# Drigg Coast, Ravenglass Estuary Intertidal Surveys (Lot 1) 2014

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Sheryl Earnshaw and Samuel Andrews

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## Natural England Project manager

Ross Bullimore

## Contractor

APEM Ltd, Riverview, A17 Embankment Business Park, Heaton Mersey, SK3 3GN

www.apemltd.co.uk

## Author

Sheryl Earnshaw and Samuel Andrews

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### Further information

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# Executive summary

The Drigg Coast EMS is one of the best examples of a small bar-built estuary complex in the UK containing the Rivers Irt, Mite and Esk which converge close to Ravenglass. The transition from freshwater to sand dunes in the estuary is hardly disturbed and this site is one of the UK's best examples of this making it important to conserve. As part of the EU Habitats Directive, Natural England must conduct a condition assessment of sub features of European Marine Sites on a 6-yearly cycle and report these to Europe through the JNCC.

APEM conducted an intertidal survey of the rocky shore biotopes within the Drigg Coast Site of Special Scientific Interest (SSSI) and Drigg Coast Special Area of Conservation (SAC) (known as the Drigg Coast European Marine Site (EMS)) from Sunday 18th to Tuesday 20th August 2013 and from Wednesday 4th to Friday 6th September 2013. The aim of the surveys was to assess the boulder and cobble skear habitats of the Drigg Coast EMS to provide additional knowledge of these features to inform condition assessments of the site as part of EMS monitoring requirements.

The primary objective of the survey was to gain as much information as possible on the boulder and cobble skear habitats present in the region and map the individual biotopes to determine their extent (Phase I) and to provide a quantitative baseline of these features in representative areas. This resulted in both good coverage of the area and quantitative data for all main boulder and cobble skear biotopes encountered.

The Phase I biotope mapping survey effort was directed across the whole of the intertidal region of the Ravenglass Estuary (including the Rivers Esk, Irt and Mite) which forms part of both the Drigg Coast SSSI and the Drigg Coast SAC. The intertidal region of this area was split into 5 sectors. Sectors 1-4 were surveyed as part of this contract. Sector 5 was targeted in a previous round of contracts for the region as part of verification surveys of the Cumbria Coast recommended Marine Conservation Zone (rMCZ).

All of the boulder and cobble skear biotopes within the intertidal region of the area of interest were mapped in detail (EUNIS level 4 and 5). Littoral sediments were not of focus for the surveys thus were not mapped. However, all areas where boulder and cobble skear biotopes were not recorded can be assumed to be littoral sediments (LS, EUNIS code A2) as 100% of the estuary was covered. The main biotopes present were barnacles and *Littorina* spp. on unstable eulittoral mixed substrate (A2.431, LR.FLR.Eph.Blitx), *Porphyra purpurea* and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock (A 1.452, LR.FLR.Eph.EntPor) and *Mytilus edulis* beds on littoral sediments (A2.721, LS.LBR.LMus.Myt).

A total of 14 different boulder and cobble skear biotopes/biotope complexes were recorded across all 4 sectors in the Ravenglass Estuary. A number of these formed part of the fucoids in variable salinity biotope complex (A 1.32, LR.LLR.FVS). Biotopes were assigned to EUNIS level 4 (2 biotopes) and EUNIS level 5 (12 biotopes). Only a *Fucus ceranoides* biotope (A1 .327, LR.LLR.FVS.Fcer) occurred in all 4 sectors.

Half of the biotopes recorded have been previously recorded in the estuary (Woombs, 1999) therefore are typical to the area, a further 4 biotopes show similarities to other previously recorded biotopes and the remaining 3 biotopes (2 *Fucus spiralis* biotopes and 1 rockpool biotope) were not recorded in historic data (Woombs, 1999) but have

potentially been recorded by the JNCC in data submitted to them (forming core and non-core but certain records in their biotope distribution maps (JNCC, 2004).

Several biotopes have changed since the original survey of the estuary in 1999 and the overall coverage of boulder and cobble habitats appears to have decreased by almost 50 % since this time. However, the estuary now appears to be slightly more diverse in terms of the biotopes observed. The estuary as a whole is still primarily littoral sediments with patches of boulder and cobble habitats throughout. Many of the biotopes observed are relatively similar to each other due to their similarity in substrate type and thus the general species composition across the estuary could also be deemed to be relatively similar with the exception of areas with *Fucus spiralis* and rockpool biotopes. As a whole, the species communities were impoverished as was found in 1999.

The quantitative survey effort was directed to representative areas of cobble skears at sites geographically spread throughout the estuary and Sectors where possible. As part of these quadrat surveys, 121 quadrats were assessed (24 transects with 5 replicates in each and an additional, 6th quadrat assessed at Transect 6 due to its vertical surfaces). The quantitative data was collected using standardised methods to ensure comparability with similar future monitoring to detect temporal trends and changes.

The quadrats contained 37 taxa (25 encrusting/colonial/canopy-forming taxa and 12 free-living taxa). Barnacles were particularly common (present in 83 quadrats and contributing to 22 % of the observed percentage coverage of encrusting/colonial/canopy-forming taxa), probably due to the large surface area of the hard substrates (boulders and cobbles) allowing settlement. Representative photographs were taken of the barnacle communities present in each quadrat for later analysis. The algal species *Fucus ceranoides*, *Fucus vesiculosus* and *Enteromorpha* spp. were also relatively common and were present in 39, 42 and 31 quadrats respectively. The two *Fucus* species contributed to 36 % and 15.4 %, respectively, of the observed percentage coverage of encrusting/colonial/canopy forming taxa and, along with barnacles, were the highest contributors. The most abundant free-living species recorded in quadrats was the blue mussel, *Mytilus edulis* (1006 individuals) with *Littorina littorea* the second most dominating species (770 individuals). Combined, these two species contributed to over 50 % of the observed abundance of free-living taxa in the quadrats (37.1 % and 28.4 % respectively). The sedimentary shore species *Lanice Conchilega* was present in some quadrats and this was likely due to the boulder and cobble skear habitats overlapping with littoral sediments (the dominant substrate in the estuary).

Sector 2 was found to have the highest mean number of taxa in hard substrate biotopes in comparison to the other sectors and this is likely due to the hard rock face of the railway bridge at Transect 6 providing suitable substrate for a number of species, however, only 2 transects were assessed which may have skewed the results slightly. Sector 1 had the lowest mean number of taxa and was also the least variable.

These quantitative data will form the baseline for future condition assessment as it is not possible to compare these data with that collected by Woombs in 1999.

Within the Ravenglass Estuary, 1 specialised biotope (A1.414, LR.FLR.Rkp.H), 1 nationally or more than nationally important community (A2.71, LS.LBR.Sab.Salv), 2 non-native species (Austrominius (Elminius) modestus, Sargassum muticum) and 3 Biodiversity Action Plan (BAP) habitats (*Sabellaria alveolata* reefs, blue mussel beds and estuarine rocky habitats) were recorded. No nationally rare or scarce species were

knowingly encountered although the brief nature of the survey limited the amount of time available to search for inconspicuous specimens.

The main anthropogenic pressure observed was the Ministry of Defence site south of Eskmeals Dunes and walkers and dog walkers at various points around the estuary. The preliminary condition assessment found that the current condition of the sub feature "extent of characteristic biotopes" is unknown. This is due to the lack of extent data between 1999 and 2013 which would be useful in determining if the decrease is part of cyclical change or an indication of a decline in the condition of the sub feature. The current condition of the sub-feature "species composition of characteristic biotopes" is also unknown due to a lack of quantitative data for comparison. The survey has, however, provided precise biotope mapping data which will allow future condition assessments in determining whether the extent of biotopes is truly changing and also a robust quantitative baseline from which to assess changes of the species abundance with accuracy.

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# 1. Introduction

## 1.1 Background

APEM were commissioned by Natural England to conduct an intertidal survey of the rocky shore biotopes, specifically boulder and cobble skear grounds within the Drigg Coast European Marine Site (EMS) covering both the Drigg Coast Site of Special Scientific Interest (SSSI), made up of several units, and the Drigg Coast Special Area of Conservation (SAC) (Figure 1 ). The survey aimed to provide additional knowledge of the boulder and cobble skear habitats of the Drigg coast to inform condition assessments of this site as part of SSSI and SAC monitoring requirements.

This document outlines the methodology and results of the rocky shore intertidal surveys, describes the presence and extent of the boulder and cobble skear grounds, gives an indication of the faunal composition of these features, and provides a general account of anthropogenic pressures identified at the time of survey that may impact the integrity of the EMS.

A preliminary condition assessment based on the data gathered has been carried out which Natural England may or may not wish to refer to when completing their own condition assessment.

## 1.2 Drigg Coast EMS

The Drigg Coast EMS contains the Drigg Coast SSSI which extends over approximately 11 $km^2$ of Cumbria's coastline from Seascale south towards Bootle and the Drigg Coast SAC which covers much the same area with both designations encompassing the extensive sand dune systems, Eskmeal Dunes and Drigg Dunes (Figure 1 ). The dunes in the area are the largest and best known example of this rare habitat on the west coast of England and Wales. There is also a Local Nature Reserve located at the mouth of the Ravenglass Estuary (Drigg Dunes and Gullery, Ravenglass).

The SSSI and SAC contain a number of features that require monitoring including boulder and cobble skear grounds and their communities, a feature of the Annex I habitat "estuaries".

Adjacent to, and partly overlapping with, the SSSI and SAC is the Cumbria Coast recommended Marine Conservation Zone (rMCZ). The Barn Scar region of the SSSI and SAC was surveyed during February/March 2013 as part of verification surveys for the rMCZ thus data from the relevant reports (MESL and APEM, 2013) should be consulted along with this current report.

The area was surveyed previously in 1999 (Woombs, 1999) and a biotope map was drawn up (Figure 2). These data have been used to give a basic assessment change in the presence and extent of the boulder and cobble skear biotopes. There are no quantitative data available to be able to fully assess the change in condition of the habitats since the original survey.


**Figure 1. Drigg Coast designations: Drigg Coast SSSI boundary (blue) with all units shown, Drigg Coast SAC boundary (red) and the Cumbria Coast recommended MCZ (yellow) that was surveyed in February/March 2013. Contains Ordnance Survey data.**

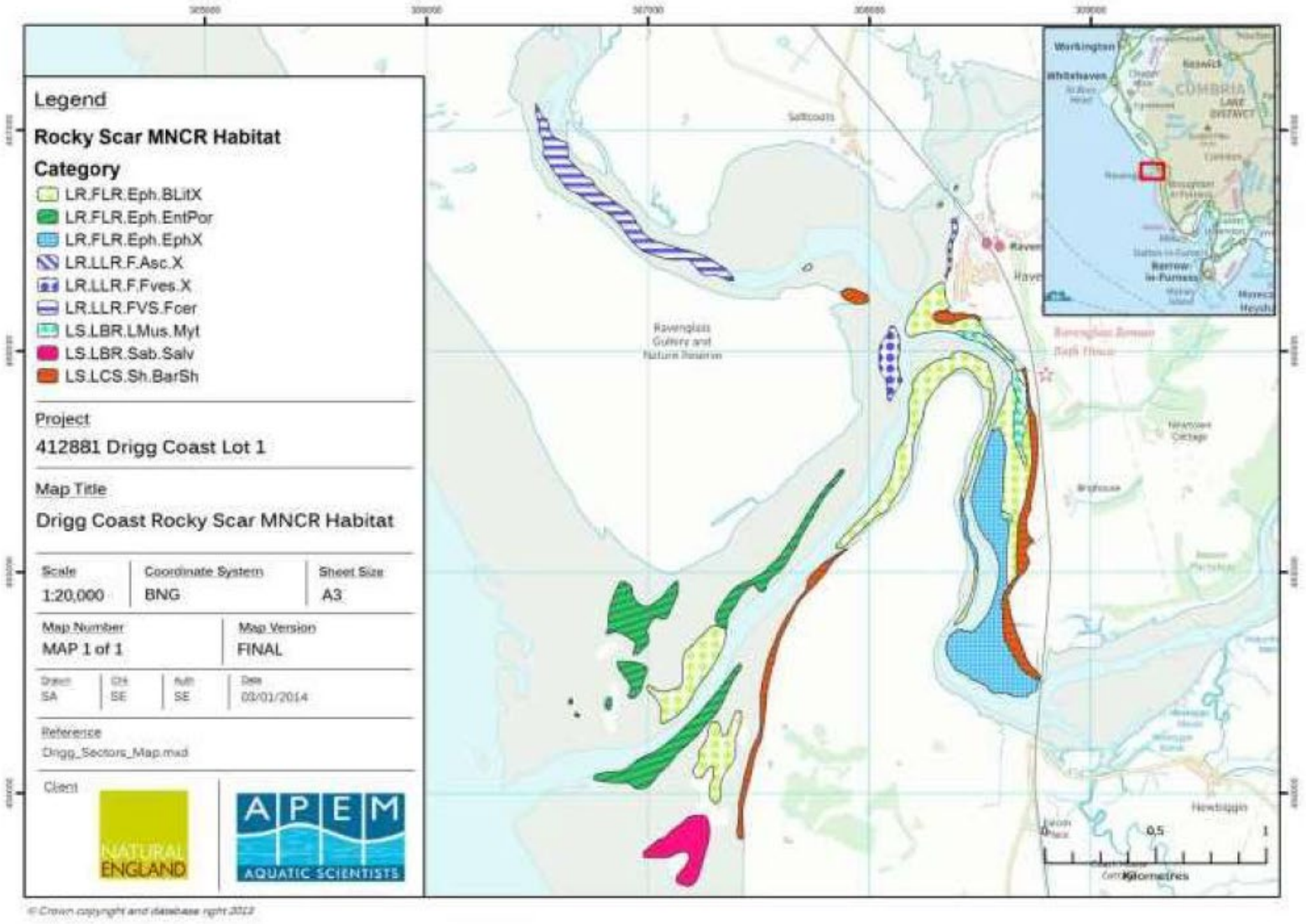


**Figure 2. Digitised biotope map of the Ravenglass Estuary from the Phase I biotope survey carried out on foot and using quad bikes in 1999 (Woombs, 1999). All biotopes converted to the 2004 JNCC classification for comparison with 2013 data. Contains Ordnance Survey data.**

## 1.3 Objectives

The main objectives of this project were:

- Conduct surveys of the boulder and cobble skear habitats of the Drigg Coast SSSI and SAC to provide additional knowledge of certain features to inform condition assessments of the site as part of EMS monitoring requirements;
- Use a combination of in situ biotope allocation (Phase I), and quantitative quadrat assessments (quadrats and subsequent laboratory analysis where required) to produce a repeatable, rigorous quantitative sampling design to allow future status to be assessed;
- Determine the location and extent of rocky shore habitats within the Ravenglass estuary as well as blue mussel *Mytilus edulis* beds and provide up-to-date maps of the intertidal rocky habitat biotopes to the highest possible classification level to provide a comparison with the previous data collected by Mark Woombs in 1999.
- Assess anthropogenic influences potentially impacting on identified features where possible.

# 2. Methods

Field survey methods incorporated a combination of qualitative in-situ biotope assessment (Phase I) and quantitative quadrat assessment approaches (Wyn, *et al*., 2000; Davies, *et al*., 2001; JNCC, 2004). The Phase I biotope allocation approach enabled a broad characterisation of the communities present within the SSSI and SAC with specific focus on intertidal hard substrate habitats, primarily boulder and cobble skear grounds. The quantitative methods provided species composition and abundance data for specific transects suitable for the application of statistical analyses.

## 2.1 Sub-features surveyed

The SSSI and SAC sub-feature relevant attributes of focus for the surveys were:

- Extent of boulder and cobble skear grounds with *Mytilus edulis* beds Species composition of Mussel beds and tide swept boulders with *Fucus ceranoides*.

## 2.2 Survey locations

The location of Phase I and quantitative survey sites were initially determined by aerial imagery collected by APEM's aerial division one month prior to the first survey mobilisation (between 15th and 19th July 2013). Survey sites and transects were then micro-located on site as necessary and according to the presence of relevant biotopes. The area of interest was split into 5 pre-determined sectors, of which Sectors 1-4 were of relevance to these surveys (Figure 3). Sector 5 (Barn Scar) was surveyed during February/March 2013 as part of the Cumbria Coast rMCZ verification surveys.

Following advice from Natural England, it was considered that a large proportion of the Drigg Coast SAC and SSSI site was easily accessible by foot thus almost 100% coverage of the site was possible at Phase I. Any areas not accessible by foot were considered to be likely to be visible from other parts of the site thus an assessment could be made as to whether any hard substrate was present. Health and safety was considered in the project planning phases (APEM Ltd, 2013) with a particular focus on the adjacent Ministry of Defence (MoD) site at Eskmeal Dunes. The MoD were contacted prior to survey to gain permission to survey and ensure surveyors were not at risk of any planned firing tests. Surveyors also attended a safety briefing to ensure they were aware of the correct procedures to follow in the event of encountering munitions on the foreshore.

For the quantitative surveys, conducted concurrently with Phase I, a total of 24 transects were surveyed (Figure 4) containing 5 quadrats per transect spread over 4 pre-determined sectors and also shore heights (where possible) to encompass the different communities present. The locations of the transects were refined in the field according to the presence and extent of the communities of interest and thus differed in direction down or across the shore depending on this (Table 1). All transects were easily accessible by foot thus can be re-visited for future condition assessments. Actual locations of each quadrat are shown in Appendix 1 for future reference in re-locating sites.

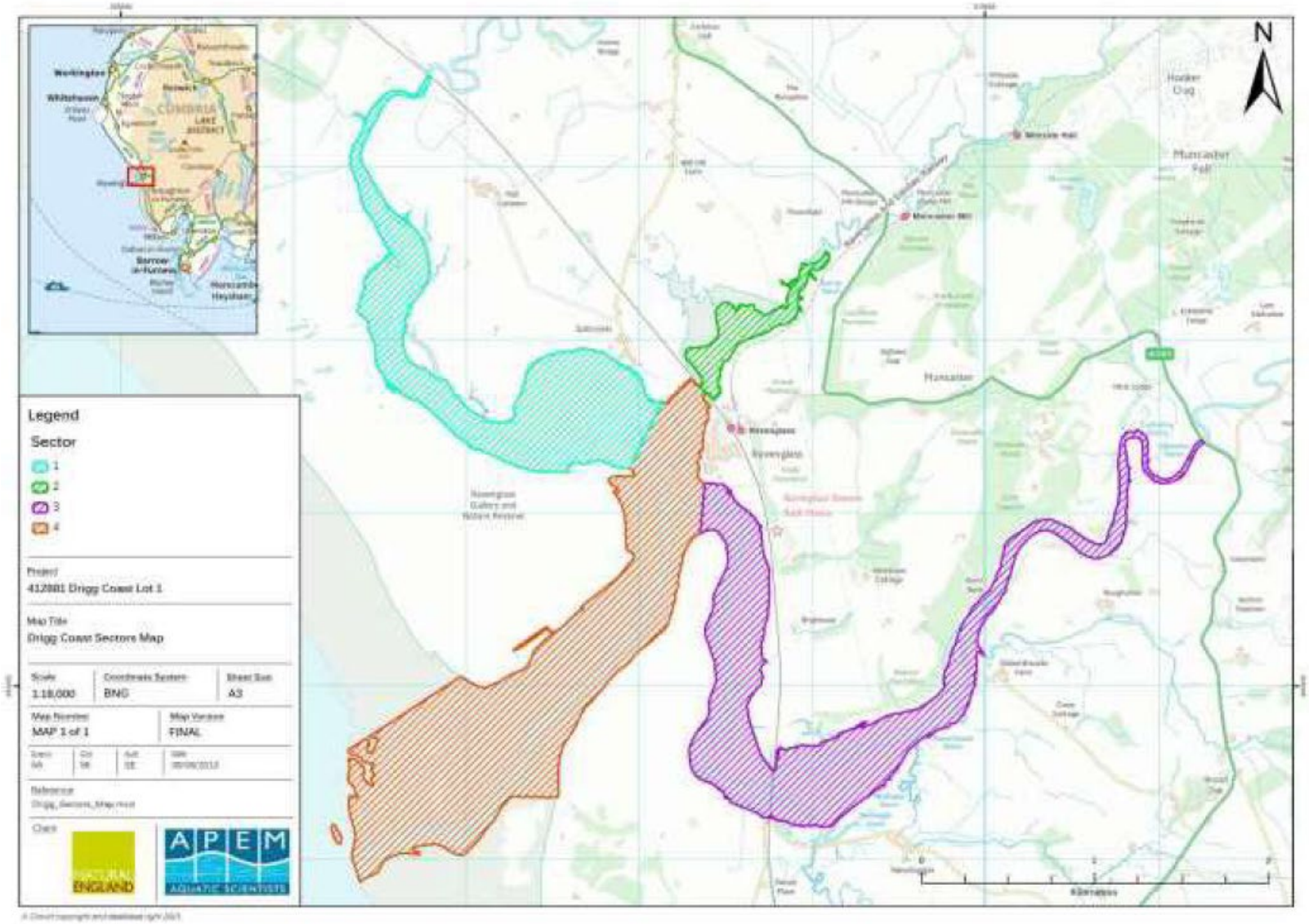


**Figure 3. Sectors 1-4 in the Ravenglass Estuary. Sector 5 (not shown) was not of relevance to the current surveys. Contains Ordnance Survey data.**

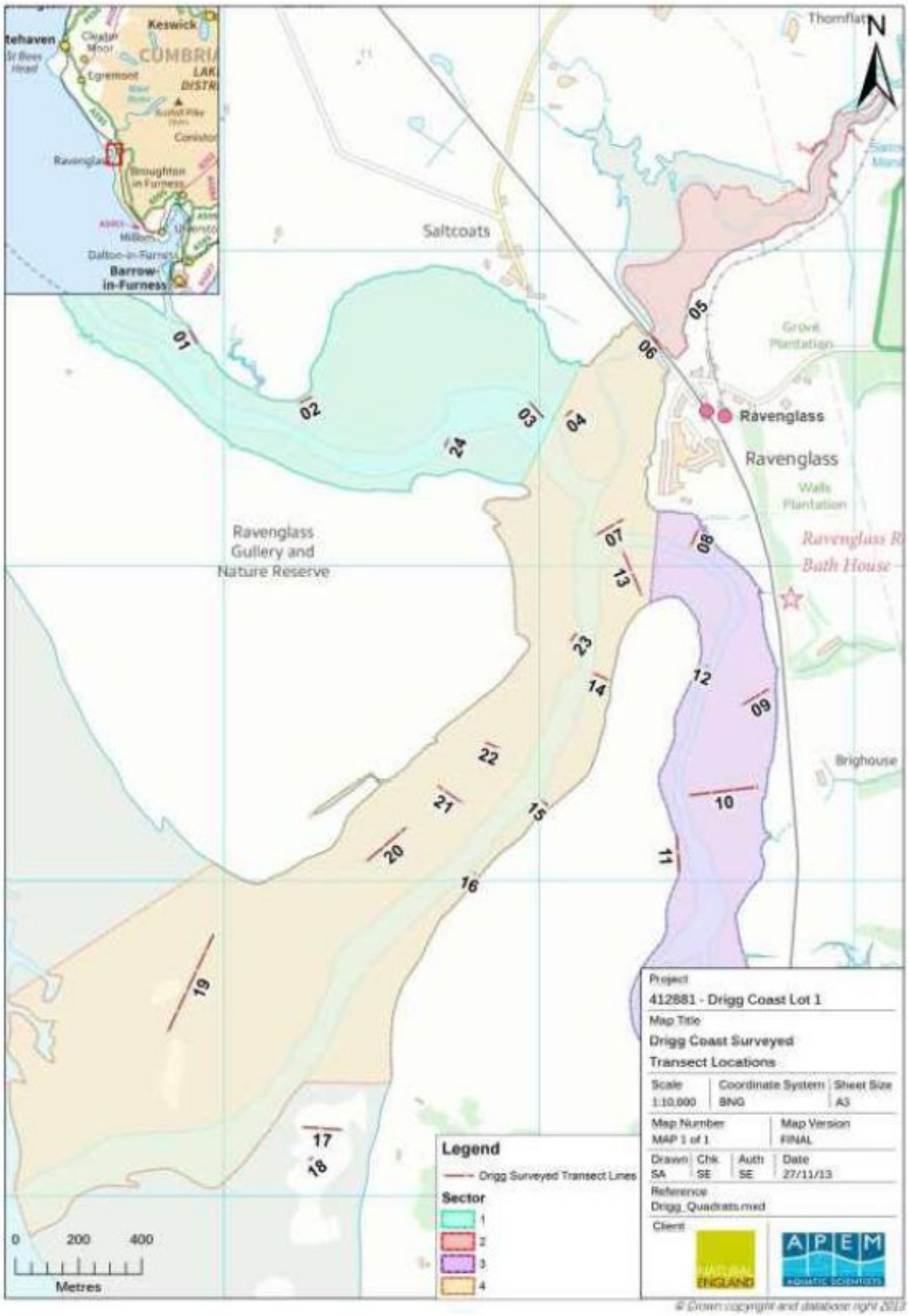


**Figure 4. Approximate locations of the 24 transects sampled across the 4 sectors of interest in the Ravenglass Estuary. A total of 5 replicate quadrats were assessed at each transect within representative biotopes. Contains Ordnance Survey data.**

**Table 1. Transect line locations and length (m)**

| Number | Start NGR | Start Easting | Start Northing | End NGR | End Easting | End Northing | Length |
|---|---|---|---|---|---|---|---|
| **1** | 8D0688696756 | 306886 | 496756 | 8D0691296705 | 306913 | 496705 | 57.35 |
| **2** | 8D0723296512 | 307233 | 496513 | 8D0727996536 | 307280 | 496536 | 52.59 |
| **3** | 8D0796596522 | 307966 | 496522 | 8D0801496468 | 308014 | 496468 | 72.72 |
| **4** | 8D0807796470 | 308077 | 496470 | 8D0810696494 | 308106 | 496494 | 37.87 |
| **5** | 8D0847896840 | 308478 | 496840 | 8D0847296833 | 308472 | 496834 | 9.26 |
| **6** | 8D0838496700 | 308385 | 496701 | 8D0835796727 | 308357 | 496727 | 37.98 |
| **7** | 8D0817696095 | 308177 | 496096 | 8D0826696147 | 308266 | 496148 | 103.46 |
| **8** | 8D0847996057 | 308479 | 496057 | 8D0850296113 | 308503 | 496113 | 61.00 |
| **9** | 8D0863895554 | 308639 | 495555 | 8D0872895608 | 308728 | 495609 | 104.24 |
| **10** | 8D0846995271 | 308470 | 495271 | 8D0869495299 | 308694 | 495299 | 226.51 |
| **11** | 8D0844295015 | 308443 | 495015 | 8D0843595145 | 308435 | 495146 | 130.61 |
| **12** | 8D0852195686 | 308521 | 495686 | 8D0853495680 | 308535 | 495681 | 14.46 |
| **13** | 8D0826396049 | 308264 | 496050 | 8D0832495905 | 308325 | 495906 | 156.75 |
| **14** | 8D0822295635 | 308222 | 495636 | 8D0817295659 | 308172 | 495660 | 55.50 |
| **15** | 8D0800895256 | 308008 | 495257 | 8D0802595239 | 308026 | 495240 | 24.80 |
| **16** | 8D0778395027 | 307784 | 495028 | 8D0779895021 | 307798 | 495022 | 15.47 |
| **17** | 8D0724794219 | 307248 | 494220 | 8D0737994209 | 307380 | 494210 | 132.31 |
| **18** | 8D0726194109 | 307262 | 494110 | 8D0728194123 | 307282 | 494124 | 24.45 |
| **19** | 8D0681994517 | 306820 | 494518 | 8D0696694830 | 306966 | 494831 | 345.50 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **20** | 8D0744895058 | 307448 | 495059 | 8D0757795170 | 307578 | 495170 | 170.68 |
| **21** | 8D0767895302 | 307678 | 495302 | 8D0775995245 | 307760 | 495245 | 99.59 |
| **22** | 8D0782895439 | 307828 | 495439 | 8D0787695419 | 307876 | 495420 | 51.55 |
| **23** | 8D0809395753 | 308093 | 495754 | 8D0811895786 | 308118 | 495786 | 40.85 |
| **24** | 8D0771496406 | 307714 | 496407 | 8D0770096376 | 307700 | 496376 | 33.84 |

## 2.3 Timings of surveys

The survey was planned to be carried out on midday spring tides to maximise the tidal extent possible to survey and during summer months (June-August) to avoid any winter algal dieback and maximise the daylight hours available. However, due to problems with access permissions within the timescales, the survey had to be conducted over two different tidal windows with the area owned by the Ministry of Defence surveyed during spring low tides from Sunday 18th to Tuesday 20th August 2013 and other intertidal areas surveyed during spring low tides from Wednesday 4th to Friday 6th September 2013 (Table 2).

Spring tides optimise the length of time available for each survey and ensure the lower reaches of the shores can be surveyed. Work was possible during one low tide per day in the first survey period and during two low tides per day in the morning and early evening in the second survey period. The timings of the tides limited the time available to reach the lower shore and also the daylight hours available. However, this schedule was considered the most practical and time efficient way to collect the maximum amount of information in the time allowed by the available tide windows during daylight hours.

**Table 2. Survey times in relation to tide times, heights, and time**

| Date | Day | Time of sunrise (BST) | Time of sunset (BST) | Time of low tide (BST) | Height of low tide (m) | Time of high tide (BST) | Height of high tide (m) | Start time (BST) | Finish time (BST) |
|---|---|---|---|---|---|---|---|---|---|
| **18/08/13** | Sunday | 05.56 | 20.39 | 16.10 | 1.5 | 09.35 | 6.9 | 15:30 | 20:30 |
| **19/08/13** | Monday | 05.58 | 20.37 | 17.15 | 1.0 | 10.40 | 7.4 | 14:00 | 20:30 |
| **20/08/13** | Tuesday | 06.00 | 20.34 | 18.05 | 0.5 | 11.30 | 7.9 | 13:00 | 19:30 |
| **04/09/13** | Wednesday | 06.27 | 19.58 | 05.46<br>18.01 | 1.61<br>1.73 | 11.36<br>23.48 | 7.44<br>7.8 | 06:30<br>16:00 | 11;00<br>20:00 |
| **05/09/13** | Thursday | 06.29 | 19.56 | 06.23<br>18.37 | 1.3<br>1.45 | 12.10<br>00.23 | 7.76<br>8.09 | 06:30<br>16:00 | 11:30<br>20:00 |
| **06/09/13** | Friday | 06.30 | 19.53 | 06.58<br>19.12 | 1.08<br>1.26 | 12.43<br>00.00 | 7.98<br>8.25 | 06:30 | 12:30 |

## 2.4 Survey design

### Phase I biotope surveys

Surveys were conducted following best practice guidance including the Countryside Council for Wales (CCW) Handbook for Marine Intertidal Phase I mapping surveys (Wyn, *et al*., 2000), Marine Monitoring Handbook (Davies, *et al*., 2001) and Common Standards Monitoring guidance (JNCC, 2004).

Wireframe maps were produced from aerial imagery obtained by APEM during a nearby survey conducted two weeks prior to the survey mobilisation and were used to sketch in-situ the locations and shapes of each hard substrate biotope in the SSSI and SAC and provide a reference document to aid accurate mapping in GIS. A handheld dGPS device (accuracy better than 5m) was used to record waypoints of important features and tracks of each large scale biotope. The intertidal region was split into 5 sectors (pre-determined by Natural England, Sector 5 was not covered during this survey) and these sectors were used as a reference for the field notes with each sector acting as a 'Site'.

Two teams of two conducted the survey. The teams jointly revised the recording methodology prior to the commencement of the surveys to ensure they both followed the same protocol and harmonisation of the task. Surveyors worked down the shore on the ebbing tide and back up the shore on the flowing tide to maximise the available time. The surveyors aimed to survey the low shore area ±1 hour either side of the predicted low tide to maximise the time available to survey this region of the shore.

At each site, the faunal assemblage was noted in-situ by experienced field taxonomists in order to enable biotope allocation. The initial biotope allocation was conducted in the field based on short biotope descriptions and confirmed on return to the office. A range of information was additionally recorded including:

- Substrate type (bedrock, cobbles, boulders, etc.)
- Presence of macroalgae (% coverage recorded if present)
- Anthropogenic pressures
- Target notes on features of interest

Biotopes were assigned according to JNCC's National Marine Habitat Classification for Britain and Ireland: Version 04.05 (Connor, *et al*., 2004). The classification used species information, relative abundances, exposure of the shore and substrate type. A proportion of assignments were verified by a second taxonomist to provide quality control and consistency in the assignments. The JNCC's correlation table (JNCC, 2010) was used to assign EUNIS codes to each biotope.

### Quantitative quadrat survey

The quantitative quadrat survey was conducted concurrently with the Phase I biotope survey as this was the most efficient approach due to access restrictions. The target transects for placement of quadrats (based on aerial imagery) were validated or modified in the field primarily according to presence of rocky shore biotopes, in particular the sub features of focus. As transect locations were determined by the presence of relevant biotopes, they were, therefore, of varying length and direction down or across the shore to

be as representative of the biotopes as possible (Table 1). Features and/or sub features attributes were quantitatively assessed using a stratified random design using feature and shore height as sampling strata. This approach maximised the level of statistical confidence at the feature level for any set level of effort (i.e., number of replicates available). Quadrat locations are given in Appendix 4.

To gather robust quantitative data, representative sampling sites were randomly selected along the length of each transect (Appendix 1) within main features of interest. A much as possible, the transects dissected the area of the main features. This practical approach ensured the necessary randomisation of the transect location and orientation. Sample sites were selected at 5 locations (1 replicate quadrat at each location) as close to the transect line as possible (Appendix 1) with a focus on collecting data from different shore heights (nested factor within feature) where possible and in accordance with how far the hard substrate biotopes extended.

Percentage coverage of macroalgae, encrusting and colonial species within each 0.25 $m^2$ quadrat was recorded along with actual abundances of solitary organisms. Data were gathered following standard methodologies and best professional practices ensuring sufficient quality to act as a baseline of the presence, extent and community composition of intertidal hard substrates to allow future condition assessment of habitats not previously surveyed. Voucher specimens were collected to confirm the field identifications.

It should be noted that whilst *Enteromorpha* spp. has recently changed genus and is now classed as *Ulva* spp., for the purposes of using the JNCC biotope classification and for reporting, this species will be referred to as *Enteromorpha* throughout the report and data with the exception of the quadrat data whereby it is referred to as *Enteromorpha*/*Ulva*. This will aid interpretation according to existing biotope descriptions and also ensure the most up to date nomenclature is used in the dataset.

All data were truncated prior to analysis. This included combining adults and juveniles of the same species and therefore removing all qualifiers, and also combining any species that formed part of a complex genus, particularly where few individuals were recorded e.g., the highly complex Hyale genus.

## 2.5 Photographic evidence

Photographs were taken of sites and representative biotopes where possible. These included records of key species present and views from each site towards the land and sea. In addition, individual specimen photographs were taken. Some features were georeferenced, others were not depending on the feature and intended use of the information e.g., a photograph of an individual for identification, and photographs of macrophytes to be used as reference for identification were generally not georeferenced. A full photograph log can be found in Appendix 5.

*Barnacle Survey*

Two photographs, each showing a quadrat size 5cm x 5cm, of the representative barnacle communities present within each quadrat were also taken for future analysis. The enumeration and identification of the barnacles in each photograph did not form part of the requirements for this contract.

## 2.6 Mapping and statistical analysis

On completion of the surveys, raw data were transferred to electronic spreadsheets. This included a GPS waypoints log, GPS tracks log, photographic log and general site descriptions. The annotated GPS waypoints and tracks logs were subsequently used to create the biotope maps showing extent and distribution of rocky shore biotopes in the Ravenglass Estuary and the resulting polygons and points were modified according to field notes and photographs where necessary. All GIS outputs were generated in ArcGIS v9.2 and metadata were produced in accordance with MEDIN standards in the MESH data exchange format (DEF). The quantitative data collected were analysed using univariate and multivariate statistics. A method statement describing the approach taken for statistical analysis of quantitative quadrat data can be found in Appendix 7.

# 3 Results

## 3.1 Phase I survey biotopes

A total of 14 different rocky shore biotopes/biotope complexes were recorded in the intertidal region of the Ravenglass Estuary during the 2013 survey, covering an area of 45.7 Ha (0.457 $km^2$) (Table 3). These consisted of 2 biotopes taken to EUNIS level 4 and 12 biotopes taken to EUNIS level 5. These biotopes can all contain some element of boulder and cobble substrate.

The most widespread recorded biotope across the Ravenglass Estuary was A1.327 (LR.LLR.FVS.Fcer) occurring across all 4 sectors. The second most widespread recorded biotopes were A2.431 (LR.FLR.Eph.BLitX), A1 .323 (LR.LLR.FVS.FvesVS) and A1 .324 (LR.LLR.FVS.AscVS). A2.431 (LR.FLR.Eph.BLitX) covered the largest area (0.079 $km^2$) and A 1.452 (LR.FLR.Eph.EntPor) covered the second largest area (0.074 $km^2$), making up 17 % and 16 % of the coverage of boulder and cobble biotopes respectively.

**Table 3. Biotopes recorded in the Ravenglass Estuary rocky shore survey detailing EUNIS code, JNCC biotope code, JNCC biotope description and the area coverage and sites the biotopes were recorded in during the 2013 survey (biotopes listed in order of highest area coverage).**

| EUNIS Code | Biotope | Description | Area of biotope in Ravenglass Estuary and sectors present |
|---|---|---|---|
| **A2.431** | LR.FLR.Eph.Blitx | Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata | 7.9 Ha (0.079 $km^2$); 1, 3, 4 |
| **A1 .452** | LR.FLR.Eph.EntPor | *Porphyra purpurea* and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock | 7.4 Ha (0.074 $km^2$); 4 |
| **A2.721** | LS.LBR.LMus.Myt | *Mytilus edulis* beds on littoral sediments | 6.7 Ha (0.067 $km^2$); 3, 4 |
| **A2.11** | LS.LCS.Sh | Shingle (pebble) and gravel shores | 6.5 Ha (0.065 $km^2$); 3 |
| **A1.327** | LR.LLR.FVS.Fcer | *Fucus ceranoides* on reduced salinity eulittoral rock | 5.1 Ha (0.051 $km^2$); 1, 2, 3, 4 |
| **A1.327** | LS.LCS.Sh.BarSh | Barren littoral shingle | 4.6 Ha (0.046 $km^2$); 4 |
| **A2.821** | LR.FLR.Eph.EphX | Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata | 4.5 Ha (0.045 $km^2$); 4 |
| **A2.711** | LS.LBR.Sab.Salv†^ | *Sabellaria alveolata* reefs on sand abraded eulittoral rock | 0.6 Ha (0.006 $km^2$); 4 |
| **A1.32** | LR.LLR.FVS | Fucoids in variable salinity | 0.6 Ha (0.006 $km^2$); 3 |
| **A1.322** | LR.LLR.FVS.FspiVS | *Fucus spiralis* on sheltered variable salinity upper eulittoral rock | 0.6 Ha (0.006 $km^2$); 4 |
| **A1.323** | LR.LLR.FVS.FvesVS | *Fucus vesiculosus* on variable salinity mid eulittoral boulders and stable mixed substrata | 0.6 Ha (0.006 $km^2$); 2, 3, 4 |
| **A1.324** | LR.LLR.FVS.AscVS | *Ascophyllum nodosum* and *Fucus vesiculosus* on variable salinity mid eulittoral rock | 0.5 Ha (0.005 $km^2$); 2, 3, 4 |
| **A1.312** | LR.LLR.F.Fspi | *Fucus spiralis* on sheltered upper eulittoral rock | 0.1 Ha (0.001 $km^2$); 1 |
| **A1.312** | LR.FLR.Rkp.H* | Hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools | 0.0073 Ha (73 $m^2$); 4 |

* Specialised biotopes

† Nationally and more than nationally important communities

^ Biodiversity Action Plan habitat

### 3.1.1 Site descriptions and biotope maps

The whole of the intertidal region of the Ravenglass Estuary was accessible by foot and therefore 100% coverage of the area was achieved for the Phase I biotope survey (Figure 5). By having two teams of two surveyors, the surveys were conducted quickly and covered a wide area, enabling all rocky shore areas to be mapped within the allocated survey days.

For the purposes of data recording and reporting, the Ravenglass Estuary intertidal region was split into 4 sectors, pre-determined by Natural England. Sector 5 (also known as Barn Scar, not shown on maps in this report) was covered during the verification surveys of the Cumbria Coast rMCZ earlier in 2013. Only rocky shore biotopes are included in the biotope maps presented in this report. All other areas not depicted on the maps as specific polygons are to be considered as littoral sediment biotopes and are not of relevance to this reporting.

It should be noted that, in some cases, the biotopes did not fully match any of the JNCC's biotope descriptions and thus the best fit approach was taken, primarily based on the species composition identified.

The majority of the foreshore in the Ravenglass Estuary was characterised by littoral sediments with patches of *Fucus ceranoides*, shingle, blue mussel (*Mytilus edulis*) beds and ephemeral green and red seaweeds. The majority of the rocky shore biotopes were found in Sector 4.

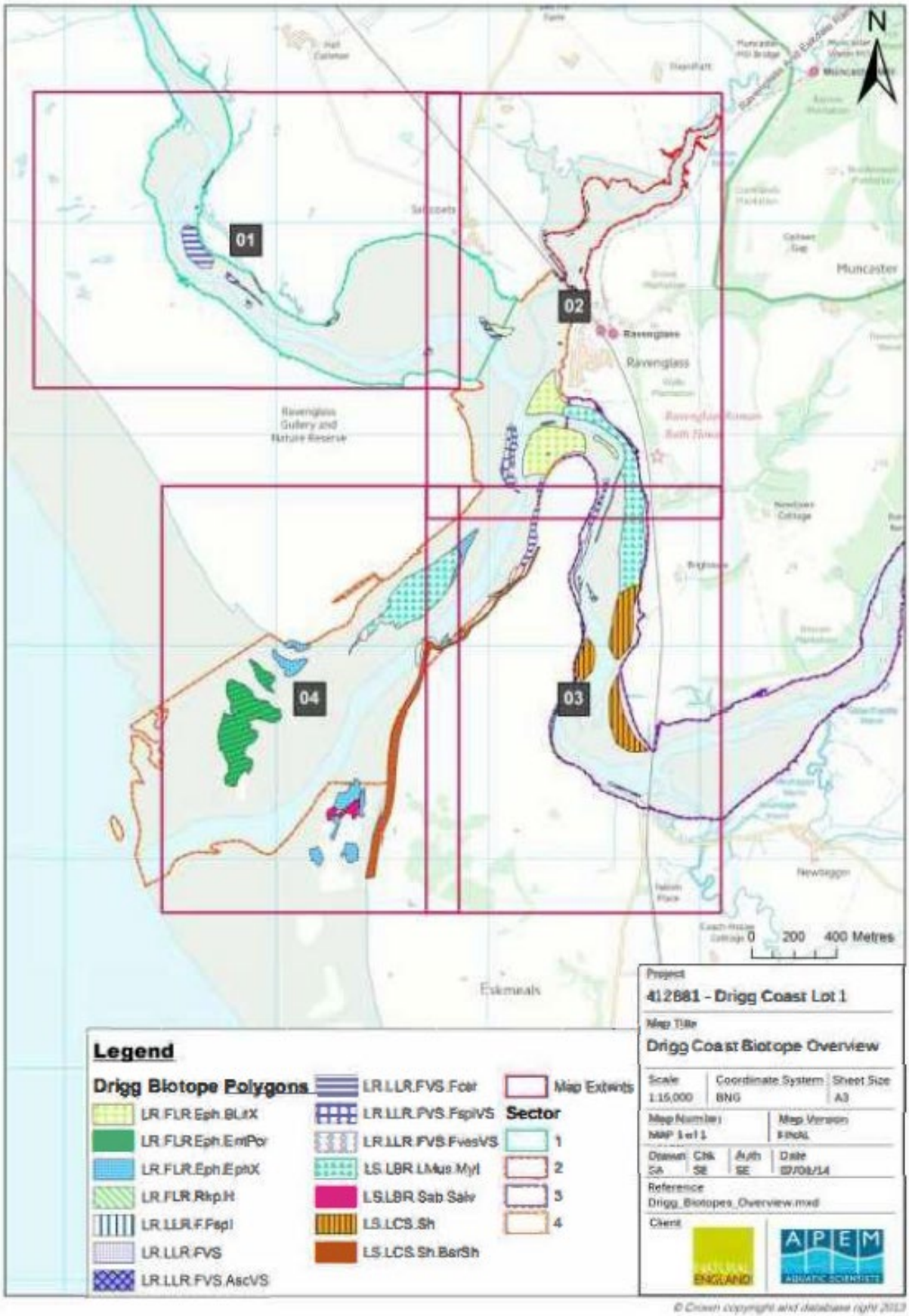


**Figure 5. Overview of the rocky shore biotopes present in the Ravenglass Estuary at Drigg with wireframe map extents shown (pink rectangles). EUNIS codes for each biotope are given in Table 3. Contains Ordnance Survey data.**

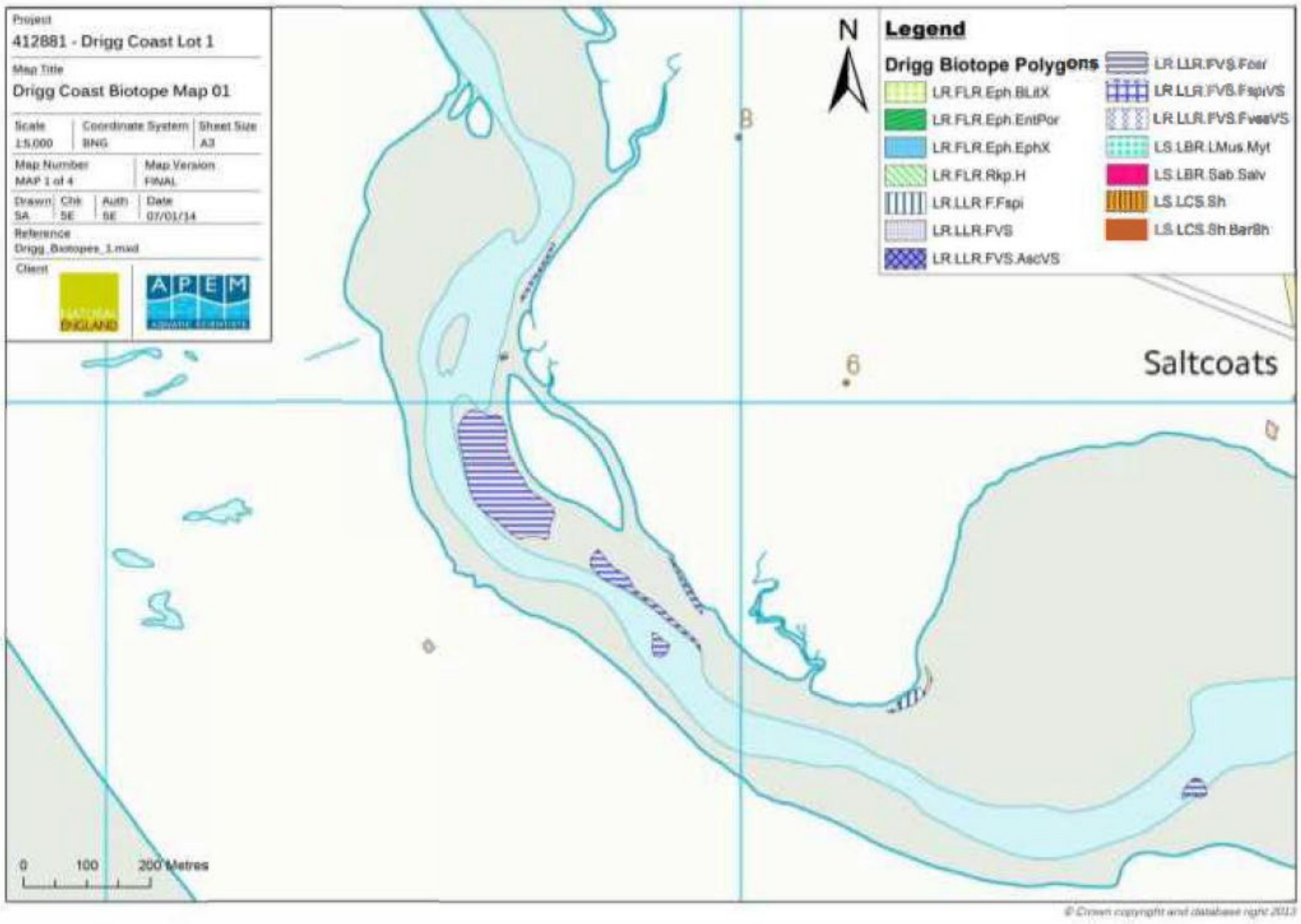


**Figure 6. Biotope map of Sector 1 from the Phase I biotope survey carried out on foot. Contains Ordnance Survey data.**


**Figure 7. Biotope map from the Phase I biotope survey carried out on foot of Sector 2 with parts of Sectors 1, 3 and 4 also shown. Contains Ordnance Survey data.**

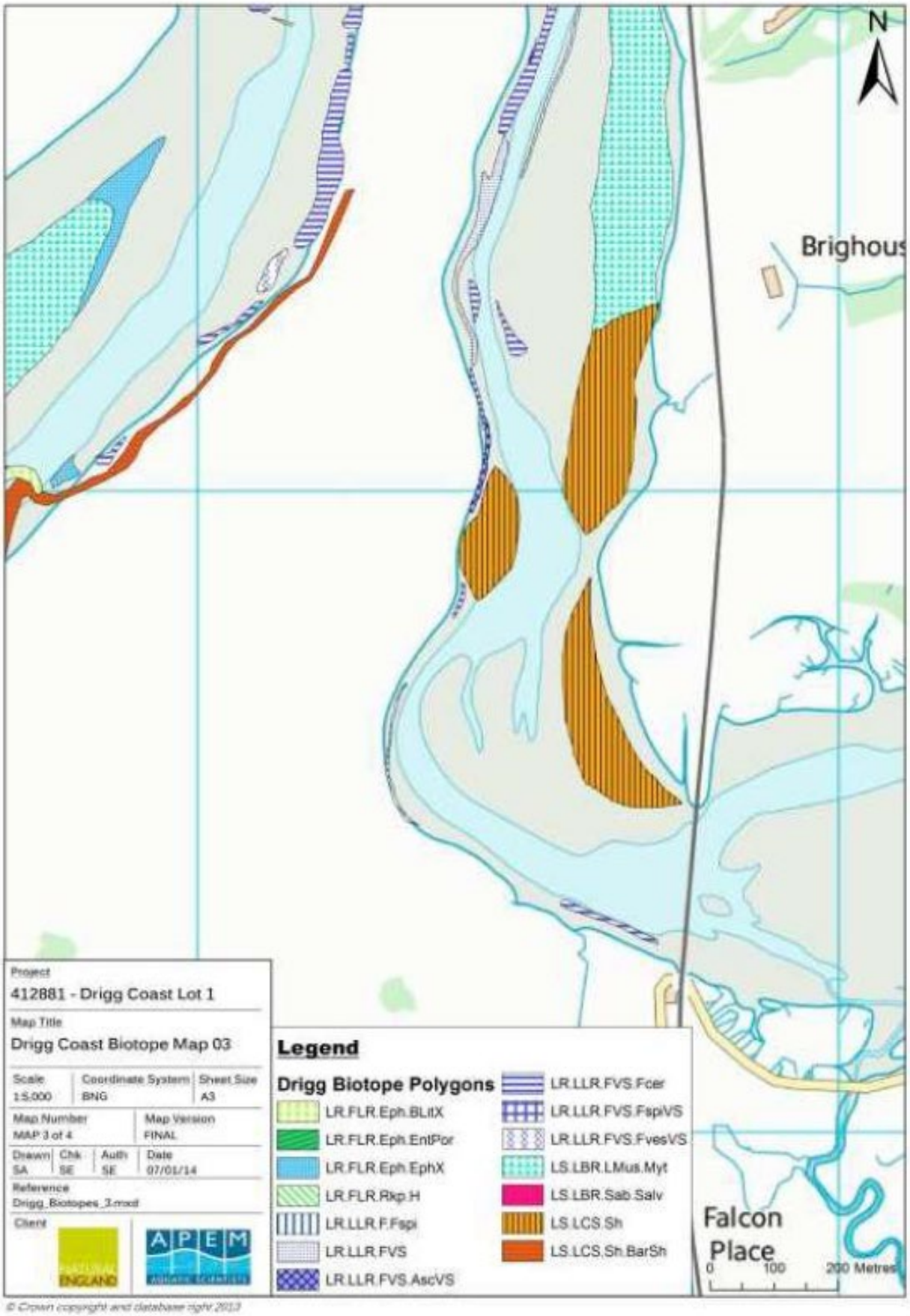


**Figure 8. Biotope map of Sector 3 from the Phase I biotope survey carried out on foot with part of Sector 4 also shown. Contains Ordnance Survey data.**

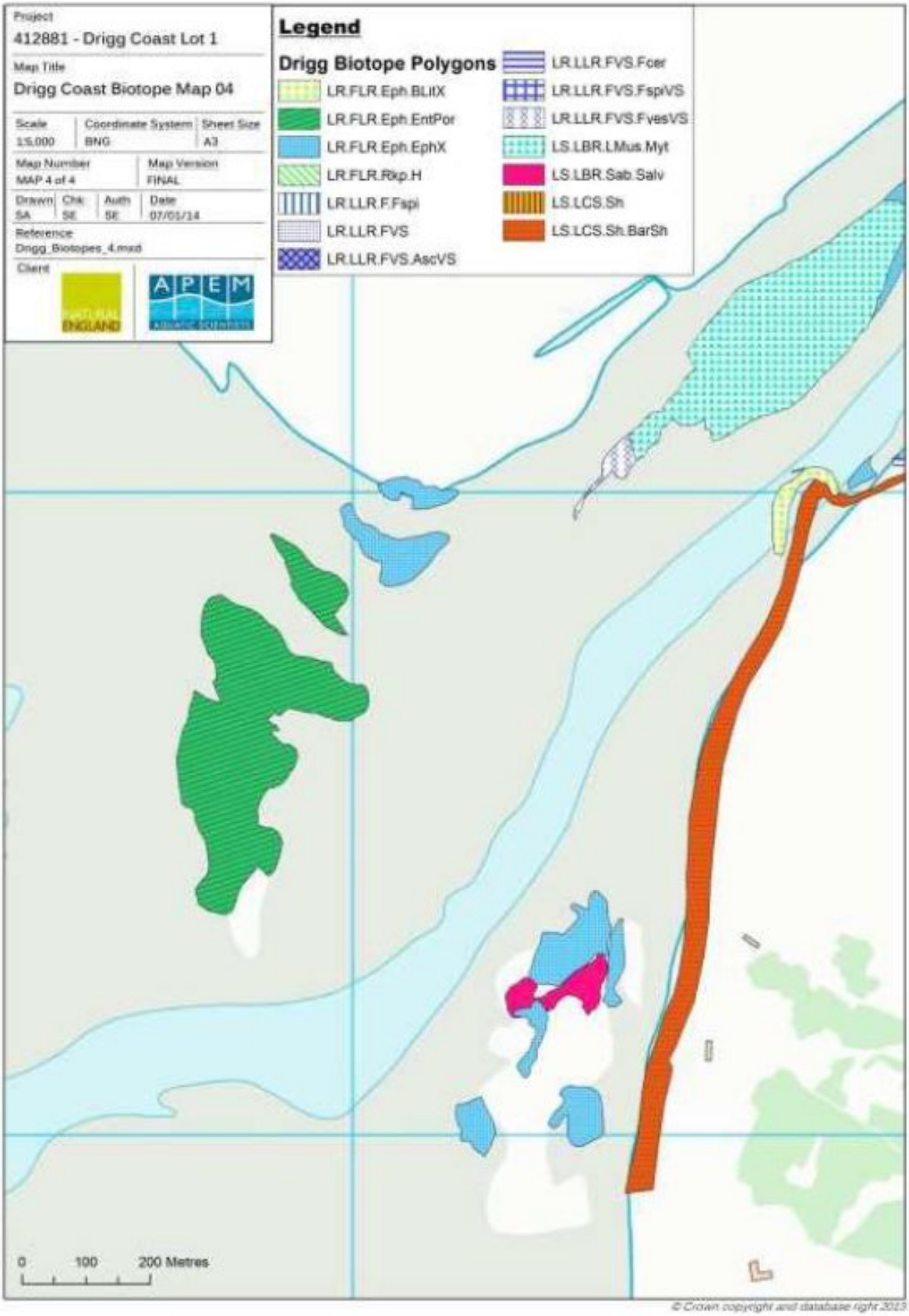


**Figure 9. Biotope map of Sector 4 from the Phase I biotope survey carried out on foot. Contains Ordnance Survey data.**

#### 3.1.1.1 Sector 1 (01 Maps and 02)

Sector 1 was located in the north western section of the estuary encompassing the downstream section of River Irt (Figure 5).

This sector was primarily littoral sediments but also contained 3 rocky shore biotopes in 2013 (Figure 6 and Figure 7). A large patch of *Fucus ceranoides* (A1.327, LR.LLR.FVS.Fcer) was located on the eastern bank of the River Irt, approximately halfway up the Sector from the upper to lower shore, and this was surrounded by smaller patches of the same biotope. Further downstream on the same bank in the south west corner of the sand flat at Saltcoats, there was a small band of *Fucus spiralis* (A1.312, LR.LLR.F.Fspi) in the upper shore. Towards the eastern edge of the sector, there were two small patches of A 1.327 in the lower shore and also a small patch of A2.431 (LR.FLR.Eph.BLitX). The remainder of Sector 1 comprised sand and muddy sand.

#### 3.1.1.2 Sector 2 (Map 02)

Sector 2 was located north of the railway bridge at Ravenglass (River Mite) (Figure 5).

A total of 3 different fucoid biotopes were recorded in this sector in 2013 (Figure 7). Small patches of *Fucus vesiculosus* (A1 .323, LR.LLR.FVS.FvesVS) were found in the central western part of the sector in the lower shore adjacent to the river, small patches of *Fucus ceranoides* (A1.327, LR.LLR.FVS.Fcer) were found in the most western part of the sector, again in the lower shore, and *Ascophyllum nodosum* (A1.324, LR.LLR.FVS.AscVS) was observed in the south and south eastern parts of the sector, primarily on the vertical surface of the man-made railway bridge and surrounding it to some extent. This sector was primarily mud with some patches of cobbles which the fucoids were attached to. The substrate was coarser further downstream around the railway bridge.

#### 3.1.1.3 Sector 3 (Maps 02 and 03)

Sector 3 was located in the east part of the Ravenglass Estuary and encompassed River Esk (Figure 5).

No rocky shore biotopes were recorded east of the southern railway bridge in this sector and mud and saltmarsh dominated this region. A total of 7 rocky shore biotopes were recorded in this sector to the west of the railway bridge, primarily cobbles, pebbles and sand with some empty shells (Figure 7 and Figure 8). Fucoid biotopes were present on the western bank of the River Esk in this area in long, thin bands. *Fucus ceranoides* (A1.327, LR.LLR.FVS.Fcer) was located in several places along this bank at various shore heights. *Fucus vesiculosus* (A1 .323, LR.LLR.FVS.FvesVS) was found in one location as a very thin band in the upper to mid shore on the meander in the south western part of Sector 3. A 1.32 (LR. LLR. FVS), a more generalised fucoid biotope containing more than one species of *Fucus*, and *Ascophyllum nodosum* (A1 .324, LR.LLR.FVS.AscVS) were present on the Eskmeals Dunes peninsular in between the patches of *Fucus ceranoides*. A patch of pebble and cobbles (A2.11, LS.LCS.Sh) was also located amongst the fucoids in the mid to lower shore. Two patches of barnacles and *Littorina* spp. (A2.431, LR.FLR.Eph.BLitX) were present to the north of the Eskmeals Dunes peninsular in the

lower shore and continued into Sector 4. On the eastern bank, there was a large blue mussel (*Mytilus edulis*) bed (A2.721, LS.LBR.LMus.Myt) from the Sector 3/4 boundary in the north down to Transect 10 in the upper to mid shore region. Littoral sediments dominated in the lower to mid shore of this region although there was a strip of fucoids (LR.LLR.FVS) in the extreme lower shore. South of the mussel bed there were two patches of shingle (pebble) and gravel shores (A2.11, LS.LCS.Sh) in the upper to mid shore down to the railway bridge in the south.

#### 3.1.1.4 Sector 4 (Maps 02, 03 and 04)

Sector 4 was located from the area where all three rivers (Irt, Mite and Esk) joined as one estuary (the Ravenglass Estuary, also known as the Esk Estuary) down to the low shore where the estuary met the sea on the Cumbria coast (Figure 5).

This sector was the most diverse in terms of rocky shore biotopes, with 11 different biotopes recorded in 2013 (Figure 7, Figure 8 and Figure 9). In the north eastern part of the sector, there was a small patch of *Ascophyllum nodosum* (A 1.324, LR.LLR.FVS.AscVS) on the foreshore at Ravenglass. There was a continuation of the patches of *Fucus ceranoides* (A1 .327, LR.LLR.FVS.Fcer) and barnacles and *Littorina* spp. (A2.431, LR.FLR.Eph.BLitX) from Sector 1 into Sector 4. In the region where Sector 3 met Sector 4, there were 2 small rockpools (A1.414, LR.FLR.Rkp.H) surrounded by LR.FLR.Eph.BLitX (A2.431) and a small patch of *Enteromorpha* spp. and *Porphyra purpurea* (A1 .452, LR.FLR.Eph.EntPor). Just below these areas there were long bands of *Fucus spiralis* (A1 .322, LR.LLR.FVS.FspiVS), *Fucus ceranoides* (A 1.327, LR. LLR. FVS.Fcer) in the lower and upper shore regions and barnacles and a small patch of *Littorina* spp. (A2.431, LR.FLR.Eph.BLitX). The central part of Sector 4 was dominated by a large blue mussel (*Mytilus edulis*) bed (A2.721, LS.LBR.LMus.Myt) on the western bank with ephemeral seaweeds to the north of the bed (A2.821, LR.FLR.Eph.EphX) and *Fucus vesiculosus* (A1 .323, LR.LLR.FVS.FvesVS) on the southern tip of the bed. Small patches of *Fucus ceranoides* (A1 .327, LR.LLR.FVS.Fcer), ephemeral seaweeds (A2.821, LR.FLR.Eph.EphX) and barnacles and *Littorina* spp. (A2.431, LR.FLR.Eph.BLitX) lined the mid shore of the eastern bank. A band of shingle (A2.111, LS.LCS.Sh.BarSh) was present in the upper shore of the eastern bank from the central part of the sector to past the southern boundary. On the south eastern side of the mouth of the estuary there were two patches of honeycomb worm (*Sabellaria alveolata*) reef (A2.711, LS.LBR.Sab.Salv) surrounded by patches of ephemeral seaweeds (A2.821, LR.FLR.Eph.EphX). On the north western side of the mouth of the estuary, there were two large patches of *Enteromorpha* spp. and *Porphyra purpurea* (A1 .452, LR.FLR.Eph.EntPor) and two smaller patches of ephemeral seaweeds (A2.821, LR.FLR.Eph.EphX). The remainder, and majority, of the sector was littoral sediments, primarily sand.

## 3.2 Quantitative quadrat survey

A total of 121 quadrats were assessed along 24 transects (5 quadrats at each transect with 6 quadrats assessed at Transect 6 in order to represent the presence of fucoids on vertical surfaces).

There were a total of 37 taxa recorded in the quadrats comprised of 25 encrusting/colonial/canopy-forming taxa (including macrophytes) and 12 free-living taxa (including the terrestrial/intertidal insect *Anurida maritima*) (Appendix 6). Some of these were not possible to take to species level in the field, primarily due to their juvenile status, e.g., Cirripedia, or the complexity of the genus, e.g., *Porphyra* spp. and *Ceramium* spp. It is also worth noting that 3 sessile species, *Mytilus edulis*, *Patella vulgata* and *Spirobranchus triqueter* were recorded as individuals present rather than percentage coverage, therefore, for the purposes of reporting they have been included in the free-living taxa results.

Species recorded included biogenic reef-forming species *Mytilus edulis* (blue mussel) and *Sabellaria alveolata* (honeycomb worm), macroalgae, barnacles, periwinkles and other species typical of rocky shores.

Barnacles were particularly common, probably due to the substrate providing suitable surfaces to attach to (boulders/cobbles/gravel) and were recorded in 83 quadrats. In 11 of these quadrats, the barnacles were identifiable and taken to species level but in the remaining 72 quadrats, they were recorded as Cirripedia due to time constraints and also as representative photographs were taken for later identification.

Of the algal species, *Fucus ceranoides*, *Fucus vesiculosus* and *Enteromorpha* spp. were relatively common present in 39, 42 and 31 quadrats respectively.

The sedimentary shore species, *Lanice Conchilega*, was also present, likely due to the rocky shore biotopes overlapping with littoral sediments (the dominant substrate in the Ravenglass Estuary). As this species in infaunal, it was the observation of intact casts that confirmed the presence of this species.

The data were split into percentage coverage data and simple counts for the purposes of description but were combined as presence/absence data for the purposes of performing community ordination analysis in PRIMER v6 (see method statement in Appendix 7).

*Fucus ceranoides* (horned wrack) was the most common sessile organism recorded in the quadrats across the Ravenglass Estuary contributing to 36 % of the observed percentage coverage of sessile species (Figure 10). This is unsurprising given that biotopes with this species were targeted for these surveys. The second and third highest contributors were Cirripedia (barnacles) (22 %) and *Fucus vesiculosus* (15.4 %). These 3 species were also the most common sessile species recorded. The remaining sessile taxa contributed to 26% of the observed percentage coverage of sessile species, 13 taxa of which contributed less than 1 % each.

Almost half of the free-living species had less than 10 individuals recorded across all quadrats. By far, the most dominating species in the quadrats was the blue mussel *Mytilus edulis* with 1006 individuals recorded. *Littorina littorea* was the second most dominating species with 770 individuals recorded and its relative *Littorina saxatilis* was the third most dominating species with 375 individuals recorded. These 3 species contributed to 37.1 %,

28.4 % and 13.8 % of the observed abundance of free-living individuals respectively (Figure 11) and all three were also the most common free-living species in the quadrats, present in 33, 57 and 43 quadrats respectively. As mussel beds were a target habitat of these surveys, this is unsurprising.

Sector 2 was found to have the highest mean number of taxa in hard substrate biotopes in comparison to the other sectors and this is likely due to the hard rock face of the railway bridge at Transect 6 providing suitable substrate for a number of species. The cobble habitats found in the other sectors are likely to be somewhat mobile and thus could potentially be a limitation of the types of species found. However, it must also be noted that the variation seen in this sector was higher than in the other sectors as only 2 transects were assessed. Sector 1 had the lowest mean number of taxa and was also the least variable. This could be partly due to this sector containing very little hard substrate biotopes and the uniformity of the biotopes observed.

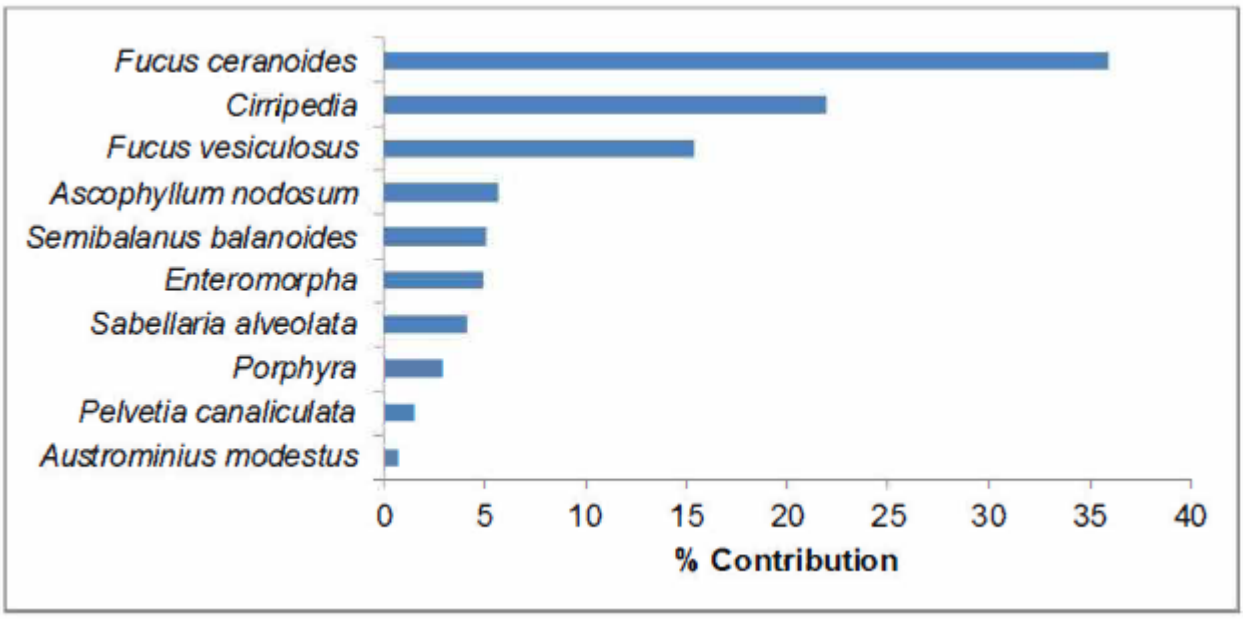


**Figure 10. Ranked percentage contribution of the ten most prominent encrusting/colonial/canopy-forming species recorded in the Ravenglass Estuary quantitative quadrat survey (based on percentage coverage data).**

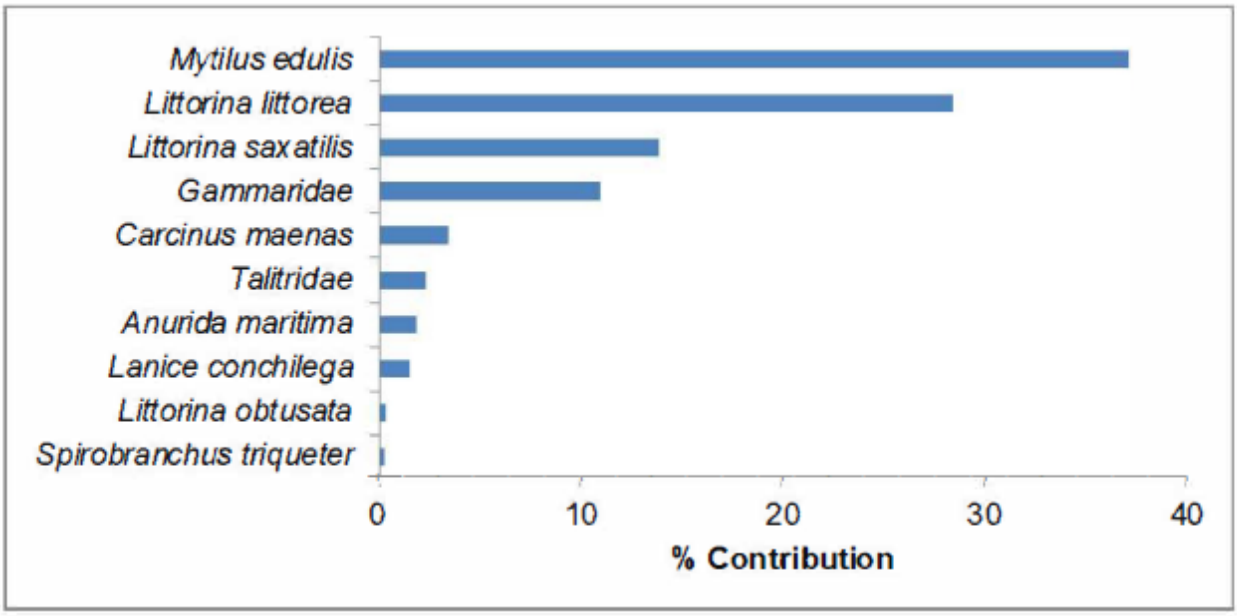


**Figure 11. Ranked percentage contribution of the ten most prominent free-living species recorded in the Ravenglass Estuary quantitative quadrat survey (based on actual abundance data).**

**Table 4. Mean number of taxa identified in each transect (% coverage and actual abundance data combined) with standard deviation, coefficient of variation (CV), biotope and sector indicated.**

| Transect | Mean No. Taxa | Standard Deviation | Coefficient of Variation | EUNIS Code | Biotope | Sector |
|---|---|---|---|---|---|---|
| 1 | 3.2 | 0.84 | 0.26 | A1.327 | LR.LLR.FVS.Fcer | 1 |
| 2 | 3.8 | 1.30 | 0.34 | A1.312 | LR.LLR.F.Fspi | 1 |
| 3 | 2.6 | 0.89 | 0.34 | A1.327 | LR.LLR.FVS.Fcer | 1 |
| 4 | 4.4 | 1.14 | 0.26 | A2.431 | LR.FLR.Eph.BLitX | 4 |
| 5 | 3.4 | 1.52 | 0.45 | A1.324 | LR.LLR.FVS.AscVS | 2 |
| 6 | 7 | 1.41 | 0.20 | A1.324 | LR.LLR.FVS.AscVS | 2 |
| 7 | 3 | 0.71 | 0.24 | A2.431 | LR.FLR.Eph.BLitX | 4 |
| 8 | 5.8 | 1.64 | 0.28 | A2.721 | LS.LBR.LMus.Myt | 3 |
| 9 | 4.8 | 0.45 | 0.09 | A2.721 | LS.LBR.LMus.Myt | 3 |
| 10 | 3.8 | 1.64 | 0.43 | A2.721 | LS.LBR.LMus.Myt | 3 |
| 11 | 4.4 | 1.52 | 0.34 | A1.324 | LR.LLR.FVS.AscVS | 3 |
| 12 | 3.4 | 2.41 | 0.71 | A1.327 | LR.LLR.FVS.Fcer | 3 |
| 13 | 2.4 | 1.34 | 0.56 | A2.431 | LR.FLR.Eph.BLitX | 4 |
| 14 | 3.4 | 0.55 | 0.16 | A1.327 | LR.LLR.FVS.Fcer | 4 |
| 15 | 5.4 | 1.14 | 0.21 | A1.327 | LR.LLR.FVS.Fcer | 4 |
| 16 | 4.4 | 1.52 | 0.34 | A2.821 | LR.FLR.Eph.EphX | 4 |
| 17 | 5.2 | 2.28 | 0.44 | A2.711 | LS.LBR.Sab.Salv | 4 |
| 18 | 3.4 | 0.55 | 0.16 | A2.821 | LR.FLR.Eph.EphX | 4 |
| 19 | 4.8 | 1.92 | 0.40 | A1.452 | LR.FLR.Eph.EntPor | 4 |
| 20 | 5 | 1.22 | 0.24 | A2.721 | LS.LBR.LMus.Myt | 4 |
| 21 | 4 | 0.00 | 0.00 | A2.721 | LS.LBR.LMus.Myt | 4 |
| 22 | 5.4 | 2.07 | 0.38 | A2.721 | LS.LBR.LMus.Myt | 4 |
| 23 | 5.6 | 1.52 | 0.27 | A1.327 | LR.LLR.FVS.Fcer | 4 |
| 24 | 2.6 | 0.55 | 0.21 | A1.327 | LR.LLR.FVS.Fcer | 1 |

**Table 5. The overall coefficient of variation (CV) based on species richness for each the biotopes assessed as part of the quantitative quadrat surveys.**

| EUNIS | Biotope | Mean No. Taxa | Standard Deviation | Overall CV (%) |
|---|---|---|---|---|
| A1.312 | LR.LLR.F.Fspi | 3.80 | 1.30 | 0.34 |
| A1.324 | LR.LLR.FVS.AscVS | 5.06 | 2.11 | 0.42 |
| A1.327 | LR.LLR.FVS.Fcer | 3.74 | 1.65 | 0.44 |
| A1.452 | LR.FLR.Eph.EntPor | 4.80 | 1.92 | 0.40 |
| A2.431 | LR.FLR.Eph.BLitX | 3.27 | 1.33 | 0.41 |
| A2.711 | LS.LBR.Sab.Salv | 5.20 | 2.28 | 0.44 |
| A2.721 | LS.LBR.LMus.Myt | 4.80 | 1.45 | 0.30 |
| A2.821 | LR.FLR.Eph.EphX | 3.90 | 1.20 | 0.31 |

The maximum number of taxa observed in a quadrat was 9 in Transect 6, Quadrat 4 (Drigg Coast_9.6, A 1.324, LR. LLR. FVS.AscVS) and Transect 17, Quad rat 1 (Drigg Coast_ 17 .1, A2.711, LS.LBR.Sab.Salv), both located in the mid shore. The maximum number of taxa observed in a quadrat taken in a mussel bed biotope was 8 in Transect 22, Quadrat 4 in the mid shore (Drigg Coast_22.4) and in a *Fucus ceranoides* biotope was 8 in Transect 23, Quadrat 2 in the lower shore (Drigg Coast_23.2). Quadrat 3 in Transect 12 (Drigg Coast_ 12.3) was afaunal. This quadrat was placed randomly in the *Fucus ceranoides* biotope and was comprised of mainly mud.

A large coefficient of variation (CV) (CV=1 00*(Standard Deviation/Mean)) indicates a more variable group, thus the results show that A1 .327 (LR.LLR.FVS.Fcer) and A2.711 (LS.LBR.Sab.Salv) had the highest variability in species richness (Table 5) and, overall, A2.721 (LS.LBR.LMus.Myt) had the lowest level of variability.

There was a significant difference in the number of taxa seen between Transects (ANOVA, F=3. 71, P=<0.001) specifically between Transect 6 and 10 other transects (most likely due to the man-made structure of the railway bridge being entirely different to the other substrate in the estuary) and between Transect 8 and 13, and also between biotopes (ANOVA, F=2.76, P=0.011) which shows the allocation of biotopes based on species composition was consistent. No significant difference in the number of taxa was detected between shore heights (ANOVA, F=2.21, P=0.114).

As the quadrat data obtained was recorded as percentage coverage for encrusting/colonial and canopy-forming organisms and as actual abundances for free-living species, as per standard guidance, statistical analysis is not normally performed. Abundances and/or % coverage are generally compared between years to assess for change within specific biotopes (Davies, *et al*., 2001). However, as some statistical analysis was required to give an assessment of the general species composition of the area, the data were transformed to presence/absence to make actual abundances and % coverage comparable. A Jaccard distance matrix was used for the ordination analysis as this was deemed most suitable in the case of presence/absence data.

Hierarchical clustering with SIMPROF analysis identified 11 distinctive faunal groups (Figure 12) whereby upper and mid-shore samples appeared to be grouped together and mid and lower shore samples were grouped together. There was no real distinction between groups according to shore height other than this. The LS.LBR.LMus.Myt samples

were generally grouped separately to the other samples. All other biotopes showed considerable overlap with each other suggesting similar species compositions. Multi-dimensional scaling (MOS) supported this and showed that the samples were all extremely similar to each other (Figure 13) and there was great overlap in similarity between samples across all shore heights and transects. Sample 2.3 was the most dissimilar to the other samples based on this ordination (upper shore sample shown in the left of Figure 13b) and could be explained by the large proportion of mud, *Talitridae* and *Pelvetia* spp. compared to other quadrats.

There was a significant difference in faunal composition both between Transects (ANOSIM test[1], R = 0.595, significance level = 0.1 %) and also between shore height (ANOSIM test, R = 0.176, significance level = 0.1 % ). However, whilst there was a significant difference in faunal composition between Transects (as to be expected as different biotopes were targeted between transects), there was a large degree of overlap observed as visually inferred in the MOS ordination (Figure 13) and supported by the R value being between 0.5 and 0.7 (Clarke & Warwick, 2001). Similarly, whilst the faunal composition between shore height was considered significant (P=0.1 % ), the R value (R<0.25) suggests they were barely separable at all.

[1] The R statistic gives an indication of the structure of the results. R = 0 indicates a lack of structure and completely random grouping. See Appendix 7 for further guidance on the interpretation of the ANOSIM test.

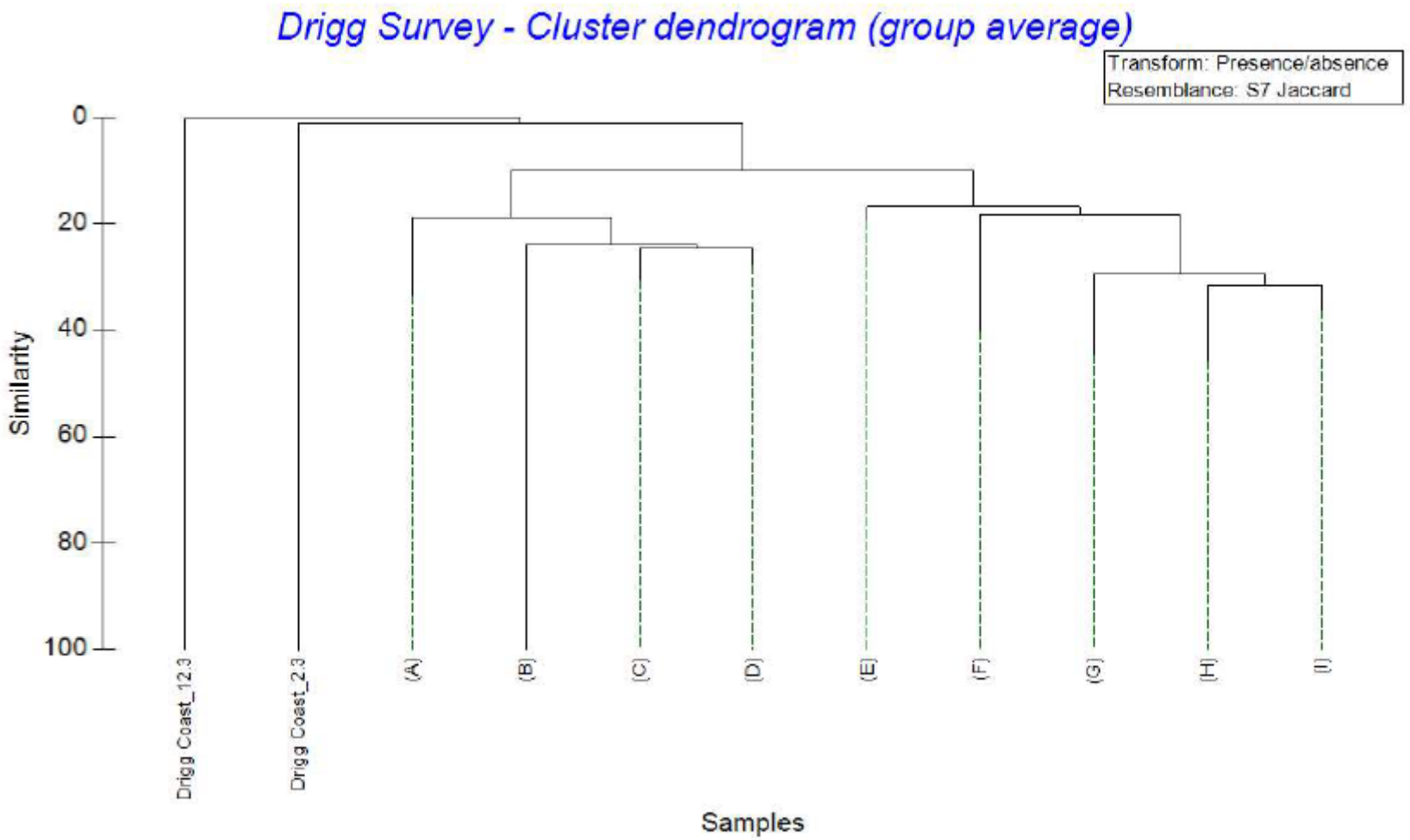


**Figure 12. A group average sorting dendrogram based on presence/absence transformed macrofaunal abundance and percentage coverage data combined (Jaccard similarity was used). A total of 11 groups were identified using the SIMPROF test, two of which were comprised of only sample.**

**Table 6. SIMPROF groupings (Presence/absence, significance level 5%).**

| SIMPROF Group | Quadrats |
|---|---|
| A | 5.4, 5.5, 11.3, 12.2 |
| B | 3.2, 24.5 |
| C | 1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 2.4, 2.5, 3.1, 3.3, 3.4, 3.5, 5.1, 5.2, 5.3, 6.4, 8.4, 10.2, 11.1, 11.2, 11.5, 14.1, 15.3, 15.4, 15.5, 16.4, 22.5, 24.2, 24.3, 24.4 |
| D | 11.4, 12.1, 14.2, 14.3, 15.2, 16.5 |
| E | 6.2, 6.5, 6.6, 10.1, 12.4, 12.5, 13.1, 13.2, 16.1, 16.2, 16.3, 17.1, 17.2, 17.3, 17.4, 17.5, 18.1, 18.2, 18.3, 18.4, 18.5, 19.1, 19.2, 19.3, 19.4, 19.5, 20.1, 24.1 |
| F | 4.1, 4.2, 4.3, 4.4, 4.5, 23.1, 23.2, 23.3, 23.4, 23.5 |
| G | 6.1, 6.3 |
| H | 7.1, 7.2, 7.3, 7.5, 8.1, 8.2, 8.3, 8.5, 9.1, 9.2, 9.3, 9.4, 9.5, 10.3, 10.4, 10.5, 13.4, 13.5, 14.5, 20.2, 20.3, 20.4, 20.5, 21.1, 21.2, 21.3, 21.4, 21.5, 22.1, 22.2, 22.3, 22.4 |
| I | 7.4, 13.3, 14.4, 15.1 |
| J | 12.3 (no letter given on dendrogram) |
| K | 2.3 (no letter given on dendrogram) |

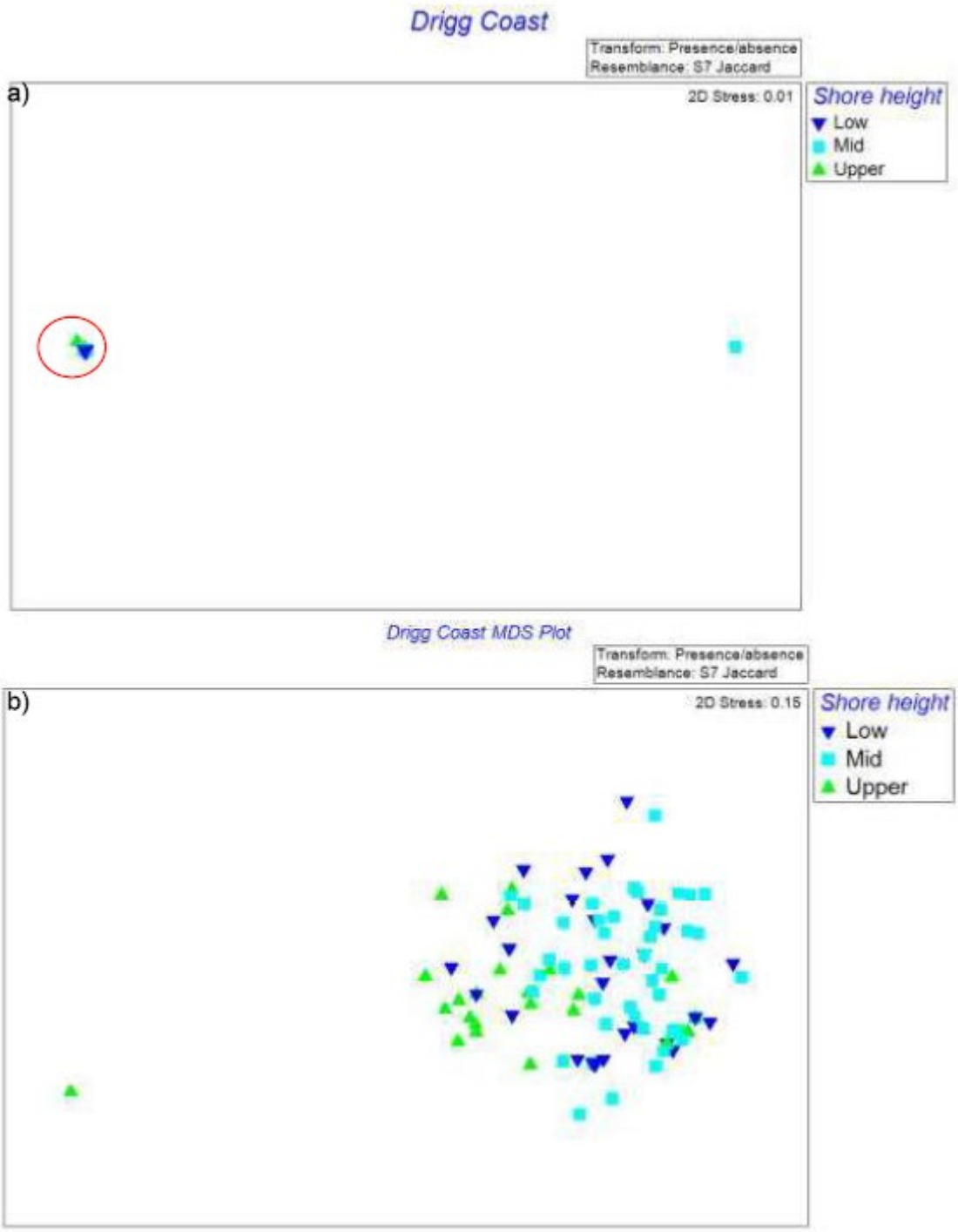


**Figure 13. Ravenglass Estuary rocky shore MDS configuration plots of species presence/absence data using Jaccard similarity. Overall MDS plot (a) including the afaunal sample 12.3 (shown as the separate mid-shore site on the right of the figure) and a subset (red circle) of the samples containing fauna (b) (Quadrat 2.3 was the outlier in this subset). Sample symbols are provided according to shore elevation. Symbol labels are given in the figure.**

## 3.3 Notable habitats and species in the area

Data from these surveys were compared against the lists of habitats and species of interest indicated in Appendices 1-5 in Wyn, *et al*. (2000). Within the Ravenglass Estuary, 1 specialised biotope, 1 nationally or more than nationally important community, 2 non-native species and 3 Biodiversity Action Plan (BAP) habitats were recorded. No nationally rare or scarce species were knowingly encountered although the brief nature of the survey limited the amount of time available to search for inconspicuous specimens.

Specialised biotopes:

*A 1.414 Hydroids, ephemeral seaweeds and Littorina littorea in shallow eulittoral mixed substrata pools (LR.FLR.Rkp.H)*

This biotope was observed as a permanent feature in Sector 4 as standing water pools, close to the confluence of River Esk with the rest of the estuary.

Nationally and more than nationally important communities:

*A2. 71 Sabellaria alveolata reefs on sand-abraded eulittoral rock (LS.LBR.Sab.Salv)*

One patch of *Sabellaria alveolata* reef was observed in the southern seaward area of Sector 4 next to the MoD site. This biotope actually fell just outside of the SSSI area as it had done in the previous survey undertaken in 1999 (Woombs, 1999).

Non-native intertidal species:

*Austrominius (Elminius) modestus*

The barnacle *Austrominius (Elminius) modestus* was positively identified in Transect 4 and 23 and was also potentially present in Transects 6-22 (photographs to be assessed at a later date). This demonstrates a potentially wide distribution of this alien species in the Ravenglass Estuary.

*Sargassum muticum*

This species was positively identified within drainage pools around the *Sabellaria alveolata* reefs located just outside of the boundary of interest.

Intertidal Biodiversity Action Plan (BAP) habitats and species in the UK:

*Priority habitat - Littoral rock- Sabellaria alveolata reefs*

See nationally and more than nationally important communities.

*Priority habitat - Littoral rock - Blue mussel beds*

Blue mussel (*Mytilus edulis*) beds on littoral sediments are now classed as a priority BAP habitat due to their role in coastal sediment dynamics, being an important food source for overwintering birds and providing areas of enhanced biodiversity (BRIG, 2008). Two large mussel beds were found across the eastern bank of Sector 3 and across the mid shore in Sector 4.

*Priority habitat - Littoral rock - Estuarine rocky habitats*

The priority habitat, estuarine rocky habitats, include a number of variable salinity biotopes, many of which were found in the Ravenglass Estuary. The contribution of 3

rivers joining into a single estuary highlights the freshwater influence in the estuary which has an effect on the communities present by providing variable salinity conditions. Key biotopes falling under this description included: LR.LLR.FVS, LR.LLR.FVS.FspiVS, LR.LLR.FVS.FvesVS, LR.LLR.FVS.AscVS and LR.LLR.FVS.Fcer. Other biotopes (not exclusive to estuarine conditions) part of this description present in the survey area included: LR.FLR.Eph.EntPor and LR.FLR.Eph.Ent.

## 4.4 Anthropogenic pressures

Few anthropogenic pressures were noted during the survey.

The main anthropogenic pressures observed were the Ministry of Defence site at Eskmeals Dunes and walkers and dog walkers utilising the site in various places.

**Table 7. Anthropogenic pressures observed in the Ravenglass Estuary. General grid references are noted.**

| Transect | Easting | Northing | Category | Anthropogenic disturbance observed | Notes |
|---|---|---|---|---|---|
| **17** | 307248 | 494220 | Collection | Bait digging at the water's edge at Transect 17 | General site coordinates given - observed from a distance. |
| **18** | 307260 | 494111 | Litter and debris | Significant amounts of metal washed up onto the cobble habitat including a large chain. | General site coordinates given. |
| **19** | 307098 | 495020 | Recreation | Walkers and dog walkers on sand dune area in Ravenglass Gullery and Nature Reserve. | General site coordinates given - observed from a distance. |
| **7 & 8** | 308503 | 496113 | Recreation | Walkers and dog walkers on and close to the mussel bed. | General site coordinates given. |
| **7** | 308214 | 496133 | Mooring | Boats moored -shore used for access | General site coordinates given. |
| **6** | 308371 | 496709 | Litter and debris | Under railway bridge - numerous large iron nails found originating from the bridge itself - very likely just littered. | Bridge coordinates given. |

# 4 Preliminary condition assessment

## 4.1 Biotope overview

In the previous survey undertaken in 1999 (Woombs, 1999), a total of 9 biotopes were recorded across the Ravenglass Estuary covering an area of 88.1 Ha (0.881 $km^2$) compared to the 14 biotopes recorded in 2013 (Table 8). Barnacles and *Littorina* spp. (A2.431, LR.FLR.Eph.BLitX) dominated the estuary covering 33.8 % of the area covered the boulder and cobble scar biotopes. This biotope now only covers 3.4 % of the area covered by boulder and cobble scar biotopes. Each of the biotopes recorded in 1999 showed a reduction in area covered during the 2013 surveys with the exception of mussel beds (A2.721, LS.LBR.LMus.Myt) which increased in size by 4.1 Ha (0.041 $km^2$) and also moved from the inner estuary (Sector 3) to the outer estuary (Sector 4). Two biotopes recorded in 1999 were not present in the survey area in 2013 and a total of 4 biotopes were added to the 2013 biotope list that were not recorded in 1999. The majority of these are relatively similar to each other (fucoid biotopes) indicating that there may have been only small changes in species composition resulting in changes to the classifications given. A 1.414 (LR.FLR.Rkp.H), however, was a newly recorded biotope in the site as rockpools were not found previously in the estuary. Whilst the diversity of the biotopes in the estuary has increased since 1999, there has been a decrease in the area covered by rocky shore biotopes of 42.4 Ha (0.424 $km^2$) over a period of 14 years.

**Table 8. Biotopes recorded in the Ravenglass Estuary rocky shore survey detailing EUNIS code, JNCC biotope code, JNCC biotope description and the area coverage and sites the biotopes were recorded in during past surveys (Woombs, 1999) and the current 2013 survey (biotopes listed in order of highest area coverage in the 2013 survey). *Greyed out boxes indicates the biotope was not recorded during that year's survey.***

| EUNIS Code | Biotope | Description | Past (1999): Area of biotope in Ravenglass estuary and sectors present | Present (2013): Area of biotope in Ravenglass Estuary and sectors present |
|---|---|---|---|---|
| **A2.431** | LR.FLR.Eph.BlitX | Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata | 29.8 Ha (0.298 $km^2$) 1, 3, 4 | 7.9 Ha (0.079 $km^2$) 1, 3, 4 |
| **A1.452** | LR.FLR.Eph.EntPor | *Porphyra purpurea* and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock | 15.2 Ha (0.152 $km^2$) 4 | 7.4 Ha (0.074 $km^2$) 4 |
| **A2.721** | LS.LBR.LMus.Myt | *Mytilus edulis* beds on littoral sediments | 2.6 Ha (0.026 $km^2$) 3 | 6.7 Ha (0.067 $km^2$) 3, 4 |
| **A2.11** | LS.LCS.Sh | Shingle (pebble) and gravel shores | | 6.5 Ha (0.065 $km^2$) 3 |
| **A1.327** | LR.LLR.FVS.Fcer | *Fucus ceranoides* on reduced salinity eulittoral rock | 8.4 Ha (0.084 $km^2$) 1, 4 | 5.1 Ha (0.051 $k^2$) 1, 2, 3, 4 |
| **A2.111** | LS.LCS.Sh.BarSh | Barren littoral shingle | 9.3 Ha (0.093 $km^2$) 3, 4 | 4.6 Ha (0.046 $km^2$) 4 |
| **A2.821** | LR.FLR.Eph.EphX | Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata | 16.2 Ha (0.162 $km^2$) 3 | 4.5 Ha (0.045 $km^2$) 4 |

| | | | | |
|---|---|---|---|---|
| **A2.711** | LS.LBR.Sab.Salv†^ | *Sabellaria alveolata* reefs on sand abraded eulittoral rock | 4.5 Ha (0.045 $km^2$) 4 | 0.6 Ha (0.006 $km^2$) 4 |
| **A1.32** | LR.LLR.FVS | Fucoids in variable salinity | | 0.6 Ha (0.006 $km^2$) 3 |
| **A1.322** | LR.LLR.FVS.FspiVS | *Fucus spiralis* on sheltered variable salinity upper eulittoral rock | | 0.6 Ha (0.006 $km^2$) 4 |
| **A1.323** | LR.LLR.FVS.FvesVS | *Fucus vesiculosus* on variable salinity mid eulittoral boulders and stable mixed substrata | | 0.6 Ha (0.006 $km^2$) 2, 3, 4 |
| **A1.324** | LR.LLR.FVS.AscVS | *Ascophyllum nodosum* and *Fucus vesiculosus* on variable salinity mid eulittoral rock | | 0.5 Ha (0.005 $km^2$) 2, 3, 4 |
| **A1.312** | LR.LLR.F.Fspi | *Fucus spiralis* on sheltered upper eulittoral rock | | 0.1 Ha (0.001 $km^2$) 1 |
| **A1.414** | LR.FLR.Rkp.H* | Hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools | | 0.0073 Ha (73 $m^2$) 4 |
| **A1 .3132** | LR.LLR.F.Fves.X | *Fucus vesiculosus* on mid eulittoral mixed substrata | 2.2 Ha (0.022 $km^2$) 4 | |

| | | | | |
|---|---|---|---|---|
| **A1.3142** | LR.LLR.F.Asc.X | *Ascophyllum nodosum* on full salinity mid eulittoral mixed substrata | 0.0225 Ha (25 $m^2$) 2 | |

* Specialised biotopes

† Nationally and more than nationally important communities

^ Biodiversity Action Plan habitat

**Table 9. Biotope codes used in the 1999 survey were converted from the 1997 JNCC classification code (Connor, Brazier, Hill, & Northern, 1997) to the 2004 JNCC classification (Connor, *et al.*, 2004) for ease of comparison.**

| 1999 Category Code (1997 JNCC classification) | New Category Code (2004 JNCC classification) | New Category Description (2004 JNCC classification) | EUNIS Code |
|---|---|---|---|
| **LGS.BarSh** | LS.LCS.Sh.BarSh | Barren Littoral Shingle | A2.111 |
| **MLR.EntPor** | LR. FLR. Eph. EntPor | *Porphyra purpurea* and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock | A2.452 |
| **MLR.Salv** | LS.LBR.Sab.Salv | *Sabellaria alveolata* reefs on sand abraded eulittoral rock | A2.711 |
| **SLR.AscX** | LR. LLR. F .Asc.X | *Ascophyllum nodosum* on very sheltered mid eulittoral rock | A1.324 |
| **SLR. BL Lit/1** | LR.FLR.Eph.BlitX | Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata | A2.431 |
| **SLR. BL Lit/2** | LR.FLR.Eph.BlitX | Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata | A2.431 |
| **SLR.EphX** | LR.FLR.Eph.EphX | Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata | A2.821 |
| **SLR.Fcer** | LR.LLR.FVS.Fcer | *Fucus ceranoides* on reduced salinity eulittoral rock | A1.327 |
| **SLR.FcerX** | LR.LLR.FVS.Fcer | *Fucus ceranoides* on reduced salinity eulittoral rock | A1.327 |
| **SLR.FucsX** | LR.LLR.F.Fves.X | *Fucus vesiculosus* on mid eulittoral mixed substrata | A1.3132 |
| **SLR.MytX** | LS.LBR.LMus.Myt | *Mytilus edulis* beds on littoral sediments | A2.721 |

## 4.2 Sector comparisons

In 1999, Sector 1 contained 3 biotopes as was found in the 2013 survey, although they differed slightly (Figure 2). There were small patches of A2.431 (LR.FLR.Eph.BLitX) and A2.111 (LS.LCS.Sh.BarSh) in the south eastern part of the sector in the lower and upper shore respectively in 1999 showing there has been a slight change in the substrate in this region since. This slight change is also seen in the addition of the *Fucus spiralis* biotope in an area where rocky shore biotopes were not recorded in 1999. A1.327 (LR.LLR.FVS.Fcer) covered a much larger area across the lower shore halfway up the sector in 1999 showing that there has since been a decrease in the extent of this biotope in this sector.

Only a single patch of an *Ascophyllum nodosum* biotope (A1 .3142, LR.LLR.F.Asc.X) was observed in 1999 in Sector 2, close to the railway bridge (Figure 2). No other rocky shore biotopes were recorded at that time. This is in contrast to the 3 biotopes recorded in 2013.

The current distribution of rocky shore biotopes is a stark contrast to the past distribution of biotopes in Sector 3 whereby the majority of the sector up to the railway bridge was rocky shore biotopes with very little littoral sediments (Figure 2). The rocky shore biotopes consisted of bands of shingle (A2.111, LS.LCS.Sh.BarSh) on the eastern bank, some blue mussel (*Mytilus edulis*) beds (A2.721, LS.LBR.LMus.Myt) on the eastern bank below the bands of shingle, large patches of ephemeral green and red seaweeds (A2.821, LR.FLR.Eph.EphX) on both sides of the river and large areas of barnacles and *Littorina* spp. (A2.431, LR.FLR.Eph.BLitX) throughout the sector on both sides of the river. It would appear that the substrate has changed slightly in this sector becoming finer and resulting in a decrease in the extent of rocky shore biotopes although it is not apparent what the cause is and whether it is a natural change. Possible explanations could include erosion of hard substrates in the area or increased sedimentation covering the available hard substrate. The overall diversity of the biotopes observed has increased slightly.

Only 5 different biotopes were recorded in 1999 in Sector 4 (Figure 2) showing that this sector has diversified over the years. In addition, there has been some change in the dominating biotopes. The areas of *Fucus ceranoides* (A1 .327, LR.LLR.FVS.Fcer) present in the northern and central parts of the sector in 2013 were previously extensive areas of barnacles and *Littorina* spp. (A2.431, LR.FLR.Eph.BLitX), and the area where *Fucus spiralis* (A1 .322, LR.LLR.FVS.FspiVS) and *Fucus ceranoides* (A1 .327, LR.LLR.FVS.Fcer) were side by side in the northern part of the sector was previously *Fucus vesiculosus* (A1.3132, (LR.LLR.F.FVES.X). The mussel bed now present in the centre of Sector 4 was previously a band of *Enteromorpha* spp. and *Porphyra purpurea* (A1 .452, LR.FLR.Eph.EntPor). Much of the rocky shore habitat at the mouth of the estuary has since gone although the patch of *Enteromorpha* spp. and *Porphyra purpurea* (A1 .452, LR.FLR.Eph.EntPor) on the north western side of the mouth in 2013 was present previously in 1999 and has only moved a little. The large area of honeycomb worm (*Sabellaria alveolata*) reef (A2. 711, LS.LBR.Sab.Salv) that was present in 1999 has since reduced and moved further upstream and towards the lower shore regions of the estuary as opposed to the mid shore. The main feature that does not seem to have shown any change is the band of shingle running from the central to southern part of the estuary on the south eastern bank.

## 4.3 Preliminary assessment

A preliminary assessment of the condition of the attributes of the sub-feature "intertidal boulder and cobble scar communities" has been made based on the results obtained (Table 10).

**Table 10. Preliminary condition assessment for each attribute.**

| Attribute | Target | Preliminary Assessment |
|---|---|---|
| **Extent of characteristic biotopes** | No decrease in extent from the established baseline (Woombs 1999), subject to natural change. | There has been an overall decrease in the total extent of characteristic biotopes in the estuary since the initial survey conducted in 1999 (Woombs, 1999). The current extent of intertidal boulder and cobble scar communities is 45.7 Ha (0.457 km2) whereas the extent in 1999 was measured to be 88.1 Ha (0.881 km2). This shows a reduction of 42.4 Ha (0.424 km2) over a period of 14 years, almost half the previous extent. It is unknown if this is a natural change or an anthropogenic one although the small number of anthropogenic pressures observed in the estuary could suggest it is a natural process of either erosion or sedimentation reducing the boulder and cobble habitats and increasing the extent of littoral sediment habitats.<br><br>The condition of this attribute could potentially be described as unfavourable if the direct comparison of area coverage between the two surveys is used. However, given the length of time since the previous survey, it is difficult to determine whether this could be part of a cyclical change. The lack of extent data between 1999 and 2013 therefore means the condition of this attribute is currently **unknown.** |
| **Species composition of characteristic rocky scar biotopes: -mussel beds and tideswept** | Presence and abundance of composite species should not deviate significantly from the established baseline (Woombs 1999), | There has a been a change in the number of biotopes in the estuary, although some of this may be attributed to the slight differences in the classification system since 1999 (for instance, some variable salinity biotopes were not present in the system in 1999 so the change from the old biotope code to the new one may not be entirely accurate in all cases). There has also been the addition of new biotopes in the estuary not related to the previous ones found suggesting a change in species composition. Both the 1999 and 2013 surveys found impoverished communities across the estuary. However, as only MNCR forms were completed for the 1999 survey and no quantitative quadrats assessed, a true comparison in |

| | | |
|---|---|---|
| **boulders with *Fucus ceranoides*** | subject to natural change. | species composition cannot be formed as it would be impossible to find every single species present within a biotope during a time-limited walkover survey.<br><br>The lack of historic quantitative data for comparison means the condition of this attribute is currently **unknown**. |

# 5 Summary and conclusions

1. APEM conducted Phase I-style biotope mapping and quantitative quadrat surveys of the rocky shore biotopes within the Ravenglass Estuary (Drigg Coast European Marine Site) from Sunday 18th to Tuesday 20th August 2013 and from Wednesday 4th to Friday 6th September 2013.
2. The objective of the surveys was to identify and map the extent, distribution and quality of littoral rock biotopes with special emphasis on the EMS sub feature boulder and cobble skear biotopes including blue mussel (*Mytilus edulis*) beds. Additional information on anthropogenic pressures with potential effects on the site's features were recorded.
3. 100 % of the intertidal region of the Ravenglass Estuary in Sectors 1-4 was surveyed on foot for the Phase I biotope mapping process and a good level of detail (EUNIS Level 4 and 5) was achieved. All areas where boulder and cobble skear biotopes were not recorded were considered to be littoral sediments. Sector 5 of the estuary was surveyed as part of a different contract.
4. Boulder and cobble skear biotopes, particularly those containing *Mytilus edulis* and *Fucus ceranoides*, were targeted for the quantitative survey.
5. The estuary as a whole was found to be primarily littoral sediments with patches of boulder and cobble habitats throughout.
6. The main biotopes present were barnacles and *Littorina* spp. on unstable eulittoral mixed substrate (A2.431, LR.FLR.Eph.Blitx), *Porphyra purpurea* and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock (A 1.452, LR.FLR.Eph.EntPor) and *Mytilus edulis* beds on littoral sediments (A2.721, LS.LBR.LMus.Myt).
7. A total of 14 different boulder and cobble skear biotopes/biotope complexes were recorded across all 4 sectors in the Ravenglass Estuary. Only a *Fucus ceranoides* biotope (A1 .327, LR.LLR.FVS.Fcer) occurred in all 4 sectors.
8. Half of the biotopes recorded have been previously recorded in the estuary (Woombs, 1999), a further 4 biotopes show similarities to other previously recorded biotopes and the remaining 3 biotopes (2 *Fucus spiralis* biotopes and 1 rockpool biotope) were not recorded in historic data (Woombs, 1999).
9. Several biotopes have changed since the original survey of the estuary in 1999 and the overall coverage of boulder and cobble habitats appears to have decreased by almost 50 % since this time, from 88.1 Ha (0.881 $km^2$) to 45.7 Ha (0.457 $km^2$). However, the estuary now appears to be slightly more diverse in terms of the biotopes observed.
10. As part of the quantitative quad rat surveys, 121 quad rats were assessed (24 transects with 5 replicates in each and an additional, 6th quadrat assessed at Transect 6 due to its vertical surfaces).
11. The quadrats contained 37 taxa (25 sessile taxa and 12 free-living taxa). Barnacles were particularly common (present in 83 quadrats and contributing to 22 % of the observed percentage coverage of sessile taxa). Representative photographs were taken of the barnacle communities present in each quadrat for later analysis.
12. Algal species *Fucus ceranoides*, *Fucus vesiculosus* and *Enteromorpha* spp. were also relatively common and were present in 39, 42 and 31 quadrats respectively. The two *Fucus* species contributed to 36 % and 15.4 %, respectively, of the

observed percentage coverage of sessile taxa and, along with barnacles, were the highest contributors.

13. The most abundant free-living species recorded in quadrats was the blue mussel, *Mytilus edulis* (1006 individuals) with *Littorina littorea* the second most dominating species (770 individuals). Combined, these two species contributed to over 50 % of the observed abundance of free-living taxa in the quadrats (37.1 % and 28.4 % respectively).
14. Sector 2 was found to have the highest mean number of taxa in hard substrate biotopes in comparison to the other sectors and Sector 1 had the lowest mean number of taxa and was also the least variable.
15. Within the Ravenglass Estuary, 1 specialised, 1 nationally or more than nationally important community, 2 non-native species and 3 Biodiversity Action Plan (BAP) habitats were recorded. No nationally rare or scarce species were knowingly encountered.
16. The main anthropogenic pressure observed was the Ministry of Defence site south of Eskmeals Dunes and walkers and dog walkers at various points around the estuary.
17. The preliminary condition assessment found that the current condition of the sub-feature "extent of characteristic biotopes" is unknown. This is due to the lack of extent data between 1999 and 2013 which would be useful in determining if the decrease is part of cyclical change or an indication of a decline in the condition of the sub feature.
18. The current condition of the sub-feature "species composition of characteristic biotopes" is also unknown due to a lack of quantitative data for comparison.

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# Appendices

**Appendix 1.** Mapped Ravenglass Estuary quadrat locations.

**Appendix 2.** Ravenglass Estuary master GPS waypoints log.

**Appendix 3.** Ravenglass Estuary master tracks log.

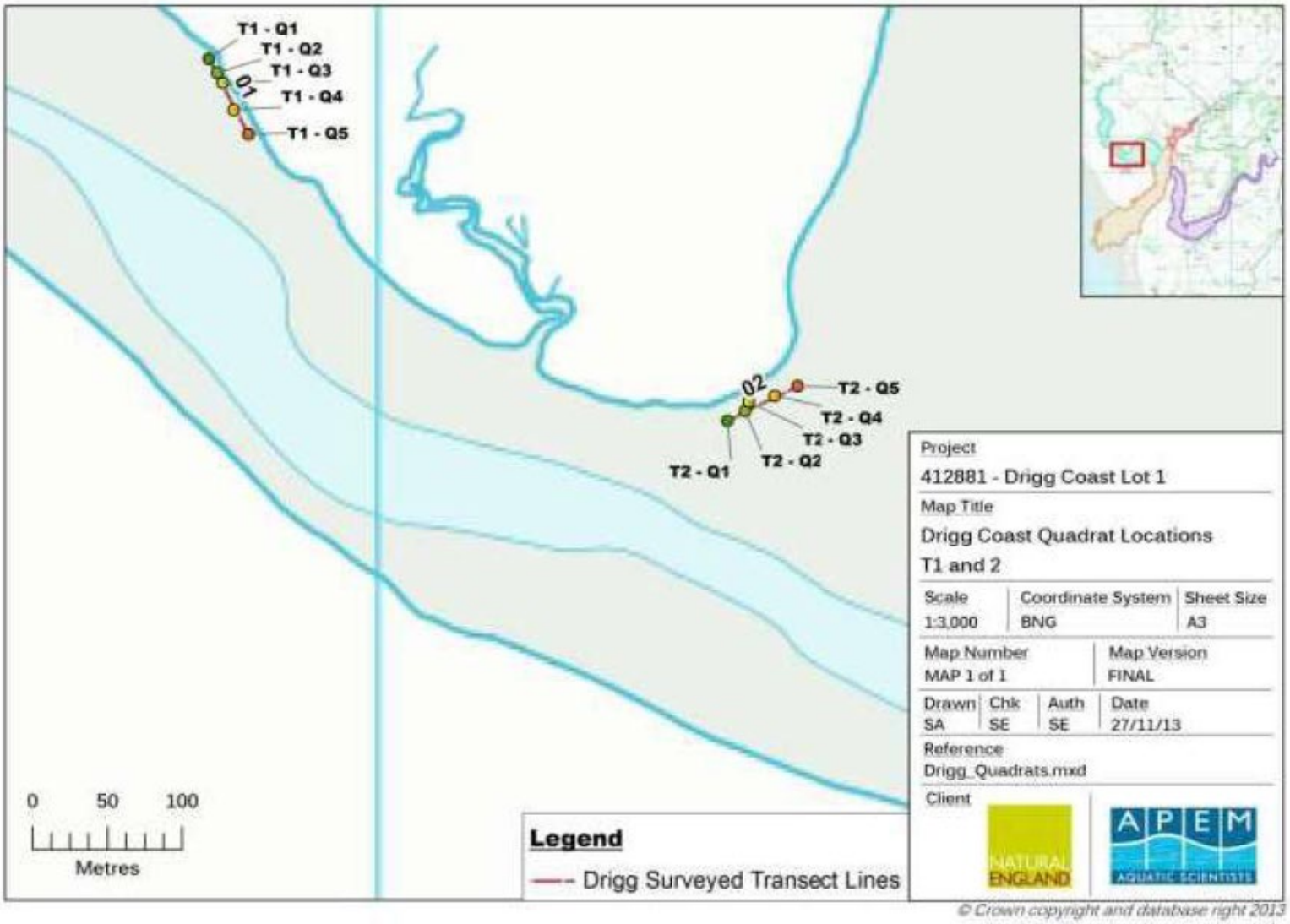
**Appendix 4.** Ravenglass Estuary quadrat locations (lifted from Appendix 1)

**Appendix 5.** Ravenglass Estuary master photo log

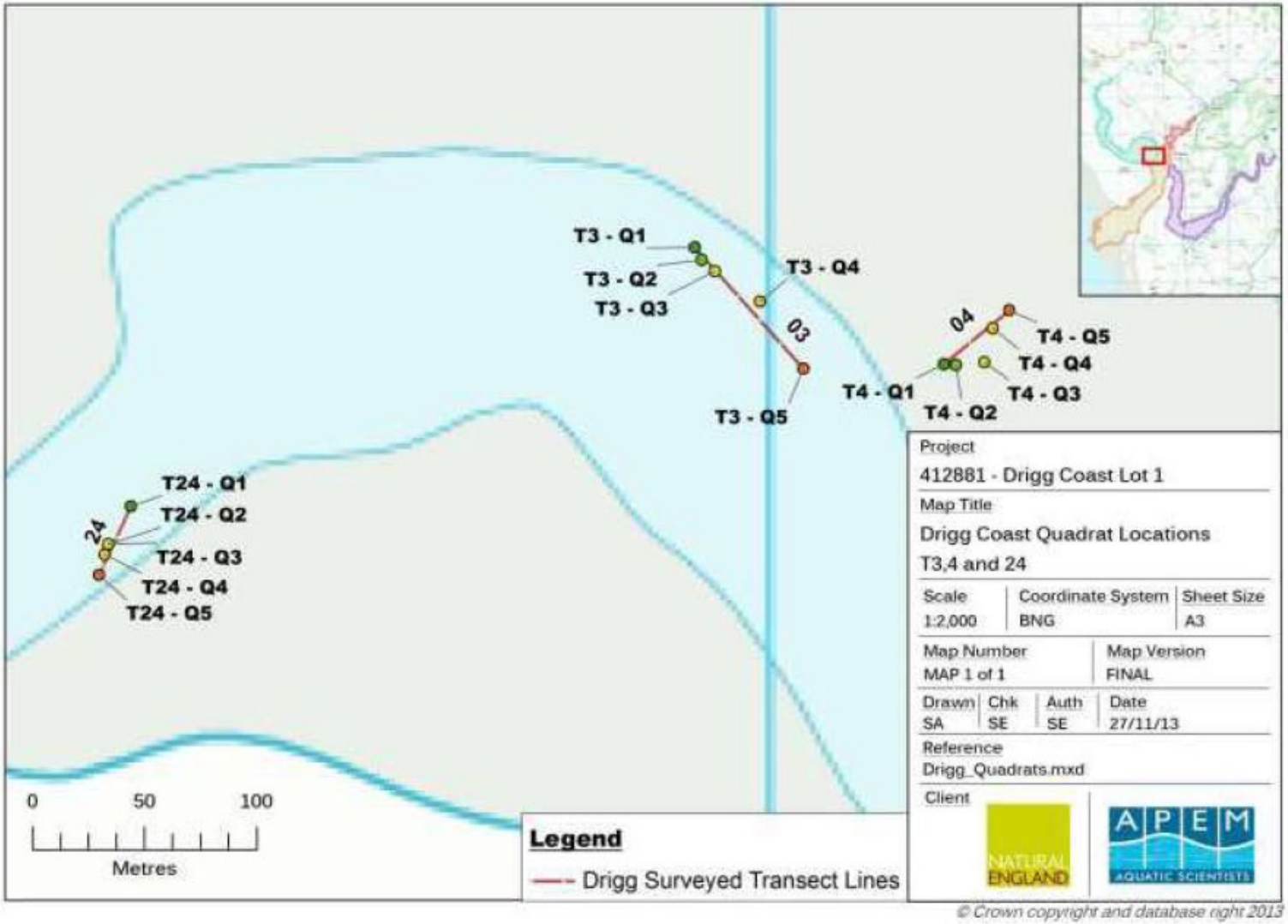
**Appendix 6.** Ravenglass Estuary quadrat data (species and physical data)

**Appendix 7.** Method statement- statistical analyses

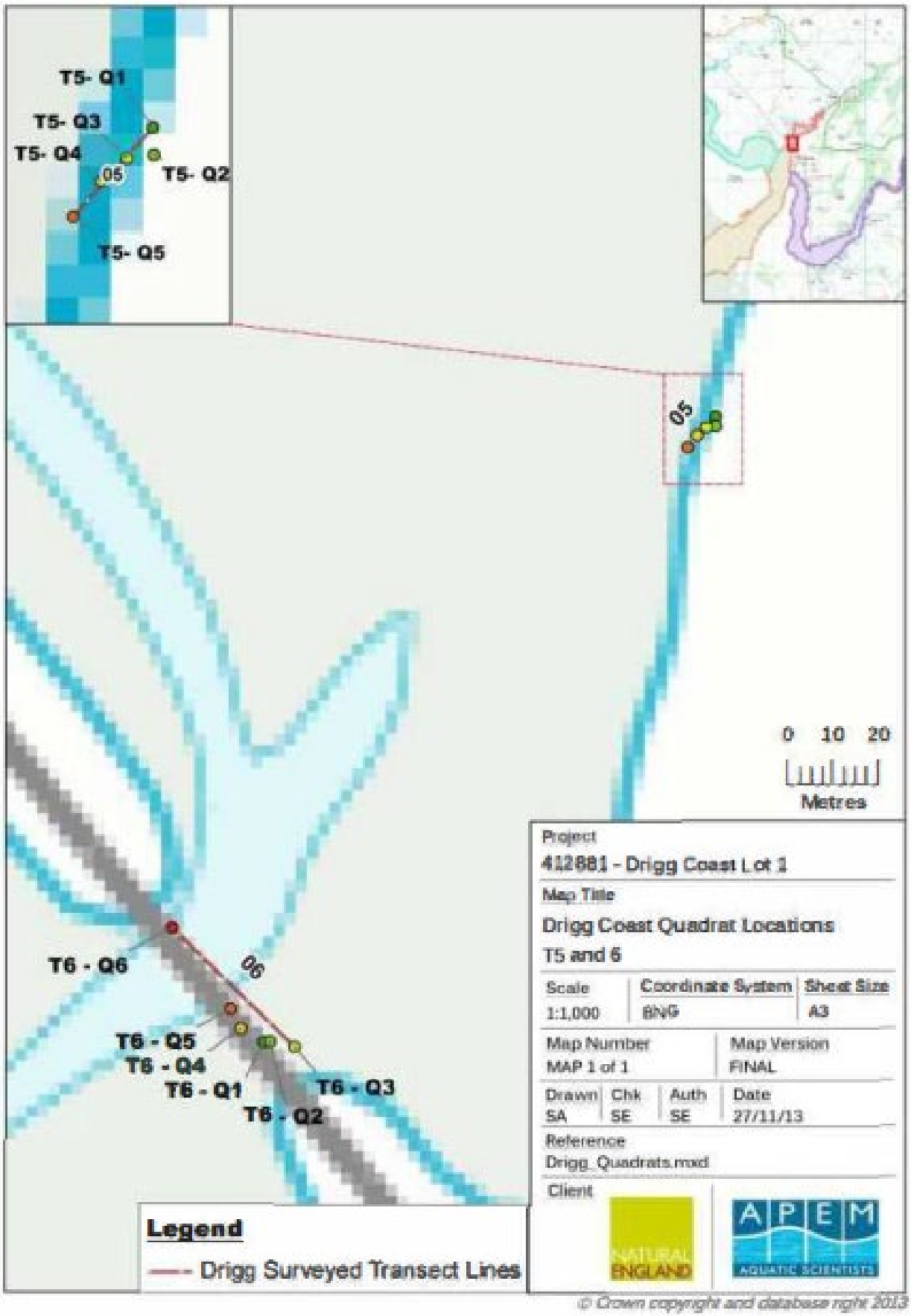
**Appendix 1.** Mapped Ravenglass Estuary quadrat locations.



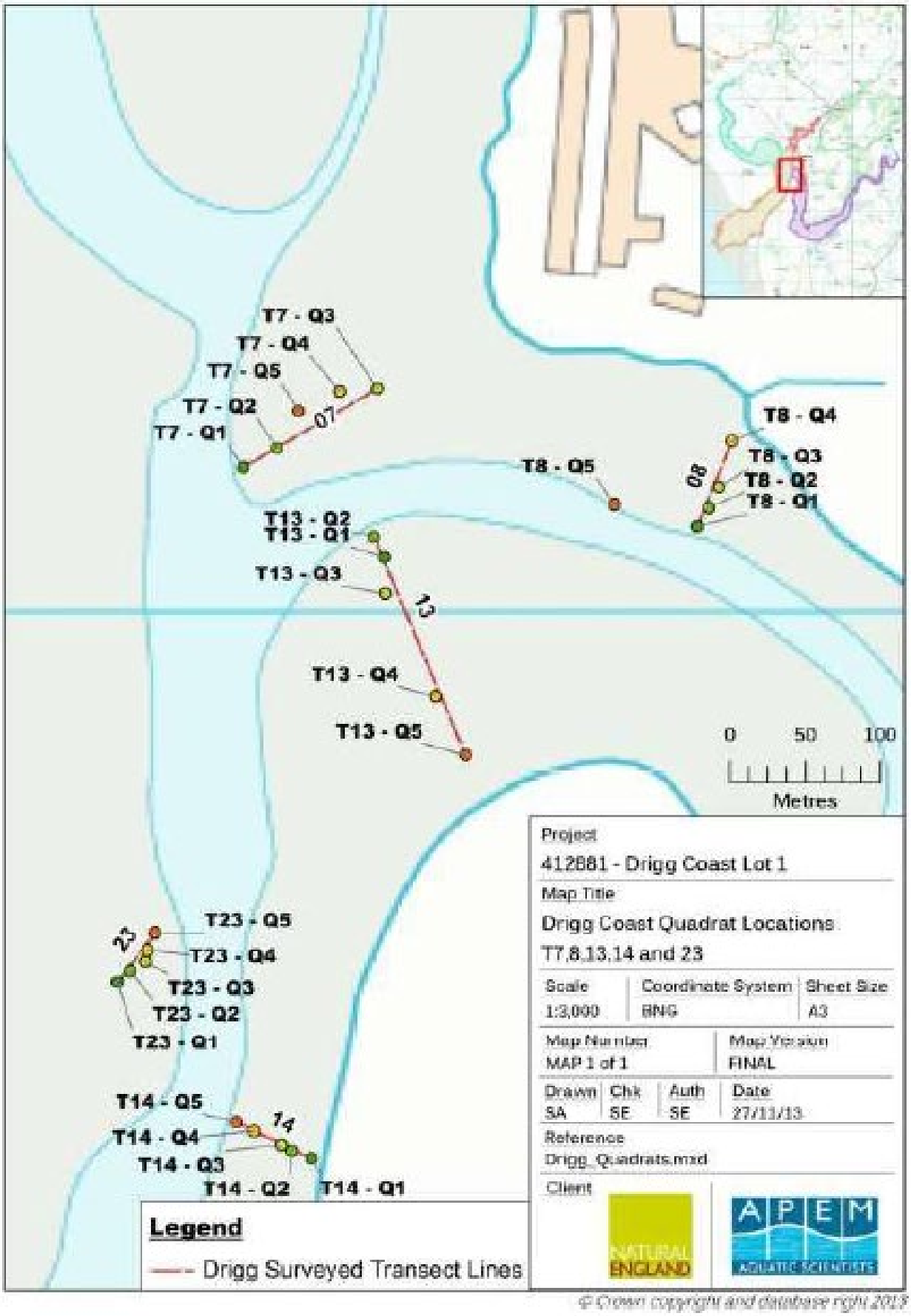

**A. Ravenglass Estuary quadrat locations -T1 and T2 (Sector 1). Contains Ordnance Survey data.**



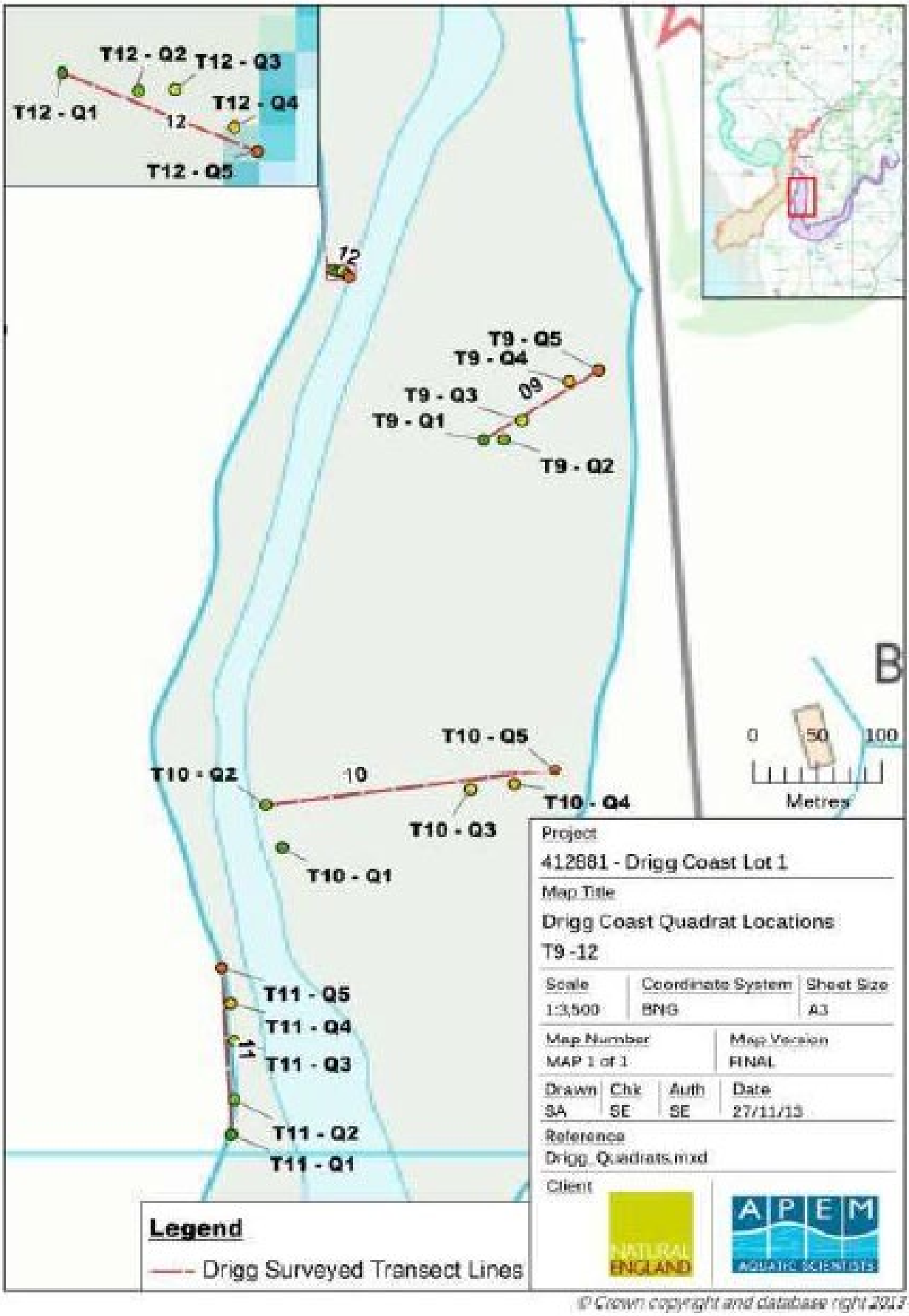

**B. Ravenglass Estuary quadrat locations -T3 and T24 (Sector 1) and T4 (Sector 4). Contains Ordnance Survey data.**



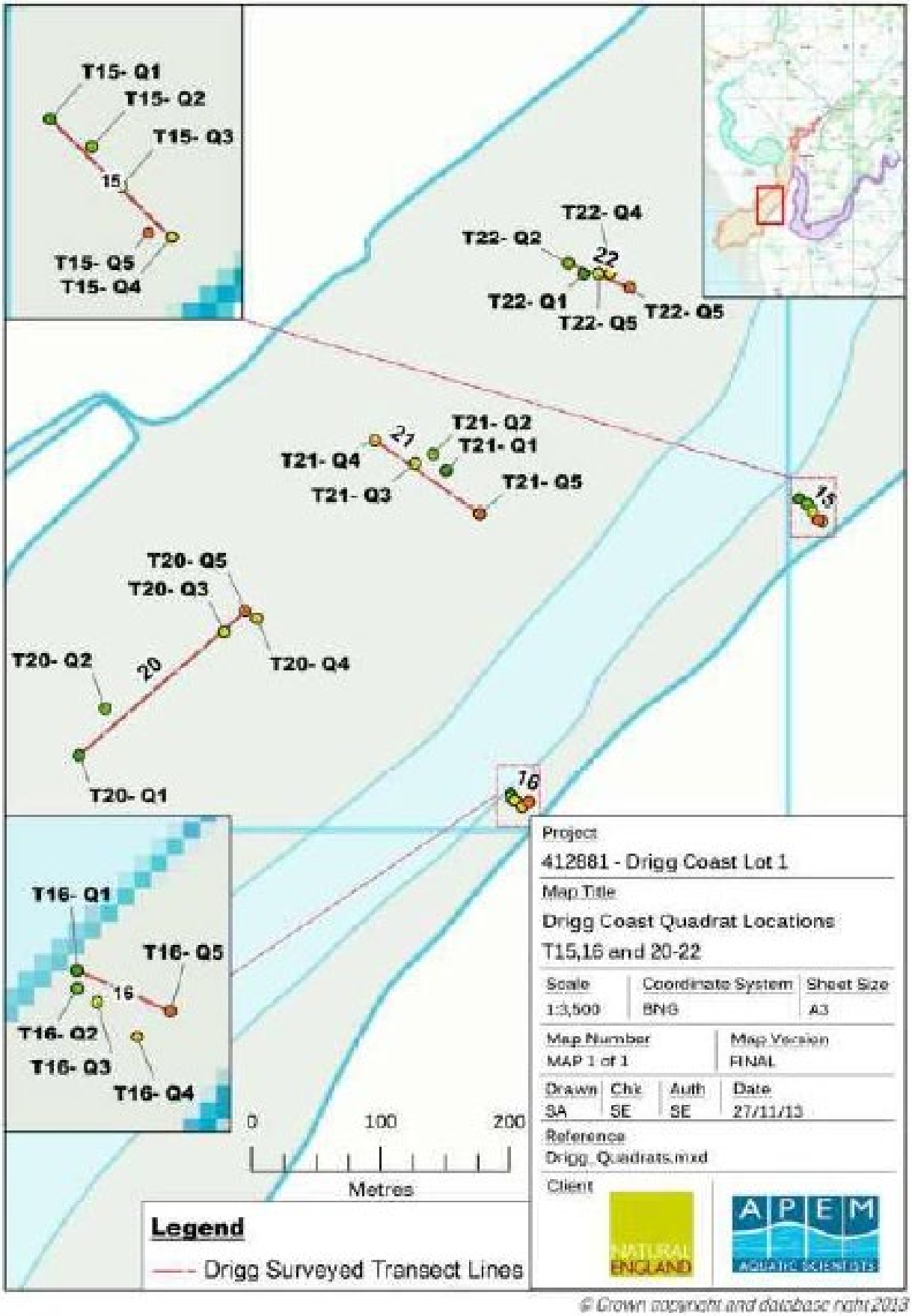

**C. Ravenglass Estuary quadrat locations - T5 and T6 (Sector 2). Contains Ordnance Survey data.**



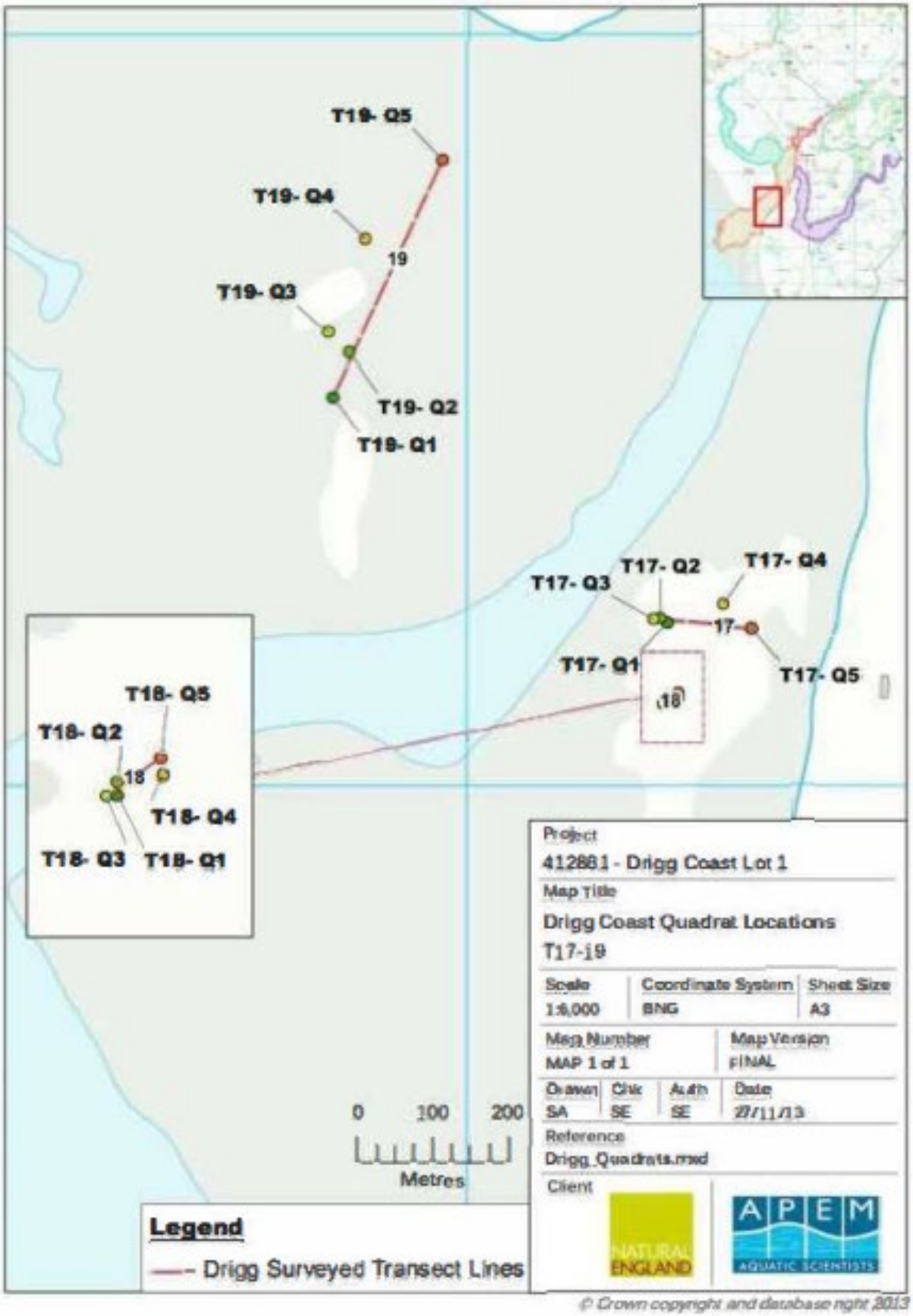

**D. Ravenglass Estuary quadrat locations - T8 (Sector 3) and T7, T13, T14 and T23 (Sector 4). Contains Ordnance Survey data.**




**E. Ravenglass Estuary quadrat locations - T9, T10, T11 and T12 (Sector 3). Contains Ordnance Survey data.**




**F. Mapped Ravenglass Estuary quadrat locations - T15, T16, T20, T21 and T22 (Sector 4). Contains Ordnance Survey data.**




**G. Mapped Ravenglass Estuary quadrat locations - T17, T18 and T19 (Sector 4). Contains Ordnance Survey data.**

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