Morecambe Bay SAC Intertidal Reef Surveys 2015: Final Report

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Natural England

APEM Ref: 414289

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Cover Image: View of the channel that divides Old Skea and Reap Skear at Morecambe Skears during field survey.

Revision and Amendment Register

Version Number	Date	Section(s)	Page(s)	Summary of Changes	Author(s)	Approved by
1.0	16.11.15	All	All	First Draft	RA	RP-D
2.0	21.03.16	All	All	Updated draft following review by Natural England	RA	RP-D

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1. Executive summary

Background

APEM was commissioned by Natural England to conduct an intertidal survey of the intertidal reef habitats within Morecambe Bay Special Area of Conservation (SAC) as part of routine and long-term monitoring of this designated area. The work has been conducted in collaboration with the Centre for Marine & Coastal Studies (CMACS). The purpose of this survey was to assess selected reef features and associated attributes associated within Morecambe Bay as part of the SAC monitoring requirements. This will allow condition assessment judgements to be made on the components of the SAC.

This document outlines the methodology and results of the intertidal reef surveys conducted in 2015. It highlights the notable communities encountered on site and provides a general account of anthropogenic pressures identified at the time of survey that may impact the SAC integrity.

Morecambe Bay Special Area of Conservation (SAC) is a large, very shallow, predominantly sandy bay at the confluence of four principal estuaries, the Leven, Kent, Lune and Wyre. The Duddon Estuary is within the SAC but north of the bay itself, although directly connected to it by Walney Channel. Morecambe Bay and Duddon Estuary are underpinned by a number of Sites of Special Scientific Interest (SSSI): Duddon Estuary SSSI, Lune Estuary SSSI, Morecambe Bay SSSI, Roundsea Wood and Mosses SSSI, South Walney and Piel Channel Flats SSSI, and Wyre Estuary SSSI. These designations highlight the value of the Morecambe Bay SAC for the conservation of a number of protected features of recognised ecological relevance.

The aim of the ecological survey work was to (1) Map the littoral intertidal reef sub-features intertidal rock, stony reef and biogenic (blue mussel bed and honeycomb worm) reef, and their associated communities (biotopes) within Morecambe Bay SAC, including Duddon, Wyre, Leven, Kent and Lune estuaries; and (2) Make an assessment of change against previously collected data sets. This will comprise an initial assessment of feature condition following the site Conservation Objectives, to enable Natural England to provide robust determination of site and feature condition using this and other data sources.

Survey design

The sampling strategy was based on a flexible stratified survey design informed by existing biotope distribution and aerial imagery. Sampling areas and effort was agreed in consultation with Natural England before the survey work commencing.

The surveys employed a combination of Phase I biotope mapping survey, Phase II 0.25 m^2 quadrat survey and a variation of the Dutch wand method (van Stralen & Boit, 2004) to assess mussel reef.

There was no quantitative dataset available to compare the results of the current survey against. However, a number of studies have been conducted of the rocky habitats, mussel beds and *Sabellaria alveolata* reef within the Morecambe Bay SAC. These data were used to inform the design of the current survey and provide a good indication of the location of intertidal stony reef and intertidal rock sub-features up to 2014.

Due to the size of Morecambe Bay and the resources allocated for this survey it was not possible to cover the whole area. Instead survey coverage was designed to (1) target known areas of the intertidal reef sub-features focus of the assessment, (2) include a range of shore heights, (3) provide good coverage of the main SSSI Sectors and all five of the SSSI sites: Duddon Estuary, South Walney & Piel Channel Flats, Morecambe Bay, Lune Estuary and Wyre Estuary, and (4) standardise survey sectors and methodologies to facilitate future surveys. Spatial data on the locations of target habitat types was provided by Natural England. The quantitative quadrat survey sampled 93 quadrats from 31 sites. The field work was conducted on foot between 29th September 2015 and 1st October 2015 and using a hovercraft to access sites (with survey conducted on foot) on 14th and 15th October 2015.

Results

The most common macroalgal taxon was *Ulva intestinalis* which was found at 39 out of 93 quadrats. The most commonly observed invertebrate was *Mytilus edulis* in 53 out of 93 quadrats.

Of the three biotope communities specifically referred to within the Conservation Objectives, only mussel beds and honeycomb worm (*Sabellaria alveolata*) reefs were found in any great areas. The tide-swept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds habitat was only recorded at one site. Mussel beds were recorded at Foulney Island, Morecambe Skears and the Wyre Estuary/ Fleetwood areas of Morecambe Bay SAC. Mussel coverage varied from 21% to 91%. The proportion of large mussels (>45 mm in length) varied by area with only 1-3% of large mussels at Morecambe Skears, 29-37% large mussels at Foulney Island and 1-7% of large mussels at Fleetwood. *Sabellaria alveolata* reef was recorded in the North Walney, Morecambe Skears and Half Moon Bay areas. In North Walney a large expanse of *S. alveolata* was recorded in the south of the area with low growths. Other smaller areas of declining reef were reported. At Morecambe Skears the main reef is at Heysham Flats with areas of reef on the seaward extents of the mussel reef. A further area of reef was recorded at Old Skear. At Half Moon Bay the reef was a thin sheet coating the lower boundary of bedrock.

The Australian barnacle *Austrominius modestus* was recorded in 54 of 93 quadrats at 18 locations which were throughout the SAC except for the Half Moon Bay area. Japanese wireweed *Sargassum muticum* was found in rockpools in the North Walney and Foulney Island areas.

In terms of anthropogenic pressures, bait digging was observed at North Walney, there is a working mussel fishery within the bay with fishermen observed hand-gathering mussels at Morecambe Skears and there are also several manmade features throughout the SAC including outfalls, seawalls, groynes and other sea defence.

Condition opinion

Overall, a comparison of the extent of intertidal reef habitats within Morecambe Bay SAC suggests no significant difference between the baseline data and the 2015 survey. Whilst changes in the extent of mussel beds and *Sabellaria alveolata* reefs have occurred over time, it is likely that this is the result of natural change and so the Conservation Objectives (CO) for these habitats have been met. There is no baseline data for the tide-swept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds habitat and so no conclusion can be made on this CO. No quantitative baseline data are available for the SAC and so comparisons of the presence and abundance of composite species of mussel beds and tide-swept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds habitat were not possible. Similarly a comparison of the percentage of sexually mature mussels was not possible as quantitative data on the mussel beds in the SAC was not available.

This survey has provided a good baseline for the communities within the SAC which can be used to make comparisons against with future surveys.

2. Introduction

2.1 Background

APEM was commissioned by Natural England to conduct an intertidal survey of the intertidal reef habitats within Morecambe Bay Special Area of Conservation (SAC) as part of routine and long-term monitoring of this designated area (Figure 1). The work has been conducted in collaboration with the Centre for Marine & Coastal Studies (CMACS). The purpose of this survey was to assess selected reef features and associated attributes associated within Morecambe Bay as part of the SAC monitoring requirements. This will allow condition assessment judgements to be made on the components of the SAC.

This document outlines the methodology and results of the intertidal reef surveys conducted in 2015. It highlights the notable communities encountered on site and provides a general account of anthropogenic pressures identified at the time of survey that may impact the SAC integrity.

2.2 Morecambe Bay SAC

Morecambe Bay is a large, very shallow, predominantly sandy bay at the confluence of four principal estuaries, the Leven, Kent, Lune and Wyre. The Duddon Estuary is within the SAC but north of the bay itself, although directly connected to it by Walney Channel (Figure 1). There are large intertidal sandflat areas, with small areas of mudflat, particularly in the upper reaches of the associated estuaries. There are diverse communities associated with the mobile sediments of the bay. There are also large beds of mussels *Mytilus edulis* on exposed 'scars' of boulder and cobble, and small areas of reefs with fucoid algal communities.

The Wyre, Lune, Leven and Kent estuaries all support areas of saltmarsh. Walney Island is a barrier island fringed by shingle with a partial sand covering. There are also shifting sand dunes at the entrance to Morecambe Bay on Walney Island and the Duddon Estuary at Sandscale Haws.

Morecambe Bay and Duddon Estuary are Special Protection Areas and Ramsar sites and are underpinned by a number of Sites of Special Scientific Interest (SSSI) (Figure 1): Duddon Estuary SSSI, Lune Estuary SSSI, Morecambe Bay SSSI, Roundsea Wood and Mosses SSSI (1 intertidal unit), South Walney and Piel Channel Flats SSSI, and Wyre Estuary SSSI. These designations highlight the value of the Morecambe Bay SAC for the conservation of a number of protected features of recognised ecological relevance.

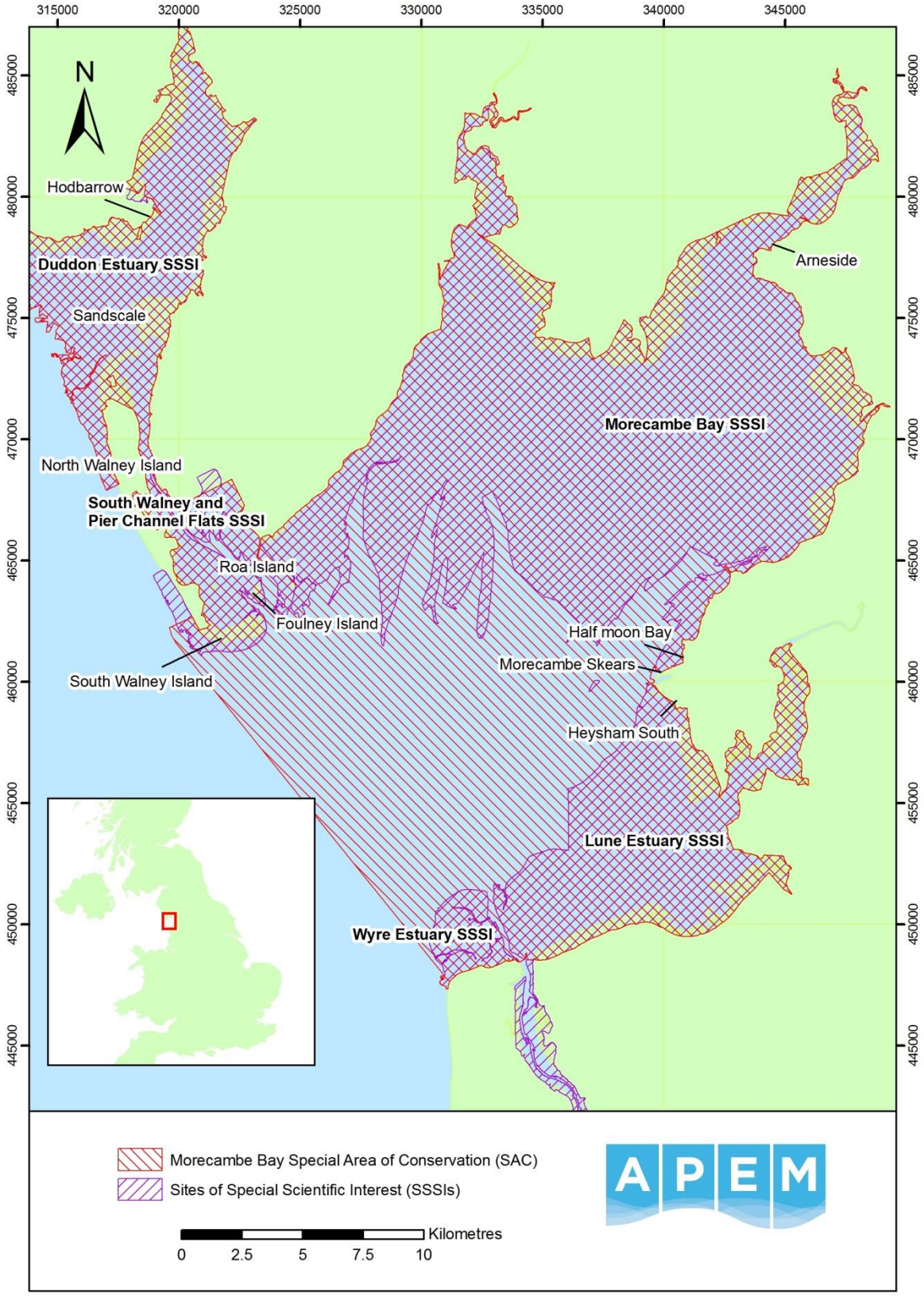

Figure 1 Morecambe Bay SAC showing SSSI sites. Site names are given in the figure.

2.3 Objectives

The aim of the ecological survey work was to:

- Map the main littoral intertidal reef sub-features and their associated communities (biotopes) within Morecambe Bay SAC, including Duddon, Wyre, Leven, Kent and Lune estuaries.

- Make an assessment of change against previously collected data sets. This will comprise an initial assessment of feature condition following the site Conservation Objectives, to enable Natural England to provide robust determination of site and feature condition using this and other data and will be provided within the full report to follow.

The intertidal reef sub-features targeted during the surveys were:

- intertidal rock;
- intertidal stony reef[1];
- intertidal biogenic reef: blue mussel bed; and
- intertidal biogenic reef: *Sabellaria alveolata*.

2.4 Historical data

There was no quantitative dataset available to compare the results of the current survey against. However, a number of studies have been conducted of the rocky habitats, mussel beds and *Sabellaria alveolata* reef within the Morecambe Bay SAC. This section summarises the main findings of the relevant previous studies.

Tooke (2015) conducted a review of spatial data of intertidal stony reef and intertidal rock sub-features of the Annex I Reef feature of Morecambe Bay SAC. This review by Tooke (2015) incorporated aerial imagery, previous datasets from North Western Inshore Fisheries and Conservation Authority (NWIFCA) and biotope mapping data from Kingfisher Seafoods Ltd to produce an ArcGIS map of these features. These data were used to inform the design of the current survey as described in Section 3.1 and provide a good indication of the location of intertidal stony reef and intertidal rock sub-features up to 2014.

[1] Stony reef was identified using the guidance provided within Irving (2009).

2.4.1 Rocky Habitats

The review by Tooke (2015) indicated the presence of intertidal stony reef from Duddon Estuary (Figure 29 in Appendix 1), off the west coast of Walney Island (Figure 30 in Appendix 1), around the Barrow area, Roa Island and Foulney Island (Figure 30), small patches near Goadsbarrow (Figure 31 in Appendix 1) and on the eastern side of Morecambe Bay SAC offshore from Morecambe and Heysham (Figure 32 in Appendix 1), at the mouth of the River Lune particularly on the southern side of the estuary (Figure 33 in Appendix 1) as well as offshore from Fleetwood and the mouth of the River Wyre (Figure 34 in Appendix 1). Tooke's review (2015) also identified areas of intertidal rock in the Duddon Estuary (Figure 29 in Appendix 1), off the southeast tip of Walney Island (Figure 30 in Appendix 1) and to the north and south of Heysham (Figure 32 in Appendix 1).

WA Marine conducted in intertidal survey in 2010 of the Foulney Island biotopes at six sites. North of Farhill Scar, the habitat was classified as LS.LMx.LMus.Myt.Mx (Version 04.05) *Mytilus edulis* beds on littoral mixed substrata which is now LS.LBR.LMus.Myt.Mx (Version 15.03)[2]. This area was described as characterised by superabundant aggregations of *Mytilus edulis* on the mid to lower eulittoral zones with a mix of mud and fine sand with empty shells. *Fucus vesiculosis* was found attached to the mussels and older mussels were encrusted with the invasive species *Elminius modestus* (now called *Austrominius modestus*). Other fauna found in this area included *Littorina littorea*, *L. saxatilis*, *Nucella lapillus* and *Carcinus maenas*. There were also small patches of *Lanice conchilega* in the lower eulittoral zone giving the biotope LS.LSa.MuSa.Lan *Lanice conchilega* in littoral sand. Pacific oysters *Crassostrea gigas* were found as well as the invasive species *Sargassum muticum*.

East of East Scar Buoy the habitat was classified as LR.HLR.FT.FserTX *Fucus serratus* with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata. This area was characterised by diverse flora of foliose and filamentous red seaweeds on a mixed substratum of mud, fine sand, pebbles, cobbles and empty *Mytilus edulis* shells.

2.4.2 Mussel Beds

There are a number of established blue mussel *Mytilus edulis* beds within the Morecambe Bay SAC that can be considered 'reef'. Commercial fishing of mussel is

[2] JNCC. 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03 [Online]. [Accessed January 2016]. Available from: jncc.defra.gov.uk/MarineHabitatClassification.

conducted in the bay primarily by hand and so the area is closely monitored by the NWIFCA to aid the management of the fishery and to ensure the mussels are fished sustainably. The main known areas of mussel bed are described below.

2.4.2.1 Duddon Estuary

The mussel bed at Hardacre is estimated to be approximately 30 ha in size following a survey in 2014 and had been fished by hand during the April 2014 to July 2015 period (NWIFCA, 2015a).

2.4.2.2 Foulney Island

There is a mussel bed at Foulney Island which varies considerably in abundance between years (WA Marine, 2010). The mussels here undergo a pattern of establishment on the cobbles and pebbles followed by a rapid build-up of pseudofaeces changing the substrate from mixed hard surface to mud. Further settlement of mussels are then unable to attach to the cobbles and pebbles and are liable to be washed away during seasonal adverse weather. Mussels are also prone to heavy predation by starfish particularly *Asteria rubens*. The distribution of mussel beds recorded by WA Marine (2010) was used to inform the design of the current survey.

A Dutch wand survey was conducted by the NWIFCA in August 2015 which estimated the bed here is currently approximately 40.8 ha with coverage of approximately 77% (NWIFCA, 2015a). Some starfish were observed on the north-eastern sections of the bed and the lower skear was covered in a dense mat of green algae covering the mussels in this area. This area had been previously inspected in July 2014 and the upper skears held large numbers of stunted mussels (NWIFCA, 2014a) but by January 2015 this area had been severely affected by December weather with a large number of mussels washed away and the remaining mussel stock deep in the mud (NWIFCA, 2015b).

The NWIFCA conducted a survey of the Foulney mussel bed on 11th September 2014 using the Dutch wand method (NWIFCA, 2014b). At this time, the bed was estimated at 40.8 Ha with 71% coverage. The survey found that the central areas of the bed contained small, seed mussels. The edge of the bed had larger mussels but these were mainly undersize.

2.4.2.3 North Morecambe Bay

In July 2015 the NWIFCA inspected the North Morecambe and South America area which did not appear to have any substantial areas of mussel beds in the areas that were accessible by quad bike (NWIFCA, 2015a).

The NWIFCA quarterly science report (2015a) states that a survey by the mussel industry in August 2015 at the Falklands beds found two areas of large mussels.

Between the Low Bottom oyster frames and Foulney Ditch, there were very few mussels observed during a NWIFCA inspection in July 2015 (NWIFCA, 2015a). Between the ditch and Foulney Island were larger mussels that are regularly recorded in this location. A previous survey by the NWIFCA on 10th October 2014 (NWIFCA, 2014b) estimated this bed was approximately 1 km^2 in size with undersize mussels.

2.4.2.4 Heysham Flats

The mussel beds at Heysham Flats were inspected by helicopter in May and on foot in July 2015 (NWIFCA, 2015a). These surveys indicated substantial recent settlement of mussel spat in this area that have covered the larger mussels and *Sabellaria alveolata* reef and the skears beyond Dallam Dyke. The main mussel bed covers an area of approximately 62.2 ha and the other two areas were 4.81 and 0.9 ha. A previous inspection by NWIFCA in February 2015 had found that an area of mussels on the lower skears were just undersize. These mussels appear to have been covered by the more recent spatfall.

2.4.2.5 Wyre Estuary

The mussels in the Wyre End area were inspected by the NWIFCA in July 2015 which cover an area of 11.53 ha (NWIFCA, 2015a). The central area of this skear was covered in green algae with very little mussel beneath with mussel coverage across the whole of the bed of approximately 30%. The area covered by mussels was estimated to be approximately 3.5 ha.

The NWIFCA inspected the mussel beds at Fleetwood in August 2015 (NWIFCA, 2015a). Not much mussel was recorded at Black Scar other than a narrow strip approximately 6 m wide along the edge of the channel for approximately 400 m covering an area of approximately 0.24 ha. At Perch Scar there were two areas of mussels. Both areas were dense in mussels but the higher area was primarily small mussels. The combined area at Perch Scar was approximately 5 ha. Further dense beds of mussels were recorded at King Scar covering an area of approximately 2.5 ha. At Neckings the mussels were loose and washed up in piles. The mussels at Rossall Scar were dense with some healthy *Sabellaria alveolata* clumps interspersed. The mussel bed at Rossall Scar is approximately 5 ha but the southern areas of this scar had been washed out. The Fleetwood area was previously inspected by the NWIFCA in January 2015 and found that Perch Scar and Black Scar beds were sanded in and that a lot of the mussels had been lost to scouring and weather (NWIFCA, 2015b).

2.4.3 Sabellaria reef

The presence, extent and health of *Sabellaria alveolata* reef within Morecambe Bay SAC has varied significantly between years. The main area of *Sabellaria* reef is at

Heysham Flats and undergoes a cyclical process of competition with blue mussel *Mytilus edulis* (Egerton *et al*, 2014). *Sabellaria* larvae tend to settle in the winter months, preferentially settling on hard, exposed substratum within the vicinity of adult *S. alveolata*. The majority of mussel spat settle in late spring or summer. Mussels have been shown to out-compete other littoral species for space (Cunningham *et al*, 1984) and this process has been observed at Heysham Flats (Foster, 2015).

The *Sabellaria* reef at Heysham Flats has been monitored for several years, and since 2011, has been the subject of formal monitoring by NWIFCA and Natural England as a Habitats Directive Annex I feature. The NWIFCA Science Report for May 2015 states the reef at Heysham Flats has undergone massive natural change over the previous 24 months and that this pattern was observed to be ongoing (IFCA, 2015c).

The most recent monitoring report on this reef (Foster, 2015) indicated significant reef expansion between summer 2011 and summer 2012 followed by a reduction in overall percentage cover but expansion at the north-west edge of skear in 2013. In 2014 the overall percentage coverage of *S. alveolata* was low although an area of higher coverage was recorded on the western end of the skear. The differences in distribution, formation and health of the reef between years was considered to the result of the cycle of competition as described above and the cycle of reproduction of the *S. alveolata* themselves which only undergo significant reproduction every three years or more (Wilson, 1974; 1976; Gruet, 1986).

Sabellaria reef was also previously described by Allen *et al* (2002) off the west coast of Walney Island in an area that is outside of the Morecambe Bay SAC but within the South Walney and Piel Flats SSSI Unit. This reef was observed on Cross Dike Scar and composed of three areas of *Sabellaria* reef (Figure 2). The southernmost reef was 4,031 m^2 with 30% coverage, the central reef was 32,230 m^2 with 30% coverage with *Sabellaria* primarily occurring on cobbles in standing water, and the northernmost reef was 33,040 m^2 with 30-50% coverage on cobbles. These reefs were described as of moderate to poor quality with hummocks of *Sabellaria* generally covered by *Fucus serratus* on the low shore.

Another area of *Sabellaria* reef was recorded by Allen *et al* (2002) off the southern coast of Walney Island at South East Point on a concrete groyne. This reef consisted of several small clumps in an area of approximately 0.25 m^2 in good condition which were thought to be newly established.

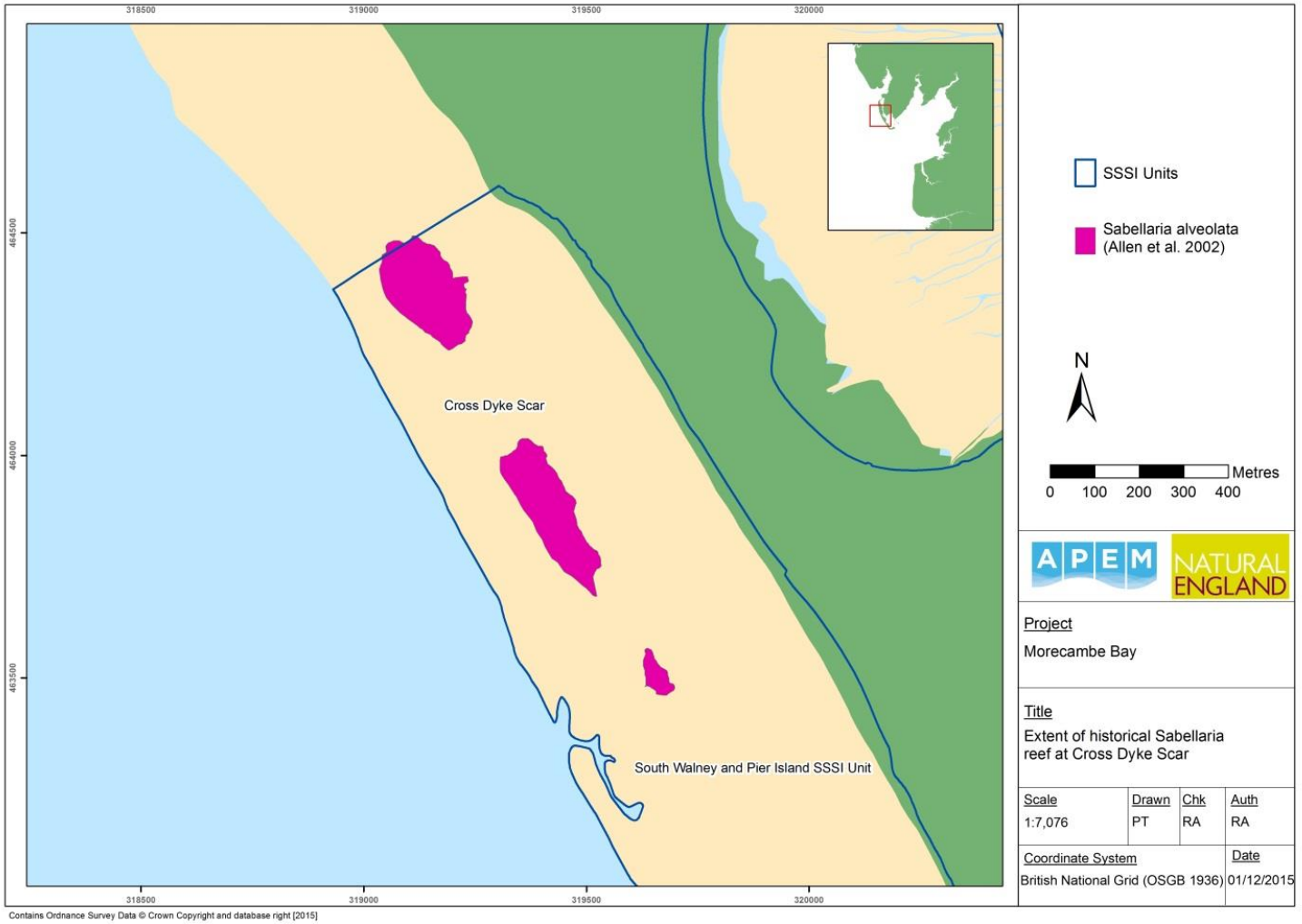

Figure 2 Recorded areas of *Sabellaria alveolata* reef on the Cross Dyke Scar, South Walney Island as surveyed by Allen et al (2002).

3 Methods

3.1 Survey design and sampling strategy

3.1.1 Pre-survey deskwork and location of sampling areas

The sampling strategy was based on a flexible stratified survey design informed by existing biotope distribution and aerial imagery. Sampling areas and effort was agreed in consultation with Natural England before the survey work commencing. The surveys employed a combination of Phase I biotope mapping survey, Phase II 0.25 m^2 quadrat survey and a variation of the Dutch wand method (van Stralen & Boit, 2004) to assess mussel reef. CMACS conducted the surveys on behalf of APEM.

Natural England and the North Western IFCA provided a number of datasets of previous reef survey data that APEM collated and reviewed. Based on this information, a draft survey design was presented at the project start up meeting (3rd September 2015). The final survey design targeting areas of hard substrata was subsequently approved by Natural England.

The placement of the transects/ survey locations was intended to provide a balanced coverage of the sub-features which were the focus of this work; rock, stony reef, blue mussel beds, and *Sabellaria alveolata* reef. For practical reasons the survey was divided in four main tasks/survey types (Table 1). This method ensures that the selected transects (survey effort) are effectively distributed across the SSSI Sectors and sub-features (target of the condition assessment) ensuring that areas of particular interest to Natural England were adequately covered. To ensure a standardised dataset that can be compared with existing data or effectively replicated in the future the survey deployed in accordance with current best practice guidance including the Countryside Council for Wales (CCW) Handbook for Marine Intertidal Phase I mapping surveys (Wyn et al., 2006), Marine Monitoring Handbook (Davies et al., 2001), Common Standards Monitoring guidance (Connor et al., 2004) and sub-feature specific guidance where necessary (van Stralen & Boit, 2004).

3.1.2 Survey sites and station locations

Due to the size of Morecambe Bay and the resources allocated for this survey it was not possible to cover the whole area. Instead survey coverage was designed to (1) target known areas of the intertidal reef sub-features focus of the assessment, (2) include a range of shore heights and (3) provide good coverage of the main SSSI Sectors and all five of the SSSI sites: Duddon Estuary, South Walney & Piel Channel Flats, Morecambe Bay, Lune Estuary and Wyre Estuary. Data on the locations of target habitat types was provided by Natural England. This data included a review of

aerial imagery by Tooke (2015) and the results of surveys of mussel beds within the area.

Phase II quantitative quadrats were geographically spread throughout the site, covering the range of habitats of interest. Individual quadrats were randomly located within the broad habitat types identified during the Phase I survey. A summary of the total number of stations targeted for each survey type is provided in Table 1 below. A total of 30 quadrat locations were identified during survey planning but once in the field not all of these locations were found to be suitable and so additional quadrat locations were sampled. Figures showing known areas of the target habitat types are provided in Appendix 1.

Table 1 Number of sites targeted with each survey

Survey Type	Number of sites targeted	SSSIs surveyed
Phase I	34*	Duddon Estuary, South Walney & Piel Channel Flats, Morecambe Bay, Lune Estuary and Wyre Estuary
Quadrat	30	Duddon Estuary, South Walney & Piel Channel Flats, Morecambe Bay, Lune Estuary and Wyre Estuary
Mussel	13	Duddon Estuary, South Walney & Piel Channel Flats, Morecambe Bay and Wyre Estuary
Sabellaria alveolata reef	12	Duddon Estuary, South Walney & Piel Channel Flats and Morecambe Bay

* This was an approximate number based on the number of habitats identified during the survey planning stage.

3.1.3 Sampling methods

Standard methodology for Phase I surveys was employed (Wyn et al., 2006). This stage served to confirm *in-situ* the extent and type of biotopes present, and validate the selection of sampling locations for detailed quantitative investigation as part of the detailed quadrat survey. Throughout the Phase I survey, site descriptions were recorded in field notes. Specific notes were made in relation to changes in biotope

identity and any potential anthropogenic pressures at a given site which could influence intertidal ecology (e.g. pipelines, point source pollution, fishing, etc.) including their locations. When possible walk overs around biotope boundaries were undertaken to map with precision the extent of the area. Alternatively sketches were done to allow the mapping of the area. All field notes were georeferenced.

The quantitative quadrat (Phase II) survey was conducted at the same time as the Phase I survey using 0.25 m^2 quadrats. At the planning stage, quadrat sampling effort was limited to 30 target locations spread as evenly as possible over the survey areas with more transects over larger areas of reef and where previous data existed. Some quadrat locations were moved in the field at the surveyor's discretion following a Phase I appraisal of representative and dominant habitats to ensure that more representative habitat was sampled. Where quadrats were moved in the field, the position was logged with GPS. All other quadrats were sampled at the target co-ordinates. For algae and encrusting organisms (including barnacles) percentage cover of the quadrat was estimated, for other species the numbers of individuals within the quadrat was counted (e.g. limpets *Patella* sp., beadlet anemones *Actinia equina* in accordance with methods outlined in CSM Guidance and the Marine Monitoring Handbook.

Due to timing restrictions it was not possible to undertake the full zig-zag transect Dutch wand method to assess mussel abundance. Instead, two 100 m transects were undertaken on each mussel bed, one along the length of the bed and one across the width. An 11 cm ring and pole (Dutch wand method) was used to randomly assess mussel presence absence within the ring (i.e. assess the bed for mussels (hits) every three paces). As agreed with Natural England, the method was modified so that a photograph was taken at every positive hit showing the mussels present within the 11 cm diameter ring. From these photographs the size and abundance of mussels on the surface was estimated.

The survey intended to map *Sabellaria alveolata* reefs as set out in Egerton (2014) which in summary involves logging the extent of the reef using a hand held GPS and areas of live worms recorded and photographed. Prior to survey *Sabellaria* target areas identified at the survey planning stage were overlaid with a 50 m x 50 m grid with the grid nodes uploaded to the hand held GPS unit. This grid was used to ensure that each 0.25 m^2 quadrat could be randomly placed with precision in each section and that samples were efficiently distributed across the entire area. The percentage cover and type of colony formation (sheet, hummock, patchy or reef) of *S. alveolata* within the quadrat would have been recorded. However, the field team did not identify any *S. alveolata* reef features at these target locations. Instead, a description of the presence of any aggregations of *S. alveolata* worms was recorded in the field target notes.

General site photographs were taken during the survey in addition to photographs of each quadrat. For the mussel survey, a photograph was taken at every positive hit

showing the mussels present within the 11 cm diameter ring. Areas of live *Sabellaria alveolata* worms were photographed.

3.2 Sampling site access and survey periods

The field work was conducted on foot between 29th September 2015 and 1st October 2015 and using a hovercraft to access sites (with survey conducted on foot) on 14th and 15th October 2015 (Table 2). All survey days were selected for spring tides in order to optimise the length of time available for each survey and to ensure the lower reaches of the shores could be sampled.

Table 2 Surveys undertaken in Morecambe Bay and Duddon Estuary

Date	Time of low water	Sunrise/Sunset	Tide Amplitude (m)	Survey team	Area surveyed
28/9/15	18:40	18:56	0.8	TH & KS	Lune Estuary
29/9/15	07:05	07:10	0.4	TH & KS	Half Moon Bay
29/9/15	19:25	18:53	0.6	TH & KS	South of Heysham
30/9/15	07:50	07:12	0.4	TH & KS	Morecambe Skear
30/9/15	20:10	18:51	0.6	TH & KS	Morecambe Skear
1/10/15	08:35	07:14	0.7	TH & KS	Morecambe Skear
15/10/15	07:35	07:40	1.8	KN & PC	Wyre Estuary
28/9/15	18:54	18:56	0.6	KN & PC	North Walney
29/9/15	07:20	07:10	0.3	KN & PC	South Walney
29/9/15	19:40	18:53	0.4	KN & PC	Hodbarrow
30/9/15	08:05	07:12	0.3	KN & PC	Foulney Island
30/9/15	20:25	18:51	0.5	KN & PC	Sandscale

1/10/15	08:48	07:14	0.5	KN & PC	Roa Island to Goadsbarrow
14/10/15	07:23	07:40	1.4	KN & PC	Foulney Island

A licence was obtained for access to the foreshore from Boughton Estates. Natural England also gained permission to access the Roa Island boat club slipway from the Commodore of the club from Wyre Council Coastal Ranger for access to slipway on Fleetwood Promenade. Other land owners and occupiers where appropriate were contacted where access to the site was required.

3.3 Post survey analysis

On completion of the surveys, raw data were transferred to electronic spreadsheets. This included a GPS waypoints log and GPS tracks log (Appendix 4). The GPS waypoints were subsequently used to create maps showing the locations of the samples taken during the survey (accurate to within 3 m).

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).

Habitat types were assigned according to JNCC's National Marine Habitat Classification for Britain and Ireland: Version 04.05 (Connor et al., 2004). All assignments were verified by a second taxonomist to provide quality control and consistency in the assignments. The GPS waypoints for the corresponding quadrat site were subsequently used to create maps showing the exact locations and biotope identity. These data were then used to confirm biotope assignations provided in the field notes. To create the final biotope maps, field notes on biotope boundaries collected during the 2015 Phase I survey were compiled and mapped in Arc GIS onto high definition aerial imagery[3] overlaid with historical biotope information and 2015 Phase II biotope results (ground truthing). The goal of this exercise was to align the existing imagery with the Phase I and quantitative quadrat survey enabling an enhanced broad scale habitat survey over the entire area (100% coverage).

[3] The most recent aerial imagery available was collected in 2012 and did not cover the full extent of Morecambe Bay SAC.

All mapping and interpretation of the aerial imagery were verified by a second GIS specialist and finally approved by the senior taxonomist to provide quality control and ensure the accuracy of the mapping. The JNCC's correlation table (JNCC 2015) was used to assign EUNIS codes to each habitat type. The JNCC Classification hierarchy was applied to EUNIS levels as follows: EUNIS level 1 Environment > level 2 Broad habitats > level 3 Main habitats > level 4 Biotope complexes > level 5 Biotope > level 6 Sub-biotope. In general, the term 'habitat types' is used where more than one level is discussed while terms for specific levels will be used where appropriate.

3.4 Statistical analysis

Microsoft Excel 2010 was used for general data formatting and exploration. PRIMER v6 (Clarke and Gorley, 2006) was used for the multivariate statistical analysis carried out.

3.4.1 Truncation and data consolidation

Data were transferred by the surveying taxonomists from field notes to electronic files in a standard format (see Appendix 4) to create factors for use in the cluster and ordination analyses e.g. shore height, physical data, biotope allocated, and enable the data to be easily manipulated into the correct format for PRIMER without losing any detail.

Final Analytical Quality Control (AQC) of the data was carried out by the project manager to ensure there were no spelling or transcription mistakes, all relevant fields had been completed and the species were in order of their species directory code.

3.4.2 Species richness

Species richness (number of taxa) was calculated using the 'Count' function in Excel. This allowed the number of taxa per quadrat to be determined. No other useful diversity indices could be calculated as the data were a combination of percentage coverage of encrusting, colonial species (e.g. barnacles etc), and actual abundances of free-living species (e.g. *Littorina* sp. etc) which cannot be directly compared due to the different units of measurement used.

3.4.3 Community analysis

The quadrat data were considered separately as 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. As the quadrat data was recorded as percentage coverage for encrusting/colonial organisms and as actual abundances for free-living species, as per standard guidance, the different units of measurement cannot be directly

compared and so a presence/absence transformation was applied. This type of transformation gives less abundant species in the matrix equal weight to more abundant species. Whilst this approach allows the use of all species data it precludes the use of quantitative information in the analysis of biological assemblages.

To enable multivariate analysis to be carried out, an appropriate definition of resemblance between samples must be provided to signify the similarity between samples. The Jaccard index was used in the current analysis. This similarity measure eliminates matching attributes that a zero (0) value as evidence of similarity and is recommended for presence/absence data. The index syntax is given by the formula:

$$J = \frac{(100 \times a)}{(a + b + c)}$$

Where:

- a is the number of species present in both samples;
- b is the number of species in sample 2 but absent from sample 1; and
- c is the number of species absent in sample 2 but present in sample 1.

Cluster analysis was used to visualise the groupings of samples based on their faunal composition. Agglomerative, hierarchical clustering was carried out on the Jaccard's resemblance (similarity) matrix. The method groups the samples into small groups first (i.e. those with the highest levels of similarity based on faunal composition). These first groups are subsequently grouped together into larger groups, based on group averages, lowering the level of similarity until all of the samples are in a single cluster at the lowest level of similarity between samples. A dendrogram was used to show the results of this clustering and indicates the level of similarity between each group of samples.

The similarity profile test (SIMPROF) was also implemented as part of the hierarchical clustering to identify how many distinct groups existed based on the null hypothesis (H_0) that the resultant sample clusters did not share a significant group structure. This test does not consider samples to be divided into groups prior to analysis and considers each sample independently. This test was carried out during the hierarchical cluster analysis using group average and the default SIMPROF setting in PRIMER for permutations (Mean: 1,000, Simulations: 999, and significance level (5%)).

Biotope codes were assigned to each quadrat sample by a technical specialist taxonomist post-survey. These assignations were added as sample factors to the faunal data for the multivariate analysis. Similarity Percentage analysis (SIMPER) was used to summarise discriminating features of the more abundant biotopes

identified in the analysis. The analysis was conducted on frequency of species sightings by biotope type. Frequencies were calculated by averaging the presence/absence-transformed data from the three replicates collected at each station. The SIMPER analysis provides the average percentage contribution from each species to the overall biotope assemblage and a measure of the variation expected within the replicate sites assigned to each biotope. This method was only applied to those biotopes found at four or more stations to prevent bias due to low replication.

3.4.4 Mussel size and abundance

The size and abundance of mussels on mussel beds was measured from the photographs taken during the modified Dutch wand survey. However, several photographs were of poor quality (unfocused, low light levels, etc.) which made analysis of the photographs difficult. This means that for some locations very small or cryptically coloured mussels may have been under-counted.

In some photographs, the shadow created by the survey equipment (the 11 cm ring) meant that mussels within the ring could not be analysed. In such cases, a new ‘boundary’ circle was measured immediately against the left side of the ring and used to count mussels elsewhere within the photograph (Figure 3). By measuring a new boundary circle within each photograph that required it, the proportional 11 cm ring size was maintained ensuring the same size area was analysed at each sample location.

Figure 3 Photograph of Dutch wand mussel survey sample with new 'boundary' circle (in red) used to analyse mussel size and abundance.

Due to the limitations of this technique, a number of assumptions were made during the analysis of size and abundance:

- If only one side of the shell was visible and appeared to be intact, the mussel was assumed to be alive.
- The photograph resolution/focus of some images was too poor to recognise the outline of individual mussels with precision, so the photo analyst used best judgement to determine whether to record a mussel as present or not.
- The approximate size of mussels was estimated by the photo analyst using the known size of the ring (11 cm) as a guide alone.
- Visible mussels were assigned to two size categories, greater (large) or smaller (small) than 45 mm[4]

[4] Egerton *et al* (2013) describe under-size mussels as those that are less than 45 mm long which has been used for this survey.

4 Results

4.1 Site descriptions

The Field Target Notes recorded by the survey team and used to inform the following site descriptions are provided in Appendix 2. The Field Target Notes were used, along with GPS co-ordinates and the quantitative quadrat data, to inform the biotope maps presented in Appendix 3.

4.1.1 Duddon Estuary SSSI Sector

Three areas of Duddon Estuary were targeted in the 2015 survey: Hodbarrow, Sandscale and North Walney.

East of Hodbarrow the rocky shore habitats include *Fucus spiralis* on full salinity upper eulittoral mixed substrata (LR.LLR.F.Fspi.X), an area of barren littoral shingle (LS.LCS.Sh.BarSh) more than 400 m long along the littoral zone and an area of barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BlitX) (Figure 35 in Appendix 3). Further south along the coastline towards the seawall at Hodbarrow zonation of habitats was observed at the splashzone on the cobble field. Higher up the habitat was yellow and grey lichens on supralittoral rock (LR.FLR.Lic.YG), then a band of *Verrucaria maura* on littoral fringe rock (LR.FLR.Lic.Ver). The lower band was LS.LCS.Sh.BarSh on the eastern side and *Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock (LR.MLR.BF.PelB) around the headland to the south with an area of *Semibalanus balanoides* on exposed to moderately exposed or vertical sheltered eulittoral rock (LR.HLR.MusB.Sem) and *Fucus spiralis* on exposed to moderately exposed upper eulittoral rock (LR.MLR.BF.FspiB) (Figure 4).

Figure 4 *Fucus spiralis* at Hodbarrow (LR.MLR.BF.FspiB).

On the northern shore of the Sandscale Haws National Nature Reserve, on the southern side of the Duddon Estuary, there is an area of barren littoral shingle almost 600 m long with an area of LR.FLR.Eph.BlitX (Figure 5 below and Figure 36 in Appendix 3).

Figure 5 Looking east at barren littoral shingle on the northern shore of the Sandscale Haws National Nature Reserve

On the southern shore of Sandscale (Figure 36 in Appendix 3), there is a band of barren littoral shingle (LS.LCS.Sh.BarSh) on the high shore followed by a large expanse of barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BlitX) (Figure 6). A small patch of hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools (LR.FLR.Rkp.H) was recorded within the LR.FLR.Eph.BlitX area. Towards the northwestern extent of the area surveyed off southern Sandscale, an area of *Fucus spiralis* on full salinity upper eulittoral mixed substrata (LR.LLR.F.Fspi.X) and *Fucus vesiculosus* on mid eulittoral mixed substrata (LR.LLR.F.Fves.X) was observed. An area of LR.LLR.F.Fves.X was also recorded near the most southern point of Sandscale with a small area of ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata (LR.FLR.Eph.EphX) was recorded to the west of this area.

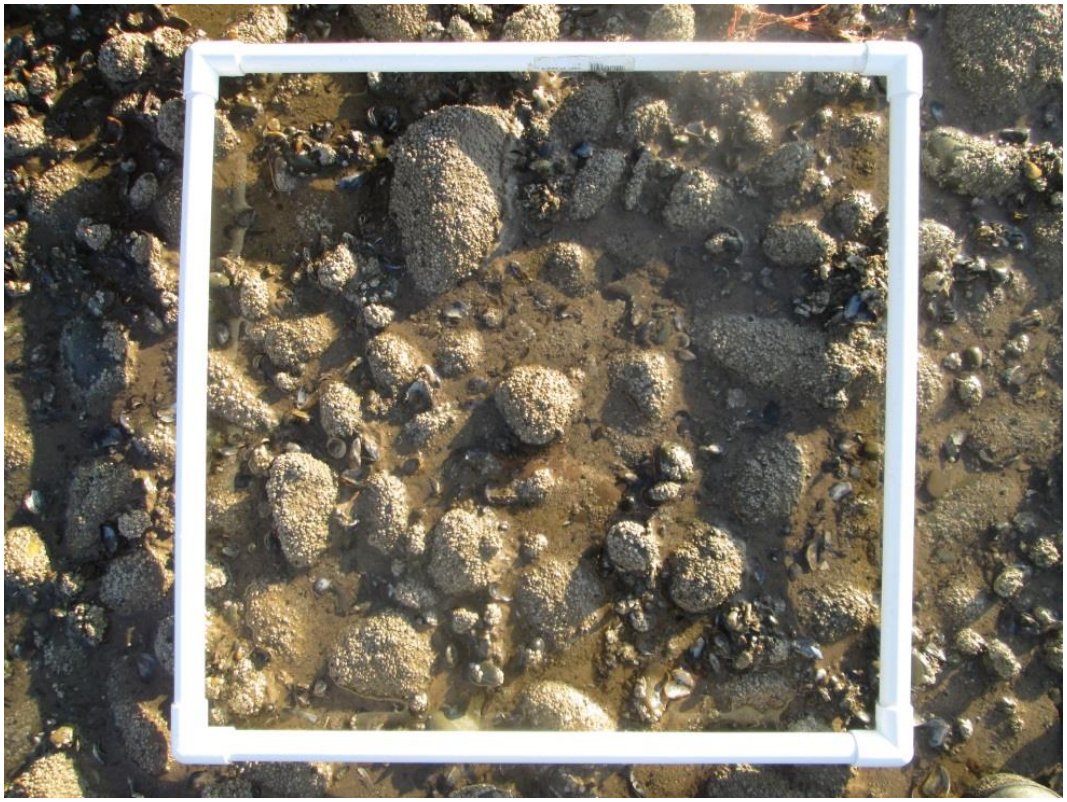

Figure 6 Photograph of Quadrat 27, southern shore of the Sandscale Haws National Nature Reserve

In the North Walney area there is a ‘fishtail’ shaped rock armour groyne (Figure 37 in Appendix 3). From this point for approximately 1.5 km south along the coastline, the habitat is barren littoral shingle (LS.LCS.Sh.BarSh). Below this area is a large expanse of barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BLitX), much like the zonation observed at Sandscale. Within the expanse of LR.FLR.Eph.BLitX areas of sand were noted as well as the following rock and reef habitats: LR.LLR.F.Fves.X, LS.LBR.LMus.Myt.Mx, coralline crust-dominated shallow eulittoral rockpools (LR.FLR.Rkp.Cor) (Figure 7), hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools (LR.FLR.Rkp.H) and *Sabellaria alveolata* reefs on sand-abraded eulittoral rock (LS.LBR.Sab.Salv). An area approximately 600 m long of LS.LBR.Sab.Salv and a smaller patch were observed further downshore as well as another patchy area north of the fishtail groyne. This patch was close to further rock and reef habitats: LR.FLR.Eph.BLitX, LR.LLR.F.Fves.X, LS.LBR.LMus.Myt.Mx, and LR.FLR.Eph.EphX.

Figure 7 Coralline crust-dominated shallow eulittoral rockpool (LR.FLR.Rkp.Cor) at North Walney

4.1.2 South Walney and Piel Channel Flats SSSI Sector

In the South Walney Island area, there are three large areas of ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata (LR.FLR.Eph.EphX) in the south west (Figure 8 and Figure 38 in Appendix 3). Near South East Point, there is a large expanse of shingle beach which supported a small area of *Mytilus edulis* bed on littoral mixed substrata (LS.LBR.LMus.Myt.Mx) and a small area of habitat that most closely resembled a variation of *Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock (LR.LLR.F.Fves.FS).

Figure 8 Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata (LR.FLR.Eph.EphX) in the south west of South Walney Island.

Between Cavendish Dock and Roa Island, in the area off the Roosecote Power Station, there is a raised bank of hard sediments (Figure 9) that comprise: barren littoral shingle (LS.LCS.Sh.BarSh); *Fucus spiralis* on full salinity upper eulittoral mixed substrata (LR.LLR.F.Fspi.X); and *Fucus vesiculosus* on mid eulittoral mixed substrata (LR.LLR.F.Fves.X) (Figure 39 in Appendix 3). To the east of this area, just off the western coastline of Roa Island is Concle Bank with an area just over 1 km long of LR.LLR.F.Fspi.X in the sheltered area between Roa Island and the greater Barrow area. At Head Scar, the habitat is primarily barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BlitX) with a small area of *Mytilus edulis* beds on littoral mixed substrata (LS.LBR.LMus.Myt.Mx).

Figure 9 Raised shingle bank which is mainly barren offshore from Roosecote Power Station.

Mussel beds (LS.LBR.LMus.Myt.Mx) were also recorded in the area known as South America and at Foulney Twist (Figure 40 in Appendix 3). Further information on these mussel beds is provided in Section 4.4.1. Foulney Twist also supported the following habitats: barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BlitX), *Fucus vesiculosus* on mid eulittoral mixed substrata (LR.LLR.F.Fves.X), ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata (LR.FLR.Eph.EphX) (Figure 10) as well as an area that has been described as a variant of red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles (SS.SMp.KSwSS.LsacR.CbPb) and *Lanice conchilega* in littoral sand (LS.LSa.MuSa.Lan). From the strandline on the south coast of Foulney Island there is a ridge of barren littoral shingle (LS.LCS.Sh.BarSh) which is more than 500 m long. Either side of this ridge, areas of LR.LLR.F.Fves.X were recorded as well as small areas of *Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock (LR.LLR.F.Fves.FS), *Fucus serratus* on full salinity lower eulittoral mixed substrata (LR.LLR.F.Fserr.X), *Sargassum muticum* in eulittoral rockpools (LR.FLR.Rkp.FK.Sar), and patchy areas of *Fucus spiralis* on full salinity upper eulittoral mixed substrata (LR.LLR.F.Fspi.X) and *Pelvetia canaliculata* on sheltered littoral fringe rock (LR.LLR.F.Pel).

Figure 10 Photograph of Quadrat 18 in the Foulney Island area.

4.1.3 Morecambe Bay 1 SSSI Sector

Off the coast from the town of Roosebeck there is a small area of *Porphyra purpurea* and *Ulva* spp. on sand-scoured mid or lower eulittoral rock (LR.FLR.Eph.EntPor) (Figure 39 in Appendix 3). Further northeast, off the coast from Goadsbarrow there is an area of predominantly ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata (LR.FLR.Eph.EphX). Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BlitX) and *Fucus spiralis* on full salinity upper eulittoral mixed substrata (LR.LLR.F.Fspi.X) (Figure 11) were also noted in this area. Off the coast between Goadsbarrow and Newbiggin there is another area predominated by LR.FLR.Eph.EphX with small areas of LR.FLR.Eph.BlitX and *Mytilus edulis* beds on littoral mixed substrata (LS.LBR.LMus.Myt.Mx), and a small area of *Fucus serratus* on full salinity lower eulittoral mixed substrata (LR.LLR.F.Fserr.X).

Figure 11 Small area of *Fucus spiralis* dominated boulders on sand (LR.LLR.F.Fspi.X).

4.1.4 Morecambe Bay 2 SSSI Sector

No substantial areas of the target habitats had been identified in this area during previous surveys and so the 2015 survey did not include this area.

4.1.5 Morecambe Bay 3 SSSI Sector

At Morecambe Skears the largest mussel beds (LS.LBR.LMus.Myt.Mx) were recorded at Heysham Flats and Old Skear (Figure 41 in Appendix 3). At the seaward edges of Heysham Flats were areas of *Sabellaria alveolata* reefs on sand-abraded eulittoral rock (LS.LBR.Sab.Salv). An area of LS.LBR.Sab.Salv was also noted between the Old Skear mussel bed and the channel that divides Old Skea and Reap Skear (Figure 12). At the landward extent of the Heysham Flats mussel bed was an area of *Ulva* spp. on freshwater-influenced and/or unstable upper eulittoral rock (LR.FLR.Eph.Ent). The fishtail shaped rock armour groynes at Morecambe and Heysham had zonation of habitats from the upper shore of *Pelvetia canaliculata* on sheltered littoral fringe rock (LR.LLR.F.Pel) with *Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock (LR.LLR.F.Fves.FS) below.

Figure 12 Old Skear mussel bed and channel between Old Skea and Reap Skear.

The habitat at Half Moon Bay showed zonation from the upper shore of the sea defences were yellow and grey lichens on supralittoral rock (LR.FLR.Lic.YG), then bands of *Verrucaria maura* on littoral fringe rock (LR.FLR.Lic.Ver), *Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock (LR.MLR.BF.PelB), *Fucus spiralis* on full salinity sheltered upper eulittoral rock (LR.LLR.F.Fspi.FS), *Ascophyllum nodosum* on full salinity mid eulittoral rock (LR.LLR.F.Asc.FS), followed by a lower band of *Semibalanus balanoides* on exposed to moderately exposed or vertical sheltered eulittoral rock (LR.HLR.MusB.Sem) in the south which was replaced by LR.LLR.F.Fves.FS along some sections of the sea defences (Figure 42 in Appendix 3). At the northern extent of Half Moon Bay, the final band of zonation was *Semibalanus balanoides* and *Littorina* spp. on exposed to moderately exposed eulittoral boulders and cobbles (LR.HLR.MusB.Sem.LitX). A small area of *Sabellaria alveolata* reef on sand-abraded eulittoral rock (LS.LBR.Sab.Salv) was also noted. Further out from the shoreline, areas of barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BlitX) and *Fucus vesiculosus* on mid eulittoral mixed substrata (LR.LLR.F.Fves.X) (Figure 13) was noted. At the base of Naze lighthouse, a habitat of *Ulva* spp. on freshwater-influenced and/or unstable upper eulittoral rock (LR.FLR.Eph.Ent) was recorded.

Figure 13 Photograph of Quadrat 8 at Half Moon Bay.

The survey area at South Heysham was focused around the rubble sea defences, outfalls from the power station, sea wall and entrance to the ferry port (Figure 43 in Appendix 3). From the entrance to the ferry port and along the sea wall at the power station for approximately 500 m a zonation of habitats was observed with *Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock (LR.MLR.BF.PelB) followed by a band of *Fucus spiralis* on full salinity sheltered upper eulittoral rock (LR.LLR.F.Fspi.FS), further south along the wall this habitat was replaced with barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BlitX). The channels leading away from the two outfalls are lined with rubble which supports *Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock (LR.LLR.F.Fves.FS) (Figure 14). The breakwater at the entrance to the ferry port also supports LR.LLR.F.Fves.FS. Further southeast is an area of *Ulva* spp. on freshwater-influenced and/or unstable upper eulittoral rock (LR.FLR.Eph.Ent) surrounded by a band of LR.LLR.F.Fspi.FS. This habitat is bordered by a mosaic of LR.LLR.F.Fspi.FS and *Ascophyllum nodosum* on full salinity mid eulittoral rock (LR.LLR.F.Asc.FS) on the western edge and by a further area of LR.FLR.Eph.BlitX on the eastern edge. The southern section of this area near the caravan park has a further band of LR.LLR.F.Fspi.FS along the upper shore.

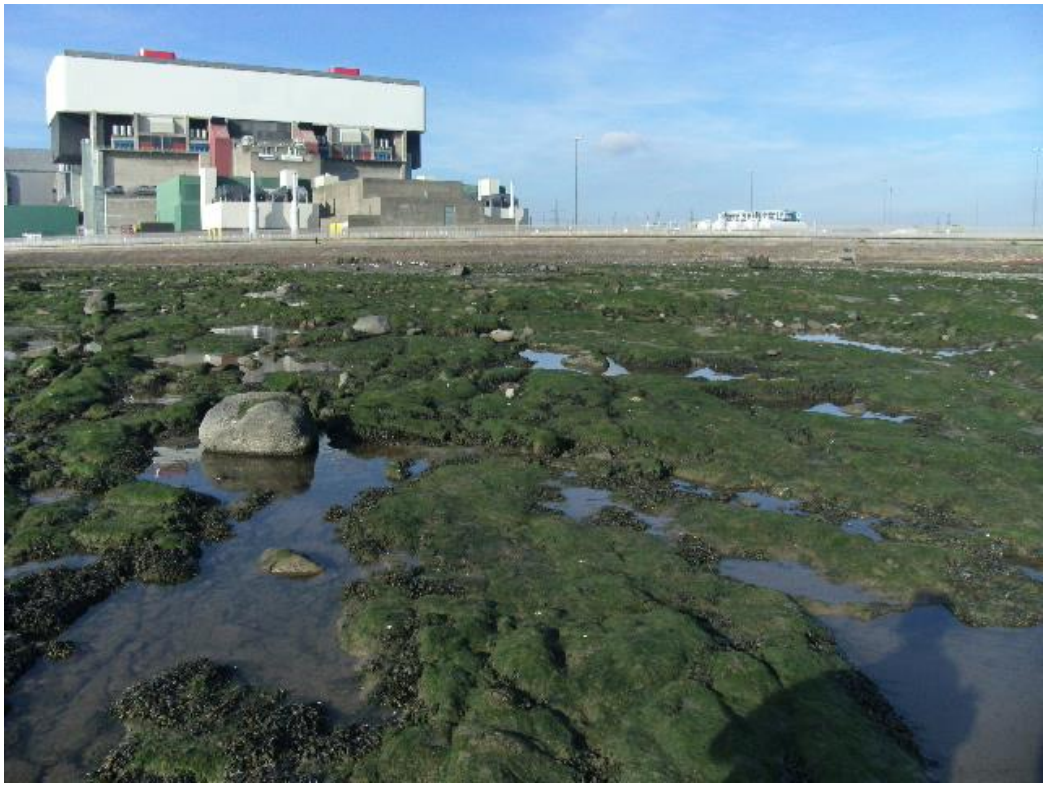

Figure 14 *Ulva* spp. on freshwater-influenced and/or unstable upper eulittoral rock (LR.FLR.Eph.EphX) in front of the Heysham Nuclear Power Station.

4.1.6 Lune Estuary SSSI Sector

The rocky intertidal habitats in the Lune Estuary were predominantly comprised of three main biotopes. Four areas of barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BlitX) were recorded (Figure 15), five areas of *Fucus spiralis* on full salinity upper eulittoral mixed substrata (LR.LLR.F.Fspi.X), two areas of *Ulva* spp. on freshwater-influenced and/or unstable upper eulittoral rock (LR.FLR.Eph.Ent) and an area along the shore which was a mosaic of LR.LLR.F.Fspi.X and LR.FLR.Eph.Ent (Figure 44 in Appendix 3). A small area of *Semibalanus balanoides* and *Littorina* spp. on exposed to moderately exposed eulittoral boulders and cobbles (LR.HLR.MusB.Sem.LitX) was also recorded at the end of the deeper channel in the centre of the Lune Estuary.

Figure 15 Quadrat 11 in the Lune Estuary (LR.FLR.Eph.BLitX).

4.1.7 Wyre Estuary SSSI Sector

South of Wyre End, at Perch Scar and Rossall Scar, mussel beds were recorded: *Mytilus edulis* beds on littoral mixed substrata (LS.LBR.LMus.Myt.Mx) (Figure 16 and Figure 45 in Appendix 3). Near King Scar, the area was recorded to have a zone of LS.LBR.LMus.Myt.Mx followed by ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata (LR.FLR.Eph.EphX), a band of barren littoral shingle (LS.LCS.Sh.BarSh) and another band of LR.FLR.Eph.EphX.

Figure 16 Photograph taken during Dutch wand mussel survey at Wyre End (MT13). Further details on the results of this survey are provided in Section 4.4.1.

4.2 Quantitative quadrat survey

4.2.1 Species distribution

A total of 93 quadrats (each 0.25 m^2) were assessed from 31 sites during the quadrat survey with a total of 49 taxa recorded: 21 macrophyte taxa, nine Mollusca, eight Crustacea, six Annelida, one Bryozoa, one Cnidaria. Two additional Insecta taxa, which were both species of springtails (Collembola), were found aggregated in rock pools. Specimens of the angiosperm *Salicornia* sp which is a succulent salt tolerant genus and includes samphire *Salicornia europaea* were also recorded. The full dataset is presented in Appendix 4.

It was not possible to identify some organisms to species level, primarily due to small size e.g. juvenile *Littorina* sp. or the complexity of the genus, e.g. *Leptochiton* sp. These were recorded at either genus or family level, whichever was most appropriate.

The macroalgal taxa *Ulva intestinalis* and *Fucus vesiculosis* (canopy forming taxa) were the most common taxa found at 39 and 17 out of 93 quadrats, respectively. The greatest percentage contribution of macroalgal cover within the quadrats was by

Ulva intestinalis, *Fucus vesiculosis*, *Fucus spiralis* and *Ascophyllum nodosum* with *Ulva intestinalis* contributing over 28% of the macroalgal cover (Figure 17).

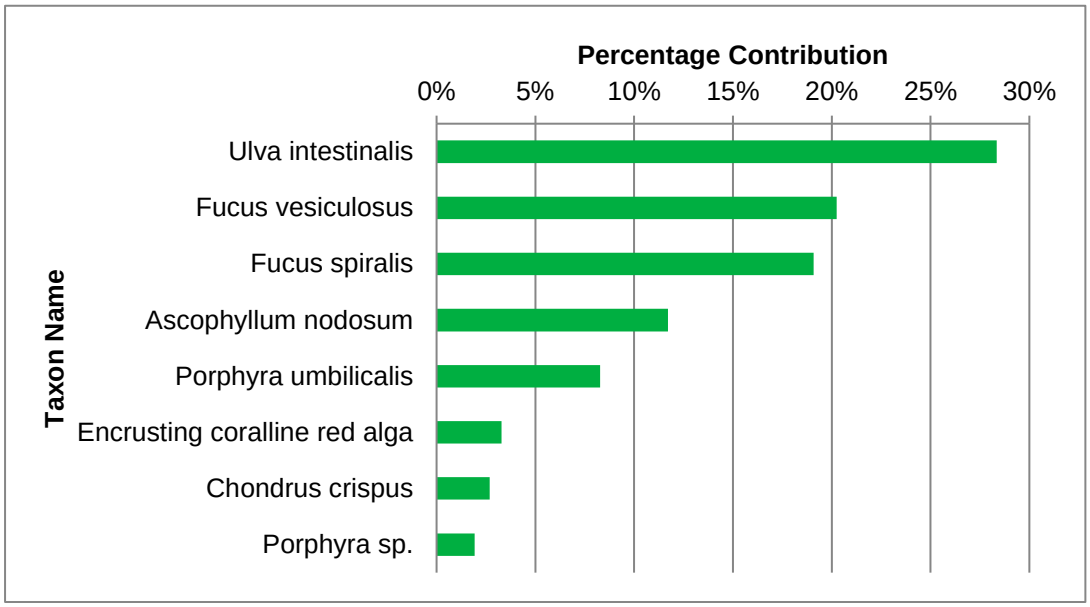

Figure 17 Morecambe Bay SAC Rocky Shore Community Survey 2015 ranked, percentage contribution of the macroalgal species comprising 95% of the total abundance (based on percentage coverage data). For the full species list see Appendix 4.

The most commonly observed invertebrate species was *Mytilus edulis* which was observed in 53 of the 93 quadrats surveyed followed by the invasive *Austrominius modestus*, *Littorina littorea* and *L. saxatilis* which were observed in 48, 37 and 23 quadrats, respectively.

The blue mussel, *Mytilus edulis* and *Austrominius modestus* had the greatest percentage contribution within the quadrats contributing more than 85% of the invertebrates recorded as percentage cover (Figure 18).

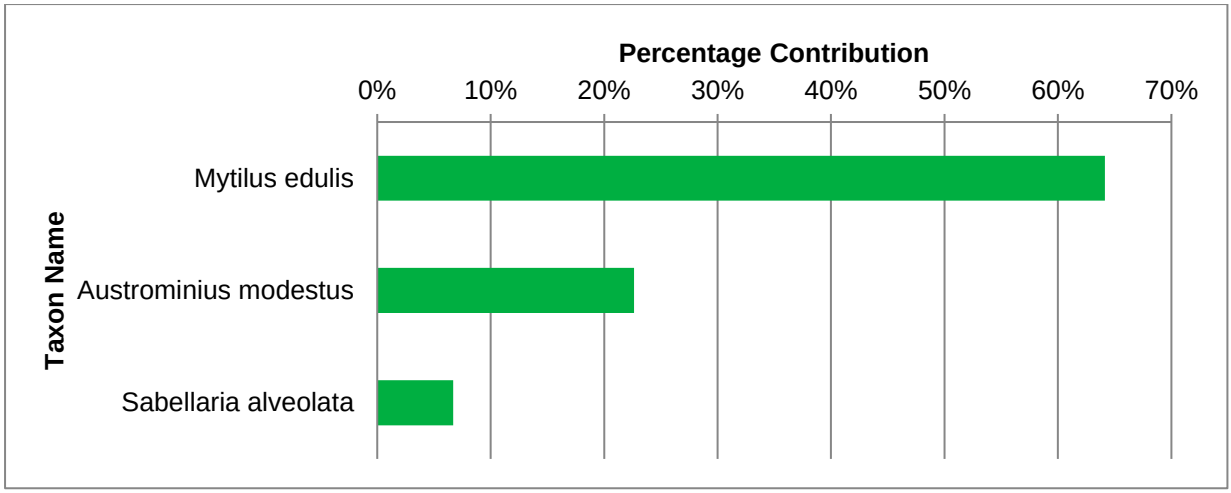

Figure 18 Morecambe Bay SAC Rocky Shore Community Survey 2015 ranked, percentage contribution of the invertebrate species comprising 95% of the total abundance (based on percentage coverage data). For the full species list see Appendix 4.

The majority of invertebrate species, however, were recorded as actual counts of individuals. The greatest percentage contribution to invertebrate abundance within the quadrats was by *Littorina* sp. with a contribution of 34% (Figure 19).

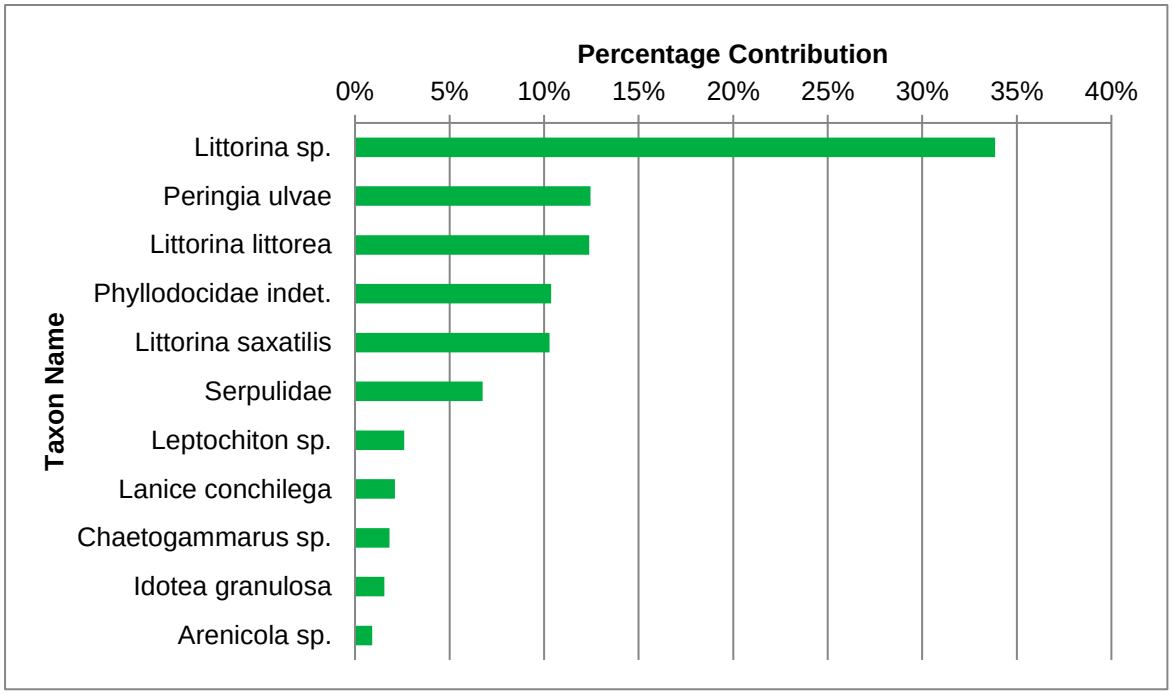

Figure 19 Morecambe Bay SAC Rocky Shore Community Survey 2015 ranked, percentage contribution of the invertebrate species comprising 95% of the total abundance (based on total abundance count data). For the full species list see Appendix 4.

4.2.2 Species diversity

The mean number of taxa varied from 1 to 10 taxa recorded at each site (averaged across three replicates). The highest mean number of taxa was found at Station 17 in the Foulney Island area with 10 taxa. The lowest mean number of taxa was recorded at Stations 4 and 5 which were both in the Morecambe Skear area. Both sites recorded only *Mytilus edulis* as present within the replicate quadrats.

Table 3 Mean number of taxa identified in each station with standard deviation (SD) and coefficient of variation (CV) indicated.

Site	Site Name	Distance to Shore (m)	Mean Number of Taxa	SD	CV
3	Morecambe Skear	500-999	1.67	0.58	35%
4	Morecambe Skear	500-999	1.00	0.00	0%
5	Morecambe Skear	500-999	1.00	0.00	0%
6	Morecambe Skear	200-499	3.00	0.00	0%
7	Halfmoon	0-99	2.33	0.58	25%
8	Halfmoon	0-99	2.67	0.58	22%
9	South Heysham	100-199	2.33	0.58	25%
10	Lune	200-499	2.00	0.00	0%
11	Lune	0-99	3.00	1.00	33%
12	Fleetwood	1000+	3.67	1.15	31%
14	Fleetwood	200-499	2.00	0.00	0%
15	Foulney	1000+	6.00	1.73	29%
16	Foulney	200-499	5.00	2.00	40%
17	Foulney	1000+	10.00	0.00	0%

Site	Site Name	Distance to Shore (m)	Mean Number of Taxa	SD	CV
18	Foulney	500-999	4.00	1.00	25%
19	Foulney	100-199	9.00	1.73	19%
20	South Walney	0-99	8.00	1.73	22%
22	South Walney	500-999	5.67	1.15	20%
23	North Walney	100-199	4.00	1.00	25%
24	North Walney	200-499	6.67	1.53	23%
25	North Walney	500-999	7.00	1.00	14%
26	North Walney	200-499	9.33	1.53	16%
27	Sandscale	200-499	4.33	0.58	13%
28	Sandscale	0-99	5.00	1.00	20%
30	Hodbarrow	0-99	2.33	0.58	25%
HMB	Halfmoon	0-99	3.67	0.58	16%
HOD	Hodbarrow	0-99	5.00	1.00	20%
HS	South Walney	100-199	3.00	1.00	33%
LU	Lune	200-499	2.33	0.58	25%
MS	Morecambe Skear	200-499	2.00	0.00	0%
SW	South Heysham	500-999	4.67	1.53	33%

4.2.3 Habitat diversity

The most common biotopes found in the quadrats were LS.LBR.LMus.Myt.Mx, LR.FLR.Eph.BLitX and LR.FLR.Eph.EphX (Table 4). These biotopes were each recorded in five of the sub-areas. LS.LBR.LMus.Myt.Mx *Mytilus edulis* beds on littoral mixed substrata is found on very sheltered to exposed shores from the lower to mid shore. The other two are found on extremely sheltered to sheltered areas of mid shore. Further discussion of all the biotopes recorded within the Morecambe Bay SAC is provided in Section 4.1. Maps of all the biotopes recorded throughout the SAC are provided in Appendix 3.

Table 4 Ranked biotopes encountered during the quantitative quadrat survey with a count of the number of times the biotopes has been assigned to a quadrat. Biotopes recorded in each sub-area of the Morecambe Bay SAC are indicated with an 'x'.

Biotope (EUNIS)	Biotope (JNCC)	No.	Hodbarrow	Sandscale	North Walney	South Walney	Foulney	Morecambe Skear	Halfmoon	South Heysham	Lune	Fleetwood
A2.7211	LS.LBR.LMus.Myt.Mx	11			x	x	x	x				x
A2.431	LR.FLR.Eph.BLitX	6	x	x	x	x					x	
A2.821	LR.FLR.Eph.EphX	6			x	x	x			x	x	
A1.3132	LR.LLR.F.Fves.X	2					x		x			
A1.3122	LR.LLR.F.Fspi.X	2								x	x	
A2.111	LS.LCS.Sh.BarSh	1	x									
A1.3142	LR.LLR.F.Asc.X	1							x			
A1.153	cf. LR.HLR.FT.FserTX	1					x					
A2.711	LS.LBR.Sab.Salv	1							x			
Total No of Quadrats		**31**										

4.2.4 Community analysis

Hierarchical clustering was conducted on pooled replicates. This approach was used to ensure a more robust dataset for the identification of community trends across the area. Similarity profile permutation tests were conducted on a Jaccard similarity matrix calculated from presence-absence data. The similarity profile (SIMPROF) (Clarke and Gorley, 2006) test suggested the presence of an underlying community structure in the dataset (Figure 20). Four distinct clusters were identified (5% significance level).

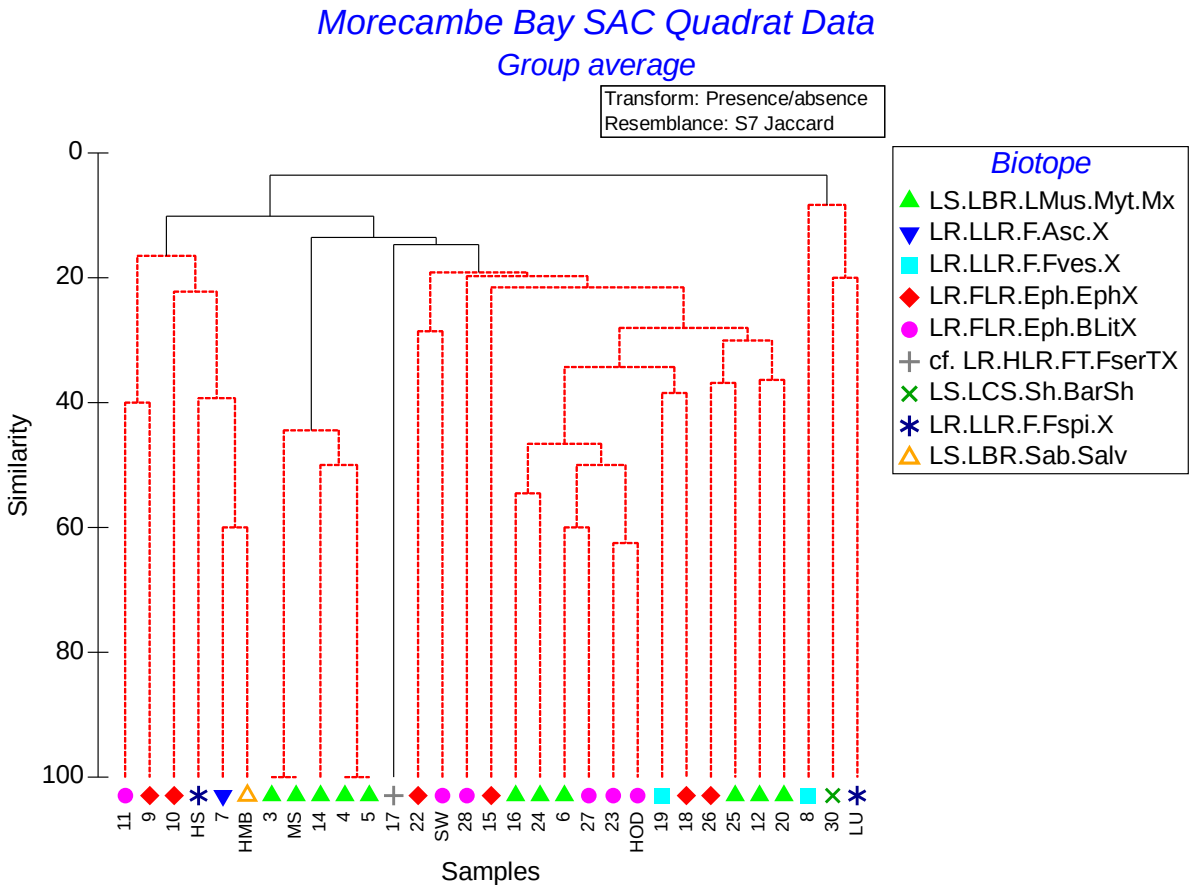

Figure 20 Morecambe Bay SAC Rocky Shore 2015 group average sorting dendrogram based on presence/absence transformed data. Samples presented by survey location with replicates combined for each site. Jaccard similarity and the SIMPROF test were used. Symbols are coded according to biotope.

Multi-dimensional scaling (MDS) (Figure 21) did not suggest a clear grouping of stations although some stations within the same sub-area of Morecambe Bay showed more similarity than stations between sub-areas.

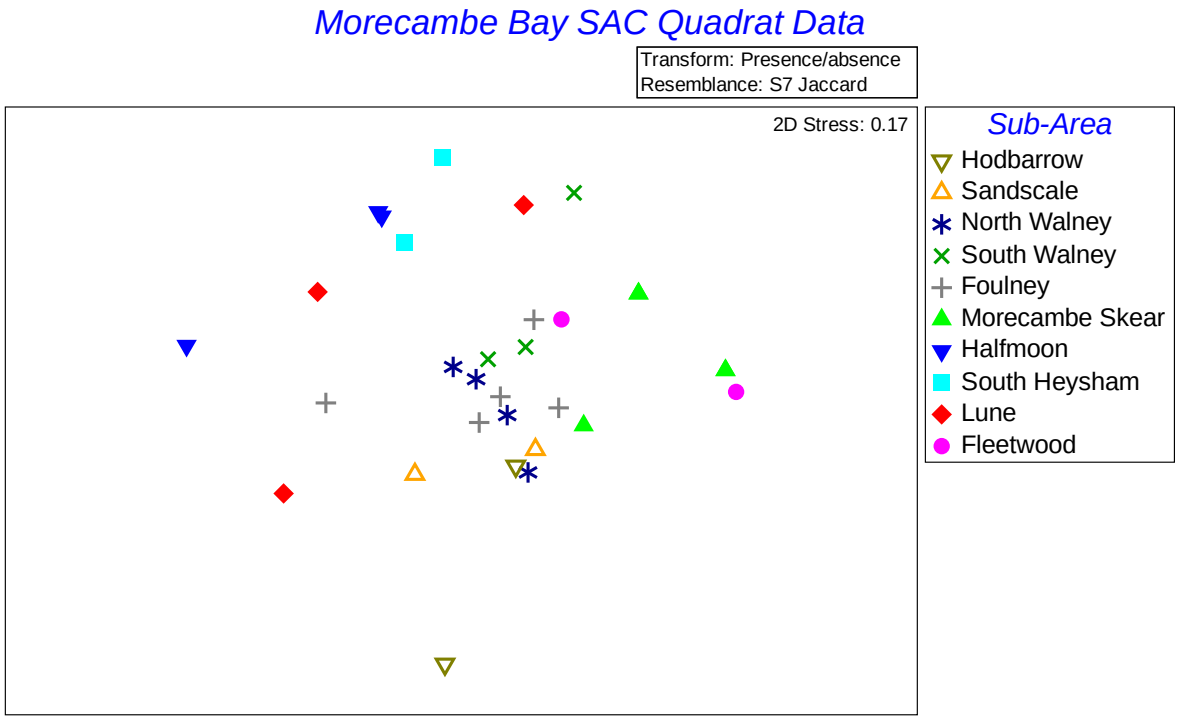

Figure 21 Morecambe Bay SAC Rocky Shore 2015 Non-metric Multidimensional Scaling (MDS) configuration plot of taxa presence/absence data using Jaccard similarity. Sample symbols are shown according to the area of Morecambe Bay in which the samples were taken. Sub-areas of the SAC are presented in the key from north (Hodbarrow on the Duddon Estuary) to south (Fleetwood on the southern coast at the mouth of Morecambe Bay).

4.3 Biotope composition

Results are presented in Section 4.3.1 to 4.3.3 together with MDS ordination plots showing the samples assigned to the biotope.

4.3.1 LS.LBR.LMus.Myt.Mx

Mytilus edulis beds on littoral mixed substrata

This is a mixed substrata habitat of primarily cobbles and pebbles on fine sediments on the mid and low shore in a wide range of exposure conditions. Aggregations of mussels may be found on the sediment between the cobbles or colonising the cobbles themselves. The characterising species of this habitat other than the mussels are: *Fucus vesiculosus*, barnacles *Semibalanus balanoides*, *Austrominius* (*Elminius*) *modestus* or *Chthamalus* spp., winkles *Littorina littorea* and *L. saxatilis*, and *Carcinus maenas*. LS.LBR.LMus.Myt.Mx was found at two sites in North Walney, one site in South Walney and Foulney each, four sites in Morecambe Skear and two sites in Fleetwood. There is no clear trend in where this biotope was found (Figure 22). Characterising species for this biotope that were either not present or had a lower than expected contribution to the recorded communities assigned to this

biotope include *Lanice conchilega*, *Carcinus maenas*, *Patella vulgata*, *Littorina saxatilis* and *Fucus vesiculosus*.

Table 5 Morecambe Bay SAC Rocky Shore 2015 SIMPER analysis table providing frequency of diagnostic species, variability and contribution to the group similarity. The table shows higher-contributing species to the cumulative similarity percentage (a cut-off value of 90% was used).

LS.LBR.LMus.Myt.Mx	Average similarity: 42.84				
Species	**Frequency**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Mytilus edulis	1	28.94	1.42	67.56	67.56
Ulva intestinalis	0.55	4.89	0.5	11.42	78.97
Austrominius modestus	0.55	3.75	0.57	8.76	87.74
Littorina littorea	0.45	2.3	0.45	5.36	93.1

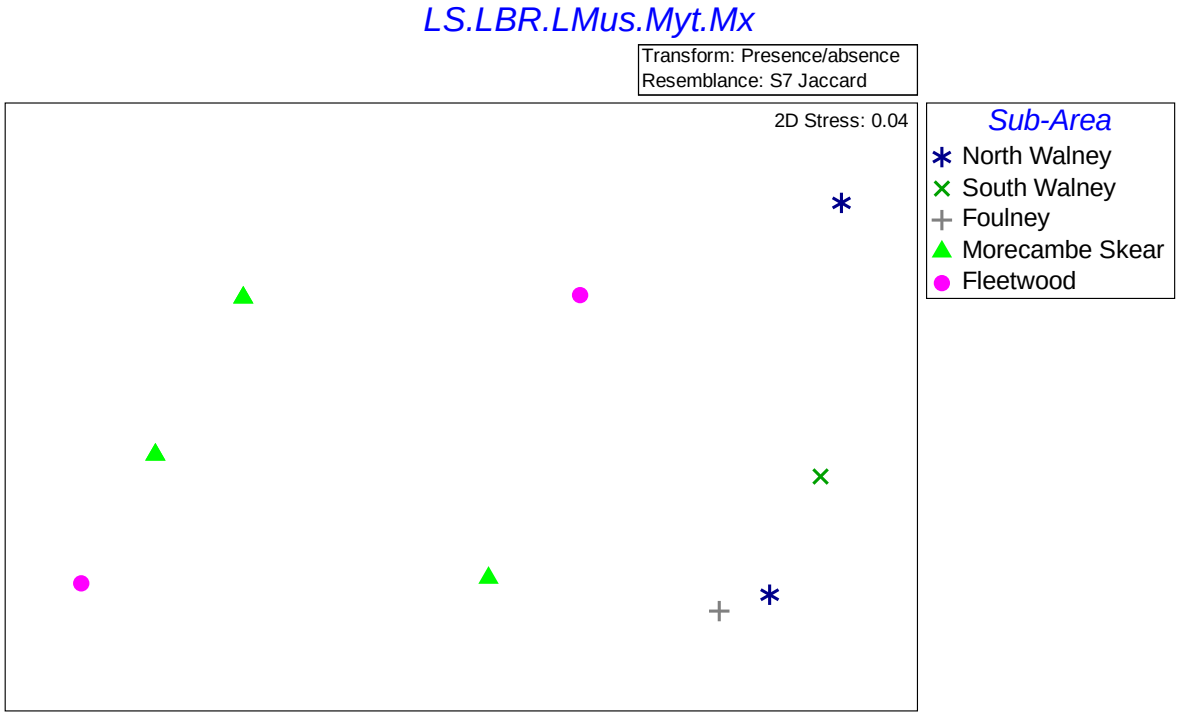

Figure 22 Morecambe Bay SAC Rocky Shore 2015 Non-metric Multidimensional Scaling (MDS) ordination plot for the samples assigned to the biotope. The symbols indicate the sub-area of Morecambe Bay SAC. Sub-areas in the key are in order from north to south.

4.3.2 LR.FLR.Eph.BLitX

Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata

This habitat mixed substrata shores is often comprised of flat banks or areas of cobbles and pebbles (on sediment) which are either too small or unstable to support

a seaweed community. It is found on the mid shore from extremely sheltered to sheltered shores. The characterising species of this habitat are barnacles *Semibalanus balanoides* or *Austrominius* (*Elminius*) *modestus*, winkles *Littorina littorea* and *L. saxatilis*, mussels *Mytilus edulis*, juvenile crabs *Carcinus maenas* and gammarids. Brown seaweeds are rare but ephemeral green seaweeds such as *Ulva intestinalis* may be present. LR.FLR.Eph.BLitX was found at one site at Hodbarrow, two sites at Sandscale, one site at North and South Walney and the Lune Estuary. There was no clear structure between stations with this biotope (Figure 23). Characterising species for this biotope that were either not present or had a lower than expected contribution to the recorded communities assigned to this biotope include *Semibalanus balanoides*, *Carcinus maenas*, *Fucus vesiculosus* and *Ulva intestinalis.*

Table 6 Morecambe Bay SAC Rocky Shore 2015 SIMPER analysis table providing frequency of diagnostic species, variability and contribution to the group similarity. The table shows higher-contributing species to the cumulative similarity percentage (a cut-off value of 90% was used).

LR.FLR.Eph.BLitX	**Average similarity: 33.77**				
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Austrominius modestus	1	16.99	6.86	50.31	50.31
Littorina littorea	0.67	6.7	0.79	19.83	70.14
Mytilus edulis	0.5	3.35	0.48	9.92	80.06
Littorina saxatilis	0.5	3.35	0.48	9.92	89.98
Porphyra sp.	0.33	1.33	0.26	3.95	93.93

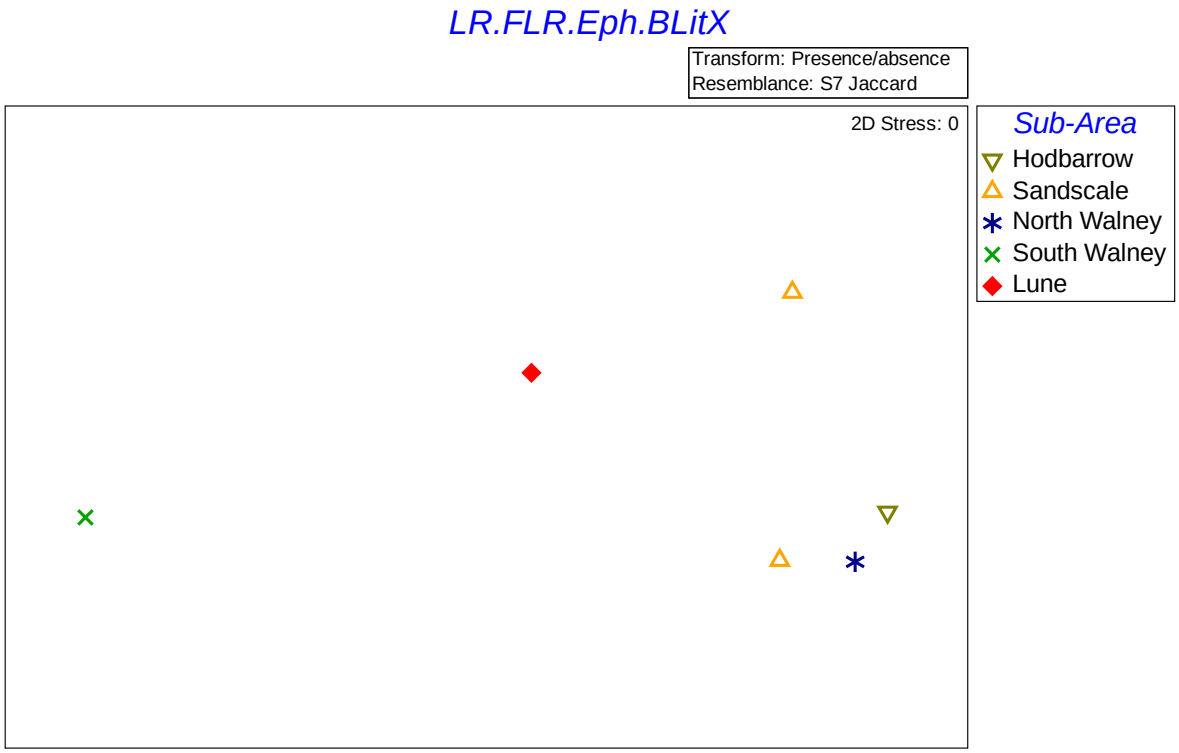

Figure 23 Morecambe Bay SAC Rocky Shore 2015 Non-metric Multidimensional Scaling (MDS) ordination plot for the samples assigned to the biotope. The symbols indicate the sub-area of Morecambe Bay SAC. Sub-areas in the key are in order from north to south.

4.3.3 LR.FLR.Eph.EphX

Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata

This habitat occurs on mixed substrata of pebbles and cobbles overlying sand or mud on the mid shore which is found on extremely sheltered to sheltered coasts. It characterised by dense blankets of ephemeral green and red seaweeds such as *Ulva intestinalis*, *Ulva lactuca* and *Porphyra* spp. The other characterising species of this habitat are: barnacles *Semibalanus balanoides* and *Austrominius* (*Elminius*) *modestus*, mussels *Mytilus edulis*, crabs *Carcinus maenas* and winkles *Littorina littorea*. LR.FLR.Eph.EphX was recorded at one site in North and South Walney areas, two sites at Foulney Island, one at South Heysham and one site in the Lune Estuary area. There was no clear structure between stations with this biotope (Figure 24). Characterising species for this biotope that were either not present or had a lower than expected contribution to the recorded communities assigned to this biotope include *Semibalanus balanoides*, *Gammaridea* sp., *Carcinus maenas*, *Porphyra* sp. and *Ulva* sp.

Table 7 Morecambe Bay SAC Rocky Shore 2015 SIMPER analysis table providing frequency of diagnostic species, variability and contribution to the group similarity. The table shows higher-contributing species to the cumulative similarity percentage (a cut-off value of 90% was used).

LR.FLR.Eph.EphX	Average similarity: 29.20				
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Ulva intestinalis	1	14.82	2.34	50.75	50.75
Mytilus edulis	0.67	4.09	0.77	14	64.76
Austrominius modestus	0.5	2.37	0.47	8.1	72.86
Littorina littorea	0.5	1.97	0.48	6.76	79.62
Ulva lactuca	0.5	1.84	0.48	6.29	85.91
Littorina saxatilis	0.33	0.83	0.26	2.85	88.77
Fucus juv.	0.33	0.78	0.26	2.69	91.45

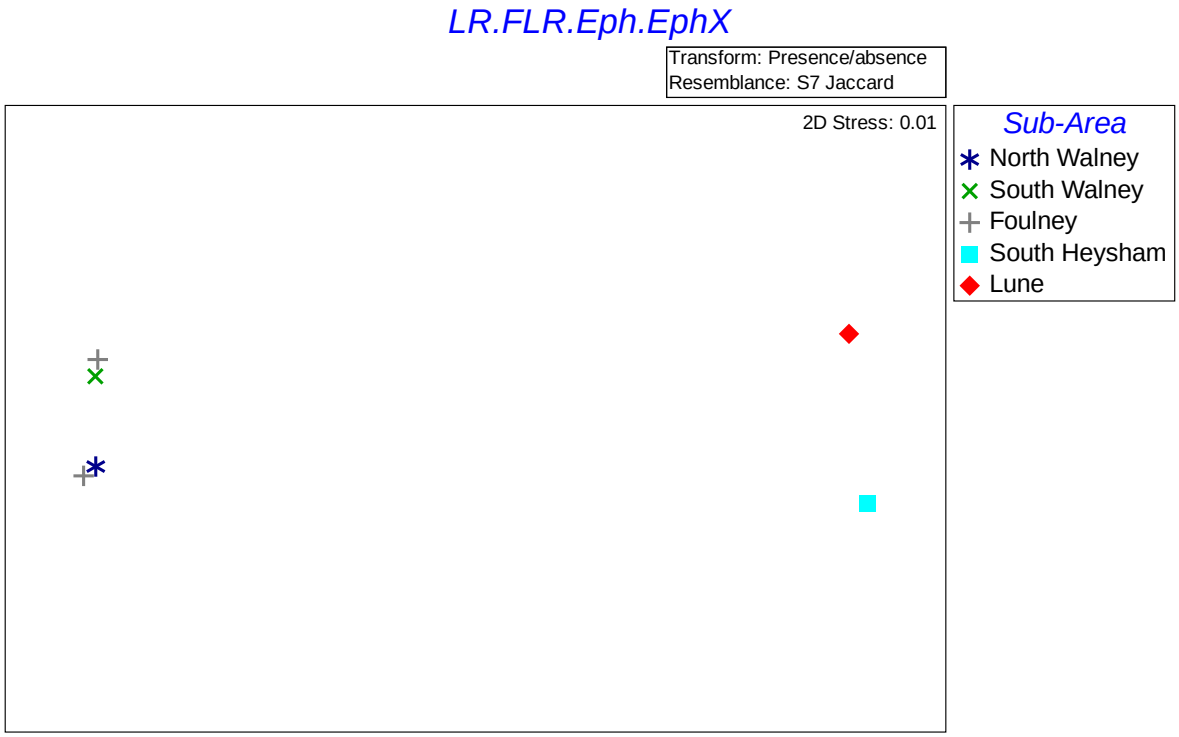

Figure 24 Morecambe Bay SAC Rocky Shore 2015 Non-metric Multidimensional Scaling (MDS) ordination plot for the samples assigned to the biotope. The symbols indicate the sub-area of Morecambe Bay SAC. Sub-areas in the key are in order from north to south.

4.4 Nationally and more than nationally important communities

The main features of conservation interest encountered in the Morecambe Bay SAC were *Sabellaria alveolata* reef and blue mussel *Mytilus edulis* reef. These are discussed in the following sections.

4.4.1 Mussel reef feature

Mussels were surveyed using the Dutch wand method in the Foulney Island (Figure 25), Morecambe Skears (Figure 26) and Fleetwood (Figure 27) areas of Morecambe Bay SAC. The mussel reef varied in quality between sites. At Morecambe Skears, the percentage coverage of mussels along the transects was high (92% and 77%) but the proportion of large mussels (>45 mm in length) was low (3% and 1%) (Table 8). The Foulney Island transects had the highest proportion of large mussels (37% and 29%) but a much lower percentage coverage (27% and 51%). The mussel coverage at Fleetwood transects varied from 22% to 64% and the proportion of large mussels was 1-7%.

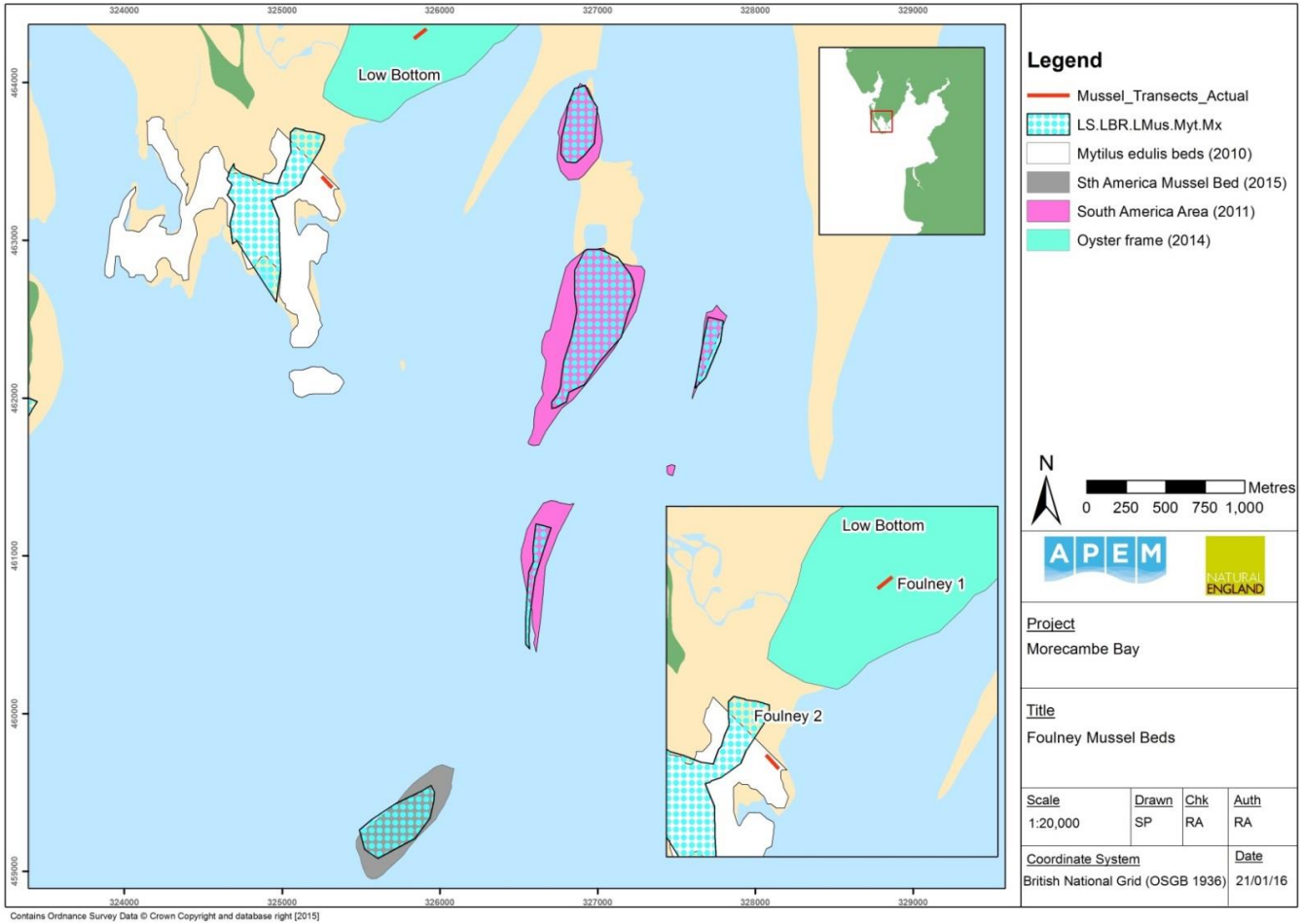

Figure 25 Location of Dutch wand survey transects in the Foulney Island area in the context of historically recorded mussel beds. See bottom insert for a closer view.

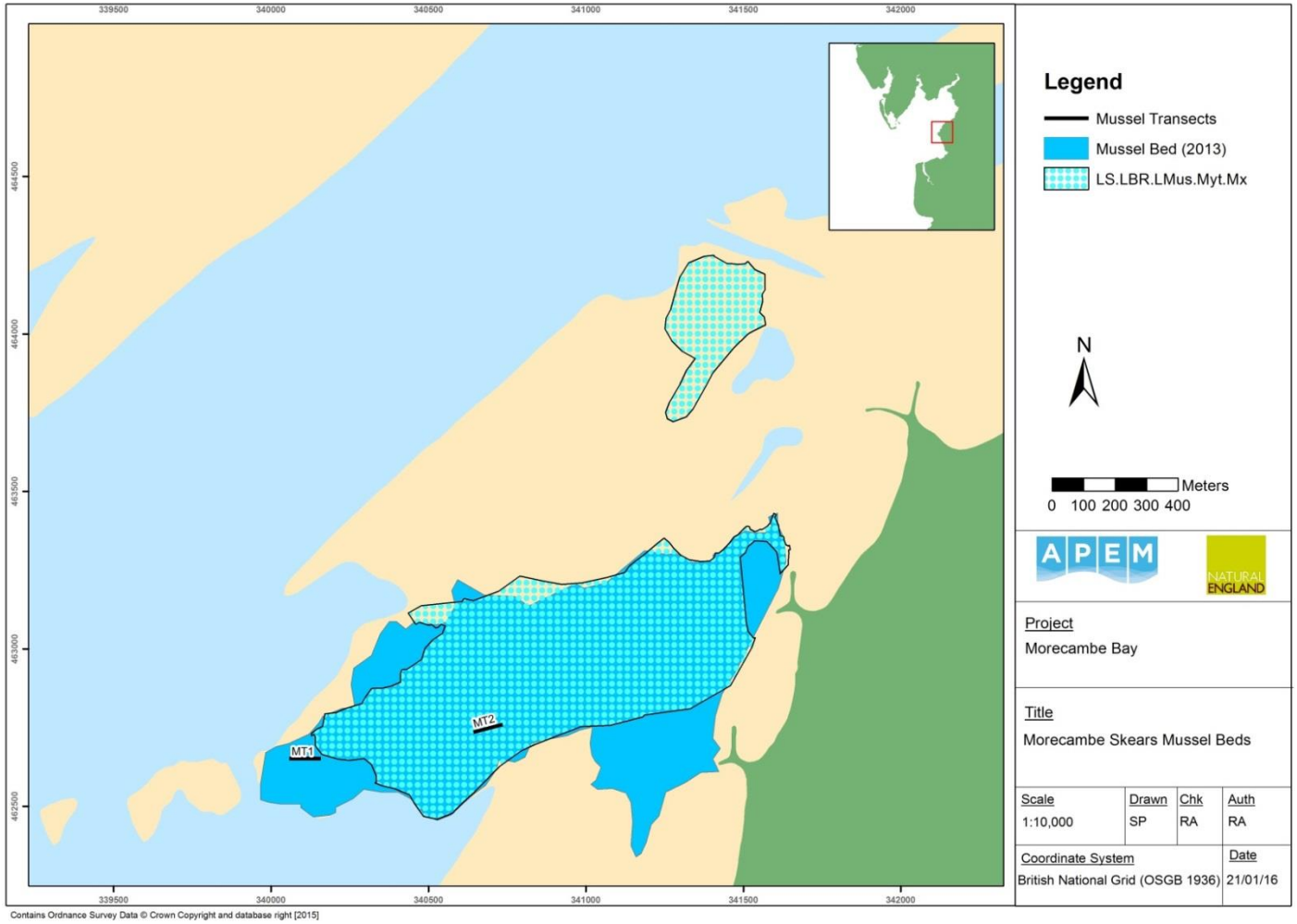

Figure 26 Location of Dutch wand survey transects in the Heysham Flats/ Morecambe Skears area of Morecambe Bay 3 in the context of historically recorded mussel beds.

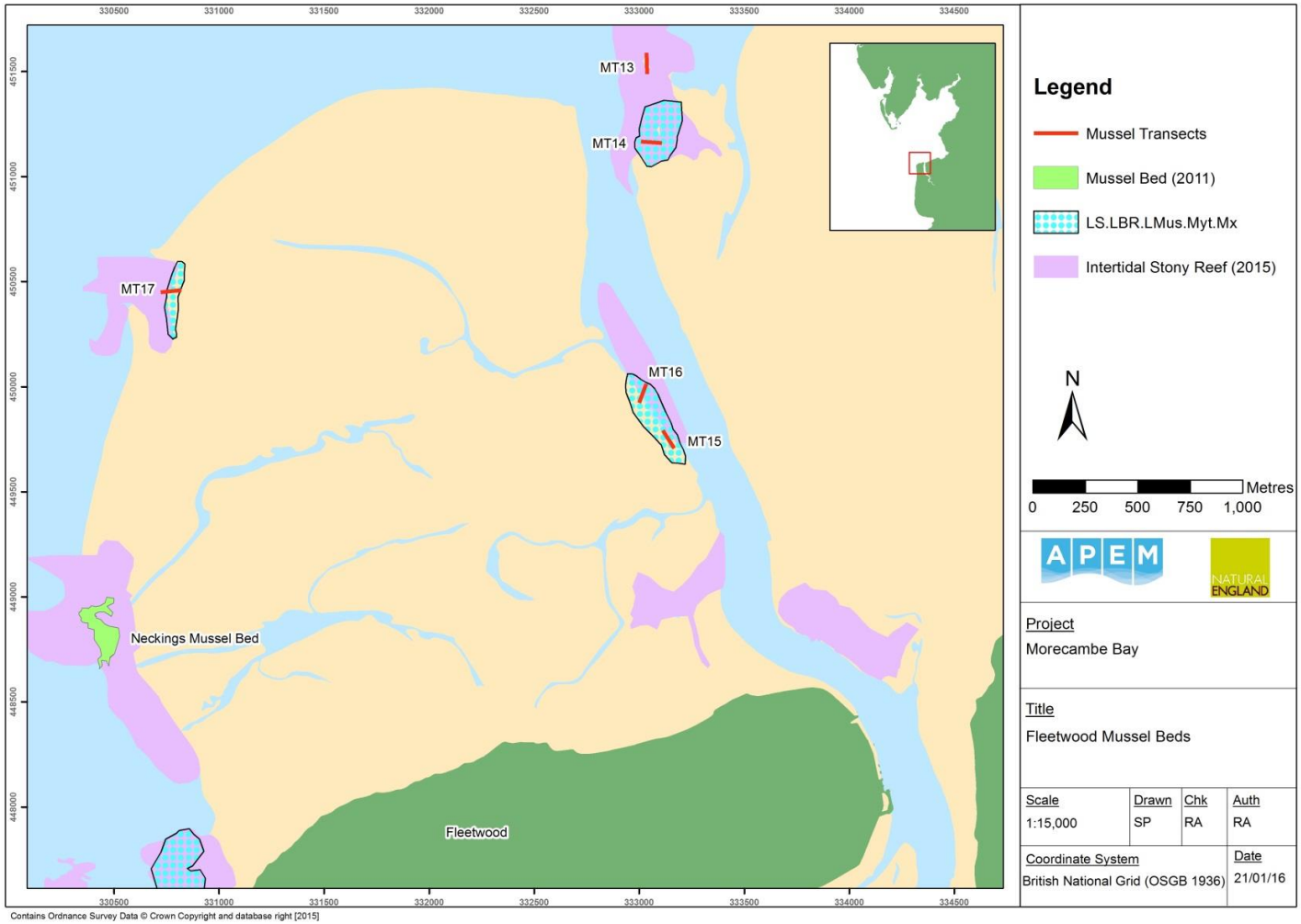

Figure 27 Location of Dutch wand survey transects in the Wyre Estuary area off Fleetwood in the context of historically recorded mussel beds.

Table 8 Quality of mussels recorded during the Morecambe Bay SAC Dutch Wand Mussel Survey.

Mussel Transect	Area of Morecambe Bay SAC	Mussel coverage (%)	Average proportion of large mussels	Average proportion of small mussels
MT1	Morecambe Skears	91.67%	3%	97%
MT2	Morecambe Skears	76.92%	1%	99%
Foulney 1	Foulney Island	27.27%	37%	63%
Foulney 2	Foulney Island	50.98%	29%	71%
MT13	Fleetwood	30.61%	6%	94%
MT14	Fleetwood	21.57%	5%	95%
MT15	Fleetwood	23.21%	7%	93%
MT16	Fleetwood	47.92%	1%	99%
MT17	Fleetwood	64.29%	3%	97%

4.4.2 Sabellaria reef feature

Patches of *Sabellaria alveolata* worms were observed in the North Walney area as well as sheet and hummock formations (Figure 37 in Appendix 3). These areas varied in extent from very small patches to an area more than 20 m^2 south of the fishtail groyne. Larger areas of *S. alveolata* including two areas of possible reef are shown in Figure 37 in Appendix 3.

In the Morecambe Skears area, Heysham Flats is a well known area of *S. alveolata* reef. This area was surveyed which found areas of reef towards the seaward extent of large mussel beds at Heysham Flats and Old Skear further north (see Section 4.1.5 and Figure 41 in Appendix 3). The survey of Heysham Flats found that much of the reef was dead with only small patches of living worms, for example, patches of 1-2 m^2 with 2-3% cover. At Old Skear the reef had low relief 10-20% cover to 10-20 cm high. The centre of the bed was dead with reef up to 1 m high. Much of this bed was also dead with small patches of live worms. Mussels were observed throughout the bed with no other noticeable epibiota.

In the Half Moon Bay area, *S. alveolata* reef was observed in the form of a thin sheet coating the lower boundary of bedrock (Figure 42 in Appendix 3). Coverage in this area varied from 0-100% cover. Much of the reef was heavily overgrown with *Fucus vesiculosis* and *Ulva intestinalis* with more extensive patches of *S. alveolata* on intertidal mud.

4.5 Non-native invasive species

The barnacle *Austrominius modestus* was recorded in 54 quadrats at 18 locations: all three replicates at the additional Hodbarrow site (HOD); all three replicates of Sites 27 and 28 at Sandscale; all three replicates of Sites 23-26 at North Walney; all three replicates of Sites 20, 22 and SW at South Walney; Site 16, two replicates at Site 17 and 19 each at Foulney Island; all three replicates of Site 6 at Morecambe Skears; one replicate at Site HS at South Heysham; two replicates at Site 10 and all three at Site 11 at Lune Estuary; and two replicates at Site 12 in Fleetwood. Coverage within the quadrats was variable, often at <1% of the area but at Site 27 at Sandscale on the southern shore of the Duddon Estuary, all three replicate quadrats had coverage of 95%. This area was predominantly barren shingle with some areas, including Site 27, of LR.FLR.Eph.BLitX: Barnacles and *Littorina* sp. on unstable eulittoral mixed substrata. The barnacle was found throughout the SAC except at the three sites within the Halfmoon Bay area near Heysham (Sites 7, 8 and HMB). This area is very close to Morecambe Skears and South Heysham and so it is likely that this species is present within the Halfmoon Bay area but was not recorded within the nine replicate quadrat samples for this survey.

Sargassum muticum was recorded in rockpools (LR.FLR.Rkp.FK.Sar) south of Foulney Island to the east of the barren shingle ridge (Figure 40 in Appendix 3) as well as in two small areas west of the fishtail rock armour groyne off the western shore of North Walney (see the field notes in Appendix 2).

4.6 Anthropogenic pressures

Bait digging was observed at North Walney (see Field Target Notes in Appendix 2). A working mussel fishery also exists within the bay which is managed by the NWIFCA. Fishermen were observed hand-gathering mussels at Morecambe Skears (Figure 28). The locations of significant mussel beds are described in Section 4.4.1. There are also several manmade features throughout the SAC including outfalls, seawalls, rubble sea defence and groynes. The sea walls/ sea defence structures are present along much of the coastline of Morecambe Bay. These features were in place before the SAC was designated and are a permanent feature of the site. The other manmade features recorded during the survey are listed in Table 9.

Table 9 Location of manmade features recorded during the 2015 survey.

Location	Anthropogenic pressure
South Walney	Damaged concrete structure
Roa Island	Ferry jetty & lifeboat station
Morecambe Skears	Fishtale shaped groynes, 1 m x 100 m concrete strip leading to green navigation marker pole
South Heysham	Ferry port, two outfalls, old groynes not clearly visible to the surveyors

Figure 28 Hand-gathering of mussels at Morecambe Skears in the Morecambe Bay 3 SSSI Sector.

5 Condition opinion

Table 10 Preliminary condition opinion for each attribute of the Intertidal Boulder & Cobble Skears sub-feature of the Morecambe Bay SAC as defined in the conservation objectives set out within the Regulation 33 Advice for Morecambe Bay.

SAC Attribute	Target (subject to natural variation)	Condition Recommendation
Extent	No decrease in extent from the established baseline (aerial photography survey 1997), subject to natural change.	Due to resource constraints, the full extent of intertidal stony reef and intertidal rock was not surveyed. Instead, the survey focused on the main areas of habitat. There is insufficient historical evidence to compare with data collated during the current survey to confirm whether the extent has changed. Generally, the extent of these habitats does not appear to have reduced, and it is highly likely any change is well within expected natural variability. There are some areas where the intertidal stony reef habitat identified as part of the Tooke (2015) project was not present. However, it is likely that this is the result of overestimation from the aerial imagery for that project rather than a loss in habitat as the Tooke (2015) project did not include ground truthing of the aerial imagery. As such **the CO target for this attribute is judged to have been met**.
Extent of characteristic biotopes: • Mussel beds • Honeycomb worm (*Sabellaria alveolata*) reefs.	No decrease in extent from the established baseline (Woombs	There are some mussel beds that have previously been recorded that are no longer present. As the mussel beds in the Morecambe Bay SAC are largely ephemeral, this is likely to be the result of natural change such as storm and weather conditions and predation. **The CO target for mussel beds has been met**.

SAC Attribute	Target (subject to natural variation)	Condition Recommendation
• Tide-swept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds.	1997[5]), subject to natural change.	All the more recent historical data available for *Sabellaria aleveolata* reef in the SAC is for the reef at Heysham Flats. This reef was inspected during the 2015 survey. The area does appear to be smaller than previously recorded. However, as described above in Section 5.1.3, this reef is ephemeral with cycles of growth and contraction as a result of competition with mussels as well as recovery from storm induced change. It is considered that the recorded reduction in extent of this habitat is likely to be the result of natural variation. Whilst Allen *et al* (2002) reported presence of *Sabellaria alveolata* reef in the South Walney area, no further studies have been published on reef in this area. Some areas of *S. alveolata* were recorded in the south of the North Walney area that was surveyed which may be considered reef. It is considered that **the CO target for *Sabellaria alveolata* reef has been met**. A variation of the habitat tide-swept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds (LR.HLR.FT.FserTX) was recorded on the low shore at the tip of Head Scar, to the west of Roa Island, covering 600 m^2. This biotope was not observed in any of the other areas surveyed. Baseline data for this habitat is not available to compare any

[5] It should be noted that it was not possible to review this report as it was not available. The 2015 data was therefore only compared with existing sources of historical evidence identified in the preliminary assessment text.

SAC Attribute	Target (subject to natural variation)	Condition Recommendation
		change in extent. **The preliminary assessment for this attribute is therefore unknown**. The results of this survey form a suitable baseline for this habitat against which future surveys can be compared.
Species composition of characteristic biotopes: • Mussel bed communities. • Tideswept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds.	Presence and abundance of composite species should not deviate significantly from the established baseline (Woombs 1997).	As described in Section 4.3.1, the species with the greatest contribution to the mussel bed communities biotope were: *Mytilus edulis*, *Ulva intestinalis*, *Austrominius modestus* and *Littorina littorea*. There is no baseline with which to compare the results of the 2015 survey and so no conclusions can be made in regard to species presence and abundance. The **condition of the attribute is assessed as unknown**. The results of this survey form a suitable baseline for presence and abundance of species against which future surveys can be compared.The tideswept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds habitat (LR.HLR.FT.FserTX) was observed at one site to the west of Road Island during the 2015 survey. As there is no baseline data available for this habitat it is not possible to compare the presence and abundance of composite species. The **preliminary condition assessment of the attribute is therefore unknown**. The results of this survey form a suitable baseline for presence and abundance of species against which future surveys can be compared.
Characteristic species	Percentage of sexually mature mussels and newly	The mussels beds surveyed using the adapted Dutch wand method indicate the beds were dominated by under size mussels (<45 mm). It is difficult to know whether this is due to the time of year or as a result of mortality of

SAC Attribute	Target (subject to natural variation)	Condition Recommendation
• Mussels *Mytilus edulis.*	recruited mussels on beds should not fall below North Western & North Wales Sea Fisheries Committee baseline, to be established, subject to natural change.	larger mussels. However, the mussel beds within the Morecambe Bay SAC are known to be ephemeral, and subject to cycles of growth and decline. As no anthropogenic changes have been caused the CO target for mussel beds has been met. Quantitative baseline data on the percentage of sexually mature and new recruited mussels on beds is not available. A Dutch wand survey of the mussel beds at Foulney Island and Low Bottom undertaken during the same season the year before (October 2014) found the majority of mussels were under size. This indicates that there has not been a change in the proportion of sexually mature mussels in these areas. However, as no statistically meaningful comparison can be made it is not possible to make a specific recommendation of the condition of this attribute. **The preliminary assessment for this attribute is, therefore, unknown**.

6 Summary and conclusions

- Survey effort was directed to the most representative areas of intertidal reef in Morecambe Bay SAC using a combination of Phase I biotope mapping survey and Phase II 0.25 m^2 quadrat survey techniques and a variation of the Dutch wand method.

- The quantitative quadrat survey sampled 93 quadrats from 31 sites. The most common macroalgal taxon was *Ulva intestinalis* which was found at 39 quadrats. The most commonly observed invertebrate was *Mytilus edulis* in 53 quadrats.

- Of the three biotope communities specifically referred to within the Conservation Objectives, only mussel beds and honeycomb worm (*Sabellaria alveolata*) reefs were found in any great areas. The tide-swept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds habitat was only recorded at one site.

- Mussel beds were recorded at Foulney Island, Morecambe Skears and the Wyre Estuary/ Fleetwood areas of Morecambe Bay SAC. Mussel coverage varied from 21% to 91%. The proportion of large mussels (>45 mm in length) varied by area with only 1-3% of large mussels at Morecambe Skears, 29-37% large mussels at Foulney Island and 1-7% of large mussels at Fleetwood.

- *Sabellaria alveolata* reef was recorded in the North Walney, Morecambe Skears and Half Moon Bay areas. In North Walney a large expanse of *S. alveolata* was recorded in the south of the area with low growths. Other smaller areas of declining reef were reported. At Morecambe Skears the main reef is at Heysham Flats with areas of reef on the seaward extents of the mussel reef. A further area of reef was recorded at Old Skear. At Half Moon Bay the reef was a thin sheet coating the lower boundary of bedrock.

- The Australian barnacle *Austrominius modestus* was recorded in 54 of 93 quadrats at 18 locations which were throughout the SAC except for the Half Moon Bay area. Japanese wireweed *Sargassum muticum* was found in rockpools in the North Walney and Foulney Island areas.

- Overall, a comparison of the extent of intertidal reef habitats within Morecambe Bay SAC suggests no significant difference between the baseline data and the 2015 survey.

- Whilst changes in the extent of mussel beds and *Sabellaria alveolata* reefs have occurred over time, it is likely that this is the result of natural change and so the Conservation Objectives (CO) for these habitats have been met. There is no baseline data for the tide-swept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds habitat and so no conclusion can be made on this CO.

- No quantitative baseline data are available for the SAC and so comparisons of the presence and abundance of composite species of mussel beds and tide-swept boulders and cobbles with serrated wrack, sponges, sea squirts and red seaweeds habitat were not possible.

- Similarly a comparison of the percentage of sexually mature mussels was not possible as quantitative data on the mussel beds in the SAC was not available.

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Appendices

APPENDIX 1 Habitat Figures showing historical data

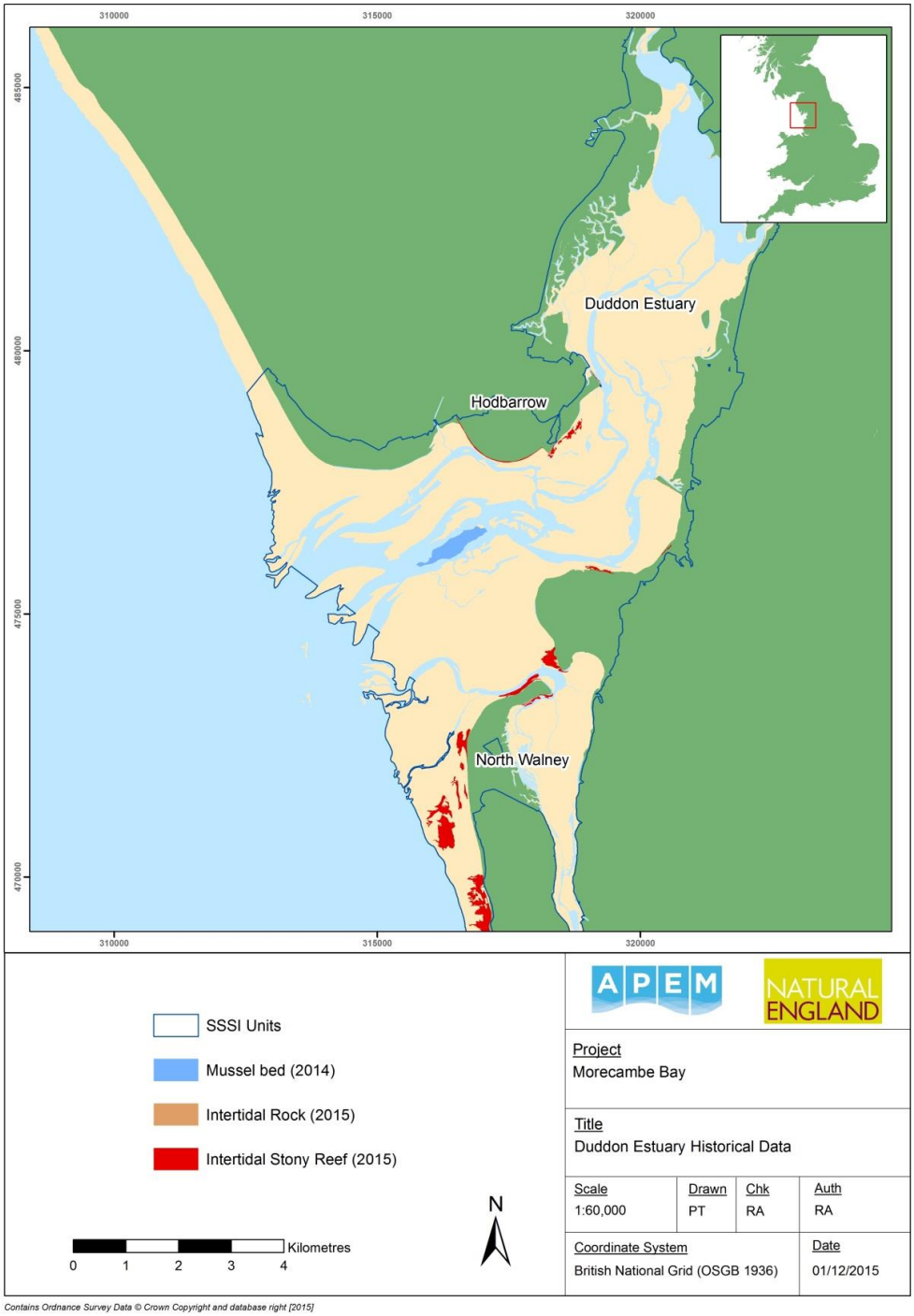

Figure 29 Intertidal rock and stony reef habitats within the Duddon Estuary area based on historical data.

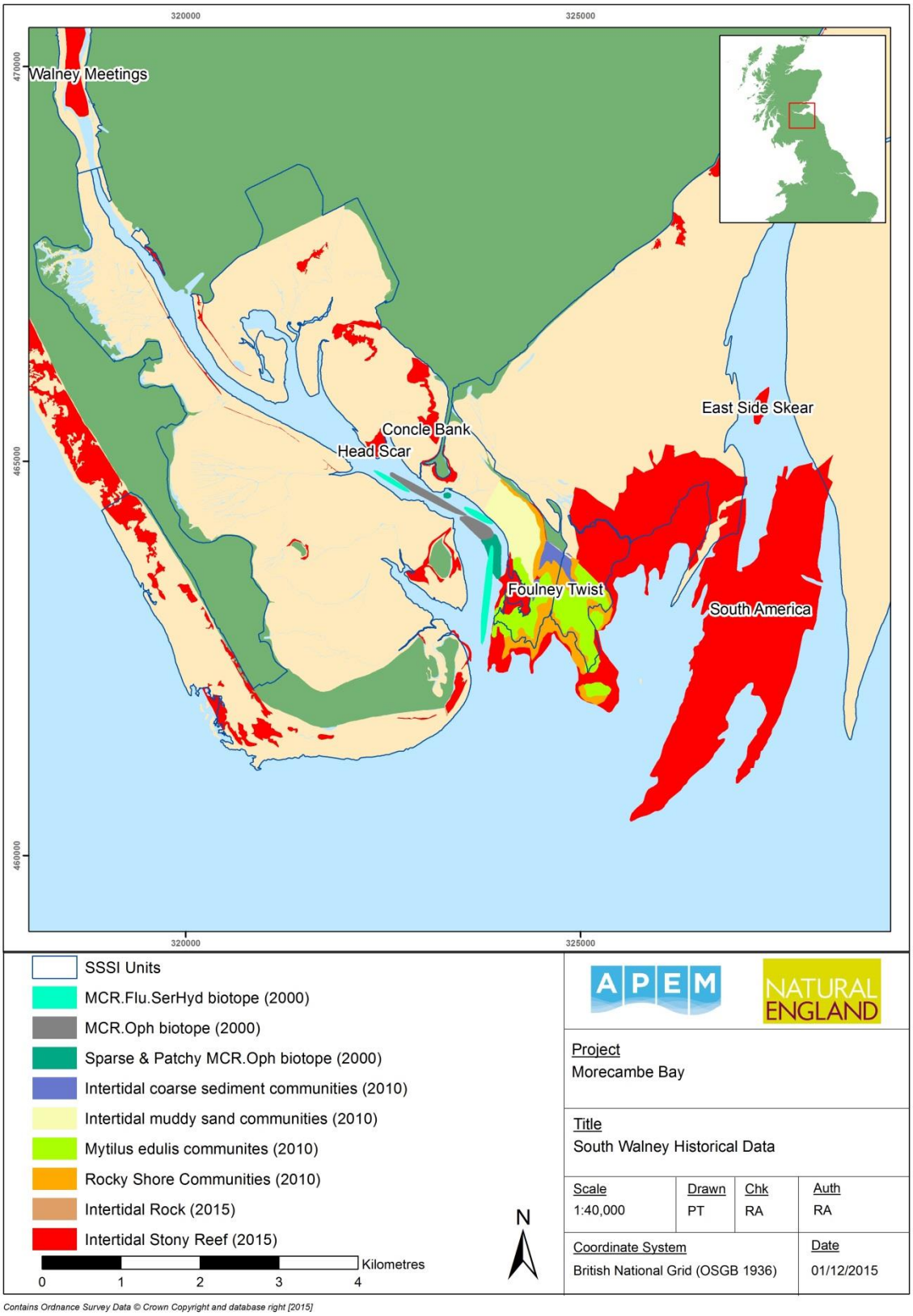

Figure 30 Intertidal rock and reef habitats within the South Walney Island area based on historical data.

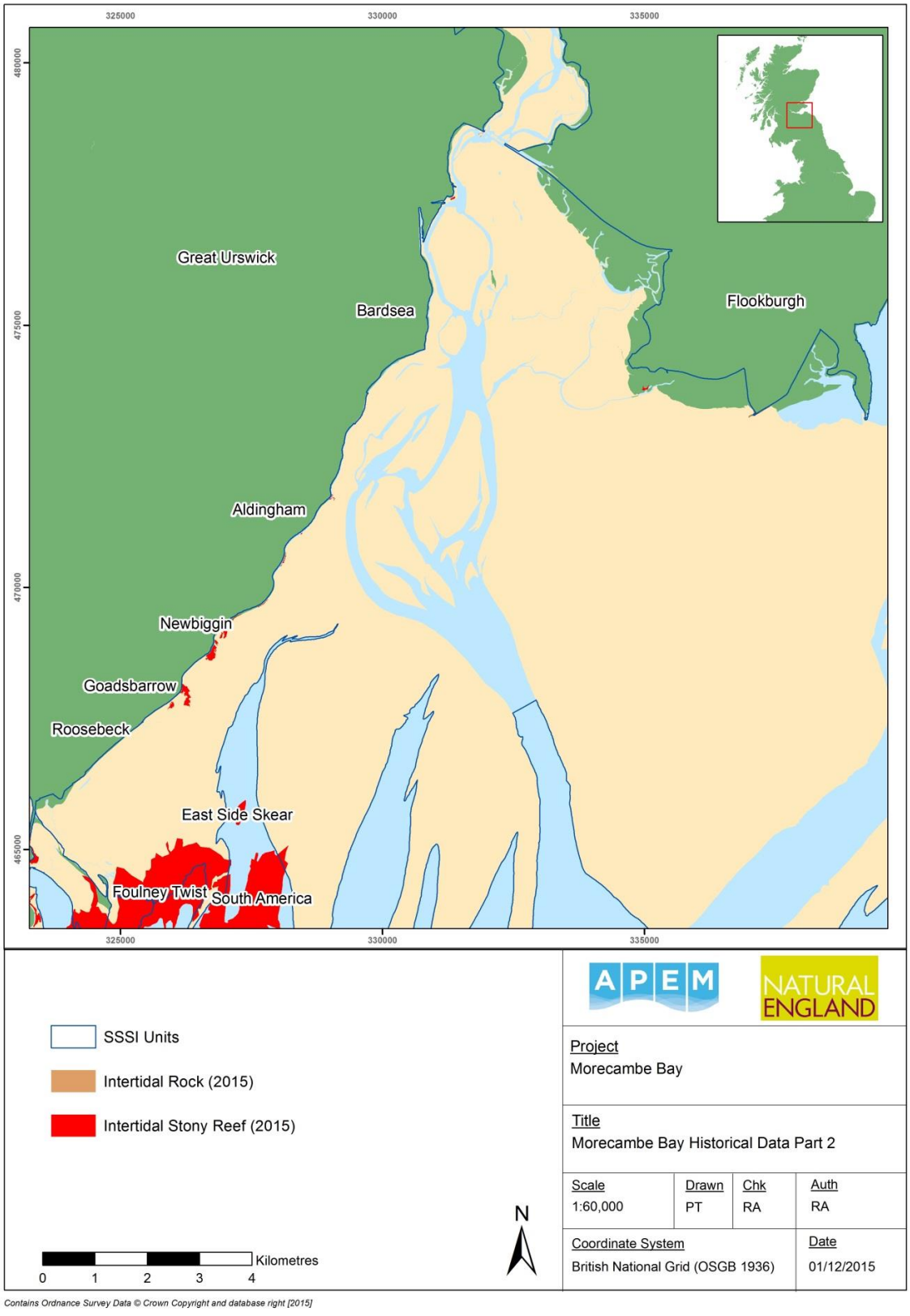

Figure 31 Intertidal rock and stony reef habitats within the Morecambe Bay 1 area based on historical data.

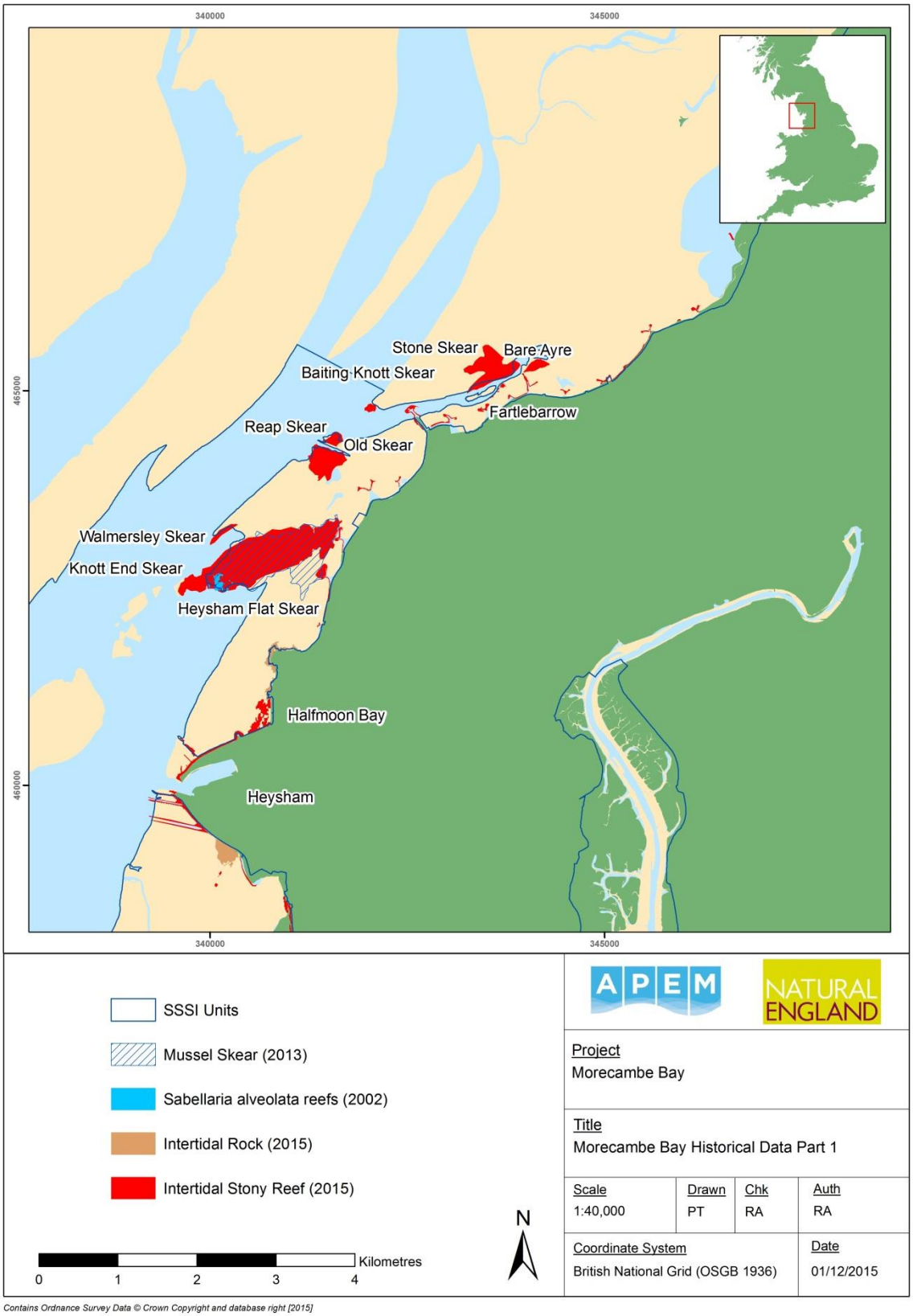

Figure 32 Intertidal rock and reef habitats within the Moreambe Bay 3 area based on historical data.

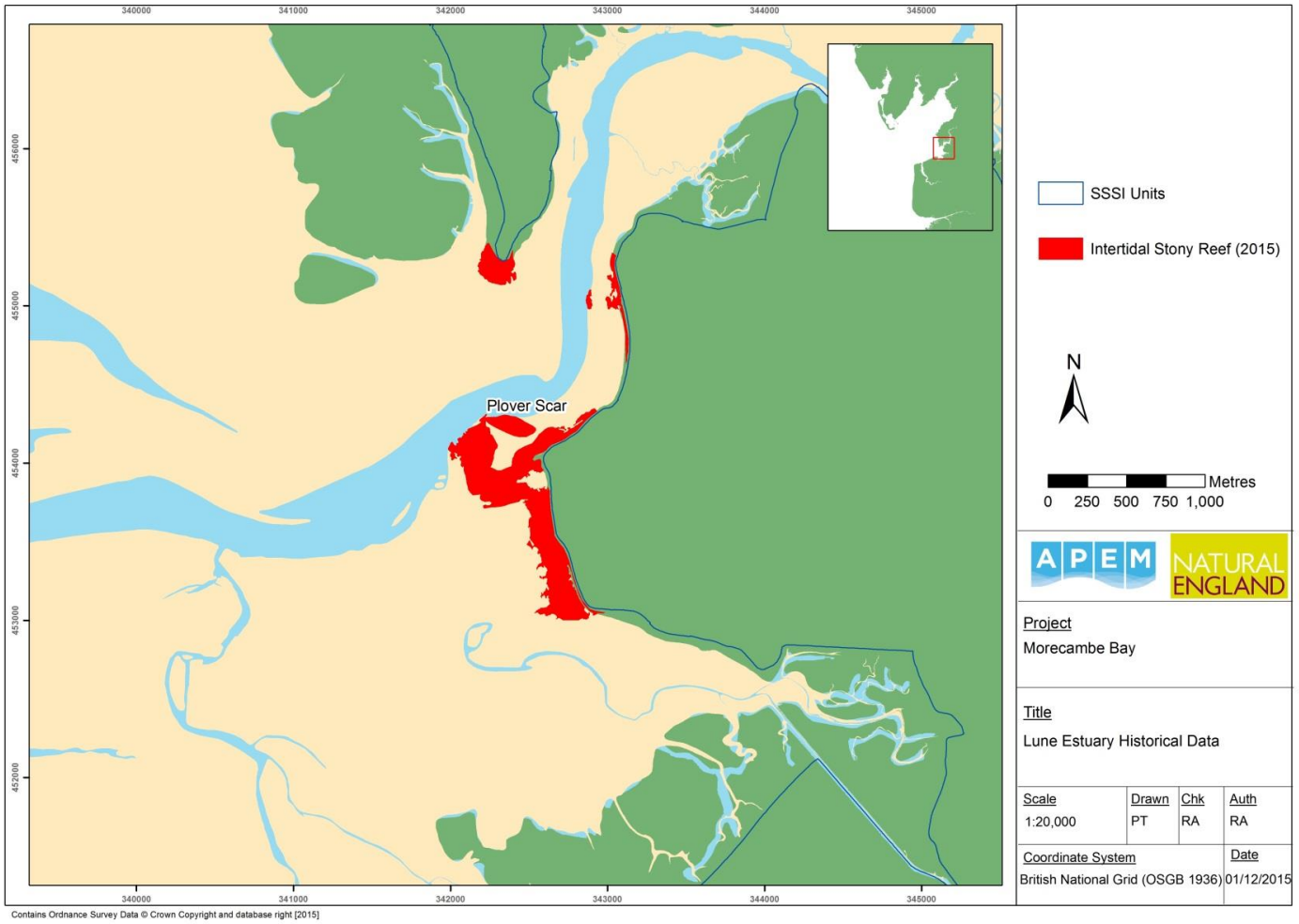

Figure 33 Intertidal rock and reef habitats within the Lune Estuary area based on historical data.

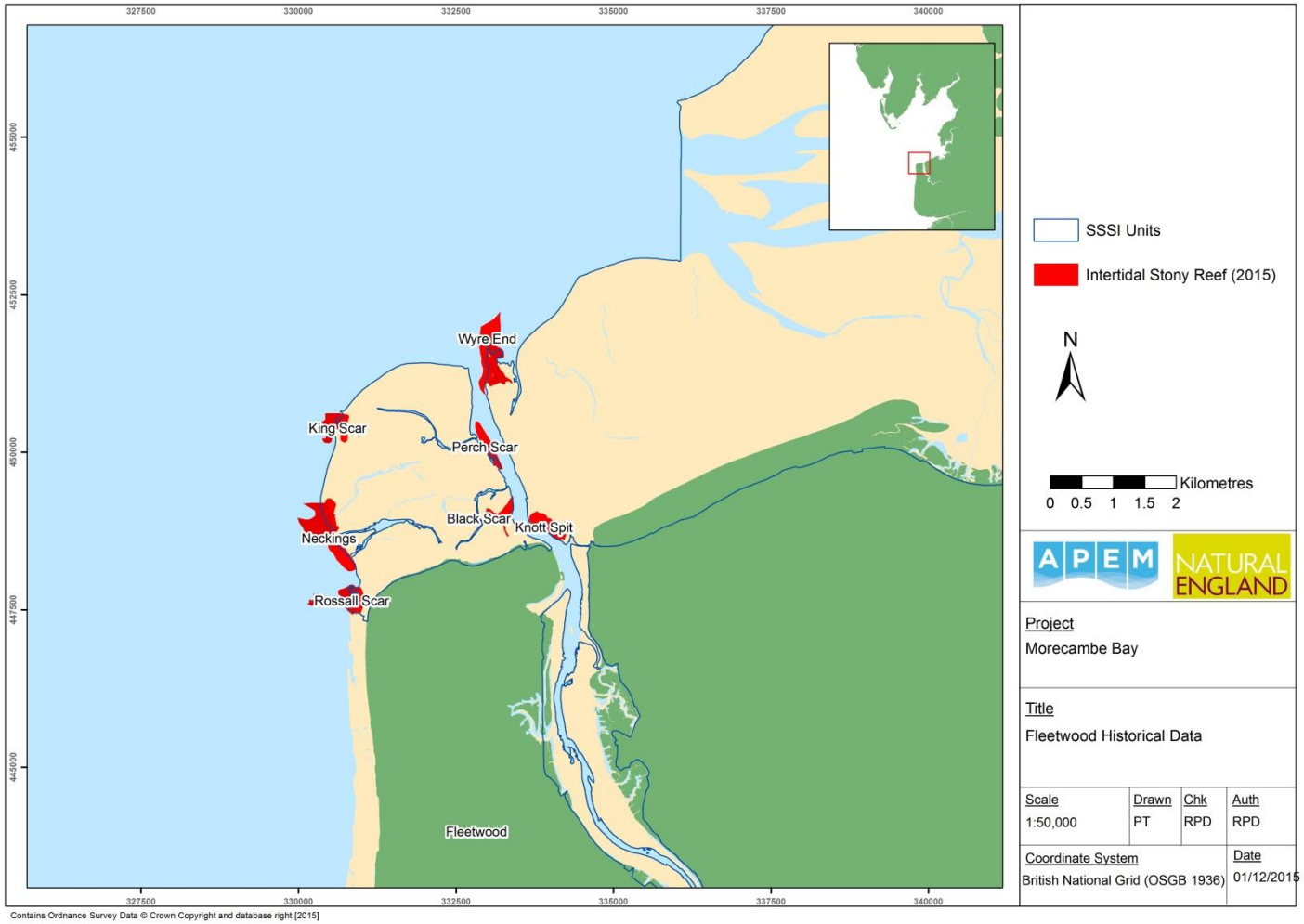

Figure 34 Intertidal rock and reef habitats within the Wyre Estuary area based on historical data.

APPENDIX 2 Field Target Notes

Provided as a separate document.

APPENDIX 3 Biotope maps

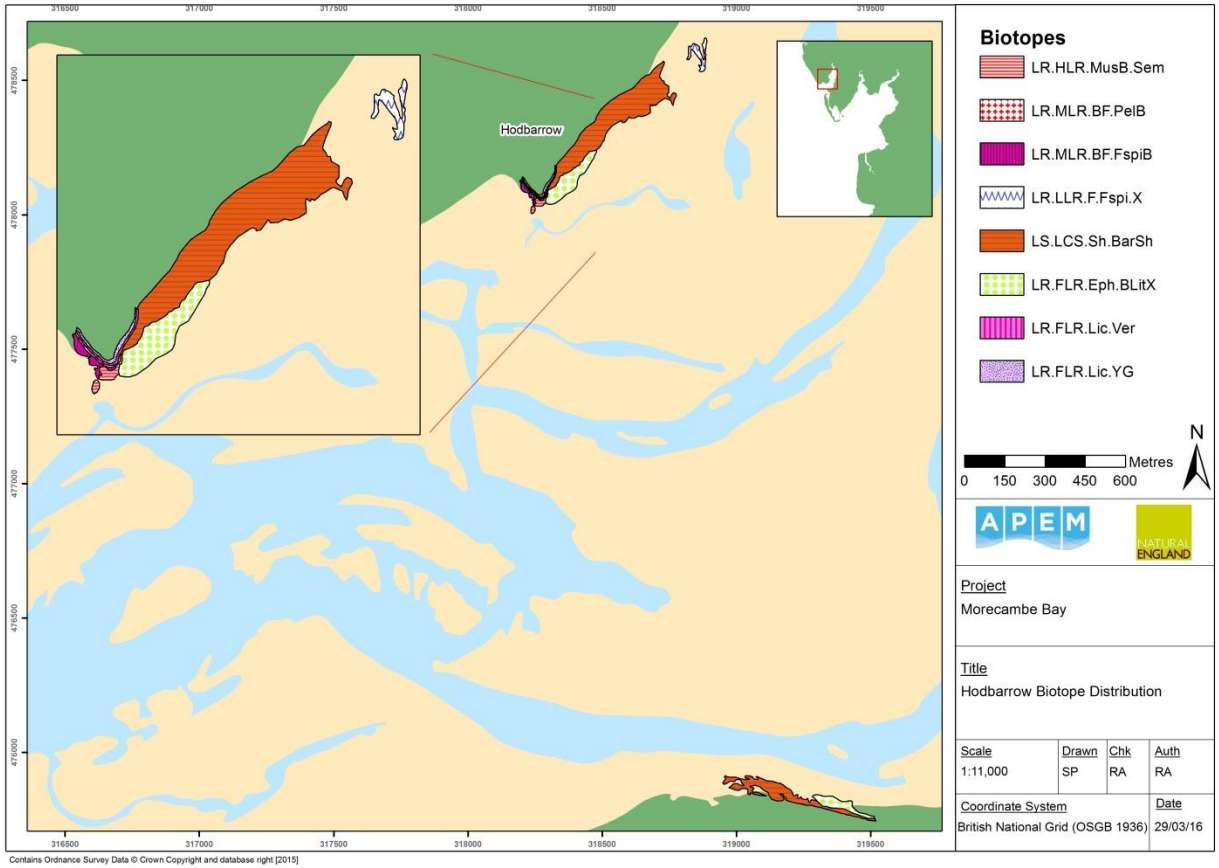

Figure 35 Biotope map for the Hodbarrow area of the Duddon Estuary based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

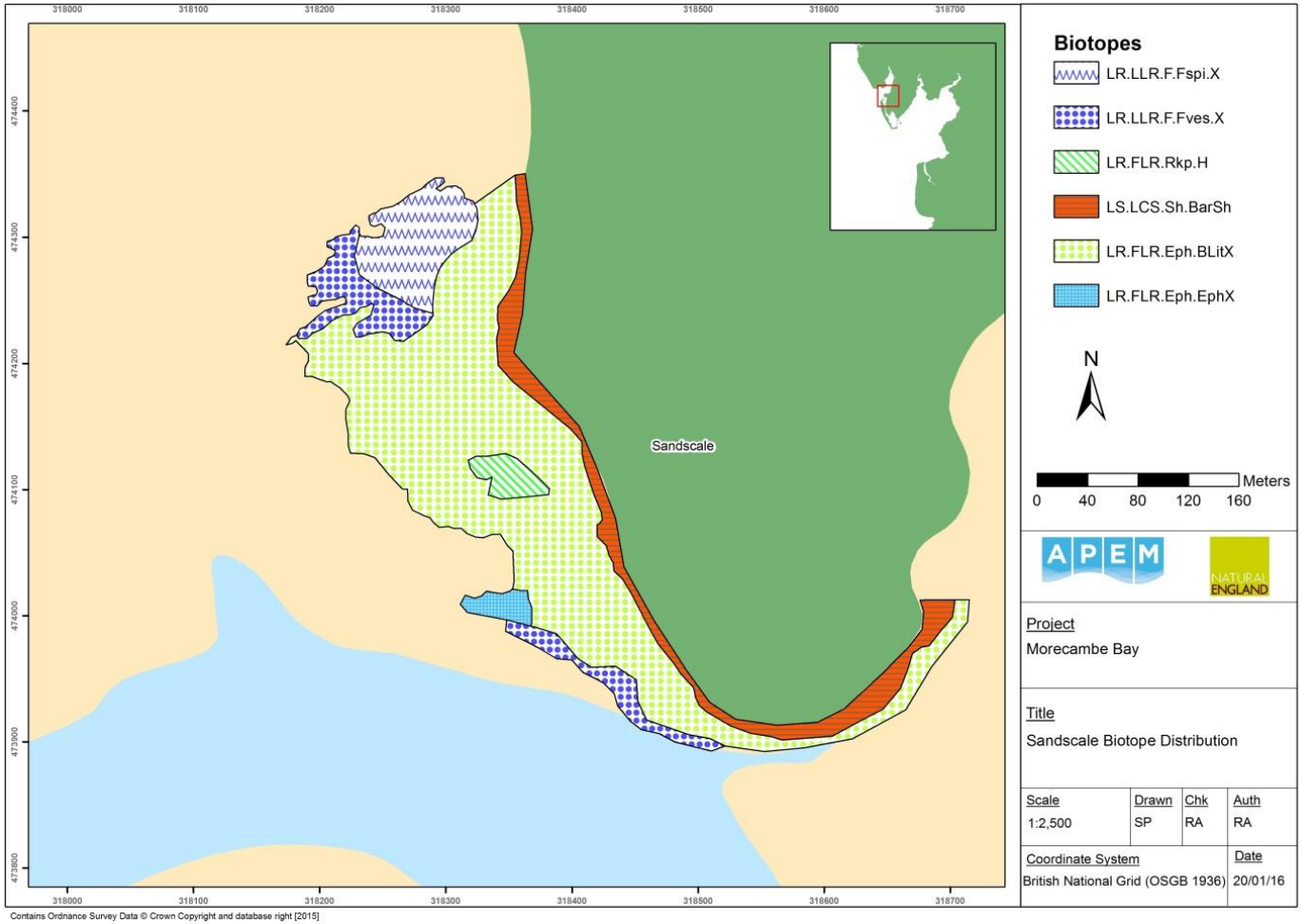

Figure 36 Biotope map for the Sandscale area of the Duddon Estuary based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

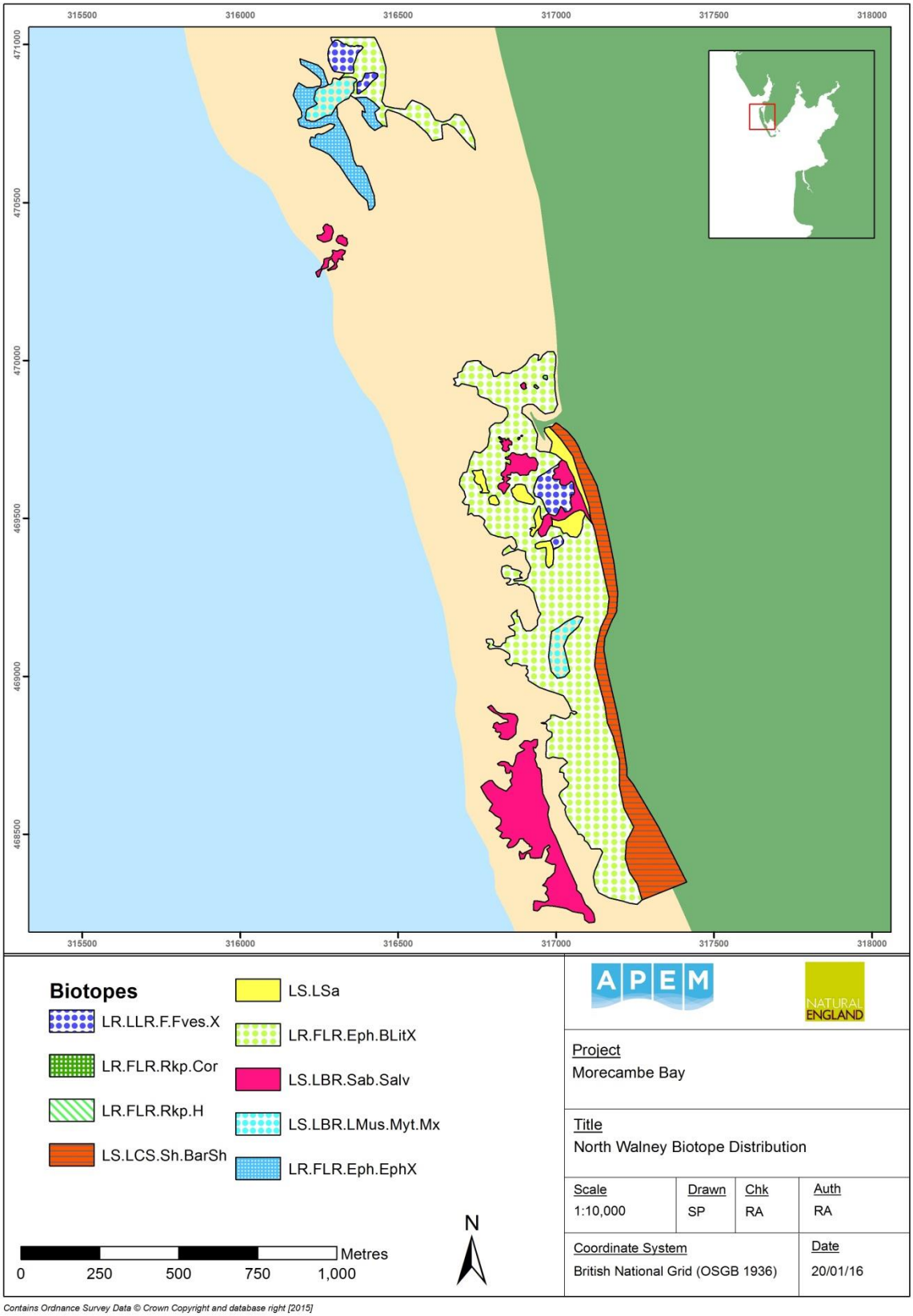

Figure 37 Biotope map for the North Walney area of the Duddon Estuary SSSI based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

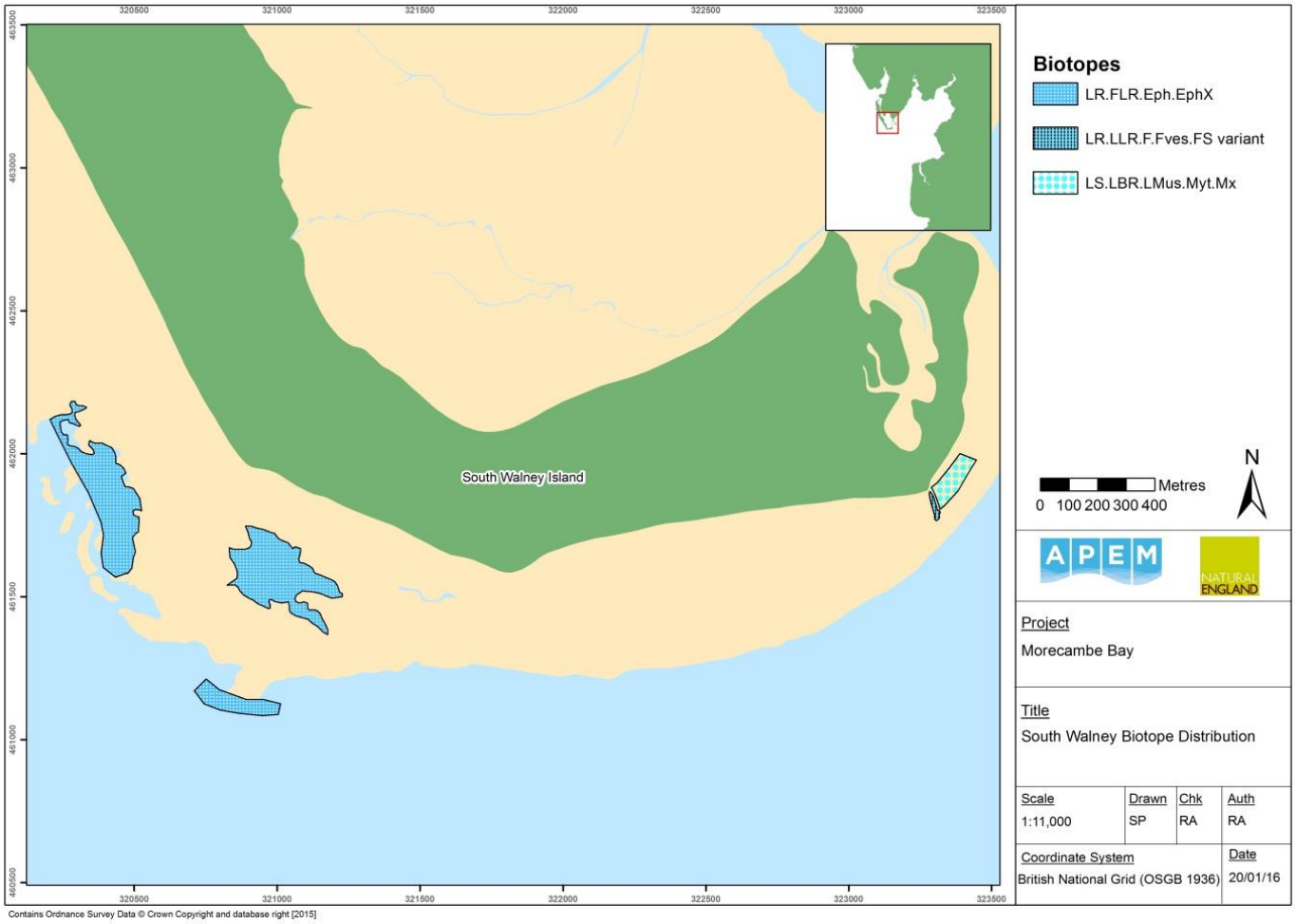

Figure 38 Biotope map for the South Walney area based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

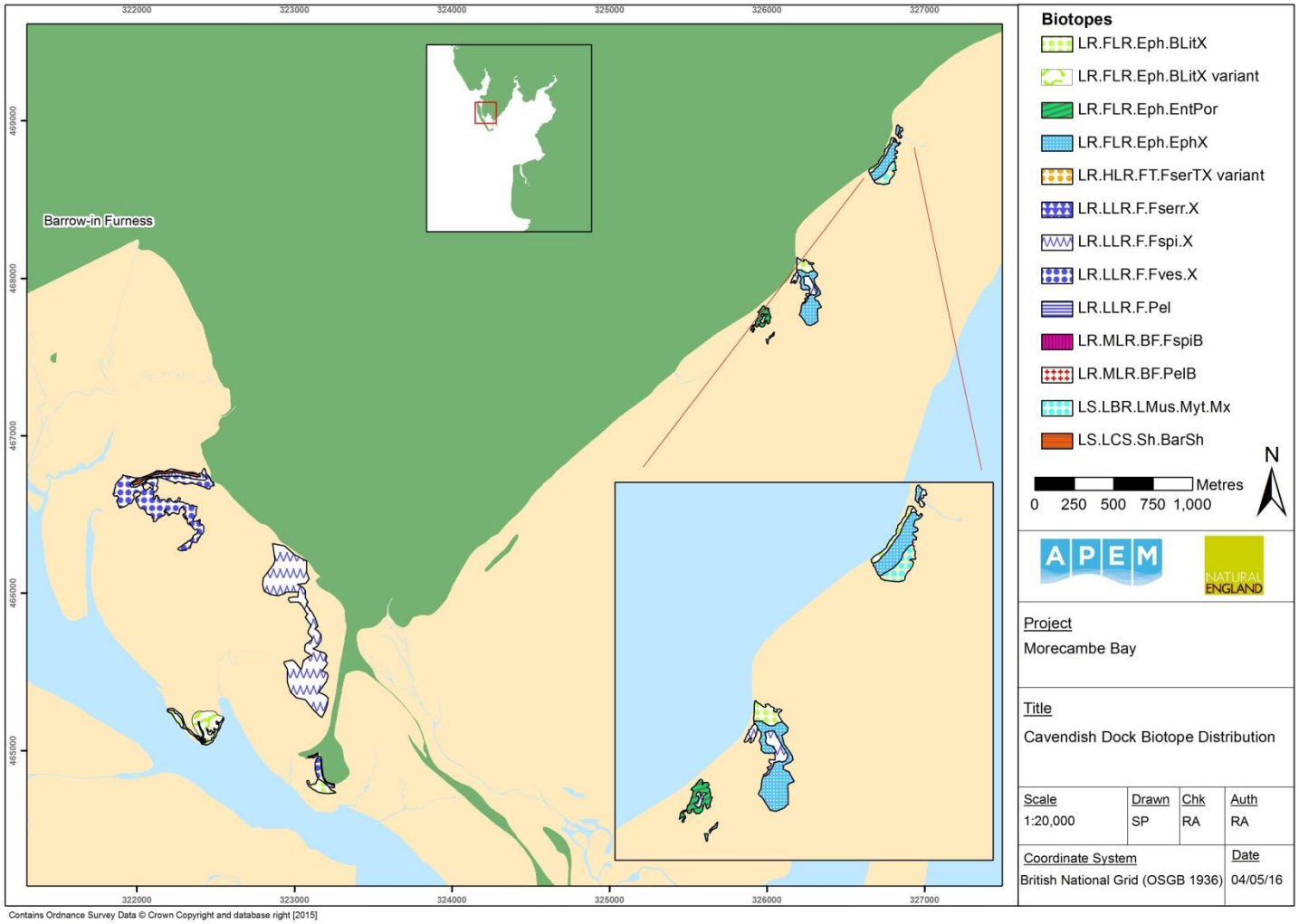

Figure 39 Biotope map for Cavendish Dock to Goadsbarrow based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

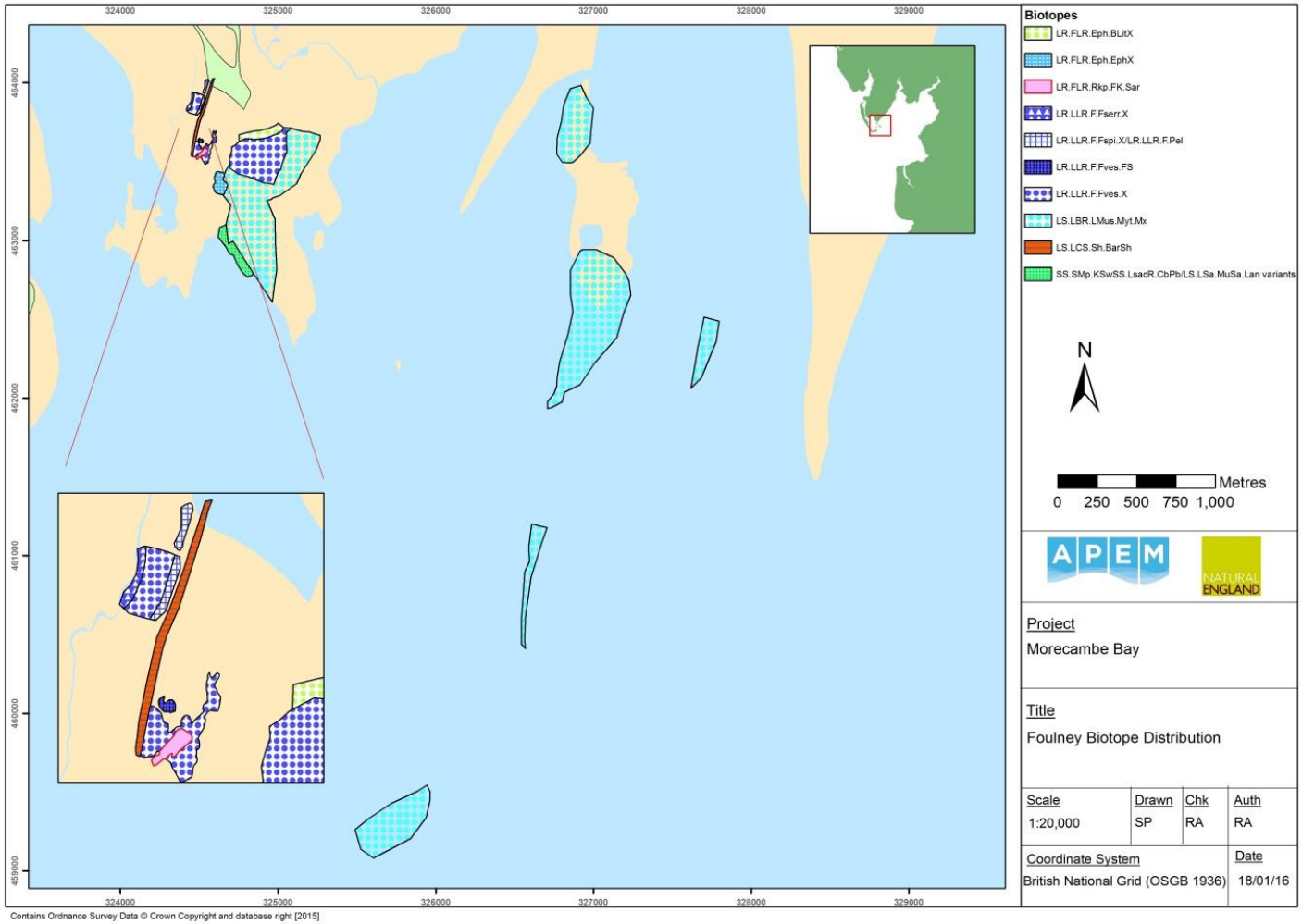

Figure 40 Biotope map for the Foulney Island area based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

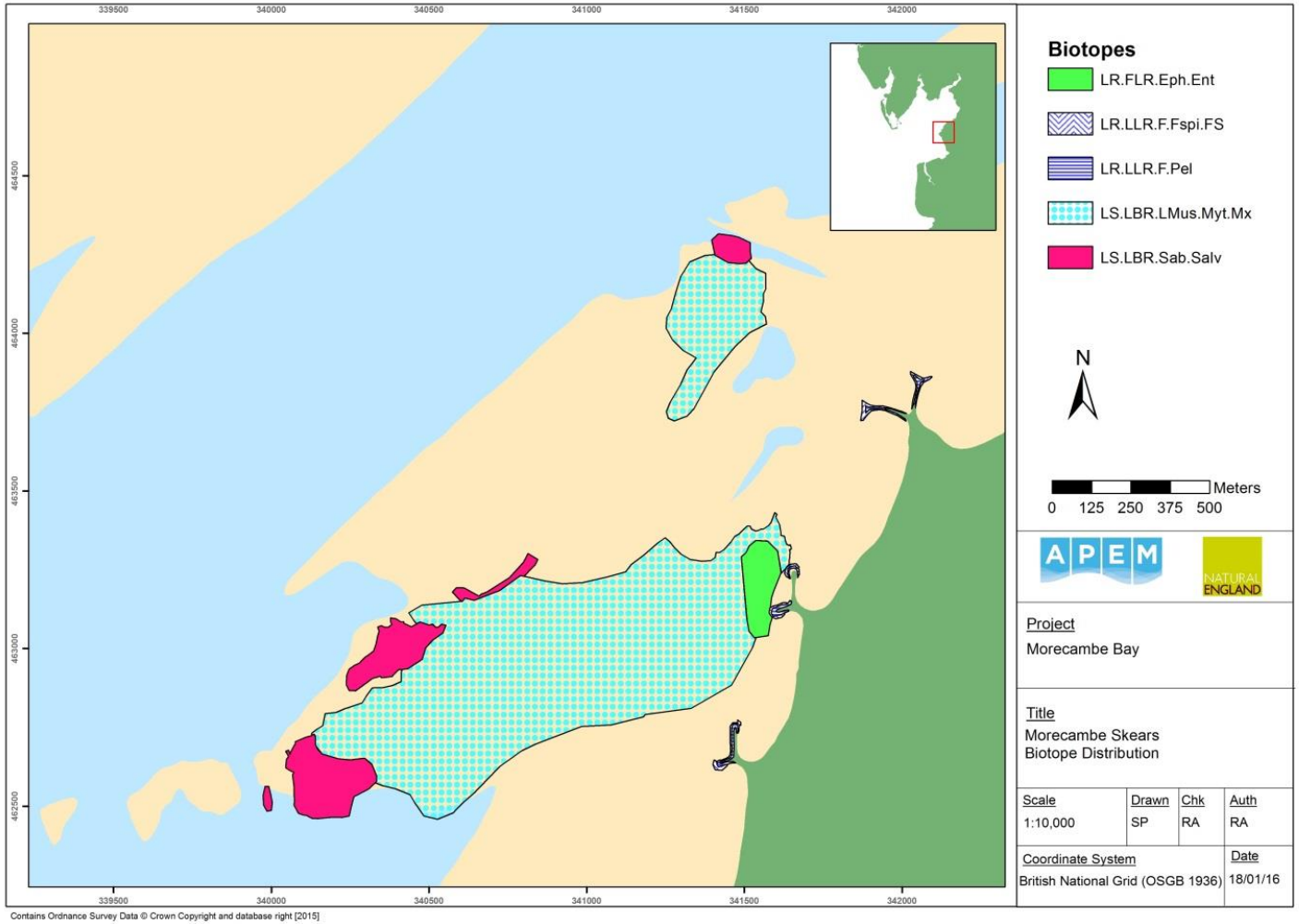

Figure 41 Biotope map for the Morecambe Skears area of Moreambe Bay 3 based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

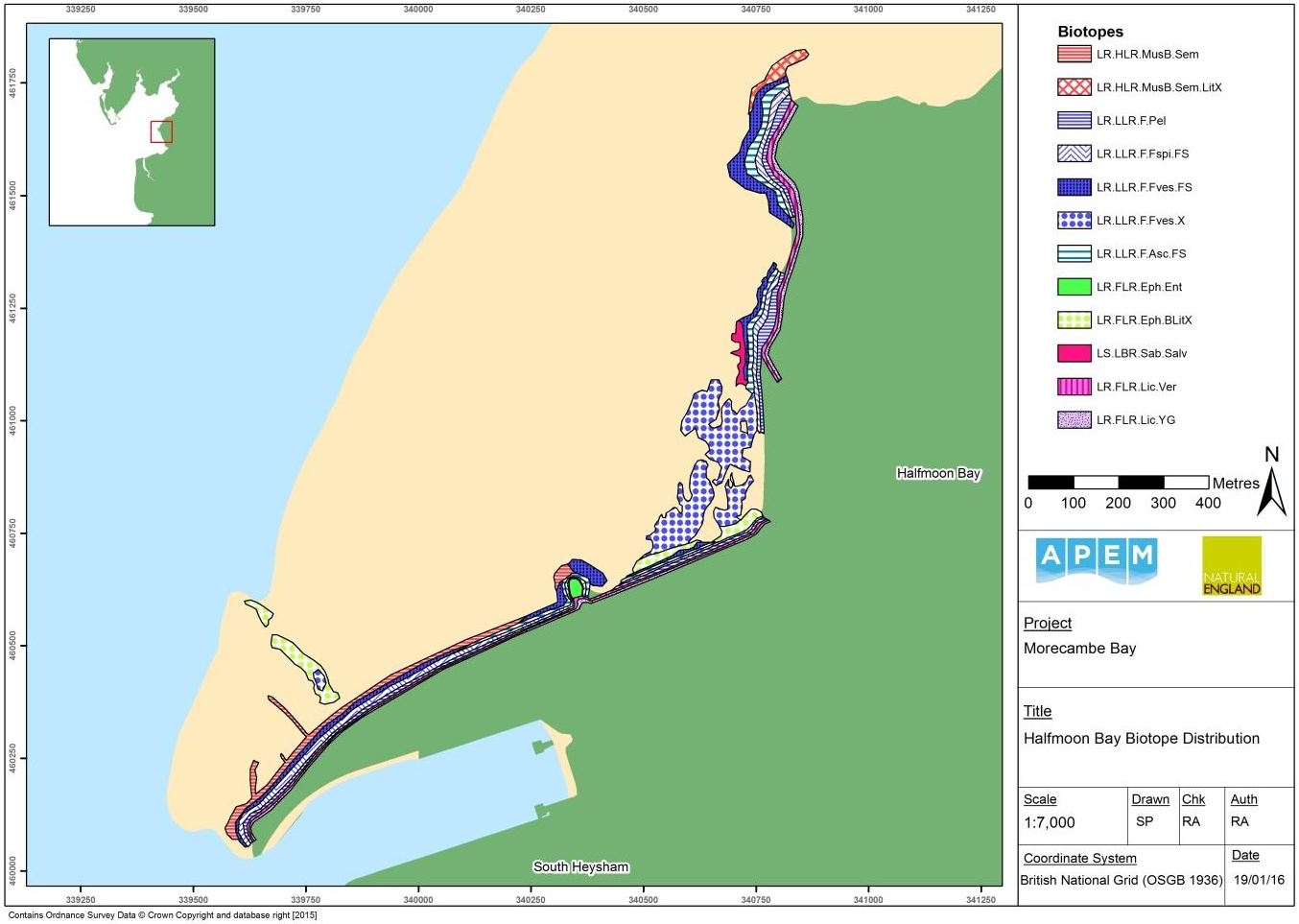

Figure 42 Biotope map for the Halfmoon Bay area of Morecambe Bay 3 based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

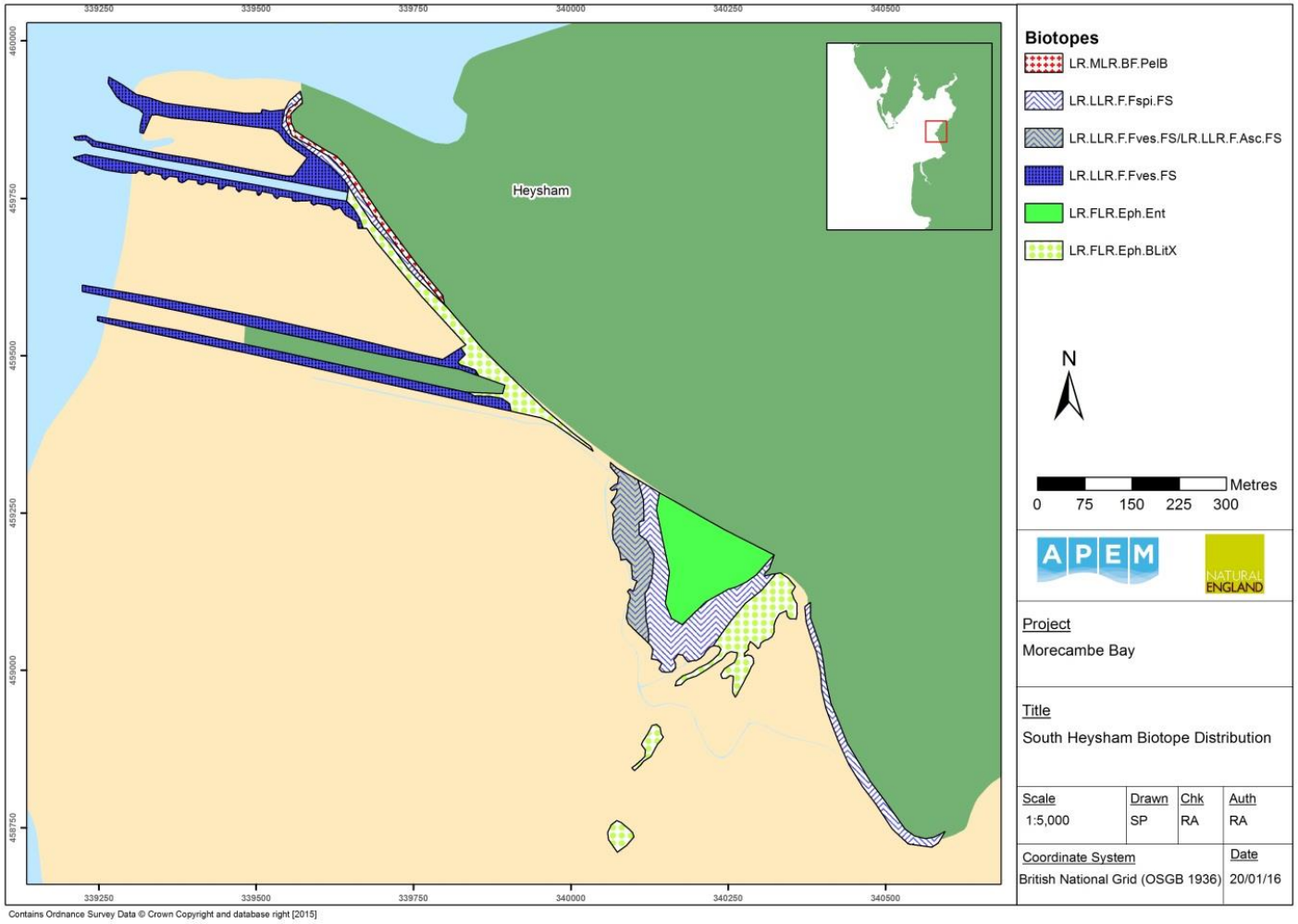

Figure 43 Biotope map for the South Heysham area of Morecambe Bay 3 based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

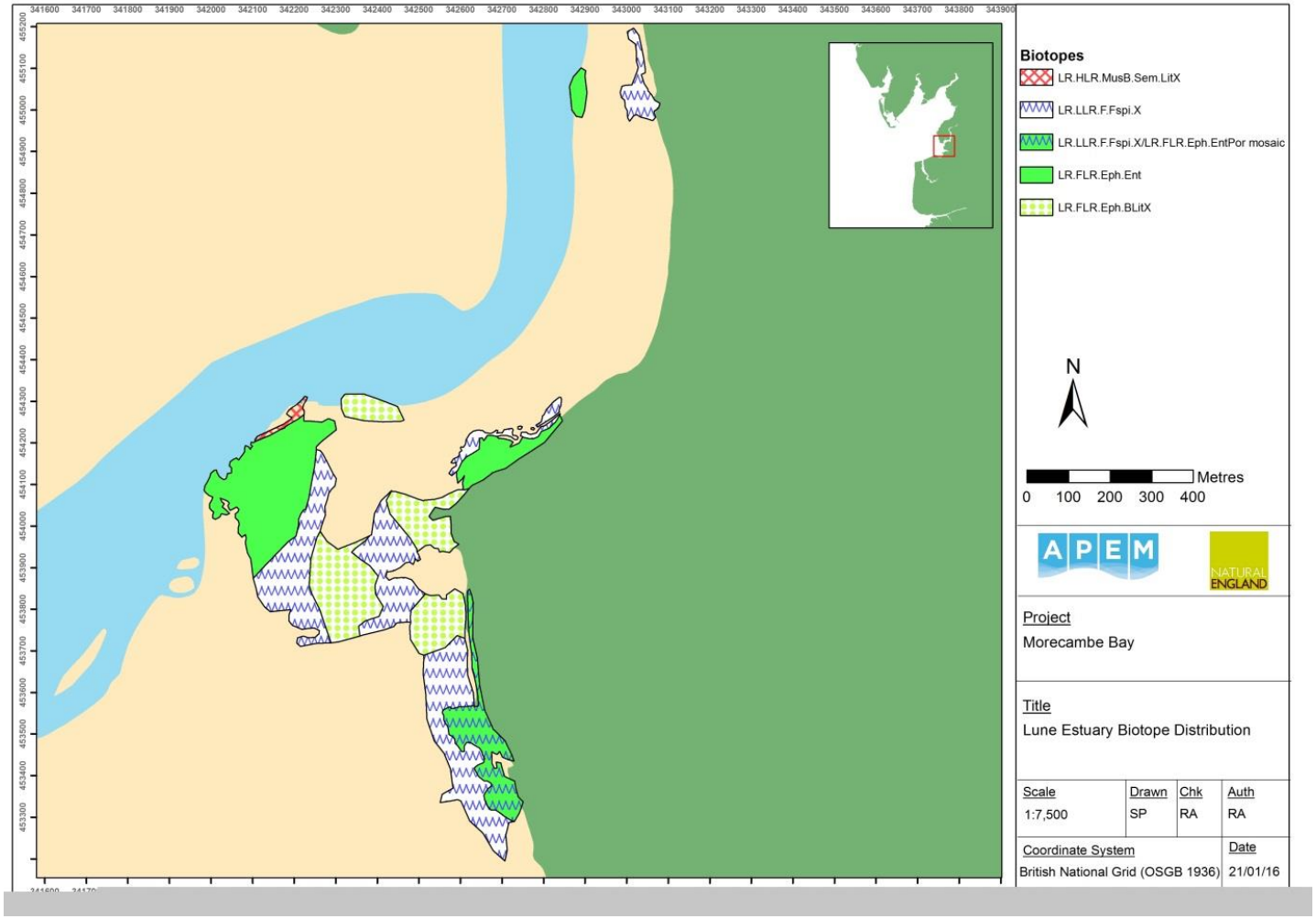

Figure 44 Biotope map for the Lune Estuary based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

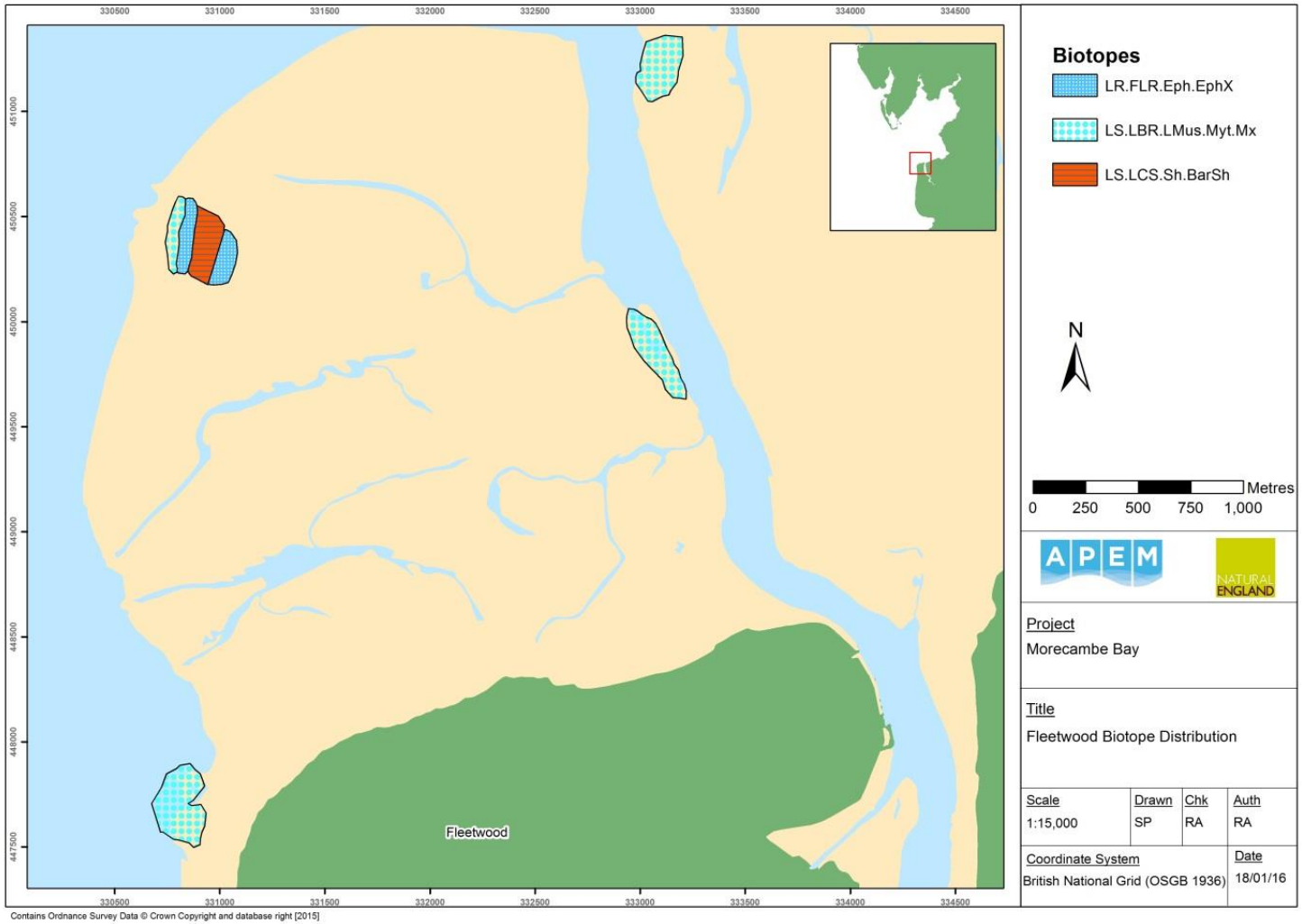

Figure 45 Biotope map for the Wyre Estuary based on the findings of the 2015 Morecambe Bay SAC intertidal rock and reef survey.

APPENDIX 4 Quadrat Data & GPS Data

Provided separately as an electronic file.

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