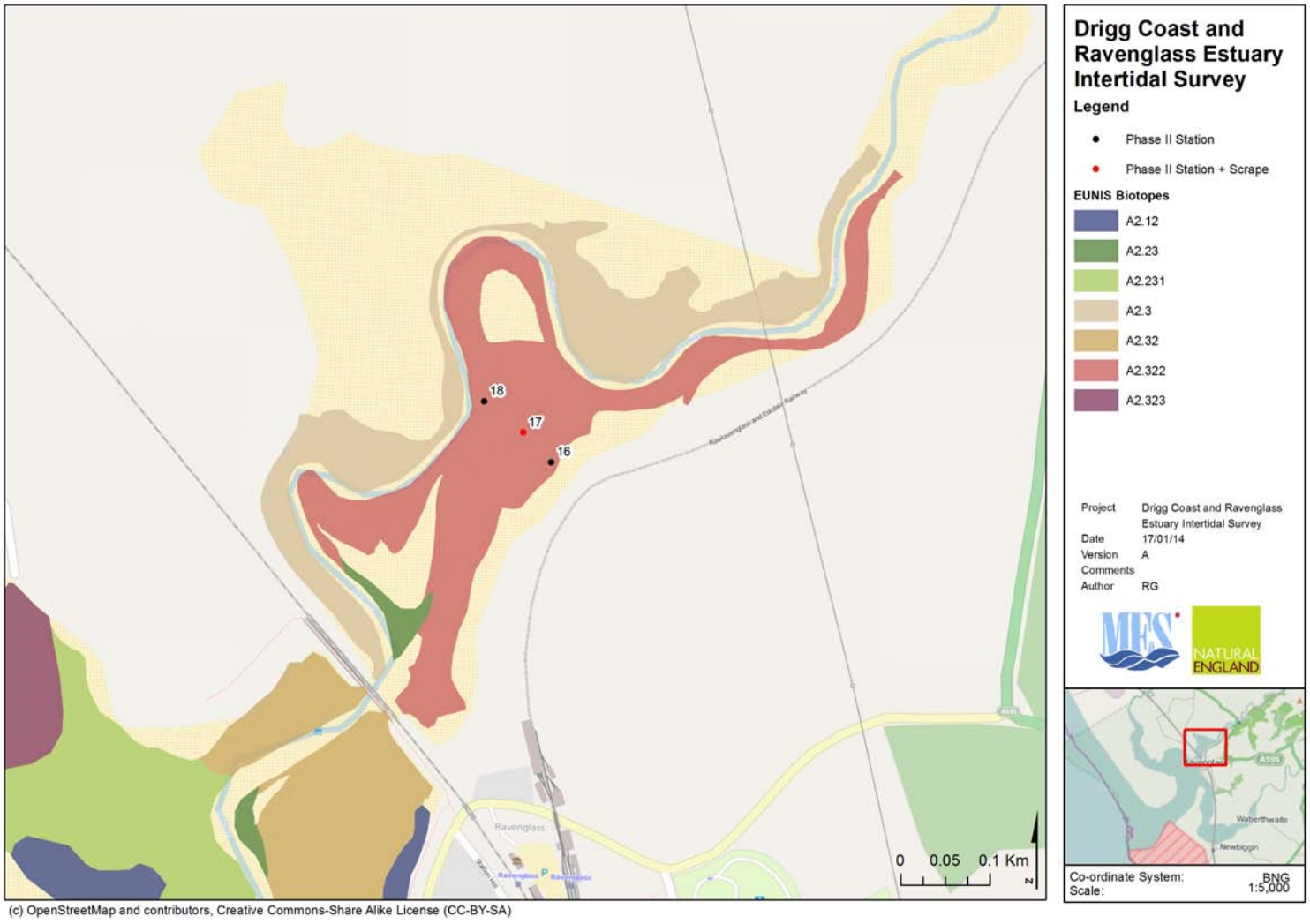

Figure 2. EUNIS biotopes and Phase II stations sampled on the River Mite as part of the Drigg Coast and Ravenglass Estuary Intertidal Survey, October 2013. Phase II stations are represented by both the black and red points, with additional sediment scrapes taken at the red points (Straw colour section is the basemap representation of the foreshore).

C.1.2. River Irt

The western side of the River Irt was predominantly characterised by 'Littoral mud' (A2.3) and 'Polychaete/oligochaete dominated upper estuarine mud shores' (A2.32).

The eastern edge of the river presented a variety of biotopes. The lower banks of the river supported 'Polychaete/oliogochaete dominated upper estuarine mud shores' (A2.32), 'Polychaete/amphipod dominated fine sand shores' (A2.23), 'Estuarine coarse sediment shores' (A2.12) and 'Littoral mixed sediments' (A2.4). Whilst the upper Irt was predominantly littoral mud, classified as 'Polychaete/oliogochaete dominated upper estuarine mud shores' (A2.32), with a small section of 'Estuarine coarse sediment shores' (A2.12).

On both sides of the River Irt the foreshore backed onto developed saltmarsh communities including Atlantic salt meadows.

Fauna identified in this section of the estuary included *Arenicola* casts observed on the low shore (near station 12) at densities of approximately 20 casts/m^2, these densities reduced as you moved up the shore. *Corophium volutator* were also present in high numbers in the A2.32 surrounding stations 10 and 11 and along the eastern banks of the river.

A small patch of seagrass (*Zostera noltii*) covering approximately 1m^2 was recorded near station 11 (Plate 2), a positional fix was taken to mark its location.

There was little evidence of anthropogenic impacts on this section of the estuary as access became limited with distance upstream. The saltmarsh habitats were grazed upon by cows and sheep.

A single Phase II transect of 3 stations was sampled on the southern extent of the river, with a contaminants scrape taken at the mid shore station. Salinity increased down shore from 24 to 30 PPT.

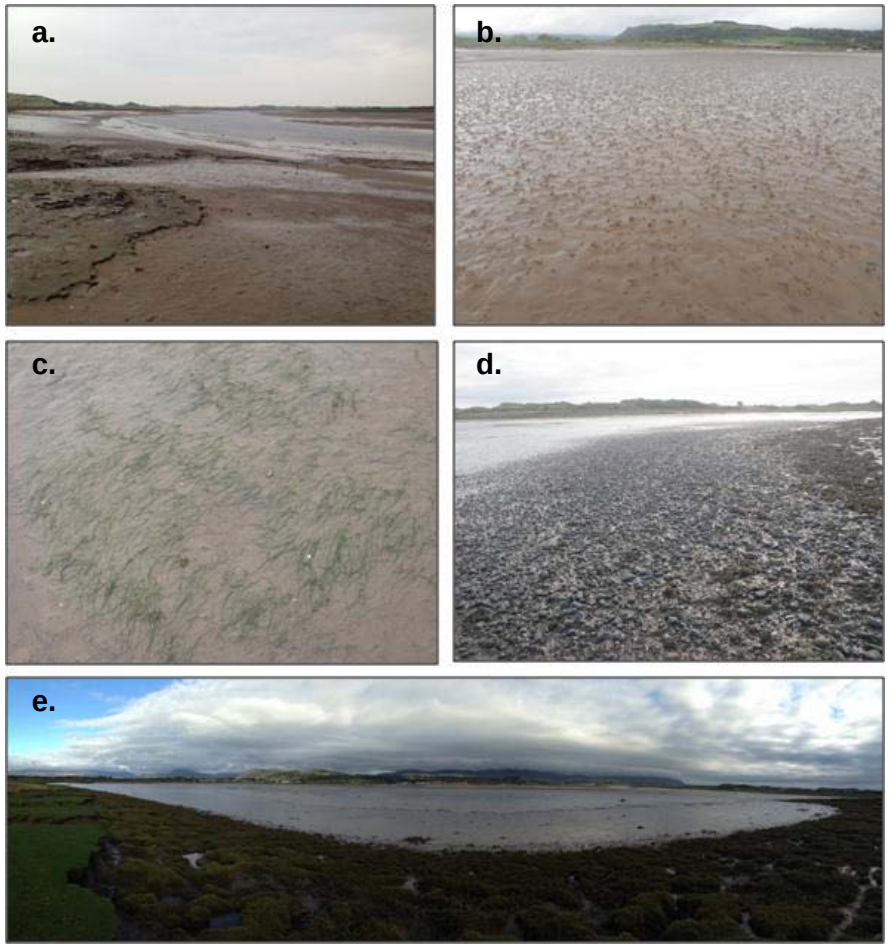

Plate 2: a.) View west across A2.32 of the western side of the Irt; **b.)** *Arenicola* casts found near station 12; **c.)** *Zostera noltii* found near station 11; **d.)** A2.12 on the meander of the Irt; **e.)** Panoramic view across lower section of the river.

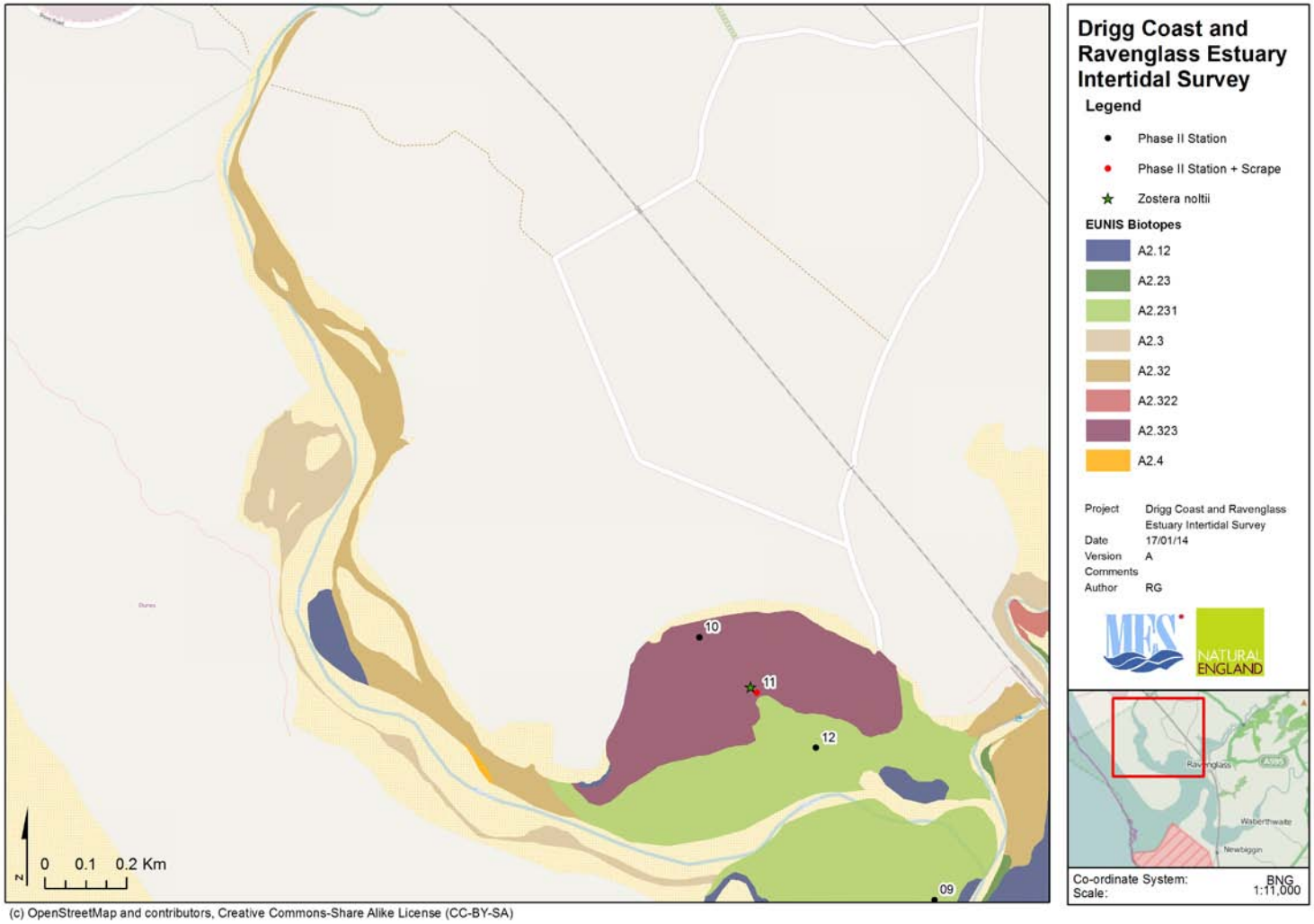

Figure 3. EUNIS biotopes and Phase II stations sampled on the River Irt as part of the Drigg Coast and Ravenglass Estuary Intertidal Survey, October 2013. Phase II stations are represented by both the black and red points, with additional sediment scrapes taken at the red points. The green star designates the patch of *Zostera noltii* (Straw colour section is the basemap representation of the foreshore).

C.1.3. The Ravenglass Estuary

The Ravenglass Estuary marks the confluence of three rivers; the Irt, Mite and Esk. Towards the mouth of the Estuary presented a large expanse of fine sand and shingle biotopes, backed by a developed sand dune complex. The foreshore was predominantly 'Polychaete/amphipod dominated fine sand shores' (A2.23), with patchy sections of 'Estuarine coarse sediment shores' (A2.12) (Plate 3). Where the three rivers converged, on the high and mid shore, near stations 07 and 08, sparse patches of *Salicornia* were recorded colonising the foreshore.

The Eskmeals peninsular graduated from 'Estuarine coarse sediment shores' (A2.12) upstream, to 'Polychaete/amphipod dominated fine sand shores' (A2.23) nearer the coast. A band of 'Shingle, (pebble) and gravel shores' (A2.11) lined the high shore, at the mouth of the Estuary (Figure 4).

In situ sieves of the fine sand, within this section of the estuary, revealed a number of amphipods, and the casts of *Arenicola* were evident on the foreshore. Wading birds (Sandpipers) were observed at the lower shore.

Small fishing vessels were moored in the mid estuary and vehicles were observed driving on the foreshore around Ravenglass. Assorted boating debris was found across the area of interest, and recreational users of the foreshore included dog walkers.

Two Phase II transects were sampled across this part of the estuary. Salinity generally decreased with increasing distance up the estuary, with values ranging from 19 to 26 parts per thousand (PPT). A contaminant scrape was taken at the mid shore station of the transect closest to the mouth of the estuary.

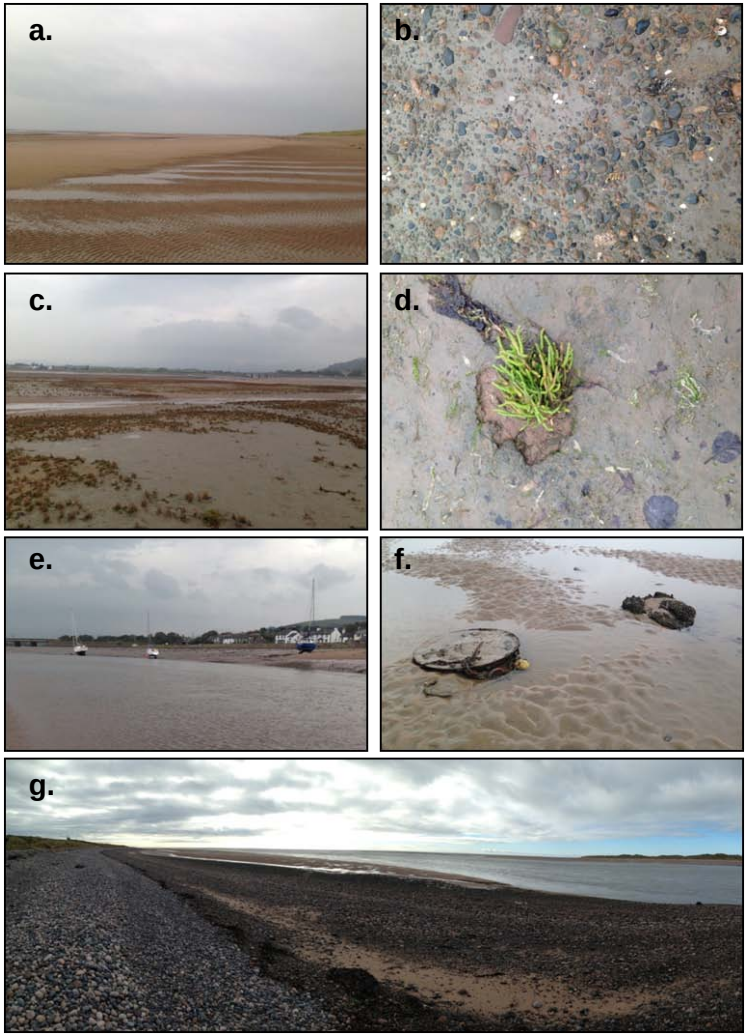

Plate 3: a.) View south west across A2.23 from station 04; **b.)** Close up of A2.12; **c.)** Sand flats colonised with *Salicornia*; **d.)** *Salicornia*; **e.)** Small vessels moored in the mid estuary; **f.)** Debris found on the foreshore; **g.)** View south west across Eskmeals peninsular.

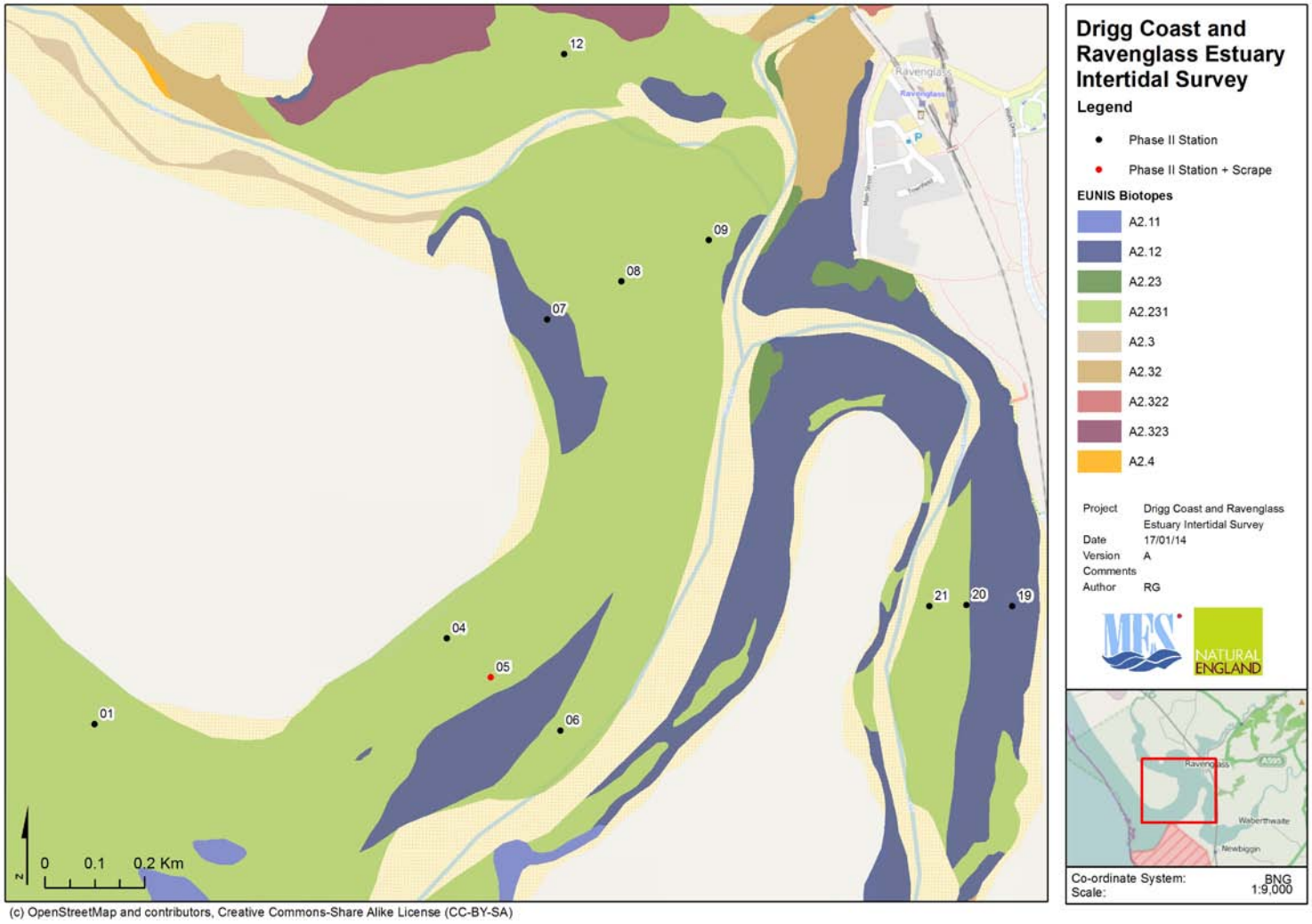

Figure 4. EUNIS biotopes and Phase II stations sampled on the Ravenglass Estuary as part of the Drigg Coast and Ravenglass Estuary Intertidal Survey, October 2013. Phase II stations are represented by both the black and red points, with additional sediment scrapes taken at the red points (Straw colour section is the basemap representation of the foreshore).

C.1.4. River Esk

The lower Esk predominantly consisted of 'Estuarine coarse sediment shores' (A2.12) with small patches of 'Polychaete/amphipod dominated fine sand shores' (A2.23) closer to Ravenglass. The lower Esk channel transitioned from coarse dominated biotopes, through to sand and mud biotopes, with distance upstream. The upper Esk was a combination of 'Polychaete/oligochaete dominated upper estuarine mud shores' (A2.32) and 'Polychaete/amphipod dominated fine sand shores' (A2.23).

The fine sand shores (A2.23) revealed *Arenicola* casts and the muddy sediments (A2.32) hosted *Corophium volutator.* Large flocks of wildfowl and wading birds were present in the upper Esk Estuary. Sand waves were evident on the fine sand shores of the upper Esk due to tidal currents.

Blue mussel (*Mytulis edulis*) beds and cockle (*Cerastoderma edule*) debris were situated within the lower Esk channel, east of Ravenglass; a positional fix was taken to note the location. Loose *Fucus* fronds and small mats of *Enteromorpha* were observed around station 21 on the foreshore.

The lower Esk had vehicular access to the foreshore used by people accessing small boats and fishing vessels. A few small boats were moored within the lower Esk river.

Two Phase II transects were sampled within the Esk. Salinity varied from 25 to 31 PPT, with the lowest values found upstream. A contaminants scrape was taken at the mid shore station in the upper Esk.

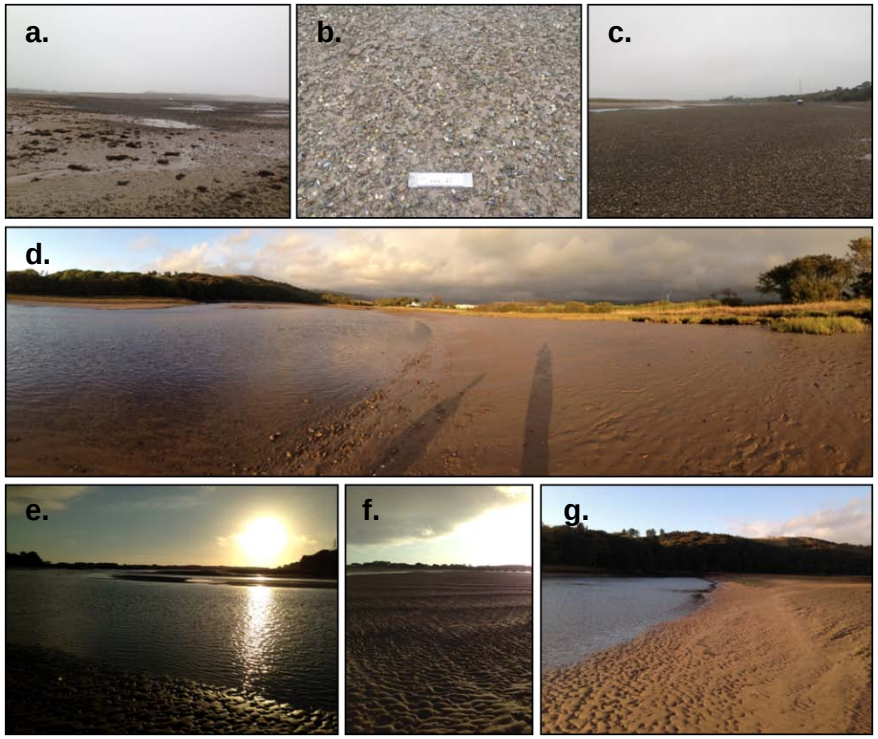

Plate 4: a.) Loose F*ucus* fronds found on the lower Esk; **b.)** Cockle and Mussel debris on the Lower Esk; **c.)** View north over blue mussel (*Mytulis edulis*) beds within the lower Esk; **d.)** View east over A2.32 on upper Esk; **e.)** View south west across upper Esk; **f.)** Sand waves of the upper Esk; **g.)** View north across A2.32 of the upper Esk.

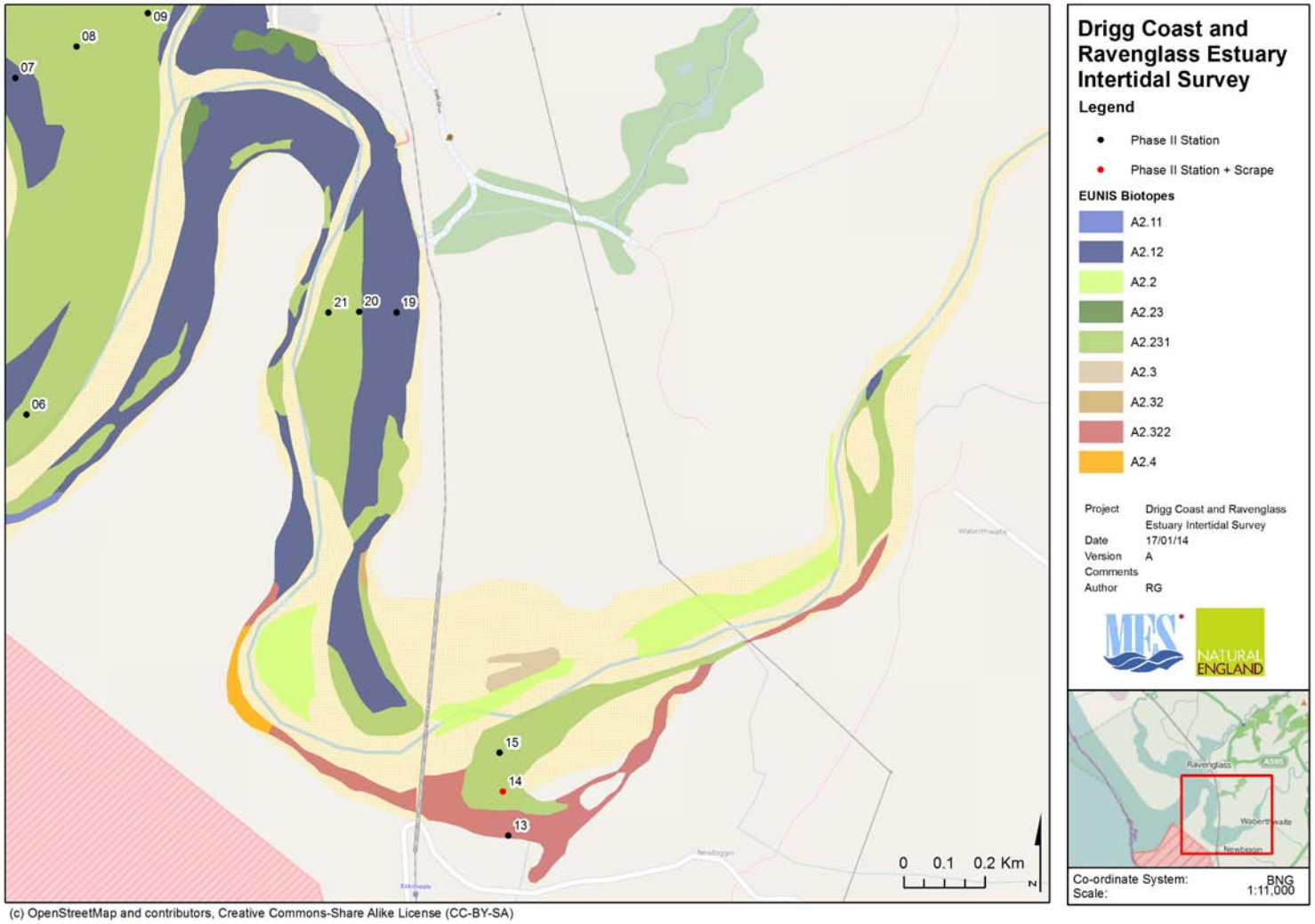

Figure 5. EUNIS biotopes and Phase II stations sampled on the River Esk as part of the Drigg Coast and Ravenglass Estuary Intertidal Survey, October 2013. Phase II stations are represented by both the black and red points, with additional sediment scrapes taken at the red points (Straw colour section is the basemap representation of the foreshore).

C.1.5. Drigg Coast

The Drigg Coast exhibited a large sand and shingle spit on which the Drigg dune systems have developed. The majority of the coast, that lies within the SAC, consisted of 'Polychaete/amphipod dominated fine sand shores' (A2.23) with patchy sections of 'Shingle (Pebble) and gravel shores' (A2.11) nearer the mouth of the estuary. A small peat exposure was also identified and boundary tracked walking the boundary at the lower shore (Plate 5).

Arenicola casts were present at the lower shore, with approximate densities of 17 casts/m^2. In situ sieves revealed a few amphipods at the high and mid shore.

Tyre tracks were evident at the high shore, and large bags of litter were observed dotted at the base of the dunes. Recreational users of the coast included dog walkers.

A single Phase II transect was sampled on the Drigg coast. Salinity increased down shore, with values ranging from 28 to 34 PPT.

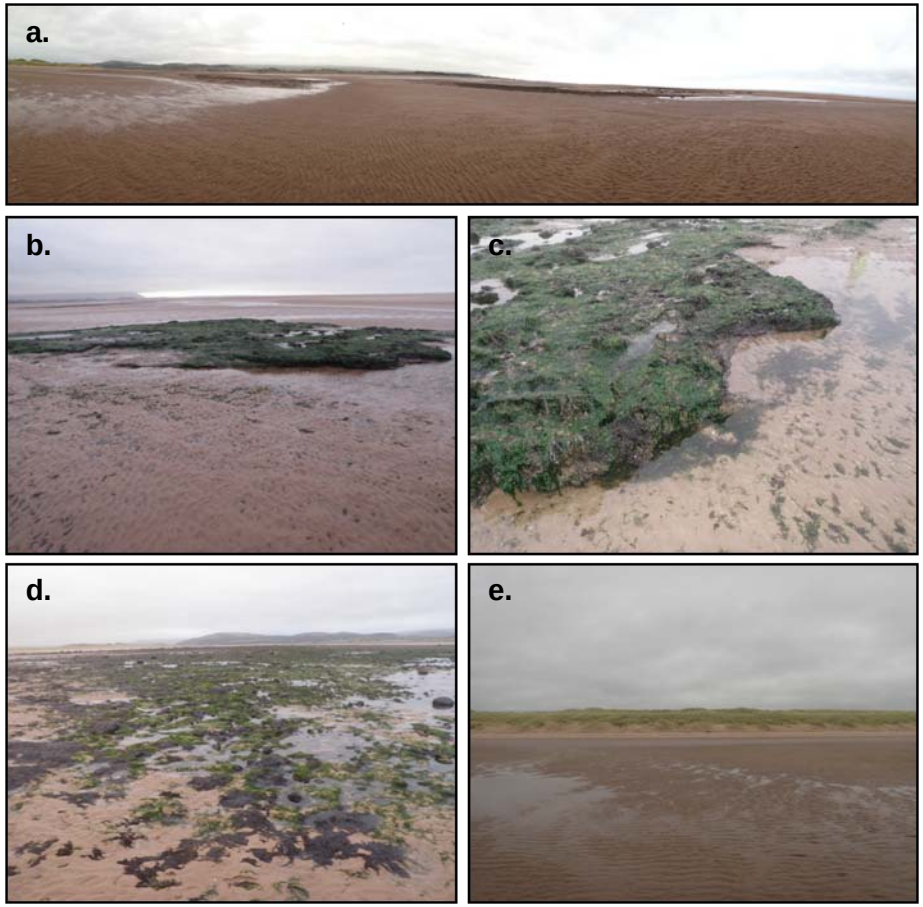

Plate 5: a.) A panoramic view east of the Drigg Coast**; b.&c.)** Peat exposure identified on the lower shore**; d.)** Section of A2.11 near to the estuary mouth; **e.)** View north east towards sand dunes from station 02.

Figure 6. EUNIS biotopes and Phase II stations sampled on the Drigg Coast as part of the Drigg Coast and Ravenglass Estuary Intertidal Survey, October 2013, including the peat exposure found on the low shore. Phase II stations are represented by both the black and red points, with additional sediment scrapes taken at the red points (Straw colour section is the basemap representation of the foreshore).

C.1.6. Summary Table

The table below provides a summary of each of the sectors of the Drigg Coast, detailing the area of intertidal mud and sand flats, percentage cover of opportunistic macroalge and the infuanal and sediment composition of each sector.

Table 2. Summary table of the 5 sectors of the Drigg Coast. Extents of sand and mud flats calculated in hectares.

Area	Biotope extent (Ha)	Biotopes Present	Infaunal Composition (Top 5 most abundant taxa)	Macroalgal cover	PSA	Anthropogenic Impacts
River Irt	A2.1, 3.69 A2.2, 28.74 A2.3, 42.92 A2.4, 0.14	A2.12 Estuarine coarse sediment shores LS.LSa.FiSa / A2.23 Polychaete/amphipod-dominated fine sand shores LS.LSa.FiSa.Po / A2.231 Polychaetes in littoral fine sand LS.LMu / A2.3 Littoral mud LS.LMu.UEst / A2.32 Polychaete/oligochaete-dominated upper estuarine mud shores LS.LMu.UEst.Tben / A2.323 [Tubificoides benedii] and other oligochaetes in littoral mud LS.LMx / A2.4 Littoral mixed sediments	Nematoda *Corophium volutator* Enchytraeidae *Manayunkia aestuarina* *Heterochaeta costata*	Station 11 - 35% *Enteromorpha* cover	The mean proportion of the sediment fractions of the River Irt were 36% Silt, 64% Sand and 0% Gravel	Minimal anthropogenic impacts, debris found on the strandline. Livestock grazing on the saltmarsh.
River Mite	A2.2, 0.27 A2.3, 11.01	LS.LSa.FiSa / A2.23 Polychaete/amphipod-dominated fine sand shores LS.LMu / A2.3 Littoral mud LS.LMu.UEst.Hed / A2.322 [Hediste diversicolor] in littoral mud	*Corophium volutator* Nematoda Enchytraeidae *Tubificoides benedii* *Manayunkia aestuarina*	No signs of macroalgal cover	The mean proportion of the sediment fractions of the River Mite were 59% Silt, 41% Sand and 0% Gravel	Minimal anthropogenic debris, a number of boats moored near the railway bridge.
River Esk	A2.1,21.05 A2.2, 29.34 A2.3,8.58 A2.4, 0.81	A2.12 Estuarine coarse sediment shores LS.LSa / A2.2 Littoral sand and muddy sand LS.LSa.FiSa / A2.23 Polychaete/amphipod-dominated fine sand shores LS.LSa.FiSa.Po / A2.231 Polychaetes in littoral fine sand LS.LMu / A2.3 Littoral mud LS.LMu.UEst / A2.32 Polychaete/oligochaete-dominated upper estuarine mud shores LS.LMu.UEst.Hed / A2.322 [Hediste diversicolor] in littoral mud LS.LMx / A2.4 Littoral mixed sediments	Nematoda *Corophium volutator* Balanomorpha Enchytraeidae *Corophium arenarium*	No signs of macroalgal cover	The mean proportion of the sediment fractions of the River Esk were 12% Silt, 67% Sand and 22% Gravel	Minimal anthropogenic impacts, debris found on the strandline.
Ravenglass Estuary	A2.1, 30.43 A2.2,86.52 A2.3, 0.67	LS.LCS.Sh / A2.11 Shingle (pebble) and gravel shores A2.12 Estuarine coarse sediment shores LS.LSa.FiSa / A2.23 Polychaete/amphipod-dominated fine sand shores LS.LSa.FiSa.Po / A2.231 Polychaetes in littoral fine sand LS.LMu.UEst / A2.32 Polychaete/oligochaete-dominated upper estuarine mud shores	Enchytraeidae Nematoda *Nephtys cirrosa* *Bathyporeia pilosa* *Bathyporeia sarsi*	No signs of macroalgal cover	The mean proportion of the sediment fractions of the Ravenglass Estuary were 21% Silt, 73% Sand and 6% Gravel	Recreational users of the foreshore from Ravenglass, commercial fisherman landing hauls and driving on the foreshore.
Drigg Coast	A2.1, 5.17 A2.2, 98.87	LS.LCS.Sh / A2.11 Shingle (pebble) and gravel shores LS.LSa.FiSa.Po / A2.231 Polychaetes in littoral fine sand Peat Exposure	*Bathyporeia pelagica* *Psammodrilus balanoglossoides* *Haustorius arenarius* *Paraonis fulgens* Nematoda	No signs of macroalgal cover	The mean proportion of the sediment fractions of the Drigg Coast were 0% Silt, 100% Sand and 0% Gravel	Minimal anthropogenic debris found on the strandline. Recreational Users.

C.2. Composition of the Intertidal Sediments

C.2.1. Sediment Particle Size Analysis (PSA)

The Particle Size Analysis (PSA) of the deposits sampled with a 0.01m^2 core from Phase II sampling stations across the Drigg Coast SAC is presented in Appendix Table 2. These data have been summarised in Appendix Table 3 to show the percentage of silt (<0.063mm), sand (0.063 to <2mm) and gravel (≥2mm) that comprised each sediment sample. A distribution map of percentage gravel, sand and silt at each station is presented in Figure 8.

Figure 8 reveals that the sediment composition of the deposits sampled across the Drigg Coast SAC were predominantly comprised of sand fractions, whilst silt and gravel fractions were found in high proportions at a number of stations.

The majority of the sediment sampled along the River Mite was made up by silt fractions, with stations 10 and 11 on the high shore of the River Irt displaying a similar sediment composition.

Stations 19, 20 and 21 sampled on the River Esk showed very similar compositions to one another, with gravel and sand fractions dominating the sediment deposits and small amounts of silt. The Drigg Coast stations constituted almost entirely of sand fractions, with negligible portions of gravel.

In order to further describe the substrate types recorded across the study area, sediment samples have been classified according to Folk (1954). These Folk classifications are shown on Figure 9, with definitions of sediment types presented in Figure 7. Figure 9 demonstrates that the site is predominantly classified as a mixture of sand (S), sandy gravel (sG) and sandy mud (sM). Whilst sediment deposits classified as muddy sand (mS), gravelly muddy sand (gmS) and slightly gravelly sand ((g)S) were also sampled across the site.

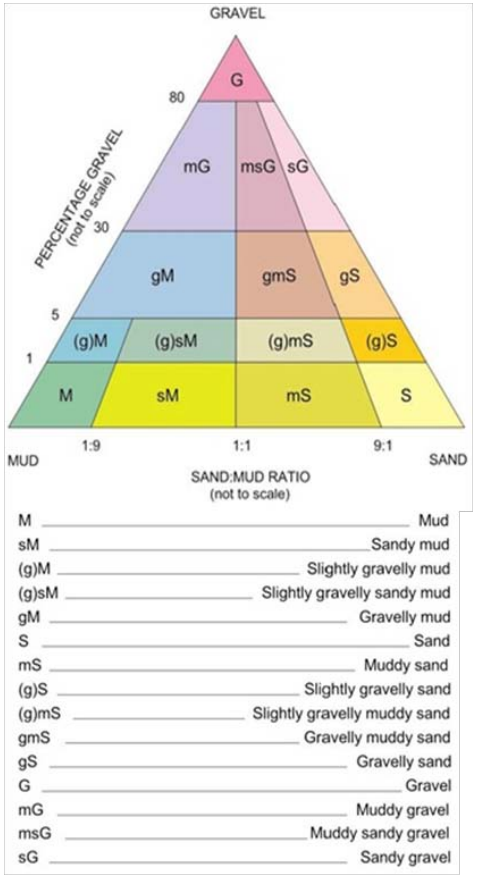

Figure 7. Modified Folk classification system used to define marine sediments, Folk (1954).

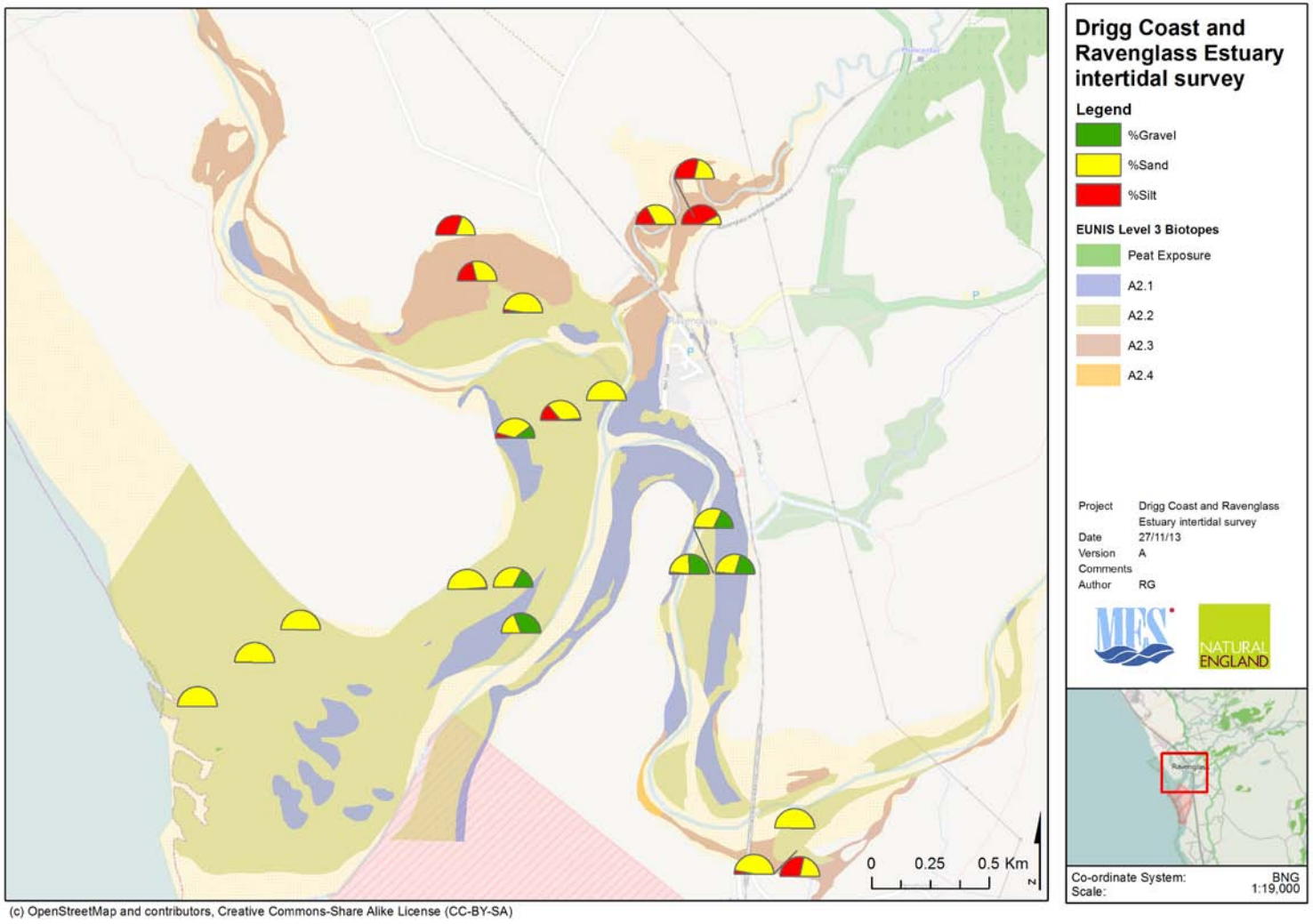

Figure 8. Distribution of sediment types, and the relative proportions of gravel, sand and silt in the PSA samples obtained from across the Drigg Coast SAC. It should be noted that half-pie charts represent the approximate locations of the sampling stations only.

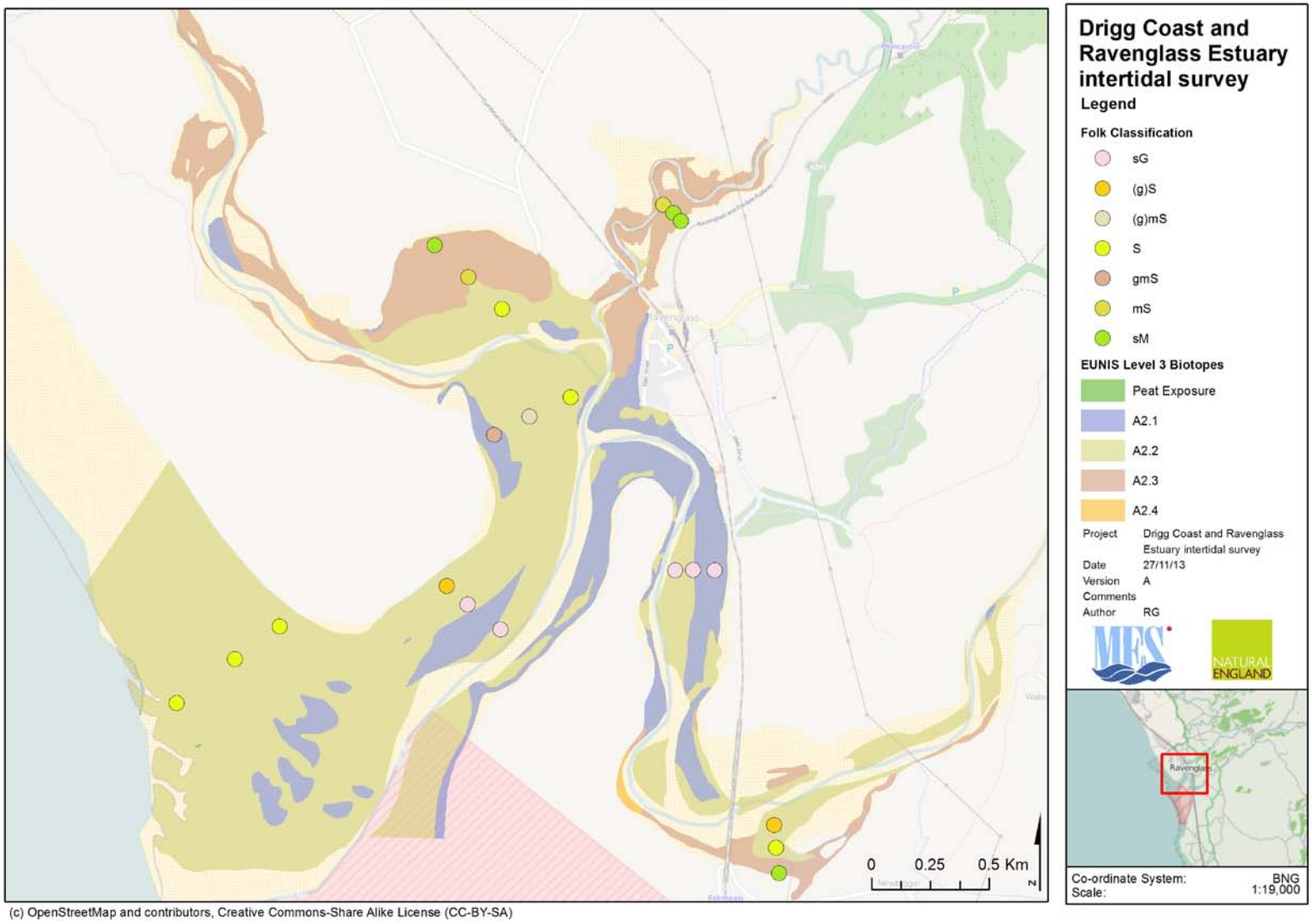

Figure 9. Distribution of sediment types according to the Folk classification obtained from across the Drigg Coast SAC.

C.3. Biological Resources

C.3.1. Description of the Benthic Fauna

A total of 78 taxa and 14884 individuals were recorded from the Phase II core samples taken across the Drigg Coast SAC. The full taxonomic list, including the numerical abundance of each taxon by station, is provided in Appendix Table 4. The mean number of taxa recorded per sample was 7.1. The mean number of organisms per sample was 141.8, and the mean biomass per sample was 170.87 mgAFDW.

Figure 10 demonstrates that taxa belonging to the Phyla Annelida and Crustacea contributed similar values in terms of abundance, representing 38% and 34% of the taxa sampled respectively. Miscellanea accounted for 27%, and Mollusca represented only 1%, of the total abundance.

Annelida contributed the greatest number of taxa, accounting for 41% of the total species diversity. Crustacea and Mollusca represented 29% and 21% of species richness respectively. Miscellanea accounted for the lowest number of taxa at 7% of the total diversity.

Biomass was dominated by the Phylum Mollusca which contributed 85% of the taxa sampled and equated to 15192.03mgAFDW. Annelida and Crusacea accounted for similar values, contributing 7% and 8% of the total biomass respectively. Miscellanea contributed the least in terms of biomass, accounting for only 0.2% of the taxa sampled.

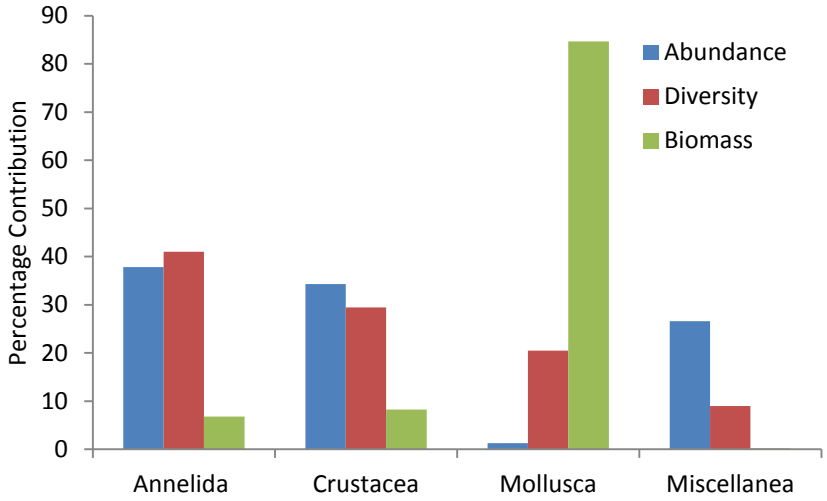

Figure 10. The relative contribution of the main faunal groups to total abundance, species richness and biomass sampled across the Drigg Coast SAC.

The contribution of the top ten organisms to the overall abundance is illustrated in Figure 11. These taxa accounted for 92% of the total abundance of all samples. The highest contributors to overall abundance were Nematoda and *Corophium volutator*, representing 26% and 23% of the total abundance respectively. *Corophium volutator* was predominantly found in the muddy sediments of the upper and mid estuary, for which this taxon is typically found.

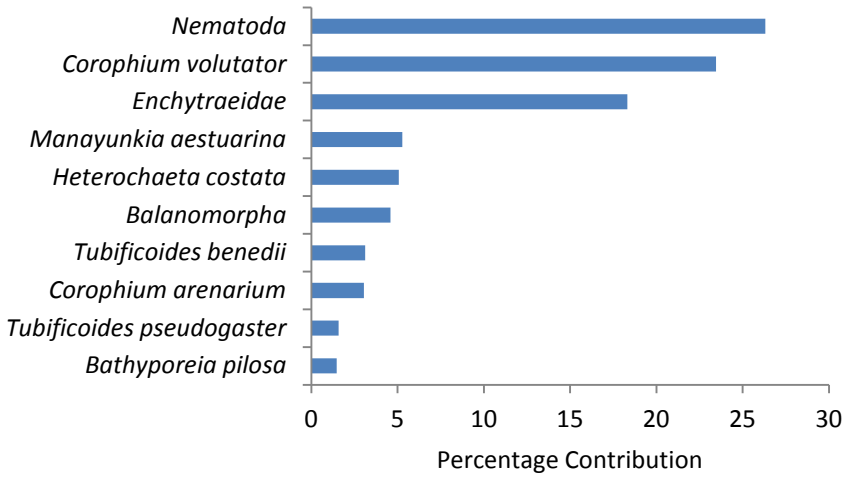

Figure 11. Ten most abundant taxa sampled across the Drigg Coast SAC.

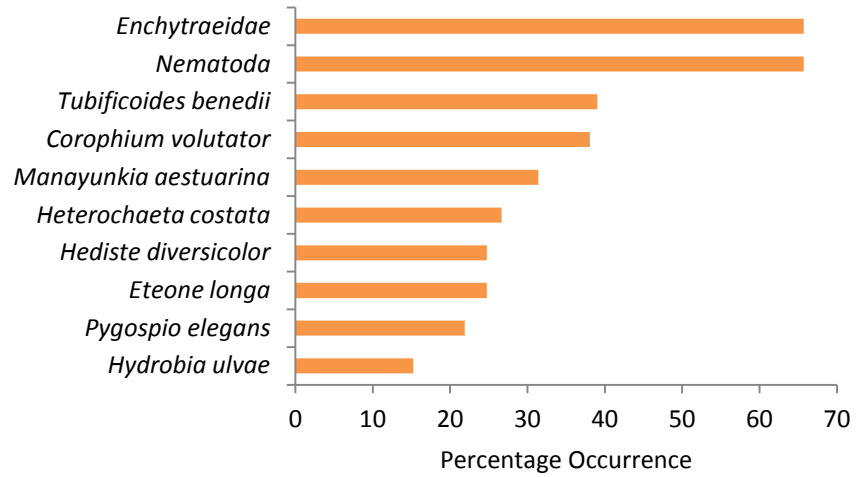

Figure 12. Ten most widely distributed taxa sampled across the Drigg Coast SAC.

Figure 12 illustrates the taxa that occurred in the highest proportion of samples collected across the Drigg Coast SAC. The most frequently occurring taxa were individuals belonging to the family Enchytraeidae, which were sampled in 66% of the samples. The oligochaete, *Tubificoides benedii*, and the polychaete, *Manayunika aestuarina*, were the most commonly occurring Annelids, occurring in 39% and 31% of samples respectively. *Corrophium volutator* was the most frequently occurring crustacean, occurring in 38% of the samples. The most commonly occurring Mollusca was *Hydrobia ulvae* which was found in 15% of samples.

Figure 13 represents the taxa that made the greatest contribution to the biomass across the Drigg Coast SAC. These taxa accounted for 96% of the total biomass of all samples. The Molluscs *Ceratoderma edule* and *Mytilus edulis,* accounted for 46% and 30% of the total biomass respectively. *Corophium Volutator* contributed the greatest biomass of the Crustacea, accounting for 6% and *Hediste diversicolor* was the greatest contributing Annelid with 2% of the total biomass.

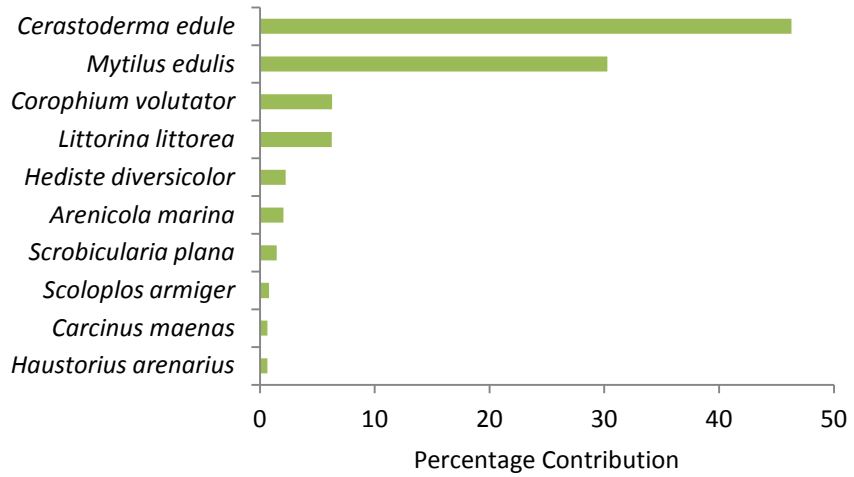

Figure 13. Top ten contributors to the biomass of taxa sampled across the Drigg Coast SAC.

Figure 14 shows the spatial distribution of the average abundance, number of taxa and biomass (mg AFDW) sampled at each station across the Drigg Coast SAC. The figure displays the low abundance and biomass values recorded across the Drigg Coast and the mouth to the estuary.

The figure also displays a trend that as you move further upstream from the mouth of the estuary, there is a generally increase in the three measures of abundance, diversity and biomass.

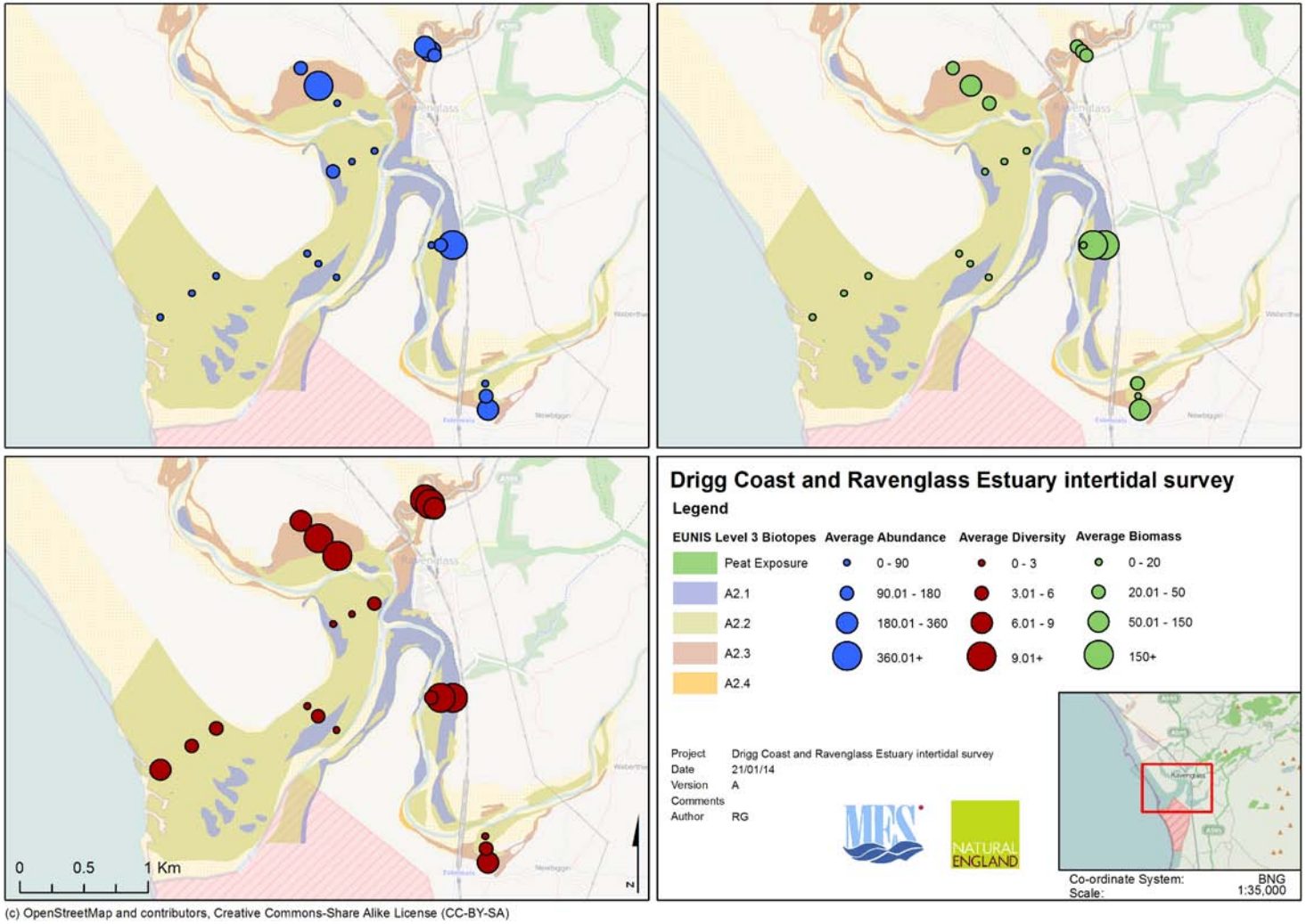

Figure 14. Spatial distribution of the average abundance, number of taxa and biomass (mg AFDW) sampled across the Drigg Coast in October 2013.

C.3.2. Multivariate Analysis of Community Composition

Figure 15 shows a group average sorting dendrogram (based on Bray-Curtis similarity of square-root transformed data) and the corresponding multidimensional scaling (MDS) plot, presented in two-dimensional format, using averaged abundance data gathered from across the Drigg Coast and Ravenglass Estuary. The moderate 2D stress value of the MDS ordination (0.161), indicates that the two-dimensional representation provides a tolerable interpretation of the interrelationships that occur between the communities sampled at the Phase II sampling locations.

As demonstrated in Figure 15, 4 faunal groups were identified using the SIMPROF routine, with an additional sample which did not group with any other samples labelled as an Outlier. The output of the analysis used to define these groups is presented in Appendix Table 6.

Table 3. Average abundance, diversity and biomass within each of the multivariate faunal groups identified in Drigg Coast SAC.

Faunal Group	Average Abundance	Average Number of Taxa	Average Biomass (mgAFDW)
Faunal Group A	319.4	18.1	1525.44
Faunal Group B	486	10.7	61.88
Faunal Group C	141.5	7.3	64.39
Faunal Group D	32.8	3.9	10.46

A description of each of the faunal groups is presented in Table 3 with discussion below. The geographical distribution of the faunal groups is shown in Figure 16.

Faunal Group A (average group similarity of 43.78) was recorded at a total of 2 stations, both located within regions classified as sandy Gravels (sG). Key fauna of this group included Balanomorpha, *Tubificoides pseudogaster, Tubificoides benedii* and Nematoda which together account for 53.72% of the group similarity. The group had a significantly larger average biomass which is largely due to the presence of *Cerastoderma edule* at the stations.

Faunal Group B (average group similarity of 68.68) encompassed 3 stations within the Drigg Coast, which were characterised by muddy Sand (mS) and sandy Mud (sM), as demonstrated in Figure 9. Key fauna of this group included Nematoda, *Corophium volutator,* Enchytraeidae and the sabellid *Manayunkia aestuarina,* which together account for 79.97% of the group similarity. This was also the most abundant of the groups as shown in Table 3.

Faunal Group C (average group similarity of 72.06) was recorded at 3 sampling stations across the site. The group was solely characterised by sandy Mud (sM) deposits. Key fauna of this group included *Corophium volutator,* Nematoda, Enchytraeidae and the ragworm *Hediste diversicolor.*

Faunal Group D (average group similarity of 22.46) was the most common multivariate group identified across the Drigg Coast SAC, sampled at 12 stations. The group was predominately found on Sand (S) deposits, but was also found on sandy Gravel (sG), slightly gravelly sand ((g)S), gravelly muddy Sand (gmS) and slightly gravelly muddy Sand

((g)mS). The key fauna of this group included Enchytraeidae, Nematoda, *Tubificoides benedii* and the amphipod *Bathyporeia pilosa* which together accounted for 74.94% of the group similarity. Table 3 illustrates that the group had the lowest value for all three indices of abundance, diversity and biomass.

Figure 16 shows the spatial distribution of the multivariate faunal groups across the Drigg Coast SAC. The figures show that **Faunal Group C** was found on the high shore of transects across 'Littoral mud' (A2.3), whilst **Faunal Group D** was predominantly found on the broad scale habitat 'Littoral sand and muddy sand' (A2.2).

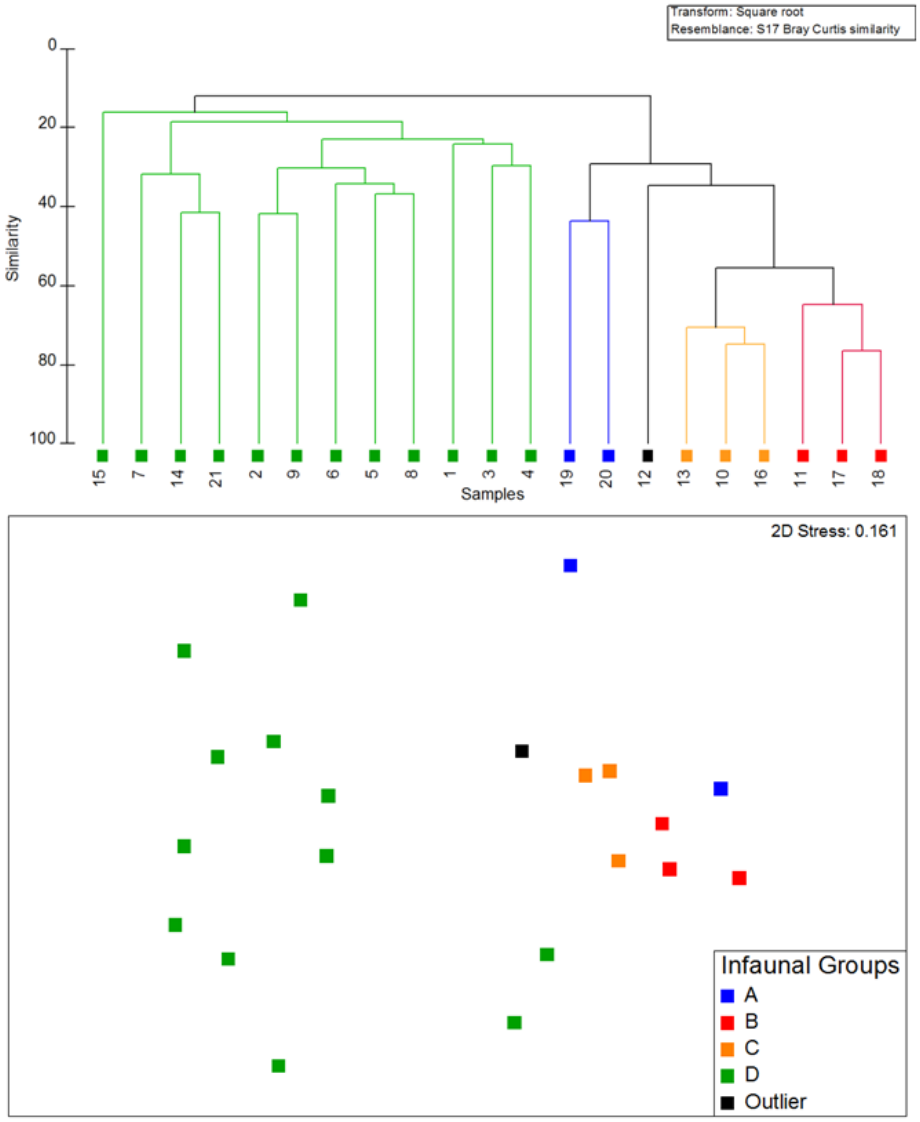

Figure 15. A group average sorting dendrogram based on the square root transformed Bray-Curtis similarity infaunal abundance data and the corresponding multidimensional scaling (MDS) ordination, presented in two-dimensional format, sampled from the Drigg Coast SAC.

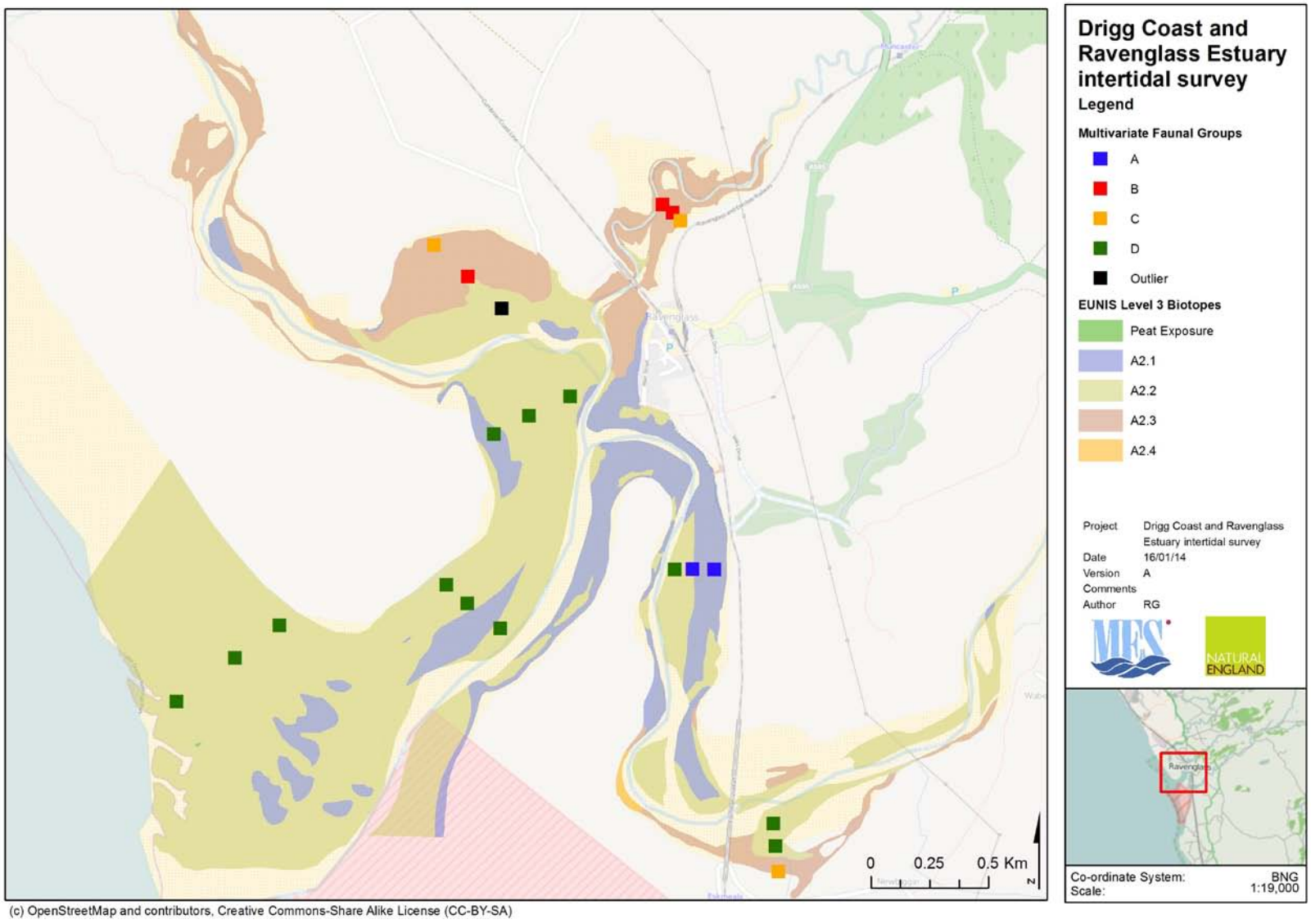

Figure 16. Distribution of faunal groups recorded across the Drigg Coast SAC.

C.4. Linking Faunal Data to Environmental Variables

A brief review of the information presented in Sections C.2 and C.3 reveals that there are apparent relationships between faunal community composition and sediment type sampled across the Drigg Coast SAC.

A more sensitive comparison across the area can be achieved by applying statistical techniques such as the RELATE routine. The RELATE routine within PRIMER v6 provides a comprehensive means of testing for correlations between faunal data and sediment data acquired from the Drigg Coast SAC and establishes the robustness of this relationship.

The full results of the RELATE test are presented in Appendix Table 7, which demonstrates that that there is a modest but apparent relationship between the multivariate patterns observed in the sediment data and in the faunal communities, which was statistically significant (Rho 0.332, Significance level 0.11%).

In order to determine which sediment particle sizes most strongly correlate with the patterns observed within the faunal communities, the faunal and sediment data were tested using the BIO-ENV routine. The full results of this test are presented in Appendix Table 7. The results indicate that the strongest correlation between the multivariate patterns in the sediment and faunal data corresponded most strongly with the combination of gravel of particle sizes 31.5, 16 and 4mm and sand particle size of 0.25mm.

C.5. The Distribution of Species of Interest

On receipt of the faunal data obtained from Phase II samples obtained from the Drigg Coast SAC, an excel add-on named TREX (Taxonomic Routines of Excel) was used to enable checks to be made on the taxonomic information contained within the data. These checks included the identification of rare and alien species of importance within the data set.

The results revealed that there were no species of conservation interest within the faunal data, obtained from Phase II sampling across the area.

A single non-native species was identified within the data which was the 'Acorn barnacle' (*Elminius modestus*) which was found at Phase II sample stations 19 and 20.

C.6. The Distibution of Habitats of Interest to Nature Conservation

Habitats of conservation interest are identified within Wyn *et al*. (2000)[8], these fall within two categories; 'Specialised Biotopes' and 'Nationally and More Nationally Important Communities'. Communities that fall within these groups were identified across the area of interest and are highlighted below:

C.6.1. Specialised Biotopes

***'Zostera noltii* beds in upper to mid shore muddy sand' (LS.LMS.ZOS.Znol)**

A small 1m^2 patch of *Zostera noltii* was found on the River Irt section of the foreshore near Phase II station 11.

C.6.2. Nationally and more than Nationally Important Communties

***'Ceramium* sp. and piddocks on eulittoral fossilised peat' (LR.HLR.FR.RPid)**

A single patch of ***'****Ceramium* sp. and piddocks on eulittoral fossilised peat' was identified on the low shore of the Drigg Coast. The small patch of peat was covered in numerous piddock burrows.

C.7. Anthropogenic Impacts

Anthropogenic impacts across the region as identified in section C.1. were recorded during the survey event. These included disturbance from littering of anthropogenic debris such as plastic waste in the form of fishing nets and bottles, particularly along the strandline and the use of the foreshore/beaches for recreational purposes such as dog walking.

Of note was also the arable land adjacent to large portions of the estuary, during periods of heavy or prolonged rainfall excess nutrients could be flushed onto the foreshore from the surrounding farmland, likely resulting in a reduced water quality and having a further ability to fuel blooms of opportunistic macroalgae.

Any noteworthy anthropogenic impact observed during the intertidal survey was photographed and recorded. A catalogue of the geo-referenced photographs taken during the survey can be found in Appendix Table 8.

[8] Wyn, G., Brazier, P., Birch, K., Bunker, A., Cooke, A., Jones, M., Lough, N., McMath, A., & Roberts, S. (2006) Handbook for Marine Intertidal Phase 1 Biotope Mapping Survey. Countryside Council for Wales. 122pp.

C.8. Contaminant Analysis

The contaminant analysis of sediments obtained from Phase II sampling stations 05, 11, 14 and 17 is presented in Table 4, below. These values will set a good baseline for future monitoring and condition assessment throughout the area of interest.

Table 4. The results of the contaminant analysis from sediment scrape samples obtained from Phase II sampling stations 05, 11, 14 and 17 collected during the October survey of intertidal sediments across the Drigg Coast SAC. Contaminants have been highlighted blue where concentrations are higher than the Background Assessment Concentrations (BACs) and red where levels are above Effects Range Low (ERLs) and Environmental Assessment Criteria (EACs).

Analyte	Units	NEDCSAC 05	NEDCSAC 11	NEDCSAC 14	NEDCSAC 17
Carbon, Organic : Dry Wt as C	%	<0.4	<0.4	<0.4	<0.4
Mercury : Dry Wt	mg/kg	0.003	0.034	0.013	0.075
Aluminium, HF Digest : Dry Wt	mg/kg	29600	30700	22000	38300
Iron, HF Digest : Dry Wt	mg/kg	12700	15700	15500	19700
Arsenic, HF Digest : Dry Wt	mg/kg	10.1	11.2	8.7	11.4
Cadmium, HF Digest : Dry Wt	mg/kg	<0.03	0.042	0.05	0.042
Chromium, HF Digest : Dry Wt	mg/kg	12.3	32.7	25.2	55.6
Copper, HF Digest : Dry Wt	mg/kg	4.02	7.82	5.01	13.2
Lead, HF Digest : Dry Wt	mg/kg	7.52	19.6	13	33.6
Lithium, HF Digest : Dry Wt	mg/kg	18.8	19.6	14.1	35.9
Manganese, HF Digest : Dry Wt	mg/kg	246	441	258	761
Nickel, HF Digest : Dry Wt	mg/kg	9.85	10.5	8.2	19.2
Zinc : HF Digest : Dry Wt	mg/kg	28.5	46.2	35	81.1
Hexachlorobenzene : Dry Wt	ug/kg	<1	<1	<1	<1
Hexachlorobutadiene : Dry Wt	ug/kg	<1	<1	<1	<1
Anthracene : Dry Wt	ug/kg	<2	7.1	<2	19.9
Benzo(a)anthracene : Dry Wt	ug/kg	<2	31.9	3.2	89.3
Benzo(a)pyrene : Dry Wt	ug/kg	<2	31.1	2.9	85.4
Benzo(ghi)perylene : Dry Wt	ug/kg	<10	17.7	<10	46.1
Chrysene + Triphenylene : Dry Wt	ug/kg	<3	30.6	<3	84.7
Fluoranthene : Dry Wt	ug/kg	<2	43.4	4.4	143
Indeno(1,2,3-c,d)pyrene : Dry Wt	ug/kg	<10	15.7	<10	39.8
Naphthalene : Dry Wt	ug/kg	<30	32.9	<30	44.1
Phenanthrene : Dry Wt	ug/kg	<10	36.8	<10	106
Pyrene : Dry Wt	ug/kg	<3	40	4.2	121
2,2,4,4,5,5-Hexabromodiphenyl ether : Dry Wt :- {PBDE 153}	ug/kg	<0.1	<0.1	<0.1	<0.1
2,2,4,4,5,6-Hexabromodiphenyl ether : Dry Wt :- {PBDE 154}	ug/kg	<0.1	<0.1	<0.1	<0.1
2,2,4,4,5-Pentabromodiphenyl ether : Dry Wt :- {PBDE 99}	ug/kg	<0.1	<0.1	<0.1	<0.1
2,2,4,4,6-Pentabromodiphenyl ether : Dry Wt :- {PBDE 100}	ug/kg	<0.1	<0.1	<0.1	<0.1
2,2,4,4-Tetrabromodiphenyl ether : Dry Wt :- {PBDE 47}	ug/kg	<0.1	<0.1	<0.1	<0.1
2,4,4-Tribromodiphenyl ether : Dry Wt :- {PBDE 28}	ug/kg	<0.1	<0.1	<0.1	<0.1
PCB - 028 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1
PCB - 052 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1
PCB - 101 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1
PCB - 118 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1
PCB - 138 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1
PCB - 153 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1
PCB - 180 : Dry Wt	ug/kg	<0.1	<0.1	<0.1	<0.1
Tributyl Tin : Dry Wt as Cation	ug/kg	<3	<3	<3	<3
Dry Solids @ 30°C	%	80.5	72.4	80.7	66.7
Accreditation Assessment	No.	2	2	3	2

C.8.1. Assessments of Concentrations of Selected Hazardous Substances in Sediments

The concentrations of hazardous substances in sediments obtained across the Drigg Coast SAC are presented in Table 4. Using the assessment criteria presented in the OSPAR Coordinated Environmental Monitoring Programme (CEMP)[9] the selected hazardous substances, which were prioritised for action by OSPAR due to their risk for the marine environment and which are being monitored under the CEMP, were assessed against current standards.

Contaminants were assessed according to **Background Assessment Concentrations** (BACs), **Effects Range Low** (ERLs) and **Environmental Assessment Criteria** (EACs):-

BACs Were developed by the OSPAR Commission (OSPAR) for testing whether concentrations are near background levels. Mean concentrations significantly below the BAC are said to be near background.

ERLs ERLs were developed by the United States Environmental Protection Agency for assessing the ecological significance of sediment concentrations. Concentrations below the ERL rarely cause adverse effects in marine organisms. Concentrations *above* the ERM will often cause adverse effects in some marine organisms.

EACs Were developed by OSPAR and the International Council for the Exploration of the Sea for assessing the ecological significance of sediment concentrations. Concentrations below the EAC should not cause any chronic effects in marine species.

Within Table 4 contaminants have been highlighted where concentrations are higher than the BACs (BLUE) and higher than either the ERLs or EACs (RED).

Table 4 demonstrates that no contaminant value for all 4 stations sampled exceeded the ERL or EAC thresholds prescribed by the OSPAR CEMP report. The full assessment criteria are presented in Appendix Table 10.

The Polycyclic Aromatic Hydrocarbon (PAH) levels at station 11 (River Irt) and 17 (River Esk) were higher than background levels (BACs) in most cases. Whilst Naphthalene levels were recorded to be above the BACs threshold at every station sampled. The widespread distribution of PAHs in the marine environment can mainly be attributed to shipping activities, for example from the burning of fossil fuels and oil spill events.

The only metal contaminant to be recorded over the BACs threshold was mercury at station 17, on the River Esk.

PCBs were below the thresholds for sediment contaminants at all 4 stations sampled.

[9] OSPAR Commission (2012) CEMP 2011 Assessment Report. Publication Number: 563/2012; 35pp.

C.9. Temporal Changes

Few historic surveys have been carried out across the intertidal sediments of the Ravenglass Estuary, of note is the Nature Conservancy Council survey carried out in 1989[10] and the Marine Nature Conservation Review carried out in 1998[11].

In 1989, the upper parts of the Esk Estuary were recorded as being composed of 70% very fine sand and 30% silt. The PSA carried out on the Phase II stations from the upper Esk (Stations 13, 14 and 15) show a very similar sediment composition as recorded in 1989, this is illustrated in Figure 8 where sand is the predominant sediment fraction with varying levels of silt. The average levels of gravel, sand and silt recorded at the three Phase II stations in the upper Esk was 1% gravel, 78% sand and 21% silt, showing a slight drop in the silt levels since 1989.

In the sheltered conditions of the upper shore and creek banks silt fractions were observed to increase, and infaunal communities shifted to more estuarine species with *Corophium volutator* dominating and the presence of *Hediste diversicolor* and occasionally *Scrobicularia plana.* This theme from 1989 was also observed during the 2013 survey in the upper Esk, but was also observed in sheltered portions of the Irk and Mite Rivers.

The presence of the oligochaetes *Tubificoides sp.* and the polychaete *Capitella capitata* and there link to typically polluted or organically enriched sediments were noted across the Esk estuary in 1989. Both species were recorded across areas of the Drigg Coast SAC, *Tubificoides benedii* was the most commonly occurring of the two species in 2013, and was found at 40% of the Phase II stations sampled.

In 1998, the single channel which connects the confluence of the Irt, Mite and Esk rivers to the sea, was characterised by 'medium and coarse grained sands with a sparse infauna of amphipods and polychaetes', this description of the channel is similar in nature to the biotope 'Polychaetes in littoral fine sand' (A2.231) prescribed during the 2013 survey.

The 1998 survey further described the middle and upper sections of the Esk and the majority of the Mite and Irt estuaries as consisting of 'fine, sandy mud with communities of the ragworm *Hediste diversicolour*'. In comparison to 2013, sections of the biotope '[*Hediste diversicolor*] in littoral mud' were found across the Esk and Mite, whilst additional biotopes comprising of coarser sediments, mixed sediments and higher abundances of nematodes and oligochaetes were recorded across sections of the 3 rivers.

The Drigg Coast portion of the survey had a 1km overlap with the verification survey of the Cumbria Coast, carried out by MESL[12] in February 2013. MESL classified the lower portion of the Cumbria Coast as 'Polychaete/amphipod-dominated fine sand shores' (A2.23), whereas in October 2013 the Drigg Coast has been classified as 'Polychaetes in littoral fine sand' (A2.231), one level higher. The slight difference in classification of biotopes between the two surveys could be attributed to the seasonality of both surveys, resulting in the Drigg Coast intertidal survey being able to classify the area to a higher level (EUNIS level 5).

[10] Covey, R., & Davies, J. (1989) Littoral survey of South Cumbria (Barrow-in-Furness to St Bees Head). Nature Conservancy Council, CSD Report, No. 985.

[11] Covey, R. (1998). MNCR Sector 11. Liverpool Bay and the Solway Firth: Area Summaries. Peterborough, JNCC. (Coasts and Seas of the UK.MNCR Series)

[12] MESL. (2013). Verification survey of intertidal habitats within the Cumbria Coast rMCZ. Report Number: NECCMCZ0613.

D. CONCLUSIONS

Marine Ecological Surveys Limited (MESL) conducted an intertidal survey of the intertidal mud and sand flats habitats across the Drigg Coast SAC between the 2nd and 10th of October 2013.

The objective of the survey was to identify, characterise and map the extent, range and distribution of intertidal mud and sand flats habitats, noting the presence of any nationally rare or specialised biotopes. Additional information on anthropogenic influences on the site's features was recorded.

The findings of the project are detailed below:

- During the Drigg Coast SAC survey of intertidal sediments, a total of 10 EUNIS biotopes were recorded across the intertidal area of interest. The biotopes that were recorded most frequently across the area were, 'Polychaetes in littoral fine sand' (A2.231), 'Estuarine coarse sediment shores' (A2.12), and 'Polychaete/oligochaete-dominated upper estuarine mud shores' (A2.32). The habitat of conservation importance 'Peat.exposure' was identified on the Drigg Coast portion of the site.

- Particle Size Analysis (PSA) of the deposits sampled at the 21 Phase II sampling locations revealed that sediment composition across the study area was dominated by sand fractions, whilst silt and gravel fractions were found in high proportions at a number of stations. The sediment deposits were classified into 7 groups according to the Folk classification system, these included; Sand (S), slightly gravelly Sand ((g)S), slightly gravelly muddy sand ((g)mS), gravelly muddy sand (gmS), muddy sand (mS), sandy mud (sM) and sandy Gravel (sG).

- A general pattern in the distribution of the sediment deposits across the Drigg Coast SAC, was that the stations furthest up the estuary had higher proportions of silt, stations found in the mid estuary were generally dominated by gravel fractions and the mouth of the estuary was almost entirely comprised of sand fractions.

- A range of benthic invertebrate species were recorded across the Drigg Coast SAC; a total of 78 taxa and 14884 individuals were identified. The mean number of taxa recorded per sample was 7.1 and the mean number of organisms per sample was 141.8.

- Taxa belonging to the Phylum Annelida were the most important in terms of both abundance and diversity, representing 38% of the total abundance and 41% of the taxa sampled. Crustacea represented only slightly smaller contributions to both indices of 34% and 30% respectively.

- Mollusca individually represented 85% of the total sampled biomass of the site, 77% of the total biomass was contributed by the two bivalves *Mytilus edulis* and *Cerastoderma edule.*

- The most abundant taxon was the phylum Nematoda, which accounted for approximately 26% of all fauna sampled, *Corophium volutator* was only slightly less representing 24%. The top ten most abundant species accounted for over 92% of the total faunal abundance.

- Four distinct faunal groups and one outlying station were identified through multivariate analysis. Faunal Group D was the largest group, sampled at a total of 12 stations. Key characterising taxa of the group included Enchytraeidae, Nematoda, *Tubificoides benedii* and the amphipod *Bathyporeia pilosa.*

- Statistical techniques revealed a significant relationship between patterns observed in the particle size distribution data to those seen in the faunal communities.

- *'Ceramium* sp. and piddocks on eulittoral fossilised peat', a habitat of conservation interest falling into the category of 'Nationally and more nationally important communities' was recorded across the Drigg Coast portion of site.

- There was no evidence of significant anthropogenic impact on intertidal features that were targeted during this study. However, anthropogenic disturbances across the full extent of the Drigg Coast SAC site were recorded. These included disturbances from commercial and recreational boats moored on the foreshore around Ravenglass, and from littering of anthropogenic waste/debris found particularly on the strandline. Large portions of the estuary were surrounded by farmland which has the potential to leach excess nutrients into the estuary, especially during periods of prolonged rainfall.

- The contaminants analysis demonstrated that all levels of contaminants were below the ERL and EAC thresholds prescribed by the OSPAR CEMP report. Slightly elevated levels of Polycyclic Aromatic Hydrocarbons were recorded at the contaminants stations on the Rivers Irt and Esk, with the River Esk also displaying mercury above the BAC threshold. The results from this analysis will set a good baseline for future monitoring and condition assessment throughout the area of interest.

- Intertidal areas, particularly those that are susceptible to eroding, are dynamic systems and the maps produced represent a 'snapshot in time'. It should be noted that habitats may change naturally through physical and biological processes.

E. APPENDICES

1. Sampling log and Positions for the infaunal hand core samples
2. Particle Size Distribution (PSD) Data
3. Simplified Sediment Composition Data and Folk Sediment Classification
4. Macrofaunal Abundance Matrix
5. Summary of Faunal Abundance, Species diversity and Biomass
6. SIMPER Analysis of Faunal Group Composition
7. RELATE and BIO-ENV Analysis
8. MESL Photo log
9. Multivariate Statistics Method Statement
10. Contaminants Assessment Criteria
11. Phase II Sample Station Contact Prints