Improvement Programme for England's Natura 2000 Sites (IPENS) – Planning for the Future IPENS022

Ribble Estuary SSSI / Ribble & Alt SPA Intertidal sediments condition monitoring

Ribble and Alt Estuaries Special Protection Area (SPA)

First published 04 September 2015

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

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

Foreword

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

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

An intertidal survey was commissioned for sections of the Ribble and Alt Estuaries Special Protection Area (SPA), which is underpinned by the Ribble Estuary Site of Special Scientific Interest (SSSI), in order to gather data on the distribution and extent of sediment types and faunal communities within the intertidal flats, and to record any anthropogenic pressures observed which could potentially impact on features within the intertidal zones. Data gathered will provide evidence for assessing changes within the site and should be used to monitor future changes.

A total of 12 habitat types were recorded across the survey area. Biotopes/sub-biotopes characteristic of muddy sand tended to be present on the upper shores, the lower shores characterised by stable fine sands with polychaetes, while the mid shore biotopes were often a combination of stable fine sand and mobile sand habitats. The mean number of taxa at each site across the estuary was 6.8 with a mean of 10,261 individuals per m^2. A contaminant analysis demonstrated that overall, the contaminants for which standards are available were below Background Assessment Concentration (BAC) values with the exception of naphthalene. This suggests that concentrations of contaminants at the sediment surface were relatively low and are unlikely to be affecting the faunal assemblages at the sites sampled.

The main anthropogenic influences recorded during the survey were general public use of the foreshore by tourists and dog walkers, and fishing for shellfish, including collecting mussels from the training wall. Watersport activities such as kite surfing and sand yachting were also recorded in the intertidal areas. The report highlights that the intertidal zone at Granny's Bay is relatively narrow and the presence of seawalls in this location could potentially contribute to coastal squeeze within the site.

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

Natural England Project officer: Ross Bullimore, **ross.bullimore@naturalengland.org.uk**

ISBN 978-1-78354-218-5

Ribble Estuary SSSI / Ribble & Alt SPA Intertidal sediments condition monitoring

PROJECT DIRECTOR:	**Dr Rafael Perez-Dominguez**
PROJECT MANAGER:	**Dr Marc Hubble**
REPORT AUTHORS:	**Dr Marc Hubble** **Jennifer Pinnion**

Riverview, A17 Embankment Business Park,
Heaton Mersey, SK4 3GN
Registered in England No. 2530851
Website: www.apemltd.co.uk

CONTENTS

FIGURES

PLATES

TABLES

EXECUTIVE SUMMARY

The Ribble Estuary is located on the Lancashire coast between Southport and Lytham St Annes and forms the Ribble Estuary Site of Special Scientific Interest (SSSI), and part of the Ribble and Alt Estuaries Special Protection Area (SPA) and Ramsar site which encompasses the adjacent Sefton Coast SSSI. A primary reason for designation is the extensive sand and mudflats throughout the estuary which are rich in invertebrates and provide an important food source for passage and wintering wildfowl.

Natural England (NE) applies Common Standards Monitoring (CSM) guidance to conduct condition assessments of SSSIs, SACs, SPAs and Ramsar sites on a six year cycle, assessing whether pre-defined targets for specific site attributes have been met across each six year period and reporting the findings to Europe via the Joint Nature Conservation Committee (JNCC).

APEM was commissioned by NE to conduct a survey of the intertidal sediments within Units 1, 8, 9 and 10 of the Ribble Estuary SSSI. The aim was to record the distribution and extent of sediment types and faunal communities within the intertidal flats, and record any anthropogenic pressures observed during the survey which could potentially be influencing conditions within the intertidal zone. These data were then compared with the results of previous surveys to inform a preliminary condition assessment of the SSSI Units as part of requirements for CSM of designated sites.

Field survey methods incorporated a combination of qualitative *in-situ* biotope assessment (Phase I) and quantitative coring survey. The Phase I approach enabled broad areas of the intertidal zone to be characterised relatively rapidly and the coring provided quantitative data suitable for the application of robust statistical analyses.

The survey covered a total of eleven transects which had been previously sampled in 2005 and/or 2007 and two transects which were within unsurveyed sections of the estuary. During the Phase I survey, waypoints were logged when the biotope complex/biotope/sub-biotope (habitat types) noticeably changed while traversing the transects and *in situ* sieving was used for a preliminary assessment of the habitat type present which enabled the linear extent of habitat types to be recorded. Quantitative coring (five cores at each site) was then conducted at forty sites considered to be representative of the range of habitat types present across upper, mid and lower shore sections of the intertidal zone. Habitat types were initially assigned according to JNCC's National Marine Habitat Classification for Britain and Ireland and the corresponding EUNIS codes were then allocated to each Phase I or quantitative coring site. At each quantitative sample site a core was also collected for Particle Size Analysis (PSA) and at one pre-determined site sediment scrapes were collected for contaminant analysis.

A total of 12 habitat types were recorded across the Units surveyed, with the dominant habitat types being the biotopes 'Polychaetes in littoral fine sand' (A2.231), '*Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand' (A2.244) and the sub-biotope '*Nephtys cirrosa* dominated littoral fine sand' (A2.2313). Broadly speaking the biotopes/sub-biotopes characteristic of muddy sand (mainly A2.244) tended to be present on the upper shore, the lower shore was characterised by stable fine sand with polychaetes while the mid shore biotopes were often a combination of stable fine sand and mobile sand habitats.

The mean number of taxa at each site across the estuary was 6.8 with a mean of 10,261 individuals per m^2. There was some notable variation in terms of the numbers of taxa and abundances recorded within different Units, however, mean summary statistics including Shannon Wiener diversity, Simpson's dominance and Pielou's evenness were relatively similar across Units. Annelids were dominant in terms of the number of taxa present and just four crustacean and mollusc taxa were represented by more than ten individuals during the survey. The mud snail *Peringia ulvae* and the amphipod *Corophium volutator* had the greatest mean densities across the combined Units generally due to the elevated densities of these species within upper shore sites with mud content. No rare or unusual species were recorded across the survey.

The dominant sediment type (based on the Folk classification) was Slightly Gravelly Sand present at three quarters of the sites sampled. Levels of contaminants for which environmental standards were available were found to be low at the one site sampled for contaminants. Anthropogenic pressures were mainly associated with public use of the foreshore, collection of shellfish and vehicle use on the foreshore by fishermen, the presence of sea walls at Fairhaven, Granny's Bay and Southport, and the training wall along the main river channel which has a strong influence on the hydromorphology of the estuary.

For the preliminary condition assessment there was a lack of quantitative data collected during previous surveys for the attributes 'oxidation-reduction profile', 'sediment type' and 'topography'. Consequently, professional judgement was applied and it was considered these attributes were likely to be in **favourable** condition but confidence in the assessment was low.

Quantitative data were also not available for faunal communities from the studies conducted previously, however, Phase I survey data was used to compared biotope distribution between 2005, 2007 and the 2013 survey, and biotope linear extent between 2007 and 2013. For each Unit the preliminary condition assessment found the 'distribution of biotopes' and the 'biotope composition of littoral sediment' attributes to be in **favourable** condition. Due to a lack of quantitative community composition data from the previous years there were limitations when assessing the condition of the attribute 'species composition of representative or notable habitats'. Based on previous experience and professional judgement it was considered likely that this attribute was in favourable condition for each SSSI Unit but confidence in the assessment was low.

Overall, there is evidence that the extent of a range of habitat types may have varied between 2005 and 2013 however, changes observed are generally considered to be part of the natural variation expected within dynamic estuarine environments. It is considered that the data collected during the 2013 survey has provided broad habitat distribution data and quantitative biotope complex/biotope/sub-biotope composition data which will form a robust baseline to effectively inform NE's condition assessment and future condition assessment of the Ribble Estuary.

1 INTRODUCTION

1.1 Background

APEM was commissioned by Natural England (NE) to conduct a survey of intertidal biotopes and invertebrate assemblages within Units 1, 8, 9 and 10 of the Ribble Estuary Site of Special Scientific Interest (SSSI), (Figure 1).

This document outlines the methodology and results of the intertidal surveys, describing the distribution, extent and faunal composition of habitat types. Data collected were compared with the results of previous surveys to inform a preliminary condition assessment of the SSSI Units surveyed which can be considered when NE completes its own condition assessment.

1.2 Ribble Estuary European Marine Site

The Ribble Estuary forms the Ribble Estuary Site of Special Scientific Interest (SSSI), and part of the Ribble and Alt Estuaries Special Protection Area (SPA) and Ramsar site which encompasses the adjacent Sefton Coast SSSI. The focus of this study is the Ribble Estuary Site of Special Scientific Interest (SSSI) which was designated in 1984. The SSSI is situated on the Lancashire coast, between Southport and Lytham St. Annes, extending inland to Longton and covers an area of 9348.45 hectares (NE 2014 Ribble Estuary SSSI Condition Assessment) (Figure 1).

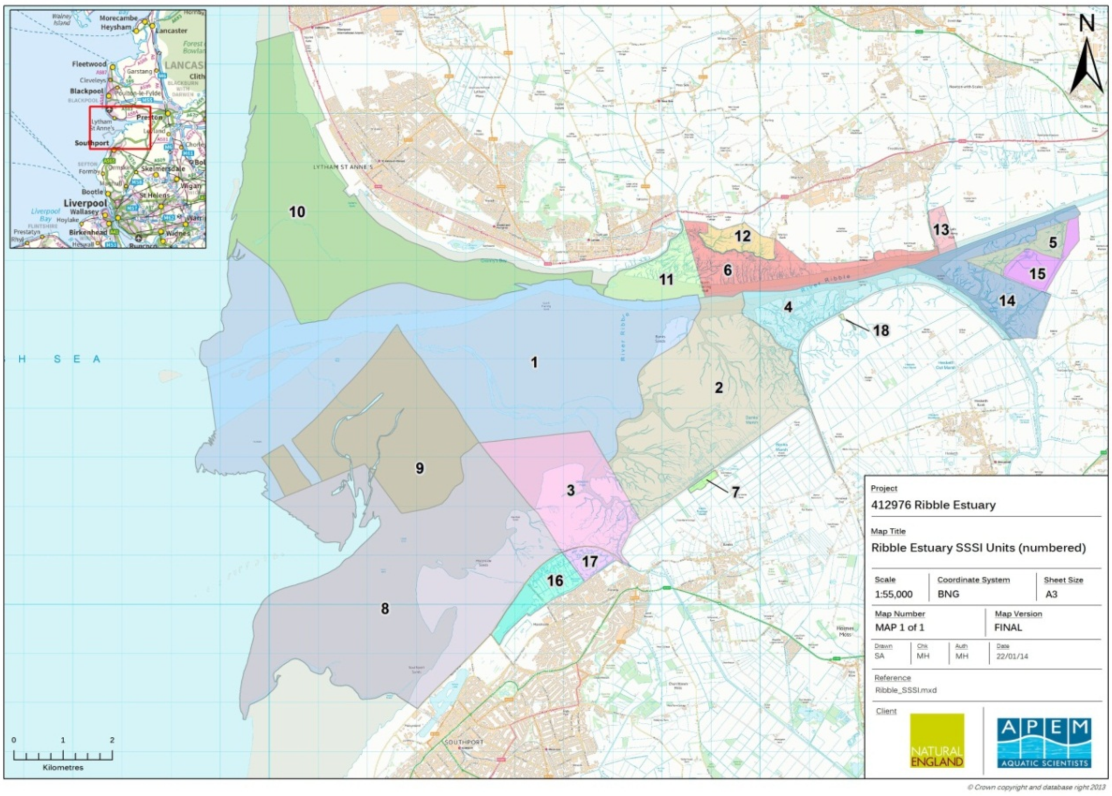


Figure 1. Ribble SSSI boundary indicating Management Units 1-18. © Crown copyright and database right 2013.

The estuary is of international importance for the passage and wintering waterfowl it supports and reasons for SSSI designation include the presence of extensive intertidal mudflats which are rich in invertebrates and provide an important food resource for waders and wildfowl, along with sandbanks which provide roosting areas for a range of bird species. The SSSI also has one of the largest areas of grazed green marsh in Britain and includes small areas of recently reclaimed saltmarsh, the saltmarsh also providing roosting areas for a range of bird species.

Although the SSSI forms the focus of the monitoring, the data collected will also contribute to the assessment of prey availability for SPA bird species which is required for condition assessment for the Ribble and Alt Estuaries SPA and Ramsar site.

1.3 Previous surveys

Few previous survey have been conducted of intertidal sediments within the Ribble Estuary, however, two recent studies provide an opportunity to assess temporal variation in SSSI site characteristics: a Maritime Monitoring Intertidal Survey of North West England 2005-2006 (Royal Haskoning (RH) 2006), and a survey in 2007 to inform condition assessment (IECS 2008). Both of these surveys deployed qualitative sampling techniques involving *in situ* sieving of sediment and biotope allocation along pre-determined transects (Phase I survey). The 2007 survey covered the same transects as the 2005 survey and a number of additional transects. There were no quantitative data available, however, from previous surveys.

1.4 Survey Aims and Objectives

The main objectives of the study were to:

- Conduct a qualitative Phase I survey to map the distribution and extent of biotopes along previously surveyed transects, and to sample previously unsurveyed areas of the SSSI;

- Conduct a quantitative coring survey (compatible with Water Framework Directive (WFD) survey methodology) to sample infauna and conduct Particle Size Analysis (PSA) within the Units surveyed and provide a repeatable, rigorous quantitative sampling design and baseline data to allow future status to be assessed;

- Collect sediment samples for contaminant analysis at a single pre-determined site;

- Record any anthropogenic pressures observed which could potentially be impacting intertidal mud and sandflats;

- Using historical datasets, as far as possible, provide an assessment of temporal changes in biotope distribution, extent and composition, and sediment characteristics to inform a preliminary condition assessment for the SSSI Units surveyed.

2 METHODOLOGY

Field survey methods incorporated a combination of qualitative *in-situ* biotope assessment (Phase I) and quantitative coring survey (Wyn *et al*., 2000; Davies *et al*., 2001; JNCC 2004). The Phase I survey provided a broad characterisation of the biotopes present within the SSSI Units while the quantitative survey focused on the dominant biotopes and provided species abundance data suitable for the application of statistical analyses.

2.1 Survey locations

A total of thirteen transects were surveyed within the SSSI management Units 1, 8, 9 and 10 (Figure 2). Seven of these had previously been surveyed in 2005 (RH 2006), and eleven had been surveyed in 2007 (IECS 2008). The remaining two transects (Transects 7 and 12) were located within previously unsurveyed areas.

The Phase I survey was conducted along the extent of each of the transects. For the quantitative coring survey a pool of 70 previously surveyed sites, and 10 new sites (across Transects 7 and 12) were selected prior to the survey as they were considered likely to encompass the range of biotopes present within the SSSI. A subset of 40 of these were then sampled quantitatively in the field based on the following criteria (Figure 2):

- Core sites were located within representative biotopes, based on the findings of the Phase I survey.

- Sites encompassed high, mid and lower shore positions on each transect.

2.1.1 Site Access

The four transects on the southern side of the estuary (Transects 9, 11, 12 and 13) were effectively and safely surveyed by foot. For the sites on the northern side of the estuary, due to health and safety (H & S) considerations and to optimise survey efficiency, a 4 x 4 vehicle (Mitusbishi L200) driven by a local fisherman was used to access and transit between sites. Local knowledge was required to identify the locations of potential obstacles on the foreshore including deep water channels, and to avoid potential dangers such as soft sediment. In some instances the vehicle was placed on skids to limit the risk of sinking into the sediment while stationary during sampling (Plate 1a).

Transect 7 was located south of the main river channel, while Transects 8 and 10 and the lower shore sections of Transect 9 were located on sandbanks including Foulnaze Bank which were in the middle of the outer estuary. These Transects were separated from the main shore by channels and were accessed by a shallow draft 19 ft boat skippered by a local fisherman (Plate 1b). For H & S reasons as much of the survey work as possible was carried out during the ebb tide, which required the boat to be beached at a midpoint on the sandbank during an ebbing tide. The boat provided a platform for the field scientists to work from and following completion of the survey the field scientists returned to the boat which was mobilised on the incoming tide. To ensure there was enough water to get across to the sand bank safely it was important to launch the boat no more than four hours after high water, consequently due to the time of low water it was necessary to navigate to the site before sunrise. Light levels increased rapidly once on site, although during low light periods head torches were required, with teams navigating using GPS and maintaining regular contact by phone, with satellite phones available as back up. Access permissions were obtained from local land owners where required.

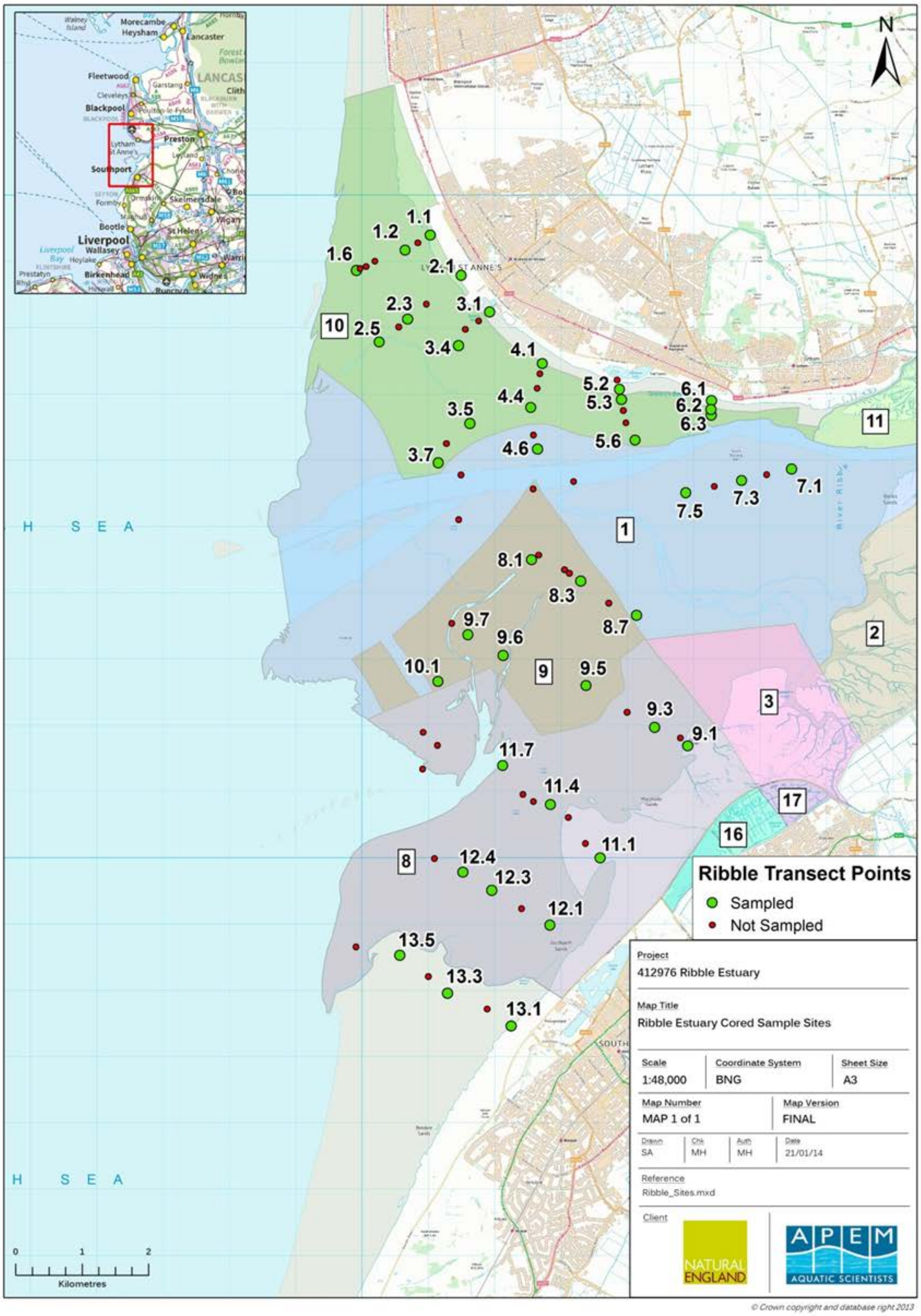


Figure 2. Map indicating the pool of sites identified pre-survey for potential sampling and the quantitative core sites sampled (indicated by green dots). Sampling locations use a two-number label system combining Transect number (1 to 13) and site code (1 to 7). Numbers of the SSSI Units are also indicated (boxed numbers). © Crown copyright and database right 2013.

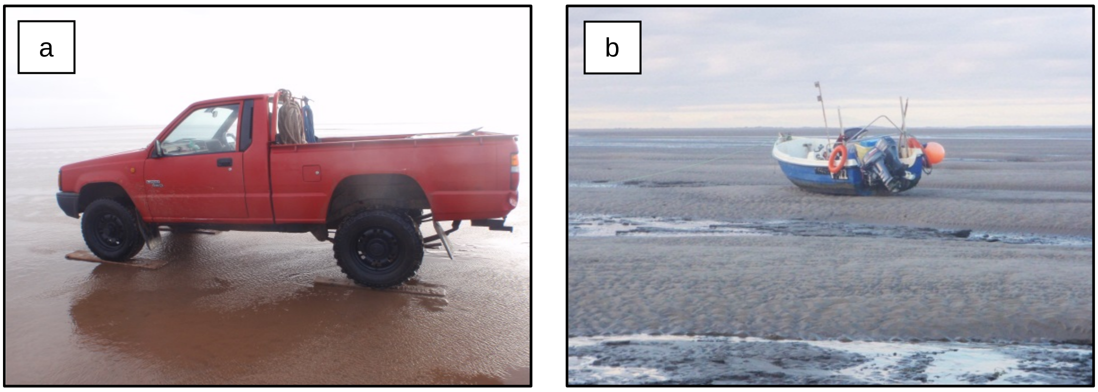


Plate 1. a) 4 x 4 vehicle on skids; b) Survey vessel beached on sandbank.

2.2 Timing of survey

Field work was conducted during spring tides to optimise the length of time available for each survey and ensure the lower reaches of the shores could be sampled. Due to the time of year, the times of low tide and available hours of daylight were not ideal for survey and in some instances it was necessary to work parts of both tides each day (Table 1). This schedule was considered the most practical and time efficient way to collect the maximum amount of information in the time available within the tidal window. Further details including consideration of H & S issues are provided in APEM (2013).

Table 1. Survey information including tide times (based on BST), tide heights, survey location, method of survey and time spent on foreshore.

Date	Time of sunrise/ sunset (BST)	Time of low tide (BST)	Height of low tide (m)	Team	Location	Method	Time on shore	Time off shore
18/09/13	06:52/ 19:20	05:16 & 17:36	1.06 & 1.17	1	Transect 1 & 2	4 x 4	15:00	19:45
				2	Transect 13	Foot	14:15	18:30
19/09/13	06:54/ 19:17	06:01 & 18:19	0.74 & 0.87	1	Transect 3 & 4	4 x 4	14:00	19:00
				2	Transect 12	Foot	07:00	09:30
						Foot	14:30	18:30
20/09/13	06:56/ 19:15	06:42 & 18:59	0.57 & 0.75	1	Transect 5 & 6	4 x 4	14:00	18:50
				2	Transect 11	Foot	07:00	10:15
						Foot	14:30	18:00
21/09/13	06:58/ 19:12	07:21 & 19:37	0.61 & 0.81	1	Transect 7	Boat and foot	05:15	08:30
				2	Transect 9 upper and mid shore	Foot	07:00	10:00
22/09/13	07:00/ 19:10	07:57 & 20:13	0.83 & 1.07	1	Transect 8	Boat and foot	04:45	08:30
				2	Transect 9 (lower shore) & 10	Boat and foot	04:45	08:30

2.3 Survey approach

2.3.1 Phase I habitat survey

A Phase I 'walkover' survey was conducted to obtain standardised information for the habitat 'Mudflats and sandflats not covered by seawater at low tide (H1140)' (EUNIS code A2), including A2.1 Littoral coarse sediment, A2.2 Intertidal sand and muddy sand and A2.3 Intertidal mud. The Phase I survey was designed to map the extent and distribution of soft sediment biotope complexes/biotopes/sub-biotopes while providing qualitative data for the invertebrate assemblages present.

Phase I *in situ* biotope mapping was undertaken following best practice guidance including the Countryside Council for Wales (CCW) Handbook for Marine Intertidal Phase I mapping surveys (Wyn *et al*. 2000), Marine Monitoring Handbook (Davies *et al*. 2001) and Common Standards Monitoring (CSM) guidance (JNCC 2004).

Habitat types were assigned according to JNCC's National Marine Habitat Classification for Britain and Ireland: Version 04.05 (Connor *et al.* 2004) based on considerations including the species present, relative abundances of species, exposure of the shore and substrate type. A proportion of assignments were verified by a second taxonomist to provide quality control and consistency in the assignments. JNCC's correlation table (JNCC 2010) was then used to assign EUNIS codes to each biotope. When discussing habitat types the JNCC Classification hierarchy has been 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 has been used where more than one level is discussed while terms for specific levels have been used where appropriate.

The Phase I survey involved moving along transects along a bearing using a handheld dGPS (either by foot or in a vehicle). The transects were followed along their whole length where possible and visual inspection of sediments was undertaken, including sediment 10 m either side of the transect. In some cases in the northern estuary, where a vehicle was used, it was not possible to follow the exact route of the transect. This was due to the necessity to avoid obstacles such as channels, and areas of soft sediment. In these instances a detour was made to avoid the obstacle and the transect was resumed as near as possible to the point of departure.

Any noticeable changes in sediment type or surface features were recorded, and a GPS reading for each boundary was taken. Within each distinct sediment type, one or more locations were sampled *in situ*. At these locations a single 0.01 m^2 core was inserted into the sediment to a depth of 15 cm, the contents sieved through a 0.5 mm mesh sieve (Plate 2) and conspicuous fauna were identified to the lowest level practicable. In some instances the location of the biotope sample site was the same as the quantitative core location to ensure that cores were being collected at appropriate locations and to provide some qualitative data that could be compared with the Phase I data collected at the same sites during the 2007 survey (IECS 2008).

In addition, at each *in situ* sieve site note was made of sediment characteristics including sorting, firmness, stability, surface relief, and depth of redox layer; the numbers of *Arenicola marina* casts and *Lanice conchilega* worm tubes per m^2; the number of *Scrobicularia plana* marks and any other conspicuous species such as macroalgae (with estimate of abundance/cover when present).

Plate 2. Core sample before (left) and after sieving (right).

2.3.2 Quantitative survey

2.3.2.1 Fauna

To gather robust quantitative faunal data for the main biotopes encountered at each of the core survey sites five 0.01 m^2 cores were collected following the CORE methodology in the Marine Monitoring Handbook (Davies *et al.* 2001).

A 0.01 m^2 sediment coring device was inserted into the sediment to a depth of 15 cm. The cores were then partially sieved on site to reduce the volume of the sample and the contents were transferred to labelled plastic sample pots. Once the team had left the intertidal zone the samples were preserved in buffered 4% formaldehyde solution and securely sealed with insulation tape ready for transportation to Hebog Environmental for analysis.

The sediment features and other site information indicated in Section 2.2.1 were recorded at each coring site. In addition height of the sites relative to chart datum was recorded using a Leica Viva GNSS GS08 receiver (horizontal accuracy 10-15 mm, vertical accuracy 20 mm).

2.3.2.2 Particle size distribution

At each coring site a single 0.01m^2 sediment core was extracted to a depth 15 cm to provide a sediment sample for PSA. Sediment samples were gathered in accordance with the National Marine Biological Analytical Quality Control Scheme (NMBAQC) best practice guidance. Samples were placed into pre-labelled sealable plastic containers, frozen within 24 hours of collection, and kept frozen until transportation to the National Laboratory Service (NLS) for analysis.

2.3.2.3 Contaminant analysis

Sediment surface scrape samples were taken from Site 7.3 in the middle of Transect 7 for the analysis of heavy metals and organic contaminants (one scrape sample for each).

A clean hand trowel was used to collect approximately 500 ml of sediment from the top 1 cm of the substrate (a plastic trowel for the heavy metal sample, and a metal trowel for the organic contaminants sample). The samples were transferred to pre-labelled sterile containers provided by NLS (a plastic container for the heavy metal sample and a glass container for the organic contaminants sample). Samples were frozen within 24 hours of collection, and kept frozen until transportation to NLS.

2.3.2.4 Invasive non-native species

Any invasive non-native species identified either on site or within the core samples were noted. APEM scientists worked in accordance with standard good practice biosecurity measures to avoid the spread of INNS. Measures adhered to on site included:

- Equipment, clothes and boots were cleaned before carrying out any work on site;
- When on or near water, equipment was drained after use and dried as far as possible; and
- Clothes and boots were dried thoroughly between survey days.

2.3.3 Recording of Anthropogenic Influences

Anthropogenic influences which may impact upon identified features were noted and, where appropriate, the GPS coordinates of the pressure were recorded along with the description of the pressure.

2.3.4 Photographic Evidence

Photographs were taken of sites and representative biotopes where possible. Photographss of Phase I biotope cores were also taken before and after sieving. A full photograph log can be found in Appendix 1.

2.4 Laboratory analyses

2.4.1 Invertebrate samples

Samples were analysed in compliance with National Marine Biological Analytical Quality Control (NMBAQC) scheme guidelines and in adherence to the guidelines set out in ISO 16665 by the analytical laboratory identified by Natural England for this contract. The samples were sieved over standard mesh tested sieves (4 mm, 2 mm, 1 mm, 0.5 mm). All of the fauna removed from the samples were identified to the lowest taxonomic level practicable, usually species, and enumerated. Colonial organisms such as hydroids, bryozoans and sponges were recorded as “Present”.

2.4.2 Sediment samples

PSA was performed based on the NMBAQC Best Practice Guidance document. Samples were homogenised by stirring before a large representative subsample was taken. Size bandings were determined by sieving for Phi sizes 0 to -6 (1000 µm to 63,000 µm) and by laser diffraction using a Malvern Laser Diffraction Particle Sizer (Mastersizer 2000) for Phi sizes 0 to 10 (1000 µm to 0.98 µm). Contaminant analysis was conducted based on standard protocols for each of the determinands and in accordance with the methodologies and limits of detection in use by NLS for marine sediment samples.

2.5 Mapping and Data Analysis

On completion of the surveys, raw data were transferred to electronic spreadsheets including general site descriptions with sediment characteristics and surface feature information. The GPS waypoints were subsequently used to create linear habitat type extent maps produced for each transect.

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).

2.5.1 Faunal data

Data truncation

The only data truncation required was to combine closely related species to a higher level taxon where appropriate.

Univariate statistics

The following indices were calculated for each faunal sample using the DIVERSE function of PRIMER (Plymouth Routines In Multivariate Ecological Research) version 6.1.15. (Clarke & Warwick 2001, Clarke & Gorley 2006).

- number of taxa (S);
    - The total number of taxa in a core sample.
- number of individuals (N);
    - The total number of individuals in a core sample.
- Shannon-Weiner Diversity Index (loge) (H');
    - An estimate of biodiversity which considers the overall species numbers along with aspects of dominance.
- Margalef's index of richness (d);
    - A measure of the number of species present for a given number of individuals i.e. overall species richness per unit of abundance.
- Pielou's evenness (J');
    - A measure of the equitability of the species assemblage in terms of the number of species and their dominance.

Values of each summary statistic were calculated for each replicate core, however, for data presentation the mean values across the five cores at each site have been provided.

Multivariate statistics

Multivariate analysis of the 2013 data was beyond the scope of the survey contract, however, multivariate techniques were applied to compare data collected in 2007 and 2013. As the data collected during previous surveys were qualitative it was not possible to compare quantitative core data from the 2013 survey with previous surveys. Counts of individual species were available, however, for biotope sieve sites sampled in 2007 and sediment from 16 of these sites was also sieved *in situ* in 2013 as part of the Phase I survey. As the volume of sediment sieved at each site in 2007 was unknown a direct comparison of count data was not appropriate and it was necessary to transform data to presence/absence prior to analysis.

Hierarchical clustering was carried out on a Jaccard similarity matrix of the transformed *in situ* sieve data in order to visualise the biological similarity between samples across the SSSI. The similarity profile (SIMPROF) test was implemented as part of the clustering routine. This permutational test was used to identify clusters of samples that could not be statistically separated at the 5% significance level. Non-metric Multi-dimensional Scaling (MDS) was used to visually explore the relationships between samples.

The analysis of similarity (ANOSIM) test was used to test for differences in species assemblages between years and between different areas of the estuary (estuary partitions). The ANOSIM test is analogous to the parametric ANOVA and tests the null hypothesis (H_0) of ‘no difference between pre-defined groups’. The global test produces a summary statistic termed ‘R’, which is an indication of the degree of separation between groups, along with a p-value to indicate significance of the results.

2.5.2 Particle size distribution

PSA data were split into size fractions (µm) and checked to ensure the total percentage of sediment was 100% (+/- 1%) to identify any discrepancies. The particle size data from all survey years was combined as consistent size fractions and entered into GRADISTAT to produce sediment classifications (following Folk (1954), Figure 3) and summary statistics, including mean (Phi), sorting, skewness and kurtosis (following Blott & Pye 2001).

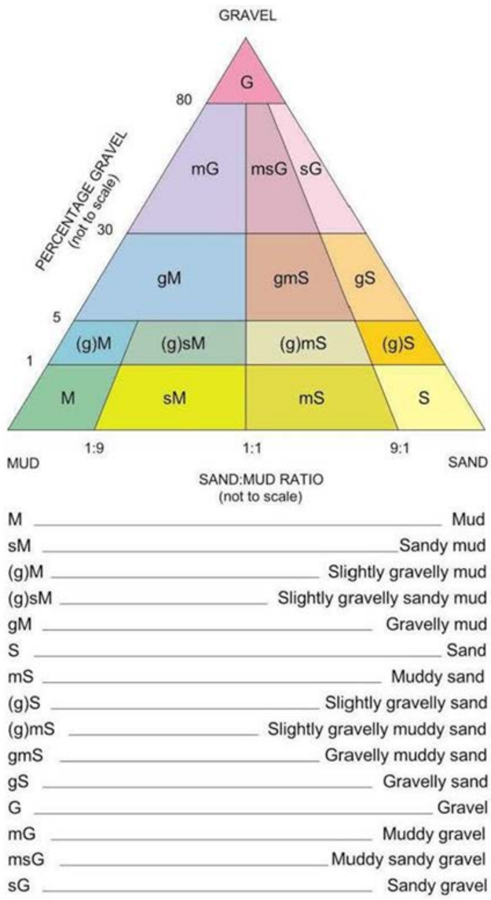


Figure 3. Folk classification system based on Folk (1954). Figure from Long (2006).

2.5.3 Contaminant data

Contaminant concentrations in the two sediment sample scrapes collected were compared to standards indicated in the OSPAR Coordinated Environmental Monitoring Programme (CEMP) (OSPAR 2012). This document provides Background Assessment Concentrations (BACs), Effects Range-Low (ERLs) and Environmental Assessment Criteria (EACs) for selected hazardous substances prioritised for action by OSPAR due to their risk for the marine environment (Appendix 2):

BACs were developed for testing whether concentrations are near background levels. Mean concentrations significantly below the BAC are said to be near background.

ERLs were developed by the United States Environmental Protection Agency for assessing the ecological significance of sediment concentrations. Concentrations below the ERL rarely cause adverse effects in marine organisms. Concentrations above the ERL will often cause adverse effects in some marine organisms. For sediment assessments, CEMP data assessment criteria only provide ERL values for polychlorinated biphenyls (PCBs) (Appendix 2).

EACs were developed by OSPAR and the International Council for the Exploration of the Sea for assessing the ecological significance of sediment concentrations. Concentrations below the EAC should not cause any chronic effects in marine species. For sediment assessments, CEMP data assessment criteria provide EAC values for all contaminant groups other than PCBs (Appendix 2).

3 RESULTS

3.1 Habitat Types

The Ribble Estuary consisted of littoral sand and muds and across the survey area a total of 12 habitat types were recorded (Table 2), (Phase I survey data are provided in Appendix 3).

Table 2. Habitat types allocated to the Ribble Estuary sample sites and the number of sites at which they were recorded.

EUNIS code	JNCC Biotope Code	Biotope Description	Number of core sites at which recorded
A2.231	LS.LSa.FiSa.Po	Polychaetes in littoral fine sand	9
A2.244	LS.LSa.MuSa.BatCare	*Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand	7
A2.2313	LS.LSa.FiSa.Po.Ncir	*Nephtys cirrosa* dominated littoral fine sand	5
A2.242	LS.LSa.MuSa.CerPo	*Cerastoderma edule* and polychaetes in littoral muddy sand	4
A2.243	LS.LSa.MuSa.HedMacEte	*Hediste diversicolor*, *Macoma balthica* and *Eteone longa* in littoral muddy sand	4
A2.2232	LS.LSa.MoSa.AmSco.Eur	*Eurydice pulchra* in littoral mobile sand	4
A2.22	LS.LSa.MoSa	Barren or amphipod dominated mobile sand shores	2
A2.312	LS.LMu.MEst.HedMac	*Hediste diversicolor* and *Macoma balthica* in littoral sandy mud	1
A2.223	LS.LSa.MoSa.AmSco	Amphipods and *Scolelepis* spp. in littoral medium fine sand	1
A2.24	LS.LSa.MuSa	Polychaete / bivalve dominated muddy sand shore	1
A2.7212	LS.LBR.LMus.Myt.Sa	*Mytilus edulis* beds on littoral sand	1
A2.221	LS.LSa.MoSa.BarSa	Barren littoral coarse sand	1

The most frequently recorded habitat type was ‘Polychaetes in littoral fine sand’ (LS.LSa.FiSa.Po) recorded at nine of the 40 sites, followed by ‘*Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand’ (LS.LSa.MuSa.BatCare) at seven sites, and ‘*Nephtys cirrosa* dominated littoral fine sand’ (LS.LSa.FiSa.Po.Ncir) at five sites. The biotope LS.LSa.FiSa.Po was recorded at upper, mid and lower shore transect sites, the sub-biotope LS.LSa.MuSa.BatCare was mainly recorded on the upper shore and the sub-biotope LS.LSa.FiSa.Po.Ncir was mainly recorded on the lower shore in Units 8 and 9 (Figures 4 and 5).

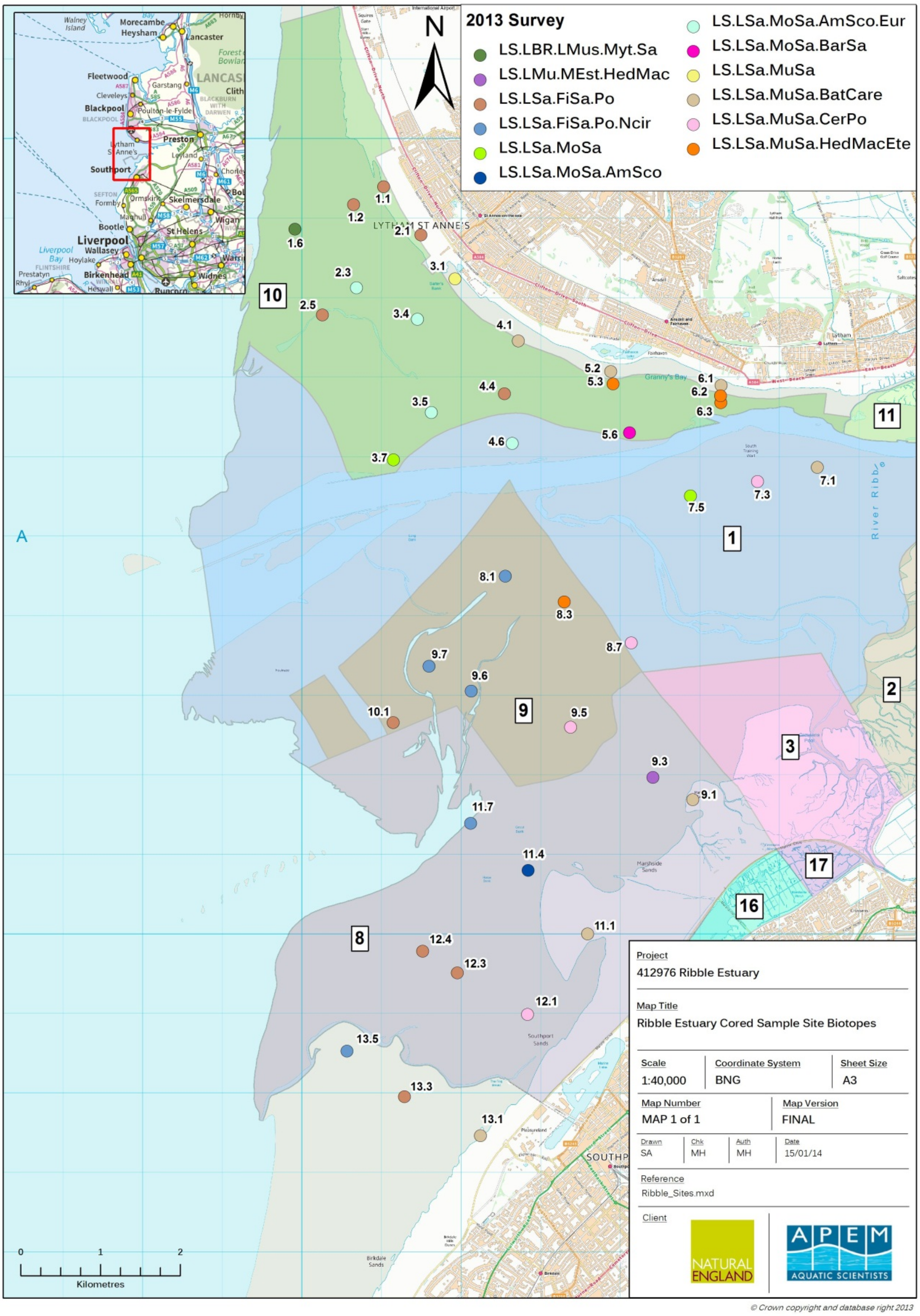


Figure 4. Map of biotopes recorded at quantitative survey sites across the Ribble Estuary. © Crown copyright and database right 2013.

Figure 5. Map of linear extent of habitat types along transects based on a combination of Phase I and quantitative coring survey across the Ribble Estuary SSSI Units 1, 8, 9 and 10. © Crown copyright and database right 2013.

3.1.1 Habitat types within SSSI Management Units

A map of linear extent of habitat types as determined during the Phase I survey element of the fieldwork is provided in Figure 5.

3.1.1.1 Management Unit 1

The lower shore sections of Transect 3 and 4 were in Unit 1, along with the eastern extent of Transect 8 and the whole of Transect 7 which ran parallel to the river channel (Figure 5).

Table 3. Habitat types recorded within Management Unit 1.

		Transect			
EUNIS code	**JNCC Biotope code**	**3**	**4**	**7**	**8**
A2.22	LS.LSa.MoSa	✓		✓	
A2.2232	LS.LSa.MoSa.AmSco.Eur		✓		
A2.244	LS.LSa.MuSa.BatCare			✓	
A2.242	LS.LSa.MuSa.CerPo			✓	✓

Sediment on the lower shore areas of Transects 3 and 4 was generally mobile sand. Fauna were sparse on the section of Transect 3 within the Unit (LS.LSa.MoSa) while on the lower shore on Transect 4 there were abundant amphipods, isopods (*Eurydice pulchra*), and a range of polychaetes including *Scolelepis squamata* (LS.LSa.MoSa.AmSco.Eur). The southern extent of Transect 8 which extended into Unit 1 was sand with some gravel content and cockle *Cerstoderma edule* was common (LS.LSa.MuSa.CerPo).

Transect 7 on the flats to the south of the river channel near the southern training wall was generally sandy with some mud at the eastern extent which was characterised by the presence of the amphipods *Bathyporeia* spp. *and Corophium* spp. with *Macoma balthica* and some polychaetes (LS.LSa.MuSa.BatCare). The sediment within the central section of Transect 7 was better drained and less muddy than at the eastern extent and *C. edule* was abundant (LS.LSa.MuSa.CerPo). Sediment at the western section of the transect was mainly sandy and *Bathyporeia* spp. were common but other infauna were sparse (LS.LSa.MoSa).

Plate 3. Examples of biotopes recorded in Management Unit 1: *Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand (LS.LSa.MuSa.BatCare); *Cerastoderma edule* and polychaetes in littoral muddy sand (LS.LSa.MuSa.CerPo).

3.1.1.2 Management Unit 8

Transects 10, 11 and 12 were located in this Unit along with upper and mid shore sections of Transect 9. Transect 13 is located just south of the southern border of the Unit but is included within the Unit description as it is characteristic of the habitat types within the Unit (Figure 5).

Table 4. Habitat types recorded within Management Unit 8.

		Transect				
EUNIS code	**JNCC Biotope code**	**9**	**10**	**11**	**12**	**13**
A2.244	LS.LSa.MuSa.BatCare	✓		✓		✓
A2.312	LS.LMu.MEst.HedMac	✓				
A2.223	LS.LSa.MoSa.AmSco			✓		
A2.2313	LS.LSa.FiSa.Po.Ncir			✓		✓
A2.231	LS.LSa.FiSa.Po		✓		✓	✓
A2.242	LS.LSa.MuSa.CerPo				✓	

The upper shore of the northern half of this management Unit is an area of saltmarsh. At the upper shore site on Transect 9 the sediment was muddy and *Salicornia* spp. was common although plants were not considered sufficiently dense to allocate the saltmarsh biotope complex. The biotope LS.LSa.MuSa.BatCare was allocated to the upper shore site as *Corophium* spp. were superabundant, however, no *Bathyporeia* spp. individuals were present and Enchytraidae was also recorded. This biotope then transitioned into sandier substrate with *M. balthica*, *Hediste diversicolor* and a range of polychaetes (LS.LMu.MEst.HedMac) which extended to the boundary of the Unit.

The upper extent of Transect 11 was similar to that of Transect 9 with some *Salicornia* plants, again there were abundant *Corophium* spp. and Enchytraidae but no *Bathyporeia* spp. (A2.244), this habitat transitioned into sandier sediment with abundant *S. squamata*, amphipods and a range of polychaetes (LS.LSa.MoSa.AmSco), with a further transition on the lower mid and lower shore to a more diverse range of polychaetes including *Nephtys cirrosa* and amphipods were largely absent (LS.LSa.FiSa.Po.Ncir).

On the upper shore on Transect 12 sediment was sandy and firm underfoot and *C. edule* was common, along with *M. balthica* and low numbers of a range of polychaetes (A2.242), the mid and lower shore was clean fine sand supporting a range of polychaetes with some *M. balthica* and amphipods on the mid shore (LS.LSa.FiSa.Po).

Transect 13 had a similar range of biotopes to other transects in the Unit with *Corophium* spp. dominating sediment on the upper shore (LS.LSa.MuSa.BatCare*)*, and a transition to polychaete dominated fine sands on the mid to lower shore (LS.LSa.FiSa.Po and LS.LSa.FiSa.Po.Ncir).

Fauna were found to be sparse where sediments were sieved at the start of the Transect 10 although some polychaetes were present and the presence of a water channel prevented access to the majority of the transect which was located on regularly reworked sand banks. The sediment, however, had well defined surface ripples and this transect was assigned the biotope LS.LSa.FiSa.Po .

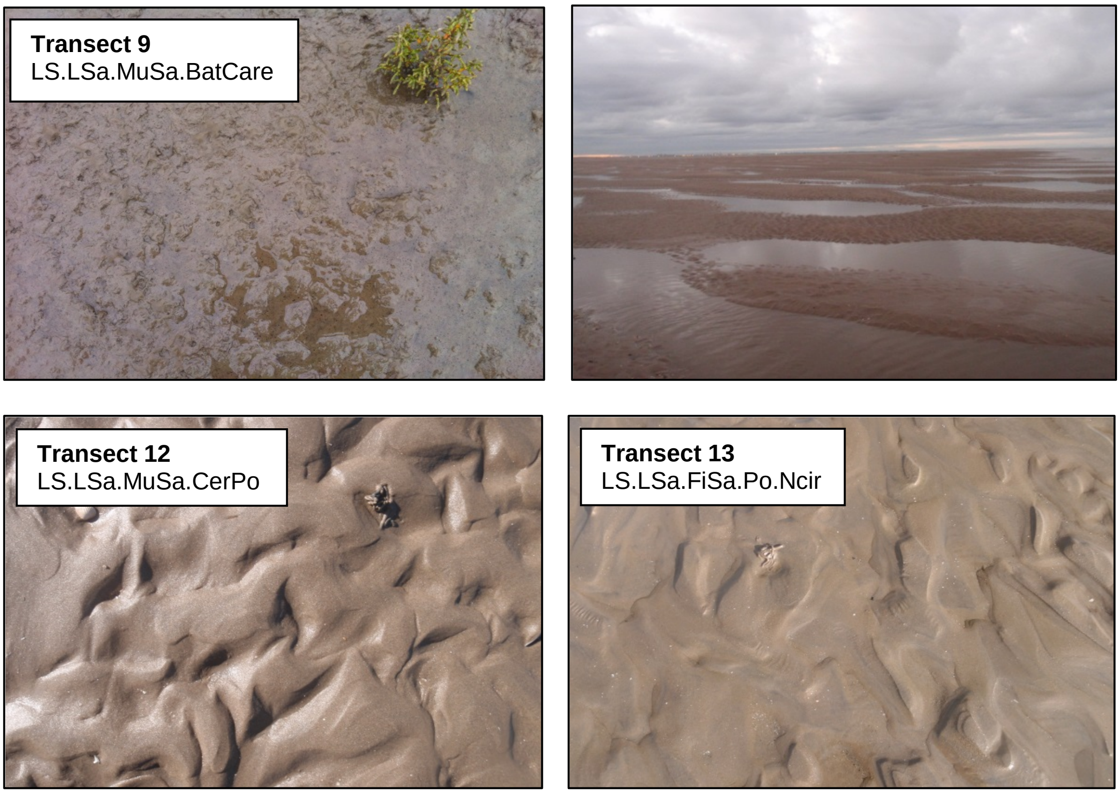


Plate 4. Examples of biotopes/sub-biotopes recorded in Management Unit 8: *Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand (LS.LSa.MuSa.BatCare); Polychaetes in littoral fine sand (LS.LSa.FiSa.Po); *Cerastoderma edule* and polychaetes in littoral muddy sand (LS.LSa.MuSa.CerPo); *Nephtys cirrosa* dominated littoral fine sand (LS.LSa.FiSa.Po.Ncir).

3.1.1.3 Management Unit 9

The majority of Transect 8 and the mid to lower section of Transect 9 were within the boundary of management Unit 9, along with the northern extent of Transect 10.

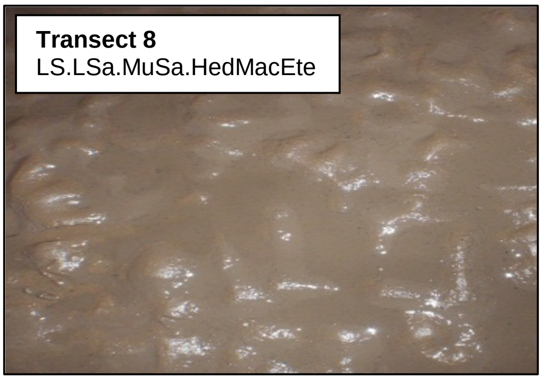
Table 5. Habitat types recorded within Management Unit 9.

		Transect		
EUNIS code	**JNCC Biotope code**	**8**	**9**	**10**
A2.231	LS.LSa.FiSa.Po			✓
A2.2313	LS.LSa.FiSa.Po.Ncir	✓	✓	
A2.243	LS.LSa.MuSa.HedMacEte	✓		
A2.242	LS.LSa.MuSa.CerPo	✓	✓	

The whole of this management Unit was comprised of mid to outer estuary intertidal flats. In general terms the mid and eastern sections of Transect 8 had greater mud content than the fine sands of the western section which had very sparse fauna due to the sediment being reworked on each tide although *N. cirrosa* was abundant (LS.LSa.FiSa.Po.Ncir). The muddier mid-section of the transect had abundant *M. balthica* and was allocated the biotope LS.LSa.MuSa.HedMacEte (although *H. diversicolor* was not recorded, a number of other polychaetes were found in low numbers). *C. edule* was also present in this area but at far lower abundances than *M. balthica*. Occasional *L. conchilega* tubes were observed on the surface along the mid-section of Transect 9 along with abundant scattered empty tubes likely washed from the sediment during a recent storm event.

Towards the east of this transect the numbers of *M. balthica* were a lot lower and *C. edule* was a more dominant component of the fauna along with abundant *Pygospio elegans* and low numbers of other polychaetes including *N. cirrosa* (LS.LSa.MuSa.CerPo).

The mid and lower parts of Transect 9 extended into Unit 9, with the mid-section characterised by abundant *C. edule* along with abundant *Spio martinensis* and common *M. balthica* and low numbers of a range of polychaetes (LS.LSa.MuSa.CerPo). This area transitioned on the mid-lower to lower part of the transect to an area where molluscs were generally in very low numbers or absent and a wide range of polychaetes characterised the infauna, including *N. cirrosa* (LS.LSa.FiSa.Po.Ncir)). The western extent of the Unit included the start of Transect 10 and was considered to be an area of fine reworked sands with some polychaetes but generally sparse infauna (LS.LSa.FiSa.Po).



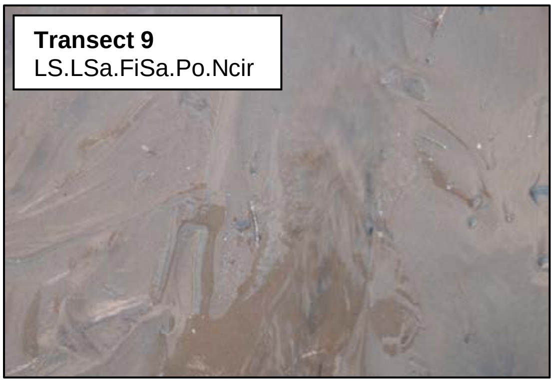


Plate 5. Examples of biotopes/sub-biotopes recorded in Management Unit 9: *Hediste diversicolor*, *Macoma balthica* and *Eteone longa* in littoral muddy sand (LS.LSa.MuSa.HedMacEte); *Nephtys cirrosa* dominated littoral fine sand (LS.LSa.FiSa.Po.Ncir); *Cerastoderma edule* and polychaetes in littoral muddy sand (LS.LSa.MuSa.CerPo); *Nephtys cirrosa* dominated littoral fine sand (LS.LSa.FiSa.Po.Ncir).

3.1.1.4 Management Unit 10

Transects 1, 2, 3, 4, 5 and 6 were located within this Unit.

Table 6. Habitat types recorded within Management Unit 10.

		Transect					
EUNIS code	**JNCC Biotope code**	**1**	**2**	**3**	**4**	**5**	**6**
A2.231	LS.LSa.FiSa.Po	✓	✓		✓		
A2.2313	LS.LSa.FiSa.Po.Ncir	✓					
A2.223	LS.LSa.MoSa.AmSco	✓	✓				
A2.2232	LS.LSa.MoSa.AmSco.Eur		✓	✓			
A2.7212	LS.LBR.LMus.Myt.Sa	✓					
A2.24	LS.LSa.MuSa			✓			
A2.22	LS.LSa.MoSa			✓			
A2.221	LS.LSa.MoSa.BarSa					✓	
A2.244	LS.LSa.MuSa.BatCare				✓	✓	✓
A2.243	LS.LSa.MuSa.HedMacEte					✓	✓
A2.312	LS.LMu.MEst.HedMac					✓	

All of the transects in this Unit ran from the upper to lower shore. The transect nearest the inner section of the estuary around Granny's Bay (Transect 6) was far muddier than each of the other transects and the sediment became sandier and firmer moving towards to the western section of Unit 10 at Lytham St Annes.

On Transects 1 and 2 at Lytham St Annes the upper shore was characterised by firm sandy habitat with a range of polychaete species although amphipods were also abundant on Transect 1 (LS.LSa.FiSa.Po). The community remained similar in the mid shore on Transect 1 with abundant *S. martinensis* and amphipod numbers were very low (LS.LSa.FiSa.Po.Ncir). The fauna in sediments on the lower shore area on Transect 1 differed from the mid to upper shore stations in that some organisms, not typical of sediment shores, were identified in the cores (e.g. high numbers of juvenile brittlestars (Ophiuroidea), and fragments of hydroids and bryozoans). A large number of empty razor shells *Ensis* spp. were also present scattered over the sediment surface. It is considered the assemblage within this areas was strongly influence by storm events which occurred in the weeks before the survey bringing the shell debris and introducing fauna which was uncharacteristic of these habitats. On the lower shore on Transect 1 the sample site was dominated by juvenile blue mussel *Mytilus edulis*, these individuals were all juveniles and although they could not be seen on the sediment surface this area was assigned the biotope (LS.LBR.LMus.Myt.Sa) due to the large numbers present.

On Transect 2, *S. squamata* was abundant and in some areas the isopod *E. pulchra* was common with these species tolerant of the well-drained medium to fine mobile sand present within this area (LS.LSa.MoSa.AmSco.Eur). Fauna were sparse on the upper shore of Transect 3 (LS.LSa.MuSa) with abundant *S. squamata* and *E. pulchra* on the mid to lower shore (LS.LSa.MoSa.AmSco.Eur) and mobile sands with very sparse fauna were recorded on the lower shore (LS.LSa.MoSa).

The main characterising fauna of the upper sections of transects 4 and 5 was the abundance of *Corophium* spp. and *Bathyporeia* spp. (LS.LSa.MuSa.BatCare), although the polychaete *P. elegans* and oligochaetes were also abundant. This biotope is often found within estuaries on sheltered, upper and mid shore areas of fine to medium grain sand. Mid and lower shore biotopes on Transect 4 were similar to those recorded on Transects 1 to 3. Within the mid shore on Transect 5 *M. balthica* was abundant along with amphipods and a diverse range of polychaetes including *H. diversicolor* (LS.LSa.MuSa.HedMacEte and LS.LMu.MEst.HedMac) and within the lower shore on Transect 5 sands were highly mobile and fauna generally sparse (LS.LSa.MoSa.BarSa).

Transect 6 located in Granny's Bay was more sheltered and had muddier sediment than the other transects along the northern shore. Overall abundances of invertebrates were higher on this transect than the other transects in this Unit. *Corophium* spp. was superabundant on the upper shore along with other abundant species including *E. pulchra*, *M. balthica*, *S. squamata* and *H. diversicolor* (LS.LSa.MuSa.BatCare). In the mid to lower shore areas of the foreshore there was a range of fauna with abundant *M. balthica*, *C. edule*, *Eteone longa*, *S. squamata* and *Tubificoides benedii* and *H. diversicolor* was common (LS.LSa.MuSa.HedMacEte).

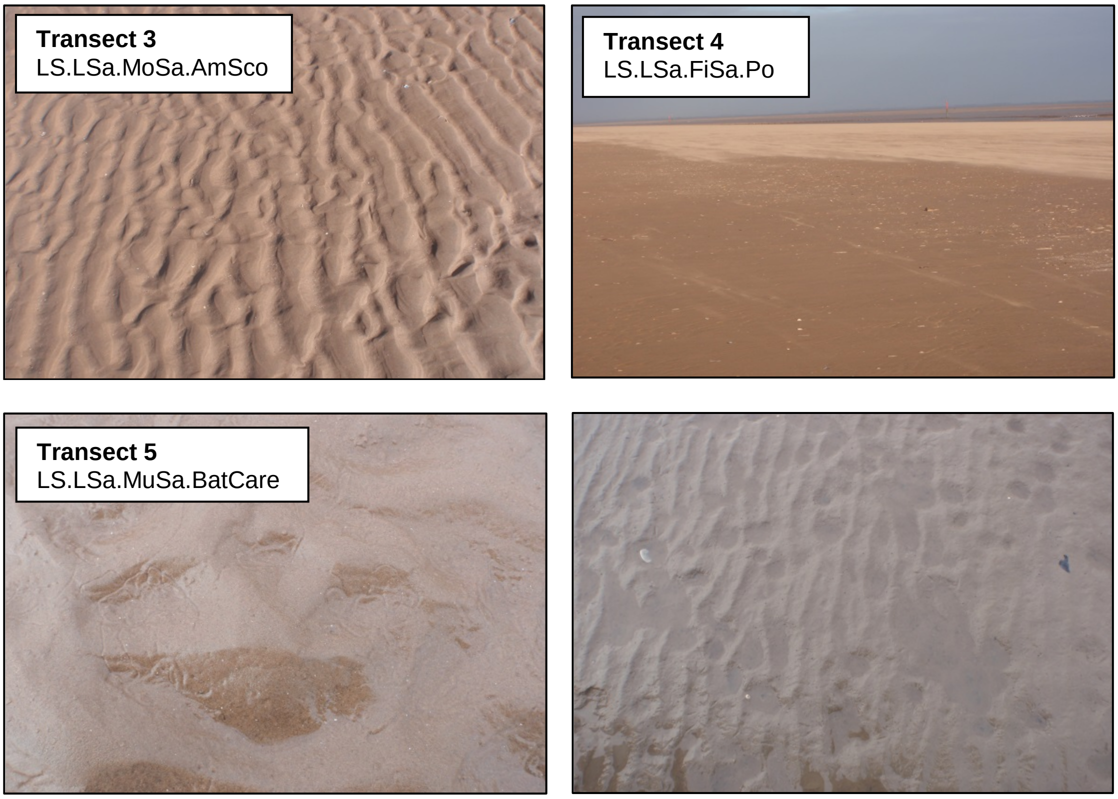


Plate 6. Examples of biotopes recorded in Management Unit 10. Amphipods and *Scolelepis* spp. in littoral medium fine sand (LS.LSa.MoSa.AmSco); Polychaetes in littoral fine sand (LS.LSa.FiSa.Po); *Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand (LS.LSa.MuSa.BatCare); *Hediste diversicolor*, *Macoma balthica* and *Eteone longa* in littoral muddy sand (LS.LSa.MuSa.HedMacEte).

3.2 Faunal communities

3.2.1 Univariate indices

Grid references for the quantitative core sites are provided in Appendix 4. The raw core data collected during the survey are provided as an Excel worksheet (Appendix 3) and summary statistics for each site are provided in Appendix 5.

When discussing faunal data below, each Unit is covered individually, however, an overall view of the Units combined is also provided which is referred to as the 'Ribble Estuary overall' for the purposes of reporting.

3.2.1.1 Summary statistics

Ribble Estuary overall

The mean number of taxa per site across the estuary was 6.8 with a range across sites of 1.6 to 13.8 taxa while the mean number of individuals across replicates at each site varied from 220 to 64,340 individuals per m^2 with an overall mean of 10,261 individuals per m^2 (Table 7). The minimum and maximum values for the Shannon Wiener diversity index (H') were 0.7 and 1.88, respectively, with a mean of 1.24 indicating that diversity was relatively low (Shannon-Weiner diversity had a theoretical range of 0 to a maximum of 4.3 when a single individual of all countable taxa recorded during the survey were found in one sample), (Table 7).

Margalef's species richness (d) had a mean of 1.66 (the maximum potential value for Margalef's index varies according to the number of species present) while the mean values of Simpson's dominance (1- λ) and Pielou's evenness (J') were 0.6 and 0.73, respectively (Pielou's evenness and Simpson's dominance index values can range from 0 to 1, with more even distribution represented by values nearer 1), (Table 7).

Individual Management Units

Unit 1 covers a large area in the centre of the estuary and five sampling sites were located within this Unit (Figure 2). The mean number of taxa across replicates at sites ranged from 4.6 (Site 7.5) to 10.4 (Site 7.3) with an overall mean of 7.44. There was considerable variation in the number of individuals per m^2 at each site ranging from 1,360 at Site 7.5 to 34,300 at Site 7.3 and the mean density across sites was 10,364 individuals per m^2. The mean number of taxa and number of individuals within the Unit was slightly greater than that recorded for the estuary overall (Table 7).

Unit 8 is on the southern side of the outer Ribble estuary extending along the foreshore at Southport (Figure 2). Eleven sampling sites were located within Unit 8 (this includes sites on Transect 13 which was just beyond the southern border of Unit 8 but is representative of the southern section of the Unit). Unit 9 in the middle of the outer Ribble estuary was covered by six sampling sites. The mean number of taxa at sites in Unit 8 and 9 were slightly lower than for the estuary overall with 5.98 and 5.07 taxa, respectively. Similarly the density of individuals in these two Units was lower than for the estuary overall with 6,078 and 4,410 individuals m^2, respectively (Table 7).

Unit 10 runs along the northern coast of the Ribble estuary from just south of Blackpool to Lytham, and south to the northern boundary of Unit 1 (Figure 2). This Unit contained the largest number of sampling locations, with eighteen sampling sites. Compared to the other Units, this Unit has the highest mean number of taxa at sites (7.71 taxa) and the greatest mean density of individuals (14,739 individuals per m^2), (Table 7).

The remaining summary statistics were very similar across Units with ranges of mean values as follows: Shannon Wiener Diversity (1.19 to 1.40), Margalef's Species Richness (1.61 to 1.91), Pielou's evenness (0.68 to 0.82) and Simpson's Dominance (0.58 to 0.67), (Table 7).

Table 7. Summary statistics for the Ribble Estuary overall and for individual Management Units. s.d. = standard deviation.

Unit	Total No. Taxa	Total No. Individs. (per m^2)	Shannon Wiener Diversity (H')	Margalef's Species Richness (D)	Pielou's Evenness (J')	Simpson's Dominance (1-λ)
Ribble estuary overall						
Max	13.8	64,340	1.88	2.63	0.99	0.81
Min	1.6	220	0.70	0.67	0.35	0.35
Mean ± s.d.	6.81 ± 3.1	10,261 ± 14,793	1.24 ± 0.32	1.66 ± 0.42	0.73 ± 0.18	0.60 ± 0.13
Unit 1						
Max	10.4	34,300	1.88	2.21	0.83	0.81
Min	4.6	1,360	1.14	1.38	0.66	0.53
Mean ± s.d.	7.44 ± 1.92	10,364 ± 12,549	1.51 ± 0.27	1.73 ± 0.29	0.75 ± 0.07	0.69 ± 0.10
Unit 8						
Max	9.8	21,540	1.70	2.28	0.95	0.79
Min	1.6	220	0.82	0.67	0.41	0.4
Mean ± s.d.	5.98 ± 2.38	6,078 ± 7,112	1.21 ± 0.33	1.61 ± 0.54	0.73 ± 0.16	0.59 ± 0.12
Unit 9						
Max	8.2	22,920	1.82	2.63	0.99	0.81
Min	2.4	240	0.70	1.22	0.36	0.35
Mean ± s.d.	5.07 ± 2.6	4,410 ± 8,295	1.22 ± 0.43	1.82 ± 0.54	0.85 ± 0.22	0.63 ± 0.16
Unit 10						
Max	13.8	64,340	1.63	2.10	0.98	0.76
Min	2.4	320	0.76	1.16	0.35	0.35
Mean ± s.d.	7.71 ± 3.49	14,739 ± 18,616	1.19 ± 0.25	1.62 ± 0.28	0.68 ± 0.19	0.58 ± 0.12

3.2.2 Taxon density

Ribble Estuary overall

Taxa for which mean densities were ≥10 individuals per m^2 across sites are indicated in Table 8 (this density was an arbitrary cut-off used for data presentation). Taxa were dominated by annelid worms and within this group the polychaete *P. elegans* and nematoda had the joint highest mean densities each with 536 individuals per m^2, these were also the two most widespread taxa recorded at 25 and 22 of the 40 sites, respectively. The oligochaete *T. benedii* had the third greatest mean density, however, it was only recorded at five of the sites and was particularly abundant at Site 6.3, this was followed by the oligochaete family Enchytraeidae which was recorded at 18 sites (Table 8). Only four crustacean taxa were frequently recorded, with the dominant taxa being *Corophium* spp. (mean of 2110 individuals per m^2) and *Bathyporeia* spp. (mean of 612 individuals per m^2) which were recorded at 28 and 30 sites, respectively. The only other crustacean taxon recorded in relatively high numbers was the isopod *E. pulchra* which was found at half of the sites sampled. The shrimp *C. crangon* was found at a quarter of the sites but at relatively low densities (Table 8).

Table 8. Mean density of invertebrate taxa across sites on the Ribble Estuary and the number of sample sites at which recorded (of the 40 sites sampled). s.d. = standard deviation.

Taxon	**Combined Units Density (indivs. m^{-2})**		
	Mean	**s.d.**	**Number of sites**
Annelida			
Pygospio elegans	536	1364	25
Nematoda	536	1177	22
Tubificoides benedii	126	663	5
Enchytraeidae	105	262	18
Scolelepis squamata	79	158	19
Spio martinensis	63	176	9
Eteone longa (agg.)	56	103	17
Psammodrilus balanoglossoides	28	79	7
Capitella capitata	22	56	14
Nemertea	21	34	14
Hediste diversicolor	21	48	10
Nephtys cirrosa	18	36	12
Magelona johnstoni	11	37	4
Crustacea			
Corophium spp.	2110	6586	28
Bathyporeia spp.	612	1315	30
Eurydice pulchra	123	245	21
Crangon crangon	10	20	11
Mollusca			
Peringia ulvae	4972	10,717	31
Macoma balthica	382	789	25
Cerastoderma edule	223	618	21
Mytilus edulis (juv)	91	361	18

The very small mud snail *P. ulvae* was found at 31 of the 40 sites and was the most dominant of the four main mollusc taxa across the sites with a mean density of 4972 individuals per m^2. The Baltic tellin *M. balthica* had the second greatest density with 382 individuals per m^2 recorded at 25 of the sites followed by the cockle *C. edule* which was found at 21 of the sites. Juvenile mussels *Mytilus edulis* were recorded at just under half of the sites sampled (Table 8). All of the other mollusc species recorded had mean densities of less than 10 individuals per m^2 and were present at eight or fewer of the sites.

Overall, the Ribble sites were characterised by relatively high densities of a range of annelid species with one or two crustacean taxa and two or three mollusc species, sometimes in high densities. Density maps across the estuary for annelida, crustacea and mollusca highlight the spatial trends in abundance indicating the relatively low density of invertebrates within Unit 9 and the majority of Unit 8 (Figures 6-8). In general the density of annelids was greater on the northern side of the estuary and at the sites on the upper shore (Figure 6). This was also the case for crustaceans, with highest densities recorded at the upper shore sites on Transects 5, 6, 9 and 11 and the mid to eastern extent of Transect 7 (Figure 7). Mollusc densities were greatest within the upper shore on Transects 5 and 6 and the middle section of Transects 7 and 8 (Figure 8).

Individual Management Units

Within Unit 1, nematoda and *P. elegans* were the two most abundant annelid taxa which was similar to the pattern for the estuary overall, although the density of nematoda was considerably higher than the mean density for the estuary (Table 8 & 9). Compared to the other Units, the density of *S. squamata* was relatively high in Unit 1 (64 individuals per m^2), with *E. longa* the fourth most abundant annelid taxon (48 individuals per m^2). In common with the overall results for the estuary, the four most abundant crustacean taxa were *Bathyporeia* spp., *Corophium* spp., *E. pulchra* and *C. crangon* although in Unit 1 the density of *Bathyporeia* spp. was twice as great as that of *Corophium* spp. (for the estuary overall *Corophium* spp. had a considerably higher mean density than *Bathyporeia* spp.). The four most abundant mollusc taxa in Unit 1 were the same as for the overall pattern for the estuary although the density of *C. edule* was relatively high compared to the other Units (Table 9).

Nematoda, Enchytraeidae and *S. martinensis* were the three annelid taxa with the greatest densities in Unit 8, although the density of nematodes was a third of that recorded in Unit 1 and half that recorded in Unit 10 (Table 9). *P. elegans* was the fourth most abundant annelid taxon. *Corophium* spp. was by far the dominant crustacean taxon in this Unit with a mean of 2626 individuals per m^2 and the second most abundant taxon, *Bathyporeia* spp., only had a density of 167 individuals per m^2. As with all of the Units *P. ulvae* had the greatest density of the molluscs. *M. balthica* had the second greatest density with 125 individuals per m^2 and *A. tenuis* was the fourth most abundant taxon with just 15 individuals per m^2 (Table 9).

The density of annelids in Unit 9 was relatively low compared to the other Units with *S. martinensis* having the greatest density with just 96 individuals per m^2, followed by *P. elegans*, *N. cirrosa* and *M. johnstoni*. Crustacean taxa density was also low with *Bathyporeia* spp. having the greatest density (103 individuals per m^2).

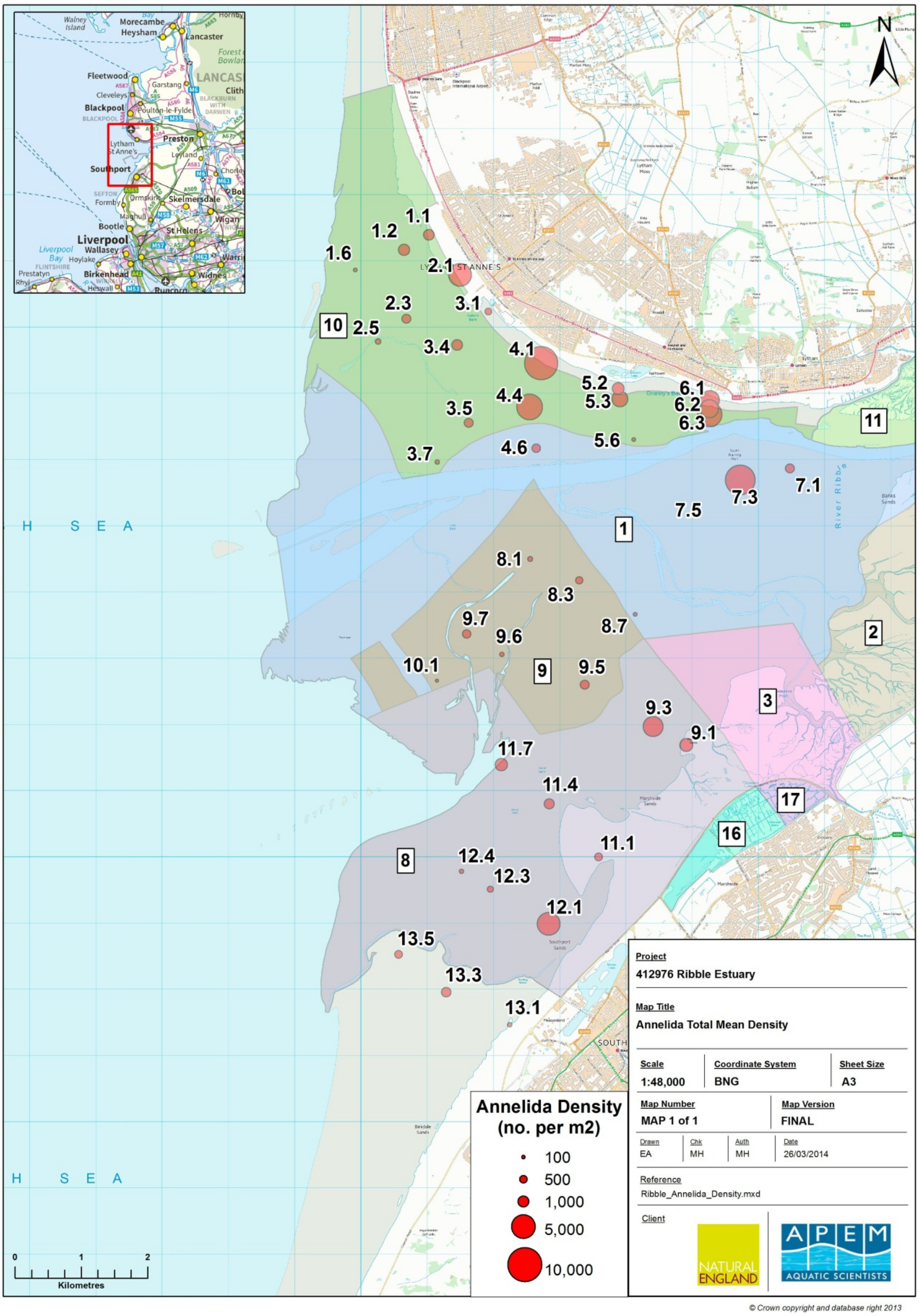


Figure 6. Density of annelids across sample sites in the Ribble Estuary. © Crown copyright and database right 2013.

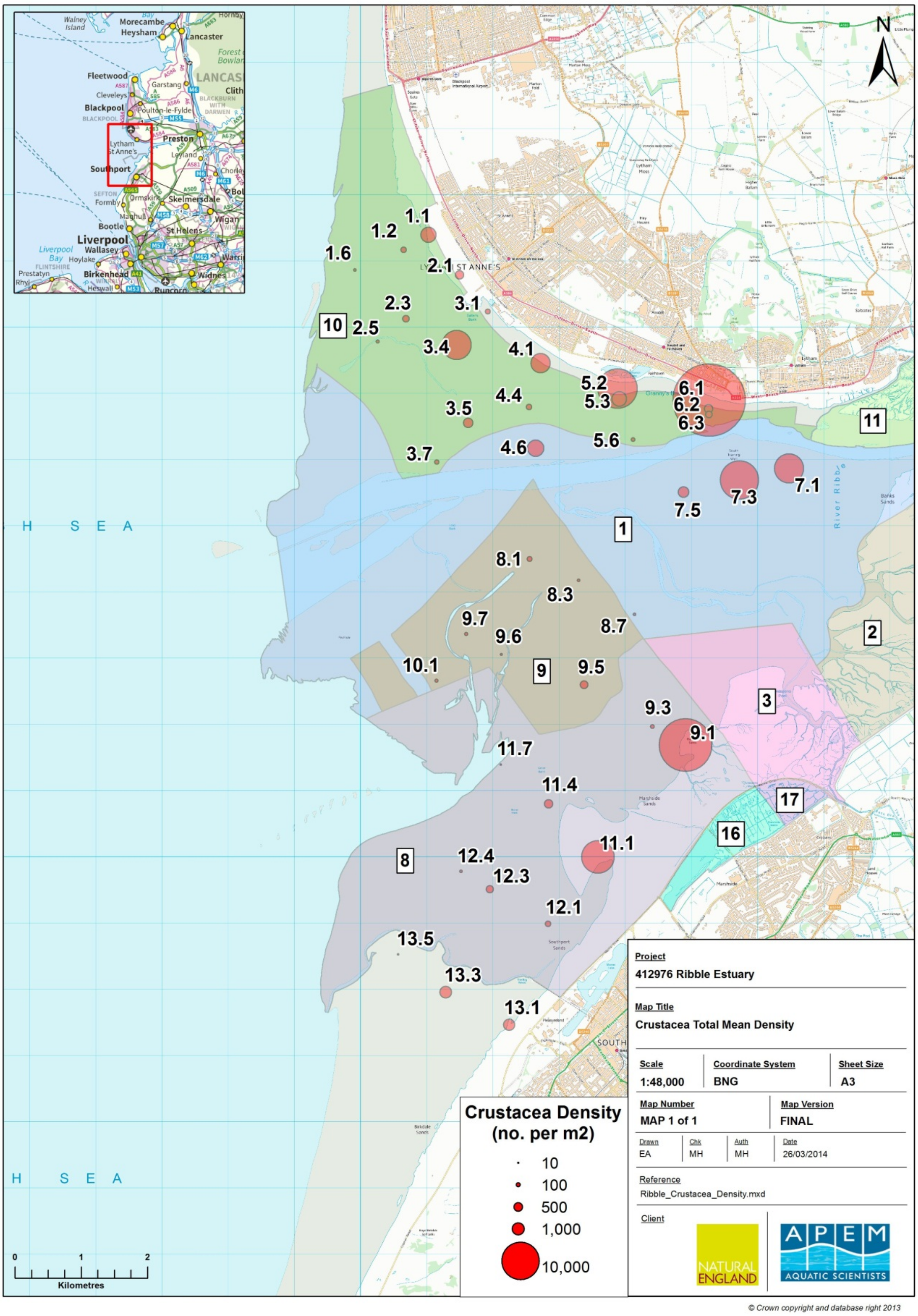


Figure 7. Density of crustaceans across sample sites in the Ribble Estuary. © Crown copyright and database right 2013.

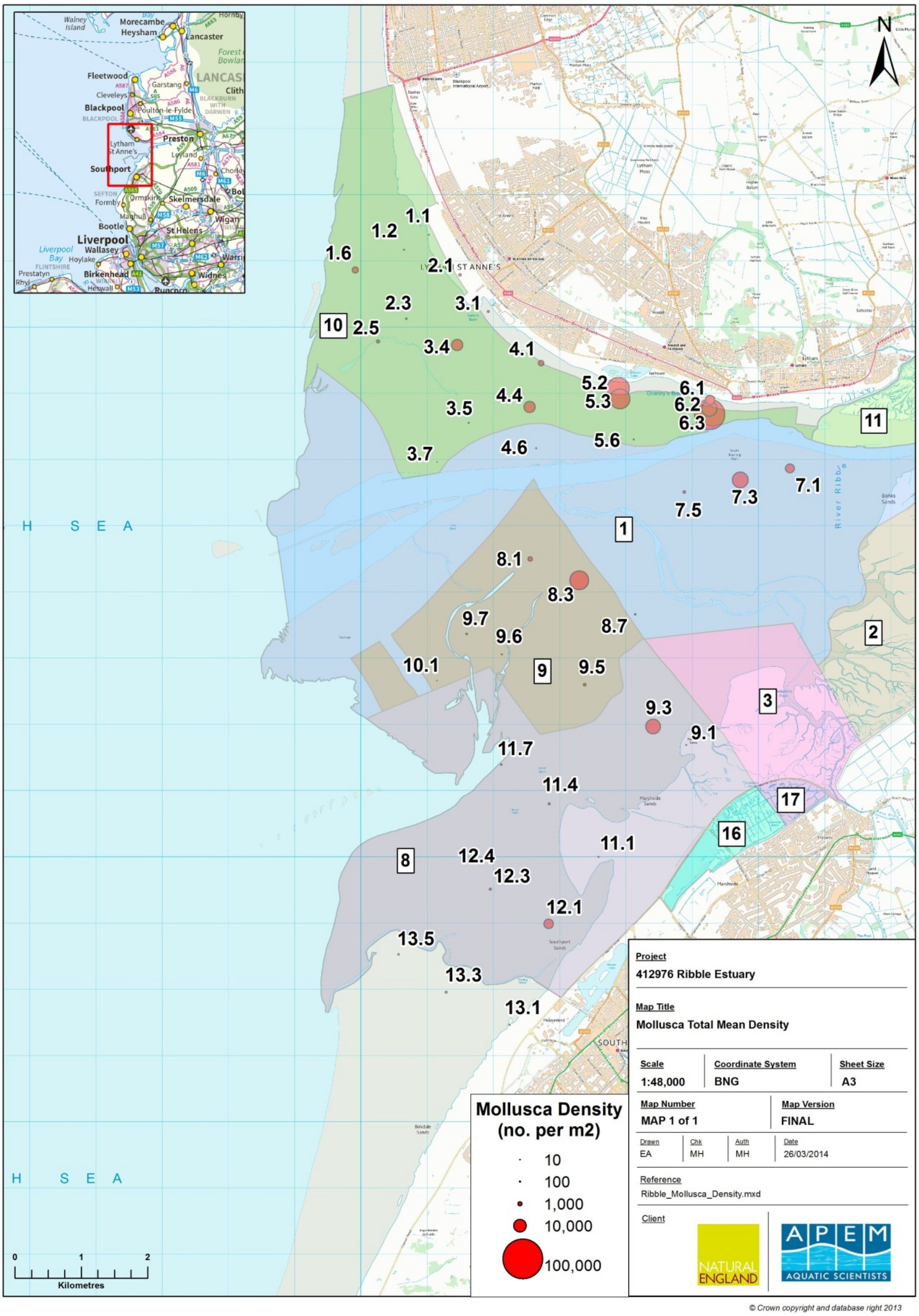


Figure 8. Density of molluscs across sample sites in the Ribble Estuary. © Crown copyright and database right 2013.

Table 9. Mean density of the four most abundant invertebrate taxa within Units 1, 8, 9 and 10 of the Ribble Estuary Site of Special Scientific Interest (SSSI) and the number of sample sites at which recorded in relation to the number of sites sampled in each Unit. s.d. = standard deviation.

Unit 1				**Unit 8**				**Unit 9**				**Unit 10**			
	Density (indivs. m^{-2})														
	Mean	**s.d.**	**No. of sites**		**Mean**	**s.d.**	**No. of sites**		**Mean**	**s.d.**	**No. of sites**		**Mean**	**s.d.**	**No. of sites**
Annelida															
Nematoda	1352	2699	3 of 5	Nematoda	585	1197	6 of 11	*S. martinensis*	96	174	3 of 6	*P. elegans*	1023	1918	14 of 18
Pygospio elegans	304	636	2 of 5	Enchytraeidae	147	367	5 of 11	*P.elegans*	47	72	2 of 6	Nematoda	454	562	12 of 18
Scolelepis squamata	64	121	3 of 5	*Spio martinensis*	124	256	3 of 11	*Nephtys cirrosa*	37	56	3 of 6	*Tubificoides benedii*	278	982	4 of 18
Eteone longa (agg.)	48	107	1 of 5	*P. elegans*	111	207	7 of 11	*Magelona johnstoni*	33	72	2 of 6	Enchytraeidae	137	265	11 of 18
Crustacea															
Bathyporeia spp.	2208	2321	5 of 5	*Corophium* spp.	2626	6147	10 of 11	*Bathyporeia* spp.	103	149	5 of 6	*Corophium* spp.	2699	8556	10 of 18
Corophium spp.	1368	2795	4 of 5	*Bathyporeia* spp.	167	316	5 of 11	*Corophium* spp.	17	15	4 of 6	*Bathyporeia* spp.	610	1290	15 of 18
Eurydice pulchra	216	400	2 of 5	*C. crangon*	6	13	2 of 11	*C. crangon*	13	24	2 of 6	*E. pulchra*	208	275	17 of 18
Crangon crangon	20	35	2 of 5	*H. arenarius*	4	12	1 of 11	*E. pulchra*	3	8	1 of 6	*C. crangon*	9	17	5 of 18
Mollusca															
Peringia ulvae	3080	4487	5 of 5	*P. ulvae*	1700	3996	9 of 11	*P. ulvae*	3193	7370	4 of 6	*P. ulvae*	8090	14628	13 of 18
Cerastoderma edule	660	1409	3 of 5	*M. balthica*	125	203	7 of 11	*M. balthica*	670	1438	4 of 6	*M. balthica*	384	647	9 of 18
Macoma balthica	588	1115	5 of 5	*C. edule*	80	142	7 of 11	*C. edule*	167	181	4 of 6	*C. edule*	208	562	7 of 18
Mytilus edulis (juv)	12	11	3 of 5	*Angulus tenuis*	15	27	3 of 11	*Angula fabula*	13	21	2 of 6	*M. edulis (juv)*	192	529	9 of 18

The mean densities of *P. ulvae* and *M. balthica* across Unit 9 were 3193 and 670 individuals per m^2, respectively but this was mainly due to very high densities of these species at Site 8.3. *C. edule* was found in densities consistent with Units 8 and 10 with 167 individuals per m^2 (Table 9).

Within Unit 10 *P. elegans* was the annelid taxon with greatest density, followed by nematoda (1023 and 454 individuals per m^2, respectively). Within this Unit *T. benedii* had a considerably greater density than in each of the other Units with 278 individuals per m^2, however, as indicated above for the estuary overall, this was due to very high numbers at Site 6.3. Crustacean densities were similar within Units 1 and 8, with *Corophium* spp. the most abundant (2699 individuals per m^2), followed by *Bathyporeia* spp. (610 individuals per m^2) and *E. pulchra* (208 individuals per m^2). Densities of the mollusc *P. ulvae* were considerably higher than within each of the other Units (8090 individuals per m^2). *M. balthica*, *C. edule* and *M. edulis* had densities within the ranges of the other Units with means of 384, 208 and 192 individuals per m^2, respectively (Table 9).

3.2.3 Rare/unusual species and Invasive Non-native Species (INNS)

No protected species/habitats, nationally rare or scarce species, or non-native species as listed in Appendices 1 to 5 of the CCW Handbook for Marine Intertidal Phase I Survey and Mapping (Wyn *et al*. 2000) were recorded in either the Phase I or quantitative core surveys.

3.2.4 Temporal variation in invertebrate assemblages

Sixteen of the Phase I biotope survey sites from the current survey were consistent with sites sampled during the 2007 survey (IECS 2008) enabling a comparison of the fauna recorded.

A SIMPROF test of data across both years identified a total of four faunal cluster groups that were statistically separated at the 5% significance level with groupings based on 20% similarity or greater. An MDS plot indicated considerable overlap between the faunal composition of Phase I samples across years (Figure 9). The stress value of 0.08 indicates the MDS plot is a good representation of the multi-dimensional characterisation.

This is supported by the results of ANOSIM which indicated a Global R statistic of 0.002 (significance level 40.3%) suggesting that there was almost complete overlapping in species assemblages across years (R-values of >0.75 are considered to be well separated, R of >0.5 indicates overlapping groups but with clear differences, and R<0.25 indicates the groups can barely be separated (Clarke & Gorley 2001). The significance level of 40.3%, however, indicates that there is a high probability that the R statistic value was generated by random chance, which highlights the limitations of the data used to conduct the assessment with relatively low numbers of taxa (generally 2 to 6 taxa) recorded per *in situ* sample site.

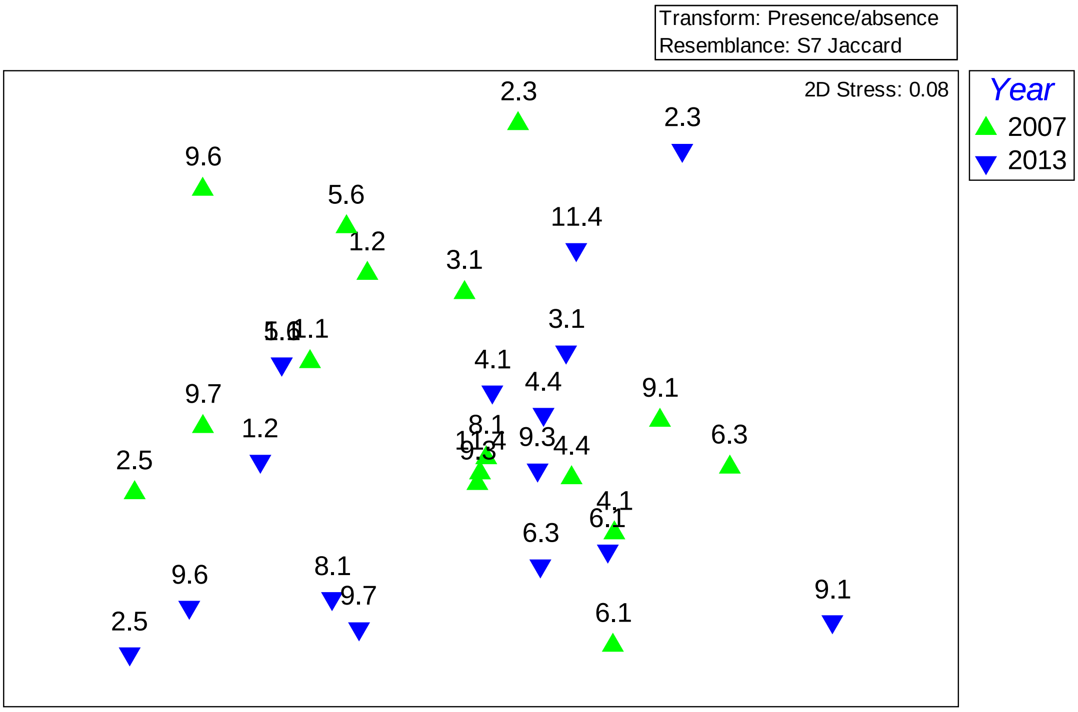


Figure 9. Non-metric multidimensional scaling ordination of a Jaccard resemblance matrix of faunal groups indicating the 2007 and 2013 sample sites.

3.3 Sediment Analysis

3.3.1 Particle Size Distribution

The data were classified into five textural groups, with the highest number of samples assigned to Slightly Gravelly Sand (28 sites), (Table 10). There was no clear trend in variation in sediment type across the estuary although muddier sediments were present on the upper shore on Transects 6, 9, 11 and 13 and in the middle of Transect 8 (Figure 10). It should be noted that the proportion of different size classes of particle within the broad mud, sand and gravel categories also contribute to the Folk classification which is why in some cases the percentage contribution of the broad categories for two or more sites is the same but the Folk classification differs (Table 10). The full results of the sediment analysis are presented in Appendix 6.

3.4 Contaminant analysis

The results of contaminants analyses carried out for sediment collected at Site 7.3 are presented in Table 11.

Guideline concentrations were available for a limited number of contaminants (those for which standards are available are indicated in Table 11), (see Section 2.5.3). Where standards were available, only the concentration of naphthalene was found to exceed BAC, and none of the contaminants exceeded ERL (for PCBs) or EAC (for groups of contaminants other than PCBs) (Table 11) indicating that overall the concentrations of contaminants with guideline standards were very low.

Table 10. Folk classification for sediment in the Ribble Estuary. The sediment class in colour coded to aid interpretation.

Site number	% Mud (<63µm)	% Sand (63-1999µm)	% Gravel (>2000µm)	Folk classification	Unit
1.1	0	99.7	0.3	Slightly Gravelly Sand	10
1.2	0	100	0	Slightly Gravelly Sand	10
1.6	0	100	0	Slightly Gravelly Sand	10
2.1	0	99.8	0.2	Slightly Gravelly Sand	10
2.3	0	99.6	0.4	Slightly Gravelly Sand	10
2.5	0	99.8	0.2	Slightly Gravelly Sand	10
3.1	0	99.9	0.1	Slightly Gravelly Sand	10
3.4	0	99.9	0.1	Slightly Gravelly Sand	10
3.5	0	99.8	0.2	Slightly Gravelly Sand	10
3.7	0	100	0	Sand	10
4.1	0	100	0	Sand	10
4.4	0	99.9	0.1	Slightly Gravelly Sand	10
4.6	0	100	0	Slightly Gravelly Sand	1
5.2	2.5	97.5	0	Sand	10
5.3	3	97.0	0	Sand	10
5.6	0	99.9	0.1	Slightly Gravelly Sand	10
6.1	21.8	78.2	0.1	Slightly Gravelly Muddy Sand	10
6.2	8.4	91.1	0.5	Slightly Gravelly Sand	10
6.3	15.1	78.0	6.9	Gravelly Muddy Sand	10
7.1	2.9	97.1	0	Slightly Gravelly Sand	1
7.3	0	99.9	0.1	Slightly Gravelly Sand	1
7.5	0	100	0	Sand	1
8.1	0	100	0	Sand	1
8.3	11.7	88.2	0.1	Slightly Gravelly Muddy Sand	9
8.7	0	99.7	0.3	Slightly Gravelly Sand	9
9.1	27.8	72.2	0	Muddy Sand	8
9.3	0	99.1	0.9	Slightly Gravelly Sand	8
9.5	0	99.6	0.4	Slightly Gravelly Sand	9
9.6	0	99.6	0.4	Slightly Gravelly Sand	9
9.7	0	100	0	Slightly Gravelly Sand	9
10.1	0	100	0	Slightly Gravelly Sand	9
11.1	19	81	0	Slightly Gravelly Muddy Sand	8
11.4	0	99.4	0.6	Slightly Gravelly Sand	8
11.7	0	99.8	0.2	Slightly Gravelly Sand	8
12.1	0	99.5	0.5	Slightly Gravelly Sand	8
12.3	0	98.2	1.8	Slightly Gravelly Sand	8
12.4	0	99.7	0.3	Slightly Gravelly Sand	8
13.1	17.2	80	2.8	Slightly Gravelly Muddy Sand	8
13.3	0	99.8	0.2	Slightly Gravelly Sand	8
13.5	0	100	0	Slightly Gravelly Sand	8

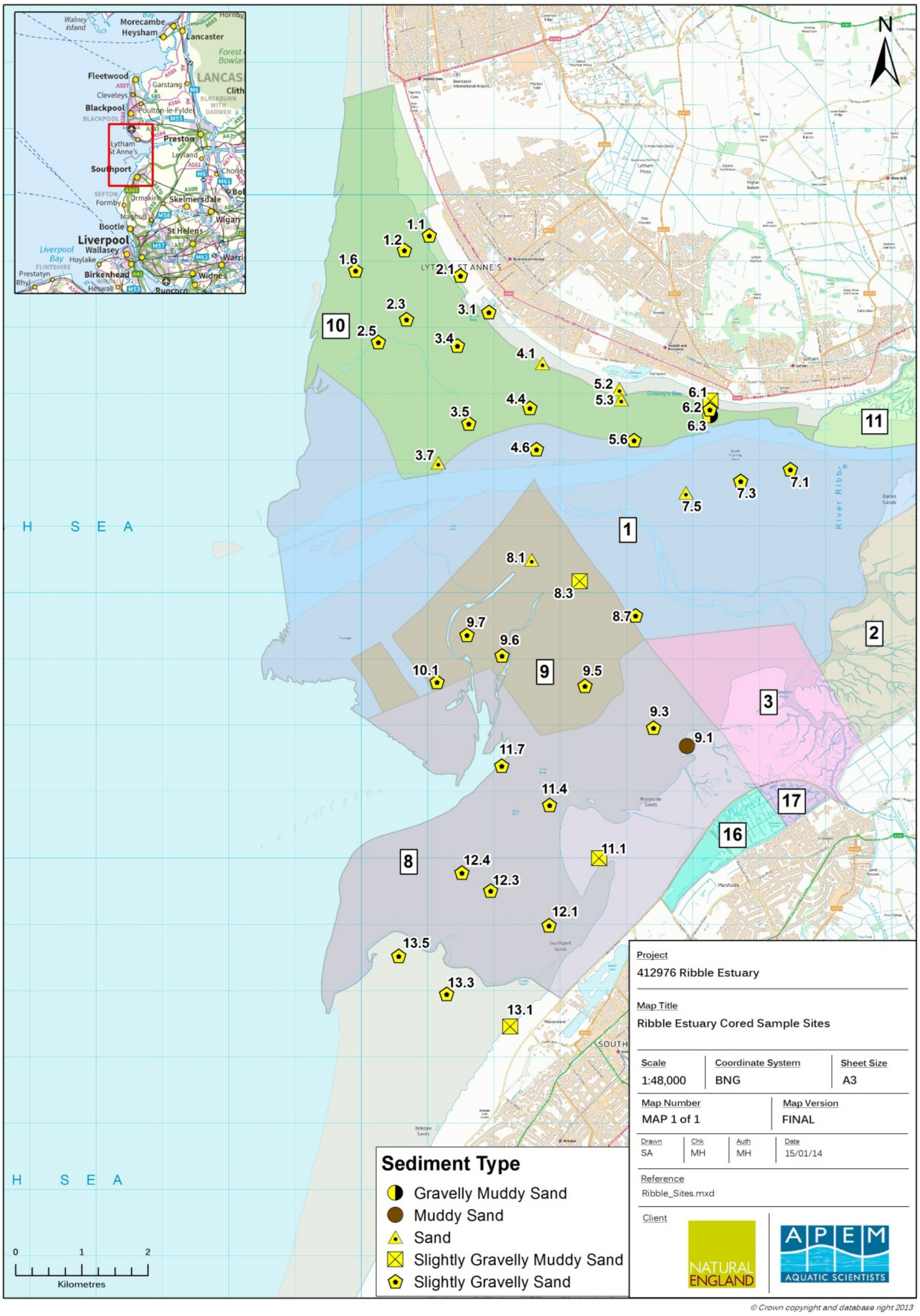


Figure 10. Map of sediment types recorded at each survey site across the Ribble Estuary based on Folk (1954). © Crown copyright and database right 2013.

Table 11. Results of the contaminant analysis from sediment surface scrape samples obtained at Site 7.3 in the Ribble Estuary. Values exceeding Background Assessment Concentrations (BACs) only are highlighted in blue, no values exceeded Effects Range-Low (ERL) or Environmental Assessment (EAC).

Analyte	Units	Site 7.3
Carbon, Organic : Dry Wt as C	%	<0.4
Dry Solids @ 30°C	%	72
Aluminium, HF Digest : Dry Wt	mg/kg	22,300
Arsenic*, HF Digest : Dry Wt	mg/kg	8.01
Cadmium*, HF Digest : Dry Wt	mg/kg	0.06
Chromium*, HF Digest : Dry Wt	mg/kg	44.6
Copper*, HF Digest : Dry Wt	mg/kg	5.72
Iron, HF Digest : Dry Wt	mg/kg	12,600
Lead*, HF Digest : Dry Wt	mg/kg	15.3
Lithium, HF Digest : Dry Wt	mg/kg	13.2
Manganese, HF Digest : Dry Wt	mg/kg	346
Mercury*: Dry Wt	mg/kg	0.026
Nickel*, HF Digest : Dry Wt	mg/kg	9.04
Zinc* : HF Digest : Dry Wt	mg/kg	46.6
Anthracene*: Dry Wt	µg/kg	2
Benzo(a)anthracene*: Dry Wt	µg/kg	3.8
Benzo(a)pyrene*: Dry Wt	µg/kg	4.2
Benzo(ghi)perylene* : Dry Wt	µg/kg	<10
Chrysene + Triphenylene*: Dry Wt	µg/kg	3.6
Fluoranthene*: Dry Wt	µg/kg	6.5
Indeno(1,2,3-c,d)pyrene* : Dry Wt	µg/kg	<10
Naphthalene*: Dry Wt	µg/kg	36.8
Phenanthrene*: Dry Wt	µg/kg	<10
Pyrene*: Dry Wt	µg/kg	7.3
PCB - 028* : Dry Wt	µg/kg	<0.1
PCB - 052* : Dry Wt	µg/kg	<0.1
PCB - 101* : Dry Wt	µg/kg	<0.1
PCB - 118* : Dry Wt	µg/kg	<0.1
PCB - 138* : Dry Wt	µg/kg	<0.1
PCB - 153* : Dry Wt	µg/kg	<0.1
PCB - 180* : Dry Wt	µg/kg	<0.1
2,2,4,4,5,5-Hexabromodiphenyl ether : Dry Wt :- {PBDE 153}	ug/kg	<0.1
2,2,4,4,5,6-Hexabromodiphenyl ether : Dry Wt :- {PBDE 154}	ug/kg	<0.1
2,2,4,4,5-Pentabromodiphenyl ether : Dry Wt :- {PBDE 99}	ug/kg	<0.1
2,2,4,4,6-Pentabromodiphenyl ether : Dry Wt :- {PBDE 100}	ug/kg	<0.1
2,2,4,4-Tetrabromodiphenyl ether : Dry Wt :- {PBDE 47}	ug/kg	<0.1
2,4,4-Tribromodiphenyl ether : Dry Wt :- {PBDE 28}	ug/kg	<0.1
Tributyl Tin : Dry Wt as Cation	µg/kg	<3
Hexachlorobenzene* : Dry Wt	µg/kg	<1
Hexachlorobutadiene : Dry Wt	µg/kg	<1

***Standards are only available for these contaminants**

3.5 Topography

The heights of chart datum (CD) relative to ordnance datum (OD, at Newlyn) are based on the closest location to the Ribble estuary with a specified CD which was Blackpool (CD at Blackpool is −4.90 m relative to OD). Topography data indicated variation in elevation across sites from 2.04 m above Chart Datum (CD) (Site 10.1) to 9.11 m above CD (Site 5.2), (Table 12).

Table 12. Grid reference and elevation of the quantitative core sites.

Transect number	Station	British National Grid		Elevation (m) relative to:	
		Easting	Northing	Ordnance Datum	Chart Datum
1	1.1	331025	429397	1.222	6.122
1	1.2	330705	429183	*	*
1	1.6	329719	428852	*	*
2	2.1	331477	428793	*	*
2	2.3	330685	428126	*	*
2	2.5	330257	427783	*	*
3	3.1	331924	428237	0.961	5.861
3	3.4	331443	427718	-1.225	3.675
3	3.5	331615	426554	2.675	7.575
3	3.7	331142	425937	1.151	6.051
4	4.1	332725	427444	3.671	8.571
4	4.4	332568	426783	3.024	7.924
4	4.6	332632	426168	1.989	6.889
5	5.2	333883	427070	4.21	9.11
5	5.3	333907	426915	2.544	7.444
5	5.6	334145	426295	0.302	5.202
6	6.1	335265	426897	2.558	7.458
6	6.2	335259	426766	2.212	7.112
6	6.3	335265	426680	1.217	6.117
7	7.1	336477	425860	2.913	7.813
7	7.3	335724	425687	2.261	7.161
7	7.5	334881	425508	1.722	6.622
8	8.1	332387	424577	1.99	6.89
8	8.3	333296	424177	1.332	6.232
8	8.7	334138	423656	-2.832	2.068
9	9.1	334912	421690	3.501	8.401
9	9.3	334411	421968	2.811	7.711
9	9.5	333376	422597	-0.152	4.748
9	9.6	332125	423054	0.307	5.207
9	9.7	331596	423365	-2.238	2.662
10	10.1	330960	422600	-2.864	2.036
11	11.1	333588	420000	3.921	8.821
11	11.4	332842	420801	2.838	7.738
11	11.7	332120	421390	-0.408	4.492
12	12.1	332834	418987	2.596	7.496
12	12.3	331954	419509	2.567	7.467
12	12.4	331519	419780	1.020	5.92
13	13.1	332245	417461	3.771	8.671
13	13.3	331289	417953	1.753	6.653
13	13.5	330567	418529	-0.326	4.574

*During the first day of survey the Leica receiver was not functioning correctly due to satellite receiver malfunction, for this reason data are not available for Transects 1 and 2.

3.6 Anthropogenic influences

Anthropogenic influences (pressures) which may impact upon identified features within the SSSI were noted and recorded. The main anthropogenic influences noted on the north side of the estuary were general public use by tourists and dog walkers, and watersport activities such as kite surfing and sand yachting in the intertidal. Permanent structures that may affect the area included old pier/jetty piles (SD 31582 27315) and the sea wall on the upper shore at Fairhaven (SD 33591 27297 to SD 34381 27315) and further east in Granny's Bay there was pebble defence structure (SD 34640 27257 to SD 34725 27220) and a concrete wall leading into saltmarsh (SD 34738 27212 to SD 35776 26872). It is known that bait diggers are periodically on the shore although there was no evidence of this during the survey.

A training wall extends along the length of the main channel to the outer estuary sand flats. On Transect 4 on the northern shore, fishermen were observed collecting mussels from the training wall. They gained access to the shore using a 4 x 4 vehicle, and then deployed a quad bike in order to proceed to the lower shore. Leisure boats were observed in the vicinity of the outer bank transect sites.

Dredging of the channel has not been conducted since the port of Preston was closed in the 1980s and as a result there has been an increase in sedimentation throughout the area (IECS 2008).

Plate 7. Fishermen mobilising their quad bike in order to access the training wall on the lower shore.

On the southern side of the estuary anthropogenic influences also included general use by the public including dog walkers and there is a popular beach resort with tourist facilities at top of the shore at Southport. Permanent structures present included the sea wall on the upper shore at Southport, and a number of ramps onto the beach (SD 32581 17423 and SD 33689 18573). Parking was permitted in some areas on the upper shore although vehicle access to the beach in general is restricted to permit holders including fishermen who drive over the foreshore to obtain shellfish. There was evidence of 4 x 4 vehicles and tracks on foreshore, as well as quad bikes in use further down the shore. A previous survey reported that sand winning was evident on the southern section of the estuary north of Southport Pier (RH 2006), however, this activity was not observed during the 2013 survey.

4 DISCUSSION

4.1 Overview

The Ribble Estuary consists of large areas of mud and sandflat extending up to 6 km offshore, intersected by numerous water channels with extensive sandbanks in the outer estuary. The area is dominated by fine sand, with some sections consisting of more stabilised sand habitats, and other areas with more mobile sands with faunal communities varying accordingly. Within the upper shore on the north and south bank are expanses of saltmarsh which are considered to be accreting, with sediments on the upper shore tending to have a greater mud content, than the mid and lower shore areas. In very broad terms, during the 2013 survey the upper shore tended to be characterised by amphipod dominated sediments with some mud content, the lower shore was generally characterised by stable fine sand with polychaetes while the mid shore biotopes were often a combination of stable fine sand with polychaetes or mobile sand with amphipods and polychaetes.

The Ribble Estuary appears to be a highly dynamic environment subject to a range of environmental influences including wave and wind action and flow from the Ribble river channel. The locations of channels and surface features of the sandflats can vary from week to week and seasonal variation in the faunal communities present and the species composition of different biotopes is expected both within and across years. Due to the dynamic nature of the estuary the locations of potential obstacles will vary across surveys and local knowledge is required to traverse the transects as efficiently as possible. In the weeks prior to the 2013 survey there had been some storms which had greatly influenced the intertidal zone in some areas and signs of the storm activity included large areas of scattered shells debris on some of the transects and at some sites species not usually found in core samples were present, e.g. high numbers of juvenile brittlestars *Ophiuroidea* spp. were recorded at the lower shore sites on Transect 1. Consequently it is important to take such natural variation into account when assessing the status of the SSSI.

Although qualitative Phase I survey is a useful rapid assessment approach when covering large areas of the intertidal zone, it is important to continue to provide quantitative data for future assessments of the SSSI. Quantitative data enables comparisons of a wide range of information across years such as diversity and density of species at specific sites or along specific transects which has not been possible for comparisons of the 2013 survey with the previous qualitative data obtained for the estuary. Core data also provides robust information to verify or amend initial biotope allocation in the field, as usually due to time and logistical constraints when sieving in the field the range of taxa and number of individuals recorded is smaller than that obtained via core analysis. In a number of the areas of the Ribble estuary the sediment is characterised by low numbers of infauna and Royal Haskoning (2006) indicated that at many sites during the 2005 survey no conspicuous infauna were found during *in situ* sieving and at many of the stations there were insufficient species recorded to be able to confidently assign a biotope. As such, survey approach also has the potential to influence the biotopes recorded on each survey which needs to be considered when conducting comparisons of data across years. As an example, no mobile sand biotopes/sub-biotopes were recorded in 2005, however amphipods and *S. squamata* in mobile sands (A2.223/A2.2232) was recorded quite frequently in both 2007 and 2013 and it is not known if this represents a definitive transition in biotope or is an artefact of the biotope allocation approach. Having the core data as a permanent quantitative record of the faunal communities present removes some of the uncertainty related to inter-survey comparisons although a degree of subjectivity invariably needs to be applied when allocating biotopes/sub-biotopes as in many instances a small number of the species characteristic of specific biotopes as indicated in JNCC (2004) are present within the samples, abundances can vary in comparison to those indicated in JNCC (2004) or there can be variation in other aspects of biotope description when compared to national average values (JNCC 2004). In addition, communities present could be representative of one or more biotope complexes/biotopes/sub-biotopes and application of professional judgement is required to assign biotopes based on available information and previous experience.

The time of year of the survey introduced some logistic constraints resulting in transit to the outer sandbanks, and commencement of survey, in low light conditions. To optimise the available working windows for future surveys it is recommended that surveys are conducted during the summer with longer day lengths and the potential to work more than one tide each day. Although use of a 4 x 4 vehicle provided to be a successful approach to survey in the north of the estuary, it is considered that the use of hovercraft would increase overall survey efficiency further, and would be especially effective for reaching and surveying the outer sandbanks with safety.

Part of the aims of the 2013 survey were to provide coverage of new areas of the intertidal zone which is why a new transect was introduced in Unit 1 (Transect 7). It is recommended for future surveys that in addition to repeating survey of Transect 7 a greater number of sites surveyed in 2007 are re-surveyed in the middle section of Unit 1 to provide broader coverage of this area of the intertidal zone to inform future condition assessment.

4.2 Contaminant analysis

Overall, the contaminants for which standards are available were below BAC values with the exception of naphthalene. This suggests that concentrations of contaminants at the sediment surface were relatively low and are unlikely to be affecting the faunal assemblages at the sites sampled. This is supported by the fact that Site 7.3 (where the sediment was sampled) had the greatest mean taxon richness and invertebrate density of the sites sampled. Of the 12 heavy metals analysed four do not have environmental standards for aquatic sediments. There are also no standards for PBDEs (all found to have concentrations <0.1 µg/kg), tributyltin (concentration of <3 µg/kg) and hexachlorobutadiene (concentration of <1 µg/kg) and it is unclear what influence levels of these contaminants could have on intertidal assemblages. It is considered that pollutants are likely to be locked into the sediment due to the historic operations of Preston Docks and industrial works along the upper reaches of the estuary and its tributaries, and contaminant concentrations could change following re-working of sediments e.g. following a storm event. Consequently, it may be beneficial during future surveys to also collect some deeper sediment for contaminant analysis to assess any differences between contaminant concentrations in surface and deeper sediments.

4.3 Anthropogenic influences

The main anthropogenic influences recorded during the survey were public use of the foreshore and fishing for shellfish, including collecting mussels from the training wall. The intertidal zone at Granny's Bay is relatively narrow and the presence of seawalls at Granny's Bay (and to a lesser extent those at Fairhaven and Southport) could potentially contribute to coastal squeeze within the SSSI.

The training wall along the main river channel has influenced the hydrodynamic regime of the estuary and the river channel morphology introducing a degree of habitat heterogeneity along the river channel. In addition, the cessation of dredging of the river channel in the 1980s appears to have led to an increase in sedimentation throughout the area.

4.4 Preliminary Condition Assessment

Natural England assesses the condition of SSSIs, SACs, SPAs and Ramsar sites on a six year cycle. Standard methodologies based on Common Standards Monitoring (CSM) guidance are applied to collect data to inform these assessments. Each special interest feature of the protected site contributing to its designation has specific measurable attributes (usually one or more habitat extent and quality definitions) and targets for these attributes. Based on identified change (or lack of change) in relation to these targets between monitoring periods SSSI Units can be described as one of the following categories (NE 2008):

- **Favourable condition**: Special habitats and features are in a healthy state and are being conserved for the future by appropriate management.
- **Unfavourable - recovering condition**: All necessary management measures are in place to address the reasons for unfavourable condition – if these measures are sustained, the site will recover over time.
- **Unfavourable - no change or Unfavourable - declining condition**: The Special Features of a site are not being adequately conserved, or are being lost. If appropriate management measures are not put in place, and damaging impacts are not addressed, these sites will never reach a favourable or recovering condition.
- **Part destroyed or Destroyed**: Sites where there has been fundamental and lasting damage - the Special Features have been lost permanently. Favourable condition cannot be achieved at such sites.

In some cases there are insufficient data, however, to confidently assign the condition of an attribute to one of the above categories. In these instances a category has been assigned for consideration by NE based on professional judgement, however, it has been assigned with a low level of confidence. Site-specific standards defining favourable condition of relevance to the Ribble Estuary SSSI and the Ribble and Alt Estuaries Special Protection Area (SPA) and Ramsar site are indicated in Table 13 (NE 2011) and form the basis of the condition assessment (it should noted that these objectives are currently under review).

4.4.1 Sediment characteristics and topography

As indicated in Section 1.3 there are a number of targets for site attributes which are related to the sediment characteristics and topography of the Units. Quantitative data for these attributes were collected during the 2013 survey, but are not available for previous surveys preventing a determination of change since the last survey event. Consequently, for each of the Units, the 2013 survey provides a baseline data set against which future survey outputs can be compared to assess change.

A brief description of potential sediment variations across years based on biotope complexes/biotopes/sub-biotopes allocated during previous surveys is provided below with a preliminary condition assessment in Table 14.

4.4.1.1 Management Unit 1

Within this Unit, sediment was sampled in the outer sandbanks in 2007 only, with numerous sample sites running north to south in the middle of the Unit in 2005 (RH 2006) and 2007 (Figure 11). In 2013 the main survey areas overlapping with the previous surveys were the southern sections of Transects 3, 4 and 8 (Figure 5).

Table 13. Site-specific standards defining favourable condition for attributes of the Littoral Sediment feature of the Ribble Estuary Site of Special Scientific Interest (SSSI), Special Protection Area (SPA) and Ramsar Site. Objectives taken from NE 2011.

Feature	Attribute	Target	Method of assessment
Littoral sediments (intertidal mud and sand)	**Distribution of biotopes**	Maintain the distribution of biotopes, allowing for natural succession / known cyclical change	Assessment of the distribution of biotope(s) identified for the site
	Biotope composition of littoral sediment	Maintain the variety of biotopes identified for the site, allowing for natural succession / known cyclical change.	Repeated assessment of overall biotope composition or a subset of biotopes identified for the site
	Species composition of representative or notable biotopes	No decline in biotope quality due to changes in species composition or loss of notable species, allowing for natural succession/known cyclical change.	Assessment of biotope quality through assessing species composition, where the biotope is representative of the site or contains a number of species of conservation importance.
	Sediment character: Organic carbon content *	Organic carbon content should not increase in relation to an established baseline.	Organic carbon content assessed in specified area.
	Sediment character: Oxidation-reduction profile (Redox layer)	Average depth to the top of the black layer should not increase in relation to baseline.	Measure oxidation-reduction profile (Redox)
	Sediment character: sediment type	No change in composition of sediment type across the feature, allowing for natural succession/known cyclical change	Distribution of sediment types should be assessed across the whole feature and compared to baseline conditions
	Topography	No change in topography of the littoral sediment, allowing for natural responses to hydrodynamic regime.	Tidal elevation and shore slope to be assessed periodically.

* data was only recorded at one site for this attribute during the monitoring based on the methodology agreed with NE and consequently this attribute is not considered within the preliminary condition assessment.

In 2007 there was evidence of a transition from mobile and fine sands on the outer sandbanks to muddier sands moving east along the unit (Figure 11). The sediment types within the middle section of the unit recorded in 2005 (RH 2006) were broadly consistent those recorded in 2007. At the southern extent of Transect 4, fine sand habitat types were recorded in 2005 and 2013, while amphipods in muddy sand were present in 2007 suggesting some potential variation in habitat type. Sediments in this area are subject to wave and wind action and this section of the estuary is in the vicinity of the Ribble River channel. Consequently, sediment type and associated faunal communities are expected to vary naturally as environmental conditions and river flow, channel morphology and sediment transport regimes change across the year, however, quantitative data from future surveys is required to confirm this. The mobile sand and muddy sand habitat types recorded on Transect 7 in the inner estuary in 2013 were consistent with the transition to muddier sediment moving east along the estuary.

4.4.1.2 Management Unit 8

Within this Unit, Transects 9 and 10 were surveyed in 2007 and 2013, Transects 11 and 13 were surveyed in 2005, 2007 and 2013, and Transect 12 was only surveyed in 2013. Sediment type within this unit appears to have remained relatively consistent across years with muddier sediment on the upper shore, dynamic mobile sediment and fine sand on the mid shore and more stable fine sand on the lower shore and outer sandbanks.

4.4.1.3 Management Unit 9

Transect 8 within the northern section of Unit 9 was surveyed across all three years, and Transect 9 was surveyed in both 2007 and 2013. Within the north section of the Unit (Transect 8) each survey indicated a transition from stable fine sands at the western extent of the transect to muddier sediment mid transect and muddy sand at the eastern extent. Along Transect 9 within the southern section of Unit 9 fine sand and mobile sand were present in 2007 and 2013

4.4.1.4 Management Unit 10

Transects 1, 3, 4 and 6 were surveyed in 2005, 2007 and 2013 while Transects 2 and 5 were surveyed in 2007 and 2013 only. Based on the habitat types allocated there is some evidence that the uppermost sites of Transects 1 to 3 may have been sandier in 2013 than in 2005 (RH 2006) and 2007 (Figure 11), however, the lack of quantitative data from previous years means this cannot be confirmed.

Generally, sediment types present appear to be relatively consistent across years although on Transect 3 the mid shore areas consisted of fine sand habitats in 2007 and more mobile sand habitats in 2013, while Transect 4 was mainly characterised by muddy sediment habitats in 2007 and fine sand in 2013. Each year the sediments were far muddier throughout the transects in the eastern section of the Unit (Transects 5 and 6).

Table 14. Preliminary condition assessment for sediment characteristic and topography attributes for SSSI Management Units 1, 8, 9 and 10.

Feature	Attribute	Target	Preliminary condition assessment
Littoral sediments (intertidal mud and sand)	**Sediment character: Oxidation-reduction profile (Redox layer)**	Average depth to the top of the black layer should not increase in relation to baseline.	Generally there was no anoxic layer within the sediment apart from the uppermost sites on a number of the transects,and throughout Transect 6, with depth of the anoxic layer ranging (when present) from 3 – 13 cm (Appendix 3). Redox depth data are not available for the surveys conducted before 2013. In broad terms wide expanses of mobile and fine sand habitats which are expected to have no anoxic layer were present during each survey year, and muddy sediments which would be expected to have an anoxic layer were generally present in similar locations. Consequently, it is considered that the condition of this attribute is **favourable**. although due to lack of quantitative data from previous years this assessment has low confidence and collection of further data is recommended.
	Sediment character: sediment type	No change in composition of sediment type across the feature, allowing for natural succession/known cyclical change.	There is evidence for site-specific changes in sediment type from e.g. muddier sediments to fine sand in the mid-section of Unit 10 (Transect 4). In general, however, sediment types appeared to have remained consistent within large sections of the estuary with variation likely to be part of natural succession/ cyclical change. It is considered, therefore, that this attribute is likely to be in **favourable** condition, however, due to the absence of quantitative PSA data from previous surveys, it is difficult to confirm apparent changes and the assessment is made with low confidence.
	Topography	No change in topography of the littoral sediment, allowing for natural responses to hydrodynamic regime.	No elevation data was available for the site from previous surveys. Based on the potential for natural variation in topography within estuaries such as the Ribble Estuary, is it considered any apparent changes would likely fall within the range of natural variation and as a preliminary assessment for this feature the condition of the attribute is expected to be **favourable**, however due to the lack of historic data confidence in this assessment is low.

4.4.2 Faunal communities

4.4.2.1 Management Unit 1

This Unit was the largest of those surveyed and had the greatest variation in survey coverage across the years making it difficult to conduct a detailed temporal comparison for some of the areas. For example, the outer section of Unit 1 (west of Unit 9 and south of the main river channel) was only sampled in 2007 (Figure 11) and consisted of clean mobile sands with polychaetes such as *Scolelepis* spp., robust amphipods and isopods (LS.LSa.MoSa.AmSco; LS.LSa.MoSa.AmSco.Eur) and some stable sands with polychaetes including *Nephtys cirrosa* (LS.LSa.FiSa.Po.Ncir) (Figure 11), (IECS 2008). Along the training wall at the edge of the river channel barnacles with *Littorina* spp. and *Sabellaria* reef were recorded (LR.FLR.Eph.BlitX/LS.LBR.Sab.Salv), along with mussels on mixed substrate (LS.LBR.LMus.Myt.Mx). The training walls were not surveyed in 2013 and these habitats are still potentially present.

The southern sections of Transect 3 just north of the river channel varied from polychaete dominated fine sand in 2005 (LS.LSa.FiSa.Po) (RH 2006), to amphipods, isopods and polychaetes in mobile sand in 2007 (LS.LSa.MoSa.AmSco.Eur) (Figure 11) to mobile sand with sparse fauna in 2013 (LS.LSa.MoSa), (Figure 5) which may reflect a shift from more stable to more mobile sands in this area. In 2007 on the lower section of Transect 4 there was a mosaic of high numbers of amphipods such as *Corophium* spp. and *Bathyporeia* spp. (LS.LSa.MuSa.BatCare) and *M. balthica* and *A. marina* (LS.LSa.MuSa.MacAre) which are habitats characteristic of slightly muddy sand (Figure 11). For the 2013 study this section of Transect 4 was characterised by well drained mobile sand with *Scolelepis* spp. and *Eurydice* spp. (LS.LSa.MoSa.AmSco.Eur) (Figure 5), suggesting a potential change in habitat type. Such changes, however, are considered to be within the range of natural variation for this section of the estuary potentially influenced by storm events, wave exposure and river flow.

During the 2005 and 2007 surveys the areas in the southern section of Unit 1 were characterised by muddy habitat with a high abundance of amphipods (LS.LSa.MuSa.BatCare), (RH 2006, Figure 11) and in 2013 this small section of Transect 8 extending into Unit 1 as characterised by high *C. edule* numbers (LS.LSa.MuSa.CerPo). The two mid transect sites were assigned the muddy sand habitat type LS.LSa.MuSa in 2005 and the mobile sand biotopes LS.LSa.MoSa.AmSco and LS.LSa.MoSa.AmSco.Eur, however, sample locations differed slightly between surveys so a direct comparison is not possible. Further sampling within this section of the Unit is recommended to facilitate assessments of change in the communities present.

Transect 7 located within an inner estuary section of Unit 1 running parallel to the River channel had not been previously surveyed. The eastern extent of this transect was found to be characterised by high numbers of amphipods (LS.LSa.MuSa.BatCare), with abundant *C. edule* in the mid-section (LS.LSa.MuSa.CerPo) and sparse fauna at the western extent (LS.LSa.MoSa). Further sampling of this transect during future surveys is required to assess temporal variation of the habitat types in this area.

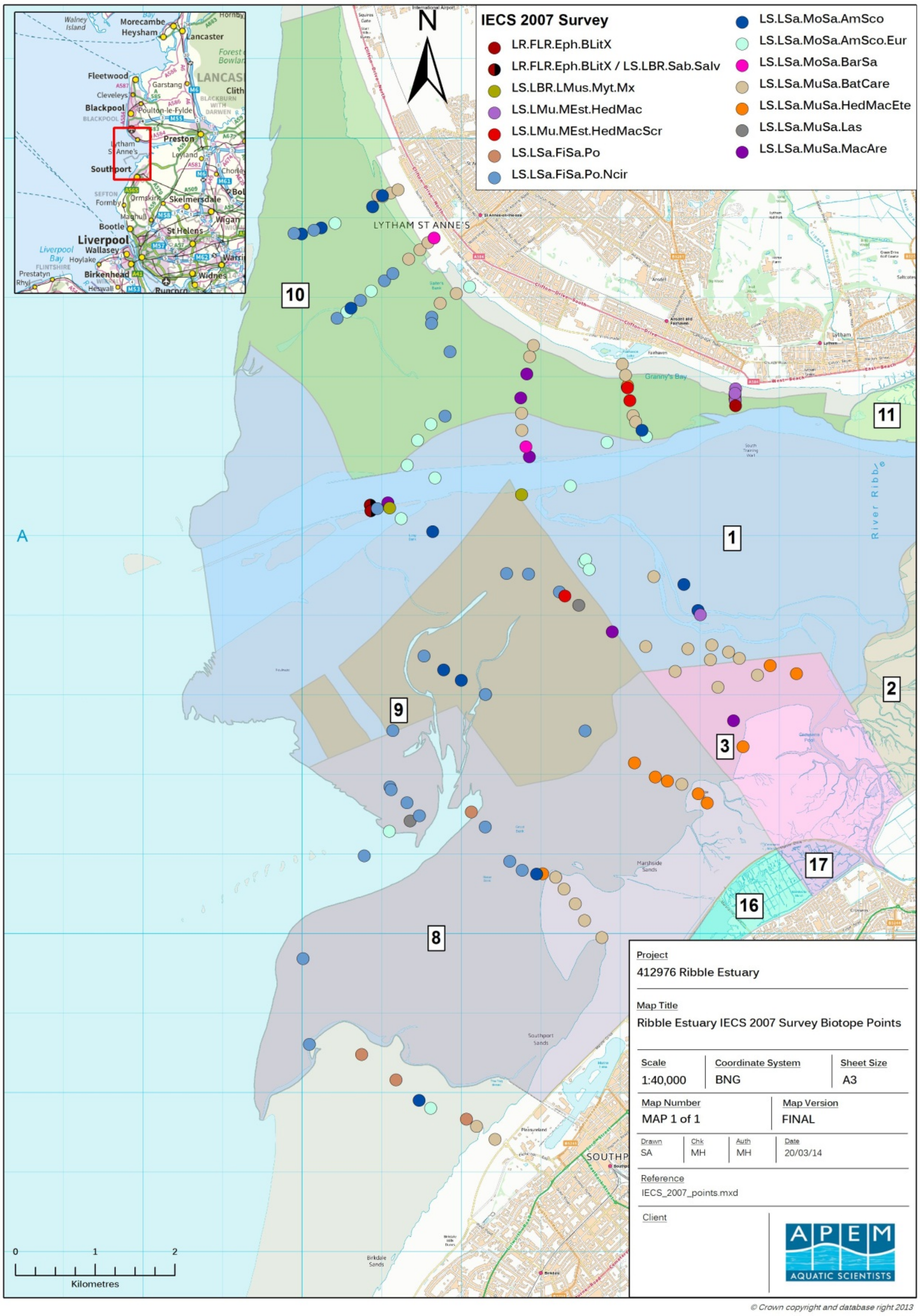


Figure 11. Sample locations and habitat types recorded during the 2007 survey (IECS 2008). © Crown copyright and database right 2013.

Table 15. Preliminary condition assessment for SSSI Management Unit 1.

Feature	Attribute	Target	Preliminary condition assessment
Littoral sediments (intertidal mud and sand)	**Distribution of biotopes**	Maintain the distribution of biotopes, allowing for natural succession / known cyclical change.	In general, based on the results obtained in 2007, sediments on the outer sandflat sections of Unit 1 consist of mobile sand and fine sand habitat types but data are not available from other years for comparison. Potential shifts in habitat types were apparent on the southern sections of Transect 3 (stable fine sand to more mobile sand communities) and Transect 4 (muddy sand communities to more mobile sand communities). It is considered likely, however, that these changes are within the range of natural variation expected for this section of the estuary which is potentially influenced by changes in river flow in addition to other environmental influences (e.g. wave and wind exposure). The mid-section of Unit 1 was not surveyed extensively in 2013 although the southern section of Transect 8 in 2013 did extend into Unit 1 and was found to be characterised by high numbers of cockles (A2.242) which differed to the muddy sediment communities recorded in 2005 and 2007 (mainly A2.244). The linear extents of different biotopes along transects were recorded during the 2007 and 2013 studies, however, within Unit 1 there was not sufficient overlap of the areas covered to enable a direct comparison of biotope extent. Overall, it is considered likely that changes in the biotopes within Unit 1 are due to environmental influences such as wave and wind exposure and are part of natural cyclical change and a preliminary assessment of the condition of this attribute is **<u>favourable</u>**. It is recommended that in future surveys a greater number of sites are sampled in the outer and mid-sections of Unit 1 to increase the area over which changes in distribution can be directly compared.
	Biotope composition of littoral sediment	Maintain the variety of biotopes identified for the site, allowing for natural succession / known cyclical change.	There were eight biotopes recorded in 2005, nine in 2007 and five in 2013. The reduced number for the 2013 survey reflects the smaller area of Unit 1 covered in 2013 compared to the other two surveys. Transect 7 covered a new section of the Unit and revealed a region of high cockle abundance (A2.242) which was not recorded at any of the sites during the previous surveys. It is considered overall, that differences in the number of biotopes recorded in different years was due to differences in the areas covered combined with natural variation in the biotopes present at specific sites. Consequently, a preliminary assessment of the condition of this attribute is **<u>favourable</u>**.

	Species composition of representative or notable biotopes	No decline in biotope quality due to changes in species composition or loss of notable species, allowing for natural succession/known cyclical change.	Multivariate analysis of species recorded in situ during Phase I survey suggested there was no distinct variation across years in terms of species composition of samples. Core sample data was not available for 2005 and 2007 and the small number number of *in situ* biotope sites sampled in both 2007 and 2013 at the same location in Unit 1 was a limiting factor and only presence/absence data could be used for the assessment. Consequently, due to the limitations of the available data it is considered that the species composition of biotopes is likely to have remained similar across years and this attribute would likely be in **favourable** condition, however, confidence in this assessment is low and sampling an increased number of sites for biotope comparisons is recommended.

4.4.3 Management Unit 8

Transect 10 was on a sandbank in the outer estuary and in 2007 was primarily characterised as fine sand with polychaetes including *Nephtys* spp. (LS.LSa.FiSa.Po.Ncir). During the 2013 survey the majority of this transect could not be accessed due to the presence of a water channel which could not be traversed by foot. The habitat, however, consisted of fine compacted sand with well-defined ripples and no anoxic layer and core samples collected at the start of the transect were impoverished with some polychaetes. Based on these observations the habitat type LS.LSa.FiSa.Po was allocated to the area and it is considered likely that the habitat has remained similar across years with LS.LSa.FiSa.Po.Ncir allocated to this area in 2007 (Figure 11).

On Transect 9 in 2013 there was muddy sand habitat on the upper shore with high densities of amphipods (LS.LSa.MuSa.BatCare), the muddy habitat was also present in 2007 with the dominant species being *M. balthica* and *H. diversicolor* (LS.LSa.MuSa.HedMacEte). Saltmarsh plants present at the upper shore sample sites in 2013, however, were not mentioned in the IECS (2008) report suggesting there may have been potential encroachment of the saltmarsh into the intertidal zone since 2007. In both 2007 and 2013 the majority of the transect consisted of a variety of polychaetes including *H. diversicolor* and abundant *M. balthica* (LS.LMu.MEst.HedMac/ LS.LSa.MuSa.HedMacEte).

On Transect 11 and 13 in each survey year the upper shore to mid shore was generally sand with some mud content, often characterised by amphipods (LS.LSa.MuSa.BatCare). The mid shore was also characterised by muddy sand communities in 2005 (RH 2006) and 2007 (Figure 11), but was comprised of the mobile sand biotope LS.LSa.MoSa.AmSco in 2013. Each year the lower shore was characterised by stable fine sands with polychaetes including *Nephtys* spp. (LS.LSa.FiSa.Po and LS.LSa.FiSa.Po.Ncir). Transect 12 was surveyed for the first time in 2013 and *C. edule* and *M. balthica* was found to be common to abundant on the upper shore (LS.LSa.MuSa.CerPo) with the rest of the transect comprised of a similar habitat as Transect 13 (LS.LSa.FiSa.Po).

A comparison of linear distances recorded for different biotopes/sub-biotopes in Unit 8 in 2007 and 2013 is provided in Table 16.

Table 16. Linear distances (km) covered by different biotopes in Unit 8 along transects surveyed in 2007 and 2013.

		Transect 9		Transect 10		Transect 11		Transect 13	
EUNIS code	**JNCC Biotope code**	**‘07**	**‘13**	**‘07**	**‘13**	**‘07**	**‘13**	**‘07**	**‘13**
A2.231	LS.LSa.FiSa.Po				1.24			1.08	1.44
A2.2313	LS.LSa.FiSa.Po.Ncir			0.96		0.92	0.72	0.6	0.68
A2.223	LS.LSa.MoSa.AmSco					0.2	1.04	0.12	
A2.2232	LS.LSa.MoSa.AmScoEur							0.4	
A2.244	LS.LSa.MuSa.BatCare	0.16	0.4			0.88	0.44	0.24	0.32
A2.245	LS.LSa.MuSa.Lan			0.28					
A2.241	LS.LSa.MuSa.MacAre					0.12			
A2.243	LS.LMu.MuSa.HedMacEte	1.24				0.08			
A2.312	LS.LMu.MEst.HedMac		1.0						

Table 17. Preliminary condition assessment for SSSI Management Unit 8.

Feature	Attribute	Target	Preliminary condition assessment
Littoral sediments (intertidal mud and sand)	**Distribution of biotopes**	Maintain the distribution of biotopes, allowing for natural succession / known cyclical change	In general, there was consistency across years in terms of the main habitat types present along different transects. Comparison of the linear distances of similar habitat types recorded in 2007 and 2013 also suggests the extent of habitat types has remained relatively consistent within this Unit (Table 16). Overall the condition of the attribute is considered to be **favourable**.
	Biotope composition of littoral sediment	Maintain the variety of biotopes identified for the site, allowing for natural succession / known cyclical change.	There were five biotopes recorded in 2005 (RH 2006), seven in 2007 and six in 2013. In general, the range of habitat types recorded in 2005, 2007 and 2013 was similar allowing for natural succession / known cyclical change. Overall the condition of the attribute is considered to be **favourable**.
	Species composition of representative or notable biotopes	No decline in biotope quality due to changes in species composition or loss of notable species, allowing for natural succession/known cyclical change.	Multivariate analysis of species recorded in situ during Phase I survey suggested there was no distinct variation across years in terms of species composition of samples. Core sample data was not available for 2005 and 2007 and the small number number of *in situ* biotope sites sampled in both 2007 and 2013 at the same location in Unit 1 was a limiting factor and only presence/absence data could be used for the assessment. Consequently, due to the limitations of the available data it is considered that the species composition of biotopes is likely to have remained similar across years and this attribute would likely be in **favourable** condition, however, confidence in this assessment is low and sampling an increased number of sites for biotope comparisons is recommended.

4.4.4 Management Unit 9

In 2005, Transect 8 was primarily assigned the fine sand habitat types 'littoral sand and muddy sand' Ls.LSa and 'polychaete/amphipod dominated fine sand shores' Ls.LSa.FiSa which encompassed the eastern extent of the transect, with an area of *L. conchilega* tubes near the middle of the transect (LS.LSa.MuSa.Lan) (RH 2006). In 2007 the western section of this transect was assigned a fine sand biotope (LS.LSa.FiSa.Po.Ncir), with a transition to biotopes characteristic of muddier sand moving east (LS.LMu.MEst.HedMacScr/LS.LSa.MuSa.MacAre) and *L. conchilega* tubes were again apparent towards the middle of the transect. The general transition from fine sand to muddy sand biotopes was again evident in 2013 with abundant *C. edule* at the eastern extent of the transect (LS.LSa.MuSa.CerPo). An extensive *L. conchilega* bed was not encountered in 2013 although isolated individuals were noted and there were large areas of empty *L. conchilega* tubes suggesting that recent storm events may have dislodged individuals.

In both 2007 and 2013 the majority of the section of Transect 9 within Unit 9 was classed as polychaetes including *N. cirrosa* in fine sand (LS.LSa.FiSa.Po.Ncir). There was a small expanse of amphipods and *S. squamata* in mobile sand at the western extent of the transect in 2007 (LS.LSa.MoSa.AmSco), and in 2013 an area in which *C. edule* was common was recorded at the western extent of the transect within Unit 9 (LS.LSa.MuSa.CerPo).

A comparison of linear distances recorded for different biotopes/sub-biotopes in Unit 9 in 2007 and 2013 is provided in Table 18.

Table 18. Linear distances (km) covered by different biotopes in Unit 9 along transects surveyed in 2007 and 2013.

		Transect 8		Transect 9	
EUNIS code	**JNCC Biotope code**	**2007**	**2013**	**2007**	**2013**
A2.2313	LS.LSa.FiSa.Po.Ncir	0.79	0.54	1.71	2.0
A2.223	LS.LSa.MoSa.AmSco			0.53	
A2.242	LS.LSa.MuSa.CerPo		0.49		0.45
A2.245	LS.LSa.MuSa.Lan	0.6			
A2.243	LS.LMu.MuSa.HedMacEte		0.61	0.25	
A2.312	LS.LMu.MEst.HedMac				0.04
A2.313	LS.LMu.MEst.HedMacScr	0.25			

Table 19. Preliminary condition assessment for SSSI Management Unit 9.

Feature	Attribute	Target	Preliminary condition assessment
Littoral sediments (intertidal mud and sand)	**Distribution of biotopes**	Maintain the distribution of biotopes, allowing for natural succession / known cyclical change	There is some evidence that the eastern end of Transect 8 may have been characterised by a fine sand biotope in 2005 although biotopes/sub-biotopes characteristic of sand with some mud content were present in 2007 and 2013. In general, however, there was consistency across years in terms of the main habitat types present along different transects. Comparison of the linear distances of similar habitat types recorded in 2007 and 2013 (Table 18) also suggests the extent of habitat types has remained relatively consistent within this Unit although the areas of cockles recorded in 2013 were not noted during the previous surveys. Overall the changes are considered to be naturally occurring and condition of the attribute is considered to be **favourable**.
	Biotope composition of littoral sediment	Maintain the variety of biotopes identified for the site, allowing for natural succession / known cyclical change.	There were three biotopes recorded in 2005, five in 2007 and five in 2013 although it should be noted the southern section of the Unit was not surveyed in 2005. In general, the range of habitat types recorded in 2005, 2007 and 2013 is considered to be similar allowing for natural succession/ known cyclical change. Overall the condition of the attribute is considered to be **favourable**.
	Species composition of representative or notable biotopes	No decline in biotope quality due to changes in species composition or loss of notable species, allowing for natural succession/known cyclical change.	Multivariate analysis of species recorded in situ during Phase I survey suggested there was no distinct variation across years in terms of species composition of samples. Core sample data was not available for 2005 and 2007 and the small number number of *in situ* biotope sites sampled in both 2007 and 2013 at the same location in Unit 1 was a limiting factor and only presence/absence data could be used for the assessment. Consequently, due to the limitations of the available data it is considered that the species composition of biotopes is likely to have remained similar across years and this attribute would likely be in **favourable** condition, however, confidence in this assessment is low and sampling an increased number of sites for biotope comparisons is recommended.

4.4.5 Management Unit 10

Transect 1 at the eastern extent of Unit 10 consisted of fine sand biotope complexes, biotopes and sub-biotopes in 2005 (mainly LS.LSa.FiSa), 2007 (LS.LSa.FiSa.Po.Ncir) and 2013 (LS.LSa.FiSa.Po and LS.LSa.FiSa.Po.Ncir). The main difference across years was that the amphipods in muddy sand biotope (LS.LSa.MuSa.BatCare) was recorded in the upper shore on Transect 1 in 2007 but not during the other years, and there were also large expanses of mobile sand biotopes in 2007 with amphipods, isopods and *S. squamata* (LS.LSa.MoSa.AmSco and LS.LSa.MoSa.AmSco.Eur). The biotopes on Transect 2 were similar in 2007 and

2013 with mobile sand and fine sand biotopes on the mid to lower shore, although again amphipods in muddy sand were recorded on the upper shore in 2007 but not in 2013 when polychaetes in fine sand were present (LS.LSa.FiSa.Po).

Muddy sand habitat types mainly characterised by high numbers of *Bathyporeia* and *Corophium* spp. were present on the upper shore on Transects 3-6 each year. The mid-shore section of Transect 3 was characterised by amphipods, *E. pulchra* and *S. squamata* in mobile sand (LS.LSa.MoSa.AmSco.Eur) in 2013, whereas the more stable fine sand biotope LS.LSa.FiSa.Po.Ncir was dominant in this area in 2007 and 2005. There were also more distinct changes on Transect 4 with fine and mobile sand biotopes present in 2013 and 2005, but muddy sand biotopes LS.LSa.MuSa.MacAre and LS.LSa.MuSa.BatCare dominated this transect in 2007.

Towards the east of the Unit sediment became muddier with biotopes/sub-biotopes changing accordingly, with amphipod habitats on the upper shore and parts of the lower shore, and biotopes with high numbers of *M. balthica*, and some *H. diversicolor* on the mid to lower shore (LS.LSa.MuSa.HedMacEte and LS.LMu.MEst.HedMacScr). Mobile sand biotopes were present near the river channel on Transect 5 in 2007 and 2013.

A comparison of linear distances recorded for different biotopes/sub-biotopes in Unit 10 in 2007 and 2013 is provided in Table 20.

Table 20. Linear distances (km) covered by different biotopes in Unit 10 along transects surveyed in 2007 and 2013.

		Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
EUNIS code	**Biotope**	**2007**	**2013**	**2007**	**2013**	**2007**	**2013**	**2007**	**2013**	**2007**	**2013**	**2007**	**2013**
A2.231	LS.LSa.FiSa.Po		0.48		0.92				0.64				
A2.2313	LS.LSa.FiSa.Po.Ncir	0.2	0.2	0.68		1.56							
A2.22	LS.LSa.MoSa						0.28						
A2.221	LS.LSa.MoSa.BarSa			0.12							0.12		
A2.223	LS.LSa.MoSa.AmSco	0.76	0.52	0.2	0.52								
A2.2232	LS.LSa.MoSa.AmScoEur	0.16		0.32	0.28	0.72	1.88						
A2.24	LS.LSa.MuSa						0.52						
A2.244	LS.LSa.MuSa.BatCare	0.2		0.4		0.4		0.52	0.36	0.52	0.34		0.16
A2.241	LS.LSa.MuSa.MacAre							0.48					
A2.243	LS.LMu.MuSa.HedMacEte										0.22	0.12	
A2.313	LS.LMu.MEst.HedMacScr									0.44			
A2.312	LS.LMu.MEst.HedMac										0.28	0.08	0.2
A2.7212	LS.LMx.LMus.Myt.Sa		0.12										
A2.431	LR.FLR.Eph.BlitX											0.06	

Table 21. Preliminary condition assessment for SSSI Management Unit 10.

Feature	Attribute	Target	Preliminary condition assessment
Littoral sediments (intertidal mud and sand)	**Distribution of biotopes**	Maintain the distribution of biotopes, allowing for natural succession / known cyclical change	In general, there was consistency across years in terms of the main habitat types present along different transects. The most distinct change was potentially on Transect 4 which was characterised solely by muddy sand biotopes in 2007 (A2.244 and A2.241) but was mainly fine sand with polychaetes in 2013 (A2.231). Other differences were the presence of amphipods in muddy sand (A2.244) in the upper shore on more Transects in 2007 compared to 2013; some mobile sand biotopes/sub-biotopes on Transect 1 in 2007 which were not recorded in 2013; and the presence of amphipods, *E. pulchra* and S. squamata in mobile sediment (A2.2232) on the mid-section of Transect 3 in 2013 in contrast to the dominant fine sand with *Nephtys* spp. (A2.2313) in 2007. A comparison of the linear distances of similar habitat types recorded in 2007 and 2013 (Table 20) indicates the extent of habitat types has remained relatively consistent within this Unit (Table 20). Overall, it is considered changes are likely to be within the range of natural succession/cyclical change and a preliminary assessment of condition of this attribute is considered to be **favourable**.
	Biotope composition of littoral sediment	Maintain the variety of biotopes identified for the site, allowing for natural succession / known cyclical change.	There were seven biotope complexes/biotopes/sub-biotopes recorded in 2005, ten in 2007 and eleven in 2013 although less transects were sampled in 2005 in comparison with the other years. The variety of these habitat types was similar across years and is considered to be within the range of natural variation. Overall the condition of the attribute is considered to be **favourable.**
	Species composition of representative or notable biotopes	No decline in biotope quality due to changes in species composition or loss of notable species, allowing for natural succession/known cyclical change.	Multivariate analysis of species recorded in situ during Phase I survey suggested there was no distinct variation across years in terms of species composition of samples. Core sample data was not available for 2005 and 2007 and the small number number of *in situ* biotope sites sampled in both 2007 and 2013 at the same location in Unit 1 was a limiting factor and only presence/absence data could be used for the assessment. Consequently, due to the limitations of the available data it is considered that the species composition of biotopes is likely to have remained similar across years and this attribute would likely be in **favourable** condition, however, confidence in this assessment is low and sampling an increased number of sites for biotope comparisons is recommended.

4.4.6 Condition Assessment Summary

For the sediment character attributes ‘Oxidation-reduction profile’ and ‘Sediment type’, and ‘Topography’ condition was assessed as **favourable** for all Units but with a low level of confidence due to lack of supporting data.

For the faunal attributes ‘Distribution of biotopes’ and ‘Biotope composition of littoral sediment’ condition was assessed as **favourable** for all Units.

For the faunal attribute ‘Species composition of representative or notable biotopes’ condition was assessed as **favourable** for all Units but with a low level of confidence due to lack of supporting data.

5 BIBLIOGRAPHY

APEM. 2013. Ribble Estuary SSSI / Ribble & Alt SPA Intertidal sediments condition monitoring. Field Report.

Connor, D. W. 2004. *The Marine Habitat Classification.* Joint Nature Conservation Committee.

Davies J. 1991. *The Marine Conservation Review.* Report No. 1217.

Folk, R. 1954. The distinction between grain size and mineral composition in sedimentary-rock nomenclature. *Journal of Geology*, 62: 344-359.

Institute of Estuarine and Coastal Science (IECS). 2008. *Condition assessment of the Ribble Estuary SSSI: Littoral sediments.* Institute of Estuarine and Coastal Studies. Report to Natural England.

JNCC. 2004. *Common Standards Monitoring Guidance for Marine.* ISSN 1743-8160.

Long, D. 2006. *BGS detailed explanation of seabed sediment modified Folk classification.*

Natural England. 2008. SSSI condition assessment: A guide for owners and occupiers.

Natural England. 2011. Conservation objectives and definitions of favourable condition for designated features of interest for Ribble Estuary SSSI and Ribble and Alt Estuaries SPA and Ramsar site. August 2011.

Popham, E. J. 1996. *The littoral fauna of the Ribble estuary, Lancashire, England.* Oikos, 17, 19-32.

Royal Haskoning (RH). 2006. *Maritime Monitoring Intertidal Survey of the North West England 2005 - 2006.* Report to Natural England. Report No. 9R5211/R/CRJ/Exet.

Wyn, G. B. 2000. *Handbook for Marine Intertidal Phas I Biotope Mapping Survey.* Counytrside Council for Wales (CCW) 112pp.

6 APPENDICES

All appendices have been provided separately as electronic files

Appendix 1 –	Master photograph log
Appendix 2 –	Assessment criteria of selected hazardous substances in sediments, taken from the CEMP data assessment (OSPAR, 2012)
Appendix 3 –	Phase I site data and Phase II core data
Appendix 4 –	Location of quantitative core sites
Appendix 5 –	Summary statistics for each site
Appendix 6 –	Outputs of GRADISTAT analysis of sediment particle size data