Biological Survey of the Intertidal Sediments of the South Shore of Solway Firth, 2014

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Biological Survey of the Intertidal Sediments of the South Shore of the Solway Firth, 2014

Report to Natural England
(Contract ref: ECM 6431)

UNIVERSITY OF Hull
Institute of Estuarine and Coastal Studies

Institute of Estuarine and Coastal Studies
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March 2015

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Executive Summary

Background

One of the key responsibilities of the statutory nature conservation agencies in the UK is the identification and protection of a series of sites intended to conserve important wildlife and earth science features. Such sites may be designated under national legislation (e.g. Sites of Special Scientific Interest ISSSIs)), or European legislation such as Special Areas of Conservation (SACs) under the Habitats Directive, and Special Protection Areas (SPAs) under the Birds Directive.

Site Condition Monitoring is undertaken to determine whether the status of the special interest features which underpin the designation of habitats or areas are being maintained, and to guide site management action where appropriate. Natural England have a duty to assess the condition of the SAC's features once every six years. The Inner Solway is designated as an SAC, and the current study therefore forms part of a long term monitoring plan being jointly administered by Natural England and Scottish Natural Heritage under the requirements of the Habitats Directive (and enabling UK legislation).

Two previous intertidal biotope surveys have been undertaken by IECS in the Solway Firth on behalf of Natural England (or English Nature as previously known), the first in September and October 2004, and the second during March 2011. The 2004 survey covered both the north and south banks of the estuary (Hemingway *et al*., 2006), whilst the inner estuary together with the outer south shore were again surveyed for biotope comparison and extent in 2011 (Cutts *et al*., 2011). The current survey programme of intertidal biotope mapping work on the south shore of the Solway covered a similar area to that of the previous 2011 survey. The ecological survey work was designed to monitor and assess the mudflats and sandflats not covered by seawater at low tide (intertidal mudflats and sandflats) of the Solway Firth SAC, and the survey objectives as defined under the project specification were therefore to report the following information:

Extent of the infaunal communities as estimated from the line transects (survey track files).

Species composition of characteristic biotopes.

Sediment characteristics (grain size, organic content, and depth of redox layer) along transects, and relationship to observed changes in biological community.

Associated biotope detail and spatial extent.

Compare and contrast changes in extent and type of biological communities and sediment character within previous studies from the same area (biotope status and change).

Alongside the above survey programme undertaken by IECS, Natural England additionally commissioned a second study undertaken by Ecospan Environmental Ltd. (Curtis, 2014) to monitor and assess the extent and condition of the intertidal rocky scars sub-feature. The methods and findings from this survey were under separate contract to Natural England and have therefore also been reported separately (Curtis, 2014; Appendix 6). However, the derived information has been incorporated into the overall analysis and mapping exercise undertaken by IECS and described within the current report.

Methods

The intertidal survey involved the *in situ* field surveying and mapping of the soft sediment habitats of the intertidal zone using a hovercraft survey platform, with the programme focussing on three study areas within the estuary: Old Graitney (North Bank) to Port Carlisle (South Bank) (Map 3); Cardurnock Flatts & Moricambe Bay (Map 4); and Blitterlees Bank to Dubmill Point (South of Silloth) (Map 5).

The methodology required a two phased survey effort with the first phase involving a general characterisation of the area. Based on the analysis of the information derived from Phase 1 (undertaken 16th-19th June 2014), samples were subsequently collected at 20 stations during Phase 2 (16th & 17th July 2014) in order to fully describe the invertebrate and sediment conditions, and the associated biotopes present. Maps 3 to 5 show both the Phase 1 transects (with potential biotopes as identified on completion of Phase 1), together with the locations from which Phase 2 samples were taken for more detailed taxonomic and sediment analysis.

Old Graitney to Port Carlisle

This extreme upper estuarine area includes two freshwater input channels into the Solway Firth, i.e. the River Esk to the north of Rockcliffe Marsh, and the River Eden to the south of the marsh. In the extreme upper part of the system between these two channels is an area of high marsh. This includes extensive high saltmarsh, as well as grazing marsh (Rockcliffe Marsh). Fronting the marsh is an extensive area of intertidal soft sediment, including areas of high sand bank, some of which appear to remain uncovered by the tide even around high water during neap phases, and extensive low sand flats which are present in both the Eden (e.g. around Burghmarsh Point) and Esk (e.g. around Redkirk Point) branches.

During the 2014 survey programme, three main intertidal soft sediment habitats were identified within the area (in addition to high saltmarsh):

Large elevated fine to medium fine sand flats;

Extensive flat low elevation firm rippled muddy sand to fine sand flats;

Relatively narrow sandy mud with occasional cobble on the fringing banks.

Box 1 summarises the littoral soft sediment biotopes assigned within the Old Graitney to Port Carlisle survey sector during 2014. The biotope **LS.LSa.FiSa** and the biotope mosaic **LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte** form the greatest components within this area.

Box 1:

Distinct Individual Biotopes	Biotope Mosaics / Transitions
LS.LSa.MoSa LS.LSa.FiSa LS.LSa.FiSa.Po.Pful LS.LSa.MuSa.BatCare LS.LMu.MEst.HedMac	LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte onto LS.LSa.MoSa
Total = 5	**Total = 2**

Cardurnock Flatts & Moricambe Bay

Cardurnock Flatts is an extensive area of intertidal sandflat in the Inner Solway (south shore), to the south of the main Eden Channel (and bounded by the channel in its northern and eastern extent). The habitat is primarily backed by tidal grazing marsh and incised by a series of drainage creeks. The southern area of the site features several cobble scars, these being situated around the mouth of Moricambe Bay. Moricambe Bay is an embayment feature also backed primarily by merse, with the small Rivers Wampool and Waver discharging into it. The main intertidal area of Moricambe Bay is incised by the river channels, which form a combined and dynamic fluvial system that enters into the main body of the estuary north of Grune Point.

At this point, the Eden Channel has developed into the Swatchway, through which the majority of the inner estuary freshwater input drains, and which forms a

substantial channel. Offshore from this location (*c*. 1km) is Middle Bank, which forms an extensive mobile mid channel sand bank.

During the 2014 survey programme, four main intertidal habitats were identified within the area (in addition to high saltmarsh):

Extensive mid shore fine sand flats (Cardurnock);

Extensive mid shore muddy sand to fine sand flats (Moricambe Bay);

Mobile scoured sands (Wampool and Waver channel 'delta');

Scar grounds surveyed by Ecospan Environmental Ltd. (Curtis 2014; Appendix 6).

Box 2 summarises the littoral soft sediment biotopes assigned within the Cardurnock Flatts & Moricambe Bay survey sector during 2014. The biotopes **LS.LSa.FiSa.Po.Pful** and **LS.LSa.MuSa.MacAre** form the greatest components within this area.

Box 2:

Distinct Individual Biotopes	Biotope Mosaics / Transitions
LS.LSa.FiSa.Po.Pful LS.LSa.FiSa.Po.Ncir LS.LSa.MuSa.MacAre LS.LSa.MuSa.HedMacEte LS.LSa.MuSa.BatCare	LS.LSa.FiSa / LS.LSa.MuSa.MacAre LS.LSa.FiSa.Po / LS.LSa.MoSa.AmSco LS.LSa.FiSa.Po / LS.LSa.MuSa.MacAre LS.LSa.MuSa.MacAre / LS.LSa.MuSa.HedMacEte LS.LSa.MuSa.CerPo / LS.LSa.MuSa.HedMacEte LS.LSa.MuSa.BatCare / LS.LSa.MuSa.MacAre LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte
Total = 5	**Total = 7**

Blitterlees to Dubmill Point

The intertidal area running south (downstream) from Silloth to Dubmill Point features extensive intertidal sandflats backed by a significant dune complex. The intertidal sandflats incorporate areas of scar and boulder field, the status of these being apparently relatively ephemeral depending on erosion and deposition cycles (e.g. as recorded from previous IECS surveys). The most extensive of these scars is located at Dubmill Point.

Running south from the Port of Silloth entrance, the intertidal habitat extent gradually increases to a width of *c*. 3km off Mawbray and down to Dubmill Point. The majority of the intertidal area consists of a fine to medium sand with areas of muddy sand, as well as some cobble/boulder scars. Some of these scars are partially covered by surficial soft sediment so that they are present as 'boulder fields' rather than a more characteristic 'cobble scar' habitat.

The extreme upper shore of the Silloth to Wolsty Bank reach is predominantly dune, which grades into a fine sand strandline habitat (predominantly LS.LSa.MoSa.BarSa), although with patches of cobble/pebble LS.LCS.Sh.BarSh also present. As with the 2011 survey programme (Cutts *et al*., 2011), these were not assessed in detail during the current 2014 survey, although they were noted as extending down onto the upper shore in the form of a relatively steeply shelving high energy beach consisting of fine to medium sand with variable gravel content over much of the reach.

The majority of the survey area consisted of a low shore fine sand flat with variable ripple features, standing water, mud content, and with some coal and shell debris. During the 2014 survey programme. Two main intertidal habitats were identified within the area (in addition to the high shore barren sand/shingle):

Extensive mid shore fine sand flats;

Scar grounds and biogenic reefs surveyed by Ecospan Environmental Ltd. (Curtis 2014; Appendix 6).

Box 3 summarises the littoral soft sediment biotopes assigned within the Blitterlees Bank to Dubmill Point survey sector during 2014. The biotope **LS.LSa.FiSa.Po** forms the greatest component within this area.

Box 3:

Distinct Individual Biotopes	Biotope Mosaics / Transitions
LS.LSa.MoSa.Ol.FS LS.LSa.MoSa.AmSco LS.LSa.FiSa.Po LS.LSa.FiSa.Po.Ncir LS.LSa.MuSa.MacAre	LS.LSa.MoSa.AmSco / LS.LSa.FiSa.Po LS.LSa.MoSa.AmSco.Eur / LS.LSa.MuSa.MacAre LS.LSa.FiSa.Po / LS.LSa.MuSa.MacAre LS.LSa.MuSa.MacAre / LS.LSa.MuSa.HedMacEte
Total = 5	**Total = 4**

Conclusions

Following analysis of the 2014 biotope data in the context of the 2011 programme findings, a series of conclusions on the condition of the SAC attributes are made. Whilst aspects of the assessment of Condition Status are slightly constrained by methodological differences between the two surveys (e.g. survey timing and differences in sample station locations), as well as by incomplete coverage of the whole site on the surveys (to cover all areas would increase survey time substantially), it is considered that the key habitat areas have been covered with sufficient rigor for some broad conclusions on status to be drawn on condition targets.

Based on a broad comparability in the extent of the coverage between the areas surveyed (2011 & 2014) it is concluded that there is no measurable decrease in the extent of the *mudflats and sandflats not covered by seawater at low tide* feature and it is highly likely that the condition target has been met. The broad sediment parameters for each of the survey areas are very similar between the two survey years (in terms of sediment particle size, penetrability and anoxia). As such, and within the context of available comparable data, it is concluded that the sediment character targets have been met. Furthermore, it is concluded that there has been no significant alteration in elevation (subject to natural change context) and the target has been met, with no change in nutrient status based on algal mat extent.

Whilst the range of sand communities was assessed as being characteristic of the site and broadly similar to those seen in 2011, it was not possible to address the status of the scar ground (gravel) communities against 2011 information. However, their status was considered characteristic, although with the potential for some localised change as a result of sand swamping as a natural process.

Sandy mud communities were not regularly encountered in either the 2014 or 2011 surveys although characteristic biotopes were recorded from both surveys for muddy sand areas. The presence of species such as *Arenicola* and *Macoma* was relatively ubiquitous and biotopes characterised by these predominated across the survey area. *Cerastoderma* was recorded from both the 2011 and 2014 surveys, in generally the same locations but with insufficient densities to be considered a ‘cockle bed’ and ascribed a specific biotope. No evidence of cockle harvesting was noted from either survey in this area and based on available data, it is considered that the targets for the presence and extent of characteristic biotopes have been met.

Contents

1. Introduction

1.1 Background

One of the key responsibilities of the statutory nature conservation agencies in the UK is the identification and protection of a series of sites intended to conserve important wildlife and earth science features. Such sites may be designated under national legislation (e.g. Sites of Special Scientific Interest (SSSIs)), or European legislation such as Special Areas of Conservation (SACs) under the Habitats Directive[1], and Special Protection Areas (SPAs) under the Birds Directive[2]. Regular monitoring of sites is undertaken in order to assess the effectiveness of legislative and policy measures in contributing to biodiversity conservation. The intertidal mudflats and sandflats are a designated interest feature of the Solway Firth estuary, and as such, the survey reported here has aimed to provide data to support the overall monitoring programme of the site. Ultimately, the data will form a part of the ongoing condition assessment for the site.

1.1.1 Condition Monitoring of the Intertidal Soft Sediments within the Solway Firth SAC

Site Condition Monitoring is undertaken to determine whether the status of the special interest features which underpin the designation of habitats or areas are being maintained, and to guide site management action where appropriate. As such, Natural England have a duty to assess the condition of the SAC's features once every six years.

Within the Inner Solway Firth SAC, the intertidal sandy mud communities which are a sub-feature of the *mudflats and sandflats not covered by seawater at low tide* qualifying habitat (Natural England & Scottish Natural Heritage, 2010), fall under the Common Standards Monitoring (CSM) guidance produced for littoral sediment habitats (Joint Nature Conservation Committee, 2004). For the purposes of monitoring, each feature of the SAC has an associated series of attributes which are

[1] Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora (commonly referred to as the 'Habitats Directive').

[2] Council Directive 79/409/EEC of 2 April 1979 on the Conservation of Wild Birds (commonly referred to as the 'Birds Directive').

measurable indicators of the condition of the feature at the site. A target is set for each attribute which is considered to correspond to the favourable condition of the feature.

Under Regulation 33 (2)(a) of The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended), Natural England (NE) and Scottish Natural Heritage (SNH) have a duty to advise other relevant authorities as to the conservation objectives for the European Marine Site. For the marine qualifying interests of the Solway Firth SAC (of which sandy mud communities are a sub-feature of the *mudflats and sandflats not covered by seawater at low tide*), the conservation objectives provided by NE and SNH (2010) are as follows:

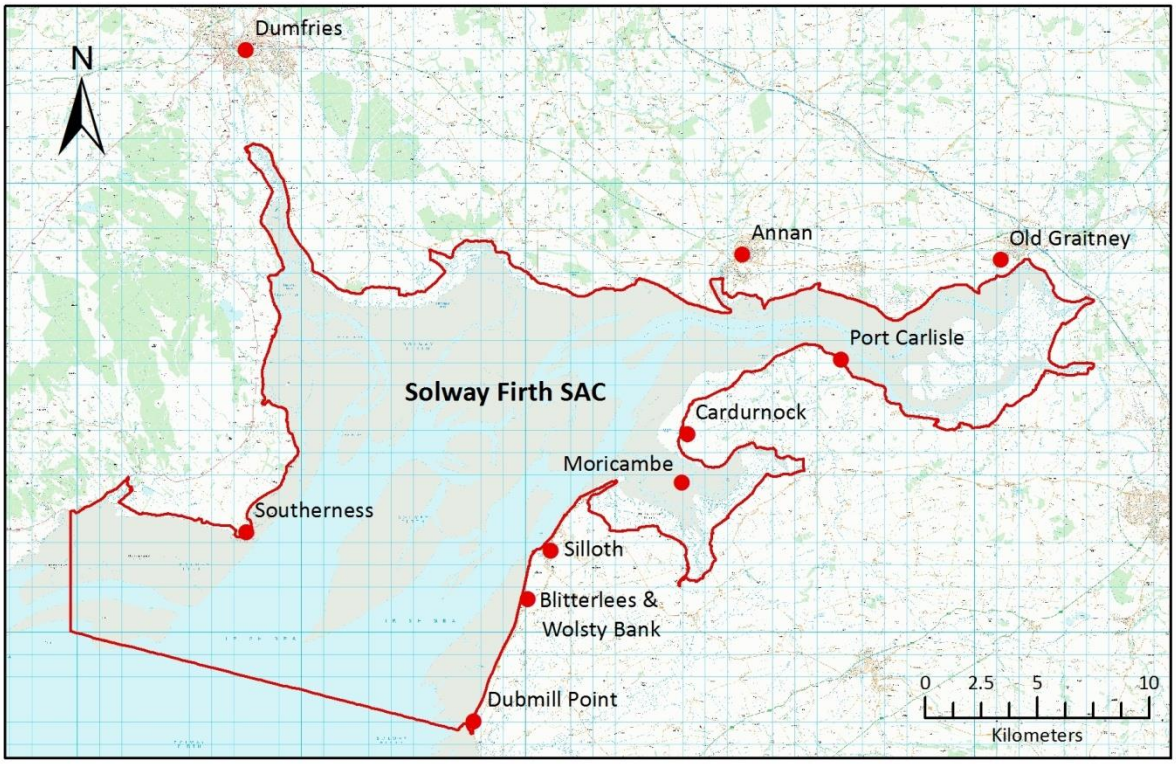
Subject to natural change, avoid deterioration of the qualifying habitat (Estuaries, Sandbanks which are slightly covered by seawater all the time, Mudflats and sandflats not covered by seawater at low tide, Reefs, Salicornia and other annuals colonising mud and sand, and Atlantic salt meadows (Glauco-Puccinellietalia maritimae)) thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status for each of the qualifying interests.

To ensure for the qualifying habitats that the following are maintained in the long term:

- *Extent of the habitat on site.*
- *Distribution of the habitat within site.*
- *Structure and function of the habitat.*
- *Processes supporting the habitat.*
- *Distribution of typical species of the habitat.*
- *Viability of typical species as components of the habitat.*
- *No significant disturbance of typical species of the habitat.*

1.2 Survey Aims and Objectives

The Inner Solway is designated as a Special Area of Conservation (SAC) (Map 1), and the current study therefore forms part of a long term monitoring programme being jointly administered by Natural England (NE), and Scottish Natural Heritage (SNH) under the requirements of the Habitats Directive (and enabling UK legislation).



Map 1: Solway Firth SAC.

An intertidal biotope survey was undertaken by IECS on behalf of Natural England (then English Nature) in 2004, with the survey covering both the north and south banks of the Solway (Hemingway *et al*., 2006). In 2011, the inner Solway together with the middle to outer south shore were again surveyed for biotope composition and extent (Cutts *et al.,* 2011).

The current survey programme of intertidal biotope mapping work on the south shore of the Solway (survey effort and platform prescribed in the project specification) covered a similar area to that of the previous 2011 survey. The ecological survey work was designed to monitor and assess the *mudflats and sandflats not covered by seawater at low tide (intertidal mudflats and sandflats)* of the Solway Firth SAC, and the survey objectives as defined under the project specification were therefore to report the following information:

- Extent of the infaunal communities as estimated from line transects (survey track files).
- Species composition of characteristic biotopes.
- Sediment characteristics (grain size, organic content, and depth of redox layer) along transects, and relationship to observed changes in biological community.
- Associated biotope detail and spatial extent.

- Compare and contrast changes in extent and type of biological communities and sediment character within previous studies from the same area (biotope status and change).

1.3 The Solway Firth

1.3.1 Background & Previous Studies

The Solway Firth is a large macrotidal estuary situated on the west coast of Britain which represents one of the largest tidal embayments in the north eastern Irish Sea. The southern shoreline of the estuary is located in England along the Cumbrian coast, whilst the northern shoreline lies in Scotland along the Dumfries and Galloway coast. The estuary is a tidally flooded synclinal feature with inputs from a number of rivers (including the Esk, Eden, Annan, and Nith), giving an average fluvial input in excess of 100 cumecs (Babtie *et al*., 1966). In extreme flood and drought conditions, this may fluctuate between 3,400 cumecs and 7.4 cumecs respectively (Babtie *et al*., 1966).

Within the estuary, the tidal range using mean low and high water spring tides at Kirkcudbright Bay is approximately 6.7m, whilst at Silloth on the Cumbrian coast, this increases to 8.4m. Further upstream at Redkirk (near the head of the estuary), the spring tide range is reduced to approximately 3.6m, and at this point, tidal height is also significantly influenced by inputs from the River Esk. The estuary additionally features strong tidal currents, with a maximum speed of up to 4 knots during spring tides, and more than 2 knots during neap tides (as derived from the Admiralty Chart tidal diamond for the area). Under certain conditions, a tidal bore may form upstream of Annan, with a speed of approximately 6 knots, and a height in extreme conditions of 1.5m (ABP, 1991).

Wave height and direction is largely dependent on the aspect and fetch, and the enclosed nature of the Irish Sea means that the Solway is generally sheltered from Atlantic swells, with fetch lengths between 200-300 km (although the Isle of Man reduces this to under 100 km). The prevailing winds for the outer Solway are from the north-west in winter, and south-west in summer (Babtie *et al*., 1989), although a degree of channelling occurs in the upper estuary, with prevailing winds from the south-west quadrant recorded at Chapelcross throughout the year (Ove Arup & Partners, 1993a, 1993b).

The mudflats and sandflats of the Solway comprise the third largest continuous area of mud and sand in the UK after the Wash and Morecambe Bay (Davidson *et al*., 1991), with intertidal flats covering an area of over 35,000 ha, and accounting for 50% of the total area of the Inner Solway (SSMA, 2004). They contribute

significantly to the habitat diversity of the site, and this environmental importance is reflected in its nature reserves and conservation designations (Section 1.3.2).

The intertidal flats are highly mobile and predominantly consist of fine sands and silt, with fine sandy sediments occurring in the inner estuary, and coarser sediments in the outer reaches. The presence of fine sands rather than muds (due to the lack of mud being imported into the system from rivers) is unusual in conditions of estuarine salinity, although a typical estuarine fauna is supported, with the dominant infauna dependant on variation in sediment composition and position on the shore. As such, the flats provide a valuable food source for feeding birds and fish as well as acting as a refuge site for roosting birds.

In general, sediment deposits within the sandbanks of the Solway are of a coarser nature than those found in most estuaries, with a mean grain size of approximately 100µm (Black *et al.*, 1994). Material within the inner estuary is mainly composed of smaller grain sizes (with the flats associated with the River Nith and the Nith estuary having an average particle size of <63 µm, thereby being classified as silt or clay), whilst in general, the outer estuary has a coarser sediment type (Black *et al*., 1994).

Material >2 mm is uncommon in the estuary, and the majority of coarse deposits (including pebble, cobble, and boulder), are associated with eroded glacigenic deposits, although shell debris may occur. These areas range from shingle and/or pebble beaches to cobble/boulder scars, and generally occur as a result of erosion of glacial material backing the site, with the larger material (by virtue of its size), remaining close to the parent source (Cutts & Hemingway, 1996). The majority of these scar grounds are located in the inner estuary close to Powfoot, and are associated with the glacial and fluviglacial material of that area. However, extensive areas of scar also occur on the south shore between Silloth and Maryport, with this material being eroded from raised shingle structures under the dunes, or removed from the offshore scar grounds and carried landwards by storm waves (Cutts & Hemingway, 1996).

The intertidal biotope survey undertaken by IECS in 2004 (Hemingway *et al*., 2006), confirmed much of the above, with the findings also consistent with previous IECS studies of the area. However, the study did identify specific examples of the dynamic nature of the soft sediment habitats within the estuary, with the presence/absence of scar grounds not always consistent with those described historically, from previous IECS studies, or from Ordnance survey maps and associated aerial photographs. This variability was noted on the north shore around Powfoot, and around the mouth of Moricambe Bay and along the Silloth to Dubmill reach.

The biotope survey of the intertidal sediments of the south shore of the Solway undertaken by IECS using a hovercraft over a three day period in the late

winter/early spring 2011 (Cutts *et al*., 2011) split the survey into three areas (upper inner, lower inner & middle to outer Solway; Map 2) and identified the following:

Upper Inner Solway: Old Graitney to Port Carlisle

This extreme upper estuarine area features two freshwater input channels from the River Esk to the north of Rockcliffe Marsh, and the River Eden to the south of the marsh. Between these two channels an area of high marsh was recorded and fronting the marsh was an extensive area of intertidal soft sediment, including areas of high sand bank and extensive low sand flats which were present in both the Eden (e.g. around Burghmarsh Point) and Esk (e.g. around Redkirk Point) branches. These areas are located adjacent to the freshwater channels, and around the confluence of these channels (e.g. upstream from around Torduff Point to Port Carlisle). Three main intertidal soft sediment habitats were identified within the area (in addition to high saltmarsh):

- Large elevated fine to medium fine sand flats;
- Extensive flat low shore firm rippled muddy sand to fine sand flats;
- Relatively narrow sandy mud with occasional cobble on the fringing banks.

Lower Inner Solway: Cardurnock Flatts and Grune Cast

The extensive area of intertidal sandflat of Cardurnock Flatts in the lower inner Solway dominated this survey area, but with the southern area of the feature supporting several cobble scars, these being situated around the mouth of Moricambe Bay, a large coastal inlet. The Grune Point feature, with an intertidal area extending out to its west (Grune Cast) lies to the south of this, with Middle Bank forming an extensive mobile mid channel sand bank off this. The survey identified two main intertidal soft sediment habitats (in addition to high saltmarsh):

- Extensive flat low to middle shore firm rippled muddy sand to fine sand flats;
- Low shore soft sediment ‘delta’ formed by the discharge from Moricambe Bay.

In addition, cobble/boulder habitats were present both in the form of intertidal scar areas and in the upper-shore along the southern section of Grune Point. These habitats featured a variable associated fauna, from absence to a relatively abundant barnacle and littorinid community.

Middle to Outer Solway: Blitterlees and Wolsty Banks

The intertidal reach running south (downstream) from Silloth to Dubmill Point featured extensive intertidal sandflats backed by a significant dune complex. The intertidal sandflats were shown to include areas of scar and boulder field, the status of these being apparently relatively ephemeral depending on erosion and deposition cycles. The survey concentrated on the intertidal area fronting the Blitterlees Bank

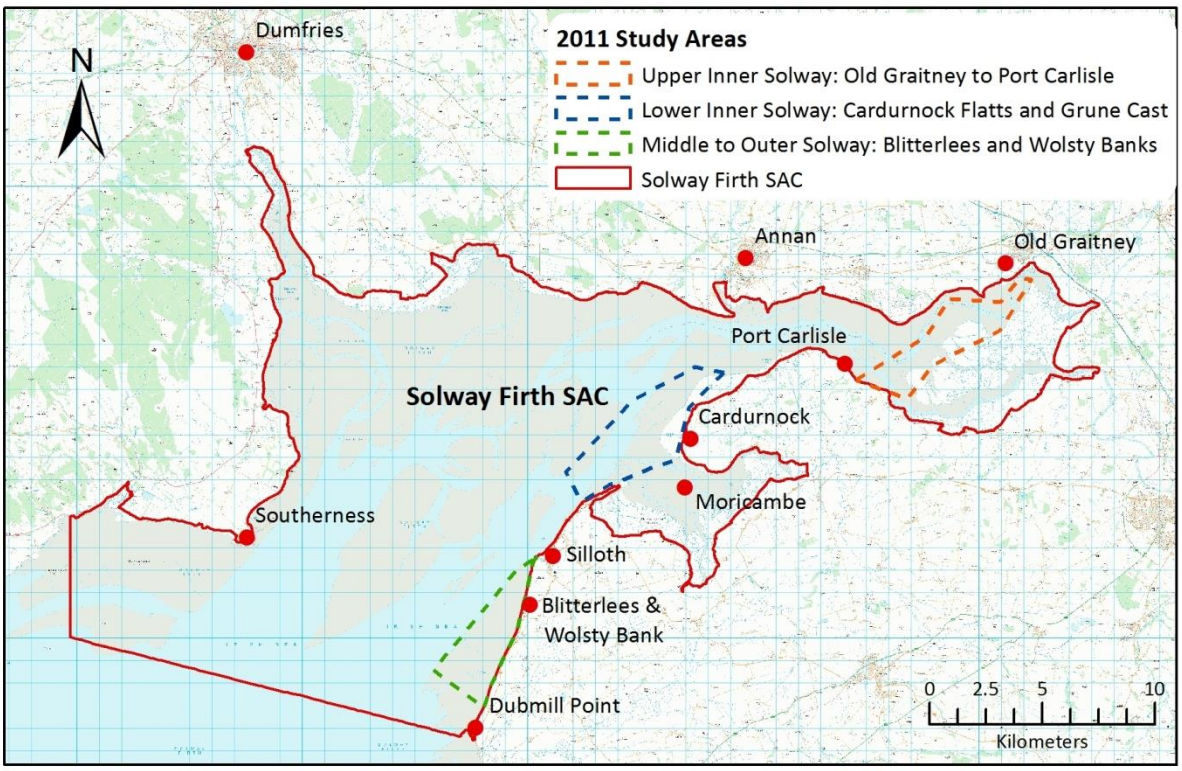
to Wolsty Bank area where three main intertidal soft sediment habitats were identified (in addition to dune communities):

- Extensive flat low to middle shore firm rippled muddy sand to fine sand flats;
- Scar ground of variable coverage and faunal diversity (inc. boulder fields);
- Biogenic reef with *Mytilus* and *Sabellaria* communities present.

In general, the soft sediment habitats of the survey area were found to be relatively impoverished during the survey, possibly as an artefact of survey timing (undertaken 16-18 March 2011), with the location of the survey area on the open coast meaning that wave action over the winter is also likely to have had an effect on the community composition.

Conclusions

The 2011 survey programme concluded that the biotope composition and extent was broadly similar to that of the 2004 survey programme where comparison allowed, with species richness generally poor from both surveys. However, some differences in extent and dominance of communities was noted, reflecting differences in survey timing, as well as a possible small shift in community composition. The biogenic reef area to the south of Lees Scar consisting of cobble and fine sediment together with *Mytilus* and *Sabellaria* was recorded from both the 2004 and 2011 surveys. However, whilst the 2011 survey recorded that the *Sabellaria* reef was in a generally poor condition, being partially smothered by pseudo-faeces, it was noted that the reef extent appeared to have extended from the 2004 survey, in particular to the south.



Map 2: 2011 Survey Areas (see Cutts *et al*., 2011).

1.3.2 Conservation Designations

The environmental importance of the Solway Firth is reflected through a wide variety of statutory and non-statutory international, national, and local mechanisms which operate within the estuary to conserve and protect its wildlife (SSMA, 2004). The estuary is of particular importance in terms of avifaunal abundance.

As a result, the Upper Solway Flats and Marshes have been designated as a Special Protection Area (SPA) under the Birds Directive, and a wetland of international importance under the Ramsar Convention[3]. Additionally, the Inner Solway has been designated as a Site of Special Scientific Interest (SSSI) notified under the Wildlife & Countryside Act 1981[4] (as amended), and a Special Area of Conservation (SAC)

[3] The Convention on Wetlands of International Importance especially as Waterfowl Habitat (commonly referred to as the 'RAMSAR' Convention).

[4] This legislation is the means by which the Convention on the Conservation of European Wildlife and Natural Habitats (the 'Bern Convention') and the European Union Directives on the Conservation of Wild Birds

under the EU Habitats Directive (SSMA, 2004). The SAC, with a total area of approximately 44,000ha, supports extensive areas of Atlantic salt meadows, pioneer saltmarsh, intertidal mudflats and sandflats, subtidal sandbanks, reefs, coastal shingle vegetation and dune grassland (NE & SNH, 2010).

The features for which the SAC, SPA, and RAMSAR have been selected (known as the qualifying interest features) are listed below and have been taken from NE and SNH (2010):

Qualifying Interest Features under the EU Habitats Directive occurring in the European Marine Site

The Solway qualifies as a SAC for the following Annex I habitats and Annex II species:

- Estuaries;
- *Salicornia* and other annuals colonising mud and sand (referred to as pioneer saltmarsh);
- Atlantic salt meadows *Glauco-Puccinellietalia maritimae*) also commonly referred to as saltmarsh);
- Mudflats and sandflats not covered by sea water at low tide (referred to as intertidal mudflats and sandflats);
- Sandbanks which are slightly covered by sea water at all times (referred to as subtidal sandbanks)
- Reefs
- *Lampetra fluviatilis* (River lamprey);
- *Petromyzon marinus* (Sea lamprey).

Qualifying Interest Features under the EU Birds Directive occurring in the European Marine Site

The Upper Solway Flats and Marshes (including Rockcliffe Marsh) qualifies as a SPA under the EU Birds Directive in that it supports:

- Internationally important populations of regularly occurring Annex 1 species;
- Internationally important populations of regularly occurring migratory species;
- An internationally important assemblage of waterfowl.

(79/409/EEC) and Natural Habitats and Wild Fauna and Flora (92/43/FFC) are implemented in Great Britain. It does not extend to Northern Ireland, the Channel Islands or the Isle of Man.

Criterion under the Ramsar Convention on Wetlands of International Importance occurring in the European Marine Site

The Upper Solway Flats & Marshes Ramsar Site qualifies under Criterion 2 as it supports vulnerable, endangered species or threatened ecological communities:

- Supports over 10% of the British population of natterjack toad, *Bufo calamita* (Habitats Directive Annex IV species (S1202)).

The Upper Solway Flats & Marshes Ramsar Site qualifies under Criterion 5 as it regularly supports:

- 20,000 or more waterfowl (5 year peak mean 1998/99 - 2002/2003).

The Upper Solway Flats & Marshes Ramsar Site qualifies under Criterion 6 as it regularly supports:

- 1% or more of the individuals in a population of one species or sub-species of waterfowl.

The Upper Solway Flats & Marshes Ramsar site (area of 43,636.73ha) was listed on 30th November 1992.

1.3.3 Biology

1.3.3.1 Invertebrates

The nature of communities present within the intertidal flats depends on a variety of factors, including sediment type (grain size/silt content), shore height, exposure to wave action, and salinity, with further variation occurring on a seasonal basis. In areas where there is considerable freshwater input, only a few tolerant brackish species persist. However, although estuarine species diversity may be low, individual species are often present in extremely high abundances. In the Solway, up to 20,000 burrowing amphipods, and 20,000 surface dwelling gastropods may be found per square metre (Solway Firth Partnership, 1996).

Towards the head of the estuary, sediments have been described as dominated by muddy silt with varying degrees of sand content (Covey & Emblow, 1992; Cutts & Hemingway, 1996). Typical species in these areas include polychaetes such as *Hediste diversicolor* (ragworm), burrowing bivalves (i.e. *Macoma balthica* - Baltic tellin), and *Cerastoderma edule* (common cockle). *Talitrus saltator* (sandhopper), together with *Hydrobia ulvae* (laver spire shell) also tend to be common on the sediment surface (Cutts & Hemingway, 1996).

In areas of fine or very fine sand under normal salinity conditions, typical species often include polychaetes such as *Nephtys* spp., *Scoloplos armiger*, *Arenicola marina* (lugworm), and the amphipod *Bathyporeia pelagica* (SSMA, 2004), whilst areas influenced by freshwater run-off are dominated by oligochaetes. In contrast,

coarse sediments occur in areas of high wave exposure and in these areas, the fauna is dominated by burrowing amphipods, mainly *Bathyporeia* species (Cutts & Hemingway, 1996). Clean medium sands to fine sands in moderately exposed reaches of the estuary are dominated by polychaetes such as *Nephtys cirrosa* and *Nephtys hombergii,* together with bivalves such as *Angulus tenuis* (thin tellin) and *Donax vittatus* (banded wedge shell). Transitional communities occur with changes in grain size (Covey & Emblow, 1992).

Intertidal scar ground mapping undertaken on the northern shore of the Solway (Allen *et al*., 1999), found the main scar ground biotopes recorded during the survey related to mid-upper shore areas. These scar grounds (Powfoot, Howgarth, Hogus Point, Nethertown, and Rough) were found to be dominated by a pebble/cobble substratum with interstitial muds, surrounded by extensive mud and sand flats. Wave exposure was low to moderate, and dominant species included *Mytilus edulis* (common mussel), and *Elminius modestus* which occurred in variable levels of abundance. *Semibalanus balanoides* were also observed on occasion, although these barnacles were not found to be as common as *E. modestus*. Littorinids were observed in relatively high densities on both the cobble and soft substratum, and *Carcinus maenas* (common shore crab) was present beneath boulders and in pools. Additional scar grounds were described for the south shore of the Solway in Hemingway *et al*. (2006).

In general, fucoid cover on the scars was found to be limited, although extensive areas were noted at Powfoot, whilst *Ulva lactuca* (sea lettuce) and *Enteromorpha* sp. were occasional at most sites. A soft substratum (predominantly sandy mud) was found both interstitially within mussel beds, and between cobbles and pebbles, forming small pans in some areas. These areas supported locally abundant to common populations of *C. volutator* and *H. ulvae*, together with polychaetes including *H. diversicolor*, and bivalves such as *M. balthica* and *Scrobicularia plana* (peppery furrow shell) (Allen *et al*., 1999).

The Marine Nature Conservation Review (MNCR) have identified a number of characteristic and returning species from within a variety of sediment types, and a fuller description of these are given by Connor *et al.* (1997, 2004). Rocky scar ground communities on the southern shoreline have also been surveyed during 2014, and are described in further detail in Curtis (2014).

1.3.3.2 Fish

The Solway supports a wide range of fish species, the most common being plaice, dab, whiting, pogge, sand goby, and flounder (Lancaster, 1999). Other species identified from beam trawls in the estuary (Lancaster, 1999) include lesser weever, sprat, Dover sole, cod, sand eel, snake pipefish, seasnail, five-bearded rockling, grey gurnard, pollock, red gurnard, deep-snouted pipefish, thornback ray, herring, lesser-

spotted dogfish, salmon, three-bearded rockling, brill, transparent goby, smelt, dog fish, dragonet, bib, haddock, butterfish, and sea lamprey.

The estuary is used as a nursery area by a number of juvenile fish species and as such, it is of regional value in the Irish Sea context. Similarly, it is an important area for migratory fish such as salmon and sea trout which migrate into the rivers of the Nith, Annan, Sark, Kirtle Water, Esk, Eden, and Derwent. The rare allis shad (*Alosa alosa*), twaite shad (*Alosa fallax*), and river lamprey *(Lampetra fluviatilis*), also migrate through the estuary to breeding grounds (Solway Firth Partnership, 1996). It is possible that allis shad may breed in the estuary itself although at present, there is no clear evidence of spawning stocks (Allen *et al*., 2003). The allis shad, twaite shad, Atlantic salmon, and sparling, have all been identified as priority species by the Dumfries and Galloway Coastal and Maritime Biodiversity Action Group (SSMA, 2004).

1.3.3.3 Avifauna

The estuary supports nationally and internationally important numbers of migrating and wintering waterfowl, and for the most recent 5 year period (2006/07 to 2010/11) supports average annual peak maxima of over 100,000 waterbirds (Holt *et al*., 2012). Both the size and location of the estuary ensure that the Solway is a vital resting and wintering area for birds migrating along the eastern Atlantic seaboard by providing productive feeding grounds (Solway Firth Partnership, 1996).

The most recent High Tide Count WeBS programme (2010/11) has recorded a number of waterbird species present in the estuary in internationally important numbers (Holt *et al*., 2012), whilst the most recent Low Tide Count WeBS programme (2010/11) has additionally recorded a number of waterbird species present in nationally important numbers (Holt *et al*., 2012).

Table 1 lists waterbird species which occur in internationally and nationally important numbers.

Table 1: Waterbirds occurring in both Internationally Important and Nationally Important Numbers in the Solway during the 2010/11 WeBS Programme (Holt *et al*., 2012).

WATERBIRD SPECIES	
INTERNATIONALLY IMPORTANT*	**NATIONALLY IMPORTANT****
Pink-footed Goose	Whooper Swan
Svalbard Barnacle Goose	Bar-tailed Godwit
Pintail	Curlew
Scaup	Dunlin
Oystercatcher	Golden Plover
Ringed Plover	Sanderling
Knot	Shelduck
Redshank	Teal

* Internationally important numbers taken from the most recent High Tide Count WeBS programme 2010/11 (Holt *et al*., 2012)

** Nationally important numbers taken from the most recent Low Tide Count WeBS programme 2010/11 (Holt *et al*., 2012).

2. Methodology (2014 Survey Programme)

2.1 Pre-survey Work

Prior to undertaking the survey work, desk-based analysis and preparation was undertaken. The desk study involved the analysis of aerial photographs and maps (provided by Natural England), together with other data pertaining to the study area. The aerial photographs were input into GIS and overlain on OS base maps. Analysis of survey work results from the 2011 programme (Cutts *et al*. 2011) was carried out in order to both ensure a degree of comparability between studies.

The survey was undertaken from a hovercraft survey platform as the use of a hovercraft was employed by IECS in the 2004 (Hemingway *et al*., 2006) and 2011 (Cutts *et al*., 2011) programmes, proving to be an extremely valuable tool, both in terms of general Health & Safety provision (in an area prone to patches of soft sediment, extensive channel banks and rapid tidal inundation), and in terms of survey coverage, allowing very large areas of tidal flat to be surveyed. However, a hovercraft has operational constraints and in particular, cannot be operated in strong or gusty winds. Furthermore, where long distance operation and a potential for water transit is required, then even moderate wind speeds have to be taken into consideration where wind against tide might create choppy conditions. This can constrain survey operations.

The priority areas to be surveyed were established at the tender stage with Natural England, with a contract specification requiring a two phase survey deployment. Phase 1 to characterise the general survey area in terms of broad habitat types and distribution, and Phase 2 (following analysis of the data from Phase 1), to take samples for invertebrate and sediment characteristics and to define biotopes.

Prior to commencement of the fieldwork, optimum survey periods around spring tides were identified in order to maximise safe working time in the intertidal zone (to low water). Tidal data for the area were derived from UKHO TotalTide™ tide prediction software. Survey dates and tidal conditions for the area for the completed survey dates are shown in Table 2.

Table 2: Tidal predictions (Solway Firth) derived from UKHO TotalTide™ tide prediction software

DATE	LOCATION								
	Silloth			**Annan Waterfoot**			**Redkirk Point**		
		Time	Height		Time	Height		Time	Height
Stage 1: 16th-19th June 2014	High	14:56	*9.1m*	High	15:17	*7.0m*	High	15:48	*3.7m*
	Low	09:42	*0.5m*	Low	11:57	*NA*	Low	13:35	*NA*
	High	15:48	*8.9m*	High	16:10	*6.7m*	High	16:48	*3.4m*
	Low	10:29	*0.6m*	Low	12:40	*NA*	Low	14:38	*NA*
	High	16:44	*8.5m*	High	17:06	*6.3m*	High	17:52	*2.9m*
	Low	11:17	*0.8m*	Low	13:22	*NA*	Low	15:47	*NA*

	High	17:42	*8.1m*	High	18:06	*5.9m*	High	18:59	*2.5m*
	Low	12:09	*1.1m*	Low	14:08	*NA*	Low	17:02	*NA*
Stage 2: 16th-17th July 2014	High	15:33	*9.2m*	High	15:54	*7.1m*	High	16:30	*3.8m*
	Low	10:19	*0.4m*	Low	12:30	*NA*	Low	14:22	*NA*
	High	16:22	*8.8m*	High	16:44	*6.6m*	High	17:27	*3.3m*
	Low	11:02	*0.6m*	Low	13:09	*NA*	Low	15:26	*NA*

Note : No tidal height is provided for low water at Annan and Redkirk as insufficient source data are available for prediction. These data are for secondary non-harmonic ports, based on Liverpool (Gladstone Dock) as the primary port. Mean high water springs for Silloth are 9.2m high and mean low water springs are 0.8m high.

Permissions for access were sought by IECS. These included contacting the Port of Silloth Harbour Master for permissions to operate in the Silloth approaches. Necessary operational information was also provided to the MCA (Liverpool) on the start and completion of each survey.

2.2 Intertidal Survey

This involved the *in situ* field surveying and mapping of the soft sediment habitats of the intertidal zone of the study area in accordance with the agreed survey schedule using a hovercraft survey platform. The line transects (track files) undertaken during the Phase 1 survey are shown in Maps 3-5, covering the upper inner estuary (Old Graitney to Port Carlisle), lower inner Solway (Cardurnock Flatts & Moricambe), and the middle estuary/open coast from Blitterlees Bank to Dubmill Point. As noted above, the current methodology required a two phase survey effort, with the first phase involving a general characterisation of the area. Based on the analysis of information derived from Phase 1, samples were subsequently collected at 20 stations during Phase 2 in order to fully describe the invertebrate and sediment conditions, and the associated biotopes present. Maps 3 to 5 show both the Phase 1 transects (with potential biotopes as identified on completion of Phase 1), together with the locations from which Phase 2 samples were taken for more detailed taxonomic analysis and biotope finalisation.

Phase 1 sampling was undertaken between 16th to 19th June 2014 (inclusive), with Phase 2 undertaken on the 16th and 17th July 2014. Table 2 above provides tide times (high and low water) for the nearest secondary ports to the survey locations.

2.2.1 Phase 1 Sampling Methods

Phase 1: In-field Broad Habitat Characterisation

During Phase 1, small representative test samples were taken along a series of broadly identified transects. These transects were identified prior to the survey from aerial images and were designed to cover most of the survey areas and habitat

variations within them, whilst also largely covering the areas covered during the 2011 programme where possible. Exact transect routes were modified somewhat during the survey in response to conditions and safe operations, with visible habitat changes logged along the transects.

Where notable changes in the substratum occurred (e.g. sediment type or surface features such as standing water, ripples etc.), and/or where there was a notable change in biological surface features which may indicate a change in species composition (e.g. tubes, casts, feeding pits, faecal mounds), then a sample was taken and analysed in the field for sediment description and visible fauna. Similarly, over extensive and continuous habitat features sampling was undertaken every *c*. 1km.

Location details were recorded using the standard MNCR proformas (survey, habitat and site), with positions logged using DGPS. Notable features were additionally recorded. The density of conspicuous organisms (e.g. *Arenicola marina*) was estimated by counting the number of surface features in a $50cm^2$ quadrat (casts, surface siphon holes etc), and where possible, the lateral extent of the habitat was also estimated and mapped.

At each distinct biotope, two spade loads of sediment (as indicated by Wyn & Brazier, 2001), dug to a depth 20-25cm, were sieved through a 0.5mm mesh and the infaunal organisms identified. An estimation of the abundance of all visible species was undertaken using the SACFOR scale, whilst small organisms which could not be identified in the field were placed in a preservative and retained for analysis back at the IECS laboratory. Holes were back-filled on completion of the sampling at each location.

The position of each sampling location along each transect and the biotope transition boundaries along the transect were logged using portable DGPS. Digital photographs of the sediment surface, characteristic species and features, and the wider area in general were taken at each sampling site and geo-referenced, together with the target notes.

Particular attention was paid to the extent of ephemeral/opportunistic algae and other algal cover, as well as any modification to the community structure which may have resulted from the presence of the algae. Evidence of human activities and pressures which may be influencing the ecology at each location were also noted and any notable avifaunal reactions to the survey were recorded.

All data recorded in the field was downloaded from equipment and backed up to a separate device at the end of the survey day on a daily basis.

Phase 1: Initial Analysis and Mapping

On return to the IECS laboratory after completion of the Phase 1 survey, the field notes were transcribed to good copy and in conjunction with speciation of small organisms retained from the survey, a series of potential biotopes and their extent was mapped (using the transect track files as a base), and with biotope transitions shown.

Based on these maps, further sampling stations were chosen in consultation with Natural England for Phase 2, these being located in a range of the potential biotopes identified and positioned towards the centre of each potential habitat area.

2.2.2 Phase 2 Sampling and Analysis Methods

Phase 2: Detailed In-field Sampling

Standard NMBAQC and WFD protocols for sampling of benthic core samples and particle size analysis (PSA) were followed during the Phase 2 survey. Twenty sampling stations (Appendix 1) were identified in order to provide core samples from each distinct biotope, these covering the inner to middle/outer estuary, and with the greatest sampling effort being in areas of highest biotope diversity.

The aim of the approach was to provide a combination of spatial coverage together with a degree of statistical robustness, allowing spatial and temporal comparisons with previous data/reports.

At each sampling station (located approximately in the centre of each distinct biotope or habitat), three replicate core samples ($0.01m^2$) were taken to a depth of 15cm. Samples were placed in pre-labelled plastic bags and transferred to labelled, clean plastic buckets at the end of each survey day. At this point, the samples were fixed using 4% buffered formaldehyde solution. An additional fourth core was taken for Particle Size Analysis with these samples being kept chilled until collection by the analysing laboratory.

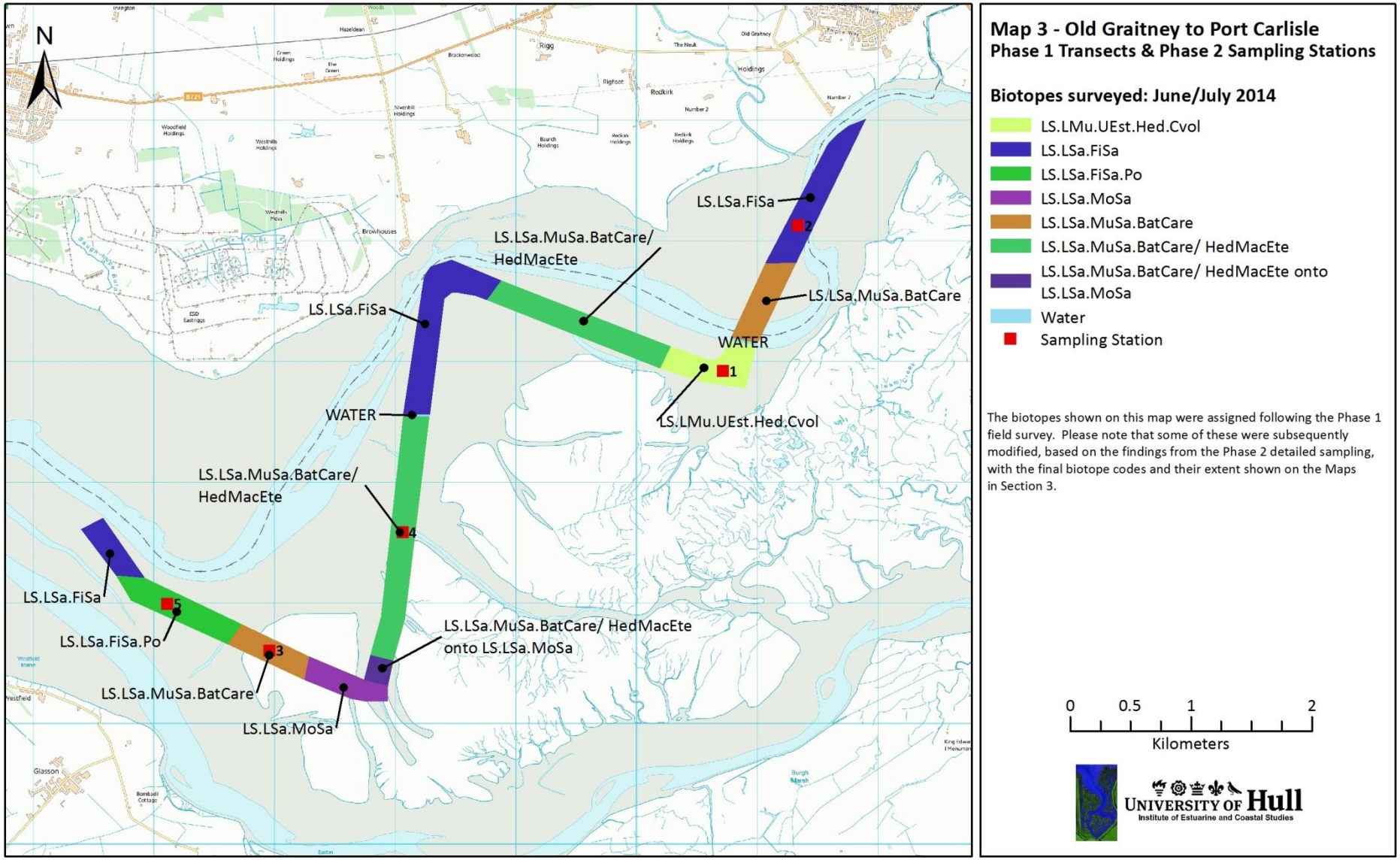
Phase 2: Laboratory Analysis

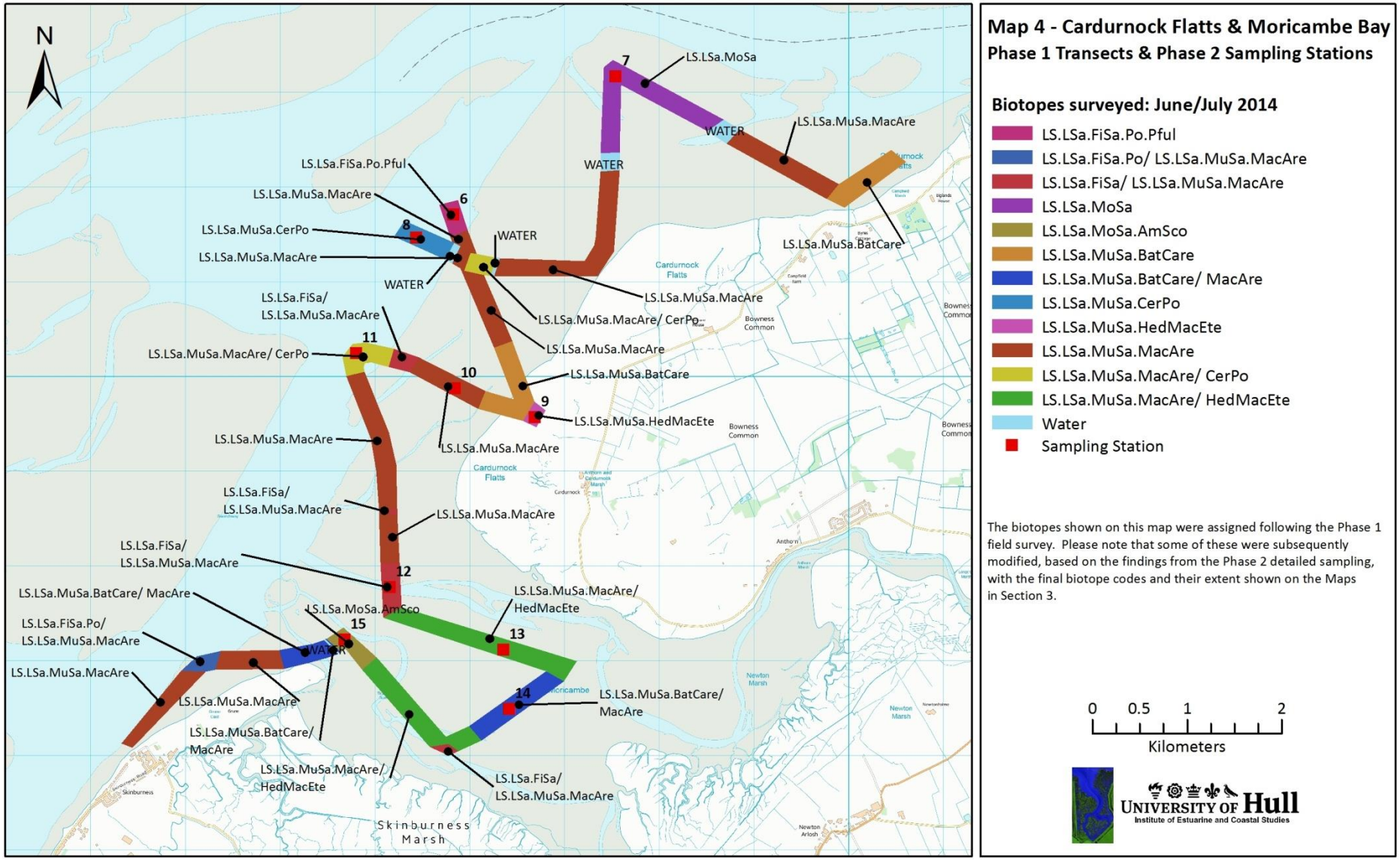
Invertebrate taxonomic analysis of the replicate core samples was carried out under contract to Natural England by APEM Ltd (Edinburgh), APEM Report No. 413565-01 issued October 2014. Appendix 2 summarises the total invertebrate abundance and dominant taxa per core replicate at each sampling station, whilst Appendix 3 provides the species list and abundance (raw data per core replicate and abundance per m^2) at each sampling station.

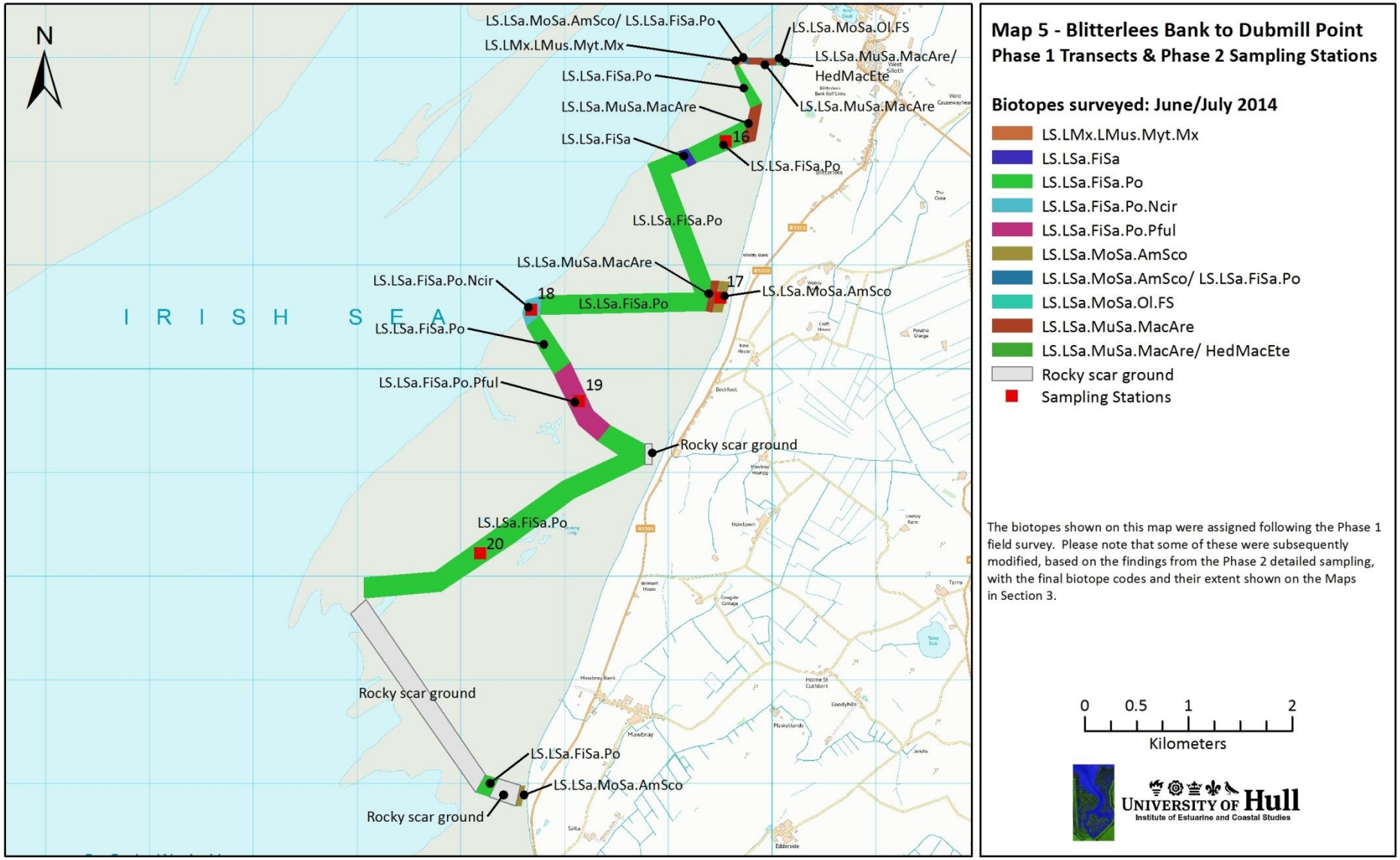
Particle size analysis (PSA) was carried out under contract to Natural England by the National Laboratory Service (Environment Agency), NLS Report ID 20072718 - 1 issued in January 2015. For ease of interpretation, the PSA data has been modified and summarised by IECS in Appendix 4 (grain size fractions, mean and kurtosis per sample station), with the original NLS report provided in full in Appendix 5.

2.2.3 Other Intertidal Sampling and Analysis

Alongside the survey undertaken by IECS to monitor and assess the intertidal mud and sandflats of the Solway Firth SAC, Natural England additionally commissioned a second study undertaken by Ecospan Environmental Ltd. to monitor and assess the extent and condition of the intertidal rocky (mixed sediment) scars sub-feature. The methods and findings from this survey were under separate contract to Natural England and have therefore also been reported separately (Curtis, 2014; Appendix 6). However, the derived information has been incorporated into the overall analysis and mapping exercise undertaken by IECS and described later in this report.







3. Survey Findings

The following section describes the results of the 2014 survey programme. The results are described on a site by site basis, the area divided into three sites (as with the 2011 programme) and described in order running from the extreme inner estuary upstream from a line joining Port Carlisle and Torduff Point, to the middle estuary (south bank) south of Silloth, using discrete areas and natural breaks in habitat as appropriate divisions.

3.1 Old Graitney (North Bank) to Port Carlisle (South Bank)

3.1.1 Phase 1 Overview

This extreme upper estuarine area includes two freshwater input channels into the Solway Firth, i.e. the River Esk to the north of Rockcliffe Marsh, and the River Eden to the south of the marsh. The two main fluvial channels dominate the morphology of the upper estuary although they are relatively narrow and shelve steeply. This channel morphology, together with the wider Solway plan-form, means that the main fluvial channels of the inner firth are subject to small bores on even moderate spring tides.

Between these two channels, in the extreme upper part of the system, is an area of high marsh. This includes extensive high saltmarsh, as well as grazing marsh (Rockcliffe Marsh). Fronting the marsh is an extensive area of intertidal soft sediment, including areas of high sand bank, some of which appear to remain uncovered by the tide even around high water during neap phases, and extensive low sand flats which are present in both the Eden (e.g. around Burghmarsh Point) and Esk (e.g. around Redkirk Point) branches. These areas are located adjacent to the freshwater channels, and around the confluence of these channels (e.g. upstream from around Torduff Point to Port Carlisle).

During the 2014 programme, three main intertidal soft sediment habitats were identified within the area (in addition to high saltmarsh):

- Large elevated fine to medium fine sand flats;
- Extensive flat low shore firm rippled muddy sand to fine sand flats;
- Relatively narrow sandy mud with occasional cobble on the fringing banks (not surveyed). This habitat was pre-excluded from the 2014 survey programme due to access constraints impacting on available survey time and associated

increased budget implications. However, their extent and nature means that their conservation value within the Solway SAC/SPA is in any case, relatively low.

As with the 2011 survey, a small tidal bore was propagated on a set of moderate spring tides, and it is considered that the habitats in this section of the estuary will therefore be influenced by both a combination of high residence time, low but variable salinity, and high current velocities. Examples of the two main habitats surveyed in this area are given in Plates 1 and 2. It should however be noted that additional Phase 1 habitats were also recorded, as well as transition habitats between the two main habitats.

Biotope details derived from both the broad-scale mapping of habitats undertaken in Phase 1, together with the detailed sampling and subsequent sediment and taxonomic analysis from Phase 2 are described in Section 3.1.2.

Plate 1: Old Graitney to Port Carlisle - Upper estuary extensive low shore sand flats.

This habitat was recorded in the upper estuary on either sides of the freshwater channels of the Rivers Esk and Eden, as well as more extensively, around their confluence. This was the dominant habitat within the survey area although several potential biotopes were recorded within it from Phase 1. The habitat consisted of a firm rippled fine sand with variable standing water in the ripples. *Arenicola* casts were variably present as well as other polychaetes and amphipod crustaceans.

Plate 2: Old Graitney to Port Carlisle - Upper estuary elevated sand flats.

This habitat was recorded in the upper estuary to the south of the channel of the River Esk, and was primarily adjacent to the main marsh area. The habitat consisted of a fine to medium fine sand, and was less firm than the majority of the lower lying habitat described above. Some ripple features were present, but not consistently and it appeared that the habitat, due to its elevation might not be covered on neap tides. The habitat appeared to be used as a bird roost, with substantial associated faecal matter observed in some areas. This habitat gradually developed from the low shore feature (Plate 1), with a transition zone noted (Plate 2 centre).

3.1.2 Phase 2 Biotope Description

The survey commenced on the southern side of the Esk channel, the hovercraft being launched at Stormont on the north bank of the inner firth. The opposite (south bank) of the Esk channel featured an extensive rippled fine sand flat of low elevation and variable standing water cover, (Plates 3 & 4), with no visible fauna and only *Bathyporeia* evident from the Phase 1 expert eye sampling. This habitat was considered extensive, in that it was observed to run downstream, along the channel of the River Esk, forming large low elevation sand flats in some areas.

Plate 3: Old Graitney to Port Carlisle - LS.LSa.FiSa (Overview).	**Plate 4: Old Graitney to Port Carlisle - LS.LSa.FiSa (Detailed).**

The absence of notable fauna, together with visible sediment characteristics indicated that the area was subject to considerable environmental stress with a low and variable salinity, relatively long exposure time to air, and high current velocities.

As such, the habitat was identified in the field as **LS.LSa.FiSa**, but not chosen for more detailed analysis under Phase 2, given the paucity of the infaunal assemblage.

With increasing distance from the channel, the sediment graded into a firmer rippled muddy sand with less standing water and an increase in infauna noted. This habitat was noted as shelving into a more mid shore elevation, this being better drained and with a surficial mud component (Plates 5 & 6). The Phase 1 survey identified *Bathyporeia* as abundant, but with an increasing presence and abundance of *Corophium* and *Macoma* in the trial samples. No anoxic layer was noted.

A Phase 2 sample station was therefore taken as the habitat transitioned from the impoverished low elevation fine rippled sand of the main channel to the more elevated and better drained muddy sand with *Bathyporeia pilosa* dominant, but with *Corophium arenarium*, *C. volutator* and *Macoma balthica* present in small numbers from the cores.

With progression away from the channel, *Corophium arenarium* became the dominant fauna, together with *Bathyporeia* and *Macoma* abundant, and with Spionids and Nematodes also present, the biotope identified as **LS.LSa.MuSa.BatCare**.

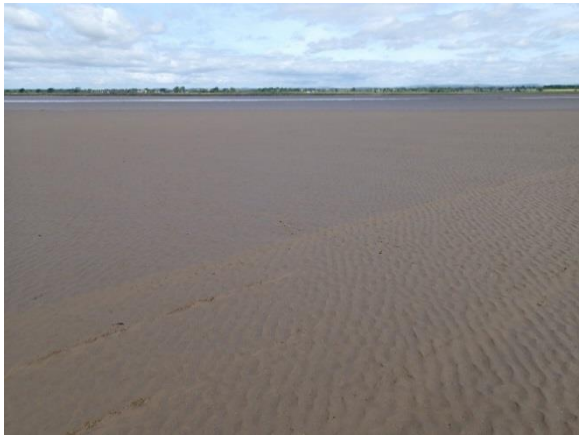


Plate 5: Old Graitney to Port Carlisle - LS.LSa.MuSa.BatCare (Overview).

Plate 6: Old Graitney to Port Carlisle - LS.LSa.MuSa.BatCare (Detailed).

With further progression along the transect, away from the channel of the River Esk, there was an increase in elevation, and a gradual shift in sediment type, to a more

soft, muddy substratum featuring less ripples, variable standing water and an ill-defined anoxic layer.

This habitat was recorded as extending along the upper shore to the edge of the saltmarsh (Rockcliffe Marsh) and was observed to have numerous waterbird (geese) foot prints as well as faecal matter (Plates 7 & 8). *Corophium* were abundant and the initial Phase 1 sampling details suggested **LS.LMu.UEst.Hed.Cvol**. However, a Phase 2 station was located in this habitat and the infaunal analysis identified abundant *Hediste diversicolor*, together with several other polychaetes (*Pygospio* and *Enchytraeidae*), as well as abundant *C. volutator* and common *M. balthica* and *Peringia ulva*. As such, the biotope was amended to **LS.LMu.MEst.HedMac**.

Plate 7: Old Graitney to Port Carlisle - LS.LMu.MEst.HedMac (Overview).

Plate 8: Old Graitney to Port Carlisle - LS.LMu.MEst.HedMac (Detailed).

This biotope was observed to be present along much of the elevated upper shore fringing Rockcliffe Marsh, grading from the **LS.LSa.MuSa.BatCare**, with elevation and increased fine sediment.

Progression further along the transect and back down to the shore from Rockcliffe marsh showed a habitat transition back to a fine rippled muddy sand with standing water. Spionid tubes were visible on the surface. A Phase 1 sample recorded *Bathyporeia*, *Corophium* and *Macoma* as abundant, with *Peringia*, *Pygospio*, *Hediste*, and *Mya arenaria* also present. The additional species present from the Phase 1 samples produced a potential biotope mix of **LS.LSa.MuSa.BatCare** and **LS.LSa.MuSa.HedMacEte** (Plates 9 & 10).

	
Plate 9: Old Graitney to Port Carlisle - LS.LSa.MuSa.BatCare & LS.LSa.MuSa.HedMacEte mix (Overview).	**Plate 10: Old Graitney to Port Carlisle - LS.LSa.MuSa.BatCare & LS.LSa.MuSa.HedMacEte mix (Detailed).**

This was an extensive mid to low elevation habitat that was recorded extending for several kilometres, before transitioning in the low shore towards the River Esk channel off Browhouses to a more impoverished rippled fine sand with only *Bathyporeia* recorded in numbers (**LS.LSa.FiSa**).

The transect then moved in a southerly direction across a very extensive low to mid shore firm, rippled fine sand flat with standing water in the ripple troughs. The Phase 1 samples in this area identified abundant *Bathyporeia*, together with common *Peringia* and *Pygospio*, as well as frequent *Macoma* and *Eteone longa* and rare *Arenicola marina*. With movement along the transect, additional Phase 1 samples showed a similar infauna, but with *Cerastoderma edule* and *Corophium* also frequent to occasional (Plates 11 & 12).

A Phase 2 sample station was located in this extensive sand flat and recorded abundant *Bathyporeia pilosa* and *Pygospio elegans*. *Eteone longa* was also common together with *Corophium arenarium* and *Macoma balthica*. *Cerastoderma edule* was recorded as rare within the samples, as was *Hediste diversicolor* and *Nephtys* sp. juveniles. Based on the sample information this extensive habitat was identified as being a mix of **LS.LSa.MuSa.BatCare** and **LS.LSa.MuSa.HedMacEte**, depending on variability in the abundance of characterising species e.g. *Corophium* and *Eteone*.

Plate 11: Old Graitney to Port Carlisle - LS.LSa.MuSa.BatCare & LS.LSa.MuSa.HedMacEte mix (Overview).

Plate 12: Old Graitney to Port Carlisle - LS.LSa.MuSa.BatCare & LS.LSa.MuSa.HedMacEte mix (Detailed).

Towards the southern extent of the transect, running to the west of Rockcliffe Marsh, the sand flat gradually increased in elevation, transitioning from the firm rippled sand described above, to a more soft rippled and well drained sand (Plates 13 & 14). Phase 1 sampling of the sediment recorded very few fauna, with occasional/frequent *Pygospio* and *Bathyporeia*, and the habitat was classed as the mobile sand biotope **LS.LSa.MoSa**. This area was bounded to the south by the channel of the River Eden, which resulted in a steep erosion edge to the biotope of *c*. 1m, with the channel bed consisting of a firm rippled sand similar in appearance to that of the upper reaches of the Esk channel described above.

Plate 13: Old Graitney to Port Carlisle - LS.LSa.MoSa (Overview).

Plate 14: Old Graitney to Port Carlisle - LS.LSa.MoSa (Detailed).

The clean and soft nature of the **LSa.MoSa** substratum would indicate that the area is subject to wave and/or current action and is mobile in nature, the habitat effectively

at the apex of the two river channels and fronting the high saltmarsh of Rockcliffe Marsh.

Moving downstream, away from the elevated sand bank feature described above, the substratum became a more firm fine sand and Phase 1 sampling identified abundant *Bathyporeia*, together with frequent *Corophium* and *Pygospio* (Plates 15 & 16). This habitat was selected for more detailed Phase 2 sampling, with the core analysis indicating a relatively low taxonomic abundance, the community dominated by *Bathyporeia pilosa*, together with frequent *Corophium arenarium* and occasional *Macoma balthica*.

The community was considered to be similar to that identified from the upper reaches of the Esk channel (see Plates 5 & 6), and was ascribed as being the **LS.LSa.MuSa.BatCare** biotope.

Plate 15: Old Graitney to Port Carlisle - LS.LSa.MuSa.BatCare (Overview).

Plate 16: Old Graitney to Port Carlisle - LS.LSa.MuSa.BatCare (Detailed).

The **LS.LSa.MuSa.BatCare** habitat was part of an extensive relatively low lying firm rippled fine sand feature that extended across most of this area of the Solway intertidal zone, albeit with some delineation by the channels of the Esk and Eden.

However, with progression along the transect downstream, the habitat feature was observed to transition into a more rippled substratum, with the presence of *Arenicola* casts on the surface, as well as Spionid tubes and some organic material. A Phase 1 sampling of the sediment recorded abundant *Bathyporeia*, together with frequent *Capitella*, *Pygospio* and *Macoma* (Plates 17 & 18). The habitat was chosen as a Phase 2 sample station, and the core data showed the infaunal community to be dominated by *Bathyporeia pilosa*, with *B. sarsi* also present (rare). Other fauna frequently present included the polychaetes *Eteone longa*, juvenile *Nephtys*, *Paraonis fulgens* and *Capitella capitata*, together with the bivalve *Macoma balthica*. The best fit biotope for this assemblage was identified as **LS.LSa.FiSa.Po.Pful**.

Further progression downstream along the transect towards the low shore recorded a broadly similar substratum, but with reduced diversity noted from a Phase 1 sampling, with *Bathyporeia* the only recorded species. This would accord with a return to the lower shore habitat adjacent to the river channels, assigned the **LS.LSa.FiSa** biotope (see above). This section of the intertidal soft sediment survey of the inner Solway was ended at this point (*c*. around a line between Port Carlisle to Torduff Point due to tidal inundation).

Plate 17: Old Graitney to Port Carlisle - LS.LSa.FiSa.Po.Pful (Overview).

Plate 18: Old Graitney to Port Carlisle - LS.LSa.FiSa.Po.Pful (Detailed).

Table 3 provides a summary of the biotopes recorded, together with values for mean total abundance and taxa per core. Stations 1 and 4 featured high abundance levels due to the presence of *Corophium*, with station 4 featuring a relatively diverse assemblage exhibiting aspects of both the **MuSa.BatCare** and **MuSa.HedMacAre** biotopes. However, the assemblage for station 2, which was taken from the edge of the extensive low lying channel of the Esk was impoverished (**LSa.FiSa**), with a low abundance and diversity indicating the relatively harsh environmental conditions. Further assemblage details are provided in Appendix 3.

Table 3: Solway 2014 Station Taxa Summary: Old Graitney to Port Carlisle.

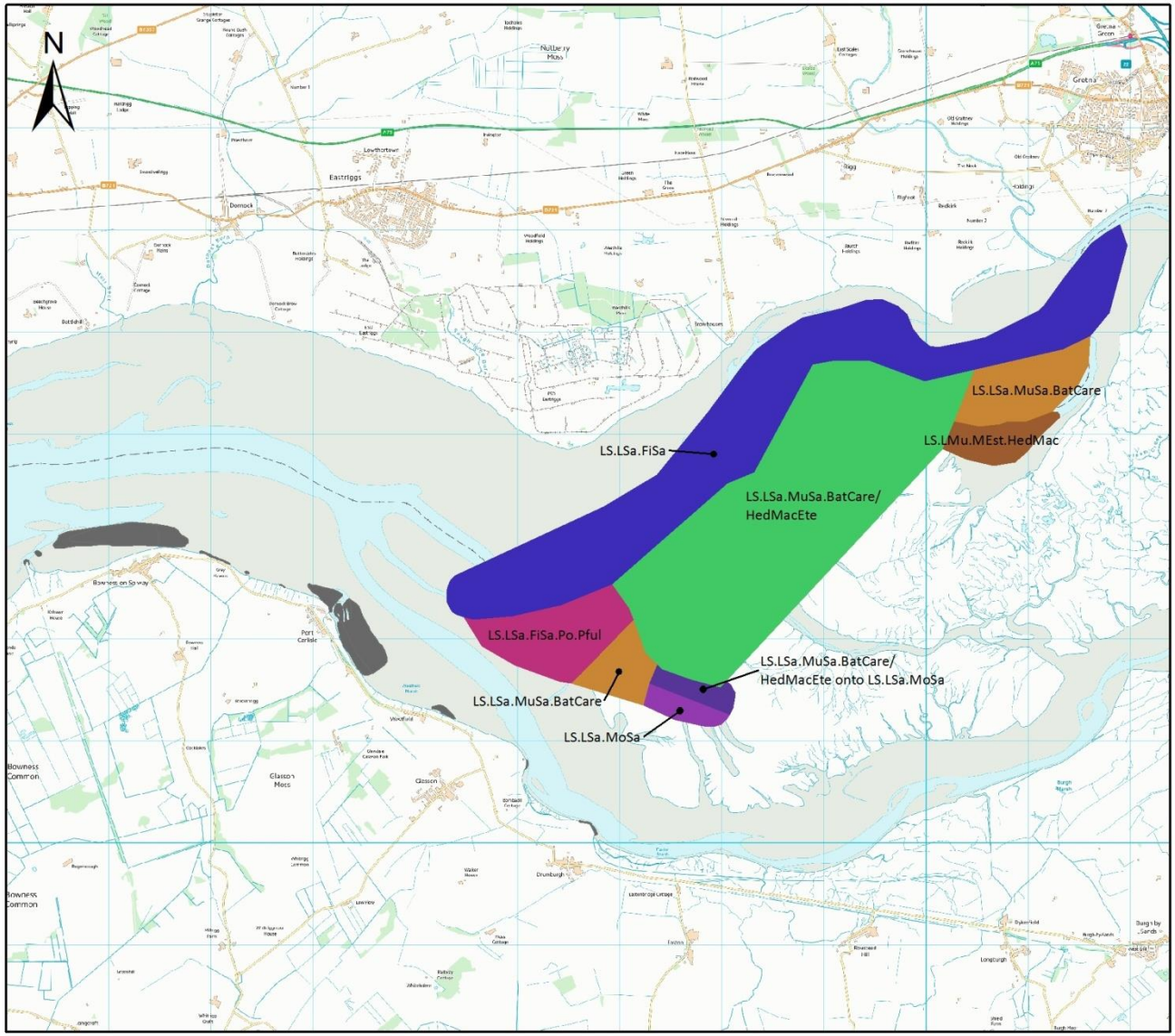
Phase 2 Station	Biotope(s)	Average Total Invertebrate Abundance per Core	Average Total Taxa per Core	Dominant Taxa
Station 1	LS.LMu.MEst.HedMac	623	8	*Corophium volutator*
Station 2	LS.LSa.FiSa	19	3	*Bathyporeia pilosa*
Station 3	LS.LSa.MuSa.BatCare	37	5	*Bathyporeia pilosa*
Station 4	LS.LSa.MuSa.BatCare / HedMacEte	384	10	*Bathyporeia pilosa*
Station 5	LS.LSa.FiSa.Po.Pful	82	6	*Bathyporeia pilosa*

Table 4 summarises the littoral soft sediment biotopes assigned within the Old Graitney to Port Carlisle survey sector during 2014. As can be seen from Map 6, the biotope **LS.LSa.FiSa** and the biotope mosaic **LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte** form the greatest components within this sector.

Table 4: Old Graitney to Port Carlisle - Summary of littoral soft sediment biotopes assigned during 2014.

Distinct Individual Biotopes	Biotope Mosaics / Transitions
• LS.LSa.MoSa • LS.LSa.FiSa • LS.LSa.FiSa.Po.Pful • LS.LSa.MuSa.BatCare • LS.LMu.MEst.HedMac	• LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte • LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte onto LS.LSa.MoSa
Total = 5	**Total = 2**

Map 6 shows the soft sediment biotopes assigned to the 'Old Graitney to Port Carlisle' sector following the Phase 2 sampling and subsequent detailed analysis. However, alongside the survey undertaken by IECS to monitor and assess the intertidal mud and sandflats of the Solway Firth SAC (southern shoreline), Natural England additionally commissioned a second study undertaken by Ecospan Environmental Ltd. to monitor and assess the extent and condition of the intertidal rocky scars sub-feature (Curtis, 2014). The rocky scar ground habitats as mapped by Ecospan within the same area have therefore been additionally integrated into Map 6, although only the extent of the rocky scar ground has been shown. More detailed maps and the associated rocky shore biotopes are given in Curtis (2014) which is also provided in Appendix 6.



Map 6
Old Graitney to Port Carlisle

Biotopes surveyed: June/July 2014

- LS.LMu.MEst.HedMac
- LS.LSa.FiSa
- LS.LSa.FiSa.Po.Pful
- LS.LSa.MoSa
- LS.LSa.MuSa.BatCare
- LS.LSa.MuSa.BatCare/ HedMacEte
- LS.LSa.MuSa.BatCare/ HedMacEte onto LS.LSa.MoSa
- Rocky scar ground (mapped by ECOSPAN Environmental)

0 0.5 1 2
Kilometers

UNIVERSITY OF Hull
Institute of Estuarine and Coastal Studies

An attempt has been made to extend observations on biotopes along the transects to adjacent areas, with these extrapolated into broad polygons. The accurate extent of these extrapolated polygons should be treated with caution.

3.2 Cardurnock Flatts & Moricambe Bay

3.2.1 Phase 1 Overview

Cardurnock Flatts is an extensive area of intertidal sandflat in the Inner Solway (south shore), to the south of the main Eden Channel (and bounded by the channel in its northern and eastern extent). For the most part, the habitat is backed by tidal grazing merse, and incised by a series of drainage creeks. The southern area of the site features several cobble scars, these being situated around the mouth of Moricambe Bay, a large coastal inlet.

Moricambe Bay is an embayment feature again backed primarily by merse, with the small Rivers Wampool and Waver discharging into it. The main intertidal area of Moricambe Bay is incised by the channels of the Rivers Wampool and Waver, which form a combined and dynamic fluvial system that enters into the main body of the estuary north of Grune Point.

At this point, the Eden Channel has developed into the Swatchway, through which the majority of the inner estuary freshwater input drains, and which forms a substantial channel. Offshore from this location by *c.* 1km is Middle Bank, which forms an extensive mobile mid channel sand bank.

During the 2014 programme, four main intertidal habitats were identified within the area (in addition to high saltmarsh):

- Extensive mid shore fine sand flats (Cardurnock);
- Extensive mid shore muddy sand to fine sand flats (Moricambe Bay);
- Mobile scoured sands (Wampool and Waver channel ‘delta’);
- Scar grounds (surveyed by Ecospan Environmental Ltd).

The 2014 survey was able to extend the coverage further into Moricambe Bay compared to the 2011 survey programme, with additional coverage also possible in the northern section of Cardurnock Flatts.

Examples of the two main habitats surveyed in this area are given in Plates 19 and 20. However, it should be noted that additional Phase 1 habitats were also recorded, as well as transition habitats between the two main habitats.

Plate 19: Cardurnock Flatts & Moricambe Bay - Extensive mid shore fine sand flats (Cardurnock).

This habitat was recorded across much of the mid shore of Cardurnock Flatts and featured a firm rippled fine sand with some standing water. *Arenicola* were evident across the habitat although in variable densities, with *Macoma* and *Bathyporeia* also noted from the Phase 1 samples.

Plate 20: Cardurnock Flatts & Moricambe Bay - Extensive mid shore muddy sand to fine sand flats (Moricambe Bay).

This habitat was recorded in the middle reaches of the Moricambe Bay embayment, between the two river channels. It featured a very fine firm rippled sand with some organic material and standing water. *Macoma* were abundant, with *Arenicola* variably present, as well as other polychaetes and amphipod crustaceans.

Biotope details derived from both the broad-scale mapping of habitats undertaken in Phase 1, together with the detailed sampling and subsequent sediment and taxonomic analysis from Phase 2 are described in Section 3.2.2.

3.2.2 Phase 2 Biotope Description

The majority of the Cardurnock Flatts intertidal area is backed by a grassland/grazed marsh merse, with a small erosion step onto the intertidal sandflats. In the northern part of the survey area the upper shore of the extensive flats featured a very fine rippled muddy sand with *Arenicola* casts in variable density, *Corophium* present and abundant *Peringia* on the surface.

Plate 21: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.BatCare (Overview).

Plate 22: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.BatCare (Detailed).

Based on Phase 1 sampling and Phase 2 information from similar habitats, this upper shore area was classed as the **LS.LSa.MuSa.BatCare** biotope, with the faunal community dominated by *Bathyporeia* and *Corophium* (Plates 21 & 22).

With increased distance from the upper shore, a transition was observed with a reduction in the mud content and the development of an extensive fine, firm rippled sand flat (Plates 23 & 24).

Plate 23: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.MacAre (Overview).

Plate 24: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.MacAre (Detailed).

This extensive area featured a number of surficial drainage rills, and was generally well drained. *Arenicola* casts were of a greater density than the upper shore (see above) at >10 per m^2 and the Phase 1 sampling recorded abundant *Macoma*, together with frequent to occasional *Bathyporeia*, *Eteone*, *Pygospio*, *Cerastoderma* and *Peringia*. The area was classed as **LS.LSa.MuSa.MacAre**.

A further transition was noted in the mid shore, with the habitat featuring more standing water. It remained a firm rippled sand but with a greater fine sand/silt fraction and some organic content present. *Arenicola* density was lower than in the upper mid shore habitat (above).

A Phase 2 sampling station was placed in this habitat and recorded a fairly diverse fauna, but with low abundances. Polychaetes present included *Paraonis fulgens*, *Eteone longa*, *Nephtys* sp., *Pygospio elegans*, *Spio martinensis*, *Spiophanes bombyx* and *Capitella capitata* together with occasional crustaceans. The habitat was coded as **LS.LSa.FiSa.Po.Pful** (Plates 25 & 26). This was an extensive habitat which effectively ran from mid shore down towards the low shore channel edge, and was characteristic of much of the mid to low shoe of the northern part of Cardurnock Flatts.

Plate 25: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po.Pful (Overview).

Plate 26: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po.Pful (Detailed).

The transect survey then continued to the south, moving back across the mid shore to the upper shore off Herd Hill, and passing back through a transition zone in the mid shore into **LS.LSa.MuSa.MacAre**. This area was observed to extend to near the top of the shore at this location, with standing water often present and an area of dense *Arenicola* recorded towards the upper shore, before transitioning into a narrow band of the **LS.LSa.MuSa.BatCare** biotope.

Again, moving back out across the shore, the transect line passed through the extensive **LS.LSa.MuSa.MacAre** biotope of a rippled very fine muddy sand, with

Arenicola present. However, in the lower shore, the very fine rippled sand transitioned into an area with *Arenicola* absent (Plates 27 & 28). Phase 1 sampling recorded *Bathyporeia, Corophium, Macoma*, juvenile *Cerastoderma, Eteone, Capitella* and *Peringia* in low numbers, and the site was also selected as a Phase 2 sampling station. The detailed core analysis recorded *Capitella* as the most abundant fauna, suggesting a degree of environmental stress, perhaps from the low shore high energy location. However, a relatively large number of other taxa were also recorded in frequent to occasional numbers, including the polychaetes *Nephtys cirrosa* and *Nephtys* juveniles, *Paraonis fulgens*, *Pygospio elegans*, *Spio martinensis* and *Spiophanes bombyx*; crustaceans including occasional *Bathyporeia pilosa, B. pelagica* and *Corophium volutator*; and molluscs including abundant *Peringia ulvae*, and occasional *Cerastoderma edule, Mya arenaria* and *Macoma balthica*.

The community as identified from the Phase 2 cores does not necessarily fit well into existing biotopes, and may be influenced by proximity to high current velocities and wave action and/or a transition between biotopes, e.g. **LS.LSa.MuSa.MacAre** and **LS.LSa.MuSa.CerPo**, but has been assigned as **LS.LSa.FiSa.Po.Ncir** due to the presence of a number of *Nephtys* in the cores.

Plate 27: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po.Ncir (Overview).

Plate 28: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po.Ncir (Detailed).

A further diagonal transect back across the flats recorded the extensive **LS.LSa.MuSa.MacAre** biotope in the mid shore, this transitioning to **LS.LSa.MuSa.BatCare** towards the upper shore. However, running along the upper shore, up to the erosion step of the merse, a band of approximately 250m was recorded. This was a firm fine muddy sand with some ripples and a fine silt layer with standing water. The Phase 1 sampling recorded a relatively low number of species, but with *Pygospio* and *Corophium* present (Plates 29 & 30).

Plate 29: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.HedMacEte (Overview).

Plate 30: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.HedMacEte (Detailed).

The site was selected for Phase 2 sampling and the taxonomic analysis recorded Nematoda as super abundant, with abundant *Pygospio elegans*, and common *Hediste diversicolor* and *Manayunkia aestuarina*. *Corophium arenarium* was also superabundant, and although not a full fit, the biotope **LS.LSa.MuSa.HedMacEte** was assigned, this transitioning into **LS.LSa.MuSa.BatCare** along the shore.

Progression of the high to low shore transect off Cardurnock recorded an area of very fine muddy sand in the mid shore, which was less firm with increased *Arenicola* density and some shell and organic debris (Plates 31 & 32). Phase 1 sampling identified abundant *Macoma*, *Bathyporeia* and common *Corophium*, *Eteone*, *Pygospio* and *Cerastoderma*, whilst the Phase 2 sampling undertaken here recorded Nematoda as superabundant, but with *Eteone longa* common, together with *Pygospio elegans* and *Manayunkia aestuarina*. *Peringia ulvae* were also super abundant on the surface, with the bivalves *Macoma balthica* abundant and *Mya arenaria* frequent, but notably with *Cerastoderma edule* (predominantly juveniles) also abundant to common.

Plate 31: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.CerPo / LS.LSa.MuSa.HedMacEte (Overview).	**Plate 32: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.CerPo / LS.LSa.MuSa.HedMacEte (Detailed).**

Based on the Phase 2 community data, the habitat was identified as a mix between **LS.LSa.MuSa.CerPo** and **LS.LSa.MuSa.HedMacEte**, with the presence of cockles probably insufficient to ascribe a full CerPo community. No evidence of cockle exploitation was observed, but such activity can have the effect of reducing cockle abundance in the biotope. A scar ground constrained the western extent of the community, the details of the communities associated with this feature described under separate report (Curtis, 2014; Appendix 6).

Adjacent and immediately above the scar was an area of more elevated, rippled firm very fine sand. A Phase 1 sampling of the area identified a relatively impoverished fauna, with frequent *Bathyporeia* and occasional *Macoma*, *Eteone*, *Capitella* and juvenile *Cerastoderma* (Plates 33 & 34).

Plate 33: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa / LS.LSa.MuSa.MacAre (Overview).

Plate 34: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa / LS.LSa.MuSa.MacAre (Detailed).

The area was somewhat impoverished and although *Cerastoderma* and occasional polychaetes were present, the abundance was considered to be insufficient for a **LS.LSa.MuSa.CerPo** biotope. As such, the habitat was identified as a fit between **LS.LSa.FiSa** and **LS.LSa.MuSa.MacAre**, transitioning into full **LS.LSa.MuSa.MacAre** a few hundred metres to the north, and into a **LS.LSa.MuSa.CerPo** / **LS.LSa.MuSa.HedMacEte** biotope to the east.

To the west of the scar ground a further Phase 2 sample point recorded abundant to common *Nephtys* juveniles, together with a number of other common to frequent polychaetes. The area featured a firm rippled very fine sand and was assigned as a continuation of the **LS.LSa.FiSa.Po.Ncir** described above (Plates 35 & 36), this then transitioning to the south into an extensive low shore **LS.LSa.MuSa.MacAre** community.

Plate 35: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po.Ncir (Overview).

Plate 36: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po.Ncir (Detailed).

A change in the basic pattern of low mid and upper shore communities described

above was recorded from the entrance to Moricambe Bay. This area, between the south-western extent of the Cardurnock peninsula and Grune Point features a braided ‘delta’ with the channels from the Rivers Wampool and Waver discharging through this area. The survey recorded a firm very fine rippled sand with occasional *Arenicola* casts and only *Bathyporeia* present in the Phase 1 sampling.

A Phase 2 sample was taken which recorded an impoverished fauna, with amphipod crustaceans most frequently recorded, as well as a few polychaetes. Due to the limited fauna within the Phase 2 sample, the biotope was assessed as a best fit between **LS.LSa.FiSa.Po** and **LS.LSa.MoSa.AmSco**, but did not meet either criteria fully (Plates 37 & 38).

Plate 37: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po / LS.LSa.MoSa.AmSco (Overview).

Plate 38: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po / LS.LSa.MoSa.AmSco (Detailed).

Moving further into the Moricambe Bay embayment, a more characteristic habitat was observed, with a firm rippled very fine sand with silt noted and standing water. *Arenicola* were more abundant, and the Phase 1 sampling recorded abundant *Bathyporeia, Peringia* and *Corophium*, with *Macoma, Cerastoderma* and *Eteone* also present. Data from the Phase 2 sample station recorded a number of polychaetes including *Hediste diversicolor* and *Pygospio elegans* in small numbers, but with *Macoma balthica* and *Cerastoderma edule* as common, and the biotope was subsequently assigned as mix of **LS.LSa.MuSa.MacAre** and **LS.LSa.MuSa.HedMacEte** (Plates 39 & 40).

Plate 39: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.MacAre / LS.LSa.MuSa.HedMacEte (Overview).

Plate 40: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.MacAre / LS.LSa.MuSa.HedMacEte (Detailed).

Further into Moricambe Bay a slight shift in community was observed, this with a reduction in *Arenicola*, and an increase in *Macoma* from the Phase 1 sampling.

A further Phase 2 station was sampled which recorded a number of polychaete species in low abundance, but with *Pygospio elegans* abundant, as well as *Bathyporeia pilosa* and *Corophium arenarium*, and with frequent *Macoma balthica* (Plates 41 & 42). The area was considered to be a mix between **LS.LSa.MuSa.BatCare** and **LS.LSa.MuSa.HedMacEte**.

Plate 41: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte (Overview).

Plate 42: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte (Detailed).

On the southern side of the entrance to Moricambe Bay (off Grune Point), an elevated area of fine rippled sand was observed, with no *Arenicola* present. Phase 1 sampling identified superabundant *Bathyporeia*, as well as frequent *Eurydice* and *Haustorius*. The Phase 2 sampling undertaken recorded the polychaetes *Hediste*

diversicolor, Eteone longa, *Glycera tridactyla, Paraonis fulgens*, and *Pygospio elegans* as occasional, together with frequent *Bathyporeia pilosa* and *Macoma balthica*. The generally impoverished fauna was considered to reflect the mobility of the substratum in this area, as well as current scour and variable salinity (Plates 43 & 44). The biotope assigned was an impoverished version of **LS.LSa.FiSa.Po.Pful**.

Plate 43: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po.Pful (Overview).

Plate 44: Cardurnock Flatts & Moricambe Bay - LS.LSa.FiSa.Po.Pful (Detailed).

Running down the western side of Grune Point, biotopes typical of the northern part of the area (described above for Cardurnock Flatts) were observed. The area featured a fine, firm, well-drained rippled sand with variable *Arenicola* density.

The majority of the mid shore was assigned as **LS.LSa.MuSa.MacAre**, although with an area of greater organic material and reduced *Arenicola* density in the lower shore potentially a **LS.LSa.FiSa.Po / LS.LSa.MuSa.MacAre** mix, and the upper mid shore off the tip of Grune Point a transition between **LS.LSa.MuSa.MacAre** and **LS.LSa.MuSa.BatCare**, with *Corophium* common (Plates 45 & 46).

Plate 45: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.BatCare / LS.LSa.MuSa.MacAre (Overview).

Plate 46: Cardurnock Flatts & Moricambe Bay - LS.LSa.MuSa.BatCare / LS.LSa.MuSa.MacAre (Detailed).

Table 5 provides a summary of the biotopes recorded, together with values for mean total abundance and taxa per core. The infaunal assemblage within the survey area was quite varied. Station 12 was impoverished, and recorded an average abundance per core of just 5 individuals and 3 species, with a best but poor fit of **FiSa.Po** or **MoSa.AmSco** assigned. In the lower shore an area of relatively species rich (max. 10 No.) but low abundance (max 60 No.) habitat was recorded from stations 6, 8 and 11 (**FiSa.Po.Ncir**), but with station 14 from the inner area of Moricambe Bay featuring the greatest abundance per core due to the presence of *Corophium*, this area categorised as a transition between a mosaic of **MuSa.HedMacEte** and **MuSa.MacAre** in the outer part of the bay and channels, to a more sheltered **MuSa.BatCare** habitat. Further assemblage details are provided in Appendix 3.

Table 6 summarises the littoral soft sediment biotopes assigned within the Cardurnock Flatts & Moricambe Bay survey sector during 2014. As can be seen from Map 7, the biotopes **LS.LSa.FiSa.Po.PfuI** and **LS.LSa.MuSa.MacAre** form the greatest components within this sector.

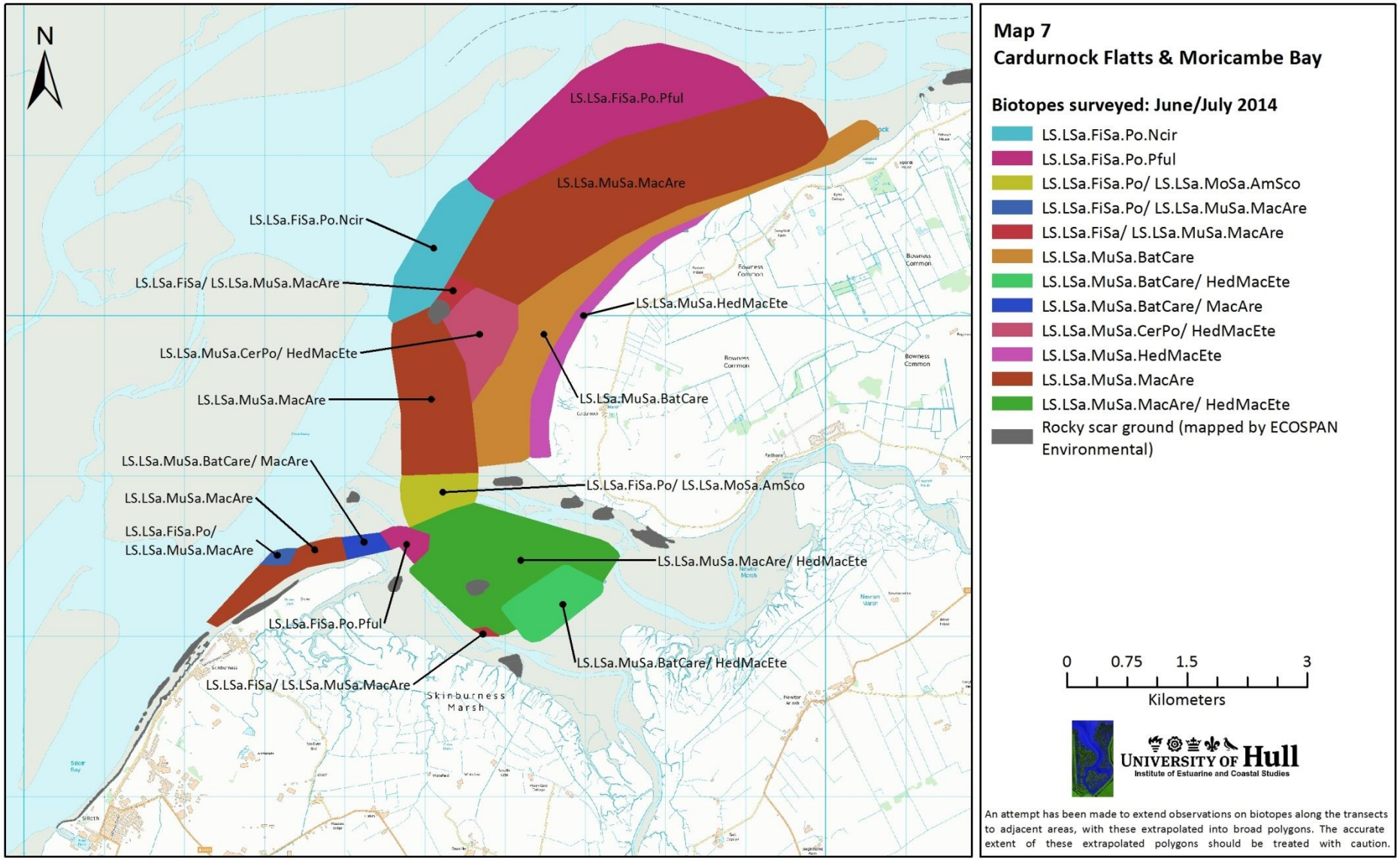
Table 5: Solway 2014 Station Taxa Summary: Cardurnock Flatts & Moricambe Bay.

Phase 2 Station	Biotope(s)	Average Total Invertebrate Abundance per Core	Average Total Taxa per Core	Dominant Taxa
Station 6	LS.LSa.FiSa.Po.Ncir	29	9	*Peringia ulvae, Capitella*
Station 7	LS.LSa.FiSa.Po.Pful	12	8	NEMERTEA, *Peringia ulvae, Pygospio elegans, Paraonis fulgens, Capitella*
Station 8	LS.LSa.FiSa.Po.Ncir	60	10	*Peringia ulvae*
Station 9	LS.LSa.MuSa.HedMacEte	156	8	*Corophium arenarium*
Station 10	LS.LSa.MuSa.BatCare	183	9	NEMATODA, *Peringia ulvae*
Station 11	LS.LSa.FiSa.Po.Ncir	20	8	*Capitella, Macoma balthica, Peringia ulvae*
Station 12	LS.LSa.FiSa.Po / LS.LSa.MoSa.AmSco	5	3	*Nephtys* juv., *Peringia ulvae*
Station 13	LS.LSa.MuSa.MacAre / LS.LSa.MuSa.HedMacEte	112	9	*Peringia ulvae*
Station 14	LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte	613	9	*Bathyporeia pilosa*
Station 15	LS.LSa.FiSa.Po.Pful	27	8	*Peringia ulvae, Bathyporeia pilosa*

Table 6: Cardurnock Flatts & Moricambe Bay - Summary of littoral soft sediment biotopes assigned during 2014.

Distinct Individual Biotopes	Biotope Mosaics / Transitions
• LS.LSa.FiSa.Po.Pful • LS.LSa.FiSa.Po.Ncir • LS.LSa.MuSa.MacAre • LS.LSa.MuSa.HedMacEte • LS.LSa.MuSa.BatCare	• LS.LSa.FiSa / LS.LSa.MuSa.MacAre • LS.LSa.FiSa.Po / LS.LSa.MoSa.AmSco • LS.LSa.FiSa.Po / LS.LSa.MuSa.MacAre • LS.LSa.MuSa.MacAre / LS.LSa.MuSa.HedMacEte • LS.LSa.MuSa.CerPo / LS.LSa.MuSa.HedMacEte • LS.LSa.MuSa.BatCare / LS.LSa.MuSa.MacAre • LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte
Total = 5	**Total = 7**

Map 7 shows the soft sediment biotopes assigned to the 'Cardurnock Flatts & Moricambe Bay' sector following the Phase 2 sampling and subsequent detailed analysis. The rocky scar ground habitats as mapped by Ecospan Environmental Ltd. (Curtis, 2014) within the same area have been additionally integrated into Map 7, although only the extent of the rocky scar ground has been shown. More detailed maps and the associated rocky shore biotopes are given in Curtis (2014) as provided in Appendix 6.



Map 7
Cardurnock Flatts & Moricambe Bay

Biotopes surveyed: June/July 2014

- LS.LSa.FiSa.Po.Ncir
- LS.LSa.FiSa.Po.Pful
- LS.LSa.FiSa.Po/ LS.LSa.MoSa.AmSco
- LS.LSa.FiSa.Po/ LS.LSa.MuSa.MacAre
- LS.LSa.FiSa/ LS.LSa.MuSa.MacAre
- LS.LSa.MuSa.BatCare
- LS.LSa.MuSa.BatCare/ HedMacEte
- LS.LSa.MuSa.BatCare/ MacAre
- LS.LSa.MuSa.CerPo/ HedMacEte
- LS.LSa.MuSa.HedMacEte
- LS.LSa.MuSa.MacAre
- LS.LSa.MuSa.MacAre/ HedMacEte
- Rocky scar ground (mapped by ECOSPAN Environmental)

0 0.75 1.5 3
Kilometers

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Institute of Estuarine and Coastal Studies

An attempt has been made to extend observations on biotopes along the transects to adjacent areas, with these extrapolated into broad polygons. The accurate extent of these extrapolated polygons should be treated with caution.

3.3 Blitterlees Bank to Dubmill Point (South of Silloth)

3.3.1 Phase 1 Overview

The intertidal area running south (downstream) from Silloth to Dubmill Point features extensive intertidal sandflats backed by a significant dune complex. The intertidal sandflats incorporate areas of scar and boulder field, the status of these being apparently relatively ephemeral depending on erosion and deposition cycles (e.g. as recorded from previous IECS surveys). The most extensive of these scars is located at Dubmill Point. For the current survey programme commissioned by Natural England, the hard and mixed sediment scar ground areas were excluded from the IECS survey programme, these being sampled and mapped by Ecospan Environmental Ltd. (Curtis, 2014) and reported separately (see Appendix 6). The low shore is constrained by the Silloth Channel which, in the south of the area, becomes effectively open coast. The survey concentrated on the intertidal area fronting the Blitterlees Bank to Dubmill Point area.

Running south from the Port of Silloth entrance, the intertidal habitat extent gradually increases to a width of *c.* 3km off Mawbray and down to Dubmill. The majority of the intertidal area consists of a fine to medium sand with areas of muddy sand, as well as some cobble/boulder scars. Some of these scars are partially covered by surficial soft sediment so that they are present as 'boulder fields' rather than a more characteristic 'cobble scar' habitat. As such, the extent of scar habitat shown on the OS Land Ranger 1:50,000 map for the area is unrepresentative of the actual current extent, but is more accurately shown on the appropriate OS Explorer 1:25,000 map. In particular, Catherinehole Scar is predominantly only present as a sparse 'boulder field' rather than a 'cobble scar' feature. As noted above, the extent and status of the scar grounds was sampled on this campaign by Ecospan and reported under separate contract to Natural England (Curtis, 2014; Appendix 6). However the mapped habitats from both soft and hard/mixed sediment programmes are combined in Maps 6-9 of this report and subsequently discussed.

The extreme upper shore of the Silloth to Wolsty Bank reach is predominantly dune, which grades into a fine sand strandline habitat (predominantly **LS.LSa.MoSa.BarSa**), although with patches of cobble/pebble **LS.LCS.Sh.BarSh** also present. As with the 2011 survey programme, these were not assessed in detail during the current survey although they were noted as extending down onto the upper shore in the form of a relatively steeply shelving high energy beach consisting of fine to medium sand with variable gravel over much of the reach.

The majority of the survey area consisted of a low to mid elevation fine sand flat with variable ripple features, standing water, mud content, and with some coal and shell

debris. During the 2014 programme, two main intertidal habitats were identified within the area (in addition to the high shore barren sand/shingle):

- Extensive mid shore fine sand flats
- Scar grounds and biogenic reefs (surveyed by Ecospan Environmental Ltd).

Given the absence of a requirement to survey the scar ground features, the 2014 was able to extend the survey coverage further south to Dubmill Point compared to the 2011 survey programme. Examples of the two main habitats in this area are given in Plates 47 and 48. It should however be noted that additional biotopes were also recorded, as well as transition habitats.

Plate 47: Blitterlees Bank to Dubmill Point - Extensive mid shore mobile fine sand flats.

This habitat was recorded across much of the upper low to lower high shore throughout the survey area. In general, the substratum was a firm, fine rippled sand with variable silt content and standing water. In some areas the habitat was associated with sand waves, with these featuring areas of less firm sand. *Arenicola* were evident across the habitat although in variable densities, together with several other polychaetes, whilst *Macoma* and *Bathyporeia* also noted from the Phase 1 sampling. The faunal assemblage was depressed in the sand wave areas suggesting a greater environmental stress perhaps from sediment mobility and increased wave/current action.

Plate 48: Blitterlees Bank to Dubmill Point - Cobble/pebble scar grounds and biogenic reefs (not surveyed by IECS, but covered by Ecospan Environmental).

Several scar ground areas were noted with *Mytilus* and *Sabellaria* reefs associated with them.

Biotope details derived from both the broad-scale mapping of habitats undertaken in Phase 1, together with the detailed sampling and subsequent sediment and taxonomic analysis from Phase 2 are described in Section 3.3.2.

3.3.2 Phase 2 Biotope Descriptions

As described above, the upper shore along the survey area was characterised by largely barren sand and/or shingle bands forming a steeply shelving upper shore. **LS.LSa.MoSa.BarSa** and **LS.LCS.Sh.BarSh** (not surveyed in detail).

The upper mid shore of the northern part of the survey area consisted of a muddy fine sand *c*. 50m wide strip, with dense but small *Arenicola* casts. Phase 1 sampling recorded abundant *Macoma* and *Pygospio*, with *Hediste* common (Plates 49 & 50), with some standing water, the habitat effectively formed in a slack between the steeply shelving beach and the elevated mid shore bank.

Based on the Phase 1 data, the narrow habitat was assigned as a fit between **LS.LSa.MuSa.HedMacEte *and* LS.LSa.MuSa.MacAre**.

Plate 49: Blitterlees Bank to Dubmill Point - LS.LSa.MuSa.HedMacEte / LS.LSa.MuSa.MacAre with LS.LSa.MoSa.BarSa at the beach top (Overview).

Plate 50: Blitterlees Bank to Dubmill Point - LS.LSa.MuSa.HedMacEte / LS.LSa.MuSa.MacAre with LS.LSa.MoSa.BarSa at the beach top (Detailed).

Fronting this area was a further narrow lateral habitat band that consisted of a rippled fine to medium sand with surficial shell and organic debris. The substratum was soft with no visible fauna and was formed on the landward side of a mid-shore bank feature. Phase 1 sampling recorded common *Pygospio* but with abundant Nemertea and Enchytraeidae present, and was ascribed the **LS.LSa.MoSa.Ol.FS** biotope (Plates 51 & 52).

Plate 51: Blitterlees Bank to Dubmill Point - LS.LSa.MoSa.Ol.FS (Overview).

Plate 52: Blitterlees Bank to Dubmill Point - LS.LSa.MoSa.Ol.FS (Detailed).

Moving down shore along the transect, an elevated bank was recorded, featuring a fine, well-drained rippled sand with a sparse coverage of *Arenicola* and shell debris (mostly *Mytilus*) present on the surface. The Phase 1 sampling recorded common to abundant *Macoma*, *Pygospio* and common *Bathyporeia*, and the area was coded as **LS.LSa.MuSa.MacAre**. Although reduced in width, this habitat was noted as a linear feature running south along the upper shore for several kilometres (Plates 53 & 54).

Plate 53: Blitterlees Bank to Dubmill Point - LS.LSa.MuSa.MacAre (Overview).

Plate 54: Blitterlees Bank to Dubmill Point - LS.LSa.MuSa.MacAre (Detailed).

Immediately adjacent to this was an area of sand waves of up to 50cm height between trough and crest. The substratum was a rippled fine to medium sand with standing water and shell debris present in the troughs (as well as *Crangon*). The substratum was of variable firmness with no anoxic band. Phase 1 sampling recorded common *Arenicola* and occasional *Scolelepis* and *Spio*, with *Bathyporeia* common (Plates 55 & 56). Given the faunal paucity, due at least in part to the likelihood of high sand mobility and scour, the habitat was assigned as a fit between **LS.LSa.MoSa.AmSco** and **LS.LSa.FiSa.Po**.

Plate 55: Blitterlees Bank to Dubmill Point - LS.LSa.MoSa.AmSco / LS.LSa.FiSa.Po (Overview).

Plate 56: Blitterlees Bank to Dubmill Point - LS.LSa.MoSa.AmSco / LS.LSa.FiSa.Po (Detailed).

The sand wave feature was fronted by an extensive *Mytilus* bed on a cobble/pebble scar, with Littorinids and Barnacles also abundant. The area was not surveyed in detail but was noted as being **LS.LMx.LMus.Myt.Mx**.

Surrounding the scar ground to the west and south was an extensive area of firm, fine rippled sand, with variable amounts of standing water and shell debris. Small

sand waves were present in some locations, as well as sparse boulder fields, it being assumed that the soft sediment biotope overlay a scar ground in these areas. *Arenicola* were present in variable densities although not achieving a high abundance, with a range of other polychaetes present in common to frequent abundances (Plates 57 & 58).

Plate 57: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po (Overview).

Plate 58: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po (Detailed).

A Phase 2 sampling station was positioned in the northern part of this extensive habitat feature and supported abundant *Pygospio elegans*, with the polychaetes *Eteone longa*, *Spio martinensis, Spiophanes bombyx* and *Psammodrilus balanoglossoides* common to frequent. *Bathyporeia sarsi* was abundant, with *B. pilosa* and *Corophium arenarium* frequent. *Peringia ulvae* was superabundant, with *Cerastoderma edule* also frequent together with *Macoma balthica.* **LS.LSa.FiSa.Po** was considered to be the best fit, given the sediment conditions and polychaete assemblage, with an absence of further characterising species to define this further.

Towards the landward side of this feature, a transition zone was recorded that ran parallel to the shore (and the main mid-shore bank), with an increase in the fine sand and mud fraction and an increase in *Arenicola* density. This area was mapped as a mix between the relatively fine clean sands of the **LS.LSa.FiSa.Po** biotope of the main mid shore bank feature, and a more muddy **LS.LSa.MuSa.MacAre**.

Approximately 50m further up the shore, the above biotope mix transitioned into a lower elevation linear slack feature with a slightly rippled soft muddy sand substratum, with abundant *Arenicola* (Plates 59 & 60).

Plate 59: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po (Overview).

Plate 60: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po (Detailed).

Phase 1 sampling recorded *Macoma* as abundant, with *Pygospio* common and *Scolelepis* frequent and the zone was considered to be a continuation of the **LS.LSa.MuSa.MacAre** biotope identified as a linear feature further north, but with the feature running out at around this location.

At the top of the shore the continuation of the **LS.LSa.MoSa.AmSco.Eur / LS.LSa.MuSa.MacAre** zone was again recorded, this a continuation of the linear feature that was observed to extend north along the shore for several kilometres and essentially was a transition out of the mud/fine sand slack onto the base of the more steeply shelving beach.

The habitat was *c*. 50m wide and featured a fine clean rippled firm sand. A Phase 1 sample identified *Scolelepis* as frequent with *Bathyporeia* abundant, with the Phase 2 sample recording *Bathyporeia pilosa* as abundant and *Eurydice pulchra* and *Macoma balthica* as common, with *Pygospio martinensis* and *Cerastoderma edule* occasional (Plates 61 & 62).

Plate 61: Blitterlees Bank to Dubmill Point - LS.LSa.MoSa.AmSco.Eur / LS.LSa.MuSa.MacAre (Overview).	**Plate 62: Blitterlees Bank to Dubmill Point - LS.LSa.MoSa.AmSco.Eur / LS.LSa.MuSa.MacAre (Detailed).**

A further high to low shore transect from the southern extent of the above feature recorded a further extensive mid shore rippled fine sand flat with *Arenicola* present in variable density and Phase 1 samples recording a range of polychaete species as common or frequent (e.g. *Pygospio, Nephtys, Scolelepis, Spio* and *Psammodrilus*). The habitat was considered to be an extension of the **LS.LSa.FiSa.Po** described above. However in the low shore, adjacent to a scar ground, *Arenicola* was almost absent from the fine rippled sand, with a Phase 1 sample recording *Nephtys, Spio, Pygospio* and *Psammodrilus* as common together with occasional *Capitella* and *Scolelepis*. A Phase 2 sampling station was located in this habitat and recorded juvenile *Nephtys* as common, with occasional adult *Nephtys cirrosa*. *Scoloplos armiger* was also common, with *Pygospio elegans*, *Spio martinensis*, *Spiophanes bombyx*, *Capitella*, and *Lagis koreni* occasional. *Macoma balthica* was also common and *Cerastoderma edule* occasional.

Plate 63: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po.Ncir (Overview).	**Plate 64: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po.Ncir (Detailed).**

The habitat, which featured a small surficial silt content as well as some shell and organic debris and had standing water in the ripples, is shown in Plates 63 & 64, and was assigned as **LS.LSa.FiSa.Po.Ncir**.

South of this feature was an extensive scar (Lowhagstock Scar), with cobbles and boulders as well as interstitial patches of soft sediment. This habitat was surveyed and reported by Ecospan Environmental under separate contract (Curtis, 2014; Appendix 6). However the mapped habitats from both soft and hard/mixed sediment programmes are combined in Maps 6-9 of this report.

A further area of very fine, rippled sand with standing water was recorded immediately inshore of the main scar, and within a sparse boulder field, the soft sediment presumably overlying the scar ground in this area. Fine shell and organic material was again recorded in the ripple troughs with *Arenicola* present in low density. Large depressions were also recorded with standing water, and where boulders/cobbles were in the water, they were colonised by algae and barnacles. Shrimp and fish (e.g. Goby (*Pomatoschistus*) sp. and Sand Eel (*Ammodytes*) sp.) were observed in these areas of water (Plates 65 & 66).

Plate 65: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po.Ncir (Overview).

Plate 66: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po.Ncir (Detailed).

The initial Phase 1 survey recorded *Paraonis* and *Pygospio* as common, with *Nephtys* and *Angulus* occasional, with the **LS.LSa.FiSa.Po.PfuI** biotope assigned in the field. However, the Phase 2 sample undertaken at the location recorded *Nephtys* juveniles as abundant to common, with *Nephtys cirrosa* adults as frequent, and although *Paraonis fulgens* was also commonly recorded, **LS.LSa.FiSa.Po.Ncir** was assigned, as a continuation of the feature recorded to the north of the scar, on the basis that the abundant juveniles were also *N. cirrosa*.

Running south from this area, a very extensive area of fine rippled sand was recorded from *c*. low to high shore (excepting the more steeply shelving high shore of largely barren sand and shingle). This area was approximately 2km x 2km but included areas of scar ground (surveyed and reported by Ecospan Environmental - Curtis, 2014; Appendix 6), e.g. around Stinking Crag. The extensive flat comprised a fine firm sand with variable ripples and standing water, and with *Arenicola* present in low to moderate densities (Plates 67 & 68). The presence of sand waves was noted in some areas (*c*. 30cm from trough to crest, but with little variation in the assemblage noted.

Plate 67: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po (Overview).

Plate 68: Blitterlees Bank to Dubmill Point - LS.LSa.FiSa.Po (Detailed).

Phase 1 sampling recorded a number of polychaete species as frequent (occasionally common) in abundance including *Pygospio, Scolelepis, Spio, Capitella* and *Nephtys*, with *Macoma, Angulus* and *Bathyporeia* also common. However, the Phase 2 cores taken within this extensive area recorded an impoverished fauna, dominated by frequent *Bathyporeia pelagica* and occasional *B. pilosa*, this area perhaps drying more than adjacent parts of the flat. Based on the moderately diverse polychaete community, but low abundance, the **LS.LSa.FiSa.Po** biotope was assigned, with this feature extending for over 5km along the coast from Silloth to Dubmill Point where it transitioned into scar ground with an increasing abundance of cobbles and boulders present.

On the upper shore off Dubmill Point, a narrow elevated band of medium rippled sand was recorded, with some coarse shell debris and silt on the surface of the ripple troughs. *Arenicola* were present in low densities, and the feature transitioned into a more steeply shelving upper beach of barren pebble, shingle and sand. A Phase 1 sample recorded an impoverished community with a few polychaete species recoded as frequent, but with the isopod crustacean *Eurydice* common, together with *Bathyporeia*. The area appeared to be moderately exposed and based on the limited faunal abundance, dominated by crustaceans, the biotope **LS.LSa.MoSa.AmSco** was assigned (Plates 69 & 70).

Off from Dubmill Point an extensive scar ground and biogenic reef was recorded, this being mapped and reported separately by Ecospan (Curtis, 2014; Appendix 6).

Table 7 provides a summary of the biotopes recorded from this survey area, together with values for mean total abundance and taxa per core. The infaunal assemblage within the survey area was moderately rich but with station 20 featuring an impoverished fauna with an average of just 2 individuals per core and only *B. pelagica* recorded from the 3 cores and *Bathyporeia pilosa* from one of the cores. A

best fit of an impoverished **FiSa.Po** biotope was assigned, given its location within a wider area of the biotope, although the paucity of fauna would make this a low certitude fit.

As with the Cardurnock Flatts section, areas of **FiSa.Po.Ncir** were recorded from the mid to low shore adjacent to scar ground features, with a moderate taxonomic diversity (max. 8 No.) but low abundance (max. 16 No.), with the upper mid to upper shore a slightly more muddy slack area of Station 17 featuring the greatest abundance (124 No.) but with a quite low taxonomic diversity (6 No.) this area identified as a transition between the main muddy slack of **MuSa.MacAre** and the more mobile base of the shelving upper beach (**MoSa.AmSco.Eur**). However, the majority of this Blitterlees to Dubmill Point survey area was identified as **FiSa.Po**, although with some variation in assemblage, and an insufficient abundance of additional characterising species to define this further. Further assemblage details are provided in Appendix 3.

Plate 69: Blitterlees Bank to Dubmill Point - LS.LSa.MoSa.AmSco (Overview).

Plate 70: Blitterlees Bank to Dubmill Point - LS.LSa.MoSa.AmSco (Detailed).

Table 7: Solway 2014 Station Taxa Summary: Blitterlees to Dubmill Point.

Phase 2 Station	Biotope(s)	Average Total Invertebrate Abundance per Core	Average Total Taxa per Core	Dominant Taxa
Station 16	LS.LSa.FiSa.Po	83	9	*Pygospio elegans, Peringia ulvae*
Station 17	LS.LSa.MoSa.AmSco.Eur / LS.LSa.MuSa.MacAre	124	6	*Bathyporeia pilosa*
Station 18	LS.LSa.FiSa.Po.Ncir	16	8	*Scoloplos armiger, Nephtys* juv.
Station 19	LS.LSa.FiSa.Po.Ncir	15	6	*Pygospio elegans Nephtys* juv.

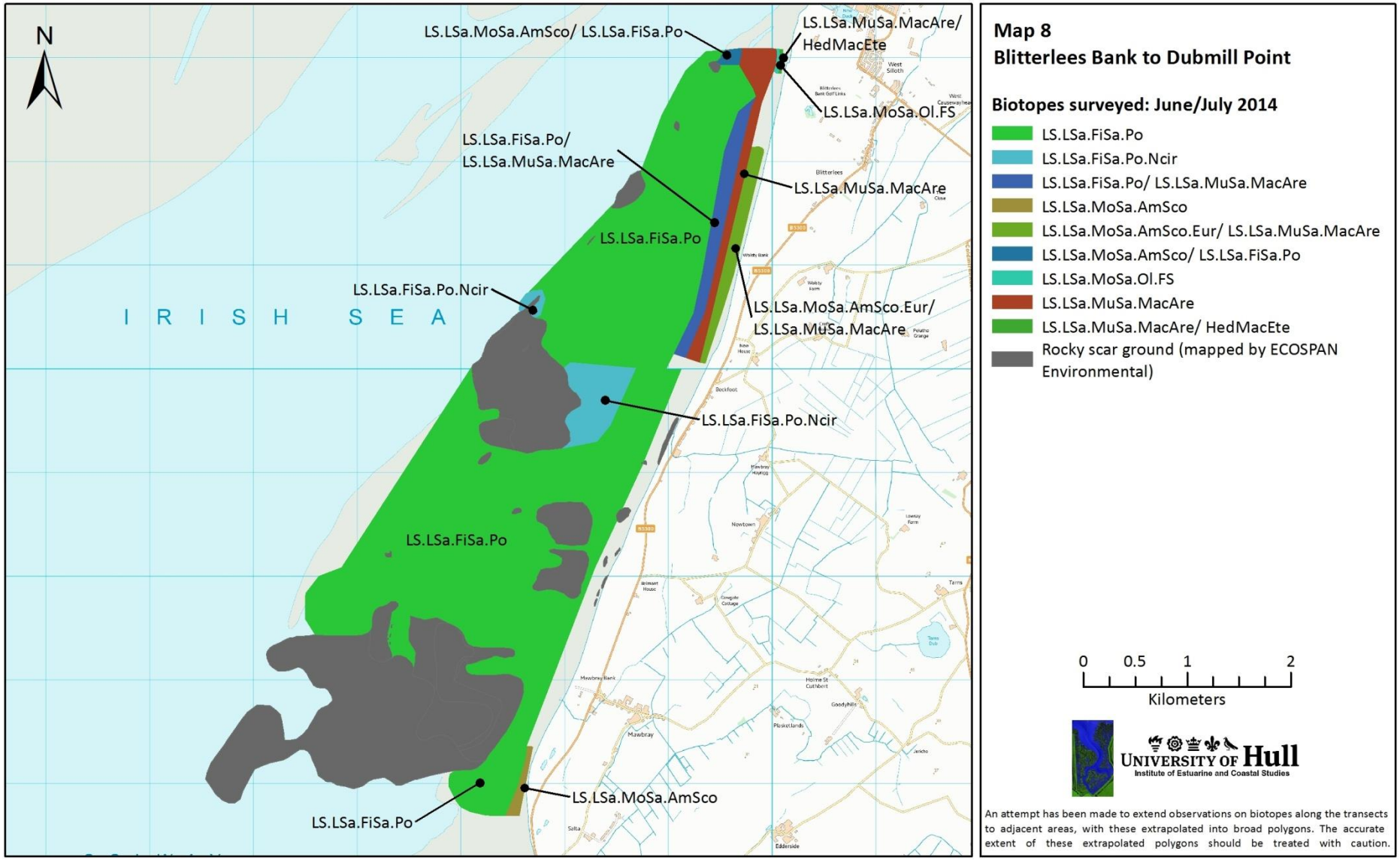
Station 20	LS.LSa.FiSa.Po	2	1	*Bathyporeia pilosa*, *Bathyporeia pelagica*

Table 8 summarises the littoral soft sediment biotopes assigned within the Blitterlees Bank to Dubmill Point survey sector during 2014. As can be seen from Map 8, the biotope **LS.LSa.FiSa.Po** forms the greatest component within this sector.

Table 8: Blitterlees Bank to Dubmill Point - Summary of littoral soft sediment biotopes assigned during 2014.

Distinct Individual Biotopes	Biotope Mosaics / Transitions
• LS.LSa.MoSa.Ol.FS • LS.LSa.MoSa.AmSco • LS.LSa.FiSa.Po • LS.LSa.FiSa.Po.Ncir • LS.LSa.MuSa.MacAre	• LS.LSa.MoSa.AmSco / LS.LSa.FiSa.Po • LS.LSa.MoSa.AmSco.Eur / LS.LSa.MuSa.MacAre • LS.LSa.FiSa.Po / LS.LSa.MuSa.MacAre • LS.LSa.MuSa.MacAre / LS.LSa.MuSa.HedMacEte
Total = 5	**Total = 4**

Map 8 shows the soft sediment biotopes assigned to the 'Blitterlees Bank to Dubmill Point' sector following the Phase 2 sampling and subsequent detailed analysis. The rocky scar ground habitats as mapped by Ecospan Environmental Ltd. (Curtis, 2014) within the same area have been additionally integrated into Map 8, although only the extent of the rocky scar ground has been shown. More detailed maps and the associated rocky shore biotopes are given in Curtis (2014) as provided in Appendix 6.



3.4 Biotope Summary

Table 9 summarises a combined list of all distinct individual littoral soft sediment biotopes and littoral soft sediment biotope mosaics assigned within the three survey sectors (Old Graitney to Port Carlisle; Cardurnock Flatts & Moricambe Bay; and Blitterlees Bank to Dubmill Point) during 2014.

Table 9: Combined summary of all individual littoral soft sediment biotopes and littoral soft sediment biotope mosaics assigned within the three survey sectors during 2014.

Distinct Individual Biotopes	Biotope Mosaics / Transitions
• LS.LSa.MoSa • LS.LSa.MoSa.Ol.FS • LS.LSa.MoSa.AmSco • LS.LSa.FiSa • LS.LSa.FiSa.Po • LS.LSa.FiSa.Po.Pful • LS.LSa.FiSa.Po.Ncir • LS.LSa.MuSa.MacAre • LS.LSa.MuSa.HedMacEte • LS.LSa.MuSa.BatCare • LS.LMu.MEst.HedMac	• LS.LSa.MoSa.AmSco / LS.LSa.FiSa.Po • LS.LSa.MoSa.AmSco.Eur / LS.LSa.MuSa.MacAre • LS.LSa.FiSa / LS.LSa.MuSa.MacAre • LS.LSa.FiSa.Po / LS.LSa.MoSa.AmSco • LS.LSa.FiSa.Po / LS.LSa.MuSa.MacAre • LS.LSa.MuSa.MacAre / LS.LSa.MuSa.HedMacEte • LS.LSa.MuSa.CerPo / LS.LSa.MuSa.HedMacEte • LS.LSa.MuSa.BatCare / LS.LSa.MuSa.MacAre • LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte • LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMacEte onto LS.LSa.MoSa
Total = 11	**Total = 10**

Whilst extensive areas of principle biotope habitats were recorded from the survey areas, as is often the case in such soft sediment estuarine environments, either a mosaic of habitats or a transition zone between two biotopes was observed, whereby either a series of patches or a gradual shift in sediment type and /or associated biological assemblage was recorded. In many cases, this reflected a relatively small variation in sediment conditions and/or the presence of a characterising species, this also being seen from the 2011 programme (Cutts *et al*. 2011).

4. Rocky and Mixed Sediment Survey (Ecospan Environmental Ltd.)

The rocky scar ground habitats as mapped by Ecospan Environmental Ltd. (Curtis, 2014; report provided in full in Appendix 6) have been integrated into Maps 6-8 (see Section 3) which feature the soft sediment biotopes as ascribed by IECS during the same 2014 survey period. Similarly, Map 9 shows the biotopes (both soft and rocky scar) along the full survey area of the southern shore. Within these maps, only the rocky scar ground extent has been shown as the more detailed maps and associated rocky shore biotopes are provided in Curtis (2014).

The Executive Summary taken from Curtis (2014) which provides an overview of the rocky scar ground monitoring study is given below:

A two phased survey of the rocky scar ground communities was undertaken by Ecospan Environmental Ltd during two periods in June 2014. A total of 12 intertidal rocky scar ground habitat types were recorded and mapped. The most substantial areas of scar ground were found in the most southwestern extent of the SAC on the shores between Mawbray and Silloth. There, the majority of the intertidal scars were on the mid-shore tidal height where mussel beds dominated. Where the scars transitioned from the mid to lower shore the mussel beds were often found to mosaic with patches of *Sabellaria alveolata*. The *Sabellaria alveolata* reefs were most extensive at the south-western boundary of the SAC off the coast at Mawbray where the honeycombe structures solely dominated a large proportion of the lower shore. On the upper shore in the lower estuary, much smaller, narrow scars either characterised by *Ulva* spp. or communities of barnacles and *Littorina* spp. were found.

Higher in the estuary, adjacent to Silloth, a variety of fucoid dominated communities were established in small patches on pebble and cobble beaches which were otherwise mostly dominated by barnacles and *Littorina* spp. Communities of *Ulva* spp. and *Porphyra* spp. were found in small areas at the interface of the cobble and muddy-sand communities, whilst mussel beds stretched along the lower shore periphery.

The scars within Moricambe Bay were limited in extent. *Ulva* spp. and *Porphyra* spp. characterised many of the scars, particularly those in the centre of Moricambe Bay which were most exposed to tidal scour. On the northern shore of the bay two of the scars were formed by dense aggregations of mostly juvenile *Mytilus edulis*. On the southern bank of the bay communities of the upper shore fucoid *Fucus spiralis* was found alongside and mosaicking with Ulva spp.

In the upper estuary the scar communities were limited to a few banks adjacent to Bowness-on-Solway where the main river channel brought about variable salinity conditions. *Ulva* spp. were again prevalent and occurred alongside the brackish water fucoid *Fucus ceranoides*. *Fucus spiralis* also occurred on the upper shore in some areas.

The non-native invasive barnacle species *Austrominius modestus* was recorded at 24 of the 35 transects that were sampled; through rarely at greater than 5% cover.

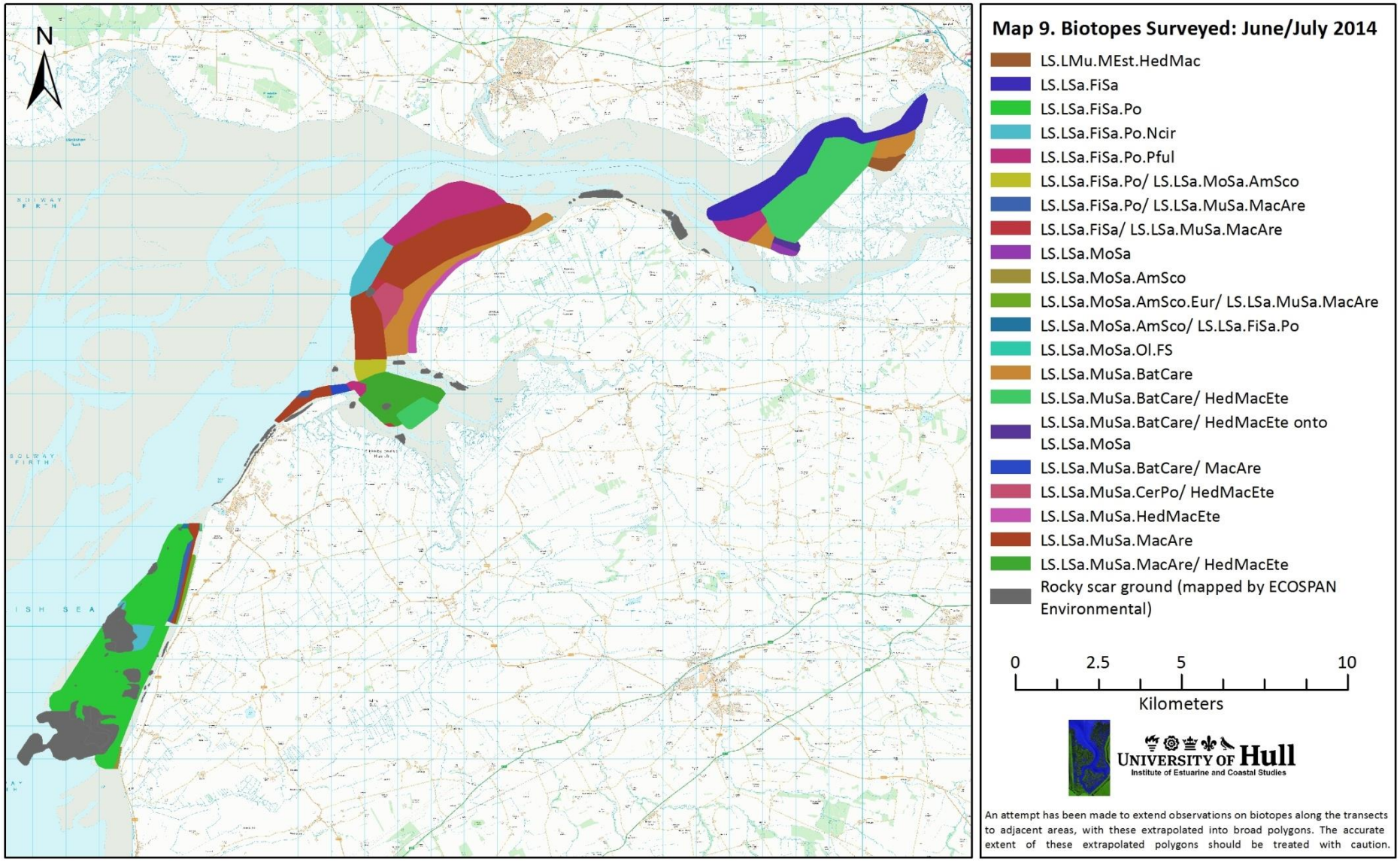
A few anthropogenic activities were identified during the course of the surveys that were mostly considered to have the potential to cause only minor or localised negative impacts within the rocky scar ground communities in the SAC although a preliminary assessment has been made. These included features such as sewage outfalls and litter. The most notable activity observed was bait digging within the mussels beds. This activity has the potential to result in a loss in extent of the characteristic biotope which is a breach of the conservation objectives for the rocky scar ground sub-feature.

Since previous relevant surveys within the study area have been limited, it has not been possible to draw definitive conclusions with regard to the condition of the rocky scar ground attributes in the Solway Firth SAC. The output from this study will however provide a baseline from which a change in the condition of the attributes can be measured within any future condition assessments.

An evaluation of methods has been carried out and a number of recommendations have been proposed for future condition assessment of the SAC, these include:

- Increasing the number/size of quadrats used on each transect to ensure that the data produced is representative of the communities present. Alternatively, consideration could be given to strategies such as using timed searches.
- Increasing the number of transects/stations in some of the habitat types which occupy relatively small areas if resources allow.
- Undertaking any future studies at the same time of year to this study to minimise any seasonally induced fluctuation in community structure.
- Revisiting the same transects.

It is concluded that by implementing these recommendations, a comparison of results from future studies will provide a sound foundation from which to base conclusions regarding any temporal changes that may be observed within the Solway Firth SAC. However, depending upon the specific aims of any future monitoring, further targeted work may be necessary to discern whether any changes observed (e.g. loss in extent of a particular habitat type) are attributable to anthropogenic factors as opposed to natural factors.



5. General Conservation Assessment & Discussion

5.1 Biotope Extent Comparison

IECS have undertaken broadly similar survey programmes of habitat mapping in the Solway during the autumn of 2004 (Hemingway *et al*., 2006) and winter of 2011 (Cutts *et al*., 2011), with the 2004 programme covering both shores of the estuary and the 2011 survey the south shore of the inner to middle estuary. Both of these surveys covered many of the areas surveyed under the 2014 programme (e.g. areas within each of the 3 main survey locations). However, as noted earlier in text, there have been differences in the timing of the surveys, with the 2004 and 2014 surveys undertaken during the summer, and the 2011 survey in the late winter/early spring.

The 2011 survey was delayed due to a combination of external factors, but primarily due to a prolonged cold spell in the early winter of 2010 which entailed a statutory wildfowling ban on the Scottish shore of the estuary and a voluntary ban elsewhere in the estuary. These bans were put in place to minimise disturbance to waterbirds using the estuary, and therefore it was considered prudent to delay the deployment of a hovercraft into the estuary until cessation of the ban period. Further operational delays occurred in the late winter, due to a series of low pressure systems on the west coast which created prolonged changeable gusty conditions during suitable working periods (e.g. around suitable spring tide periods).

As such, it is considered that the abundance and taxonomic diversity metrics recorded from much of the 2011 survey area are as a result of the survey timing, rather than indicating a reduction (and subsequent increase) in condition status. In fact, it is likely that these seasonal differences were compounded, both by the prolonged and relatively unusual hard early winter weather period, as well as a stormy late winter period, with increased faunal die-off and predation possible from the cold weather, as well as elevated sediment perturbation and scour from the increased storminess.

Although the 2004 survey utilised a relatively different methodology (e.g. polygon mapping on foot and quad bike), the 2011 survey utilised a hovercraft with biotopes assessed along a series of transects with adjacent extent assessed visually in much the same way as the current programme. However, it should be noted that the 2011 survey included mapping of both intertidal soft sediment and hard/mixed sediment scar ground communities.

Given the survey dates and techniques used, the majority of comparison in the following text is between the findings from the 2011 and 2014 surveys, e.g. approximately the same areas covered). However, it is emphasised that the Phase 1 transects (e.g. the survey track files) and sampling techniques were not identical, and as such direct comparison of the derived data are not always possible. For example, whilst the same areas were largely covered between the two surveys, there were differences in survey timing, with the 2011 survey undertaken in March, following a winter where there had been extreme storms on the west coast, followed by a prolonged period of cold weather that necessitated a wildfowling ban. As such, it might be expected that the infaunal assemblage of sites from the 2011 survey would be relatively impoverished, particularly compared to the 2014 survey when samples were taken in the mid-summer, creating some differences in likely biotope assignation.

Further contributing to a potential variation in the survey outcomes, there was some variation in the location of the transects reflecting a range of constraints such as timing and physical barriers, with these also compounded by necessary differences in sampling locations.

However, also of importance in this is the difference in sampling technique between the two surveys. The 2011 sampling campaign used a single replicate approach, with a large number of single replicate cores taken from the transects and within each of the identified habitats. This is compared to the 2014 approach where following from the broad-scale Phase 1 sampling (e.g. a large number of in-field digs along the track files), a smaller number of cores were taken using a three replicate approach. Whilst this assisted in better defining an individual biotope based on sediment and infaunal characteristics, it meant that extent was more difficult to accurate assess. The relative merits associated with differing sampling approaches are discussed further in text in Section 6.

5.1.1 Old Graitney (North Bank) to Port Carlisle (South Bank)

The 2011 survey identified an area of LS.LSa.MuSa.MacAre in the upper reaches, south of the River Esk channel, with this grading into LS.LSa.MuSa.BatCare area downstream in the low shore extensive flats around the confluence of the two river channels. An area of LS.LSa.MuSa.BatCare / LS.LSa.MuSa.HedMac was recorded on the more muddy edge of the high banks adjacent to Rockcliffe Marsh, this identified as LS.LSa.MuSa.MacAre / LS.LSa.MuSa.HedMacEte / LS.LSa.MuSa.BatCare in 2004.

The 2014 survey recorded the area immediately adjacent to the Esk channel as being LS.LSa.FiSa, although sediment conditions were broadly comparable across most of this upper estuary area, consisting of a very fine sand in 2011, but with the

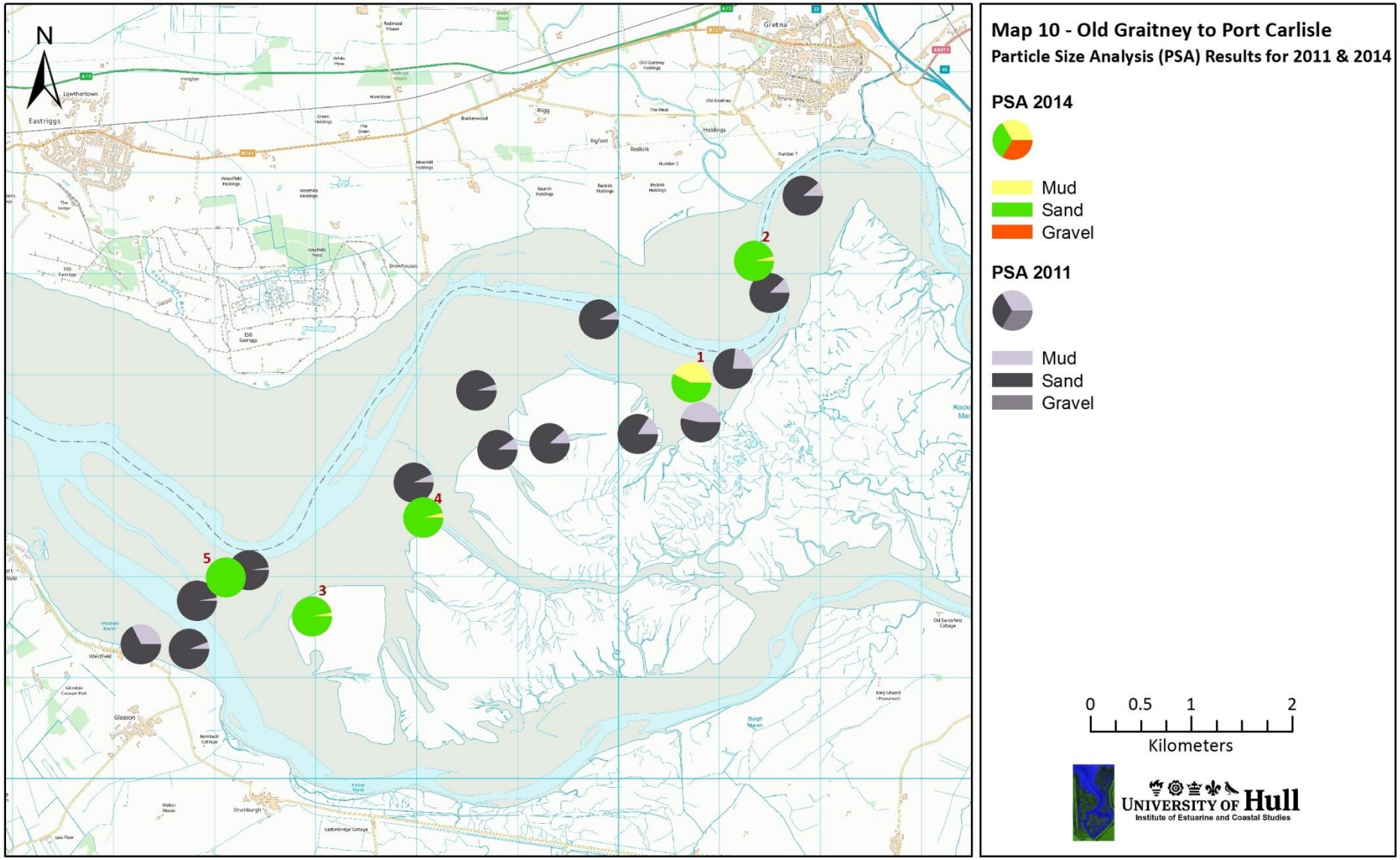
2014 survey recording an impoverished fauna dominated by *Bathyporeia*. However, a similar level of impoverishment was observed from the 2011 programme, but with a suggestion that the faunal community of the area may have been affected by the time of year (the survey having been carried out in the late winter).

On the extensive flats adjacent to Rockcliffe Marsh, the LS.LSa.MuSa.BatCare biotope was predominantly recorded in 2014, transitioning into LS.LSa.MEst.HedMac in some areas. Similar biotopes were recorded from the 2011 programme, with LS.LSa.MuSa.BatCare recorded, but with this transitioning to a LS.LSa.MuSa.HedMac or LS.LSa.MuSa.MacAre community. However, it is again emphasised that the 2011 survey recorded a generally depressed faunal community (with best fit biotopes applied), and as such, slight variations in community and associated biotopes between surveys may be an artefact of survey timing.

Towards the edge of the channel of the River Eden, the 2014 survey recorded an area of LS.LSa.FiSa.Po.Pful, with a number of polychaetes in the assemblage including *Paraonis fulgens*. The same area in 2011 featured an extremely impoverished community with only *Bathyporeia* abundant, and a very small number of other faunal species, but with *Corophium* and *Macoma* present and hence the BatCare / HedMac biotopes being assigned across much of the area. Again, this is considered primarily an artefact of survey methods and timing rather than a community shift, and the majority of the soft sediment area covered by both the 2011 and 2014 show a broadly comparable community.

Map 10 shows the broad sediment composition from sample stations in the extreme inner Solway from both the 2011 and 2014 surveys, and clearly shows both the dominance of the sand fraction in the samples, as well as the greater mud component identified at stations immediately adjacent to Rockcliffe Marsh from both years.

Therefore, in general, there was a strong similarity in broad habitat presence and extent between the two surveys in this area. However, for the most part, fauna were less abundant from the 2011 (Cutts *et al*., 2011) survey compared to the 2014 survey. The 2011 assemblage was also more impoverished than that seen from the 2004 survey (Hemingway *et al*., 2006), with the differences in the 2011 survey timing between the surveys suggested as being a key driver of this variation (see Section 5.1 and Section 6 for further discussion.)



5.1.2 Cardurnock Flatts and Moricambe Bay

The Cardurnock Flatts and Grune Cast area was surveyed in 2011 (Cutts *et al*., 2011), but with the Moricambe Bay embayment excluded due to time constraints (as a result of scar grounds also being mapped during this survey). However, during the 2004 survey programme (Hemingway *et al*., 2006), part of Cardurnock Flatts and Grune Cast were covered on foot, with Moricambe Bay undertaken by hovercraft. As such, coverage between all three surveys is not fully comparable, but given the extensive soft sediment flats present in this area, some direct comparison is possible between surveys where tracks were broadly convergent.

Both the 2004 (Hemingway *et al*., 2006) and 2011 (Cutts *et al*., 2011) surveys recorded primarily very fine to fine sands within the survey areas, with a similar sediment composition being recorded during the current 2014 survey. Map 11 shows the general dominance of the sand fraction from the 2011 and 2014 surveys.

The majority of the Cardurnock Flatts upper shore was identified as LS.LSa.MuSa.BatCare from the 2014 survey, with the same biotope recorded in 2011, this being consistent with the 2004 survey findings. However, as described above, the assemblage recorded from Phase 2 sampling stations in 2014 is somewhat more diverse and abundant than for stations from broadly similar locations in 2011. This is considered to be an artefact of survey timing and methods rather than a shift in community status. The 2014 survey however was able to identify a transition in the extreme upper shore intertidal zone off Cardurnock between the BatCare biotope and the erosion edge of the saltmarsh, with LS.LSa.MuSa.HedMacEte recorded. However, this was a 'best fit' resulting from a muddy fine sand supporting abundant *Pygospio elegans* and common *Hediste diversicolor* and *Manayunkia aesturina*, rather than the presence of *Eteone* (which was only identified in the Phase 1 sampling).

The mid to low shore of Cardurnock Flatts was recorded as a LS.LSa.MuSa.MacAre community in 2014, with the same biotope recorded form the 2011 survey and from 2004 where locations matched. However, the 2014 survey was able to differentiate further biotopes within the main Cardurnock mid to low shore area, with a large expanse of LS.LSa.FiSa.Po.Pful recorded to the north of the area, this area not covered by the 2011 or 2004 surveys.

An area of LS.LSa.FiSa.Po.Ncir was however recorded adjacent to the scar area on the lower shore of the intertidal flats, this area not recorded from the 2011 survey. As noted above, this is likely to have been an artefact of survey timing given that the majority of *Nephtys* records were for juveniles, which would not have been present at the time of the 2011 survey.

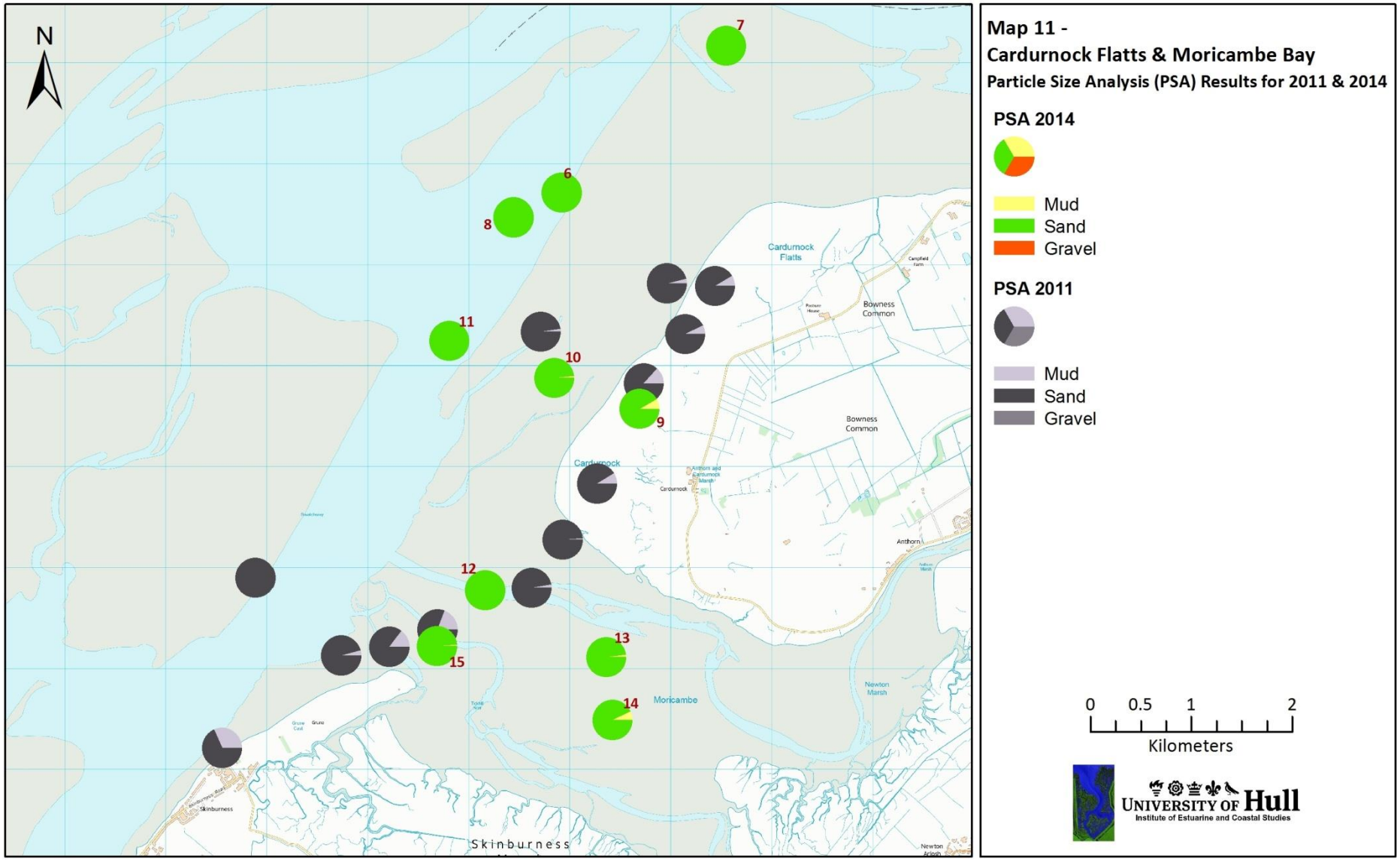
Notably, an area of LS.LSa.MuSa.CerPo / LS.LSa.MuSa.HedMacEte was recorded from the mid shore in the south of Cardurnock Flatts, this area not covered directly

from the 2011 survey, although with *Cerastoderma* density considered insufficient to be a full CerPo fit. *Cerastoderma edule* were recorded as present during sampling of the wider Cardurnock area during the 2011 survey, but from an area slightly to the south-east of the 2014 zone, with the habitat recorded as a mix of LS.LSa.MuSa.CerPo / LS.LSa.MuSa.MacAre / LS.LSa.MuSa.BatCare. In 2014, this area was recorded as just LS.LSa.MuSa.MacAre / LS.LSa.MuSa.BatCare although *Cerastoderma* were present within the samples. As such, it is considered that there is little significant difference in communities in the lower area of Cardurnock Flatts, with relatively small differences in relative abundances of key species affecting the biotopes assigned. Given that the difference in survey timing will also have influenced these variations, then it is likely that there has been no substantial shift in community. Furthermore, whilst cockle exploitation can substantially affect the abundance of *Cerastoderma*, there was no evidence of this occurring at the site during the 2014 survey.

A mix of LS.LSa.FiSa.Po, LS.LSa.MoSa.AmSco, LS.LSa.FiSa.Po.Pful, LS.LSa.MuSa.BatCare and LS.LSa.MuSa.MacAre biotopes were recorded form the 'delta' of channels at the mouth of Moricambe Bay from the 2014 survey, compared to a LS.LSa.MuSa.CerPo / LS.LSa.MuSa.BatCare / LS.LSa.MuSa.MacAre mix (see above) LS.LSa.MuSa.MacAre and LS.LSa.MoSa.BarSa biotopes from 2011 (Cutts *et al*., 2011).

The variation in these biotopes between years is considered to reflect changing morpho-dynamics in the channel over time, as well as artefacts of survey differences, rather than a substantial shift in community (these habitats being characteristic of the area and recorded elsewhere from the survey programme). This is also evident from the sediment data comparison, with the stations in the Moricambe Bay delta from 2011 showing a greater mud component to the nearest station from 2014.

The intertidal area of the middle of Moricambe Bay was not surveyed in 2011 due to time constraints and so direct comparison cannot be made.



5.1.3 Blitterlees Bank to Dubmill Point (South of Silloth)

A broadly comparable coverage to that of 2014 was achieved by the survey in 2011 (Cutts *et al*., 2011), with small areas also covered by the 2004 survey (Hemingway *et al*., 2006). However, importantly the 2014 survey was able to cover intertidal areas further to the west (to low water) and to the south (Dubmill Point).

Despite the reduced sediment sample coverage from 2014, there would appear to be broad correlation between the sediment conditions recorded from 2011 and 2014, or at least that those areas containing a mud fraction were seen to have one from both years. Similarly, where a gravel fraction was present, then this was recorded from both surveys, albeit perhaps in differing percentage values.

However, comparison between the assigned biotopes in 2014 to those from 2011 does show some variation. The majority of the intertidal area from the 2014 survey was classed as LS.LSa.FiSa.Po, and featured a fine firm sand with variable standing water, ripples, and sand waves. This very extensive habitat was consistently characterised by the presence of *Arenicola*, with a range of other polychaete species in variable presence/absence and abundance, but with the presence of any further characterising species largely absent.

The 2011 survey (Cutts *et al*., 2011) frequently recorded an assemblage that would fit the LS.LSa.FiSa.Po biotope requirements and a considerable area of the mid shore was designated as such. However, the taxonomic data for much of the area indicated a relatively impoverished community, such that the paucity of species meant that several biotopes could be ascribed. As such, a number of potential combination fit biotopes were recorded from the late winter 2011, which from a more suitable summer sampling in 2014, could be ascribed to a single biotope.

However, in the north of the survey area, it would appear that the LS.LSa.MoSa.AmSco / LS.LSa.MoSa.Ol.FS mobile sand biotopes were more stable in the 2014 survey, with much of the area shifting to a LS.LSa.FiSa.Po biotope, possibly reflecting a change in environmental conditions due to differing survey timing.

Similarly, the upper shore area north of Beckfoot assigned as LS.LSa.MoSa.Ol.FS (fronting the barren shingle and sand beach), was identified as a transition between LS.LSa.MuSa.MacAre and LS.LSa.MoSa.AmSco.Eur in 2014, the area fronted by MacAre.

Lowhagstock Scar was surveyed by Ecospan Environmental Ltd. for the 2014 rocky scar ground programme (Curtis, 2014), but surrounding this feature, an area of LS.LSa.FiSa.Po.Ncir was recorded (to the north and east) from the soft sediment survey. This is broadly consistent with the biotope mapping from 2011 (Cutts *et al*., 2011) which recorded an area of LS.LSa.FiSa.Po.Ncir to the east of Lowhagstock

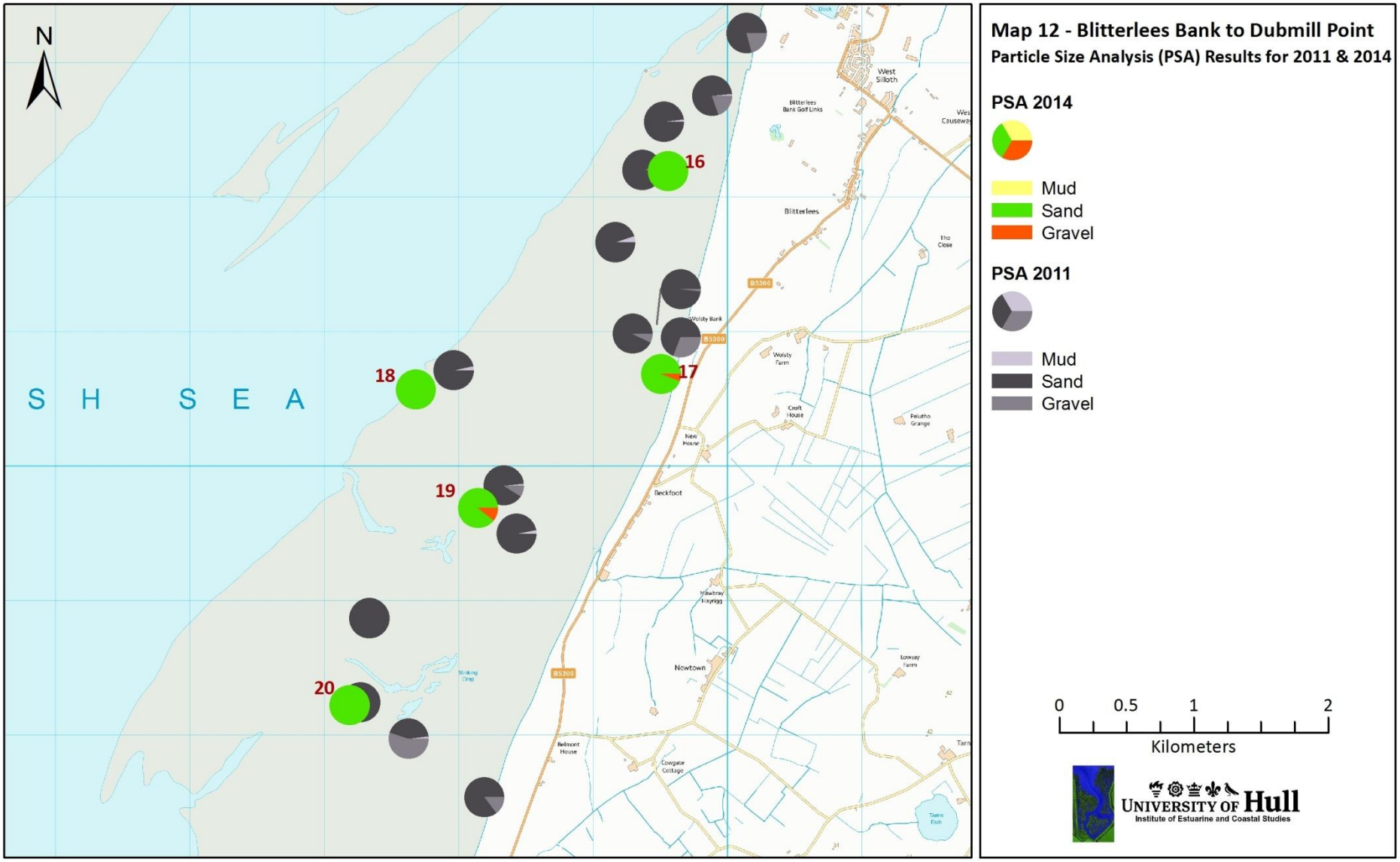
scar, together with a mix of LS.LSa.FiSa.Po.Ncir and LS.LSa.MoSa.AmSco to the north of the scar.

Between Lowhagstock Scar and the scar grounds of Dubmill Point the 2014 survey recorded a variable firm rippled sand with a range of polychaetes present in moderate to low abundance. As such, the area was mapped as a continuation of the LS.LSa.FiSa.Po biotope. This area was less extensively surveyed in 2011, but with the LS.LSa.FiSa.Po biotope present across the area, albeit given the paucity of fauna present from the samples, often identified as a potential mix with other similar mobile sand biotopes e.g. LS.LSa.MoSa.AmSco. However, both surveys recorded the LS.LSa.MoSa.AmSco biotope in the relatively high energy area immediately off Dubmill point, fronting the more steeply shelving beach of largely barren sand and shingle.

Map 12 shows the broad sediment composition from sample stations in the middle Solway from the 2011 and 2014 surveys. As with the other areas surveyed, sand is the dominant fraction of the sediment, but for the middle Solway gravel replaces mud as the other main fraction, with upper shore sites containing a substantial percentage gravel fraction.

In general, the broad landforms of the steeply shelving upper shore, extensive intertidal sand flats, sand waves, boulder fields and scars were comparable to those identified from the earlier survey programmes (2011 and limited coverage from 2004). However, it would appear that the 2014 sediment composition was more uniform than that of 2011, and more comparable to that of 2004, with fine sands tending to dominate. This may reflect survey timing, with the 2011 survey carried out in the late winter/early spring following a period of storms and hard weather.

Certainly during the assignation of biotopes following the 2011 survey (Cutts *et al.* 2011), there was difficulty in many locations, with an extremely sparse fauna recorded from the single replicate stations creating difficulty in accurately fitting the ecological data to a specific biotope. In many cases, a ‘best fit’ was required based on only a very small number of species and very low abundances, such that the biotope(s) decided on may have been either a ‘standard’ impoverished habitat reflecting normal environmental rigors or a ‘seasonally’ impoverished version of a more usually rich and diverse habitat.



5.2 Biogenic Reefs and Scar Grounds

As previously noted, the 2014 IECS survey programme undertaken for Natural England excluded the mapping of scar ground communities, these being mapped and reported under separate contract by Ecospan Environmental Ltd. (Curtis, 2014; Appendix 6). However, the broad findings of the scar ground survey are included in Section 4 (the Executive Summary from the Ecospan report), and within Maps 6-9 (Sections 3 and 4) which combine the soft and hard/mixed sediment biotopes mapped from both surveys. For the most part, the scar habitats recorded from the 2014 survey appear relatively consistent with those mapped (with reduced survey effort) from 2011, with communities largely based around ephemeral algae, fucoid algae, barnacle coverage and mussel beds, and with *Sabellaria* reefs also present.

However, notably from the 2014 Ecospan survey polygon data (Maps 8 & 9), it would appear that the low shore scar ground biogenic reef recorded as a mix of LS.LMx.LMus.Myt.Mx and LS.LBR.Sab.Salv by IECS in 2011 off Wolsty Bank (Cutts *et al*., 2011) has reduced in size in the 2014 survey with a large amount of the southern extent of this feature not showing as present on the Ecospan maps for 2014.

It would appear from analysis of maps from the two survey years that the *Sabellaria* reef which extended for *c*. 1.5km in the lower shore off from Wolsty Bank, has reduced in size to 500m in length in 2014. However, it should be noted that the habitat can be ephemeral in nature. The 2011 IECS survey (Cutts *et al*., 2011) recorded the habitat as a mix of *Mytilus* and *Sabellaria* reef with a potential extension of the reef area by several hundred metres to the south when compared to the 2004 data (Hemingway *et al*., 2006) for the area. However, the reef in 2011 was found to be in relatively poor condition, with the structures partially covered by sand and pseudo-faeces, and it is quite possible that this area of reef has subsequently become covered by sediment. This loss of *Sabellaria* has been observed by IECS in the past, with an extensive reef of large *Sabellaria* structures being recorded from a survey in 1994 off the north shore of the inner estuary (Cutts & Hemingway, 1996), but with no evidence of it when the area was resurveyed a few years later.

5.3 Anthropogenic Activities

The operation of the hovercraft platform was again noted as being relatively benign in relation to bird disturbance, although given the survey timing (summer), there were relatively few waterbird receptors present. The hovercraft was however noted as being able to operate at a distance of approximately 100m from a Cormorant roost in Moricambe Bay without disturbance, although no closer approach was made.

IECS in conjunction with the hovercraft operator, are continuing to collect data on disturbance levels to waterbirds from hovercraft operation, with a view to publishing the data when a suitably robust evidence base has been gathered. However, as with previous operations, the use of a hovercraft for such surveys across extensive intertidal areas is considered to be considerably less impacting in terms of waterbird disturbance responses than that of a traditional 'on foot' survey.

Evidence of bait digging was recorded in an *Arenicola* bed off the southern part of Wolsty Bank, with relatively large areas of sediment disturbed at three locations, each area of digging approximately 25m^2, with the sediment material mounded around the diggings.

Fixed Haaf net structures were observed on the north bank of the extreme inner estuary, but no recreational fishing was recorded. Similarly, whilst *Cerastoderma edule* were present in beds at a relatively low abundance, no evidence of their exploitation was noted, and the relatively low cockle abundances appeared to be natural.

There was no evidence of wildfowling, but this would be expected as the survey timing was outwith the wildfowling season.

Despite the timing of the surveys during the summer months, general recreational activity during the surveys appeared to be at a relatively low level and restricted to limited beach activity primarily in the area south of Silloth. No vehicular access was observed onto the intertidal areas.

6. Habitat Condition and Recommendations

6.1 Temporal Community Comparison

As described earlier in text, whilst both the 2011 (Cutts *et al*., 2011) and 2014 surveys used a hovercraft platform to survey the intertidal areas (and covered similar locations with expert eye and core sampling techniques used), there was considerable difference in methodological detail. In particular, the surveys were undertaken during different seasons (the 2011 survey in the late winter/early spring and the 2014 survey in mid-summer), with differences also in the positioning, number, and replication of cores (discussed further in Section 2).

As such, empirical comparison of core data between the two surveys is flawed, although we have attempted to undertake some basic statistical analyses on those 2011 and 2014 sample stations located relatively close to each other (e.g. within 1km). However, whilst this might be a reasonable sample station proximity in extensive intertidal flats, there still remains the potential for considerable substratum, and thus invertebrate assemblage, variation in some areas of the shore, e.g. where elevation is changing or where there is a mosaic of habitats present. As such, the following potential associations and/or dissimilarities between survey years should be treated with caution.

6.1.1 Old Graitney to Port Carlisle

The MDS plot for the invertebrate communities from the proximal stations from the 2014 and 2011 surveys are shown in Figure 1.

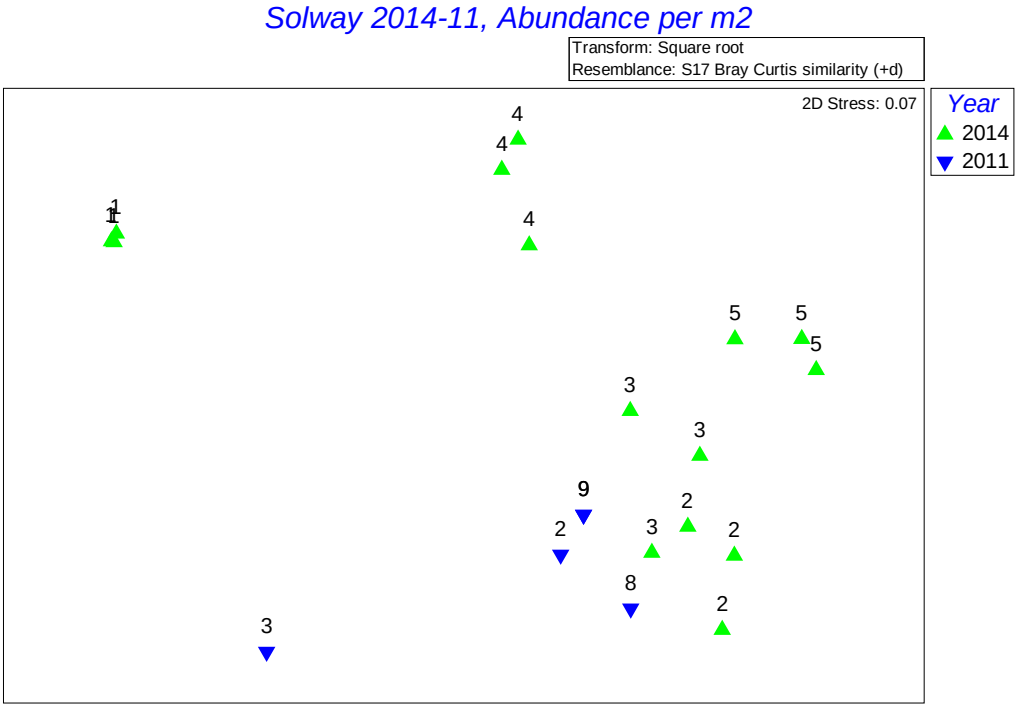


Figure 1: MDS Plot for the 2014 and 2011 Sample Stations.

The figure indicates that, as might be expected, there is considerable similarity between the three replicates from each of the 2014 stations, with Stations 2 and 3 also very similar and Station 1 relatively dissimilar. This would be expected as Station 1 was taken from the upper shore adjacent to Rockcliffe Marsh and featured a far greater mud component than the other 2014 stations from this area of the Solway, whilst Station 2 was at the extreme upper estuary and Station 3 approximately 5km downstream (both however in generally similar mid channel rippled sand areas).

Figure 1 also indicates that the greatest similarity between years was between Stations 2, 8 and 9 from 2011, and Stations 2 and 3 from 2014. Station 2 from both survey years was in a similar location, on the extensive rippled firm sand biotope adjacent to the river channel, whilst Station 9 from 2011 was located close to Station 3 from 2014 in a broadly similar habitat of mid shore extensive sand flat designated predominantly as LS.LSa.MuSa.BatCare. Station 8 from 2011, although several kilometres away from the location of Station 3 was in a broadly similar habitat. The dissimilarity between Station 3 from 2011 and Station 1 from 2014 (which are spatially adjacent) probably reflects the relatively large and rapid changes in habitat type and composition found in the upper sand flats close to Rockcliffe Marsh. Based on the above, whilst it would appear that there are some shifts in community, these may well be a result of inter-year samples being located in areas of relatively small habitat extent (and thus a potential for considerable variation over a short separation

distance), whilst there is a broadly similar correlation between years in the samples from the more extensive sand flat areas in the lower elevation areas.

6.1.2 Cardurnock Flatts and Moricambe Bay

As with the extreme inner Solway, there were few close spatial matches for sample stations between survey years, and a clear cluster of stations for each of the years evident from Figure 2. The less clustered nature of the replicates from stations 7, 12 and 15 of the 2014 programme is considered primarily an artefact of the very low abundances from the replicates, whereby the presence or absence of a species can considerably alter the analysis results.

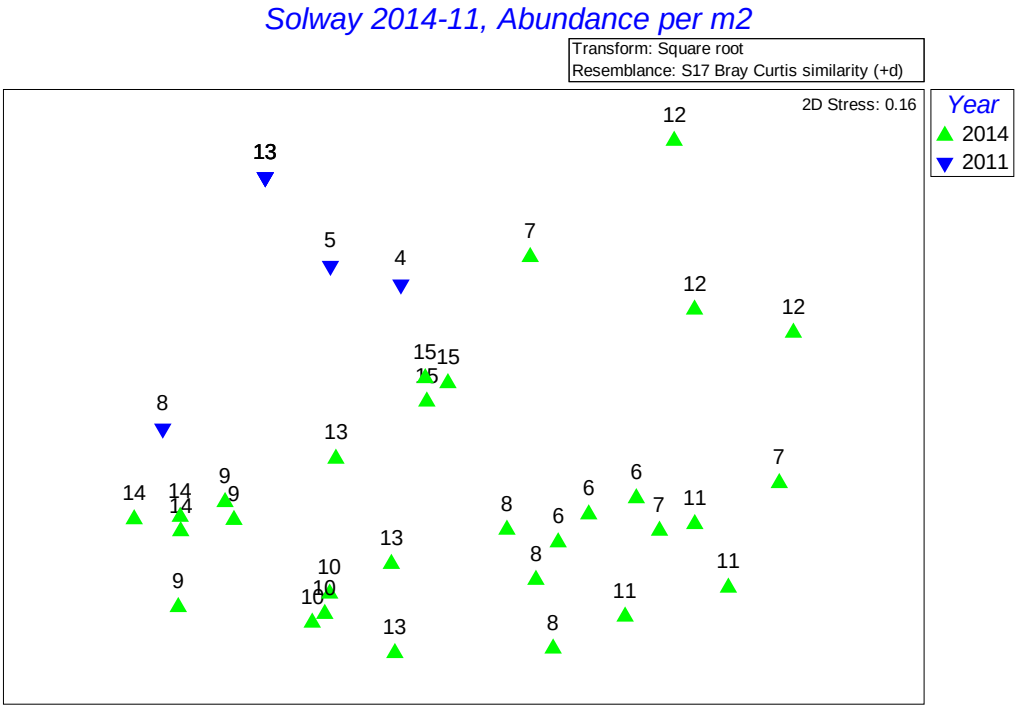


Figure 2: MDS Plot for the 2014 and 2011 Sample Stations.

Station 8 from 2011 does however match quite closely with Station 9 from 2014, these two stations being spatially close in the lower shore of the main flats. However, Station 8 from 2011 was also close on the MDS plot to Station 14 from 2014, which was located within Moricambe Bay. Station 4 from 2011 also correlates relatively closely with Station 15 from 2014, and these two stations are located in the 'delta' of the mouth of Moricambe Bay.

In general, there is a clear clustering of stations from each of the survey years. Given the detailed description of community status and extent in Section 3, there would not appear to be any substantial shift in high level biotopes between the two surveys, although with some modification in detail based on characterising species. Primarily, this variation is considered to be an artefact of survey timing and sample

location shifts rather than a significant change in the communities present in the area.

6.1.3 Blitterlees Bank to Dubmill Point (South of Silloth)

As with the survey areas described above (Sections 6.1.1 and 6.1.2), for the Blitterlees Bank to Dubmill Point sector, there was a limited spatial match in survey stations between years, and an evident clustering of stations from the MDS analysis between the two survey years (Figure 3).

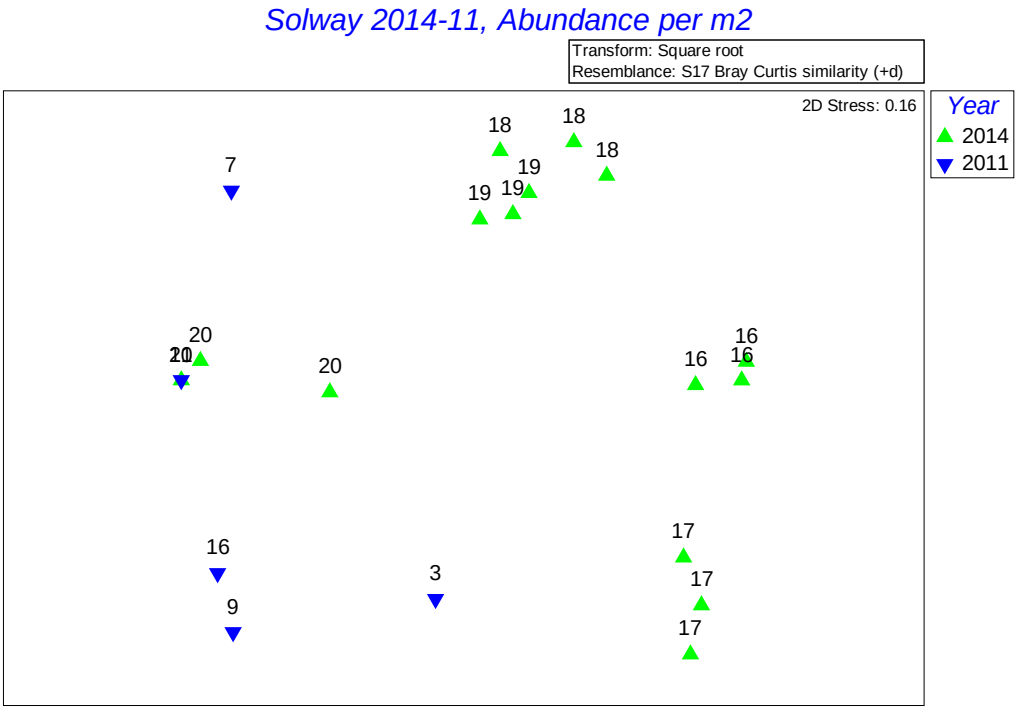


Figure 3: MDS Plot for the 2014 and 2011 Sample Stations.

However, a very close association was identified between Station 20 in 2014 and Station 11 in 2011, the location of these stations also being close in the mid shore to the north of Dubmill scar. These stations were both assigned the LS.LSa.FiSa.Po biotope which is characteristic of much of the soft sediment mid shore habitat in this survey area and the association is therefore of value in indicating that there is a general correlation in the extensive biotopes between survey years.

In general however, across the survey area as a whole there is a relatively clear differentiation in communities between the two survey years which may primarily be an artefact of survey timing, although with sample locations not matched during the methodology. As such, in some instances, the dissimilarities may reflect a clear variation in substratum where stations, although located within 1km of each other, may be in differing environmental conditions, e.g. as seen between the upper shore

muddy slack area and the more extensive firm rippled fine sands of the mid shore, which are separated by <100m.

6.2 Assessment of Condition

The 2014 survey recorded a broadly similar biotope assemblage to that of the 2011 programme (Cutts *et al*., 2011), and indeed, to the relevant findings from the 2004 programme (Hemingway *et al*., 2006). However, it should be noted that there were differences between all methodologies that will have introduced variability into the recording process. Perhaps of greatest relevance (given the apparent similar general methodologies), are the differences in survey timing between the 2011 (late winter) and 2014 (mid summer) hovercraft surveys.

A series of faunally depressed communities were recorded form the 2011 survey (Cutts *et al*., 2011), compared to the 2014 taxonomic data, this difference compounded by differing core sampling methods. The 2011 survey used a single replicate at a number of stations, in comparison to the 2014 programme which used 3 replicate cores at a smaller number of sample stations. However, despite these methodological differences, the biotope data for the three main survey areas were largely comparable, with the spatially dominant biotopes present from both surveys.

An empirical analysis of spatial extent is difficult to achieve, as in many cases it has been necessary to provide a 'best fit' across two or more biotopes depending on faunal character. In particular, it is emphasised that in 2011 a number of biotopes were suggested for some locations, based on very limited faunal assemblage data in the late winter. As such, direct comparison of their variation over time in terms of change in condition is considered potentially misleading.

Certainly, a higher level biotope assessment would suggest that there has been no significant change in condition within the surveyed areas between 2011 and 2014. The sandflats were seen to support an invertebrate community characteristic of moderately exposed inner to middle estuarine conditions, with a range of polychaete species present and *Arenicola* commonly recorded in densities greater than 10/m^2. *Macoma* was also regularly recorded within the Phase 2 cores, but with *Bathyporeia* the most abundant organism in most samples.

Sediment composition data from the 2014 and 2011 surveys (Section 5, Maps 10-12) were broadly consistent where stations were closely located. Similarly, 'in field' observations of a generally very fine to fine sand from the extreme inner and inner estuary survey areas, with a greater gravel component recorded for most sites south of Silloth in the middle estuary were consistent between surveys.

However, whilst the area south of Silloth was primarily recorded as consisting of fine sands from a partial survey of the area in 2004 (Hemingway *et al*., 2006), it was

observed to include a greater variability in 2011 ranging from very fine sand to very fine gravel. The 2014 survey, whilst featuring gravel in some locations was recorded as being more generally comprised of a fine sand. This may reflect the higher energy nature of this open coastal area, particularly with survey timing for the 2011 programme being in the late winter, and therefore probably featuring an increased storm effect at this time.

Although not part of the soft sediment survey programme, it was noted that between the 2004 and 2011 programmes, the biogenic reef area to the south of Lees Scar (consisting of cobble and fine sediment together with *Mytilus* and *Sabellaria*), had extended in extent to the south. However, the *Sabellaria* was observed to be in generally poor condition during 2011 and mapping data from the 2014 programme would indicate that there has been a reduction in the extent of this feature, with the southern half of the reef's extent now covered by sand. The ephemeral nature of this community is well documented and management needs to acknowledge that a range of natural processes can affect its status.

Table 10 summarises the intertidal soft sediment features, sub-features, measures and targets, and where data allow, an assessment of their target status is made in the comments column.

Table 10: Condition Assessment (adapted from Natural England & Scottish Natural Heritage, 2010).

Feature	Sub-feature	Attribute	Measure	Target	Comments for the 2014 survey
Mudflats and sandflats not covered by seawater at low tide		Extent	Area (ha.), measured periodically (frequency to be determined).	No decrease in extent from an established baseline (aerial photos 1997), subject to natural change	No observable change in extent recorded between 2011 and 2014 surveys. Whilst there is some variation in biotopes present (composition and coverage), some of these variations are considered artefacts of slight differences in survey methods rather than an indicator of condition change. Furthermore, not all areas of the feature could be surveyed (either from 2011 nor 2014) given timing and access constraints. However, based on a broad comparability in the extent of the coverage between the two areas that were surveyed (2011 & 2014) it is concluded that there is no measurable decrease in the extent of the feature and it is highly likely that the target has been met.
		Sediment character	1. Sediment grain size. Particle size analysis. Parameters include % sand/silt/gravel, mean and median grain size and sorting co-efficient, used to characterise sediment type.	Average sediment parameters should not deviate significantly from an established baseline (IECS, 1996), subject to natural change.	Soft sediment intertidal areas continued to be dominated by sands, with small mud and gravel fractions also present. As described in text, methodological variation will probably have led to small scale variations in sediment type (e.g. surveys conducted in the late winter/early spring vs the mid-summer together with variation in station locations). However, whilst there are some small variations in the sediment composition observable between stations located relatively adjacent to each other (2011 & 2014), the broad sediment parameters for each of the survey areas are very similar between the two survey years (and indeed to earlier surveys). As such, and within the context of available comparable data, it is concluded that this sediment character target has been met.

Table 10 *cont*.

Feature	Sub-feature	Attribute	Measure	Target	Comments for the 2014 survey
Mudflats and sandflats not covered by seawater at low tide		Sediment character	2. Sediment penetrability, degree of sinking.		Sediment conditions were very similar to those recorded from the 2011 survey, with the majority of intertidal flats consisting of a firm fine rippled sand. Slightly muddier areas were recorded in sheltered locations, as well as aerated soft sand in high energy areas. As identified above, direct comparability between stations from the two recent survey years has not been possible due to slight methodological variations. However, broad sediment characteristics between surveys are very similar and it can be concluded that the sediment penetrability target is met.
			3. Organic carbon. % organic carbon from sediment sample.	Average organic carbon content should not increase in relation to the baseline, subject to natural change.	Metrics for organic carbon were not provided with the sediment data for the 2014 programme. As such it is not possible to identify whether targets have been met.
			4. Redox potential.	Average black layer depth / Eh should not increase in relation to baseline, subject to natural change.	Anoxic layers were not regularly recorded from the coring process, with any anoxic discoloration generally ill defined. Severely anoxic sediments were not recorded and based on an albeit relatively sparse sample coverage, it is assumed the target is met given the absence of any extensive an clear anoxic layer from the samples.

Table 10 *cont*.

Feature	Sub-feature	Attribute	Measure	Target	Comments for the 2014 survey
Mudflats and sandflats not covered by seawater at low tide		Topography	Tidal elevation and shore slope measured in the summer months (frequency to be determined).	Tidal elevation and shore slope should not deviate significantly from an established baseline, subject to natural change.	Comparison in general elevation data was between a late winter 2011 survey (Cutts *et al*., 2011) and a mid-summer 2014 programme. However, sand flat topography was consistent between surveys, including the high shore sand banks adjacent to Rockcliffe Marsh and the sand wave features in the lower mid shore off Beckfoot. Based on the data collected, and subsequent analysis, it is concluded that there has been no significant alteration in elevation (subject to natural change context) and the target has been met. It is however noted that the extent of the *Sabellaria* reef appears to have reduced in size, perhaps indicating an increase in soft sediment cover in this location (see below).
		Nutrient Status - green algal mats	Area (ha.), measured annually.	No increase in extent from an established baseline, subject to natural change.	No algal mats were recorded from the survey, with small areas of sparse *Ulva* sp. recorded from the upper inner shore off Rockcliffe Marsh in both the 2011 (Cutts *et al*., 2011) and 2014 programmes. Elsewhere, the presence of *Ulva* was restricted to scar grounds and/or adjacent lag deposits. Based on this, the target for no increase in the extent of algal cover has been met.

Table 10 *cont*.

Feature	Sub-feature	Attribute	Measure	Target	Comments for the 2014 survey
Mudflats and sandflats not covered by seawater at low tide	Gravel and sand communities	Range of gravel and sand communities.	Range of littoral gravel and sand biotopes, measured once during reporting cycle.	Range of littoral gravel and sand biotopes should not deviate significantly from an established baseline (Cutts & Hemingway, 1996; Covey & Emblow, 1992), subject to natural change.	Gravel communities are largely restricted the upper shore of the Blitterlees to Dubmill Point, and feature an impoverished community. The location and extent of this habitat was consistent between surveys. Small areas of gravel are also present in the scar grounds, these surveyed and reported by Ecospan Environment Ltd. (Curtis, 2014). The majority of the areas surveyed in the 2014 programme were sand communities, with the fine sand component dominating the fraction. The extent of this sediment type was very similar to that seen from the 2011 survey (Cutts *et al*., 2011), with size fractions and invertebrate assemblages also largely comparable when methodological variations are taken into account. Based on the sample location and sediment comparison, it is concluded that in general, the range of biotopes has not substantially varied. However, this aspect was primarily covered by Ecospan Environment (see appended report) and they were not able to definitely comment on changes and target meeting due to the limited baseline data. It has been noted in the 2014 survey that that an area of *Sabellaria* reef on scar present in the 2011 survey was recorded as a sand community in 2014, the scar having apparently been covered by surficial soft sediment. However, such swamping events are known to occur in dynamic estuarine systems, and as such any change is effectively within natural variation. As such, it is likely that at a broad level, the target has been met.

Table 10 *cont*.

Feature	Sub-feature	Attribute	Measure	Target	Comments for the 2014 survey
Mudflats and sandflats not covered by seawater at low tide	Sandy mud communities	Range of biotopes.	Distribution of littoral sandy mud communities, measured once during reporting cycle.	Range of biotopes should not deviate significantly from an established baseline (Cutts & Hemingway, 1996; Covey & Emblow, 1992), subject to natural change.	Sandy mud habitats were generally not encountered during both the 2011 (Cutts *et al*., 2011) and 2014 surveys, although with muddy sand present in a number of lower energy locations from both surveys. It is concluded that on this basis the target has been met, given results between surveys are comparable.
		Characteristic biotope - extent of lugworms, Baltic tellins and soft-shelled clams in muddy sand.	Area (ha.), measured in the summer months, once during reporting cycle.	No decrease in extent from an established baseline (Covey & Emblow, 1992), subject to natural change.	A direct area comparison is not possible, given the 2011 survey (Cutts *et al*., 2011) was undertaken in late winter. However, the extent and general abundance of *Arenicola* and *Macoma* were broadly comparable. There may have been a reduction in the extent of the MacAre community between 2011 and 2014, but this is considered more an artefact of greater faunal diversity in 2014 than an actual change in the status of these two species. *Mya* was generally absent from both surveys. As such, whilst a detailed spatial comparison is not possible, a broad identification of key biotopes and close associations would suggest that there has been little change in composition or extent other than that which may be an artefact of slight methodological variations.

Table 10 *cont*.

Feature	Sub-feature	Attribute	Measure	Target	Comments for the 2014 survey
Mudflats and sandflats not covered by seawater at low tide	Sandy mud communities	Characteristic species - cockles *Cerastoderma edule*	Population size measure - age class/size structure, measured periodically (frequency to be determined).	Age class/size structure should not deviate significantly from an established baseline, subject to natural change.	The presence of *Cerastoderma edule* was recorded from both the 2011 (Cutts *et al*., 2011) and 2014 surveys, in generally the same location (on Cardurnock Flatts immediately north of the mouth of Moricambe Bay). Whilst the CerPo biotope was assigned on both surveys, the abundance of *Cerastoderma* was always considered to be relatively low and insufficient for the area to be considered a 'cockle bed'. No evidence of harvesting was noted from either survey in this area. Based on the data from the sample stations and taking into account slight methodological variations, it is concluded that there is no measurable variation in the status of *Cerastoderma* in the area. However, it is noted that given the differences in survey timing and sample station location, it cannot be concluded that age class/structure has not varied, as the data are not available to allow this.

6.3 Recommendations

The methods adopted within this study have enabled the aims and objectives set out by Natural England to be met as far as practicably possible. However, the differences in survey timing between the 2011 (Cutts *et al*., 2011) and 2014 programmes have meant that it has not been possible to draw definitive conclusions with regard to some of the condition attributes.

The timing of the survey in the mid summer for 2014 was considered to have a great benefit in maximising available survey time. However, it was again noted that in the extreme upper estuary, there is a very limited working period around spring tide periods, with a small tidal bore curtailing any working on a rising tide. There is little potential to avoid this feature, but it should be considered when calculating available survey hours.

Whilst the survey effort employed in 2014 allowed for the majority of the inner estuary to be covered and assessed, the logistical issues associated with hovercraft operation (e.g. suitable safe launch areas), together with morphological features in some areas means that to cover all of the area would require a number of additional survey days. For example, spatial coverage per day would reduce as some areas would be more difficult to reach and map (e.g. the upper reaches of Moricambe Bay).

However, it is considered that the current programme has provided a reasonable baseline from which future changes to the condition of the key attributes can be measured with a degree of empirical certainty.

The use of a hovercraft is essential to gain reasonable coverage across the key areas, and without the use of such a platform, the survey area would be substantially constrained, or survey effort substantially increased. Disturbance to waterbirds from hovercraft use was again considered to be low, and in the context of an alternative prolonged ‘on foot’ survey campaign, is considered to have net benefit in terms of disturbance impacts.

The two phase approach to the survey work was considered to be of value, but there are opportunities to enhance the potential for stronger statistical comparisons in future. There is a trade-off between the number of stations and the number of replicates in terms of overall survey cost, with increased replication considered of value if the same location is to be sampled during the next survey programme at the site. However, if the location of the survey stations is again determined on the basis of fully characterising a biotope, then replication could be reduced. Certainly, there is value from both approaches assuming that a finite number of samples can be taken based on a relatively fixed budget.

A three replicate approach with a small number of stations is of value to provide a greater potential for statistical power to assess community change, if the station is to be re-sampled during the next programme (or at least a sample location within a 10m radius of the original station). However, a single replicate approach, with a greater number of stations is of value to assist in the general assignation of biotopes and the identification of

their extent/transition, as it is not always possible to accurately define a biotope in the field when the presence or absence of a characterising species may only be determined by detailed taxonomic analysis.

This is an important decision, as the sampling approach will have an implication on the type of ecological data which is generated. Both approaches are essentially valid, but it depends what information Natural England wishes to attain from the survey.

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Appendices

Appendix 1: Phase 2 Sampling Station Numbers and Locations

WGS84 Decimal Degrees

Survey Area	Station Number	Date Taken	Latitude	Longitiude
Old Graitney to Port Carlisle	1	17/07/2014	54.96502961	-3.08229633
	2	17/07/2014	54.97594167	-3.07288256
	3	17/07/2014	54.94368726	-3.14036128
	4	17/07/2014	54.95264344	-3.12341626
	5	17/07/2014	54.94703018	-3.15368373
Cardurnock Flatts & Moricambe	6	17/07/2014	54.94288634	-3.31410444
	7	17/07/2014	54.95624949	-3.28779706
	8	17/07/2014	54.94062236	-3.32014098
	9	17/07/2014	54.92379894	-3.30012122
	10	17/07/2014	54.92640475	-3.31337613
	11	17/07/2014	54.92952509	-3.32970421
	12	17/07/2014	54.90738747	-3.32344139
	13	17/07/2014	54.90165534	-3.30455823
	14	17/07/2014	54.89606105	-3.30342367
	15	17/07/2014	54.90236107	-3.33071654
Blitterlees Bank to Dubmill Point	16	16/07/2014	54.85626652	-3.40906174
	17	16/07/2014	54.84269615	-3.40940503
	18	16/07/2014	54.84132732	-3.43776168
	19	16/07/2014	54.83350160	-3.43030215
	20	16/07/2014	54.82014166	-3.44467741

Appendix 2: Total Invertebrate Abundance & Dominant Taxa per Core Replicate

Site Description	Total Invertebrate Abundance	Dominant Taxa
Station 1 Rep 1	619	*Corophium volutator*
Station 1 Rep 2	584	*Corophium volutator*
Station 1 Rep 3	666	*Corophium volutator*
Station 2 Rep 1	31	*Bathyporeia pilosa*
Station 2 Rep 2	12	*Bathyporeia pilosa*
Station 2 Rep 3	13	*Bathyporeia pilosa*
Station 3 Rep 1	43	*Bathyporeia pilosa*
Station 3 Rep 2	42	*Bathyporeia pilosa*
Station 3 Rep 3	25	*Bathyporeia pilosa*
Station 4 Rep 1	218	*Bathyporeia pilosa*
Station 4 Rep 2	518	*Bathyporeia pilosa*
Station 4 Rep 3	415	*Bathyporeia pilosa*
Station 5 Rep 1	75	*Bathyporeia pilosa*
Station 5 Rep 2	94	*Bathyporeia pilosa*
Station 5 Rep 3	76	*Bathyporeia pilosa*
Station 6 Rep 1	36	*Peringia ulvae*
Station 6 Rep 2	27	*Peringia ulvae*
Station 6 Rep 3	25	*Capitella*
Station 7 Rep 1	12	*Paraonis fulgens* /*Capitella*
Station 7 Rep 2	11	NEMERTEA
Station 7 Rep 3	14	*Capitella* /*Peringia ulvae* /*Pygospio elegans*
Station 8 Rep 1	58	*Peringia ulvae*
Station 8 Rep 2	54	*Peringia ulvae*
Station 8 Rep 3	68	*Peringia ulvae*
Station 9 Rep 1	200	*Corophium arenarium*
Station 9 Rep 2	127	*Corophium arenarium*
Station 9 Rep 3	140	*Corophium arenarium*
Station 10 Rep 1	212	NEMATODA
Station 10 Rep 2	187	*Peringia ulvae*
Station 10 Rep 3	151	NEMATODA
Station 11 Rep 1	15	*Capitella*
Station 11 Rep 2	16	*Macoma balthica* /*Capitella*
Station 11 Rep 3	28	*Peringia ulvae*
Station 12 Rep 1	5	*Nephtys* juv
Station 12 Rep 2	6	*Peringia ulvae*
Station 12 Rep 3	4	*Peringia ulvae*
Station 13 Rep 1	124	*Peringia ulvae*
Station 13 Rep 2	154	*Peringia ulvae*
Station 13 Rep 3	57	*Peringia ulvae*
Station 14 Rep 1	552	*Bathyporeia pilosa*
Station 14 Rep 2	698	*Bathyporeia pilosa*
Station 14 Rep 3	589	*Bathyporeia pilosa*
Station 15 Rep 1	27	*Peringia ulvae*
Station 15 Rep 2	28	*Peringia ulvae*
Station 15 Rep 3	25	*Bathyporeia pilosa*
Station 16 Rep 1	70	*Peringia ulvae*
Station 16 Rep 2	65	*Pygospio elegans* /*Peringia ulvae*
Station 16 Rep 3	114	*Peringia ulvae*
Station 17 Rep 1	106	*Bathyporeia pilosa*
Station 17 Rep 2	156	*Bathyporeia pilosa*
Station 17 Rep 3	111	*Bathyporeia pilosa*
Station 18 Rep 1	10	*Scoloplos armiger*
Station 18 Rep 2	21	*Nephtys* juv
Station 18 Rep 3	18	*Nephtys* juv
Station 19 Rep 1	14	*Nephtys* juv
Station 19 Rep 2	19	*Pygospio elegans*
Station 19 Rep 3	13	*Pygospio elegans*
Station 20 Rep 1	2	*Bathyporeia pilosa* /*Bathyporeia pelagica*
Station 20 Rep 2	4	*Bathyporeia pelagica*
Station 20 Rep 3	1	*Bathyporeia pelagica*

Appendix 3: Species Abundance (raw data per core replicate & per m^2)

Species Abundance*: Old Graitney to Port Carlisle (Stations 1-5)

Raw Data: Individuals per core replicate	Estuary:	**Solway Firth**															
	Area:	Old Graitney to Port Carlisle															
	Sample Date:	17/07/2014															
			Station 1			**Station 2**			**Station 3**			**Station 4**			**Station 5**		
			Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
Code	**Taxa ID**	**Qualifiers**															
-	ANIMALIA	eggs															
D0491	*Campanulariidae*																
F0120	*Dalyelliidae*												5	4			
G0001	NEMERTEA																
HD0001	NEMATODA		104	82	113					1	1	17	19	30			
P0118	*Eteone longa*	aggregate										8	5	2	2	1	4
P0265	*Glycera tridactyla*																
P0462	*Hediste diversicolor*		23	20	39							1		1			
P0494	*Nephtys*	juvenile											1		2		1
P0498	*Nephtys cirrosa*																
P0672	*Scoloplos armiger*																
P0677	*Aricidea minuta*																
P0704	*Paraonis fulgens*														1		
P0776	*Pygospio elegans*		11	13	11					1		3	106	102			
P0791	*Spio martinensis*																
P0794	*Spiophanes bombyx*																
P0807	*Magelona johnstoni*																
P0863	*Psammodrilus balanoglossoides*																
P0906	*Capitella*								1	1					9	8	19
P0931	*Arenicola marina*																
P1107	*Lagis koreni*																
P1294	*Manayunkia aestuarina*		1	1	1												
P1501	*Enchytraeidae*		58	21	21												
R0142	COPEPODA									1							
S0456	*Bathyporeia pelagica*																
S0457	*Bathyporeia pilosa*					27	11	9	34	31	22	127	237	182	55	81	51
S0458	*Bathyporeia sarsi*																
S0462	*Haustorius arenarius*														4		
S0609	*Corophium arenarium*					2		2	2	4	1	30	96	74			
S0616	*Corophium volutator*		407	437	467	1											
S0854	*Eurydice pulchra*																
S1188	*Cumopsis goodsir*																
S1385	*Crangon crangon*											1		1			
S1577	*Liocarcinus*	juvenile															
S1595	*Carcinus maenas*	juvenile			1												
W0385	*Peringia ulvae*		7	4	10			1	5	3		7	13	4		1	
W1695	*Mytilus edulis*	juvenile															
W1961	*Cerastoderma edule*																
W1961	*Cerastoderma edule*	juvenile										2		1			
W2029	*Macoma balthica*		8	6	3	1	1	1	1		1	22	35	14	2	3	1
W2149	*Mya arenaria*	juvenile											1				
Y0172	*Conopeum reticulum*																

* Species analysis of core samples undertaken by APEM Ltd.

Abundance per m^2	Estuary:	**Solway Firth**																
	Area:	Old Graitney to Port Carlisle																
	Sample Date:	17/07/2014																
			Station 1			**Station 2**			**Station 3**			**Station 4**			**Station 5**		
			Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
Code	**Taxa ID**	**Qualifiers**																
-	ANIMALIA	eggs																
D0491	*Campanulariidae*																	
F0120	*Dalyelliidae*												500	400				
G0001	NEMERTEA																	
HD0001	NEMATODA		10400	8200	11300					100	100	1700	1900	3000				
P0118	*Eteone longa*	aggregate										800	500	200	200	100	400	
P0265	*Glycera tridactyla*																	
P0462	*Hediste diversicolor*		2300	2000	3900							100		100				
P0494	*Nephtys*	juvenile											100		200		100	
P0498	*Nephtys cirrosa*																	
P0672	*Scoloplos armiger*																	
P0677	*Aricidea minuta*																	
P0704	*Paraonis fulgens*														100			
P0776	*Pygospio elegans*		1100	1300	1100					100		300	10600	10200				
P0791	*Spio martinensis*																	
P0794	*Spiophanes bombyx*																	
P0807	*Magelona johnstoni*																	
P0863	*Psammodrilus balanoglossoides*																	
P0906	*Capitella*								100	100					900	800	1900	
P0931	*Arenicola marina*																	
P1107	*Lagis koreni*																	
P1294	*Manayunkia aestuarina*		100	100	100													
P1501	*Enchytraeidae*		5800	2100	2100													
R0142	COPEPODA									100								
S0456	*Bathyporeia pelagica*																	
S0457	*Bathyporeia pilosa*					2700	1100	900	3400	3100	2200	12700	23700	18200	5500	8100	5100	
S0458	*Bathyporeia sarsi*																	
S0462	*Haustorius arenarius*														400			
S0609	*Corophium arenarium*					200		200	200	400	100	3000	9600	7400				
S0616	*Corophium volutator*		40700	43700	46700	100												
S0854	*Eurydice pulchra*																	
S1188	*Cumopsis goodsir*																	
S1385	*Crangon crangon*											100		100				
S1577	*Liocarcinus*	juvenile																
S1595	*Carcinus maenas*	juvenile			100													
W0385	*Peringia ulvae*		700	400	1000			100	500	300		700	1300	400		100		
W1695	*Mytilus edulis*	juvenile																
W1961	*Cerastoderma edule*																	
W1961	*Cerastoderma edule*	juvenile										200		100				
W2029	*Macoma balthica*		800	600	300	100	100	100	100		100	2200	3500	1400	200	300	100	
W2149	*Mya arenaria*	juvenile											100					
Y0172	*Conopeum reticulum*																	

* Species analysis of core samples undertaken by APEM Ltd.

Species Abundance*: Cardurnock Flatts & Moricambe (Stations 6-15)

Raw Data: Individuals per core replicate	Estuary:	**Solway Firth**
	Area:	Cardurnock Flatts & Moricambe
	Sample Date:	16/07/2014

			Station 6			Station 7			Station 8			Station 9			Station 10		
			Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
Code	**Taxa ID**	**Qualifiers**															
-	ANIMALIA	eggs		P													
D0491	*Campanulariidae*									P	P						
F0120	*Dalyelliidae*												1				
G0001	NEMERTEA						2								1		1
HD0001	NEMATODA		2				1		1		1	47	21	20	93	49	64
P0118	*Eteone longa*	aggregate		1		1	1	1							3	6	1
P0265	*Glycera tridactyla*																
P0462	*Hediste diversicolor*											3	3	3			
P0494	*Nephtys*	juvenile		1				1		3	4						
P0498	*Nephtys cirrosa*					1					1						
P0672	*Scoloplos armiger*																
P0677	*Aricidea minuta*																
P0704	*Paraonis fulgens*		1		1	3	1				1						
P0776	*Pygospio elegans*			1	3		1	3		1		10	4	8	10	9	23
P0791	*Spio martinensis*		4		1	1					4						
P0794	*Spiophanes bombyx*			2	2	1	1	1	1		2						
P0807	*Magelona johnstoni*			1													
P0863	*Psammodrilus balanoglossoides*																
P0906	*Capitella*		10	5	8	3	1	3	17	9	10						
P0931	*Arenicola marina*																
P1107	*Lagis koreni*																
P1294	*Manayunkia aestuarina*											8	4	1			
P1501	*Enchytraeidae*																
R0142	COPEPODA				1			1			1					1	
S0456	*Bathyporeia pelagica*		2	3	5				1	1	1						
S0457	*Bathyporeia pilosa*			1	1		1		1		2		1	3		2	
S0458	*Bathyporeia sarsi*																
S0462	*Haustorius arenarius*								1								
S0609	*Corophium arenarium*						1					121	79	82	1	1	
S0616	*Corophium volutator*										3	2		2			
S0854	*Eurydice pulchra*																
S1188	*Cumopsis goodsir*																
S1385	*Crangon crangon*						1								2		
S1577	*Liocarcinus*	juvenile															
S1595	*Carcinus maenas*	juvenile															
W0385	*Peringia ulvae*		16	11	2	2		3	31	38	37	9	14	20	81	98	43
W1695	*Mytilus edulis*	juvenile								1				1		1	
W1961	*Cerastoderma edule*														1		2
W1961	*Cerastoderma edule*	juvenile							1		1				8	11	8
W2029	*Macoma balthica*		1	1	1			1	4						12	7	7
W2149	*Mya arenaria*	juvenile								1						2	2
Y0172	*Conopeum reticulum*																

* Species analysis of core samples undertaken by APEM Ltd.

Abundance per m^2	Estuary:	**Solway Firth**															
	Area:	Cardurnock Flatts & Moricambe															
	Sample Date:	16/07/2014															
			Station 6			**Station 7**			**Station 8**			**Station 9**			**Station 10**		
			Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
Code	**Taxa ID**	**Qualifiers**															
-	ANIMALIA	eggs		P													
D0491	*Campanulariidae*									P	P						
F0120	*Dalyelliidae*												100				
G0001	NEMERTEA						200								100		100
HD0001	NEMATODA		200				100		100		100	4700	2100	2000	9300	4900	6400
P0118	*Eteone longa*	aggregate		100		100	100	100							300	600	100
P0265	*Glycera tridactyla*																
P0462	*Hediste diversicolor*											300	300	300			
P0494	*Nephtys*	juvenile		100				100		300	400						
P0498	*Nephtys cirrosa*					100					100						
P0672	*Scoloplos armiger*																
P0677	*Aricidea minuta*																
P0704	*Paraonis fulgens*		100		100	300	100				100						
P0776	*Pygospio elegans*			100	300		100	300		100		1000	400	800	1000	900	2300
P0791	*Spio martinensis*		400		100	100					400						
P0794	*Spiophanes bombyx*			200	200	100	100	100	100		200						
P0807	*Magelona johnstoni*			100													
P0863	*Psammodrilus balanoglossoides*																
P0906	*Capitella*		1000	500	800	300	100	300	1700	900	1000						
P0931	*Arenicola marina*																
P1107	*Lagis koreni*																
P1294	*Manayunkia aestuarina*											800	400	100			
P1501	*Enchytraeidae*																
R0142	COPEPODA				100			100			100					100	
S0456	*Bathyporeia pelagica*		200	300	500				100	100	100						
S0457	*Bathyporeia pilosa*			100	100		100		100		200		100	300		200	
S0458	*Bathyporeia sarsi*																
S0462	*Haustorius arenarius*								100								
S0609	*Corophium arenarium*						100					12100	7900	8200	100	100	
S0616	*Corophium volutator*										300	200		200			
S0854	*Eurydice pulchra*																
S1188	*Cumopsis goodsir*																
S1385	*Crangon crangon*						100								200		
S1577	*Liocarcinus*	juvenile															
S1595	*Carcinus maenas*	juvenile															
W0385	*Peringia ulvae*		1600	1100	200	200		300	3100	3800	3700	900	1400	2000	8100	9800	4300
W1695	*Mytilus edulis*	juvenile								100				100		100	
W1961	*Cerastoderma edule*														100		200
W1961	*Cerastoderma edule*	juvenile							100		100				800	1100	800
W2029	*Macoma balthica*		100	100	100			100	400						1200	700	700
W2149	*Mya arenaria*	juvenile								100						200	200
Y0172	*Conopeum reticulum*																

* Species analysis of core samples undertaken by APEM Ltd.

Raw Data: Individuals per core replicate	Estuary:	**Solway Firth**															
	Area:	Cardurnock Flatts & Moricambe															
	Sample Date:	16/07/2014															
			Station 11			**Station 12**			**Station 13**			**Station 14**			**Station 15**		
			Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
Code	**Taxa ID**	**Qualifiers**															
-	ANIMALIA	eggs															
D0491	*Campanulariidae*		P		P												
F0120	*Dalyelliidae*								1		1	8	10	1			
G0001	NEMERTEA							1							1	3	
HD0001	NEMATODA								3	2	7	68	141	98	4	1	2
P0118	*Eteone longa*	aggregate		1											1		
P0265	*Glycera tridactyla*		1										1			1	1
P0462	*Hediste diversicolor*								1			1		1			
P0494	*Nephtys*	juvenile	3	3	4	2											1
P0498	*Nephtys cirrosa*																
P0672	*Scoloplos armiger*																
P0677	*Aricidea minuta*																
P0704	*Paraonis fulgens*			1											1		
P0776	*Pygospio elegans*		2						7	2	4	31	9	17		1	
P0791	*Spio martinensis*			1	6												
P0794	*Spiophanes bombyx*		1														
P0807	*Magelona johnstoni*																
P0863	*Psammodrilus balanoglossoides*																
P0906	*Capitella*		4	4	4	1			3								
P0931	*Arenicola marina*								1								
P1107	*Lagis koreni*																
P1294	*Manayunkia aestuarina*																
P1501	*Enchytraeidae*											2	1	1			
R0142	COPEPODA															3	
S0456	*Bathyporeia pelagica*		1				1								1		
S0457	*Bathyporeia pilosa*					1			4		15	302	363	322	6	5	10
S0458	*Bathyporeia sarsi*										1						
S0462	*Haustorius arenarius*		1				2										
S0609	*Corophium arenarium*			1							3	101	150	114			
S0616	*Corophium volutator*																
S0854	*Eurydice pulchra*							1									
S1188	*Cumopsis goodsir*																
S1385	*Crangon crangon*								1		1						
S1577	*Liocarcinus*	juvenile															
S1595	*Carcinus maenas*	juvenile															
W0385	*Peringia ulvae*			1	10	1	3	2	92	142	20	33	23	30	9	12	6
W1695	*Mytilus edulis*	juvenile			2				1	1		1					
W1961	*Cerastoderma edule*																
W1961	*Cerastoderma edule*	juvenile							8	4	3						1
W2029	*Macoma balthica*		2	4	2				2	3	2	5		5	4	2	4
W2149	*Mya arenaria*	juvenile															
Y0172	*Conopeum reticulum*																

* Species analysis of core samples undertaken by APEM Ltd.

Abundance per m^2	Estuary:	**Solway Firth**																
	Area:	Cardurnock Flatts & Moricambe																
	Sample Date:	16/07/2014																
			Station 11			**Station 12**			**Station 13**			**Station 14**			**Station 15**			
			Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
Code	**Taxa ID**	**Qualifiers**																
-	ANIMALIA	eggs																
D0491	*Campanulariidae*		P		P													
F0120	*Dalyelliidae*								100		100	800	1000	100				
G0001	NEMERTEA							100							100	300		
HD0001	NEMATODA								300	200	700	6800	14100	9800	400	100	200	
P0118	*Eteone longa*	aggregate		100											100			
P0265	*Glycera tridactyla*		100										100			100	100	
P0462	*Hediste diversicolor*								100			100		100				
P0494	*Nephtys*	juvenile	300	300	400	200											100	
P0498	*Nephtys cirrosa*																	
P0672	*Scoloplos armiger*																	
P0677	*Aricidea minuta*																	
P0704	*Paraonis fulgens*			100											100			
P0776	*Pygospio elegans*		200						700	200	400	3100	900	1700		100		
P0791	*Spio martinensis*			100	600													
P0794	*Spiophanes bombyx*		100															
P0807	*Magelona johnstoni*																	
P0863	*Psammodrilus balanoglossoides*																	
P0906	*Capitella*		400	400	400	100			300									
P0931	*Arenicola marina*								100									
P1107	*Lagis koreni*																	
P1294	*Manayunkia aestuarina*																	
P1501	*Enchytraeidae*											200	100	100				
R0142	COPEPODA															300		
S0456	*Bathyporeia pelagica*		100				100								100			
S0457	*Bathyporeia pilosa*					100			400		1500	30200	36300	32200	600	500	1000	
S0458	*Bathyporeia sarsi*										100							
S0462	*Haustorius arenarius*		100				200											
S0609	*Corophium arenarium*			100							300	10100	15000	11400				
S0616	*Corophium volutator*																	
S0854	*Eurydice pulchra*							100										
S1188	*Cumopsis goodsir*																	
S1385	*Crangon crangon*								100		100							
S1577	*Liocarcinus*	juvenile																
S1595	*Carcinus maenas*	juvenile																
W0385	*Peringia ulvae*			100	1000	100	300	200	9200	14200	2000	3300	2300	3000	900	1200	600	
W1695	*Mytilus edulis*	juvenile			200				100	100		100						
W1961	*Cerastoderma edule*																	
W1961	*Cerastoderma edule*	juvenile							800	400	300						100	
W2029	*Macoma balthica*		200	400	200				200	300	200	500		500	400	200	400	
W2149	*Mya arenaria*	juvenile																
Y0172	*Conopeum reticulum*																	

* Species analysis of core samples undertaken by APEM Ltd.

Species Abundance*: Blitterlees Bank to Dubmill Point (Stations 16-20)

Raw Data: Individuals per core replicate	Estuary:	Solway Firth
	Area:	Blitterlees Bank to Dubmill Point
	Sample Date:	16/07/2014

			Station 16			Station 17			Station 18			Station 19			Station 20		
			Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
Code	**Taxa ID**	**Qualifiers**															
-	ANIMALIA	eggs		P													
D0491	*Campanulariidae*																
F0120	*Dalyelliidae*																
G0001	NEMERTEA			1													
HD0001	NEMATODA		1		4	1				1	2						
P0118	*Eteone longa*	aggregate		1						1	2						
P0265	*Glycera tridactyla*																
P0462	*Hediste diversicolor*																
P0494	*Nephtys*	juvenile							1	6	8	6	4	1			
P0498	*Nephtys cirrosa*									1	1	1	1	1	Frag.		
P0672	*Scoloplos armiger*								3	2	2			2			
P0677	*Aricidea minuta*													1			
P0704	*Paraonis fulgens*																
P0776	*Pygospio elegans*		8	22	21			1	2	4		5	11	7			
P0791	*Spio martinensis*		2						1		1						
P0794	*Spiophanes bombyx*				1						1	1					
P0807	*Magelona johnstoni*																
P0863	*Psammodrilus balanoglossoides*		3		1												
P0906	*Capitella*								1	4	1		1				
P0931	*Arenicola marina*																
P1107	*Lagis koreni*								1								
P1294	*Manayunkia aestuarina*																
P1501	*Enchytraeidae*																
R0142	COPEPODA							1									
S0456	*Bathyporeia pelagica*												1		1	4	1
S0457	*Bathyporeia pilosa*		2			90	142	96							1		
S0458	*Bathyporeia sarsi*		16	16	1												
S0462	*Haustorius arenarius*																
S0609	*Corophium arenarium*		2				1										
S0616	*Corophium volutator*												1				
S0854	*Eurydice pulchra*					9	7	7									
S1188	*Cumopsis goodsir*									1							
S1385	*Crangon crangon*											1		1			
S1577	*Liocarcinus*	juvenile								1							
S1595	*Carcinus maenas*	juvenile															
W0385	*Peringia ulvae*		34	22	77	2	1	1									
W1695	*Mytilus edulis*	juvenile	1						1								
W1961	*Cerastoderma edule*				1												
W1961	*Cerastoderma edule*	juvenile		2	2		1										
W2029	*Macoma balthica*		1	1	6	4	4	5									
W2149	*Mya arenaria*	juvenile															
Y0172	*Conopeum reticulum*									P							

* Species analysis of core samples undertaken by APEM Ltd.

Abundance per m^2	Estuary:	**Solway Firth**															
	Area:	Blitterlees Bank to Dubmill Point															
	Sample Date:	16/07/2014															
			Station 16			**Station 17**			**Station 18**			**Station 19**			**Station 20**		
			Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
Code	**Taxa ID**	**Qualifiers**															
-	ANIMALIA	eggs		P													
D0491	*Campanulariidae*																
F0120	*Dalyelliidae*																
G0001	NEMERTEA			100													
HD0001	NEMATODA		100		400	100				100	200						
P0118	*Eteone longa*	aggregate		100						100	200						
P0265	*Glycera tridactyla*																
P0462	*Hediste diversicolor*																
P0494	*Nephtys*	juvenile							100	600	800	600	400	100			
P0498	*Nephtys cirrosa*									100	100	100	100	100	Frag.		
P0672	*Scoloplos armiger*								300	200	200			200			
P0677	*Aricidea minuta*													100			
P0704	*Paraonis fulgens*																
P0776	*Pygospio elegans*		800	2200	2100			100	200	400		500	1100	700			
P0791	*Spio martinensis*		200						100		100						
P0794	*Spiophanes bombyx*				100						100	100					
P0807	*Magelona johnstoni*																
P0863	*Psammodrilus balanoglossoides*		300		100												
P0906	*Capitella*								100	400	100		100				
P0931	*Arenicola marina*																
P1107	*Lagis koreni*								100								
P1294	*Manayunkia aestuarina*																
P1501	*Enchytraeidae*																
R0142	COPEPODA							100									
S0456	*Bathyporeia pelagica*												100		100	400	100
S0457	*Bathyporeia pilosa*		200			9000	14200	9600							100		
S0458	*Bathyporeia sarsi*		1600	1600	100												
S0462	*Haustorius arenarius*																
S0609	*Corophium arenarium*		200				100										
S0616	*Corophium volutator*												100				
S0854	*Eurydice pulchra*					900	700	700									
S1188	*Cumopsis goodsir*									100							
S1385	*Crangon crangon*											100		100			
S1577	*Liocarcinus*	juvenile								100							
S1595	*Carcinus maenas*	juvenile															
W0385	*Peringia ulvae*		3400	2200	7700	200	100	100									
W1695	*Mytilus edulis*	juvenile	100						100								
W1961	*Cerastoderma edule*				100												
W1961	*Cerastoderma edule*	juvenile		200	200		100										
W2029	*Macoma balthica*		100	100	600	400	400	500									
W2149	*Mya arenaria*	juvenile															
Y0172	*Conopeum reticulum*									P							

* Species analysis of core samples undertaken by APEM Ltd.

Appendix 4: PSA Summary Data

PSA Data (Stations 1-4)

	Analyte			Units	Station 1	Station 2	Station 3	Station 4
	Grain Size Inclusive Kurtosis			mm	0.255	0.51	0.511	0.51
	Grain Size Inclusive Mean			mm	0.064	0.111	0.119	0.113
	Inclusive Graphic Skewness :- {SKI}			Unitless	-0.371	0.0303	0.0192	0.0245
	Kurtosis			Unitless	1.97	0.972	0.968	0.973
	Particle Diameter : Mean			mm	0.718	1.2	1.34	0.122
	Particle Diameter : Median			mm	0.0685	0.111	0.119	0.113
	Sorting Coefficient			Unitless	1.16	0.53	0.565	0.537
Sorting Coefficient	Fraction	Additional	Component		Station 1	Station 2	Station 3	Station 4
< 0.98 microns : {>10 phi}	clay (>8phi)		Mud	%	0.59	0.00	0.00	0.00
0.98 to 1.38 microns : {10 to 9.5 phi}	clay (>8phi)		Mud	%	0.52	0.00	0.00	0.00
1.38 to 1.95 microns : {9.5 to 9 phi}	clay (>8phi)		Mud	%	0.63	0.00	0.00	0.00
1.95 to 2.76 microns : {9 to 8.5 phi}	clay (>8phi)		Mud	%	0.96	0.00	0.00	0.00
2.76 to 3.91 microns : {8.5 to 8 phi}	clay (>8phi)		Mud	%	1.42	0.00	0.00	0.00
3.91 to 5.52 microns : {8 to 7.5 phi}	silt (4 to 8 phi)	VF silt	Mud	%	1.58	0.00	0.00	0.00
5.52 to 7.81 microns : {7.5 to 7 phi}	silt (4 to 8 phi)	VF silt	Mud	%	1.90	0.00	0.00	0.00
7.81 to 11.1 microns : {7 to 6.5 phi}	silt (4 to 8 phi)	F silt	Mud	%	2.22	0.00	0.00	0.00
11.1 to 15.6 microns : {6.5 to 6 phi}	silt (4 to 8 phi)	F silt	Mud	%	1.82	0.00	0.00	0.00
15.6 to 22.1 microns : {6 to 5.5 phi}	silt (4 to 8 phi)	M silt	Mud	%	0.68	0.00	0.00	0.00
22.1 to 31.3 microns : {5.5 to 5 phi}	silt (4 to 8 phi)	M silt	Mud	%	1.11	0.00	0.00	0.00
31.3 to 44.2 microns : {5 to 4.5 phi}	silt (4 to 8 phi)	C silt	Mud	%	8.24	0.02	0.00	0.02
44.2 to 62.5 microns : {4.5 to 4 phi}	silt (4 to 8 phi)	C silt	Mud	%	20.90	3.77	3.20	3.71
		Total Mud Fraction		%	42.57	3.79	3.20	3.73
62.5 to 88.4 microns : {4 to 3.5 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	28.00	21.30	17.90	20.30
88.4 to 125 microns : {3.5 to 3 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	21.30	37.80	33.40	36.80
125 to 177 microns : {3 to 2.5 phi}	sand (-1 to 4 phi)	F sand	Sand	%	7.65	28.30	29.90	29.20
177 to 250 microns : {2.5 to 2 phi}	sand (-1 to 4 phi)	F sand	Sand	%	0.49	8.37	13.10	9.41
250 to 354 microns : {2 to 1.5 phi}	sand (-1 to 4 phi)	M sand	Sand	%	0.00	0.46	2.00	0.59
354 to 500 microns : {1.5 to 1 phi}	sand (-1 to 4 phi)	M sand	Sand	%	0.00	0.00	0.02	0.00
500 to 707 microns : {1 to 0.5 phi}	sand (-1 to 4 phi)	C sand	Sand	%	0.00	0.00	0.21	0.00
707 to 1000 microns : {0.5 to 0 phi}	sand (-1 to 4 phi)	C sand	Sand	%	0.00	0.00	0.28	0.00
1000 to 1400 mic : {0 to -0.5phi}	sand (-1 to 4 phi)	VC sand	Sand	%	0.00	0.00	0.00	0.00
1400 to 2000 mic : {-0.5 to -1.0phi}	sand (-1 to 4 phi)	VC sand	Sand	%	0.00	0.00	0.00	0.00
		Total Sand Fraction		%	57.44	96.23	96.81	96.30
2000 to 2800 mic : {-1.0 to -1.5phi}	gravel (-1 to -8 phi)	granules	Gravel	%	0.00	0.00	0.00	0.00
2800 to 4000 mic : {-1.5 to -2.0phi}	gravel (-1 to -8 phi)	granules	Gravel	%	0.00	0.00	0.00	0.00
4000 to 5600 mic : {-2.0 to -2.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
5600 to 8000 mic : {-2.5 to -3.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
8000 to 11200 mic : {-3.0 to -3.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
11200 to 16000 mic : {-3.5 to -4.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
16000 to 22400 mic : {-4.0 to -4.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
22400 to 31500 mic : {-4.5 to -5.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
31500 to 45000 mic : {-5.0 to -5.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
45000 to 63000 mic : {-5.5 to -6.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
> 63000 microns : {< -6.0 phi}	gravel (-1 to -8 phi)	cobble	Gravel	%	0.00	0.00	0.00	0.00
	Total Gravel Fraction			%	0.00	0.00	0.00	0.00
	Mud, Sand & Gravel			%	100	100	100	100
	Mud & Sand Fractions (>0 phi)			%	100	100	100	100
	Coarse Sand & Gravel (<0 phi)			%	0	0	0	0
	Summary				Station 1	Station 2	Station 3	Station 4
	Total Mud Fraction			%	42.6	3.8	3.2	3.7
	Total Sand Fraction			%	57.4	96.2	96.8	96.3
	Total Gravel Fraction			%	0.0	0.0	0.0	0.0
	Description				SM	FS	FS	FS

* PSA analysis undertaken by the Environment Agency National Laboratory Service. The information included above has been taken from the NLS report and re-ordered by IECS into increasing grain size fraction. Percentage composition of mud, sand & gravel fractions have also been additionally calculated for ease of interpretation.

PSA Data (Stations 5-8)

	Analyte			Units	Station 5	Station 6	Station 7	Station 8
	Grain Size Inclusive Kurtosis			mm	0.539	0.512	0.512	0.51
	Grain Size Inclusive Mean			mm	0.149	0.162	0.179	0.163
	Inclusive Graphic Skewness :- {SKI}			Unitless	0.0119	0.0173	0.0405	0.0162
	Kurtosis			Unitless	0.891	0.967	0.966	0.971
	Particle Diameter : Mean			mm	1.6	0.177	2.06	1.79
	Particle Diameter : Median			mm	0.149	0.163	0.177	0.164
	Sorting Coefficient			Unitless	0.502	0.552	0.626	0.547
Sorting Coefficient	Fraction	Additional	Component		Station 5	Station 6	Station 7	Station 8
< 0.98 microns : {>10 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
0.98 to 1.38 microns : {10 to 9.5 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
1.38 to 1.95 microns : {9.5 to 9 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
1.95 to 2.76 microns : {9 to 8.5 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
2.76 to 3.91 microns : {8.5 to 8 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
3.91 to 5.52 microns : {8 to 7.5 phi}	silt (4 to 8 phi)	VF silt	Mud	%	0.00	0.00	0.00	0.00
5.52 to 7.81 microns : {7.5 to 7 phi}	silt (4 to 8 phi)	VF silt	Mud	%	0.00	0.00	0.00	0.00
7.81 to 11.1 microns : {7 to 6.5 phi}	silt (4 to 8 phi)	F silt	Mud	%	0.00	0.00	0.00	0.00
11.1 to 15.6 microns : {6.5 to 6 phi}	silt (4 to 8 phi)	F silt	Mud	%	0.00	0.00	0.00	0.00
15.6 to 22.1 microns : {6 to 5.5 phi}	silt (4 to 8 phi)	M silt	Mud	%	0.00	0.00	0.00	0.00
22.1 to 31.3 microns : {5.5 to 5 phi}	silt (4 to 8 phi)	M silt	Mud	%	0.00	0.00	0.00	0.00
31.3 to 44.2 microns : {5 to 4.5 phi}	silt (4 to 8 phi)	C silt	Mud	%	0.00	0.00	0.00	0.00
44.2 to 62.5 microns : {4.5 to 4 phi}	silt (4 to 8 phi)	C silt	Mud	%	0.08	0.07	0.07	0.05
		Total Mud Fraction		**%**	**0.08**	**0.07**	**0.07**	**0.05**
62.5 to 88.4 microns : {4 to 3.5 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	4.93	3.82	3.40	3.47
88.4 to 125 microns : {3.5 to 3 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	25.00	19.50	16.40	19.00
125 to 177 microns : {3 to 2.5 phi}	sand (-1 to 4 phi)	F sand	Sand	%	39.50	35.10	30.00	35.40
177 to 250 microns : {2.5 to 2 phi}	sand (-1 to 4 phi)	F sand	Sand	%	25.00	29.40	28.70	29.90
250 to 354 microns : {2 to 1.5 phi}	sand (-1 to 4 phi)	M sand	Sand	%	5.40	11.20	16.00	11.30
354 to 500 microns : {1.5 to 1 phi}	sand (-1 to 4 phi)	M sand	Sand	%	0.07	0.90	4.29	0.83
500 to 707 microns : {1 to 0.5 phi}	sand (-1 to 4 phi)	C sand	Sand	%	0.00	0.00	0.58	0.00
707 to 1000 microns : {0.5 to 0 phi}	sand (-1 to 4 phi)	C sand	Sand	%	0.00	0.00	0.40	0.00
1000 to 1400 mic : {0 to -0.5phi}	sand (-1 to 4 phi)	VC sand	Sand	%	0.00	0.00	0.04	0.03
1400 to 2000 mic : {-0.5 to -1.0phi}	sand (-1 to 4 phi)	VC sand	Sand	%	0.00	0.00	0.04	0.02
		Total Sand Fraction		**%**	**99.90**	**99.92**	**99.86**	**99.95**
2000 to 2800 mic : {-1.0 to -1.5phi}	gravel (-1 to -8 phi)	granules	Gravel	%	0.00	0.00	0.02	0.02
2800 to 4000 mic : {-1.5 to -2.0phi}	gravel (-1 to -8 phi)	granules	Gravel	%	0.00	0.00	0.02	0.01
4000 to 5600 mic : {-2.0 to -2.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
5600 to 8000 mic : {-2.5 to -3.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.05	0.00
8000 to 11200 mic : {-3.0 to -3.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
11200 to 16000 mic : {-3.5 to -4.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
16000 to 22400 mic : {-4.0 to -4.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
22400 to 31500 mic : {-4.5 to -5.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
31500 to 45000 mic : {-5.0 to -5.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
45000 to 63000 mic : {-5.5 to -6.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
> 63000 microns : {< -6.0 phi}	gravel (-1 to -8 phi)	cobble	Gravel	%	0.00	0.00	0.00	0.00
	Total Gravel Fraction			**%**	**0.00**	**0.00**	**0.09**	**0.02**
	Mud, Sand & Gravel			%	100	100	100	100
	Mud & Sand Fractions (>0 phi)			%	100	100	100	100
	Coarse Sand & Gravel (<0 phi)			%	0	0	0	0
	Summary				**Station 5**	**Station 6**	**Station 7**	**Station 8**
	Total Mud Fraction			%	0.1	0.1	0.1	0.1
	Total Sand Fraction			%	99.9	99.9	99.9	100.0
	Total Gravel Fraction			%	0.0	0.0	0.1	0.0
	Description				FS	FS	FS	FS

* PSA analysis undertaken by the Environment Agency National Laboratory Service. The information included above has been taken from the NLS report and re-ordered by IECS into increasing grain size fraction. Percentage composition of mud, sand & gravel fractions have also been additionally calculated for ease of interpretation.

PSA Data (Stations 9-12)

	Analyte			Units	Station 9	Station 10	Station 11	Station 12
	Grain Size Inclusive Kurtosis			mm	0.495	0.515	0.516	0.507
	Grain Size Inclusive Mean			mm	0.109	0.134	0.143	0.169
	Inclusive Graphic Skewness :- {SKI}			Unitless	-0.0333	0.00334	-0.0138	0.00693
	Kurtosis			Unitless	1.01	0.958	0.955	0.98
	Particle Diameter : Mean			mm	1.2	1.47	1.54	1.82
	Particle Diameter : Median			mm	0.11	0.132	0.142	0.169
	Sorting Coefficient			Unitless	0.629	0.574	0.576	0.525
Sorting Coefficient	Fraction	Additional	Component		**Station 9**	**Station 10**	**Station 11**	**Station 12**
< 0.98 microns : {>10 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
0.98 to 1.38 microns : {10 to 9.5 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
1.38 to 1.95 microns : {9.5 to 9 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
1.95 to 2.76 microns : {9 to 8.5 phi}	clay (>8phi)		Mud	%	0.13	0.00	0.00	0.00
2.76 to 3.91 microns : {8.5 to 8 phi}	clay (>8phi)		Mud	%	0.24	0.00	0.00	0.00
3.91 to 5.52 microns : {8 to 7.5 phi}	silt (4 to 8 phi)	VF silt	Mud	%	0.26	0.00	0.00	0.00
5.52 to 7.81 microns : {7.5 to 7 phi}	silt (4 to 8 phi)	VF silt	Mud	%	0.35	0.00	0.00	0.00
7.81 to 11.1 microns : {7 to 6.5 phi}	silt (4 to 8 phi)	F silt	Mud	%	0.49	0.00	0.00	0.00
11.1 to 15.6 microns : {6.5 to 6 phi}	silt (4 to 8 phi)	F silt	Mud	%	0.50	0.00	0.00	0.00
15.6 to 22.1 microns : {6 to 5.5 phi}	silt (4 to 8 phi)	M silt	Mud	%	0.24	0.00	0.00	0.00
22.1 to 31.3 microns : {5.5 to 5 phi}	silt (4 to 8 phi)	M silt	Mud	%	0.00	0.00	0.00	0.00
31.3 to 44.2 microns : {5 to 4.5 phi}	silt (4 to 8 phi)	C silt	Mud	%	0.22	0.00	0.00	0.00
44.2 to 62.5 microns : {4.5 to 4 phi}	silt (4 to 8 phi)	C silt	Mud	%	5.92	1.77	0.82	0.01
		Total Mud Fraction		**%**	**8.35**	**1.77**	**0.82**	**0.01**
62.5 to 88.4 microns : {4 to 3.5 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	21.00	13.10	9.43	2.31
88.4 to 125 microns : {3.5 to 3 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	32.70	29.80	26.80	16.70
125 to 177 microns : {3 to 2.5 phi}	sand (-1 to 4 phi)	F sand	Sand	%	26.20	32.50	34.60	35.80
177 to 250 microns : {2.5 to 2 phi}	sand (-1 to 4 phi)	F sand	Sand	%	10.40	18.30	22.30	32.30
250 to 354 microns : {2 to 1.5 phi}	sand (-1 to 4 phi)	M sand	Sand	%	1.30	4.34	6.01	12.20
354 to 500 microns : {1.5 to 1 phi}	sand (-1 to 4 phi)	M sand	Sand	%	0.00	0.10	0.06	0.70
500 to 707 microns : {1 to 0.5 phi}	sand (-1 to 4 phi)	C sand	Sand	%	0.00	0.00	0.00	0.00
707 to 1000 microns : {0.5 to 0 phi}	sand (-1 to 4 phi)	C sand	Sand	%	0.00	0.00	0.00	0.00
1000 to 1400 mic : {0 to -0.5phi}	sand (-1 to 4 phi)	VC sand	Sand	%	0.00	0.02	0.00	0.00
1400 to 2000 mic : {-0.5 to -1.0phi}	sand (-1 to 4 phi)	VC sand	Sand	%	0.00	0.02	0.00	0.00
		Total Sand Fraction		**%**	**91.60**	**98.18**	**99.20**	**100.01**
2000 to 2800 mic : {-1.0 to -1.5phi}	gravel (-1 to -8 phi)	granules	Gravel	%	0.00	0.01	0.00	0.00
2800 to 4000 mic : {-1.5 to -2.0phi}	gravel (-1 to -8 phi)	granules	Gravel	%	0.00	0.04	0.00	0.00
4000 to 5600 mic : {-2.0 to -2.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
5600 to 8000 mic : {-2.5 to -3.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
8000 to 11200 mic : {-3.0 to -3.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
11200 to 16000 mic : {-3.5 to -4.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
16000 to 22400 mic : {-4.0 to -4.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
22400 to 31500 mic : {-4.5 to -5.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
31500 to 45000 mic : {-5.0 to -5.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
45000 to 63000 mic : {-5.5 to -6.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
> 63000 microns : {< -6.0 phi}	gravel (-1 to -8 phi)	cobble	Gravel	%	0.00	0.00	0.00	0.00
	Total Gravel Fraction			**%**	**0.00**	**0.05**	**0.00**	**0.00**
	Mud, Sand & Gravel			%	100	100	100	100
	Mud & Sand Fractions (>0 phi)			%	100	100	100	100
	Coarse Sand & Gravel (<0 phi)			%	0	0	0	0
	Summary				**Station 9**	**Station 10**	**Station 11**	**Station 12**
	Total Mud Fraction			%	8.4	1.8	0.8	0.0
	Total Sand Fraction			%	91.6	98.2	99.2	100.0
	Total Gravel Fraction			%	0.0	0.1	0.0	0.0
	Description				FS	FS	FS	FS

* PSA analysis undertaken by the Environment Agency National Laboratory Service. The information included above has been taken from the NLS report and re-ordered by IECS into increasing grain size fraction. Percentage composition of mud, sand & gravel fractions have also been additionally calculated for ease of interpretation.

PSA Data (Stations 13-16)

	Analyte			Units	Station 13	Station 14	Station 15	Station 16
	Grain Size Inclusive Kurtosis			mm	0.512	0.51	0.509	0.503
	Grain Size Inclusive Mean			mm	0.127	0.107	0.133	0.186
	Inclusive Graphic Skewness :- {SKI}			Unitless	0.00562	-0.00429	-0.00586	-0.00585
	Kurtosis			Unitless	0.966	0.972	0.973	0.99
	Particle Diameter : Mean			mm	1.37	1.16	1.43	2.07
	Particle Diameter : Median			mm	0.126	0.107	0.132	0.186
	Sorting Coefficient			Unitless	0.557	0.574	0.543	0.51
Sorting Coefficient	Fraction	Additional	Component		Station 13	Station 14	Station 15	Station 16
< 0.98 microns : {>10 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
0.98 to 1.38 microns : {10 to 9.5 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
1.38 to 1.95 microns : {9.5 to 9 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
1.95 to 2.76 microns : {9 to 8.5 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
2.76 to 3.91 microns : {8.5 to 8 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
3.91 to 5.52 microns : {8 to 7.5 phi}	silt (4 to 8 phi)	VF silt	Mud	%	0.00	0.10	0.00	0.00
5.52 to 7.81 microns : {7.5 to 7 phi}	silt (4 to 8 phi)	VF silt	Mud	%	0.00	0.26	0.00	0.00
7.81 to 11.1 microns : {7 to 6.5 phi}	silt (4 to 8 phi)	F silt	Mud	%	0.00	0.28	0.00	0.00
11.1 to 15.6 microns : {6.5 to 6 phi}	silt (4 to 8 phi)	F silt	Mud	%	0.00	0.07	0.00	0.00
15.6 to 22.1 microns : {6 to 5.5 phi}	silt (4 to 8 phi)	M silt	Mud	%	0.00	0.00	0.00	0.00
22.1 to 31.3 microns : {5.5 to 5 phi}	silt (4 to 8 phi)	M silt	Mud	%	0.00	0.00	0.00	0.00
31.3 to 44.2 microns : {5 to 4.5 phi}	silt (4 to 8 phi)	C silt	Mud	%	0.00	0.18	0.00	0.00
44.2 to 62.5 microns : {4.5 to 4 phi}	silt (4 to 8 phi)	C silt	Mud	%	2.20	6.22	1.10	0.00
		Total Mud Fraction		**%**	**2.20**	**7.11**	**1.10**	**0.00**
62.5 to 88.4 microns : {4 to 3.5 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	14.90	23.50	11.90	0.56
88.4 to 125 microns : {3.5 to 3 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	32.00	35.70	31.20	10.60
125 to 177 microns : {3 to 2.5 phi}	sand (-1 to 4 phi)	F sand	Sand	%	32.40	25.50	34.90	33.50
177 to 250 microns : {2.5 to 2 phi}	sand (-1 to 4 phi)	F sand	Sand	%	15.80	7.73	17.80	36.80
250 to 354 microns : {2 to 1.5 phi}	sand (-1 to 4 phi)	M sand	Sand	%	2.68	0.44	3.09	16.40
354 to 500 microns : {1.5 to 1 phi}	sand (-1 to 4 phi)	M sand	Sand	%	0.00	0.00	0.00	1.66
500 to 707 microns : {1 to 0.5 phi}	sand (-1 to 4 phi)	C sand	Sand	%	0.00	0.00	0.00	0.01
707 to 1000 microns : {0.5 to 0 phi}	sand (-1 to 4 phi)	C sand	Sand	%	0.00	0.00	0.00	0.00
1000 to 1400 mic : {0 to -0.5phi}	sand (-1 to 4 phi)	VC sand	Sand	%	0.00	0.00	0.00	0.11
1400 to 2000 mic : {-0.5 to -1.0phi}	sand (-1 to 4 phi)	VC sand	Sand	%	0.00	0.00	0.00	0.11
		Total Sand Fraction		**%**	**97.78**	**92.87**	**98.89**	**99.75**
2000 to 2800 mic : {-1.0 to -1.5phi}	gravel (-1 to -8 phi)	granules	Gravel	%	0.00	0.00	0.00	0.11
2800 to 4000 mic : {-1.5 to -2.0phi}	gravel (-1 to -8 phi)	granules	Gravel	%	0.00	0.00	0.00	0.09
4000 to 5600 mic : {-2.0 to -2.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.01
5600 to 8000 mic : {-2.5 to -3.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
8000 to 11200 mic : {-3.0 to -3.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
11200 to 16000 mic : {-3.5 to -4.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
16000 to 22400 mic : {-4.0 to -4.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
22400 to 31500 mic : {-4.5 to -5.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
31500 to 45000 mic : {-5.0 to -5.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
45000 to 63000 mic : {-5.5 to -6.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
> 63000 microns : {< -6.0 phi}	gravel (-1 to -8 phi)	cobble	Gravel	%	0.00	0.00	0.00	0.00
	Total Gravel Fraction			**%**	**0.00**	**0.00**	**0.00**	**0.22**
	Mud, Sand & Gravel			%	100	100	100	100
	Mud & Sand Fractions (>0 phi)			%	100	100	100	100
	Coarse Sand & Gravel (<0 phi)			%	0	0	0	0
	Summary				**Station 13**	**Station 14**	**Station 15**	**Station 16**
	Total Mud Fraction			%	2.2	7.1	1.1	0.0
	Total Sand Fraction			%	97.8	92.9	98.9	99.7
	Total Gravel Fraction			%	0.0	0.0	0.0	0.2
	Description				FS	FS	FS	FS

* PSA analysis undertaken by the Environment Agency National Laboratory Service. The information included above has been taken from the NLS report and re-ordered by IECS into increasing grain size fraction. Percentage composition of mud, sand & gravel fractions have also been additionally calculated for ease of interpretation.

PSA Data (Stations 17-20)

	Analyte			Units	Station 17	Station 18	Station 19	Station 20
	Grain Size Inclusive Kurtosis			mm	0.24	0.51	0.23	0.507
	Grain Size Inclusive Mean			mm	0.29	0.164	0.283	0.19
	Inclusive Graphic Skewness :- {SKI}			Unitless	0.319	0.0194	0.36	-0.0285
	Kurtosis			Unitless	2.06	0.971	2.12	0.979
	Particle Diameter : Mean			mm	7.35	2.13	10.6	2.02
	Particle Diameter : Median			mm	0.283	0.165	0.265	0.191
	Sorting Coefficient			Unitless	0.944	0.561	1.38	0.507
Sorting Coefficient	Fraction	Additional	Component		Station 17	Station 18	Station 19	Station 20
< 0.98 microns : {>10 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
0.98 to 1.38 microns : {10 to 9.5 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
1.38 to 1.95 microns : {9.5 to 9 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
1.95 to 2.76 microns : {9 to 8.5 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
2.76 to 3.91 microns : {8.5 to 8 phi}	clay (>8phi)		Mud	%	0.00	0.00	0.00	0.00
3.91 to 5.52 microns : {8 to 7.5 phi}	silt (4 to 8 phi)	VF silt	Mud	%	0.00	0.00	0.00	0.00
5.52 to 7.81 microns : {7.5 to 7 phi}	silt (4 to 8 phi)	VF silt	Mud	%	0.00	0.00	0.00	0.00
7.81 to 11.1 microns : {7 to 6.5 phi}	silt (4 to 8 phi)	F silt	Mud	%	0.00	0.00	0.00	0.00
11.1 to 15.6 microns : {6.5 to 6 phi}	silt (4 to 8 phi)	F silt	Mud	%	0.00	0.00	0.00	0.00
15.6 to 22.1 microns : {6 to 5.5 phi}	silt (4 to 8 phi)	M silt	Mud	%	0.00	0.00	0.03	0.00
22.1 to 31.3 microns : {5.5 to 5 phi}	silt (4 to 8 phi)	M silt	Mud	%	0.00	0.00	0.24	0.00
31.3 to 44.2 microns : {5 to 4.5 phi}	silt (4 to 8 phi)	C silt	Mud	%	0.00	0.00	0.20	0.00
44.2 to 62.5 microns : {4.5 to 4 phi}	silt (4 to 8 phi)	C silt	Mud	%	0.00	0.07	0.01	0.00
		Total Mud Fraction		**%**	**0.00**	**0.07**	**0.47**	**0.00**
62.5 to 88.4 microns : {4 to 3.5 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	0.00	3.66	0.98	0.52
88.4 to 125 microns : {3.5 to 3 phi}	sand (-1 to 4 phi)	VF sand	Sand	%	0.44	18.80	5.79	9.51
125 to 177 microns : {3 to 2.5 phi}	sand (-1 to 4 phi)	F sand	Sand	%	9.47	34.40	15.30	31.80
177 to 250 microns : {2.5 to 2 phi}	sand (-1 to 4 phi)	F sand	Sand	%	28.10	29.40	23.40	38.10
250 to 354 microns : {2 to 1.5 phi}	sand (-1 to 4 phi)	M sand	Sand	%	33.60	11.90	23.20	18.60
354 to 500 microns : {1.5 to 1 phi}	sand (-1 to 4 phi)	M sand	Sand	%	17.30	1.11	13.40	1.50
500 to 707 microns : {1 to 0.5 phi}	sand (-1 to 4 phi)	C sand	Sand	%	3.44	0.00	4.37	0.00
707 to 1000 microns : {0.5 to 0 phi}	sand (-1 to 4 phi)	C sand	Sand	%	0.09	0.00	0.75	0.00
1000 to 1400 mic : {0 to -0.5phi}	sand (-1 to 4 phi)	VC sand	Sand	%	0.75	0.10	0.65	0.00
1400 to 2000 mic : {-0.5 to -1.0phi}	sand (-1 to 4 phi)	VC sand	Sand	%	1.03	0.10	1.12	0.00
		Total Sand Fraction		**%**	**94.22**	**99.47**	**88.96**	**100.03**
2000 to 2800 mic : {-1.0 to -1.5phi}	gravel (-1 to -8 phi)	granules	Gravel	%	0.83	0.11	1.30	0.00
2800 to 4000 mic : {-1.5 to -2.0phi}	gravel (-1 to -8 phi)	granules	Gravel	%	1.08	0.03	1.40	0.00
4000 to 5600 mic : {-2.0 to -2.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.48	0.01	1.63	0.00
5600 to 8000 mic : {-2.5 to -3.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	1.13	0.02	1.77	0.00
8000 to 11200 mic : {-3.0 to -3.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.44	0.07	2.49	0.00
11200 to 16000 mic : {-3.5 to -4.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	1.75	0.14	1.51	0.00
16000 to 22400 mic : {-4.0 to -4.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.38	0.00
22400 to 31500 mic : {-4.5 to -5.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
31500 to 45000 mic : {-5.0 to -5.5phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
45000 to 63000 mic : {-5.5 to -6.0phi}	gravel (-1 to -8 phi)	pebble	Gravel	%	0.00	0.00	0.00	0.00
> 63000 microns : {< -6.0 phi}	gravel (-1 to -8 phi)	cobble	Gravel	%	0.00	0.00	0.00	0.00
	Total Gravel Fraction			**%**	**5.71**	**0.39**	**10.48**	**0.00**
	Mud, Sand & Gravel			%	100	100	100	100
	Mud & Sand Fractions (>0 phi)			%	93	99	88	100
	Coarse Sand & Gravel (<0 phi)			%	7	1	12	0
	Summary				**Station 17**	**Station 18**	**Station 19**	**Station 20**
	Total Mud Fraction			%	0.0	0.1	0.5	0.0
	Total Sand Fraction			%	94.2	99.5	89.0	100.0
	Total Gravel Fraction			%	5.7	0.4	10.5	0.0
	Description				S	FS	S	FS

* PSA analysis undertaken by the Environment Agency National Laboratory Service. The information included above has been taken from the NLS report and re-ordered by IECS into increasing grain size fraction. Percentage composition of mud, sand & gravel fractions have also been additionally calculated for ease of interpretation.

Appendix 5: National Laboratory Service Analytical Report

Appendix 6: Ecospan Environmental Ltd. Rocky Scar Ground Report

Natural England is here to secure a healthy natural environment for people to enjoy, where wildlife is protected and England's traditional landscapes are safeguarded for future generations.

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