Solway Firth SAC Rocky Scar Ground Community Condition Monitoring 2014

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Executive summary

The Solway Firth is a large macrotidal estuary situated on the west coast of Britain and represents one of the largest tidal embayments in the north eastern Irish Sea. It has been designated as a Special Area of Conservation (SAC) under the EU Habitats Directive and as such Natural England (and Scottish Natural Heritage), have a duty to assess the condition of the SAC's features once every six years. Natural England has commissioned this study in order to monitor and assess the extent and condition of the intertidal rocky scars sub-feature on the English side of the Solway Firth SAC.

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.

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1. Introduction

Natural England has commissioned this study in order to monitor and assess the extent and condition of the intertidal rocky scars on the English side of the Solway Firth SAC.

The Solway Firth is a large macrotidal estuary situated on the west coast of Britain and 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 Solway is characterised by extensive areas of mud and sandflat and these comprise the third largest continuous area of mud and sand in the UK after the Wash and Morecambe Bay[1].

The Inner Solway has been designated as a wetland of international importance under the Ramsar Convention, and a Special Protection Area (SPA) under the Birds Directive. The inner Solway has also been designated as a Site of Special Scientific Interest (SSSI) as notified under the Wildlife & Countryside Act 1981 (as amended), and a Special Area for Conservation (SAC) under the EU Habitats Directive. The extent of the Solway Firth SAC is shown in Figure 1.

The majority of the cobble/boulder scar grounds in the Solway Firth are associated with the glacial and fluviglacial material located in the inner estuary (and particularly in the vicinity of Powfoot on the north bank), but extensive areas of scar also occur on the Cumbrian coast in the mid to outer estuary between Silloth and Maryport.

Scar grounds in the Solway Firth have been described[2] as: " *A hard substratum emergent from the widespread areas of mobile sand and liable to periodic inundation by the sand. While some may be composed of one type of substratum, others may be a mixture of two or more*". Areas of scar ground increase the biodiversity of the area as they support a range of other species characteristic of harder substrata which may not be otherwise present. In addition, such areas may also include other habitats of conservation importance such as biogenic reefs. Such features (notably *Sabellaria alveolata* reefs and mussel beds) have been recorded in a number of previous surveys. Extensive areas of *Sabellaria alveolata* reef are present on the southern shore along the Cumbrian coast[3]. *Sabellaria alveolata* is particularly abundant in this region as it favours fairly exposed conditions with relatively high water current velocities where the water holds a high load of sand and food particles in suspension. The species requires a hard substratum (rock, boulders or scar ground) on which to form reefs. The distribution of scar grounds (and associated biogenic reefs) appears to exhibit a degree of temporal variability in the Solway, which is in part related to the tidal or wave driven movement of finer sedimentary material which may periodically cover such features[3].

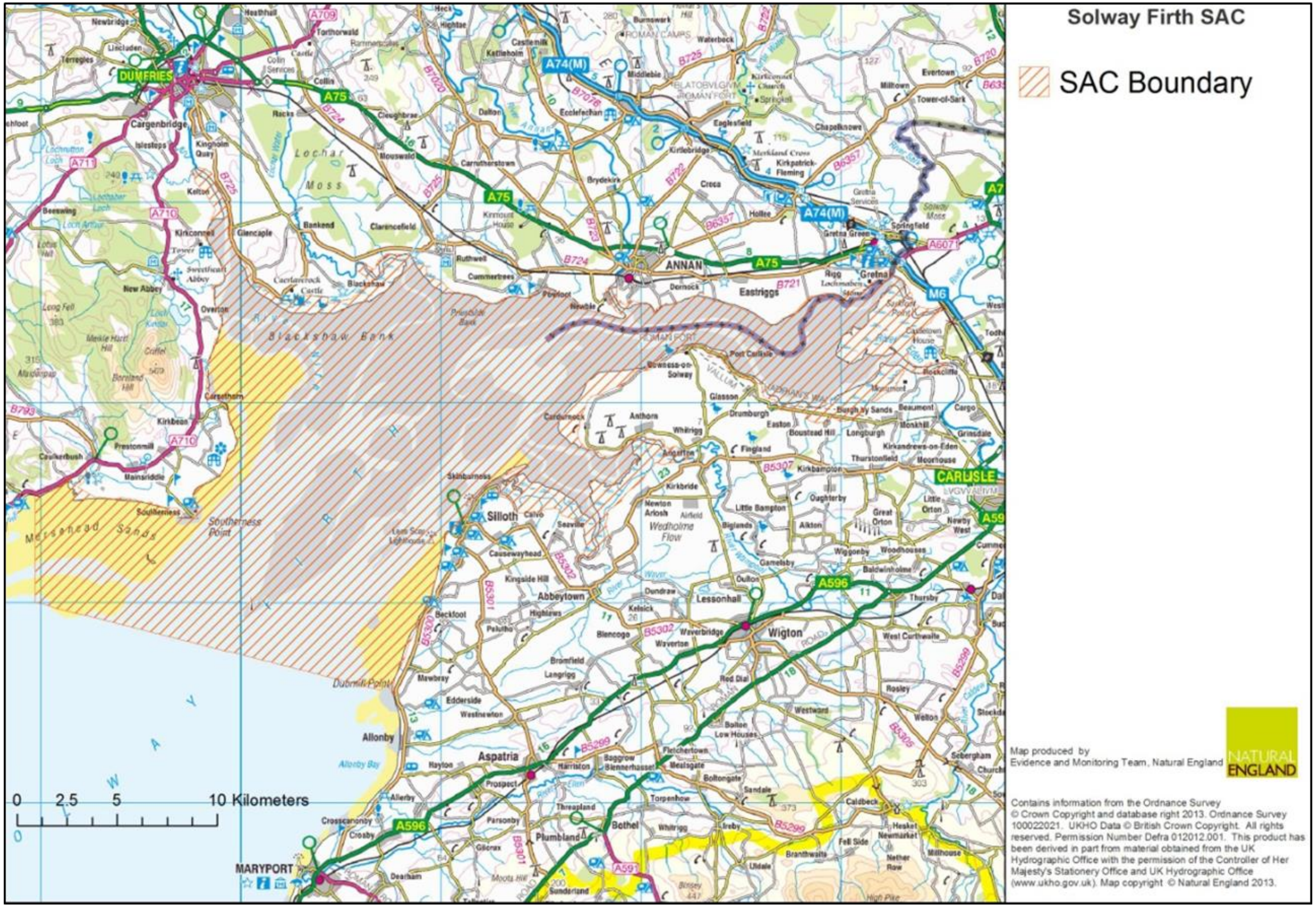

Figure 1. Boundaries of the Solway Firth SAC

1.1 Condition Monitoring of the Rocky Scar Ground Community in the Solway Firth SAC

Site Condition Monitoring (SCM) 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.

Natural England in association with other countryside agencies has established a series of common standards for the monitoring of sites of nature conservation interest. These common standards apply to a number of statutory designated sites, including SACs, and are used, together with other relevant guidance, to ensure that a consistent approach is taken when monitoring such sites. Within the Solway Firth SAC, the rocky scar ground communities (which are a sub-feature the reef qualifying habitat [4]), fall under the Common Standards Monitoring (CSM) guidance produced for littoral rock habitats[5].

For the purposes of monitoring, each feature of the SAC has an associated series of attributes which are 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.

The conservation objectives for the reef feature (of which the rocky scar ground is a sub-feature), are as follows[4]:

Subject to natural change, avoid deterioration of the qualifying habitat, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status. Maintain in the long term:

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

**Extent data from a previous surveys 2002[3] and 2006[6] are available as a partial baseline for this attribute, but this study provides a more relevant and robust baseline for future condition assessment of the intertidal rocky scar ground communities.*

Δ *This study provides the baseline for future condition assessment of this attribute*

1.2 Existing Information on the Solway Firth SAC Rocky Scar Ground Communities on the English Coast

Previous studies focusing on the extent and distribution of *Sabellaria alveolata* reefs[3] and sub-tidal scar grounds[6] along the Cumbrian coast of the Solway estuary were carried out on behalf of Natural England in 2002 and 2006 respectively. Given that the previous studies were not specifically aimed at assessing the attributes of all of the intertidal rocky scar communities, only limited comparisons can be made between the results of the historical studies and those presented here. The most relevant historical baseline data is that provided by Allen *et al*. in 2002 who mapped and assessed the condition of *Sabellaria alveolata* reefs along the southern Solway coastline.

Maps of the extent and distribution of *Sabellaria alveolata* within the SAC reported during the 2002 study[3] have been extracted from the report and geo-referenced using GIS. The resulting map is shown in Figure 2. The reefs were differentiated based on their physical characteristics such as size and patchiness and assigned a 'type'. Full descriptions of each of the types mapped in Figure 2 are provided in Appendix 1. The distribution of subtidal scars reported in 2006 are shown in Figure 2.

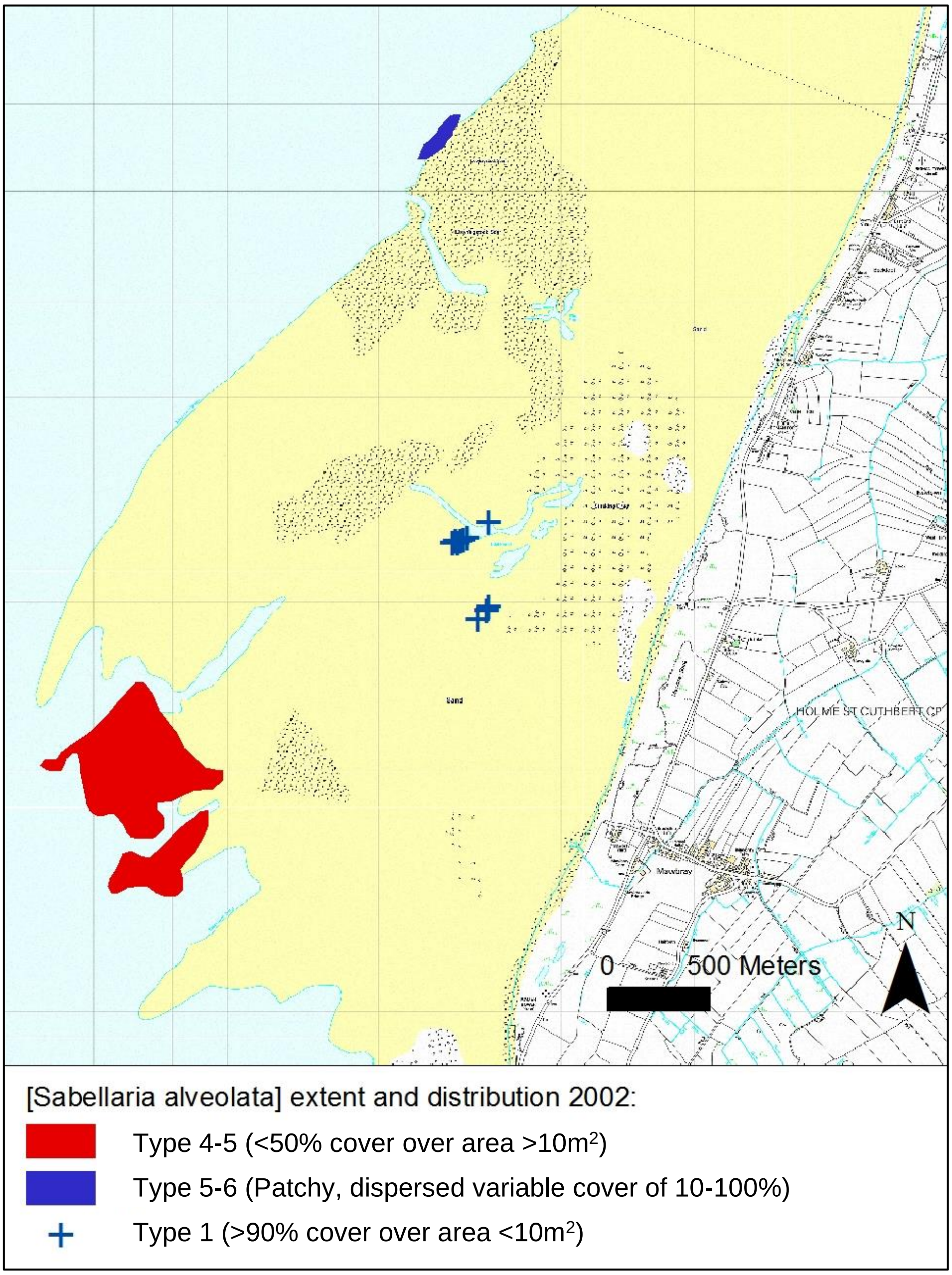

Figure 2. Extent and distribution of *Sabellaria alveolata* within the SAC between Mawbray and Silloth as reported in 2002[3].

The habitat map produced from the study of the subtidal scars in the SAC in 2006[6] is shown in Figure 3.

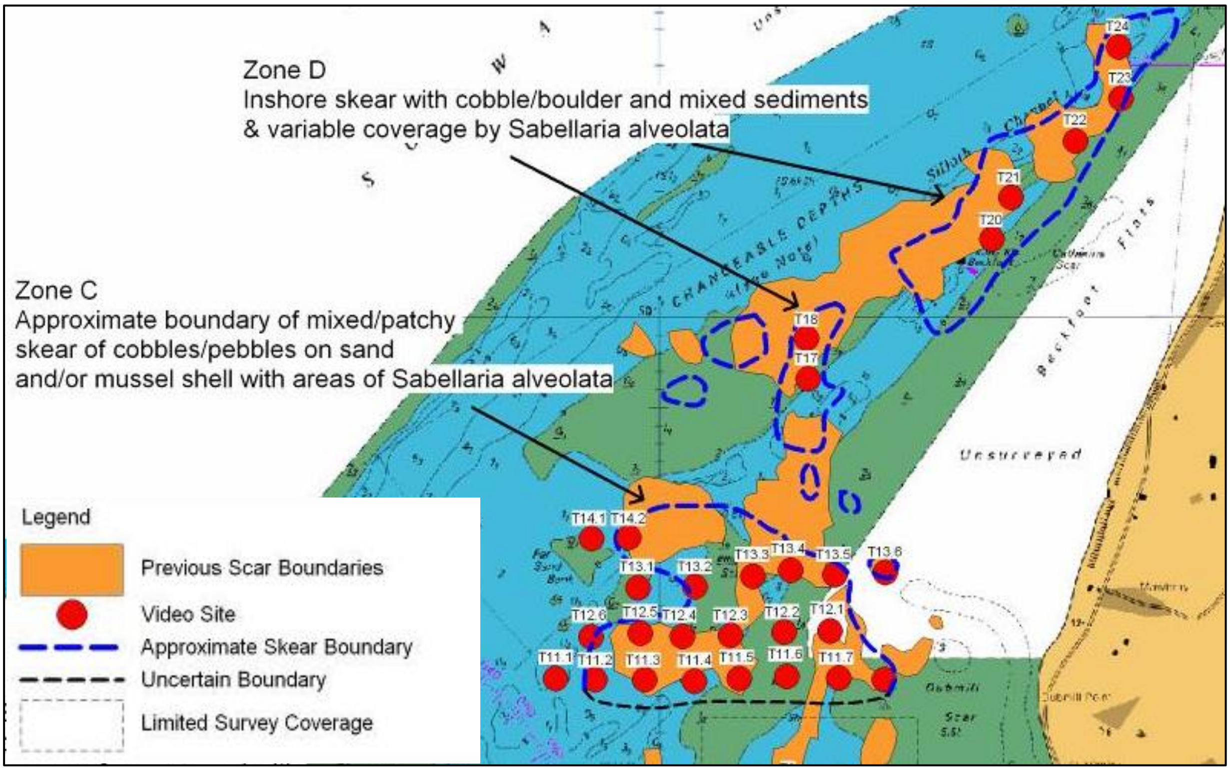

Figure 3. Sub-tidal scar ground distribution within the SAC between Mawbray and Silloth as reported in 2006[6].

2. Aims and objectives

The specific aims for this condition assessment of the intertidal rocky scar ground sub-feature within the Solway Firth SAC were:

- To identify and map the rocky scar communities on the English side of the Solway Firth SAC to the highest possible level.
- To acquire biological data suitable for undertaking an assessment of the direction of ecological change within the rocky scar communities.
- To provide fully detailed methodology for the work undertaken to ensure that methods can be repeated in the future.
- To identify and record the nature and location of any obvious anthropogenic influences which are potentially impacting the sub-feature. Where possible quantify such pressures to enable analysis to focus on investigation of the potential impacts.
- To identify and record the presence, and as far as possible the abundance, of non-native invasive species (INNS) listed in Table 1.
- To provide an evidence based preliminary assessment of the condition of the key attributes of the sub-feature following Common Standards Monitoring Guidance[5] (using previous relevant data where available). The key attributes to be considered were:
  - Extent of rocky scar ground communities.
  - Distribution and extent of characteristic habitat types within the rocky scar ground communities.
  - Species composition of representative and notable habitat types.

Table 1. INNS to be noted where encountered during surveys.

INNS previously recorded in the Solway Firth and/or which were noted to particularly look out for.	INNS not yet recorded in the Solway, but should be noted if sighted
• *Sargassum muticum* – Wireweed • *Crassostrea gigas* – Pacific Oyster • *Spartina anglica* – Common cord-grass • *Corella eumyota* – Orange tipped sea squirt • *Austrominius modestus* – Darwin barnacle • *Styela clava* – Leathery sea squirt • *Codium fragile* – Green sea fingers • *Fipomactus enigmaticus* – Trumpet worm	• *Eriocheir sinensis* – Chinese Mitten Crab • *Didemnum vexillum* – Carpet sea squirt • *Crepidula fornicata* – Slipper limpet • *Dikerogammerus villosus* – Killer shrimp • *Dreissena polymorpha* – Zebra mussel • *Caprella mutica* – Japanese skeleton shrimp

3. Methods

3.1 Access

All of the necessary land access permissions were gained prior to the survey by Natural England. Access was mostly achieved using Ecospan Environmental Ltd's 4 man MCA coded hovercraft *Redshank*, but a small area of shore at Silloth and the some of the extensive lower shore scars off Mawbray were more safely and easily accessed on foot.

3.2 Survey Strategy

In order to deliver the objectives set out by Natural England in the most efficient and cost effective manner, a two phased survey approach was carried out.

During both phases of the survey the presence and abundance of notable habitats and/or species (e.g. habitats or species of conservation interest) were recorded where encountered. The positions of such habitats/species were recorded using differential global positioning system (DGPS) and a photograph was also taken.

Any potential anthropogenic influences (e.g. sewers, land drains etc.) were also recorded throughout both survey phases and any obvious impacts noted.

3.3 Survey Dates

Spring tides were required to ensure that the lower shore habitats were exposed sufficiently to study. For this reason, the Phase I survey was undertaken during the morning and evening spring tides that occurred between the 16th and 18th of June 2014 (LW at Silloth ranged between 0.6m and 0.9m above chart datum during that time). The Phase II survey was undertaken between the 27th and 30th of June 2014 (LW at Silloth ranged between 1.2m and 1.3m above chart datum).

3.4 Phase I Protocol

All Phase I sampling undertaken was consistent with the relevant guidelines[5,7,8]. The aim of the Phase I survey was to determine the distribution and extent of rocky scar (littoral rock) habitat types, interest features, and species that were representative and/or notable within the study area. This was achieved by producing a set of pre-determined target stations at 500-750m intervals throughout the study area. Given that the only aerial photography available had mostly been collected during high tide, the target areas mostly had to be established using a combination of historical and current admiralty charts/OS maps. The target areas were then added to the OS maps/aerial photographs and loaded into a handheld DGPS which was used for all position fixing during the course of the survey. Subsequent ground-truthing defined habitats via field survey in order to establish the Habitat types present (as far as possible according to the Procedural Guidelines 1-1 and 3-1 in the Marine Monitoring Handbook[8]).

The survey covered 100% of the study area moving from one target station to another. At each target station surveyors proceeded on foot into the scar. Where changes in habitat types were observed the perceived boundaries of the changes were marked on the aerial/OS map (and on DGPS where necessary). Given the ephemeral nature of the scars, the OS maps often didn't accurately represent their distribution. Therefore, wherever practical, the periphery of the scars was tracked using the DGPS. Additional target stations were added where scars had been encountered but had not previously been mapped. Habitat types were identified according to the Marine Habitat Classification for Britain and Ireland Version 04.05[9].

At each Phase I station the following information was recorded:

- The exact position of the sampling stations (using DGPS).
- Approximate tidal height (upper, mid, low)
- Habitat type
- Abundance (SACFOR) of characterising species.
- Estimated extent (in metres)
- Comments (such as the presence of negative indicators, species of conservation interest etc.)
- Digital images of the substrate & habitat type including upshore, downshore and alongshore shots
- Date and time

The presence of habitats/species of conservation interest as well as any negative indicators or anthropogenic pressures were also noted and mapped where encountered.

The locations of stations sampled during the Phase I are shown in Figures 4 to 7. The preliminary habitat type map that resulted from the Phase I survey was used to inform the design of the Phase II survey.

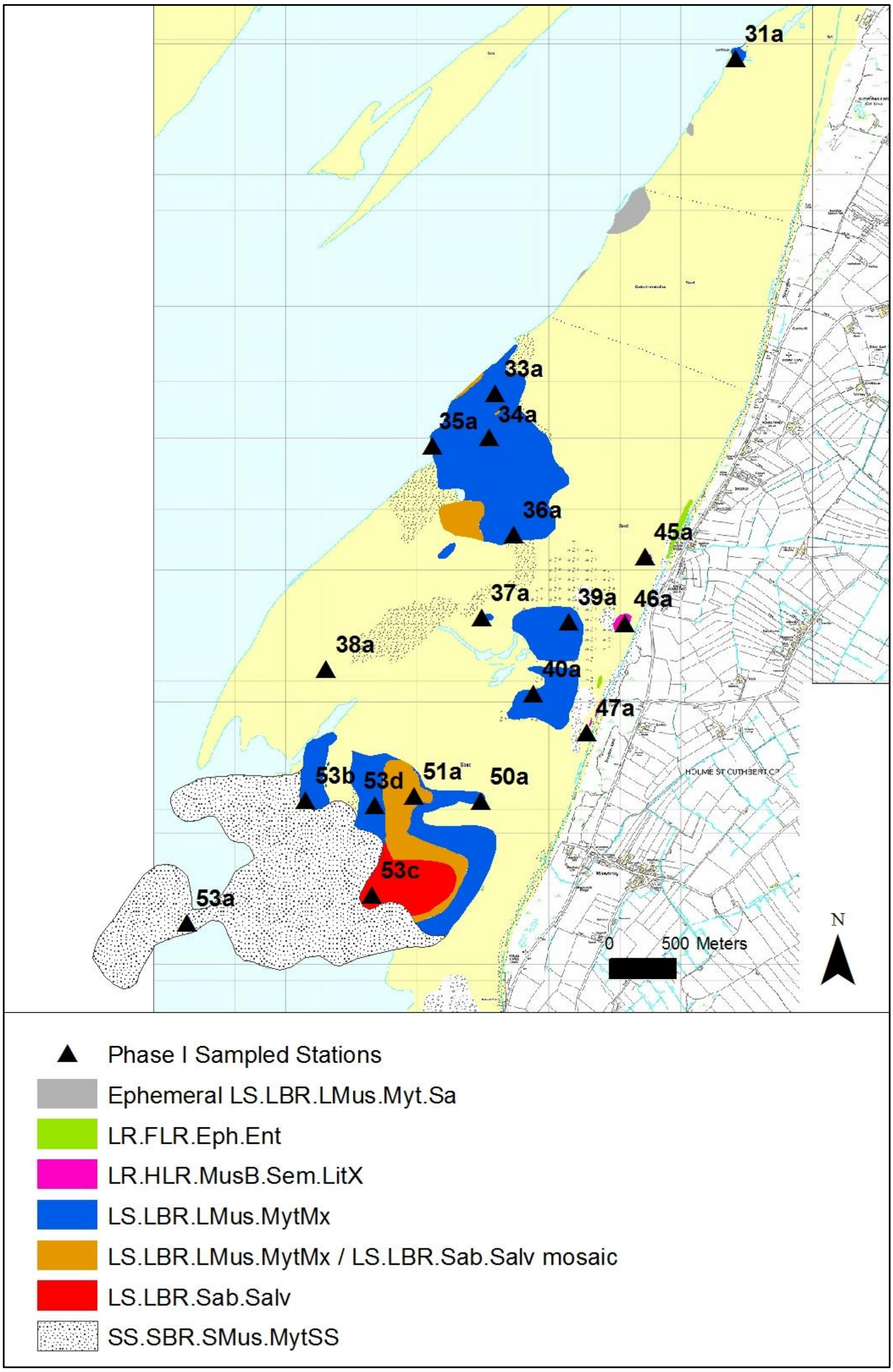

Figure 4. Map of Sampled Phase I Stations in the Solway Firth SAC – Mawbray to Silloth

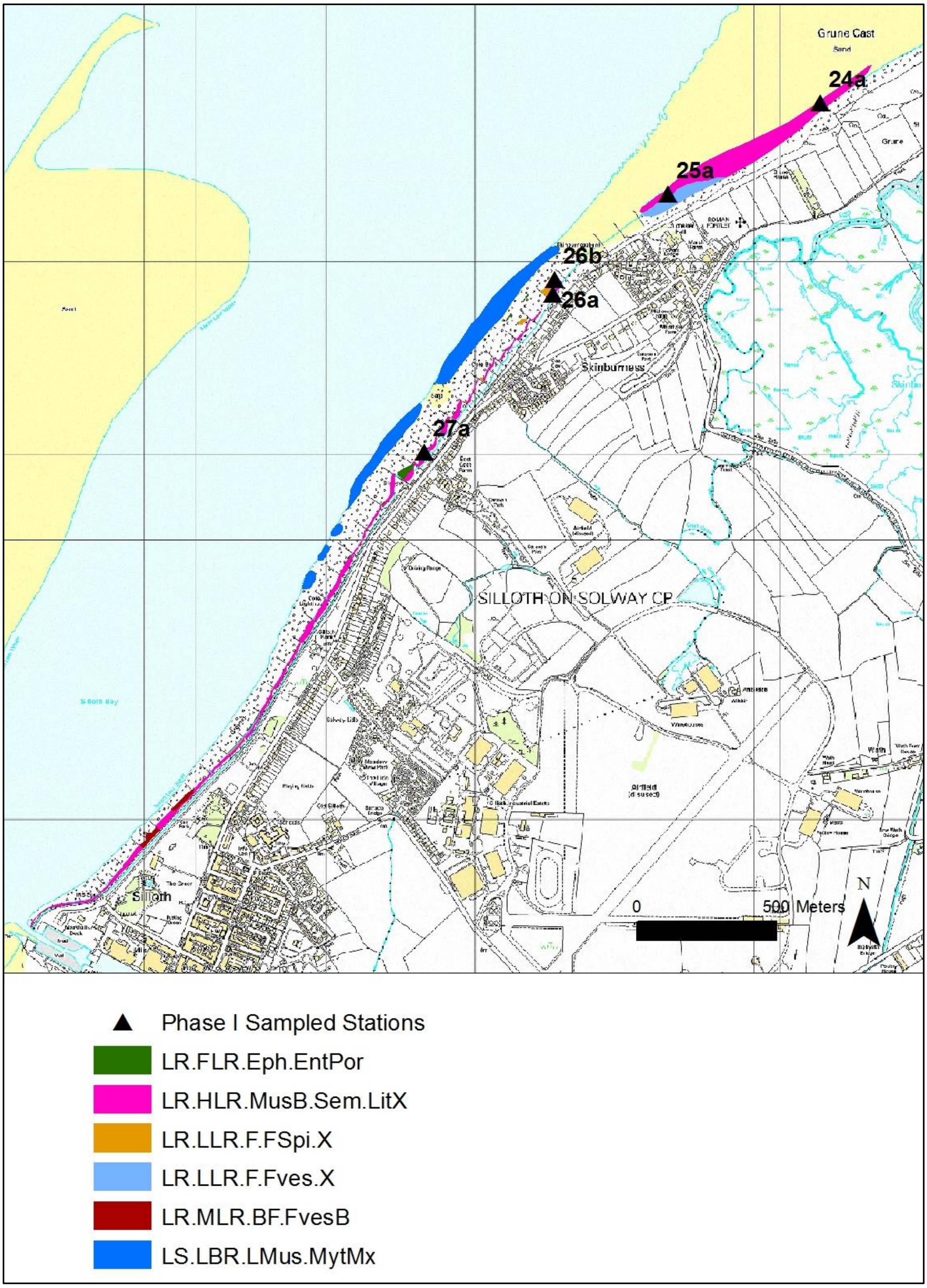

Figure 5. Map of Sampled Phase I Stations in the Solway Firth SAC – Silloth

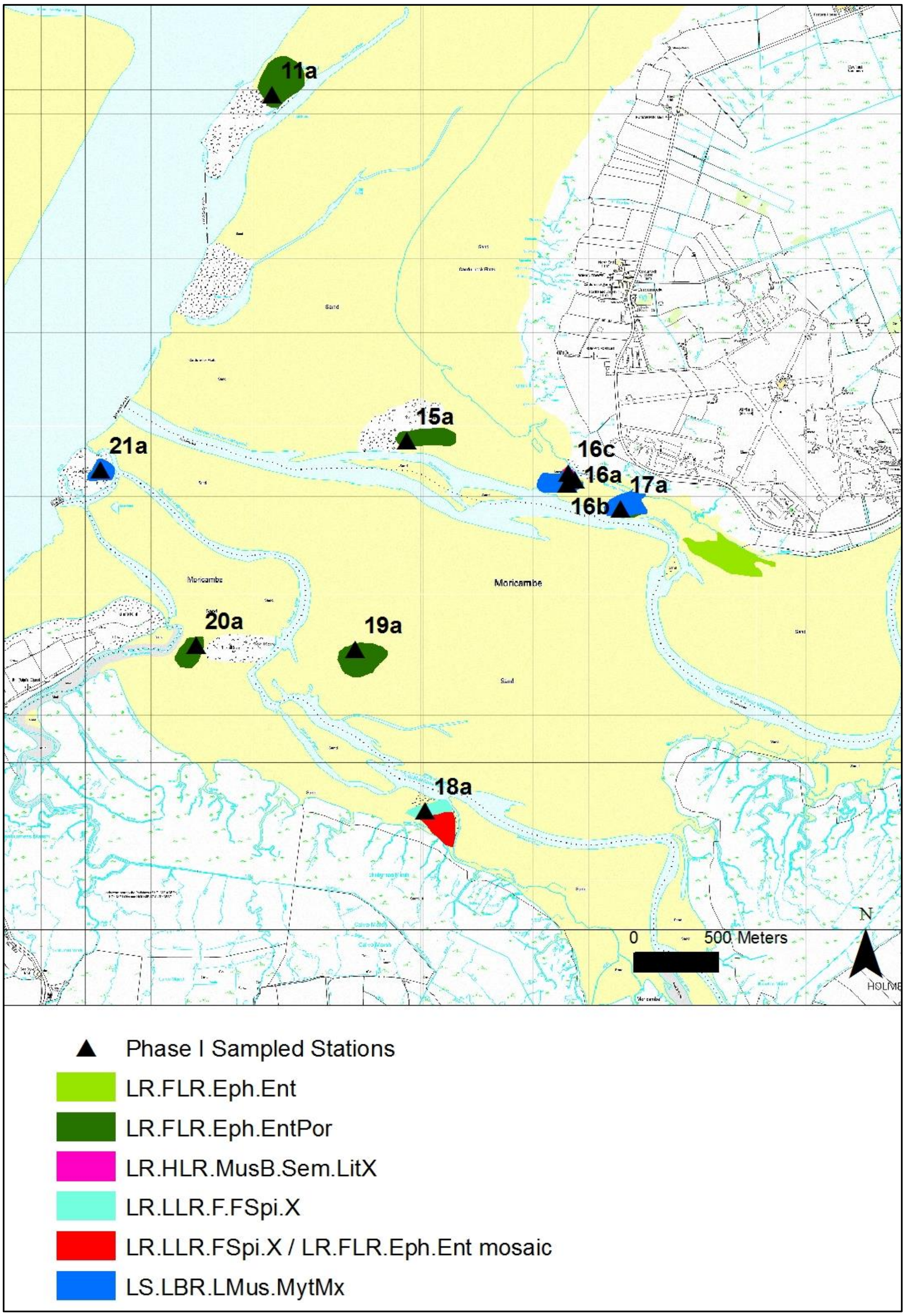

Figure 6. Map of Sampled Phase I Stations in the Solway Firth SAC – Moricambe Bay

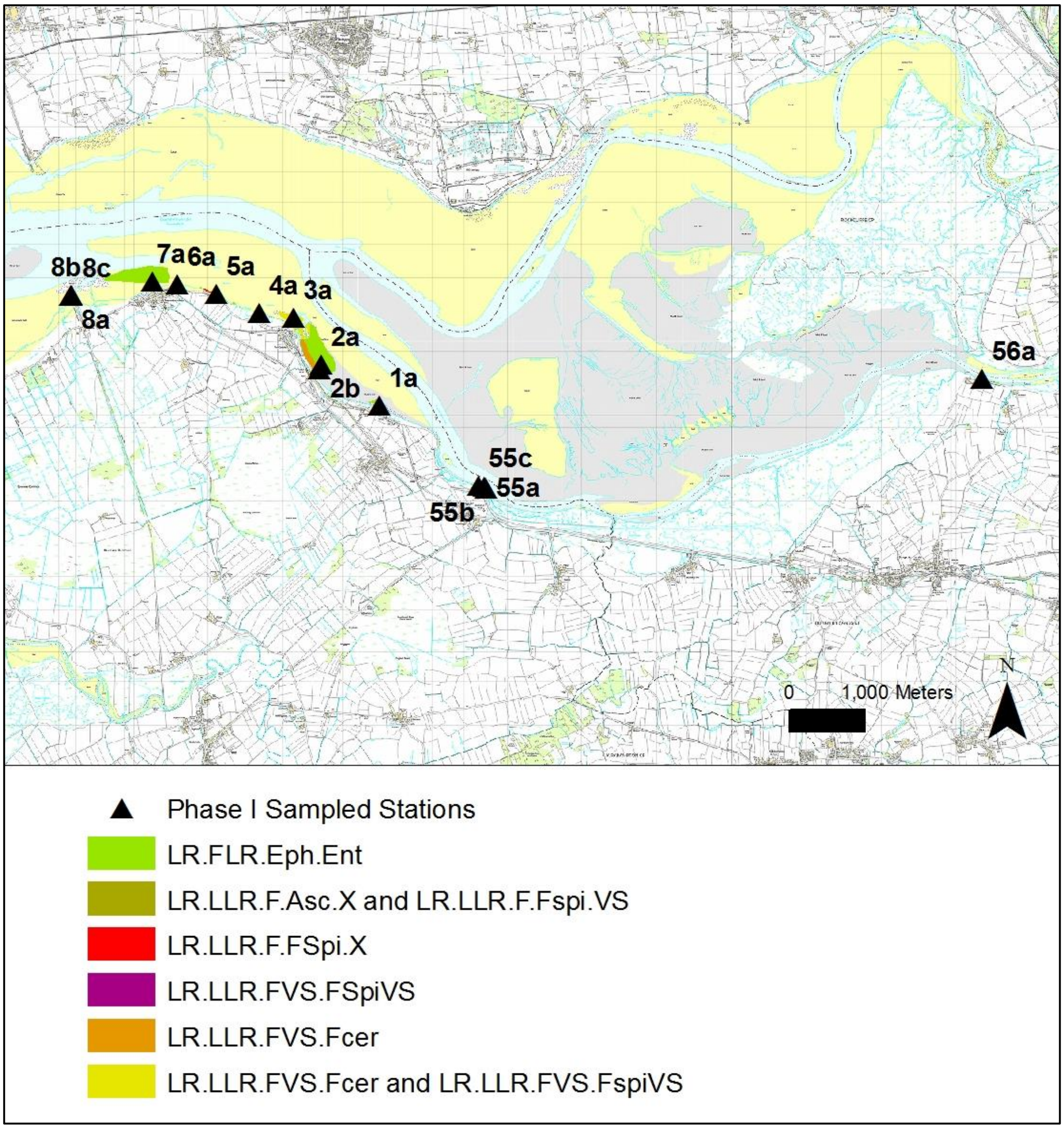

Figure 7. Map of Sampled Phase I Stations in the Solway Firth SAC – Bowness-on-Solway to Rockcliffe

3.5 Phase II Protocol

The aim of the Phase II survey was to gather information sufficient to produce detailed descriptions of the littoral rock habitat types present within the study area including species composition.

In consultation with the Natural England project officer, 30 sampling stations were selected for quantitative sampling. The number of sampling stations assigned within each habitat type was based on the extent and distribution of each. Efforts were made to ensure that the number of replicates/stations was largely proportional and representative of the total area of each habitat type sampled.

At each station, random number tables were used to randomly place three $0.25m^3$ quadrats on a 30m transect. The exact co-ordinates of each transect as well as each individual quadrat was recorded using differential GPS which is typically accurate to with 5 m. The sampling co-ordinates (OSGB36 BUG) are provided in Appendix 2. In some parts of the Solway Firth, the rock habitats consisted of fairly sparse cobble/boulder fields interspersed by littoral sediment habitat types. Therefore, if the quadrat did not land on a relevant habitat type, the next random number was used so that the three quadrats sampled the 'scar' rather than littoral sediment. The number of 'empty' quadrats was also recorded. As far as possible transects were placed at high, mid and low shore, but many of the habitat types occurred over a single tidal height. The abundance of fauna and flora in each quadrat was recorded on the survey forms. Where possible individual fauna were counted, but for some species that were very numerous (e.g. barnacles) abundances were recorded using the SACFOR scale (derived from percentage cover estimates).

Where present the under-boulder fauna and flora was further sampled using a two minute timed search on each transect. The abundances of the species observed in the under-boulder communities were recorded using the SACFOR scale. In many areas the boulders were partially covered by sediment preventing them from being lifted. Where *Sabellaria alveolata* was present under-boulder searches were not carried out as doing so would have damaged the biogenic reefs.

As well as the species lists and abundance data, detailed habitat descriptions were gathered using a Marine Nature Conservation Review (MNCR) type detailed littoral habitat survey form that included aspects such as substrate characteristics, features and modifiers. The time, date and tidal height were also recorded.

3.6 Anthropogenic Influences and Negative Indicators

During both phases of the survey, the presence of potential anthropogenic influences (e.g. sewers, land drains etc.) were mapped (in line with the CCW Handbook for Phase I Survey and Mapping[7]), and any obvious impacts noted. An accurate assessment of the magnitude of anthropogenic impacts would require a more targeted sampling strategy which was not possible given the budgetary constraints of this project.

3.7 Statistical Analysis of Biological Data

Two methods have been used to statistically analyse the data from all habitat types identified: a univariate approach using diversity statistics and multivariate community analysis.

Simple univariate statistics such as mean number of taxa per sample, mean abundance, and diversity/equitability indices such as the Shannon Wiener diversity index, Margalef species richness and Pielou's eveness have been calculated and compared for each transect. The univariate indices have been calculated using the count and percentage cover data recorded from both within the quadrats and during the timed searches, but the indices for the timed search data were limited to the total number of taxa and mean abundance. Although the univariate analysis of the semi-quantitative data from the timed searches is limited, the calculable indices provide a broad indication of the habitat types/areas in which the underboulder communities were most rich. The timed search data required conversion into a usable numerical format by assigning a number from 1 to 6 to each SACFOR abundance category.

Multivariate community analysis in PRIMER 6[10] has used multidimensional scaling (MDS) plots and the multivariate Bray-Curtis similarity statistic to assess the community similarities between transects both in terms of their constituent taxa and relative abundance. MDS plots represent the similarity in community structure of transects in two dimensions where the distances between points represent the differences between the communities sampled. All quadrat and core data was first subjected to a square root transformation in order to reduce the influence of very numerous species on the results. This was not necessary for the data gleaned during the timed searches as the SACFOR scale is essentially a log transformation of the abundance data.

SIMPER ('similarity percentage') analysis was also used to determine the contribution of each species to the observed similarity between habitat types. This enabled the identification of the species that are most important in creating the observed patterns of similarity. For the reasons mentioned above, the quadrat data set was subjected to a single square root transformation prior to resemblance analysis; this was not necessary for the data gleaned during the timed searches.

Multivariate methods of data analysis are considered to provide a more sensitive measure of community change than univariate methods[11] since there is no loss of information such as occurs when reducing the data to a single number or univariate statistic.

3.8 Quality Assurance

Ecospan Environmental Ltd has an ISO 9001 accredited quality management system to ensure that we work to the highest standards expected by our customers. We undertake all work in accordance with standard operating procedures and recognised national and international guidelines.

4. Results

4.1 Extent and Distribution of Habitat Types

A total of 12 intertidal rocky scar ground habitat types were recorded and mapped on the English side of the Solway Firth SAC. Ten of these are described as intertidal rock habitat types, whilst 2 (*Mytilus edulis* beds and *Sabellaria alveolata* reefs) corresponded more closely with intertidal sediment habitat types as defined by the Marine Habitat Classification for Britain and Ireland[9]. An additional subtidal habitat type (SS.SBR.SMus.MytSS) was also exposed sufficiently to map during the Phase I Survey (the slightly higher low-water levels during the Phase II survey meant that these subtidal communities were not exposed at that time). The 13 habitat types observed in total are listed below, 10 were included within the Phase II sampling (either individually or as a mosaic) and these are annotated with a '*':

LR.HLR.MusB.Sem.LitX *	*Semibalanus balanoides* and Littorina spp. on exposed to moderately exposed eulittoral boulders and cobbles.
LR.MLR.BF.FvesB *	*Fucus vesiculosus* and barnacle mosaics on moderately exposed mid eulittoral rock
LR.LLR.F.FSpi.X *	*Fucus spiralis* on full salinity upper eulittoral mixed substrata
LR.LLR.F.FVes.X *	*Fucus vesiculosus* on mid eulittoral mixed substrata
LR.LLR.F.Asc.X	*Ascophyllum nodosum* on full salinity mid eulittoral mixed substrata
LR.LLR.FVS.FSpiVS *	*Fucus spiralis* on sheltered variable salinity upper eulittoral rock

LR.LLR.FVS.Fcer *	*Fucus ceranoides* on reduced salinity eulittoral rock
LR.FLR.Eph.Ent *	*Ulva spp.* (previously *Ulva* spp.) on freshwater influenced and/or unstable upper eulittoral rock
LR.FLR.Eph.EntPor *	*Porphyra purpurea* and *Ulva spp.* on sand-scoured mid or lower eulittoral rock
LS.LBR.LMus.MytMx *	*Mytilus edulis* beds on littoral mixed substrata
LS.LBR.Sab.Salv*	*Sabellaria alveolata reefs on sand-abraded eulittoral rock*
SS.SBR.SMus.MytSS	*Mytilus edulis* beds on sublittoral sediment

The extent and distribution of all 13 habitat types mapped during the study are shown in Figures 6 to 9 in relation to the Phase II sampling stations. There were distributional patterns to habitat types which are related to geography (lower, mid and upper estuary) as well as some zonation relating to shore height.

In the lower extent of the SAC between Mawbray and Silloth, the majority of the intertidal scars were on the mid-shore tidal height. On the mid shore, mussel beds over sandy silt, pebbles and cobbles (LS.LBR.LMu.MytMx) dominated (Figure 8). Where the scars transitioned from the mid to lower shore, the mussel beds were often found to mosaic with patches of *Sabellaria alveolata* (LS.LBR.Sab.Salv). The *Sabellaria alveolata* reefs were most extensive at the south-western boundary of the SAC off the coast at Mawbray. At Mawbray a large expanse of the lower shore was colonised solely by *Sabellaria alveolata* before transitioning with mussel beds higher on the shore.

On the upper shore between Mawbray and Silloth much smaller, narrow scars were formed of boulders and cobbles on sediment were found. These were either characterised by the green algae *Ulva intestinalis* (LR.FLR.Eph.Ent), or were dominated instead by communities of barnacles and *Littorina* spp. (LR.HLR.MusB.Sem.LitX).

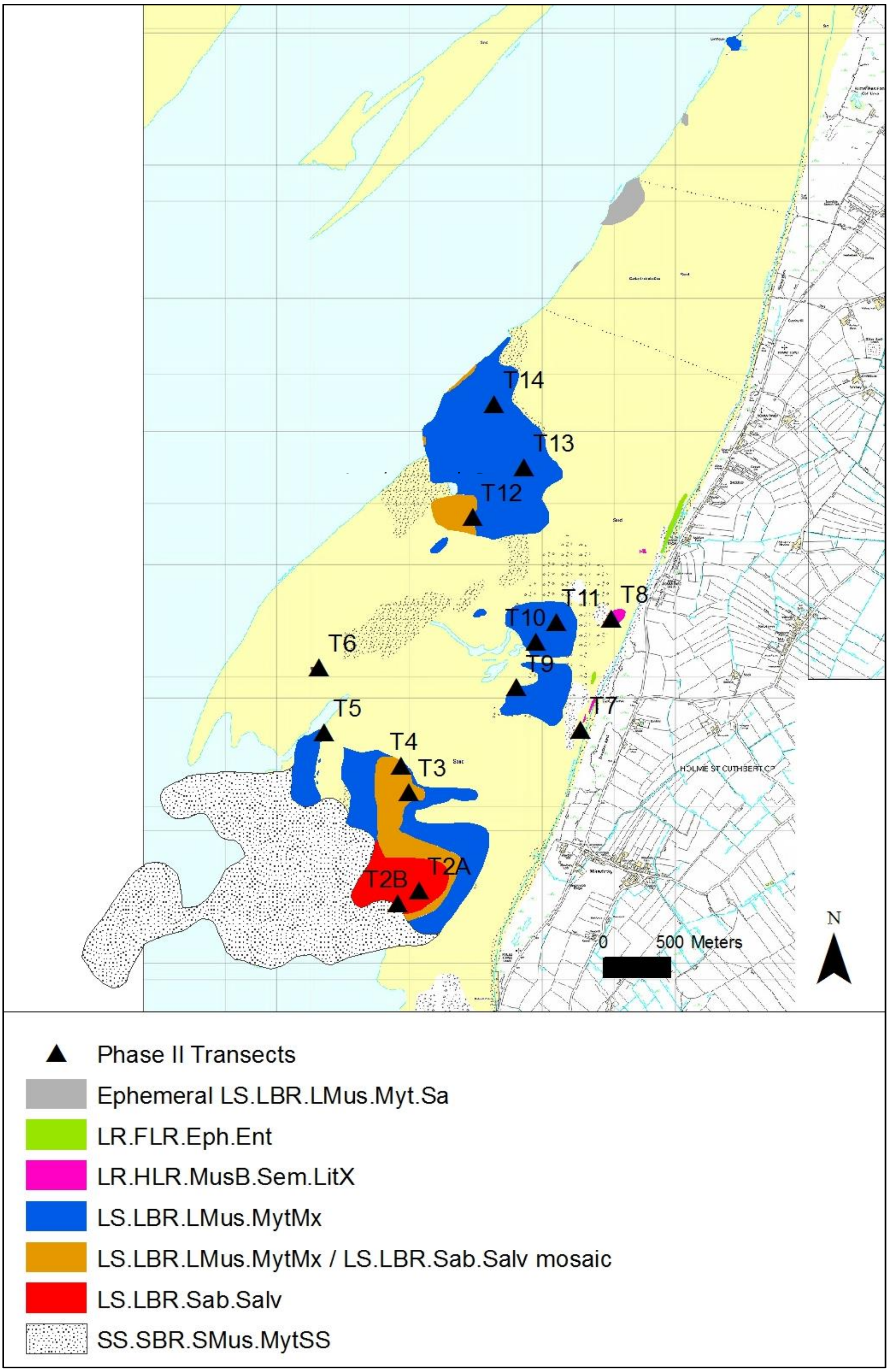

Figure 8. Extent and distribution of rocky scar ground communities in relation to Phase II stations – Mawbray to Silloth

Adjacent to Silloth the shoreline was formed by moderately sloping, relatively sheltered pebble and cobble beaches between groynes, which plateaued off to muddy substrates on the mid to lower shore (Figure 9). The cobbles and pebbles on the upper shore mostly supported communities of barnacles and *Littorina* spp. (LR.HLR.MusB.Sem.LitX). In small areas on the upper shore, and particularly on the mid shore, fucoids colonised more stable cobbles and the larger boulders. The fucoids observed included *Fucus Spiralis* (LR.LLR.F.FSpi.X) and *Fucus vesiculosus* (LR.MLR.F.FVesB). *Fucus vesiculosus* was also found to colonise finer mixed sediments (LR.LLR.F.FVes.X) north of Silloth. Communities of *Ulva* spp. and *Porphyra* spp. were found in small areas at the interface of the cobble and muddy-sand communities (LR.FLR.Eph.EntPor). Mussel beds continued along the lower shore.

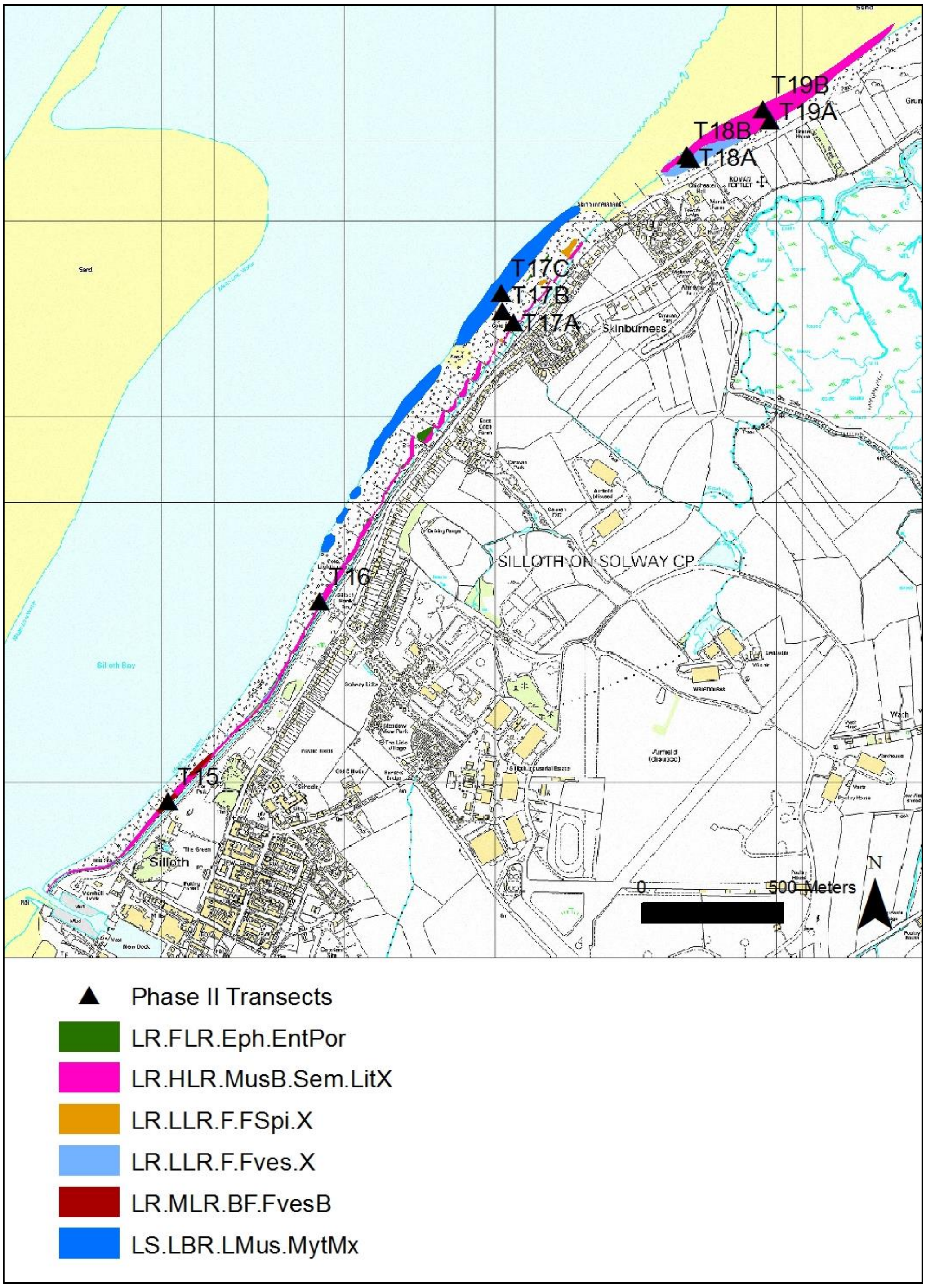

Figure 9. Extent and distribution of rocky scar ground communities in relation to Phase II stations – Silloth

The scars within Moricambe Bay were limited in extent (Figure 10). *Ulva* spp. and *Porphyra* spp. (LR.FLR.Eph.EntPor) 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 (<2cm) *Mytilus edulis* which were set amongst sandy mixed sediments (LS.LBR.LMu.MytMx). On the upper shore adjacent to one of the mussel beds a small area of the barnacle and *Littorina* spp. communities was found (LR.HLR.MusB.Sem.LitX). On the southern bank of the bay communities of the upper shore fucoid *Fucus Spiralis* (LR.LLR.F.FSpi.X) were found alongside and mosaicking with *Ulva* spp.

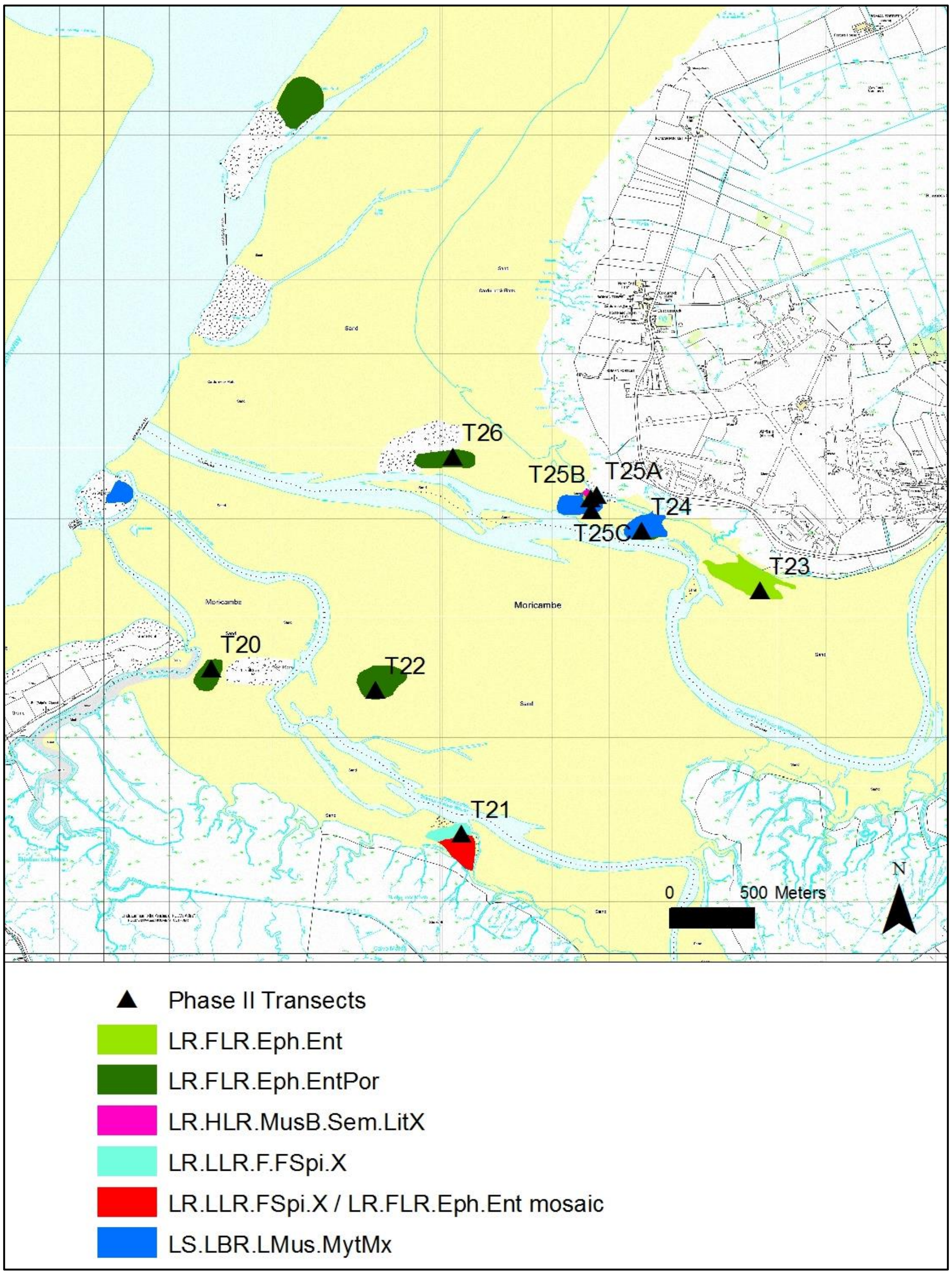

Figure 10. Extent and distribution of rocky scar ground communities in relation to Phase II stations – Moricambe Bay

In the upper estuary the scar communities were limited to a few banks adjacent to Bowness-on –Solway and Port Carlisle where the main river channel brought about variable salinity conditions (Figure 11). *Ulva* spp. were again prevalent and occurred alongside the brackish water fucoid *Fucus ceranoides* (LR.LLR.FVS.Fcer). *Fucus spiralis* also occurred on the upper shore where the shore sloped more steeply and where freshwater ran-off from the land adjacent (LR.LLR.FVS.FSpiVS). Patches of *Fucus Spiralis*, not considered to be strongly influenced by freshwater, were also found on the upper shore further west, away from the main river channel.

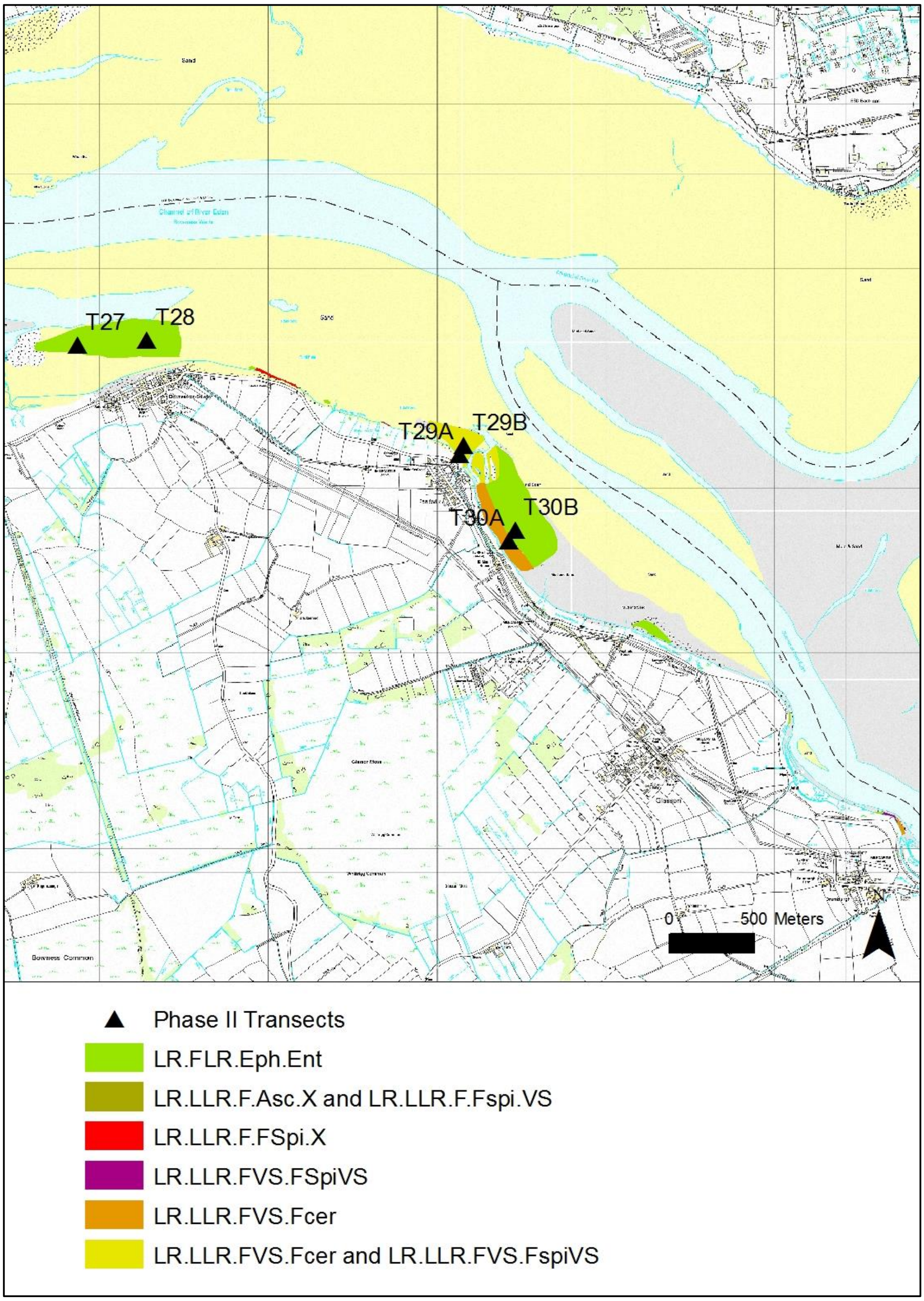

Figure 11. Extent and distribution of rocky scar ground communities in relation to Phase II stations – Bowness-on-Solway to Port Carlisle.

Table 2 provides figures for the estimated total area occupied by each habitat type within the Solway SAC. The table shows that LS.LBR.LMus.MytMx communities account for the largest area of the intertidal scar grounds.

Table 2. Estimated total area (m^2) occupied by scar ground habitat types within the SAC

Habitat type	Area Covered by habitat type (km^2)	% of Total Area Mapped
LR.HLR.MusB.Sem.LitX	0.09	1.7
LR.MLR.BF.FvesB	0.00	0.1
LR.LLR.F.FSpi.X	0.04	0.8
LR.LLR.FSpi.X / LR.FLR.Eph.Ent mosaic	0.03	0.5
LR.LLR.F.Fves.X	0.01	0.3
LR.LLR.F.Asc.X	0.00	0.0
LR.LLR.FVS.FspiVS	0.03	0.5
LR.LLR.FVS.Fcer	0.07	1.3
LR.FLR.Eph.Ent	0.39	7.2
LR.FLR.Eph.EntPor	0.16	3.1
LS.LBR.LMus.MytMx	1.91	35.4
LS.LMx.LMus.MytMx / S.LBR.Sab.Salv mosaic	0.35	6.5
LS.LBR.Sab.Salv	0.24	4.4
SS.SBR.SMus.MytSS	2.06	38.3

4.2 Habitat Type Descriptions

A description of the biotic and abiotic features within each of the rocky scar ground communities/habitat types identified within the SAC are provided in sections 4.2.1 to 4.2.11.

Species abundance data from the quadrats and under-boulder timed searches on each Phase II transect are presented in tables. Within the tables, numbers represent counts or percentage cover and the letters represent the abundance according to the SACFOR scale.

The mean similarity between communities within each habitat type has also been calculated (where more than 1 transect was sampled) using the Bray-Curtis index. This is supported by the results of the SIMPER routine which looks at the role of individual species in contributing to the overall similarity of both quadrat timed search data within each habitat type (where two or more samples exist).

4.2.1 LR.HLR.MusB.Sem.LitX

The LR.HLR.MusB.Sem.LitX sub-biotope (Semibalanus balanoides and Littorina spp. on exposed to moderately exposed eulittoral boulders and cobbles) is described by the Marine Habitat Classification (04.05)[9] as:

"*Large patches of boulders, cobbles and pebbles in the eulittoral zone on exposed to moderately exposed shores colonised by the barnacle [Semibalanus balanoides] and, on larger rocks, the limpet [Patella vulgata]. The winkles [Littorina littorea] and [Littorina saxatilis] and the whelk [Nucella lapillus] are typically found in high numbers on and around cobbles and smaller boulders, while the anemone [Actinia equina] occurs in damp areas between and underneath larger boulders. Between the cobbles and pebbles, the mussel [Mytilus edulis] occasionally occurs, but always at low abundance, as does the crab [Carcinus maenas] and gammarid amphipods. Ephemeral green seaweeds such as [Ulva intestinalis] may cover cobbles and boulders. The foliose red seaweeds [Chondrus crispus], [Mastocarpus stellatus] and [Osmundea pinnatifida] as well as the wrack [Fucus vesiculosus] may also occur in low abundance on cobbles and boulders. The top shells [Gibbula cineraria] and [Gibbula umbilicalis] can, on more sheltered shores, be found among the seaweeds or underneath the boulders. The barnacle [Austrominius modestus] is present on some shores*."

The LR.HLR.MusB.Sem.LitX communities were found to occupy the small mid-upper shore scars throughout the study area which were formed ubiquitously of boulders and cobbles over sediment (Figures 6 to 9). The communities that were dominated by barnacle and *Littorina* spp. were most prevalent on the coastline adjacent to Silloth where they stretched almost continuously along the shore for approximately 4km (Figure 7). The width of shore over which the sub-biotope stretched ranged between 5m and 20m at Silloth, up to ca. 90m on the broad flats off Mawbray. Photographs of the LR.HLR.MusB.Sem.LitX sub-biotope at Transect T8 (between Mawbray and Silloth), and at Transect T25A (in Moricambe Bay) are shown in Plates 1 and 2 respectively. A comparison of the Plates highlights the variations in the physical attributes within the sub-biotope between the inner and outer estuary.

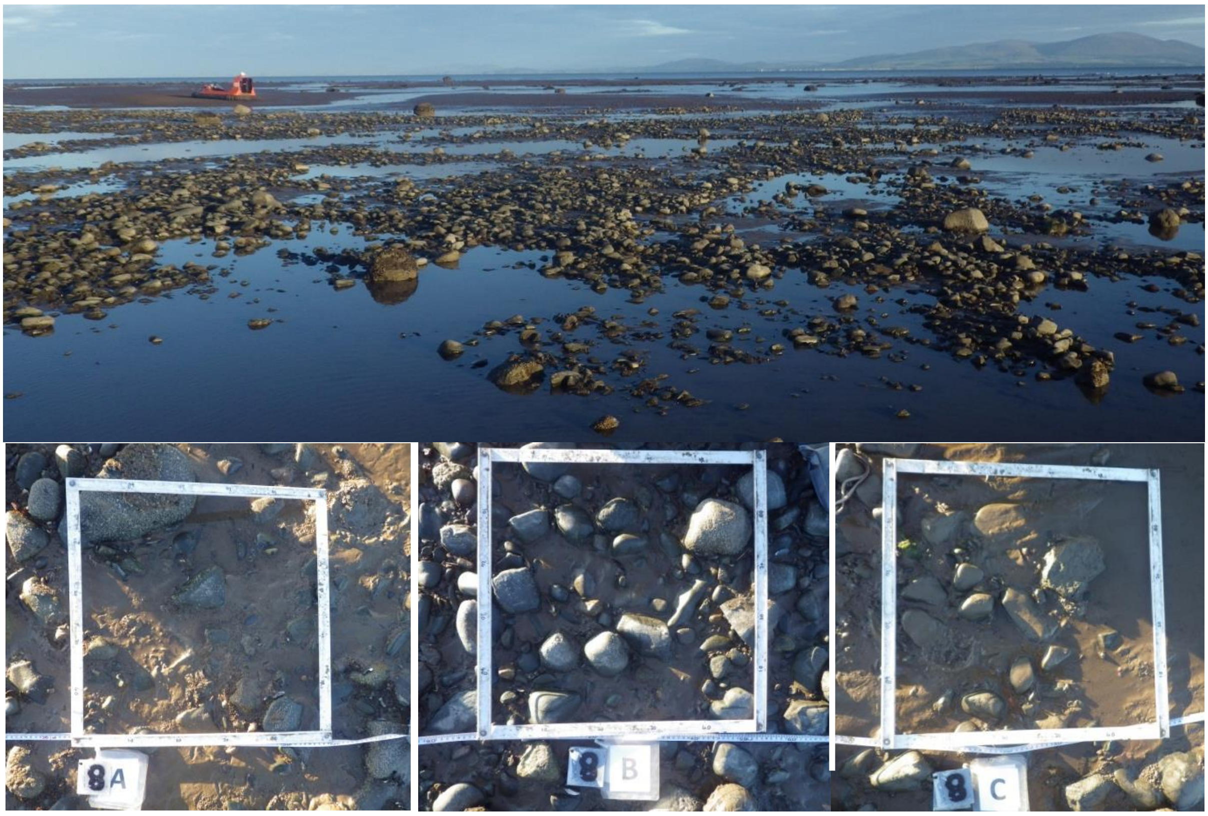

Plate 1. Photographs of the LR.HLR.MusB.Sem.LitX sub-biotope within the Solway Firth SAC at T8.

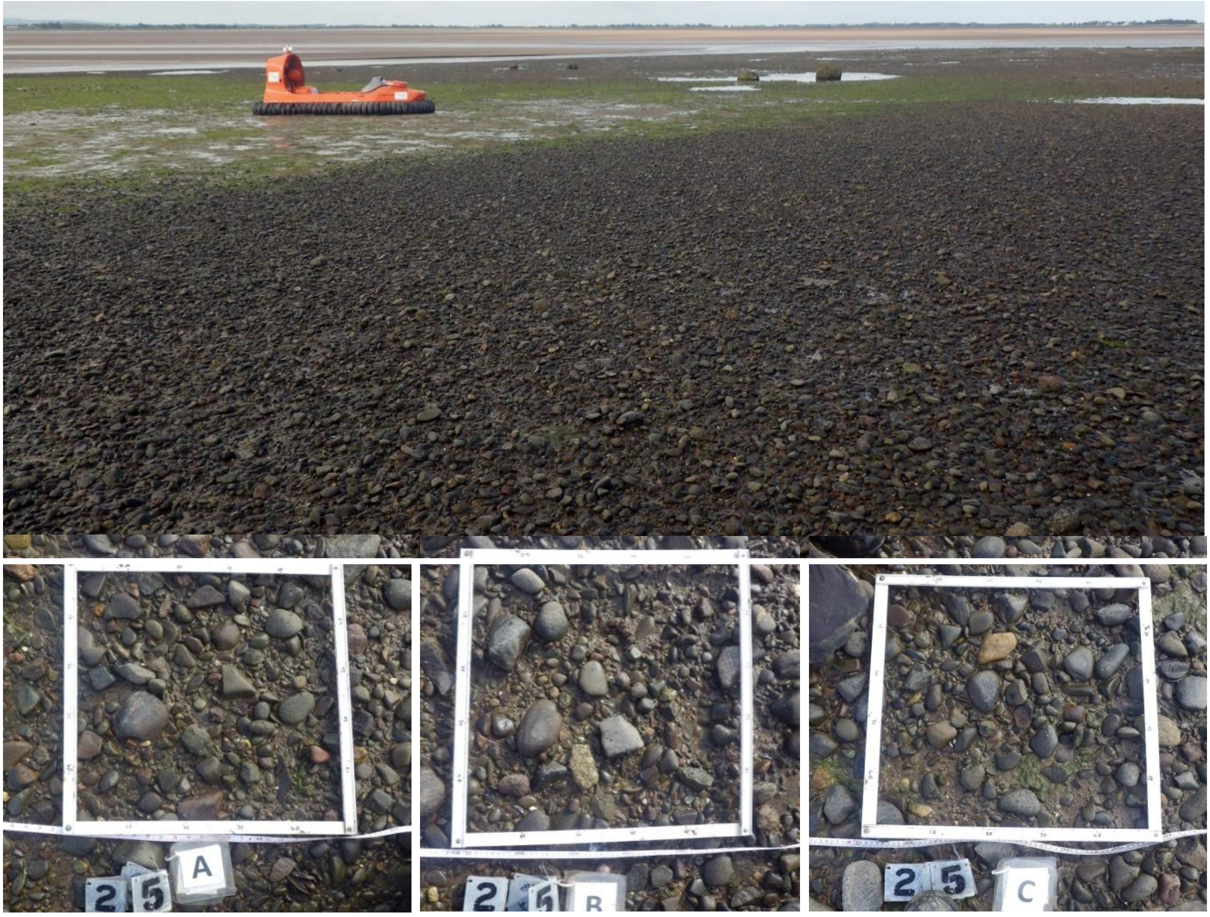

Plate 2. Photographs of the LR.HLR.MusB.Sem.LitX sub-biotope within the Solway Firth SAC at T25A.

The LR.HLR.MusB.Sem.LitX communities sampled within the Solway SAC correspond well with the description of the sub-biotope in the Marine Habitat Classification[9]. Dog whelks (*Nucella lapillus*) were absent however, as were anemones (*Actinia* spp.) and limpets (*Patella* spp.) (Table 3). The absence of these species is probably associated with the lack of boulders which would otherwise provide more stable substrate, as well as shaded damp niches for such species. With the exception of the very rare occurrence of *Porphyra* spp., red algae were absent (probably because of the mid-high shore height). Fucoids were also rare except at transect T18B where the LR.HLR.MusB.Sem.LitX communities transitioned with *Fucus vesiculosus* dominated communities (LR.LLR.F.Fves) higher on the shore. Green algae species including *Ulvae* and *Chaetomorpha* were rare throughout the habitat type. Barnacles (*Semibalanus balanoides*) were most numerous (frequent to abundant) on the transects adjacent to Silloth. Elsewhere, their cover was occasional according to the SACFOR scale. The upper shore insect *Anurida maritima* was found in low numbers at transects T17 and T18, adjacent to Silloth. The largest of the British *Littorina* species, *Littorina littorea,* was most frequently sampled on the transects adjacent to Mawbray. This species appeared to become displaced by greater numbers of the smaller species *Littorina saxatilis* higher in the estuary*.* *Littorina littorea* were absent from the transects upstream of Silloth*,* whilst *Littorina saxatilis* were most abundant in Moricambe Bay. The Australasian barnacle *Austrominius modestus* was also rare on 6 of the 8 transects sampled.

The taxa observed during the timed search of the under-boulder communities are listed in Table 4. Clusters of *Littorina saxatilis* and individuals of the green shore crab *Carcinus maenas* were the most frequently observed species in the under-boulder communities.

The mean Bray-Curtis similarity between the communities sampled in quadrats on the 8 transects was relatively low at 34%. Those species which provided the highest percentage contribution to similarity are listed in Table 5. The two main characterising taxa, *Littorina saxatilis* and *Semibalanus balanoides*, accounted for the highest proportions of similarity in the biotic data set each accounting for 53% and 19% respectively. The under-boulder communities were less alike (just 22%). *Littorina saxatilis* and *Carcinus maenas* each counted for 68% and 20% of the similarity respectively (Table 6).

Table 3. Species composition in quadrats within the LR.HLR.MusB.Sem.LitX sub-biotope.

Transect	T7			T8			T16B			T17A		
Quadrat	**a**	**b**	**c**	**a**	**b**	**c**	**d**	**e**	**f**	**a**	**b**	**c**
Cirripedia juv.							12	15	10			
Semibalanus balanoides				6	1	<1	18	40	55	20	25	35
Carcinus maenas juv.											2	
Anurida maritima										10	1	
Arenicola marina						2						
Littorina littorea	8	16	5	17	4	4			15	5		1
Littorina saxatilis					2	1	5	16	6	25	11	20
Mytilus edulis (Count)				40		2						
Porphyra purpurea							1					
Fucus vesiculosus									1			
Ulva lactuca						1						
Ulva intestinalis	1	<1	4									
Austrominius modestus (%)	<1	<1			1	<1						
Austrominius modestus (Count)									5			25

Table 3 contd. Species composition in quadrats within the LR.HLR.MusB.Sem.LitX sub-biotope.

Transect	T18B			T19A			T19B			T25A		
Quadrat	**d**	**e**	**f**	**a**	**b**	**c**	**d**	**e**	**f**	**a**	**b**	**c**
Cirripedia juv.									10			
Semibalanus balanoides	8	15	6		<1	<1	2	1	10			
Anurida maritima	6	7										
Littorina saxatilis	26	46	35	1	4	59	30	28	39	69	29	48
Mytilus edulis (Count)									2			
Chaetomorpha												3
Fucus vesiculosus	6	25	3						6			
Peringia ulvae										30	50	40
Austrominius modestus (%)										10	2	24
Austrominius modestus (Count)	4	15	6	<1		<1	<1	1	2	<1	<1	1

Table 4. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LR.HLR.MusB.Sem.LitX biotope.

Transect	T16B	T17A	T18B	T19A	T19B	T25A
Corophium volutator			F			
Austrominius modestus (%)						O
Semibalanus balanoides					F	
Carcinus maenas	F	R	F		C	
Anurida maritima		R				
Lineus spp.					O	O
Arenicola marina	F					
Littorina saxatilis	F	C		F	F	C
Mytilus edulis juv. (Count)	R					
Macoma balthica			O		O	

Table 5. Species contribution in the LR.HLR.MusB.Sem.LitX communities derived from quadrat data.

Species	Mean Abundance per Quadrat	Mean Similarity	% Contribution	Cumulative % Contribution
Littorina saxatilis	4.0	18	53	53
Semibalanus balanoides	2.3	7	19	72
Littorina littorea	1.2	4	11	83
Austrominius modestus	1.2	4	10	93
Austrominius modestus (%)	0.6	1	2	95
Fucus vesiculosus	0.7	1	2	97
Cirripedia juv.	0.7	0	1	98
Anurida maritima	0.5	0	1	99

Table 6. Species contribution in the LR.HLR.MusB.Sem.LitX communities derived from under-boulder timed search data.

Species	Mean Abundance per Transect	Mean Similarity	% Contribution	Cumulative % Contribution
Littorina saxatilis	2	15	68	68
Carcinus maenas	1	4	20	88
Hediste diversicolor	1	1	5	92

4.2.2 LR.MLR.BF.FvesB

The LR.MLR.BF.FvesB biotope (*Fucus vesiculosus* and barnacle mosaics on moderately exposed mid eulittoral rock) is described in the Marine Habitat Classification (04.05)[9] as:

"*Exposed to moderately exposed mid eulittoral bedrock and boulders are frequently characterised by a mosaic of the barnacle [Semibalanus balanoides] and the wrack [Fucus vesiculosus]. The limpet [Patella vulgata] and the whelk [Nucella lapillus] are* *typically present, whilst the anemone [Actinia equina] and small individuals of the mussel [Mytilus edulis] are confined to crevices. Underneath the [F. vesiculosus] is a community of red seaweeds, including [Corallina officinalis], [Mastocarpus stellatus] and [Osmundea pinnatifida], usually with the winkles [Littorina littorea] and [Littorina] spp. present. Opportunistic seaweeds such as [Ulva intestinalis] may occur in patches recently cleared on the rock or growing on the [M. edulis]."*

Communities of *Fucus vesiculosus* on boulders were limited to two small areas of shore adjacent to Silloth where boulders and larger cobbles were set amongst sandy sediments over a shore width of 15 to 25 m (Figure 7, Plate 3). Where *Fucus vesiculosus* dominated elsewhere in the SAC, it grew on less stable, mixed substrates (LR.LLR.F.Fves.X). Where present, the LR.MLR.BF.FvesB communities were either the only littoral rock communities found on the mid-upper shore (above littoral sediments), or they were present on the mid-shore below *Littorina* spp. and barnacle communities (LR.HLR.MusB.Sem.LitX).

Plate 3. Photographs of the LR.MLR.BF.FvesB biotope within the Solway Firth SAC at T15.

The species composition of the LR.MLR.BF.FvesB biotope within the Solway Firth SAC (Table 7) corresponds only loosely with the description of the biotope in the Marine Habitat Classification[9]. The distribution of the communities, particularly the distribution of *Fucus vesiculosus* (the main characterising species), was patchy at the scale of sampling. Consequently only rare abundances of *Fucus vesiculosus* were captured in the randomly placed quadrats, despite the abundance of the fucoid visually defining the biotope quite well (Plate 3, top photograph). Communities were species-poor compared to those usually expected within the biotope. Secondary characterising taxa such as *Nucella lapillus*, *Actinia* spp., and red and green algae were not recorded within the quadrats, nor were they observed in the wider area of biotope. *Mytilus edulis* was found in under-boulder communities, as were small individuals of *Carcinus maenas* (Table 8). *Patella* spp. were rare on the underside of the boulders, whilst *Hediste diversicolor* inhabited the under-boulder sediments in frequent numbers. The low species richness observed within the LR.MLR.BF.FvesB biotope in the SAC is likely to be associated with scouring and smothering effects of the muddy sands which mosaic with the rocky communities.

Table 7. Species composition in quadrats within the LR.MLR.BF.FvesB biotope.

Transect	T15		
Quadrat	a	b	c
Cirripedia juv.		10	3
Semibalanus balanoides	25	20	50
Littorina littorea	11	9	15
Littorina saxatilis		40	11
Fucus vesiculosus	2		5
Austrominius modestus	10	3	20

Table 8. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LR.MLR.BF.FvesB biotope.

Transect	T15
Carcinus maenas	C
Patella spp.	R
Littorina saxatilis	C
Mytilus edulis juv. (Count)	C
Hediste diversicolor	F

4.2.3 LR.LLR.F.FSpi.X

LR.LLR.F.FSpi.X (*Fucus spiralis* on full salinity upper eulittoral mixed substrata) is described in the Marine Habitat Classification (04.05)[9] as:

"*Moderately exposed to sheltered full salinity upper eulittoral mixed substrata characterised by a band of the wrack [Fucus spiralis]. Occasional clumps of the wrack [Pelvetia canaliculata] can be overgrowing the black lichen [Verrucaria Maura] and the olive green lichen [Verrucaria mucosa]. On the more stable boulders underneath the fronds the red crust [Hildenbrandia rubra] can be found along with the barnacle [Semibalanus balanoides] and the limpet [Patella vulgata]. The winkles [Littorina littorea] and [Littorina saxatilis] can be found on and among the boulders and cobbles, while amphipods and the crab [Carcinus maenas] can be present either underneath the boulders or among the brown seaweeds. The green seaweed [Ulva intestinalis] can occur in some abundance especially during the summer*."

The communities that were characterised by *Fucus spiralis* and *not* subject to variable salinity were limited in extent on the English shores of the Solway Firth SAC. The LR.LLR.F.FSpi.X sub-biotope was found in two small patches on the mid-upper shore adjacent to Kinburness (just north of Silloth, Figure 7). They were also found on the southern shore of Moricambe Bay (Figure 8). At Kinburness the LR.LLR.F.FSpi.X sub-biotope occupied widths of shore between 15 and 40 m wide below much narrower bands of LR.HLR.MusB.Sem.LitX. In Moricambe Bay the the LR.LLR.F.FSpi.X communities stretched over a much broader area (ca. 70m) but the fucoid wracks were more patchy and more obviously influenced by silt deposition. In the bay, *Fucus spiralis* continued to mosaic with communities dominated by *Ulva* spp. over an additional 140 m up the shore (Figure 8). This area was mapped as a mosaic of LR.LLR.F.FSpi.X and LR.FLR.Eph.Ent communities. Photographs of the *Fucus spiralis* communities in Moricambe Bay taken during the Phase I and Phase II survey are shown in Plates 3 and 4.

Plate 4. Photographs of the LR.LLR.F.FSpi.X sub- biotope in Moricambe Bay taken during the Phase I survey.

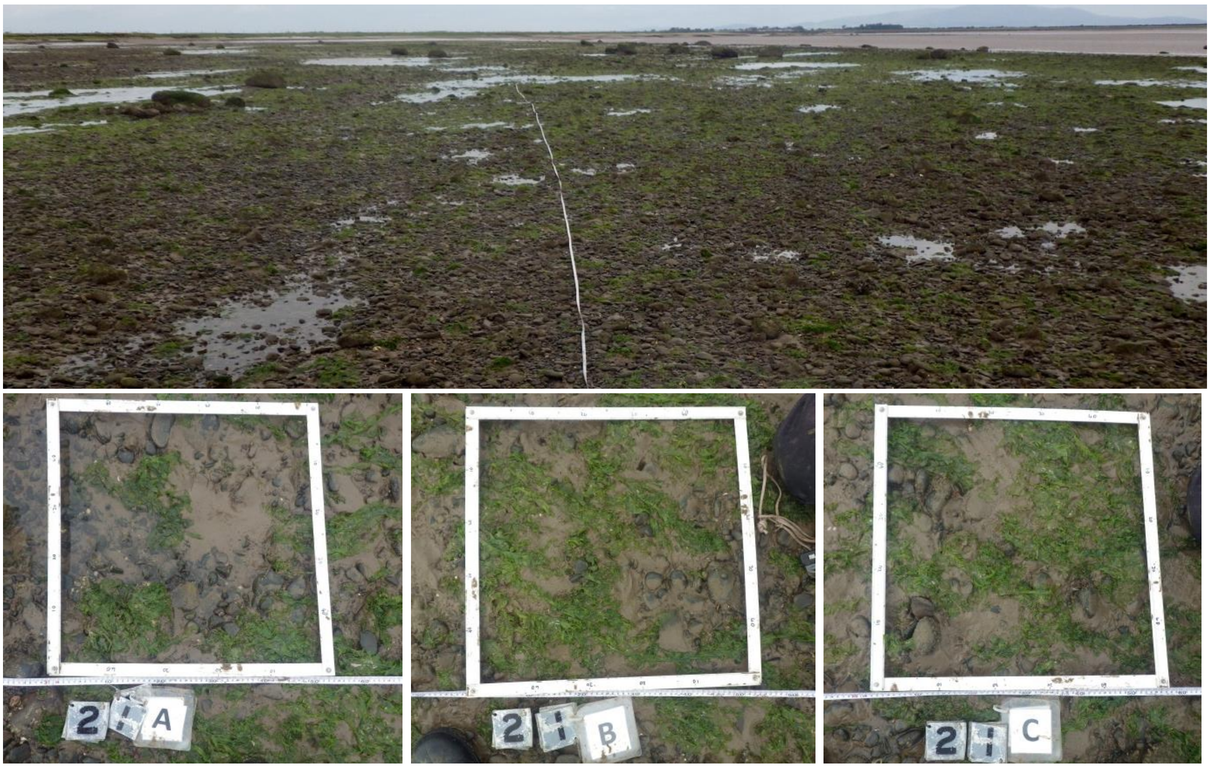

Plate 5. Photographs of the LR.LLR.F.FSpi.X sub-biotope within the Solway Firth SAC at T21.

Due to the limited extent of the LR.LLR.F.FSpi.X sub-biotope, quantitative sampling was limited to a single transect within Moricambe Bay. Due to the patchiness of *Fucus spiralis*, which is the main characterising species, the communities recorded on transect T21 (Table 9) fit only weakly with the Marine Habitat Classification description[9] of the sub-biotope. *Fucus spiralis* was recorded in rare abundance in just one quadrat. A number of secondary charactesing species such as barnacles (including the non-native species *Austrominius modestus*) were present in rare abundance, whilst *Littorina spp.* were occaionally present. The percentage cover of the opportunistic green macrolgae *Ulva lactuca* in the three quadrats sampled was either abundant or superabundant accoring to the SACFOR scale. The abundance the algae appeared to have increased in the LR.LLR.F.FSpi.X sub-biotope in Moricambe Bay between the Phase I and the Phase II surveys.

Additional species observed during searches of the under-boulder communities included juvenile mussels, *Carcinus maenus* and the ragworm *Hediste Diversicolor* (Table 10).

Table 9. Species composition in quadrats within the LR.LLR.F.FSpi.X sub-biotope.

Transect	T21		
Quadrat	a	b	c
Cirripedia juv.	<1	1	
Semibalanus balanoides	<1	<1	1
Littorina littorea	6	5	
Littorina saxatilis			1
Fucus spiralis	1		
Ulva lactuca	25	70	65
Austrominius modestus	<1		

Table 10. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LR.LLR.F.FSpi.X sub-biotope.

Transect	T21
Carcinus maenas	O
Littorina littorea	O
Littorina saxatilis	O
Mytilus edulis juv. (Count)	F
Hediste diversicolor	O

4.2.4 LR.LLR.F.FVes.X

The LR.LLR.F.FVes.X habitat type (*Fucus vesiculosus* on mid eulittoral mixed substrata) is described in the Marine Habitat Classification (04.05)[9] as:

"*Sheltered and very sheltered mid eulittoral pebbles and cobbles lying on sediment in fully marine conditions typically characterised by the wrack [Fucus vesiculosus]. The wrack [Ascophyllum nodosum] can occasionally be found on larger boulders while the barnacle [Semibalanus balanoides] and the limpet [Patella vulgata] also can be present on the cobbles with the whelk [Nucella lapillus] preying on the barnacles and on the mussel [Mytilus edulis]. Winkles, particularly [Littorina littorea] and [Littorina obtusata], commonly graze the biofilm on the seaweeds, while [Littorina saxatilis] can be found in crevices. Ephemeral seaweeds such as [Ulva intestinalis] may be present in this sub-biotope. The sediment between patches of hard substrata often contains the polychaete [Arenicola marina] or the polychaete [Lanice conchilega], while a variety of gastropods and the crab [Carcinus maenas] occur on and under cobbles*."

The only place where *Fucus vesiculosus* was observed to colonise mixed substrates was on a small patch of the mid-upper shore (ca. 40 m wide) just north of Kinburness (Figure 7). There, boulders and cobbles overlaid each other amongst compacted muddy sands. The *Fucus vesiculosus* communities transitioned with slightly more scoured areas lower on the shore and to the east which were devoid of fucoids. These communities were instead characterised by barnacles and *Littorina* spp. (LR.HLR.MusB.Sem.LitX).

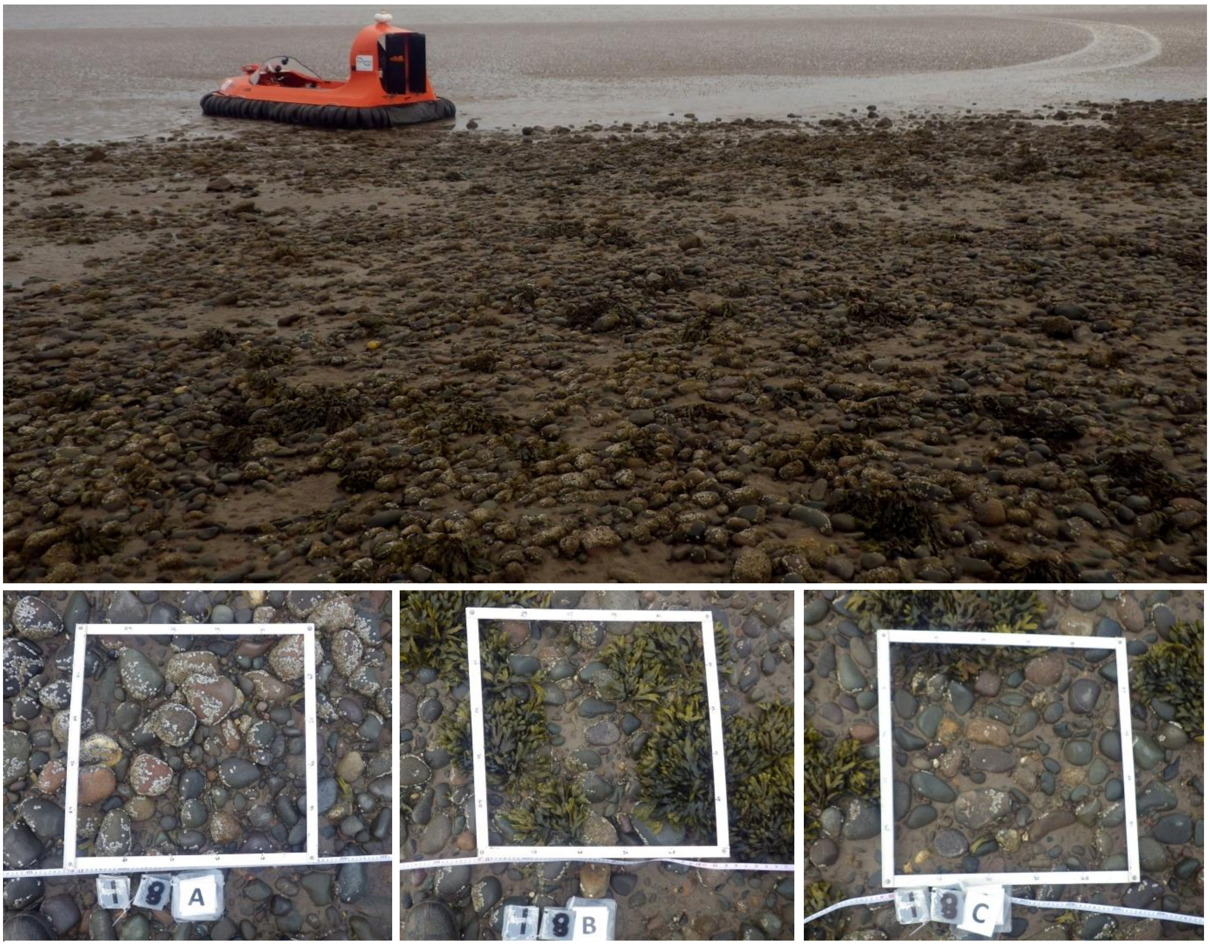

Plate 6. Photographs of the LR.LLR.F.FVes.X sub-biotope within the Solway Firth SAC at T18A.

Table 11 lists the species and abundance data gathered at transect T18A. The communities recorded within the LR.LLR.F.FVes.X sub-biotope are consistent with the Marine Habitat Classification[9] in terms of the main characterising species, but the secondary communities within the Solway Firth SAC were comparatively species-poor. *Fucus vesiculosus* was the only algae species present, whilst the fauna was mostly limited to common numbers of *Littorina saxatilis* (which were less than 1cm in size), and an occasional cover of barnacles. The barnacle populations were comprised of roughly equal numbers of *Semibalanus balanoides* and *Austrominius modestus*.

Given the compactness of the substrate, the under-boulder communities were also poor, with additional species observed during the two minute search being limited to just a single individual of *Carcinus maenas* (Table 12).

Table 11. Species composition in quadrats within the LR.LLR.F.FVes.X sub-biotope.

Transect	T18A		
Quadrat	a	b	c
Semibalanus balanoides	12	5	2
Anurida maritima	2	2	2
Littorina saxatilis	42	52	35
Fucus vesiculosus	1	45	4
Austrominius modestus	8	5	2

Table 12. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LR.LLR.F.FVes.X sub-biotope.

Transect	T21
Carcinus maenas	R
Littorina saxatilis	F

4.2.5 LR.LLR.FVS.FSpiVS

The LR.LLR.FVS.FSpiVS biotope (*Fucus spiralis* on sheltered variable salinity upper eulittoral rock) is described in the Marine Habitat Classification[9] as:

"*Sheltered to extremely sheltered upper eulittoral bedrock or mixed substrata (boulders, large cobbles or shells on mud) in variable salinity conditions characterised by a band of the spiral wrack [Fucus spiralis]. The ephemeral green seaweed [Ulva intestinalis] is usually found in this species poor biotope. The barnacles [Semibalanus balanoides] and [Austrominius modestus] can be found where suitable substrata are available, while gammarids can be found underneath the fronds of [F. spiralis] and/or underneath the boulders and cobbles. Also found underneath the fronds and among the boulders are the winkles [Littorina saxatilis] and [Littorina littorea] and the crab [Carcinus maenas]*."

The LR.LLR.FVS.FSpiVS biotope was another fucoid dominated biotope that was found to be extremely limited in extent as well as distribution in the study area. The biotope was limited to an area of upper shore (ca. 20 m wide) adjacent to Port Carlisle where surface water from land drains entered the estuary (Figure 9). Lower on the shore a much broader band (ca. 120m) of the brackish water fucoid *Fucus ceranoides* colonised the mid shore. The substrate was comprised of a mixture of cobbles and pebbles on sediment, but in some areas the muddy sands had smothered the stony substrate altogether, particularly where water pooled. Photographs of the biotope and the quadrats that were sampled within it at transect T29 A can be seen in Plate 7.

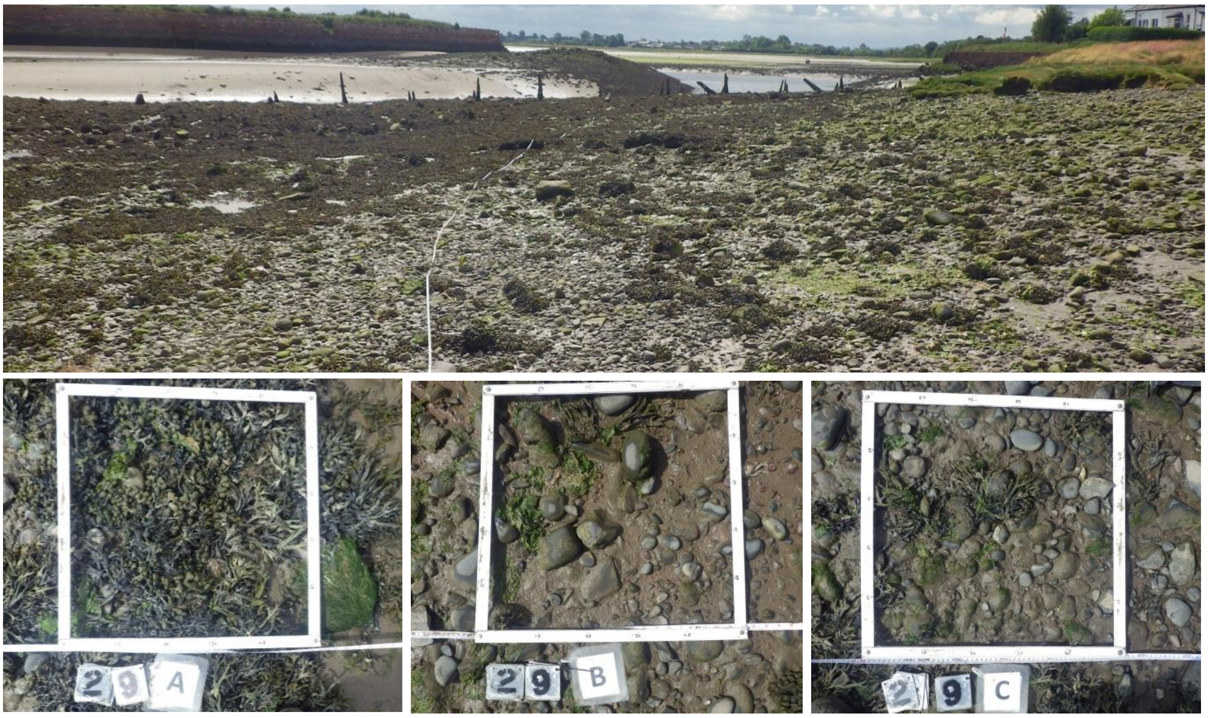

Plate 7. Photographs of the LR.LLR.FVS.FSpiVS habitat type within the Solway Firth SAC at T29.

The species listed as present on transect T29A (Table 13) are largely consistent with the Marine Habitat Classification description of the LR.LLR.FVS.FSpiVS biotope[9]. *Fucus spiralis* was very patchy at the scale of sampling however, and ranged from being absent in quadrat ‘b’ to superabundant in quadrat ‘a’. *Barnacles* and *Littorina* spp. were altogether absent, whilst *Fucus ceranoides* was an additional species that was present, and represents transitioning of LR.LLR.FVS.FSpiVS with the communities of *Fucus ceranoides* (LR.LLR.FVS.Fcer) lower on the shore.

Hediste diversicolor were abundant in the sediments beneath the cobbles and pebbles whilst Gammarids were a rare feature of the under-boulder communities (Table 14).

Table 13. Species composition in quadrats within the LR.LLR.FVS.FSpiVS habitat type.

Transect	T29A		
Quadrat	a	b	c
Gammaridae	1		
Carcinus maenas	1		
Carcinus maenas juv.		1	1
Fucus ceranoides	25	6	12
Fucus spiralis	55		3
Ulva lactuca	4	15	1
Ulva intestinalis	2		10

Table 14. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LR.LLR.FVS.FSpiVS habitat type.

Transect	T29A
Gammarus salinus	R
Hediste diversicolor	A

4.2.6 LR.LLR.FVS.Fcer

The LR.LLR.FVS.Fcer biotope (*Fucus ceranoides* on reduced salinity eulittoral rock) is described in the Marine Habitat Classification[9] as:

"*Very sheltered to extremely sheltered bedrock and stable boulders in the eulittoral zone that are subject to reduced salinity and characterised by the wrack [Fucus ceranoides]. Species richness is typically low in this biotope. The green seaweeds [Ulva intestinalis] and [Ulva lactuca] may be present together with the crab [Carcinus maenas] and the occasional barnacle [Austrominius modestus] and [Semibalanus balanoides]*."

The communities which were characterised by the brackish water fucoid *Fucus ceranoides* were found in one area on the English side of the Solway Firth SAC, adjacent to Port Carlisle (Figure 9). The distribution of *Fucus ceranoides* was split into two distinct patches that were separated by a channel which directed freshwater from land drains out to the main channel of the estuary. The proportion of muddy sand that was mixed with the cobble/pebble substrate varied considerably between the two areas. This distinction can be clearly seen by comparing Plates 8 and 9.

Plate 8. Photographs of the LR.LLR.FVS.Fcer biotope within the Solway Firth SAC at T29B.

Plate 9. Photographs of the LR.LLR.FVS.Fcer biotope within the Solway Firth SAC at T30A.

The two areas were sampled independently (Transect T29B and T30A, Table 15). Despite slight differences in the flora and fauna at each transect, both sets of communities correspond with the EUNIS description[9] of the biotope as a result of the main characterising species. As could be expected, the wracks of *Fucus ceranoides* were more dense at T29B where the proportion of hard substrate was greatest, whilst species more usually associated with littoral sediment habitat types were more prevalent at T30A (e.g. the mud shrimp *Corophium volutator* and mud snail *Peringia ulvae*). Additional under-boulder taxa were not identified at T30A due to lack of underboulder space, but at T29A, the lesser amount of sediment enabled colonisation of under-boulder niches by species such as *Carcinus maenas*, Gammaridae and *Semibalanus balanoides* (Table 16).

The mean similarity between the LR.LLR.FVS.Fcer communities sampled at the two transects using quadrat methods was 40%. Table 17 shows that the main characterising species, *Fucus ceranoides*, contributed 81% to the similarity of the communities. *Ulva lactuca* accounted for the remaining 19%.

Table 15. Species composition in quadrats within the LR.LLR.FVS.Fcer habitat

Transect		**T29B**			**T30A**	
Quadrat	**d**	**e**	**f**	**a**	**b**	**c**
Gammaridae	5		3			
Corophium volutator				4	4	2
Fucus ceranoides	92	18	30	6	6	55
Ulva lactuca	3	<1		15	8	4
Peringia ulvae				80	60	
Ulva intestinalis	1		20			
Austrominius modestus (%)		<1				

type.

Table 16. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LR.LLR.FVS.Fcer habitat type.

Transect	**T29B**	**T30A**
Gammaridae	O	
Semibalanus balanoides	R	
Carcinus maenas	O	

Table 17. Species contribution in the LR.LLR.FVS.Fcer communities derived from quadrat data.

Species	Mean Abundance per Quadrat	Mean Similarity	% Contribution	Cumulative % Contribution
Fucus ceranoides	5.8	33	81	81
Ulva lactuca	2.0	7	19	100

4.2.7 LR.FLR.Eph.Ent

The LR.FLR.Eph.Ent biotope (*Ulva* spp. on freshwater influenced and/or unstable upper eulittoral rock) is described in the Marine Habitat Classification[9] as:

"*Upper shore hard substratum that is relatively unstable (e.g. soft rock) or subject to considerable freshwater runoff is typically very species poor and characterised by a dense mat of [Ulva intestinalis], though [Ulva lactuca] can occur as well. It occurs in a wider zone spanning from the supralittoral down to the upper eulittoral, across a wide range of wave exposures range. This biotope is generally devoid of fauna, except for occasional limpets [Patella vulgata], winkles [Littorina littorea] or [Littorina saxatilis] and barnacles [Semibalanus balanoides]*."

The LR.FLR.Eph.Ent biotope was widely distributed on the rocky scars on the English side of the Solway Firth SAC, but the extent of the biotope, where present, was relatively limited. The LR.FLR.Eph.Ent communities accounted for 7% of the total area of the scar grounds. They were most frequently found on the upper shore, but sometimes extended into the mid-shore. The communities of green algae were distributed intermittently along the shores between Mawbray and Silloth (Figure 6), and on the northern and southern shores of Moricambe Bay (Figure 8, Plate 10). The largest areas of the LR.FLR.Eph.Ent communities by far were found in the inner estuary next to Bowness-on-Solway and Port Carlisle (Figure 9, Plate 11) where the biotope occupied bands on the mid shore ca. 220 m wide. At Port Carlisle the biotope occurred below a narrower band of *Fucus ceranoides* on the upper shore, but elsewhere the biotope more commonly accounted for the entire area of scars which were surrounded by littoral sediments.

Plate 10. Photographs of the LR.FLR.Eph.Ent habitat type within the Solway Firth SAC at T23.

Plate 11. Photographs of the LR.FLR.Eph.Ent habitat type within the Solway Firth SAC at T28.

The communities within the LR.FLR.Eph.Ent biotope found within the Solway Firth SAC (Table 18) broadly match with those in the Marine Habitat Classification[9]. The main characterising species *Ulva intestinalis* was only found to form a dense covering at transect T25B however. Elsewhere, the species was just rare or occasional in abundance. *Ulva lactuca* ranged from being abundant to super abundant in quadrats at T23, and occasional to superabundant at T30B, but was absent from the remaining 3 transects. Species richness was noticeably lower at transects T27 and T28 (adjacent to Bowness-on-Solway) where just two taxa were recorded. At the remaining three transects a number of species associated with littoral sediments added substantially to the overall number of taxa, such species included *Corophium volutator*, the lugworm *Arenicola marina*, the Baltic tellin *Macoma balthica*, and the mud snail *Peringia ulvae*. *Chaetomorpha* spp. was an additional green algae that was present in rare abundance at T25B.

Juvenile mussels (*Mytilus edulis*) and the ragworm *Hediste diversicolor* were other taxa that were recorded in the biotope as a result of carrying out searches of under-boulder communities (Table 19).

The mean similarity between the communities sampled using quadrats within the LR.FLR.Eph.Ent biotope was just 23% (this was the lowest mean Bray-Curtis value of all the communities sampled in this study). The mean similarity of the under-boulder communities was higher at 52%.

Those species which provided the highest percentage contribution to similarity within both the data derived from the quadrats and that from the timed searches within the LR.FLR.Eph.Ent biotope are listed in Tables 20 to 21. The main characterising species, *Ulva* spp., collectively contributed 73% to the overall similarity of the communities sampled using quadrats. The green shore crab *Carcinus maenas* and the polychaete *Hediste diversicolor* equally contributed and accounted for 100% of the similarities between the under-boulder communities.

Table 18. Species composition in quadrats within the LR.FLR.Eph.Ent habitat type.

Transect	T23			T25B			T27			T28			T30B		
Quadrat	23a	23b	23c	25d	25e	25f	27a	27b	27c	28a	28b	28c	30d	30e	30f
Corophium volutator													3	2	1
Semibalanus balanoides	<1	1	<1		2										
Carcinus maenas juv.			2										1		
Arenicola marina juv.		1													
Littorina saxatilis	4	3	4	1		7									
Macoma balthica													1		
Chaetomorpha				1		4									
Ulva lactuca	30	25	45										75	6	15
Peringia ulvae		7													
Ulva intestinalis			1	40	80	12	1		1	4	5	8		1	
Austrominius modestus (%)					<1		6	12	20			3			
Austrominius modestus	<1	<1	<1												

Table 19. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LR.FLR.Eph.Ent habitat type (No timed search was carried out at T25B due to lack of boulders).

Transect	T23	T27	T28	T30
Corophium volutator		O		
Austrominius modestus (%)		F		
Austrominius modestus (Count)	O			
Carcinus maenas	O	O	O	O
Littorina saxatilis	O			
Mytilus edulis juv. (Count)	R			
Hediste diversicolor		C	C	A

Table 20. Species contribution in the LR.FLR.Eph.Ent communities derived from quadrat data.

Species	Mean Abundance per Quadrat	Mean Similarity	% Contribution	Cumulative % Contribution
Ulva intestinalis	2.2	11	50	50
Ulva lactuca	2.3	5	23	72
Austrominius modestus (%)	1.0	4	16	89
Littorina saxatilis	0.7	1	6	95
Semibalanus balanoides	0.3	1	3	98
Carcinus maenas juv.	0.3	1	2	100

Table 21. Species contribution in the LR.FLR.Eph.Ent communities derived from under-boulder timed search data.

Species	Mean Abundance per Transect	Mean Similarity	% Contribution	Cumulative % Contribution
Carcinus maenas	2	26	51	51
Hediste diversicolor	3	26	49	100

4.2.8 LR.FLR.Eph.EntPor

The LR.FLR.Eph.EntPor biotope (*Porphyra purpurea* and *Ulva* spp. on sand-scoured mid or lower eulittoral rock) is described in the Marine Habitat Classification[9] as:

"*Exposed and moderately exposed mid-shore bedrock and boulders occurring adjacent to areas of sand which significantly affects the rock. As a consequence of sand-abrasion, wracks such as [Fucus vesiculosus] or [Fucus spiralis] are scarce and the community is typically dominated by ephemeral red or green seaweeds, particularly the foliose red seaweed [Porphyra purpurea] and green seaweeds such as [Ulva] spp. Under the blanket of ephemeral seaweeds, the barnacles [Semibalanus balanoides] or [Austrominius modestus] and the limpet [Patella* *vulgata] may occur in the less scoured areas, along with the occasional winkles [Littorina littorea] and [Littorina saxatilis]. Few other species are present*."

These communities were mostly found on the mid-low and lower shore rocky scars in Moricambe Bay (Figure 8, Plate 12), but were also found in small areas on the mid shore adjacent to Silloth (Figure 7). As was found for to the LR.FLR.Eph.Ent biotope, the LR.FLR.Eph.EntPor communities mostly occupied entire scars and did not form zonation patterns with other habitat types. Adjacent to Silloth however, the small patches which occupied widths of shore 5-30 m wide were found between littoral sediment communities on the lower shore, and cobbles and pebbles dominated by barnacles and *Littorina* spp. on the mid-upper shore.

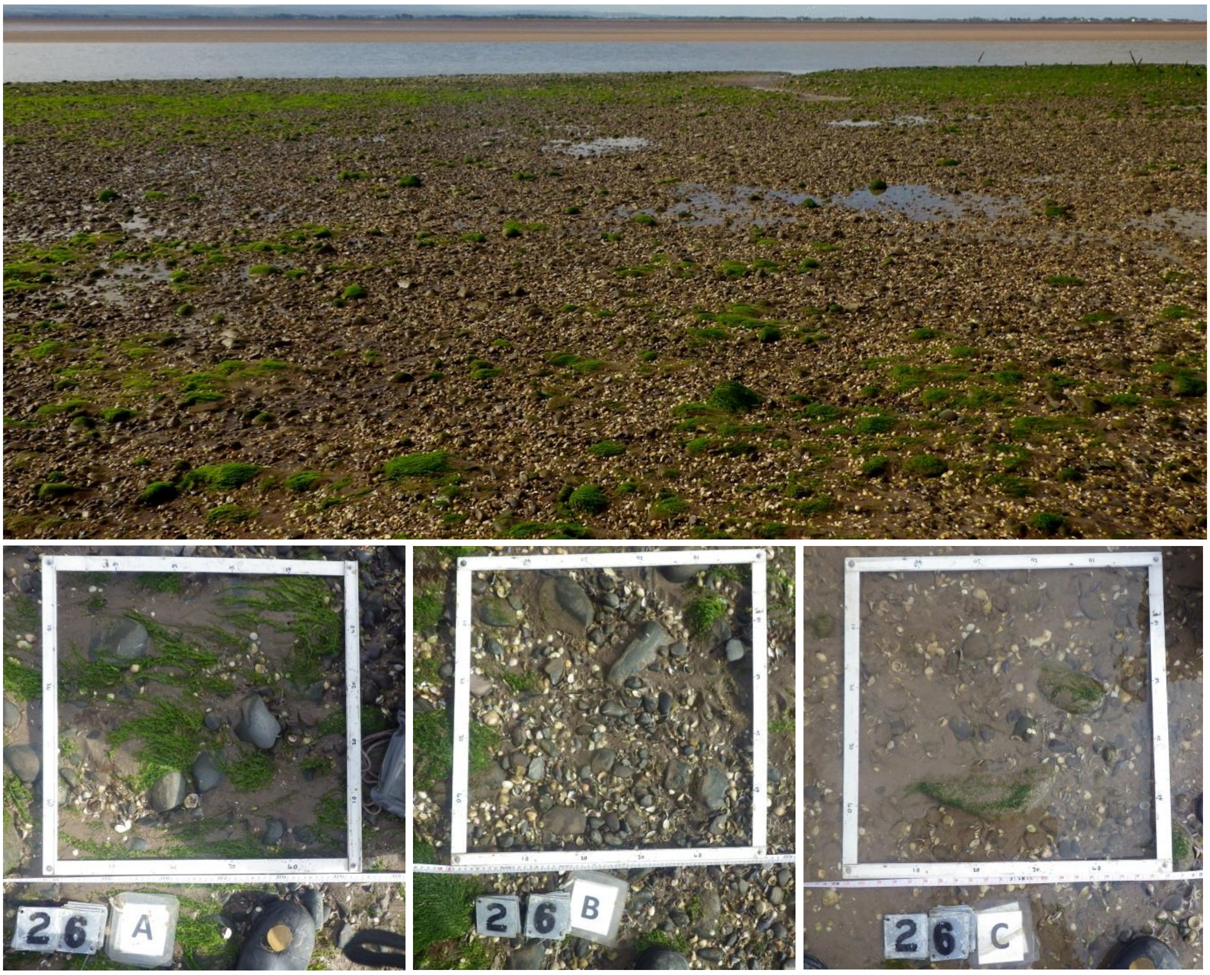

Plate 12. Photographs of the LR.FLR.Eph.EntPor biotope within the Solway Firth SAC at T26.

The LR.FLR.Eph.EntPor communities observed within the Solway Firth SAC in this study closely resemble those described in the Marine Habitat Classification[9]. The presence of *Porphyra purpurea* was very patchy however which meant that the species was only represented by the quadrat data at transect T26 (Table 22). The red algae was noted as being present in the broader area of rocky scar around transects T20 and T22, but never with the same consistency or abundance as the green *Ulva* spp.. The faunal communities which had colonised the mainly mixed substrates were extremely species-poor.

The mean Bray-Curtis similarity between the communities at the three transects was 48%. *Ulva intestinalis* accounted for 73% of the overall similarity whilst *Arenicola marina* (which was quantified by counting casts) contributed the remaining 23% (Table 23).

The under-boulder fauna was richest at transect T26 which was adjacent to the main channel, and included two species of barnacles, as well as juvenile mussels and *Hediste diversicolor* (Table 24). The under-boulder communities were variable between transects (just 14% similar), with juvenile mussels accounting for 68% of the small similarity (Table 25).

Table 22. Species composition in quadrats within the LR.FLR.Eph.EntPor biotope.

Transect	T20			T22			T26		
Quadrat	a	b	c	a	b	c	a	b	c
Arenicola marina	3	3	5	2	2	5			
Arenicola marina juv.									3
Porphyra purpurea							4	1	2
Ulva intestinalis	8	3	30		2	1	30	6	8
Austrominius modestus				<1		<1			

Table 23. Species contribution in the LR.FLR.Eph.EntPor communities derived from quadrat data.

Species	Mean Abundance per Quadrat	Mean Similarity	% Contribution	Cumulative % Contribution
Ulva intestinalis	2.8	35	73	73
Arenicola marina	1.2	13	27	100

Table 24. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LR.FLR.Eph.EntPor biotope.

Transect	T20	T22	T26
Gammarus salinus			O
Austrominius modestus (%)			O/R
Semibalanus balanoides			O/R
Carcinus maenas		R	
Littorina littorea		R	
Mytilus edulis juv. (Count)	O		F
Hediste diversicolor		R	C

Table 25. Species contribution in the LR.FLR.Eph.EntPor communities derived from under-boulder timed search data.

Species	Mean Abundance per Transect	Mean Similarity	% Contribution	Cumulative % Contribution
Mytilus edulis juv. (Count)	2	10	68	68
Hediste diversicolor	2	4	32	100

4.2.9 LR.FLR.Eph.Ent / LR.LLR.F.Fves.X

A mosaic of the *Ulva* spp. dominated communities (LR.FLR.Eph.Ent) and wracks of *Fucus vesiculosus* on mixed substrates (LR.LLR.Fves.X) described above were found on a small area of the mid shore adjacent to Skinburness (Figure 7). The mosaic of communities had established on boulders and cobbles amongst sandy mud over a width of the mid shore which ranged between approximately 10 and 35 m wide. Higher on the shore, communities that were void of algae and which were characterised instead by *Littorina* spp. and barnacles were found (LR.HLR.MusB.SemLitX). Lower on the shore much broader beds of *Mytilus edulis* on mixed sediments were mapped (LS.LBR.LMu.MytMx). Patches of littoral muddy sand communities separated the three rocky substrate habitat types in the area (Plate 13).

This habitat type was considered as a mosaic because of the co-dominance of the two main characterising species, *Ulva intestinalis* and *Fucus vesiculosus*. The two species were roughly equal in abundance in the area, but by chance, a greater percentage cover of *Ulva intestinalis* was sampled (Table 26). The area was obviously subject to tidal scouring which left some areas more disturbed by sediment mobility and smothering than others. For example, the cobbles captured in quadrat 'E' appeared to have been recently uncovered and as such, fewer taxa were recorded than in the two other quadrats. Where scouring appeared to be less severe, species such as *Semibalanus balanoides* and *Littorina saxatilis* were more frequent.

Plate 13. Photographs of the LR.FLR.Eph.Ent / LR.LLR.F.Fves.X mosaic within the Solway Firth SAC at T17B.

Table 26. Species composition in quadrats within the LR.FLR.Eph.Ent / LR.LLR.F.Fves.X mosaic.

Transect	T17B		
Quadrat	d	e	f
Cirripedia juv.		2	1
Semibalanus balanoides	15		3
Anurida maritima	6		
Littorina saxatilis	3		2
Mytilus edulis (Count)		5	1
Porphyra purpurea			2
Fucus vesiculosus	10		2
Ulva intestinalis	35	7	60

4.2.10 LS.LBR.LMus.MytMx

The LS.LBR.LMus.MytMx sub-biotope (*Mytilus edulis* beds on littoral mixed substrata) is described best by the Marine Habitat Classification[9] under the biotope code of LS.LMx.LMus.Myt.Mx (which is no longer accepted):

"*Mid and lower shore mixed substrata (mainly cobbles and pebbles on fine sediments) in a wide range of exposure conditions and with aggregations of the* *mussel [Mytilus edulis] colonising mainly the sediment between cobbles, though they can extend onto the cobbles themselves. The mussel aggregations can be very dense and support various age classes. In high densities the mussels bind the substratum and provide a habitat for many infaunal and epifaunal species. The wrack [Fucus vesiculosus] is often found attached to either the mussels or the cobbles and it can occur at high abundance. The mussels are also usually encrusted with the barnacles [Semibalanus balanoides], [Austrominius modestus] or [Chtamalus] spp., especially in areas of reduced salinity. The winkles [Littorina littorea] and [L. saxatilis] and small individuals of the crab [Carcinus maenas] are common amongst the mussels, whilst areas of sediment may contain the lugworm [Arenicola marina], the sand mason [Lanice conchilega] and other infaunal species. Pools are often found within the mussel beds that support algae such as [Chondrus crispus]. Where boulders are present they can support the limpet [Patella vulgata], the dogwhelk [Nucella lapillus] and the anemone [Actinia equina]. [Ostrea edulis] may occur on the lowest part of the shore. There are few infaunal samples for this biotope, hence the characterising species list below shows only epifauna. Where infaunal samples have been collected for this biotope, they contain a highly diverse range of species including nematodes, [Anaitides mucosa], [Hediste diversicolor], [Polydora] spp., [Pygospio elegans], [Eteone longa], oligochaetes such as [Tubificoides] spp., [Semibalanus balanoides], a range of gammarid amphipods, [Corophium volutator], [Jaera forsmani], [Crangon crangon], [Carcinus maenas], [Hydrobia ulvae] and [Macoma balthica]*."

The LS.LBR.LMus.MytMx sub-biotope accounted for 35% of the total area of intertidal scar ground in the study area; it covered the largest expanse of all the habitat types observed by a considerable margin (Table 2). Beds of mussels (where individuals were ca. 3cm long) dominated the mid-lower shore in the lower extent of the SAC between Mawbray and Silloth (Figure 6, Plate 14). The largest bed in that area stretched over 1200 m from the mid to the lower shore and was ca. 750 m wide. The mussels were generally found settled on a few inches of sandy silt that was layered above a more firm foundation of pebbles and cobbles. At the transition from the mid to lower shore, the mussel beds were often found to mosaic with patches of *Sabellaria alveolata* (LS.LBR.Sab.Salv), particularly at the south-western boundary of the SAC off the coast at Mawbray. Communities of mussels continued intermittently along the lower shore towards Silloth. Two patches of mussels at the low water mark had settled loosely on well-sorted medium sand and were therefore considered likely to be ephemeral. These patches were not considered to fall within the definition of rocky scars, but to ensure that the habitat information was not lost between the separate rocky scar and littoral sediment survey contracts, these beds have been mapped as 'ephemeral LS.LMx.LMus.Myt.Sa' (Figure 6). Beds of mussels on mixed substrates returned further towards the inner estuary and continued along the lower shore between Silloth and Kinburness. There, tidal scouring had removed the finer muddy sediments which characterised the mid shore in that area (below boulder and cobbles communities higher on the shore).

The scars that were characterised by LS.LBR.LMus.MytMx communities within Moricambe Bay were more limited in extent (Figure 8). The mussel communities were comprised of dense aggregations of smaller *Mytilus edulis* (<2cm) which had established amongst sandy mixed sediments and were often covered by a thin layer of silt (Plate 15).

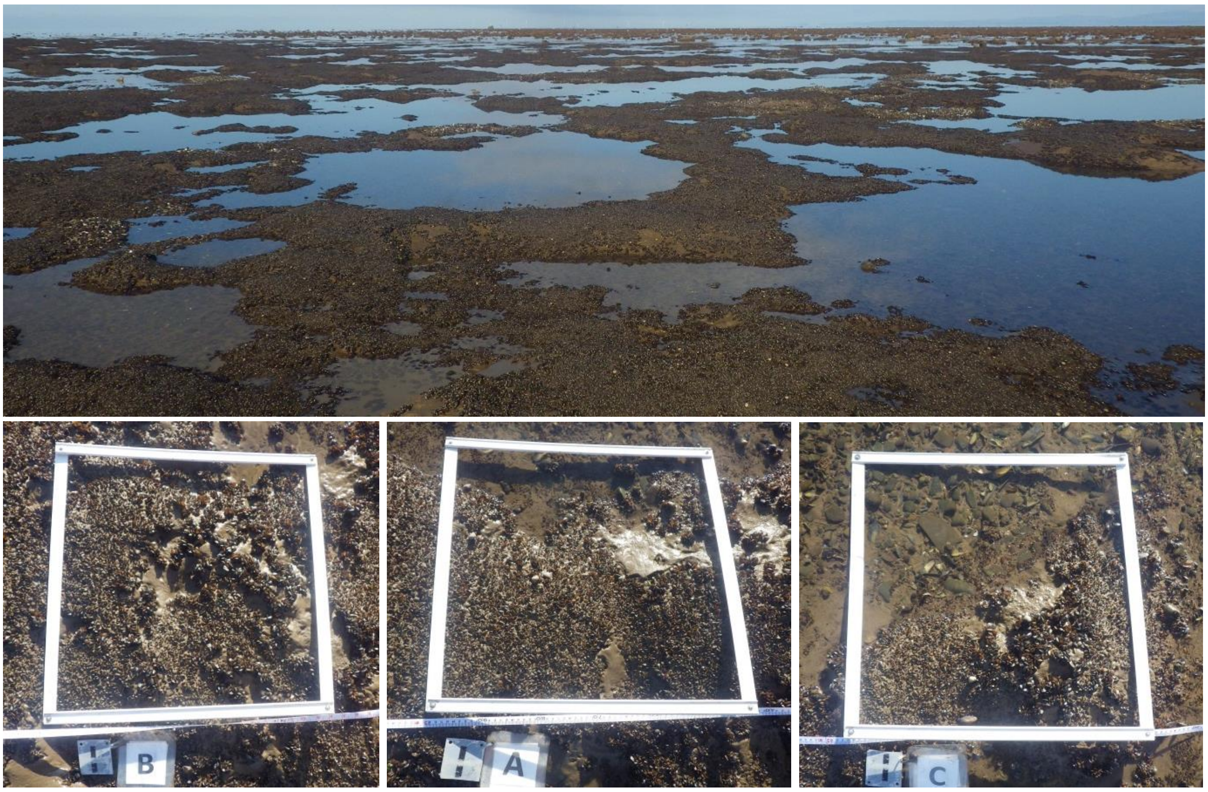

Plate 14. Photographs of the LS.LBR.LMus.MytMx sub-biotope within the Solway Firth SAC at T1.

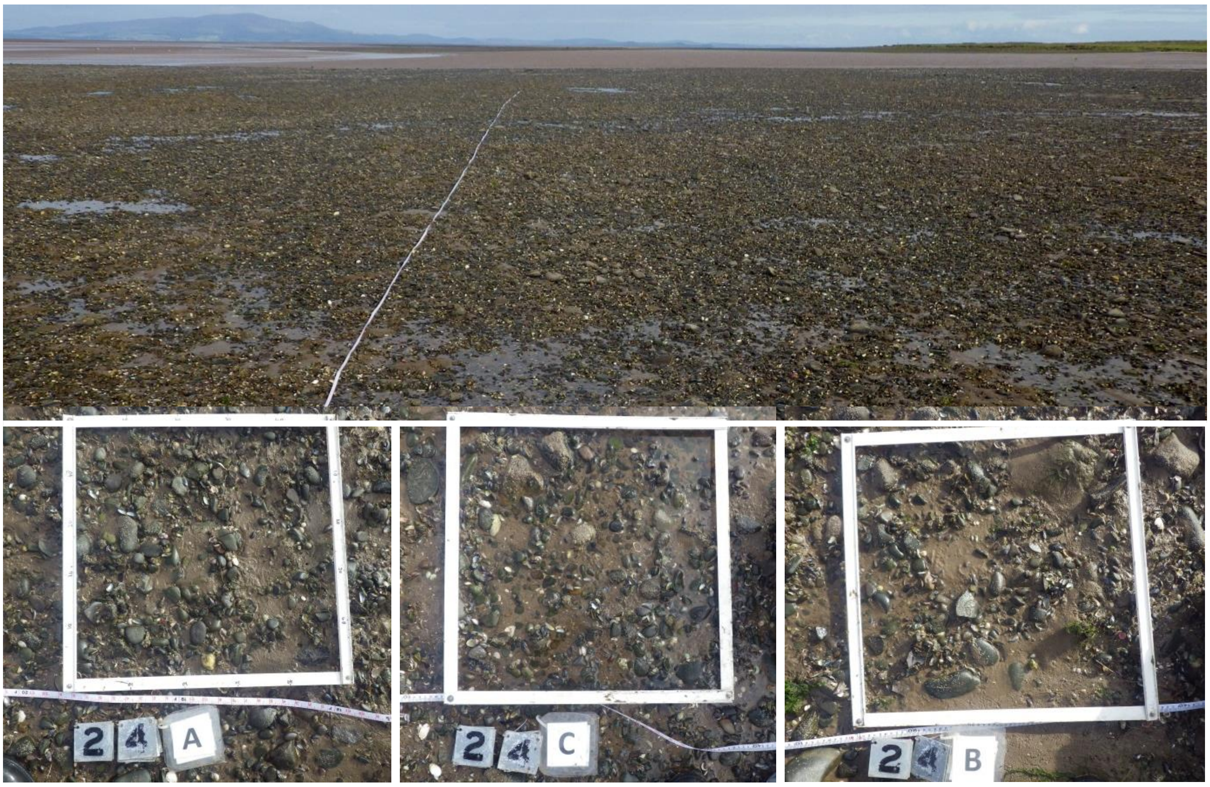

Plate 15. Photographs of the LS.LBR.LMus.MytMx sub-biotope within the Solway Firth SAC at T24.

The LS.LBR.LMus.MytMx communities sampled during the Phase II surveys of the rocky scars correspond closely with the description of the sub-biotope in the Marine Habitat Classification[9]. A range of age classes of Mytilus edulis dominated the communities, whilst many of the secondary characterising taxa, including green and red algae species and barnacles, were present but were rare (Table 27). *Littorina* spp. were often recorded in the quadrats however, and were usually frequent in abundance. The infauna was not specifically sampled, but *Arenicola marina* casts, *Macoma balthica* and Gammaridae were occasionally observed on the sediment surface.

The mean similarity between the LS.LBR.LMus.MytMx communities that were sampled using quadrats was 41%. Not surprisingly SIMPER analysis determined that the main characterising species *Mytilus edulis* accounted for the greatest contributions to community similarities in the quadrats (Table 28). *Littorina littorea* and two species of barnacle followed, each contributing 19% and 10% respectively.

An additional 5 taxa were recorded within the sub-biotope during the timed search of under-boulder communities (Table 29). These species were *Actinia equina*, *Nucella lapillus* (which prey upon mussels), gammarid shrimp and the polychaetes *Hediste diversicolor* and *Spirobranchus*. The under-boulder communities were just 23% similar between the transects, with *Nucella lapillus* accounting for 47% of the similarity.

Table 27. Species composition in quadrats within the LS.LBR.LMus.MytMx sub-biotope.

Transect	T1			T5			T6			T9			T10			T11		
Quadrat	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Semibalanus balanoides (%)							<1		2	1	1	<1	8	1	<1	<1	<1	3
Arenicola marina											1					1		
Sabellaria alveolata (%)							1	4	1									
Littorina littorea	12	1	12		1		1			32	30	22	4	4	4	21	5	8
Littorina saxatilis														1				
Nucella lapillus							11	1	5							1		
Mytilus edulis juv. (%)	80	85	55	20	8	15	20	4	6	75	75	75	6	2	20	20	45	2
Mytilus edulis (count)				1														
Porphyra purpurea						3												
Ulva intestinalis						3	1											
Austrominius modestus (%)					<1	<1				<1	<1	<1	2	1	1	2	<1	1
Hydrozoa								1										

Table 27 contd. Species composition in quadrats within the LS.LBR.LMus.MytMx sub-biotope.

Transect	T12			T13			T14			T17C			T24			T25C		
Quadrat	a	b	c	a	b	c	a	b	c	g	h	i	a	b	c	g	h	i
Cirripedia juv.											2							
Gammaridae							8	10										
Semibalanus balanoides (%)				1		1							1	1	1	<1	<1	2
Carcinus maenas juv.															1	1		
Arenicola marina				2														
Littorina littorea				15	13	67								7	10	6	3	14
Mytilus edulis juv (%)	20	75	10	35	35	6	40	60	60				3	3	1	4	4	2
Mytilus edulis (Count)	2	5								25	25	2	15	12	6	20	17	7
Macoma balthica										1	1		1					
Chaetomorpha															1	1	1	
Cladophora													1	2				
Porphyra purpurea		2								1		1						
Ulva lactuca		1	<1	1						1	1	2				1	1	
Ulva intestinalis			<1							3	5	2						
Austrominius modestus (%)				2	1	3										<1	<1	4
Austrominius modestus													2	1	2			

Table 28. Species contribution in the LS.LBR.LMus.MytMx communities derived from quadrat data.

Species	Mean Abundance per Quadrat	Mean Similarity	% Contribution	Cumulative % Contribution
Mytilus edulis (%)	4.5	26	62	62
Littorina littorea	2.1	8	19	82
Semibalanus balanoides	0.6	2	6	88
Austrominius modestus (%)	0.5	2	4	91
Mytilus edulis (Count)	0.9	1	3	95
Ulva intestinalis	0.3	1	1	96
Ulva lactuca	0.3	1	1	98
Porphyra purpurea	0.2	0	1	99
Arenicola marina	0.2	0	0	99

Table 29. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LS.LBR.LMus.MytMx habitat type.

Transect	T5	T6	T9	T10	T14	T17C	T24	T25C
Actinia equina		3	2	2	3			
Gammarus salinus			2					
Austrominius modestus (%)				3				
Semibalanus balanoides				3				
Spirobranchus			1					
Nucella lapillus	5	3	3	2	3			
Mytilus edulis juv. (%)	3			4	4			
Hediste diversicolor						4	4	

Table 30. Species contribution in the LS.LBR.LMus.MytMx communities derived from under-boulder timed search.

Species	Mean Abundance per Transect	Mean Similarity	% Contribution	Cumulative % Contribution
Nucella lapillus	2	11	47	47
Actinia equina	1	5	22	70
Hediste diversicolor	1	4	16	85
Mytilus edulis juv. (%)	1	3	15	100

4.2.11 LS.LBR.Sab.Salv

The LS.LBR.Sab.Salv biotope (*Sabellaria alveolata* reefs on sand-abraded eulittoral rock) is described in the Marine Habitat Classification[9] as:

"*The sedentary polychaete [Sabellaria alveolata] (honeycomb worm) builds tubes from sand and shell. On exposed shores, where there is a plentiful supply of* *sediment, [S. alveolata] can form honeycomb reefs on boulders and low-lying bedrock on the mid to lower shore. These [S. alveolata] reefs are quite distinct from the mosaic of seaweeds and barnacles or red seaweeds (FK; MB) generally associated with moderately exposed rocky shores though many of the same species are present. These include the anemone [Actinia equina], the barnacles [Semibalanus balanoides] and [Austrominius modestus], the limpet [Patella vulgata], the top shell [Gibbula cineraria] and the winkle [Littorina littorea]. The whelk [Nucella lapillus] and the mussel [Mytilus edulis] is also present on the boulders whereas the polychaete [Lanice conchilega] is restricted to the associated sediment areas. Scour resistant red seaweeds including [Palmaria palmata], [Corallina officinalis], [Mastocarpus stellatus], [Chondrus crispus], [Ceramium nodulosum], [Osmundea pinnatifida], [Polysiphonia] spp. and coralline crusts can also be present where suitable substrata exist. Brown and green seaweeds also present include [Fucus serratus], [Fucus vesiculosus], [Cladostephus spongiosus], [Enteromorpha intestinalis] and [Ulva lactuca].*"

There was just one area on the English side of the SAC where reefs of *Sabellaria alveolata* solely dominated the intertidal scars; that area was at the far south-western extent of the SAC, off the coast at Mawbray. The distinctive honeycomb reefs (Plate 16) covered an area of 0.24 km^2 on the lower shore which stretched from the low water mark up the shore to a maximum distance of 720 m (Figure 6). The communities of *Sabellaria alveolata* were surrounded by mussel beds (LS.LBR.LMu.MytMx) which resulted in broad transitional areas up the shore (e.g. southwest-northeast direction) where the two habitat types mosaicked.

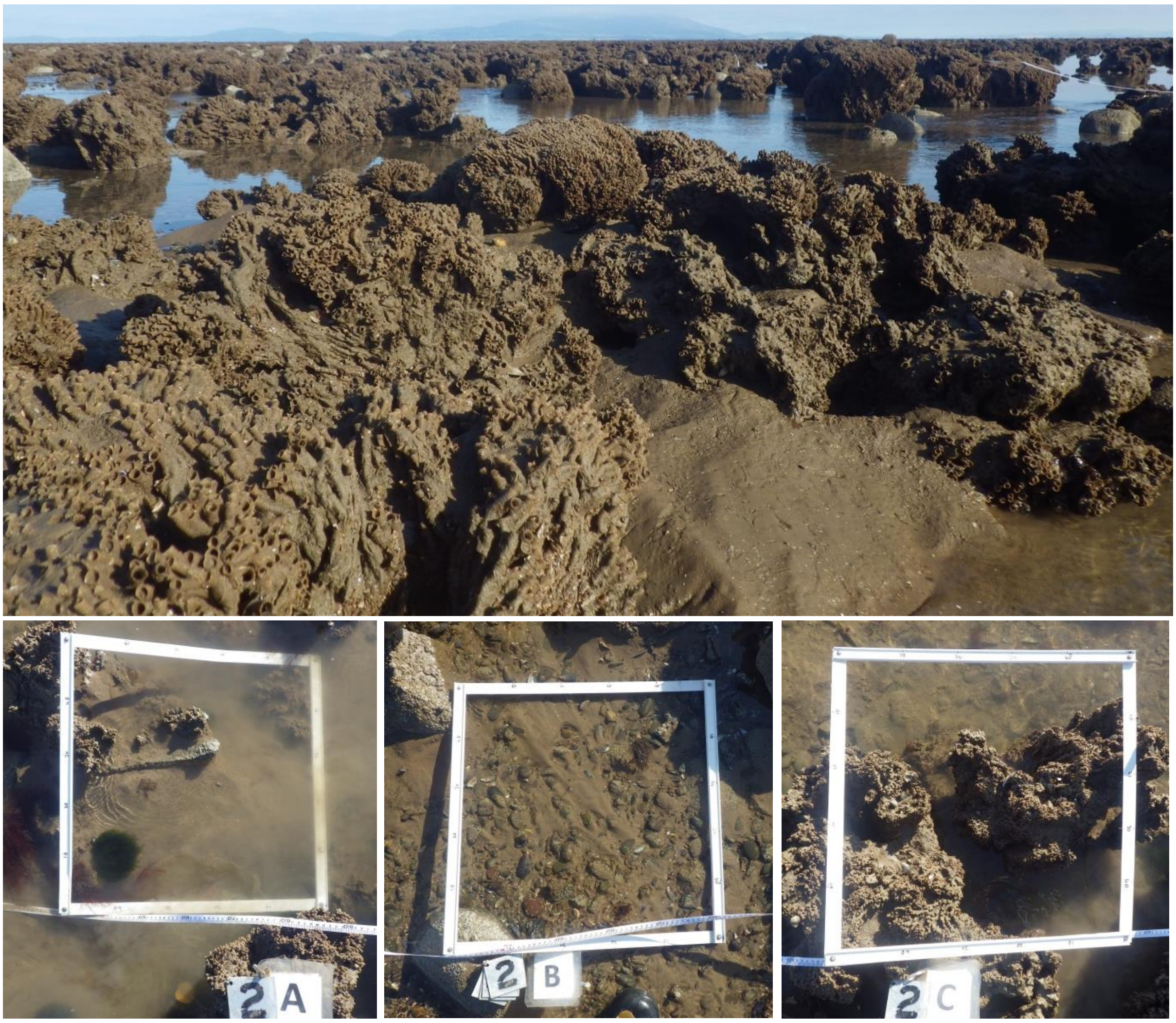

Plate 16. Photographs of the LS.LBR.Sab.Salv biotope within the Solway Firth SAC at T2B.

The communities sampled within the LS.LBR.Sab.Salv biotope in this study correspond with the Marine Habitat Classification[9]. There are discrepancies however, in particular far fewer algae species were observed within the biotope than are listed in the Marine Habitat Classification description (Table 31). Fucoids were absent and green algae were limited to rare occurrences of the lower shore species *Bryopsis hypnoides.* Red algae were also rare and included just three taxa; banded pincer weeds (*Ceramium* spp.), *Chondrus crispus* and *Polysiphonia fucoides* (a species which is known for its tolerance of sand cover[12]). Fauna that are considered to be secondary characterising species for the biotope were present in low abundances and included *Actinia equina*, barnacles (*Semibalanus balanoides* and the non-native *Austrominius modestus*), *Nucella lapillus*, and *Littorina littorea*. The abundance of the main characterising polychaete *Sabellaria alveolata* was measured by estimating the percentage cover of the honeycomb structure. The honeycomb formations were patchily distributed, consequently the cover of *Sabellaria* in quadrats ranged from 0 to 70% cover.

The mean Bray-Curtis similarity value that was derived from the sampled communities was 64%. The presence of *Sabellaria alveolata* contributed 65% to the overall similarity (Table 32). The Australasian barnacle *Austrominius modestus* was the second highest contributing species and accounted for 15% of the community similarity.

Timed searches of the under-boulder communities within this biotope were avoided to prevent damage to the feature. If the reef structures had been intrusively investigated it is very likely that many more species would have been recorded.

Table 31. Species composition in quadrats within the LS.LBR.Sab.Salv biotope.

Transect	T2A			T2B		
Quadrat	a	b	c	d	e	f
Porifera - orange			<1			
Actinia equina		1				
Semibalanus balanoides (%)	4				<1	<1
Crangonidae					1	
Carcinus maenas juv.		2				
Sabellaria alveolata (%)	12		70	50	4	45
Littorina littorea		7	2	1	1	1
Nucella lapillus						1
Ceramium spp.	3		2			
Bryopsis hypnoides	3		3			
Polysiphonia fucoides		2				
Chondrus crispus		<1				
Austrominius modestus (%)	<1	6			<1	4

Table 32. Species contribution in the LS.LBR.Sab.Salv communities derived from quadrat data.

Species	Mean Abundance per Quadrat	Mean Similarity	% Contribution	Cumulative % Contribution
Sabellaria alveolata (%)	5.5	42	65	65
Austrominius modestus (%)	1.4	10	15	80
Littorina littorea	1.4	8	12	93
Semibalanus balanoides	0.9	5	7	100

4.2.12 LS.LBR.LMus.MytMx / LS.LBR.Sab.Salv

Relatively large areas of the lower shore scars between Mawbray and Silloth were comprised of mosaics of LS.LBR.LMus.MytMx and LS.LBR.Sab.Salv communities, and as a result these communities were sampled as a distinct habitat type. The mosaic communities were generally formed by outcrops of the honeycomb structures of *Sabellaria alveolata* amongst sandy beds of *Mytilus edulis* which were frequently submerged in tidal pools (Plate 17). The largest area of the mussel/*Sabellaria* mosaics were found where the LS.LBR.Sab.Salv transitioned into LS.LBR.LMus.MytMx communities on the most south-westerly scar in the SAC

(Figure 6). The mosaics were also found on the scar known as Lowhagstock. On this scar the mussel / *Sabellaria* communities characterised the lower shore periphery as well as some of the communities higher up the shore where a channel drained water from the mid-upper shore.

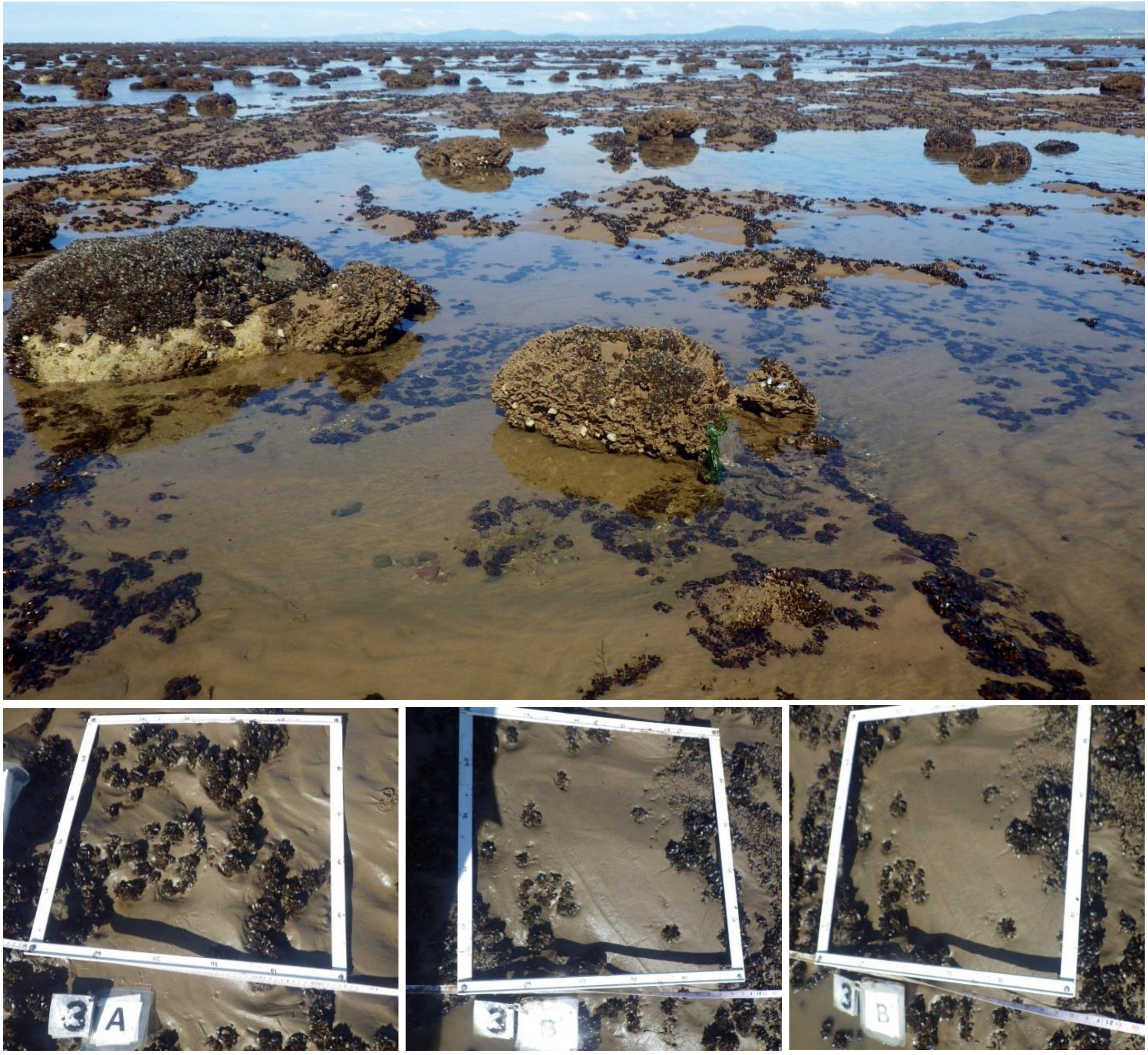

Plate 17. Photographs of the LS.LBR.LMus.MytMx / LS.LBR.Sab.Salv habitat type mosaic within the Solway Firth SAC at T2B.

Due to the intrinsically patchy nature of mosaic communities and the random sampling methods employed, the *Sabellaria* honeycomb structures were not captured within any of the six quadrats that were sampled (Table 33). The quadrats fell upon substrates that were dominated by sand and mussels and consequently the communities sampled were extremely species-poor. Species such as *Nucella lapillus* which were commonly observed on the *Sabellaria* structures were not represented by the quadrat sampling. The reef structures formed by *Sabellaria* are known to provide a unique habitat for colonisation by associated communities, and therefore the mosaic communities are likely to have been under-represented by the quadrat data. The timed search of under-boulder communities in the mosaic communities was limited to a visual inspection of the *Sabellaria* structures, and did not involve lifting or breaking apart the honeycomb structure. Consequently, just two additional species were observed in frequent to occasional abundance. These were anemones (*Actinaria* spp.) and the dogwhelk *Nucella lapillus* (Table 34).

The communities that were sampled both within the quadrats and during the timed searches were the most similar of all the rocky scar communities sampled within the SAC (the mean Bray-Curtis value was 68% and 93% respectively). Unsurprisingly *Mytilus edulis* accounted for 100% of the similarity in the quadrat data (Table 35), but the bivalve also accounted for the greatest proportion of the similarity in the under-boulder communities (Table 36). However, had the *Sabellaria* structures been more vigorously investigated (involving more destructive techniques) it is likely that a greater number of taxa would have been recorded as contributors to the community structure of the mosaic.

Table 33. Species composition in quadrats within the LS.LBR.LMus.MytMx / LS.LBR.Sab.Salv habitat type mosaic.

Transect		T3			T4	
Quadrat	3a	3b	3c	4a	4b	4c
Lanice conchilega						5
Littorina littorea					1	
Mytilus edulis (%)	30	20	25	50	65	70

Table 34. SACFOR abundance of taxa observed during timed search of under-boulder communities on transects within the LS.LBR.LMus.MytMx / LS.LBR.Sab.Salv mosaic

Transect	T3	T4
Actinia equina	O	O
Nucella lapillus	F	O
Mytilus edulis juv. (%)	F	F

Table 35. Species contribution in the LS.LBR.LMus.MytMx / LS.LBR.Sab.Salv mosaic communities derived from quadrat data.

Species	Mean Abundance per Quadrat	Mean Similarity	% Contribution	Cumulative % Contribution
Mytilus edulis (%)	6.4	68	100	100

Table 36. Species contribution in LS.LBR.LMus.MytMx / LS.LBR.Sab.Salv mosaic communities derived from under-boulder timed search data.

Species	Mean Abundance per Transect	Mean Similarity	% Contribution	Cumulative % Contribution
Mytilus edulis juv. (%)	3	40	42.86	42.86
Actinia equina	2	26.67	28.57	71.43
Nucella lapillus	2.5	26.67	28.57	100

4.2.13 Statistical Analysis of Flora and Fauna in Littoral Rock Habitat Types

The results of the univariate analysis for each transect and the mean diversity indices for each habitat type have been incorporated into Table 36. A degree of caution should be applied when comparing these indices between habitat types given that the level of replication within each was variable.

The often patchy nature of the rock scar communities at the scale of sampling has led to variable univariate indices both within and between habitat types. A comparison of both the quadrat data and under-boulder community data reveals no correlation between shore height and species diversity and richness. An exception to this is within the lower shore LS.LBR.Sab.Salv biotope where, despite just two transects being sampled, the mean species richness was clearly higher than the remaining habitat types. However, the species diversity and evenness within the LS.LBR.Sab.Salv communities were broadly comparable to that of the remaining habitat types.

A disparity in diversity between the lower shore and upper shore communities would usually be expected given the more fluctuating and extreme environmental variables that fauna are exposed to on the upper shore. On the upper shore, generally, only a few species that are tolerant of desiccation, temperature and salinity stress can survive. Collectively, the richness and diversity values which have been derived from sampling the rocky scars in the Solway Firth SAC are low relative to values that would normally be expected on a moderately exposed fully marine rocky shore. It is therefore likely that the environmental conditions brought about by the extreme tidal scour in the Solway Firth (e.g. mobility, turbidity, scour and sediment smothering) act similarly as environmental stressors on the mid and lower shore communities, resulting in the establishment of only a few taxa which are adapted to tolerate the challenging conditions.

Table 37. Univariate community analysis of scar ground communities in the Solway Firth SAC.

Shore Height	Habitat Type	Quadrat Data							Under-boulder Data	
		Transect	Total No. Taxa per Transect S	Mean Abundance (%Cover & Counts) N	Margalef's Species Richness d	Pielou's Evennes s J'	Shannon Wiener Index H'(log10)	Simpson Diversity Index 1-Lambada'	Total No. Taxa per Station S	Total Abundance (SACFOR Rank) N
Upper	LR.HLR.MusB.Sem.LitX	T7	3	12	0.6	0.5	0.6	0.3	2	7
		T8	7	27	1.4	0.6	1.3	0.6	5	14
		T16	7	66	1.1	0.6	1.2	0.6	4	10
		T17A	6	60	1.0	0.7	1.3	0.7	3	6
		T18B	5	69	0.7	0.8	1.3	0.7	3	8
		T19A	3	22	0.5	0.1	0.2	0.1	1	3
		T19B	6	44	1.0	0.5	1.0	0.4	5	14
		T25A	5	102	0.7	0.7	1.0	0.6	3	8
		Mean	**5**	**50**	**0.9**	**0.6**	**1.0**	**0.5**	**3**	**9**
	LR.LLR.FSpi.X	T21	7	59	1.2	0.2	0.4	0.2	5	11
	LR.LLR.FVS.FspiVS	T29A	7	46	1.2	0.7	1.4	0.7	2	6
	LR.FLR.Eph.Ent	T23	8	42	1.4	0.4	0.8	0.4	4	7
		T25B	5	49	0.8	0.3	0.4	0.2	-	-
		T27	2	13	0.3	0.3	0.2	0.1	4	11
		T28	2	7	0.3	0.6	0.4	0.3	2	6
		T30B	5	35	0.9	0.2	0.4	0.2	2	7
		Mean	**4**	**29**	**0.7**	**0.4**	**0.5**	**0.2**	**3**	**8**
	LR.MLR.BF.FvesB	T15	6	78	0.9	0.9	1.5	0.7	5	16
	LR.LLR.F.Fves.X	T18A	5	73	0.7	0.7	1.1	0.6	2	4
	LR.LLR.FVS.Fcer	T29B	5	58	0.8	0.4	0.7	0.3	3	5
		T30A	4	81	0.5	0.8	1.0	0.6	0	0
		Mean	**5**	**70**	**0.7**	**0.6**	**0.9**	**0.5**	**2**	**3**
	LR.FLR.Eph.Ent / LR.LLR.F.Fves.X	T17B	8	51	1.4	0.6	1.2	0.5	3	7
	LR.FLR.Eph.EntPor	T20	2	17	0.3	0.7	0.5	0.3	1	2
		T22	3	4	0.8	0.7	0.8	0.5	3	3
		T26	3	18	0.5	0.5	0.6	0.3	5	12
		Mean	**3**	**13**	**0.5**	**0.7**	**0.6**	**0.4**	**3**	**6**
	LS.LBR.LMus.MytMx	T1	2	82	0.2	0.5	0.3	0.2	-	-
		T5	6	17	1.3	0.4	0.7	0.3	2	8
		T6	7	20	1.5	0.7	1.3	0.7	2	6
		T9	5	105	0.7	0.4	0.7	0.4	4	8
		T10	5	18	1.0	0.8	1.2	0.7	5	14
		T11	6	37	1.1	0.5	1.0	0.5	-	-
		T12	5	39	0.8	0.3	0.4	0.2	-	-
		T13	6	61	1.0	0.5	0.9	0.6	-	-
		T14	2	59	0.2	0.5	0.3	0.2	3	10
		T17C	6	24	1.2	0.5	1.0	0.5	1	4
		T24	9	24	1.9	0.7	1.6	0.7	1	4
		T25C	8	30	1.6	0.7	1.4	0.7	0	0
		Mean	**6**	**43**	**1.0**	**0.5**	**0.9**	**0.5**	**2**	**7**
	LS.LBR.LMus.MytMx/ LS.LBR.Sab.Salv	T3	1	25	0.0	0.0	0.0	0.0	3	8
		T4	3	64	0.4	0.1	0.2	0.1	-	-
		Mean	**2**	**44**	**0.2**	**0.1**	**0.1**	**0.0**	**-**	**-**
	LS.LBR.Sab.Salv	T2A	11	40	2.1	0.5	1.2	0.5	-	-
		T2B	6	37	1.1	0.3	0.4	0.2	-	-
Lower		Mean	**9**	**38**	**1.6**	**0.4**	**0.8**	**0.3**	-	-

Community analysis in PRIMER[10] used the multivariate Bray-Curtis similarity statistic and MDS to assess the communities at each transect. The MDS plot in Figure 10 represents the data recorded from quadrats (within each habitat type) in two dimensions, where the distances between points represent the similarities between the faunal communities (i.e. the closer together the points the more similar the sampled communities).

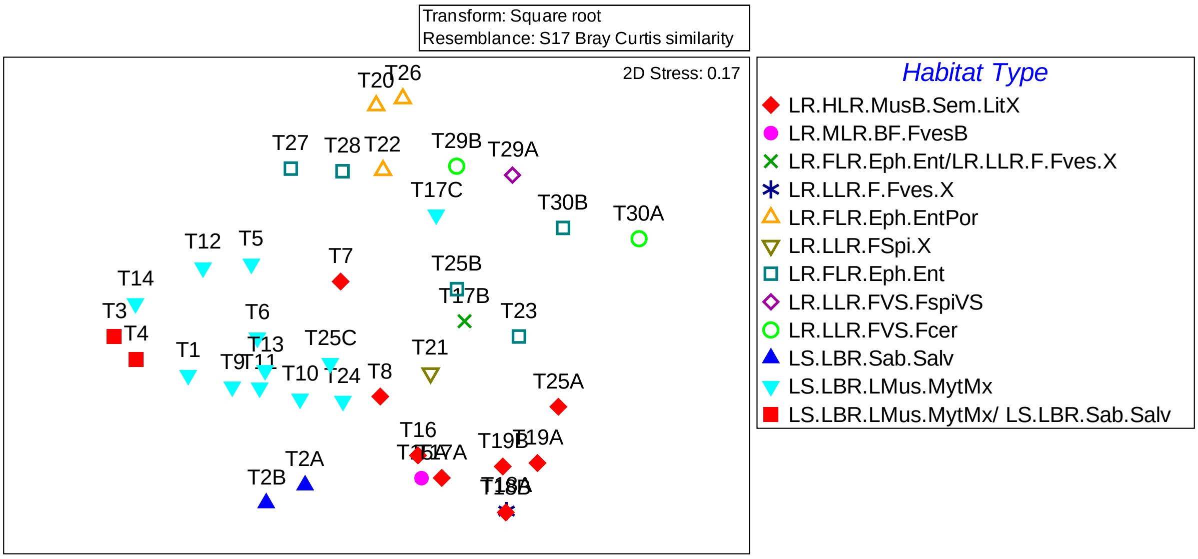

Figure 12. Two dimensional MDS plot of all habitat type communities sampled using quadrats within the Solway Firth SAC.

The plot in Figure 10 demonstrates a reasonably good similarity and therefore grouping of transects within habitat types. Some habitat types do however demonstrate better mean Bray-Curtis similarity values than others. The LS.LBR.LMus.MytMx / LS.LBR.Sab.Salv mosaic for example generated the highest value of 68% whilst the LR.FLR.Eph.Ent biotope generated the lowest value of just 23%. The stronger similarities observed within the LS.LBR.LMus.MytMx / LS.LBR.Sab.Salv mosaic are as a consequence of the patchy nature of the communities and the fact that all 6 of the quadrats sampled on the 2 transects fell, by chance, only on sandy patches that were dominated by mussels. The 2 transects were also geographically just 200 m apart which meant that the environmental variables to which the sampled communities were exposed will have been very similar. It therefore follows that the flora and fauna present would also be expected to be similar. The weaker similarity value which has been generated from the data collected within the LR.FLR.Eph.Ent biotope is likely to be as a result of the 5 transects having been sampled over a much broader area of the estuary. Transects T27 and T28 that were located adjacent to the main channel at the headland at Bowness-on-Solway displayed the most impoverished communities, probably as a result of the additional environmental stress caused by the exacerbated tidal scour in that location.

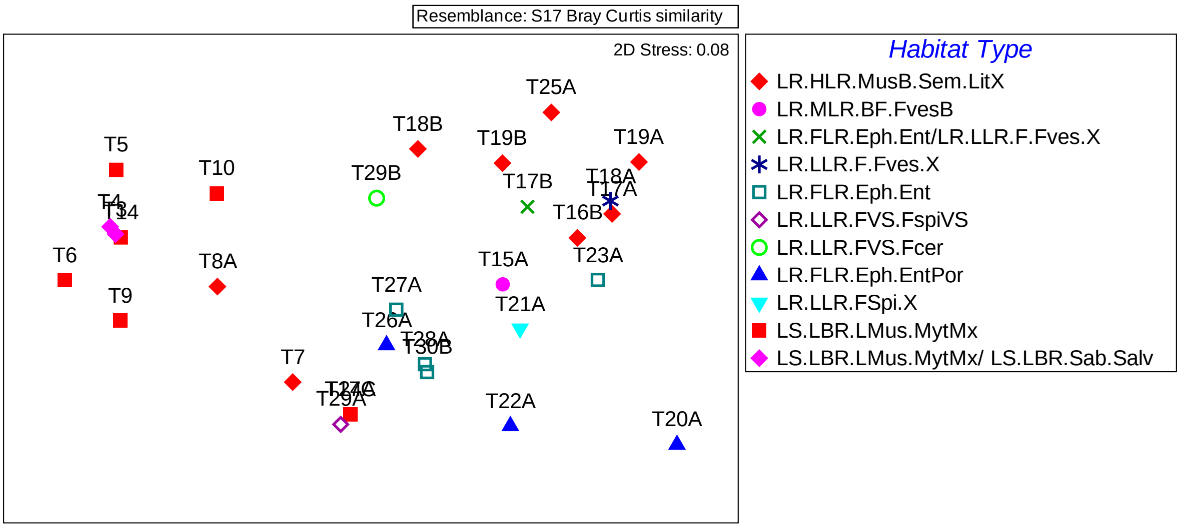

Figure 13. Two dimensional MDS plot of all habitat type communities sampled during timed searches of the under-boulder communities within the Solway Firth SAC (T30A and T25C are not included due the absence of observed under-boulder fauna).

The MDS plot in Figure 11 represents the same transects but instead represents the data gathered during the timed searches of the under-boulder communities that were carried out within each habitat type. Again analysis of the data from some habitat types produced better mean Bray-Curtis similarity values than others. The under-boulder communities sampled at the 4 transects in the LR.FLR.Eph.Ent biotope were 52% similar, whilst those from 3 transects within the very similar LR.FLR.Eph.EntPor biotope were just 14% similar. The disparities between the underboulder communities within the same habitat types are likely to be associated with subtle differences in the type and/or proportion of sediments in the substrates, although a number of other environmental factors are also likely to have had an influence. All of the LR.FLR.Eph.EntPor communities for example were described as being present on boulders and cobbles over sediment. However, sometimes relatively small differences in the proportion of mud and/or the volume of sediments were observed to alter the space and therefore habitat niches available beneath stones. Consequently, the type and/or abundance of underboulder communities varied accordingly. To explore this assumption the under-boulder fauna data was grouped into four geographical areas within the estuary: Mawbray to Silloth (transects in Figure 6), Silloth (transects in Figure 7), Moricambe Bay (transects in Figure 8) and Bowness-on-Solway to Port Carilse (transects in Figure 9). Each of these areas is relatively distinct in terms of position in the estuary and local environmental variables (e.g. scour, shelter, salinity).

Although the majority of the rocky scars throughout the SAC are described as being formed either by boulders and cobbles on sediment, or cobbles and pebbles on sediment, it can be seen from Tables 38 to 41 that the main contributing under-boulder species in each of the areas clearly changed as the sediments generally became more sheltered towards the inner estuary (exceptions to this were in areas such as at Bowness-on-Solway where tidal scouring was evident). The ragworm *Hediste diversicolor* and the green shore crab *Carcinus maenas* were more frequently sampled under boulders in the more sheltered muddy sediments, whilst taxa such as *Actinia equina* and *Nucella lapillus* were more frequently observed where sand made up greater proportions of the substrate and/or where the boulders and the under-boulder spaces were larger.

Table 38. Species contribution to under-boulder communities at transects between Mawbray and Silloth.

Species	Mean Abundance per Transect	Mean Similarity	% Contribution	Cumulative % Contribution
Nucella lapillus	3	22	45	45
Actinia equina	2	14	27	72
Mytilus edulis juv.	2	13	26	98

Table 39. Species contribution to under-boulder communities at transects near Silloth.

Species	Mean Abundance per Transect	Mean Similarity	% Contribution	Cumulative % Contribution
Littorina saxatilis	3	24	64	64
Carcinus maenas	2	11	30	94

Table 40. Species contribution to under-boulder communities at transects in Moricambe Bay.

Species	Mean Abundance per Transect	Mean Similarity	% Contribution	Cumulative % Contribution
Hediste diversicolor	1	5	35	35
Mytilus edulis juv.	1	5	30	64
Littorina saxatilis	1	3	16	80
Carcinus maenas	1	2	13	93

Table 41. Species contribution to under-boulder communities at transects between Bowness-on-Solway and Port Carilse.

Species	Mean Abundance per Transect	Mean Similarity	% Contribution	Cumulative % Contribution
Hediste diversicolor	3	23	67	67
Carcinus maenas	1	11	33	100

The mean number of taxa in under-boulder communities was calculated for each of the areas and was 3 in areas 1 to 3 (Mawbray to Moricambe Bay), and 2 at area 4 (Bowness-on-Solway to Port Carlise). Although the difference in the mean values is small, it may suggest that the underboulder communities become slightly more impoverished where the salinity is more variable (although there may be a number of confounding environmental variables responsible e.g. tidal scour, substrate type). Similarly, the community data collected using quadrats methods was grouped into areas and a similar pattern in the number of taxa as well as richness occurred. From areas 1 to 4 the mean number of taxa was 5, 6, 6 and 4, and the mean community richness was 0.9, 0.9, 1.0 and 0.7 respectively. The pattern of depletion in the richness of communities higher in the estuary follows a long established pattern along the estuarine salinity gradient described by Carriker (1967)[13].

4.3 Identification of anthropogenic impacts and negative indicators

A few anthropogenic activities were identified during the course of the surveys that were mostly considered to have the potential to cause only minor and localised negative impacts within the rocky scars of the Solway Firth SAC. These are summarised and mapped in Figure 12.

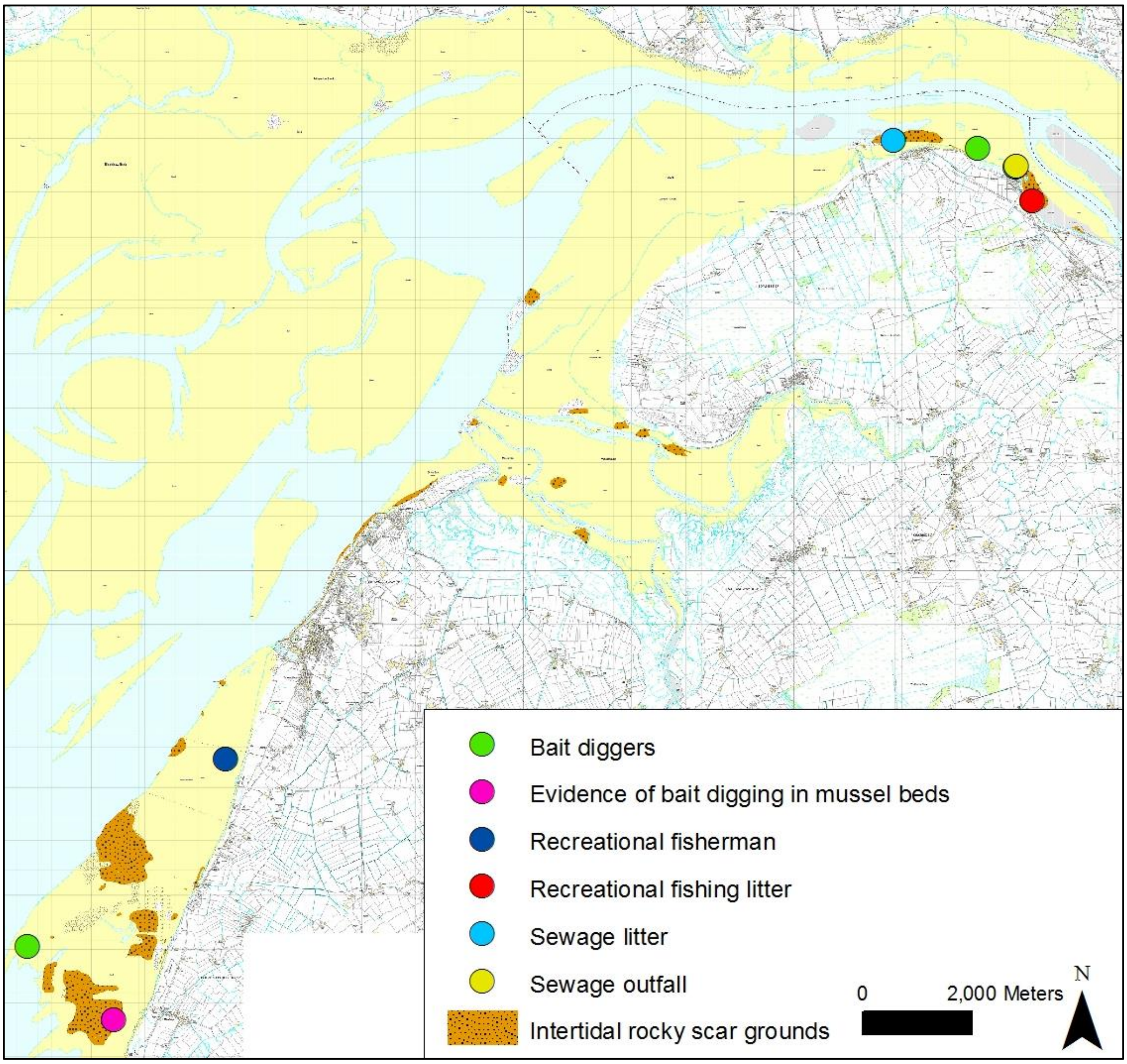

Figure 14. Location of anthropogenic activities on the English side of the Firth of Forth SAC.

Bait digging and recreational fishing was popular along the beach between Silloth and Mawbray. Most notably, the mussel beds along the shore at Mawbray showed evidence of having been dug which had left behind obvious hollows 1 to 1.5 m^2 in the bed (Plate 18). The frequency of this activity is unknown and it is difficult to determine the level of impact from such activity without further targeted studies. However, bait digging in the mussel beds is potentially the most significant anthropogenic activity that has been identified within the SAC, as it has the potential to cause damage to a habitat which has been identified as a characteristic biotope in the Solway Firth SAC. Specifically, areas of mussels may be disturbed and/or removed altogether in patches. The resulting holes left by digging may increase the vulnerability of the remaining bed to wash-out during storm events. This activity therefore has the potential to result in a loss in extent of the characteristic biotope, which could lead to a breach of the conservation objectives for the rocky scar ground sub-feature.

Plate 18. Hollows/scars created by bait digging in the mussel beds off Mawbray.

A number of what appeared to be sewage outfall pipes were observed between Bowness-on-Solway and Drumburgh, though these were not seen discharging at the time of survey. A small amount of sewage litter was observed in the vicinity of pipes at Bowness-on-Solway and Port Carlise.

Bait digging for ragworm (*Hediste diversicolor*) was observed on one occasion in the muddy sand at Milecastle.

4.4 Invasive Non-Native Species

The non-native invasive barnacle species *Austrominius modestus* was frequently observed during the course of the surveys, through rarely in abundances of greater than 5% cover. Abundance exceeded 5% cover at just three transects adjacent to Silloth where between 8% and 25% cover was recorded. The location of transects on which the species was recorded as present/absent in the SAC is shown in Figure 13.

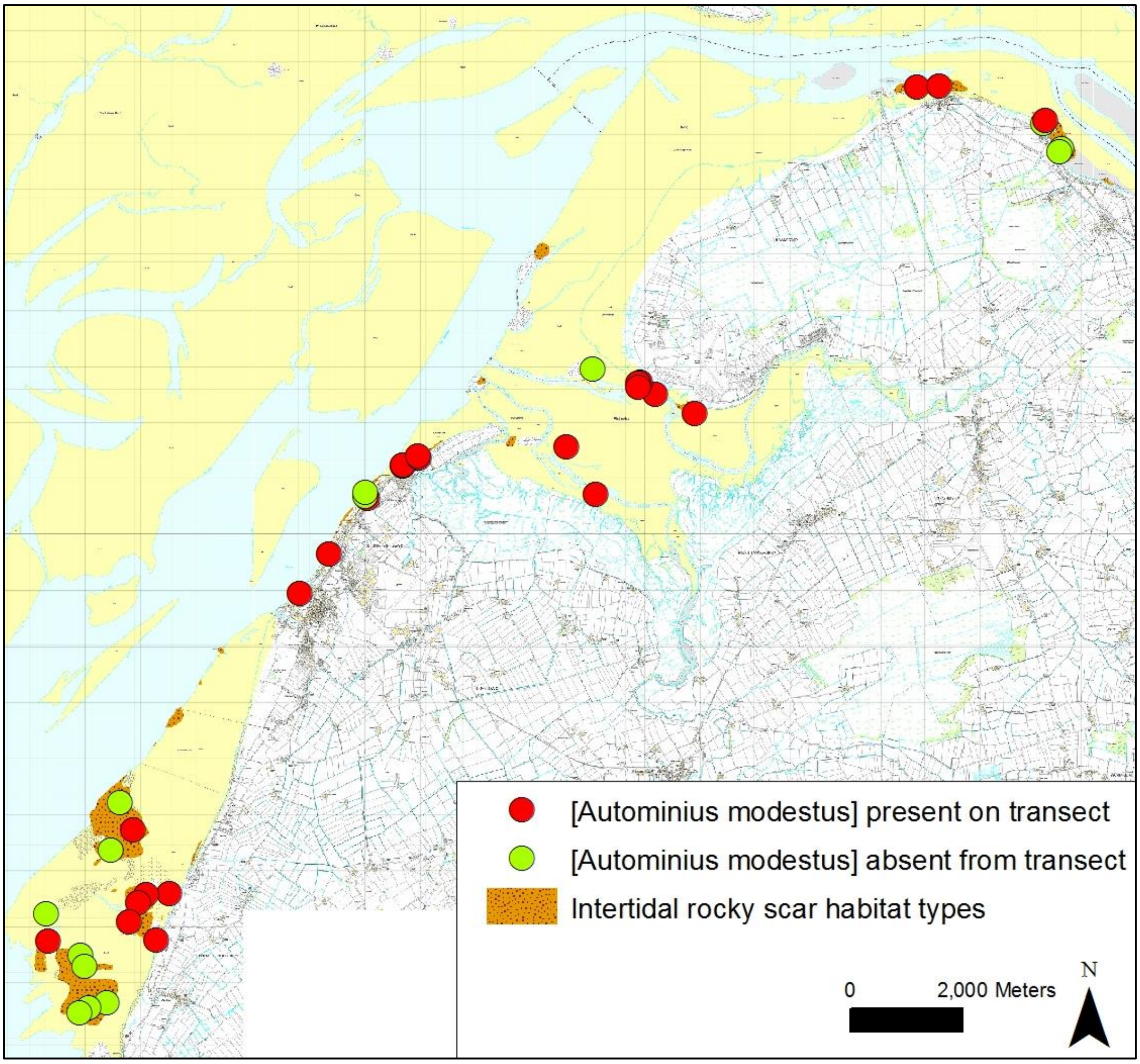

Figure 15. Presence/absence of *Austrominius modestus* on transects in the Solway Firth SAC.

5. Discussion

5.1 Condition Assessment

5.1.1 Temporal Comparisons

Due to a lack of previous relevant studies, the ability to make temporal comparisons of the attributes of the rocky scar ground communities in the Solway Firth SAC has been limited. The most relevant historical baseline data available is that provided by Allen *et al*. in 2002. Allen *et al,* mapped and assessed the condition of *Sabellaria alveolata* reefs on the southern Solway shores as part of a larger study of the eastern Irish sea coast. The study only focused on the extent and distribution of *Sabellaria alveolata* reefs however, and not the intertidal rocky scar communities generally. Consequently, comparisons are mostly limited to the extent and distribution of the honeycomb structures formed by *Sabellaria alveolata*.

Maps of the extent and distribution of *Sabellaria alveolata* within the SAC reported in the 2002 report[3] have been extracted and geo-referenced in GIS. This historical extent data has been mapped alongside the *Sabellaria alveolata* extent data collected during this study (Figure 14).

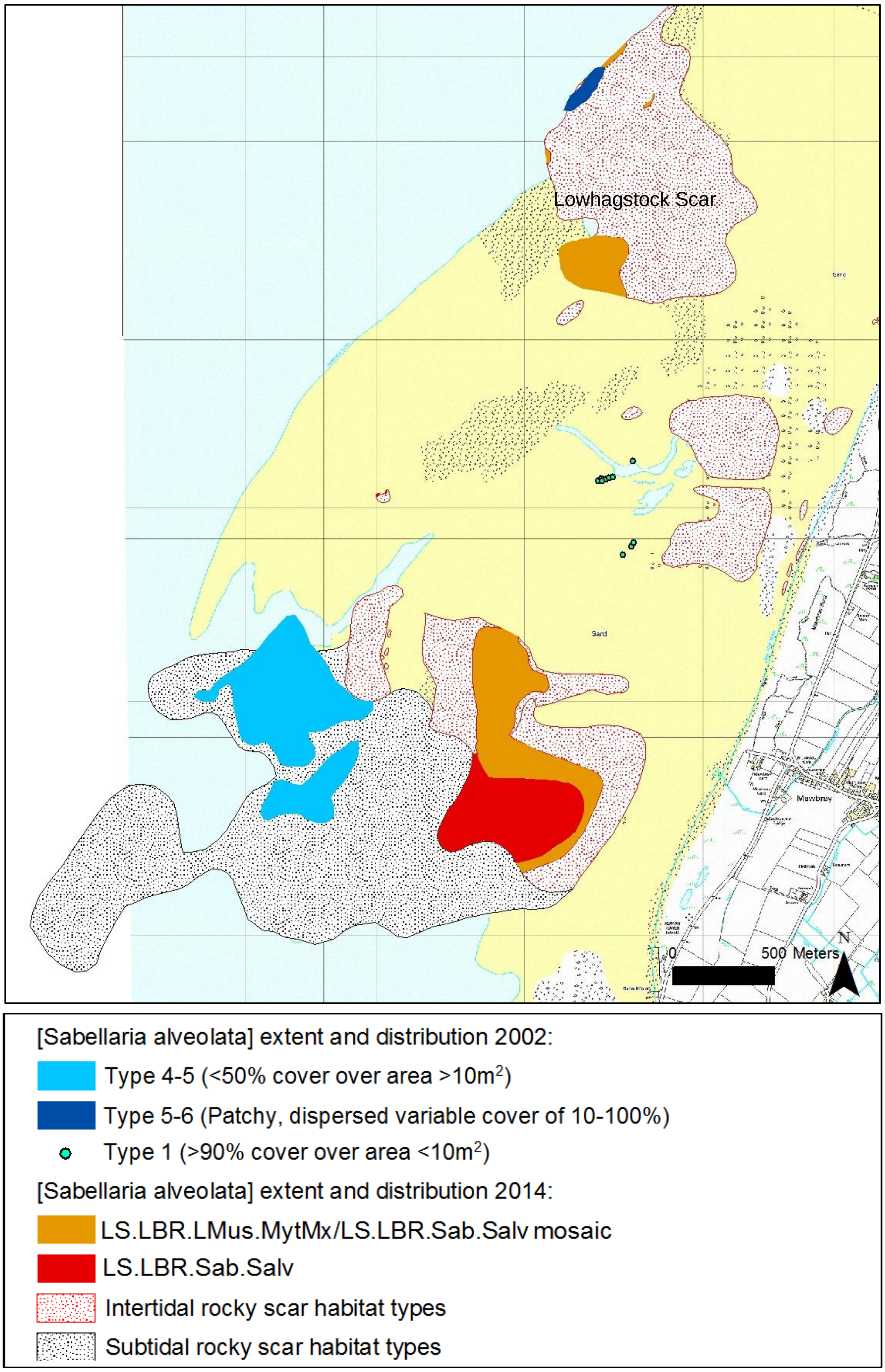

Figure 16. Extent and distribution of *Sabellaria alveolata* in 2002 and 2014.

A comparison of the previous extent and distribution of *Sabellaria alveolata* with that mapped during this study does reveal what appears to be some definite temporal change in both the extent, and distribution, of *Sabellaria* reef. However, the precise differences in extent are unclear because of the different methods employed between studies. The total area of *Sabellaria* mapped in the SAC in 2002 equates to 0.41 km^2. That area was mostly formed by reefs which were described as very-patchy (type 4 - 20-50% cover) to extremely-patchy (type 5- <20% cover) (see full descriptions in Appendix I). The majority of the *Sabellaria* mapped as the LS.LBR.Sab in 2014 is thought to have equated to 'type 4 – very patchy' as defined by Allen *et al*. 2002. Much of the reef which existed as a mosaic with mussel beds (LS.LBR.LMus.MytMx / LS.LBR.Sab.alv) in 2014 compared more closely to 'type 5 – extremely patchy'. The total area over which *Sabellaria* was mapped in 2014 (including the mosaic communities) equated to 0.59 km^2. The area of *Sabellaria* reef has therefore potentially increased on the English side of the Solway Firth SAC by 43% since 2002.

More definitive changes in the distribution of *Sabellaria* were observed, particularly on the scar at the most south-western extent of the SAC. The area of reef that was mapped in 2002 appears to have moved eastwards and also spread further toward the mid shore. Additional areas of reef were also mapped on the western side of the scar known as Lowhagstock where there were large areas of standing water and/or shallow drainage channels. The extent and distribution of the low lying and marginal *Sabellaria* on the north-western extent of Lowhagstock scar appears to have largely remained unchanged. Outcrops of reef <10 m^2 were previously mapped on the mid shore (Figure 13 'Type 1'). These areas of reef were no longer apparent in 2014, but similar proportions of the *Sabellaria* honeycomb structure were mapped approximately 750 m to the west.

A study of the sub-tidal scar grounds was carried out in 2006[6]. Broad comparisons with the habitat types mapped and reported following that study correspond with the findings of this study. Principally, the large area of subtidal mussel beds mapped at the most south-western extent of the SAC (SS.SBR.SMus.MytSS in Figure 6) correspond with the mixed/patchy scar of cobbles/pebbles on sand and/or mussels with areas of *Sabellaria alveolata* described in the area in 2006[6] (Figure 3).

5.1.2 Preliminary Condition Assessment

A preliminary condition assessment of a selection of the rocky scar attributes has been made where a suitable baseline exists to make recommendations possible. The attributes which have been addressed have been selected by Natural England as specific objectives of this study.

Table 42. Condition recommendation of attributes that, subject to natural change, contribute to defining the condition of the rocky scar ground community sub-feature of the Solway Firth SAC

SAC Attribute	Target (from Reg 33[4])	Condition Recommendation
Extent of rocky scar ground communities.	Maintain in the long term	No suitable baseline data exists with which to compare current results. Consequently it has not been possible to make temporal comparisons of the extent of rocky scar ground communities in the SAC. The condition of this attribute is therefore **unknown**[Δ].
Distribution and extent of characteristic biotopes within rocky scar ground communities.	Maintain in the long term	Some changes in this attribute have been observed. Specifically, the *Sabellaria alveolata* reefs (which are also a characteristic biotope in the Solway Firth SAC) have changed in distribution and potentially extent. It cannot be determined whether the changes observed are as a consequence of natural estuarine processes or anthropogenic influences (or a combination of both). However, given that that the distribution and extent of the exposed scars are known to vary considerably as a result of the natural estuarine processes of scouring and deposition, and no human pressures were identified within the areas of *Sabellaria* reef, it is very unlikely that the changes have resulted from negative human pressures. Due to the absence of suitable baseline data, it has not been possible to determine whether there have been changes in the extent and/or distribution in the remaining 11 habitat types/mosaics that were identified within the SAC during this study. The overall condition of this attribute must currently therefore be assessed as **unknown** [Δ].

[Δ] *This study provides the baseline for future condition assessment of these attributes.*

Table 43 contd. Condition recommendation of attributes that, subject to natural change, contribute to defining the condition of the rocky scar ground community sub-feature of the Solway Firth SAC

SAC Attribute	Target (from Reg 33[4])	Condition Recommendation
Species composition of characteristic biotopes within rocky scar ground communities.	Maintain in the long term.	No baseline data exists with which to compare current results. Consequently changes in the composition of communities cannot be determined. The condition of this attribute is therefore **unknown** [Δ].

[Δ] *This study provides the baseline for future condition assessment of these attributes.*

5.2 Evaluation of Methods

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. 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 attributes. 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.

A relatively high degree of infaunal community variation both between transects within a habitat type, and between the transects and the communities described as characteristic for the habitat types was observed for all communities. This highlights some of the inherent weaknesses of biotope mapping. The variations are most likely to be attributable to the high degree of natural fluctuations that are found at both a local and regional scale in estuarine environments[12] (e.g. salinity, wave exposure, carbon matter and nutrient input). The Solway estuary in particular is distinctive in its geographic scale and tidal energy.

There are opportunities to enhance the potential for stronger statistical comparisons in future. An adequate level of replication within the rocky scar communities is considered to have been achieved except perhaps in the habitat types which were extremely limited in their distribution and consequently were subject to sampling at either just one transect (e.g. LR.LLR.F.Fves.X, LR.LLR.FSpi.X, LR.LLR.FVS.FspiVS and LR.MLR.BF.FvesB) or not at all (e.g. LR.LLR.F.AscX). The sampling effort was tailored to fit the budget available, and as such, only the most representative habitat types were targeted during the design of the Phase II surveys. Some of these less extensive habitat types were therefore sampled in the course of other, more widespread habitat types being targeted (as at each transect, each shore height was sampled).

The 0.25m^2 quadrat size that was stipulated by Natural England for use within the survey is a quarter of the size of the 1m^2 assessment area that is stipulated in the Procedural Guideline No.3-1 in the Marine Monitoring Handbook[8] (which is also the guideline recommended in the CSM guidelines for littoral rock and sub-littoral rock habitats[5]). The quadrat size used may sufficiently represent open coast habitat types where the communities tend to be more homogenous, but is unlikely to be adequate in many of the rocky scar communities in the Solway that are inherently variable and patchy unless a greater area is sampled. For example, particularly within the LR.MLR.BF.FvesB, LR.LLR.FSpi.X and LS.LBR.Sab habitat types the main characterising species were often consistently missed by the quadrats, or their abundance was sporadic and ranged between absent and superabundant. Consequently, if the main characterising species in the wider scar area are not taken into consideration, the assignment of a habitat type in an area may change between surveys as a result of sampling variability rather than real changes.

The similarity between quadrats on the same transects throughout the rocky scars was variable and ranged between 14% and 96%, with an overall mean value 58% (it may be useful to remember that main characterising species do not have added weighting during SIMPER analysis). This variability means that the confidence of the results being representative of the actual communities present is reduced. Therefore either greater replication is necessary, or alternatively, depending upon the budgets available, consideration could be given to strategies such as using timed searches.

A likely consequence of low replication and/or sample area in future monitoring programmes is that the power to detect change within individual habitat types will be lowered and it may not be possible to distinguish impacts or changes in communities in the future unless the changes are sufficiently large. Alternatively, the potential for an erroneous indication of temporal change is increased since a lower sampling effort/sample size may not result in the data set being representative of the community structure actually present (particularly as the precise placement of quadrats is random).

Similarly, the power to detect change in the less widespread rocky scar habitat types may be constrained by the fact that less than three transects were sampled in each. However, any directional change over time at the sampled transects will become apparent. Therefore, the limitations brought about by the low replication may be mitigated to some degree by treating transects as sentinel stations. Any directional change over time in the communities at each of the sentinel stations should become apparent and may be used as an indicator of change in the wider communities. However, it will only be possible to make comparisons at sentinel stations where scars remain in the same place. Given the dynamic nature of the scar communities which are subject to constant scouring and deposition processes, this may not always be possible.

The LR.LLR.F.AscX biotope was not included in the Phase II sampling and therefore only comparisons in the extent of these communities can be made within future surveys.

In contrast, the higher level of replication within the most extensive habitat type LS.LBR.LMus.MytMx (which accounts for 35% of the scar communities within the SAC) as well as the widespread LR.HLR.MusB.Sem.LitX sub-biotope will more confidently provide a robust baseline of data. From that baseline, any temporal change in communities within this habitat type should become apparent. Such comparisons will enable Natural England to fulfil their statutory duty to report on a range of attributes for the rocky scar sub-feature of the Solway Firth SAC.

5.3 Recommendations for Future Condition Assessment

In order to carry out future condition assessments the results presented here should be used as a baseline from which to compare the attributes and targets outlined in Table 42 Section 5.1.2.

As discussed in section 5.2 the number of stations should ideally be increased within the less prevalent habitat types. Sampling a minimum of three and preferably five stations in each habitat type would increase the likelihood that the communities are accurately represented and that factors affecting them would be detected. If future monitoring is required to be carried out within the same sampling budget, then the additional replicates could be taken from habitat types which were sampled at more than 5 transects; though this would weaken the power to detect change in habitats that account for much larger proportions of the SAC.

The sampling method could be modified to provide a more robust basis from which to detect any significant temporal change in communities in the future. Given the sparse/patchy nature of the rocky scare communities, it is thought that increasing the quadrat size and/or the replication (e.g. number of transects) would enhance the data. Alternatively, consideration could be given to strategies such as using timed searches.

It is considered that where possible (e.g. where the scars have not moved substantially) the same transects should be re-visited (+/- 10m), but the precise location of quadrats on each transect should be re-randomised. Not only will this minimise the potential for an erroneous indication of temporal change as a function of different sampling locations, but this will also, over time, enable any directional changes in communities at stations to be identified if they occur.

In order to provide a better understanding for the reasons in differences in underboulder communities, particularly within the same habitat types, the physical attributes of the underboulder habitats could be described in addition to the fauna. For example, the amount of space under the boulders/cobbles could be described using a scale, and a description of the sediments present could be recorded using the Wentworth scale[15].

In order to eliminate the introduction of variability in estuarine communities as a result of seasonal fluctuations, future sampling for the purposes of condition monitoring should be carried out at the same time of year as this study. Seasonal variability may otherwise indicate temporal changes in communities where none exist.

As in the current study, the habitat types present should be determined in accordance with the most up-to-date Marine Habitat Classification for Britain and Ireland (currently Vs 04.05). The distribution, extent and variety of biotopes will be most efficiently compared using GIS software to map and measure the attributes area.

In future monitoring of the rocky scar communities within the Solway Firth SAC, particular emphasis should be placed on faunal and floral community structures using a combination of univariate and multivariate statistics. Such an approach is the most effective method of showing any temporal changes caused by natural or anthropogenic factors. By plotting community data from this survey alongside future survey data, temporal trends in community assemblages should become apparent. Any directional changes in these plots could indicate anthropogenic stressors (particularly if the changes are not reflected at other transects within a habitat type) or natural changes caused for example by changing weather patterns.

By implementing these recommendations, a comparison of results from future studies will provide a sound foundation from which to base scientifically robust conclusions regarding any temporal changes that may be observed within rocky scar ground sub-feature of the Solway Firth SAC. However, the rocky scar communities are known to be influenced by the morphological evolution of the estuary and its naturally highly dynamic nature. As such, the gross distribution of habitats and species can be expected to change over time naturally. Therefore, depending upon the specific aims of any future monitoring, it 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. This distinction is necessary to determine the condition of the SAC given that attribute targets stipulate changes ‘subject to natural change’. If it is not possible to derive the information to make such distinctions from the information available, then further work outside the remit if the initial condition assessment may be necessary.

Glossary

Abundance	Total number of all animals (individuals) in a sample
Bray-Curtis similarity	Statistic that compares the similarity of the community structure between samples
BSH	Broad scale habitat
CCME	Canadian Council of Ministers of the Environment
Community	A collection of fauna (or flora) cohabiting in and characteristic of an area of the environment
Community analysis	Statistical technique used to identify areas with a similar biological community
Diversity	The range of animals (taxa) in a sample
Infauna	Animals that live within the sediment
MDS	Multi-Dimensional Scaling, a statistical manipulation used to identify groups of distinct fauna (communities).
Multivariate Statistics	Statistics which can be applied to a complete taxa abundance data matrix without any loss of information i.e. not requiring reduction of the data to a single number or index
Margalef's species richness	A measure of the variety of species present.
Pielou's evenness	A measure of how evenly the total number of individuals is distributed between the species present
Shannon Wiener diversity index	An index (single number) of fauna diversity, increases with fauna diversity
Simpson's diversity index	An index of fauna diversity, increases with fauna diversity

SOCI	Species of Conservation Importance
STW	Sewage Treatment Works
Taxon	A grouping of the fauna, may be a species or, if different species are indistinguishable, it may be based on a higher taxonomic group such as the genus, family or phylum
Univariate	Statistics that describe the fauna in terms of a single number
Wentworth scale	Recognised 12 band scale of sediment particle size

LR.HLR.MusB.Sem.LitX	*Semibalanus balanoides* and Littorina spp. on exposed to moderately exposed eulittoral boulders and cobbles.
LR.MLR.BF.FvesB	*Fucus vesiculosus* and barnacle mosaics on moderately exposed mid eulittoral rock
LR.LLR.F.FSpi.X	*Fucus spiralis* on full salinity upper eulittoral mixed substrata
LR.LLR.F.FVes.X	*Fucus vesiculosus* on mid eulittoral mixed substrata
LR.LLR.F.Asc.X	*Ascophyllum nodosum* on full salinity mid eulittoral mixed substrata
LR.LLR.FVS.FSpiVS	*Fucus spiralis* on sheltered variable salinity upper eulittoral rock

LR.LLR.FVS.Fcer	*Fucus ceranoides* on reduced salinity eulittoral rock
LR.FLR.Eph.Ent	*Ulva spp.* (previously *Ulva* spp.) on freshwater influenced and/or unstable upper eulittoral rock
LR.FLR.Eph.EntPor	*Porphyra purpurea* and *Ulva spp.* on sand-scoured mid or lower eulittoral rock
LS.LBR.LMus.MytMx	*Mytilus edulis* beds on littoral mixed substrata
LS.LBR.Sab.Salv	*Sabellaria alveolata reefs on sand-abraded eulittoral rock*
SS.SBR.SMus.MytSS	*Mytilus edulis* beds on sublittoral sediment

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Appendices

Appendix 1:

Extract from Allen et al, 2002[3]:

1. Individual reefs of well developed *S. alveolata* forming continuous colonies (>90% coverage) < 10 m^2 in area, generally >30cm height (but at least >10cm) and sufficiently separated from other reefs in order to justify individual status (see points 3-5).

2. Individual reefs of well developed *S. alveolata* forming continuous colonies or platforms (>90% coverage) > 10 m^2 in area and >30cm in height.

3. Recognisable areas of *S. alveolata* over 10m^2 with patchy distribution (>50% coverage). Individual patches of *S. alveolata* are of varying size but forming recognisable reef structures (e.g. >10cm diameter/height) and forming a recognisable area as opposed to discrete individual reefs (type 1). The critical distance between individual *S. alveolata* patches used to differentiate between an area and an individual reef will vary depending on the size of the area as a whole and best judgement will be required to determine this, although <2m was found to be applicable during the survey.

4. Areas of *S. alveolata* over 10m^2 in area with very patchy distribution (20-50% coverage) but still forming a recognisable area of reef structures (>10cm diameter/height) as opposed to discrete type 1 reefs. The critical distance between individual *S. alveolata* patches used to differentiate between an area and an individual reef will vary depending on the size of the area as a whole and best judgement will be required to determine this although <5-10m was found to be applicable during the current survey.

5. Dispersed areas of *S. alveolata* over 10m^2 in area with extremely patchy distribution and very low coverage (<20% coverage) but forming a recognisable area of proper reef structures (>10cm diameter/height) as opposed to discrete reef patches (type 1). The critical distance between individual *S. alveolata* patches used to differentiate between an area and an individual reef will vary depending on the size of the area but between 10m-20m was found to be applicable during the current survey. However, best judgement will be required to determine whether reefs in areas of very low coverage e.g. <10% should be considered as individual type 1 reefs and this will be dependant on the size of the areas and the time available for logging of individual points.

6. Low lying patches/areas of *S. alveolata* often forming 'barnacle' like coverage on rocks/sediment and may include juvenile forms following settlement. Although this type of reef generally occurs at the margins of more developed reefs in relatively low abundance, the coverage may be highly variable (10-100%) and may in some areas form the entire reef. The above guidelines for extent and patchiness apply.

7. Low lying heavily silted and predominantly dead areas of relict *S. alveolata*. Although this type of reef generally occurs at the margins of more developed reefs in relatively low abundance, the coverage may be highly variable (10-100%) and may in some areas form the entire reef. The above guidelines for extent and patchiness apply.

** Example photographs will be produced with text.

Whilst the forms of *S. alveolata* outlined above cover most situations the differences between them (type, patchiness, fragmentedness, colonisation) will inevitably vary from one area to the next and best judgement is required to determine the differences between the various forms. However in terms of the field methodology such differences are relatively unimportant with any discrete

Appendix 2

Table 1. Transect coordinates (OSGB 36 BUG) and assigned habitat types

Transect	Habitat Type	Tidal Height	Transect Coordinates		
			Start/Finish	X	Y
T1A	LS.LBR.LMus.MytMx	Lower	Start	307404	546627
			Finish	307390	546652
T2A	LS.LBR.Sab.Salv	Lower	Start	307075	546546
			Finish	307055	546566
T2B	LS.LBR.Sab.Salv	Lower	Start	306917	546451
			Finish	306903	546477
T3A	LS.LBR.LMus.MytMx/ LS.LBR.Sab.Salv	Lower	Start	307000	547284
			Finish	306999	547258
T4A	LS.LBR.LMus.MytMx/ LS.LBR.Sab.Salv	Lower	Start	306939	547484
			Finish	306935	547452
T5A	LS.LBR.LMus.MytMx	Lower	Start	306363	547732
			Finish	306350	547710
T6A	LS.LBR.LMus.MytMx	Lower	Start	306325	548225
			Finish	306300	548239
T7A	LR.HLR.MusB.Sem.LitX	Upper	Start	308294	547756
			Finish	308304	547784
T8A	LR.HLR.MusB.Sem.LitX	Upper	Start	308526	548590
			Finish	308514	548565
T9A	LS.LBR.LMus.MytMx	Mid	Start	307807	548072
			Finish	307892	548011
T10A	LS.LBR.LMus.MytMx	Mid	Start	307954	548418
			Finish	307937	548393
T11A	LS.LBR.LMus.MytMx	Mid	Start	308113	548562
			Finish	308097	548537
T12A	LS.LBR.LMus.MytMx	Lower	Start	307479	549353
			Finish	307496	549381
T13A	LS.LBR.LMus.MytMx	Lower	Start	307869	549725
			Finish	307856	549698
T14A	LS.LBR.LMus.MytMx	Lower	Start	307643	550200
			Finish	307627	550175
T15A	LR.MLR.BF.FvesB	Mid	Start	310843	553939
			Finish	310824	553919
T16A	LR.MLR.BF.FspiX	Upper	Start	311394	554636
			Finish	311411	554663
T16B	LR.HLR.MusB.Sem.LitX	Mid	Start	311381	554648
			Finish	311398	554674
T17A	LR.HLR.MusB.Sem.LitX	Upper	Start	312069	555639
			Finish	312058	555609
T17B	LR.FLR.Eph.Ent/LR.LLR.F. Fves.X	Mid	Start	312030	555678
			Finish	312013	555660
T17C	LS.LBR.LMus.MytMx	Lower	Start	312024	555746
			Finish	312010	555722
T18A	LR.LLR.F.Fves.X	Upper	Start	312695	556220
			Finish	312722	556235
T18B	LR.HLR.MusB.Sem.LitX	Mid	Start	312684	556233
			Finish	312709	556246
T19A	LR.HLR.MusB.Sem.LitX	Upper	Start	312980	556357
			Finish	313006	556371
T19B	LR.HLR.MusB.Sem.LitX	Mid	Start	312954	556397
			Finish	312980	556413

Table 1 contd. Transect coordinates (OSGB 36 BUG) and assigned habitat types

Transect	Habitat Type	Tidal Height	Transect Coordinates		
			Start/Finish	X	Y
T20A	LR.FLR.Eph.EntPor	Mid-Lower	Start	314647	556690
			Finish	314672	556707
T21A	LR.LLR.FSpi.X	Mid	Start	316132	555714
			Finish	316103	555708
T22A	LR.FLR.Eph.EntPor	Mid-Lower	Start	315622	556563
			Finish	315634	556589
T23A	LR.FLR.Eph.Ent	Mid-Upper	Start	317903	557156
			Finish	317876	557171
T24A	LS.LBR.LMus.MytMx	Mid-Upper	Start	317201	557508
			Finish	317174	557521
T25A	LR.HLR.MusB.Sem.LitX	Upper	Start	316933	557719
			Finish	316910	557742
T25B	LR.FLR.Eph.Ent	Mid	Start	316896	557704
			Finish	316916	557683
T25C	LS.LBR.LMus.MytMx	Lower	Start	316905	557632
			Finish	316876	557637
T26A	LR.FLR.Eph.EntPor	Mid-Upper	Start	316079	557948
			Finish	316049	557946
T27A	LR.FLR.Eph.Ent	Mid	Start	321872	562985
			Finish	321896	562981
T28A	LR.FLR.Eph.Ent	Mid	Start	322284	563013
			Finish	322313	563010
T29A	LR.LLR.FVS.FspiVS	Upper	Start	324139	562336
			Finish	324160	562315
T29B	LR.LLR.FVS.Fcer	Mid	Start	324164	562386
			Finish	324192	562377
T30A	LR.LLR.FVS.Fcer	Upper	Start	324467	561885
			Finish	324486	561859
T30B	LR.FLR.Eph.Ent	Mid	Start	324430	561823
			Finish	324440	561795

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