Joint Nature Conservation Committee
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Marine Nature Conservation Review

Littoral survey of the Ribble, Duddon and Ravenglass estuary systems, east basin of the Irish Sea

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September 1992

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PREFACE

Marine Nature Conservation Review

Reports of Field Surveys

The Marine Nature Conservation Review (MNCR) was initiated by the Nature Conservancy Council in 1987 to consolidate the information already collected on British marine ecosystems, particularly the extensive data collected from marine survey projects commissioned by NCC since 1974, and to complete survey work and interpretation of data. Since April 1991, preparation of the Marine Nature Conservation Review has been undertaken within the United Kingdom's Joint Nature Conservation Committee which is the statutory body constituted by the Environmental Protection Act 1990 to be responsible for research and advice on nature conservation both at UK and international levels. It is established by English Nature, Scottish Natural Heritage and the Countryside Council for Wales, together with independent members and representatives from the Countryside Commission and Northern Ireland; the JNCC is supported by specialist staff.

The area included in the MNCR is the coastline of England, Scotland and Wales (excluding the Isle of Man and the Channel Isles) extending from the lower limit of terrestrial flowering plants out to the limit of British territorial seas, and into estuaries to the limits of maritime influence. In practice, most of the survey work is limited to the littoral and sublittoral within the 50 m depth contour. The MNCR is based on descriptions of habitats and the recorded abundance of conspicuous species.

The MNCR is drawing together information on marine ecosystems around Great Britain with the objectives of:

- extending our knowledge of benthic marine habitats, communities and species in Great Britain, particularly through description of their characteristics, distribution and extent;
- identifying sites of nature conservation importance.

The data collected also provides information to support more general measures to minimise adverse effects of development and pollution, particularly on sites and species of nature conservation importance.

Field surveys contributing to the MNCR are undertaken both by in-house staff and by contractors. The procedures adopted for survey work and the recording forms used are defined by JNCC to ensure as high a level of consistency as possible. Survey reports are produced on each of the areas surveyed, and will contribute to a MNCR report series on the main themes of the Review.

Copies of the field survey reports (which may be freely photocopied) are available on loan from: English Nature, Information and Library Services, Northminster House, Peterborough, PE1 1UA.
Application should be made to the English Nature Headquarters library through local or institutional library services. Reports produced for NCC, and carrying a CSD number, can be purchased on microfiche from the same address. JNCC reports can be purchased on microfiche from:
Chadwyck-Healey Ltd., Cambridge Place, Cambridge, CB2 1NR.

Field data and computer print-outs of species distributions within each area surveyed are only available by direct contact with MNCR staff.

Keith Hiscock

Head, Marine Nature Conservation Review

SYNOPSIS

Estuaries are the interface between river systems and the open sea where the continual mixing of salt and fresh water combined with tidal movements result in complex ecosystems. Physical conditions within an estuary are complex and vary considerably even between adjacent estuarine systems. Physical and biological gradients are established from the tidal limit to the entrance and any estuary exhibits a wide range of the factors limiting the distribution of the flora and fauna. Estuaries therefore have considerable marine biological and conservation importance. A number of major estuarine systems enter the eastern basin of the Irish Sea (Colwyn Bay to the Mull of Galloway). These estuaries include the Ribble Estuary in Lancashire and the Duddon & Ravenglass estuarine systems in south Cumbria. The Ribble Estuary is a large coastal plain estuary of simple structure with sandy outer shores and a series of large saltmarshes fringing the inner muddy shores. The Duddon Estuary, located at the south-west corner of the Lake District, is a large coastal plain estuary formed by the River Duddon and the smaller Kirby Pool. At the mouth, there are extensive, highly mobile, flat sand plains; sand extends beyond high water to form large sand dunes. Mid and upper reaches of the estuary become muddier with increasing distance up the estuary and are flanked by saltmarsh. The Ravenglass system is composed of three estuaries of the Rivers Esk, Irt and Mite which join at Ravenglass to form a single channel leading to the open sea.

The Ribble, Duddon and Ravenglass estuarine systems were surveyed during the period 11-17 July 1991. Sites were surveyed following standard MNCR methods and the information recorded on MNCR recording forms. Within each site, detailed biological records were collected from each clearly distinguishable habitat. Habitats were selected to ensure records were collected for all the major biological zones and major substrata types present. A total of 76 habitats were described from 25 sites surveyed during the present survey. A total of 140 taxa were recorded during the present survey. A total of ten communities have been described from the data collected during the present survey and incorporating data collected by previous MNCR surveys for the Ribble, Duddon and Ravenglass estuary systems. Of these ten community types identified, six were hard substrata (mainly stones on sediment), and four were sedimentary communities. Sedimentary communities were distinguished on the basis of their biotic composition and on their sediment type.

The Ribble Estuary has been extensively modified by man and receives a considerable anthropogenic input of waste material. In contrast, the Duddon and Ravenglass estuary systems

are set in rural areas with little conspicuous anthropogenic influence. Habitats within these estuarine are predominantly sedimentary with occasional small areas of small stones and shingle on the surface of the sediment. Sedimentary communities were characterised by infaunal species with few epibenthic species recorded. At the entrance to these estuaries, mobile medium and fine sand flats had a low species richness with occasional polychaetes and crustaceans. In the middle estuaries, sediment became muddier and species richness initially increased with infaunal communities characterised by polychaetes, burrowing crustaceans and bivalve molluscs. With increasing distance up the estuary towards the tidal limit, sediment changed to mud and the ambient salinity declined. Species richness of the infaunal community decreased; the communities were characterised by oligochaete worms and burrowing crustaceans. At the tidal limit, marine species richness declined to zero and freshwater species were recorded. Hard substrata are restricted to man-made structures such as coast protection, training walls and railway bridges. Consequently, total habitat diversity was low with only ten community types identified within the three estuarine systems. Communities on hard substrata had a low species richness and low abundance which was probably a consequence of low salinity, siltation and/or tidal scour.

1 INTRODUCTION

Estuaries are the interface between river systems and the open sea and the continual mixing of salt and fresh water combined with tidal movements result in complex ecosystems. The continual input, trapping and recycling of nutrients makes estuaries amongst the most fertile and productive ecosystems in the world (Davidson *et al.* 1991). Physical conditions within an estuary are complex and vary considerably even between adjacent estuarine systems. Physical and biological gradients are established from the tidal limit to the entrance and any estuary exhibits a wide range of the factors limiting the distribution of the flora and fauna (Popham 1966). Therefore estuaries have considerable marine biological and conservation importance.

A number of major estuarine systems enter the eastern basin of the Irish Sea (Colwyn Bay to the Mull of Galloway). These estuaries include the Ribble Estuary in Lancashire and the Duddon & Ravenglass estuarine systems in south Cumbria. These estuaries are set in contrasting locations; areas adjacent to the Ribble Estuary are primarily urban and industrial whilst the Duddon and Ravenglass systems are set in primarily rural areas and form the northern and southern coastal boundaries of the Lake District National Park and are therefore rural in character. Figure 1 shows the location of these estuaries and the main geographical features of the survey area.

Plate 1 A view north across an extensive sand-flat towards Lytham St Annes, at the mouth of the Ribble Estuary. [MNCR slide N°: S38.1.4 Jon Davies]

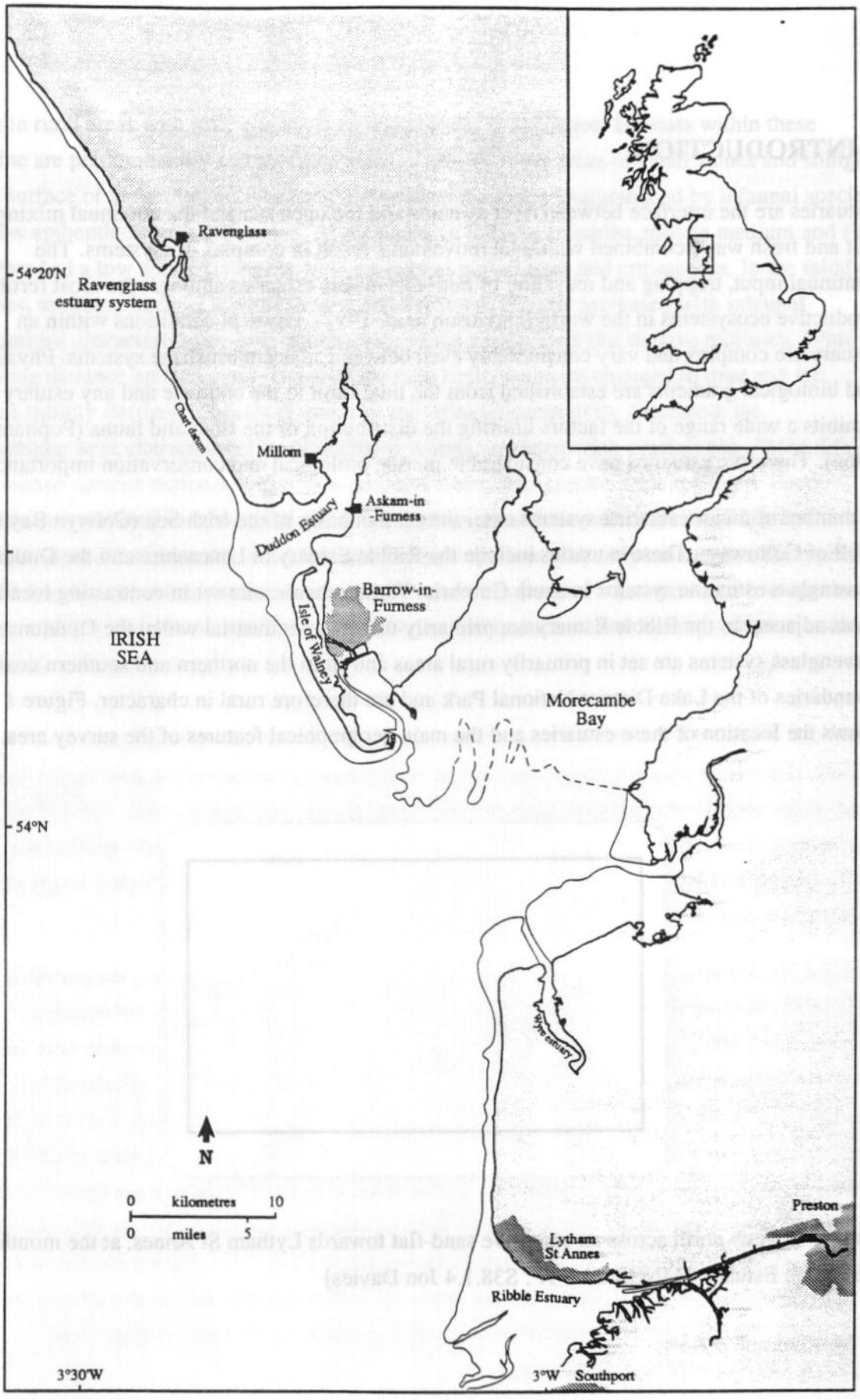


Figure 1 Geographical location of the Ribble, Duddon and Ravenglass estuarine systems

The Ribble Estuary is a large coastal plain estuary of simple structure with sandy outer shores and a series of large saltmarshes fringing the inner muddy shores (.i.Davidson *et al.* 1991;). At the upper tidal limit lies the town of Preston which was an important centre for the Lancashire linen industry in the nineteenth century. Preston Docks were established as one of the main centres for the import of the raw materials and the export of the finished product.

In 1806, training walls were built from the docks to the seaward limit to straighten the estuary and the main channel dredged to facilitate shipping movements. These walls resulted in the rapid accumulation and development of fringing marshes. Dredging of the channel has now ceased and the docks were closed to shipping in 1981. Recently the dockland area has been redeveloped as a residential area and the dock itself converted to a marina. On the northern and southern shores at the mouth of the estuary are located the towns of Lytham St Annes and Southport respectively, large resort towns which developed in the mid-nineteenth century.

Plate 2 A view north-east accross the extensive sand flats at the mouth of the Duddon Estuary. [MNCR slide N°: S20.8.1 Roger Covey]

The Duddon Estuary, located at the south-west corner of the Lake District, is a large coastal plain estuary formed by the River Duddon and the smaller Kirby Pool. It has a south-west to north-east orientation and Walney Island, an unusual barrier island, forms the southern seaward limit of the estuary. At the mouth, there are extensive, highly mobile, flat sand plains; sand extends beyond high water to form large sand dunes. Mid and upper reaches of the estuary become muddier with increasing distance up the estuary and are flanked by saltmarsh. In the nineteenth century, large deposits of iron ore were discovered adjacent to the estuary and expansion of the ore industry has created artificial habitats within, or adjacent to, the estuary. At Hodbarrow, mining operations created a series of saline lagoons and at Askam, dumping of 'slagcrete' waste has created a pier. Other than the urban developments at Millom and Barrow-in-Furness, the estuary is set in a predominantly rural area.

The Ravenglass system is composed of three estuaries of the Rivers Esk, Irt and Mite which join at Ravenglass to form a single channel leading to the open sea. This system is often known as the Esk Estuary although for the purpose of the present report it will be called the Ravenglass system.

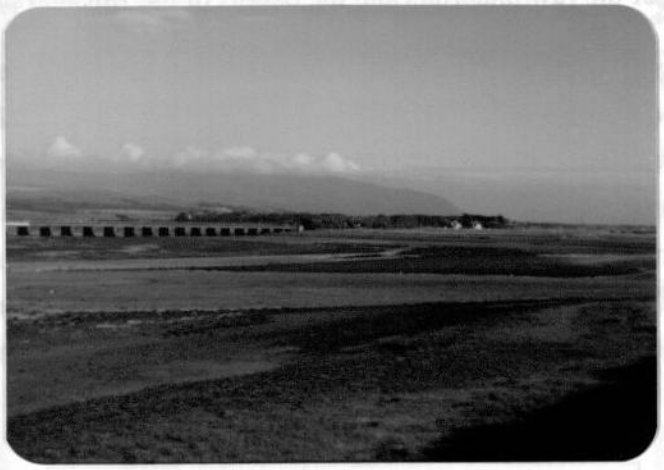


Plate 3 Lower River Esk with the railway viaduct in the background, note the sand and gravel banks within, and adjacent to, the river channel. [MNCR slide N°: S38.GEN.1 Chris Emblow]

2 PHYSICAL CONDITIONS

2.1 Geology

Coastal geology for the survey area has been described by Steers (1969) and Taylor *et al.* (1971) and the following notes are based on these texts together with information provided by Covey & Davies (1989) and Davies (1991). At no point throughout the survey area was the underlying hard geology encountered and therefore the following descriptions are necessarily brief as geology does not influence the marine communities present. The general form of the coast within the survey area was the result of tectonic movements but the land-sea boundary is the result of sea-level rise relative to the land in the Flandrian period (5000 BP) which has resulted in large flat areas covered with sand.

The south Cumbrian coast forms the transition between the Lakeland massif and the eastern Irish Sea basin which is composed of Permo-Triassic sediments. The topography of the valleys and plains to the west of the Lake District is the result of glacial erosion and deposition, sediments within the Duddon and Ravenglass estuarine systems have glacial origins together with sands and cobbles deposited as a result of erosion of the coastal Permian and Triassic rocks. Coastal hard geology surrounding the Ravenglass system is predominantly Triassic sandstone which gives way to the metamorphic Ordovician rocks of Lakeland further inland. Geology of the

Duddon Estuary is more complex with many rock types of varying age outcropping in the area. It is thought that the Duddon estuary itself is the result of a massive tear fault which formed a glacial out-wash channel from Lakeland. Perhaps the most significant rock outcrop within the Duddon Estuary is haematite upon which the local iron ore industry was based (see above). Walney Island at the mouth of the estuary has significant geomorphological importance being one of only a few barrier islands within Britain. Associated with the spit at North Walney are cobble and boulder scars which are a characteristic form of the Cumbrian coast.

Geology of the Ribble Estuary is similar to that outlined above for the Duddon and Ravenglass systems. Evolution of the Lancashire coast is intrinsically related to relative changes in sea-level. Construction of the major land forms - shingle spits, sand bars, sand dunes - occurred at the opening of the Flandrian period. Superficial sediments have been transported in from the east basin of the Irish Sea: most deposition occurred during the period 9270 - 805 BP forming ten marine transgressions (Lytham I - X). South of the Ribble Estuary, there are extensive sand dune systems formed by blown sand resting on alluvium or peat. It should be emphasized that the evolution these geomorphological features (tidal flats, sand dunes, saltmarshes, shingle spits, off-shore bars) is inextricably linked to changes in sea-level. Recent changes in sea-level, if substantiated, may result in wholesale changes to the Ribble Estuary.

2.2 Topography

Coastal aspect of the Lancashire and Cumbrian coast is west to south west and therefore exposed to the prevailing westerly wind and swell. Where the three estuaries join the open coast there are broad sediment beaches with a gradual seaward slope. Offshore, the bed of the Irish Sea slopes very gradually (estimated at 1 in 620 off the Ribble - Popham (1966)) and therefore the energy of the prevailing swell is dissipated off-shore. Nevertheless, winds of >100 km . h^{-1} do occur within the Irish Sea and therefore littoral habitats are exposed to vigorous wave action. Sediments at the mouth of the Ribble, Duddon and Ravenglass systems are composed of clean, mobile sand.

Apart from the entrance channel, the three rivers comprising the Ravenglass system are protected from the prevailing wind and swell by the extensive sand dunes of the Drigg coast. To the east of the dunes are extensive sediment flats forming the lower reaches of the Rivers Esk, Mite and Irt. East beyond Ravenglass, the Rivers Esk and Mite become much narrower and the littoral zone is bounded by saltmarsh backed by agricultural land. In contrast, the River Irt has a north-south aspect and littoral habitats are bounded by dunes to the west and agricultural land to the east.

At the entrance to the Duddon Estuary there are very extensive sediment flats with the sands being very mobile. These mobile flats extend into the upper estuary grading into more sheltered

muddier conditions beyond the railway bridge at Foxfield. Littoral habitats at the mouth of the estuary are bounded by sand dunes. Mid and upper reaches of the estuary are flanked by saltmarsh backed by agricultural land. Urban developments are present at Haverigg, Millom, Askam-in-Furness and Kirby-in-Furness. Slag-waste from the iron ore industry has been dumped on the shore at Askam and Millom to form large banks: Askam Pier and Borwick Rails. Extraction of ore created Hodbarrow Lagoon, the largest coastal lagoon in north-west England.

Extensive sediment flats form the seaward limit of the Ribble Estuary although the littoral zones are bounded by the extensive urban developments of Lytham St Annes and Southport. At the mouth between these towns, the estuary is about 15 km wide but to the east, the littoral extent narrows sharply and from Freckleton to Preston the river has been canalised between two training banks about 0.5 km apart. Middle reaches of the estuary are bounded by saltmarsh which itself is bounded by embankments. Land-claim has significantly reduced the area of the saltmarsh and most areas behind the banks have become unimproved brackish grazing marsh. Towards the tidal limit, the river is increasing bounded by urban and industrial developments culminating in the town of Preston at the tidal limit.

2.3 Bathymetry and tidal heights

Nearshore areas adjacent to the Lancashire and Cumbria coast are generally shallow and very gently shelving, the 20 m isobath varying from 9 to 22 km off-shore.

The Ravenglass and Duddon estuary systems drain at low water only to leave the main river channels and numerous smaller drainage creeks. In the Ribble Estuary, low water leaves the main navigation channel between the training banks.

Mean tidal ranges for spring and neap tides are approximately 8.0 and 4.3 m respectively for the Ribble Estuary, 7.5 and 3.5 m respectively for the Duddon and Ravenglass estuary systems (Anon 1990).

2.4 Wave exposure and tidal streams

Maximum fetch to the west and north west of the southern part survey area is approximately 200 and 150 km respectively while further north, the Isle of Man reduces the westerly fetch to approximately 80 km. Despite these long fetches, wave exposure for littoral habitats is to some degree ameliorated by shallow near-shore waters and is characterised as 'exposed' (Hiscock 1990). Within the estuaries, fetch decreases rapidly and, together with the ameliorating effect of sediment flats at the mouth of these estuaries, reduces wave exposure of littoral habitats: 'moderately exposed' and 'sheltered' in the middle reaches, 'very' to 'extremely sheltered' in the upper reaches towards the tidal limit.

Plate 4 Erosion marks leading to a sediment 'cliff' approximately 1 m high adjacent to the Duddon channel. [MNCR slide N°: S38.14.10 Dave Mills]

Tidal streams along the open coast are weak, generally less than 1-2 knots (Admiralty Chart 1826). Within the estuaries, there will be much higher current velocities within the channels especially on the ebb tide where the direction of tidal flow and bulk river flow coincide. Current speeds of 1-4 knots have been reported for the Esk channel (joint Esk, Mite and Irt) and Duddon channel (Lee & Ramster 1981). Monitoring data supplied by the National Rivers Authority, North West Region, for the Ribble channel, gives current speeds of 7-9 $m^3 . s^{-1}$. These high current speeds in each of these river channels will result in high tidal scour on hard substrata (training walls) and mobile sediments. Sediment 'cliffs' of up to 1.5 m were observed along the main Duddon channel (Plate 4) in the upper estuary and up to 1 m in a drainage creek at Lytham, Ribble Estuary. These 'cliffs' were being continually eroded by the currents within the channel, fallen sediment was quickly washed downstream.

2.5 Sea temperature and salinity

For the open coast, mean sea surface temperature ranges from 5 °C in February to a maximum of 16 °C in August (Lee & Ramster 1981). Shallow water will be subject to fluctuations of several degrees outside this range during cold winter and hot summer conditions. In winter, excess freshwater input after heavy rain or snow melt will also reduce the temperature of near-shore areas. Data are not available for the seawater temperatures within the Duddon and Ravenglass systems and, for the reasons outlined above, it is likely that the temperature range will exceed the that of the open coast. Data for the water temperature within the Ribble channel for 1991 were provided by the National Rivers Authority, North West Region: 11-18 °C with a mean temperature of c. 15 °C. It should be noted that, whilst these data give the *mean* seawater temperature, littoral habitats will be subject to marked temperature fluctuations during periods of aerial exposure which will influence the biotic composition.

Salinities on the open coast range from 31 $^{o}/_{oo}$ in February to 32 $^{o}/_{oo}$ in August (Lee & Ramster 1981). Data are not available for the salinities within the Duddon and Ravenglass systems although salinity will decline with increasing distance up the estuary. Only two small rivers enter the Duddon Estuary with extensive sand flats extending into the upper estuary. It is likely that there will be insufficient freshwater inflow to markedly reduce the ambient salinity below the open coast salinity over these flats. Nevertheless, lower salinity conditions will prevail adjacent to the river channels. A similar situation will exist over the sediment flats in the lower part of the Ravenglass system. From personal observation, the Rivers Esk, Mite and Irt appear to have a higher volume of flow than the Duddon channel and thus the mid and upper estuaries will be subject to more marked salinity reductions. Dent (1986) recorded the salinity over the mussel beds at Lytham St Annes, Ribble Estuary at low and high water. Salinity varied from 5 to 13.5 $^{o}/_{oo}$ from low to high water respectively. Data for the salinity within the Ribble channel for 1991 were provided by the National Rivers Authority, North West Region: salinity varied from c. 18 $^{o}/_{oo}$ near Preston to c. 34 $^{o}/_{oo}$ at the mouth (salinity calculated from chloride concentration: 9.3 & 18.8 $g \cdot l^{-1}$ respectively).

Fluctuations in ambient salinity have a profound influence on the biotic composition of benthic communities. Marine species vary in their tolerance to lowered salinity which sets the limit to distribution within an estuary. A cline will exist up an estuary with only the most tolerant marine species extending towards the upper limit. Similarly, estuarine and freshwater species have varying tolerance to increasingly saline water and a reverse cline will exist down an estuary towards the mouth for these species.

3 HUMAN INFLUENCES

3.1 Water quality

Coastal water quality has been the subject of intense debate over recent years, particularly in the east basin of the Irish Sea with reference to the input of sewage and radioactive waste (Irish Sea Study Group 1990). Bathing water quality is subject to EC standards laid down in Directive N° 76/160/EEC and beaches monitored by the National Rivers Authority. Sewage input to estuaries raises considerable cause for concern and the Ribble Estuary in particular receives a considerable input of industrial and domestic sewage (Plate 5).

Plate 5 A sewage outfall into the Ribble channel. The habitat in the foreground is muddy sand in the foreground, with a training wall composed of boulders and cobbles on the opposite bank of the channel. [MNCR slide N°: S38.5.3 Dave Mills]

Data are not available for the water quality within the Duddon and Ravenglass estuary systems although being located within predominantly rural areas will reduce the likely anthropogenic input to these systems. An exception concerns a low-level radioactive waste repository at Drigg which had an outfall into the River Irt. Recently, waste has been redirected to a sea outfall although local concern remains over radioactive input to the Ravenglass estuary system.

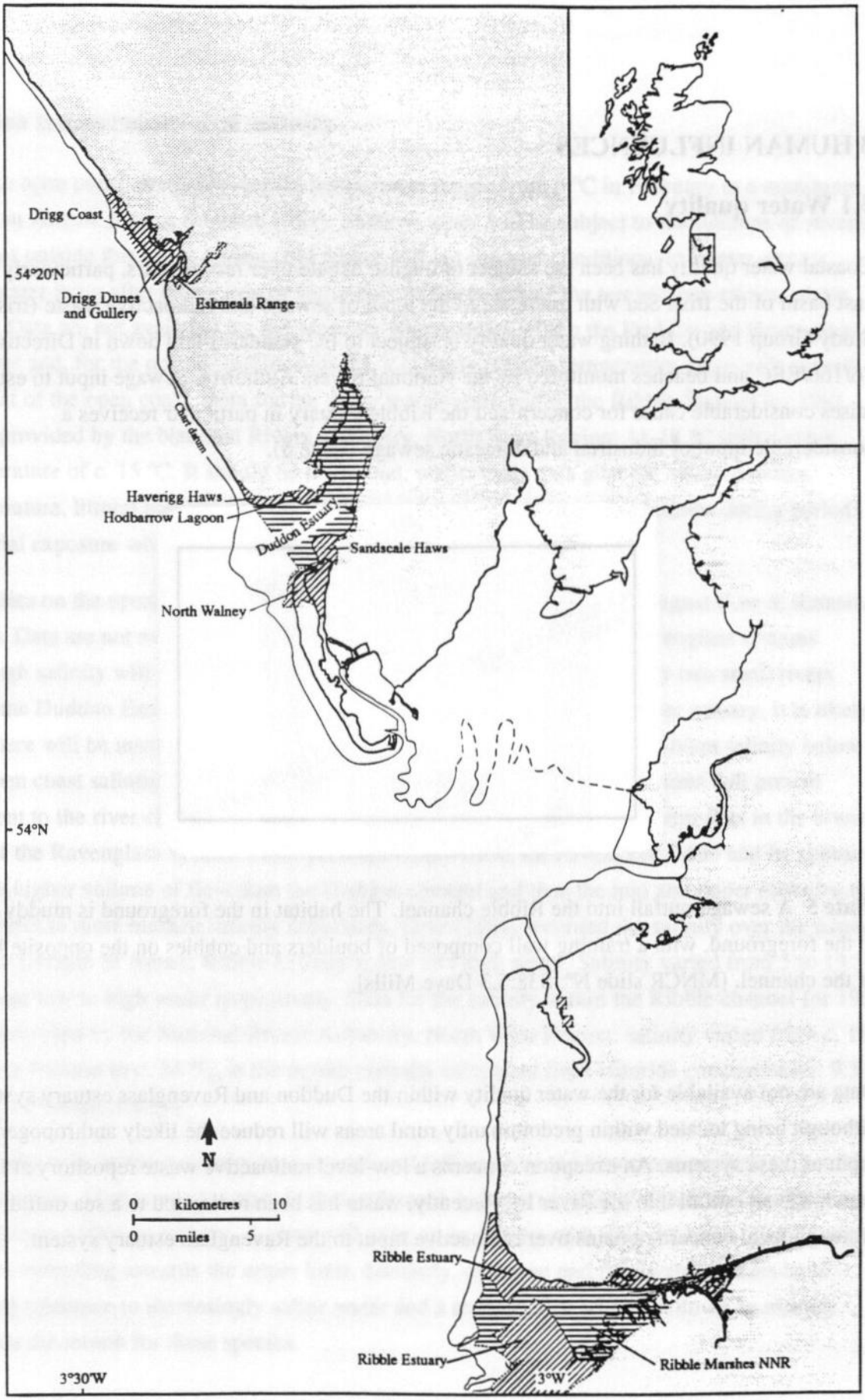


Figure 2 Established sites of nature conservation importance within the survey area

3.2 Sand extraction

Large quantities of sand are commercially extracted from the Ribble Estuary at Salter's Bank, off Lytham St Annes, and Horse Bank, off Southport (Davies 1991). Salter's Bank is licensed for the extraction of 150, 000 m^3 of sand per annum. Extraction at Horse Bank, which requires the marking of tracks across the sand bank, raises concern over the possible impact of this extraction on bird populations and on beach sedimentation and structure.

3.3 Established nature conservation importance

Within these estuarine systems there is considerable established nature conservation importance. Figure 2 indicates the location of protected sites within the survey area. The Ribble Estuary, and Ribble Marshes National Nature Reserve in particular, has significant nature conservation importance primarily for ornithological interest. Ribble Marshes has been designated a Special Protection Area (SPA) and the Ribble/Alt Estuaries are a proposed SPA. It is an important estuary for waterfowl, holding twelve internationally important and six nationally important wintering populations of waterfowl; it is also the main centre in Britain for pink-footed geese. In addition to the ornithological interest, the Ribble Estuary has a rich and varied terrestrial and aquatic invertebrate fauna is home to two rare amphibians: the natterjack toad and the sand lizard (Information from JNCC Coastal Review Unit).

The Duddon Estuary SSSI has international and national importance for wintering wildfowl and waders and provides a vital link in the chain of west coast estuaries used by migrating birds. Estuaries on the Lancashire and Cumbria coast support over 95% of the British population of the Natterjack Toad, a nationally rare species, with 18-24% of the population recorded within the Duddon Estuary. Further to its ornithological and amphibian interest, the Duddon Estuary has nationally important sand dune, salt-marsh, invertebrate and geological conservation interest. Duddon Estuary is a proposed SPA and Ramsar site.

The Ravenglass estuary system is within the Lake District National Park and forms an important part of the Drigg Coast SSSI. Within the SSSI are located Eskmeals Range, a Cumbria Wildlife Trust Reserve, and Drigg Dunes and Gullery, a Local Nature Reserve. Conservation interest centres on the most extensive sand dune system in Cumbria which harbours a Natterjack Toad population (>20% of GB population), several uncommon maritime plants including the Isle of Man cabbage (*Rhyncosinapsis monensis*), and two Red Data Book species of beetle: *Hypocaccus rugiceps* (RDB 1) and *Cincindela hybrida* (RDB 2). Ravenglass is a proposed Ramsar site.

4 PREVIOUS MARINE STUDIES OF THE LITTORAL ZONE

Most studies of the east basin of the Irish Sea have concentrated on the open coast and off-shore areas and few investigations have considered the Ribble and Duddon Estuaries or the Ravenglass system. Previous MNCR surveys have followed this trend of concentrating on the open coast although some sites have been surveyed within these estuarine systems. Figures 3, 4 & 5 detail the location of sites of previous marine biological investigations for which data have been incorporated into the analyses and descriptions of the communities in the present report.

Davies (1991) reported the results of a survey of the coast from Crosby to Fleetwood which included three sites at the entrance of the Ribble Estuary with one site at the extreme northern limit and one site at the southern limit of the estuary mouth. Davies (1991) described nine communities of which three were located within the estuary and two at the outer limits: ***Mytilus* (CF3), *Cerastoderma & Macoma* (CF8)** and ***Scrobicularia & Hediste* (CF9)** were present within the estuary while **crustacean/polychaete (CF5)** and ***Mactra, Fabulina & Donax* (CF6)** were present on the open coast at the estuary limits.

Covey & Davies (1989) described the littoral communities of the Cumbrian coast from St Bees Head to Barrow-in-Furness which included two sites in the Ravenglass system and eleven sites in the Duddon Estuary; of the latter sites, four were located on the 'slagcrete' pier at Askam and one site in Scarth Bight at the northern end of Walney Channel where it opens into the Duddon Estuary. In addition, the present survey revisited an open coast site at Tarn Bay which was first surveyed by Covey & Davies (1989). In the latter report, a total of seven community/site types were described of which four were present at some sites within the Duddon Estuary or Ravenglass system: **crustacean/polychaete; sheltered muddy sand; moderately exposed bedrock & boulder shores; sheltered mussel beds on pebbles, gravel & mud.**

Data from both these previous MNCR surveys has been incorporated into the analyses of the data collected from the present survey. Community descriptions presented in Appendix 3 indicate both the stations surveyed during the present survey and stations surveyed by Davies (1991) and Covey & Davies (1989).

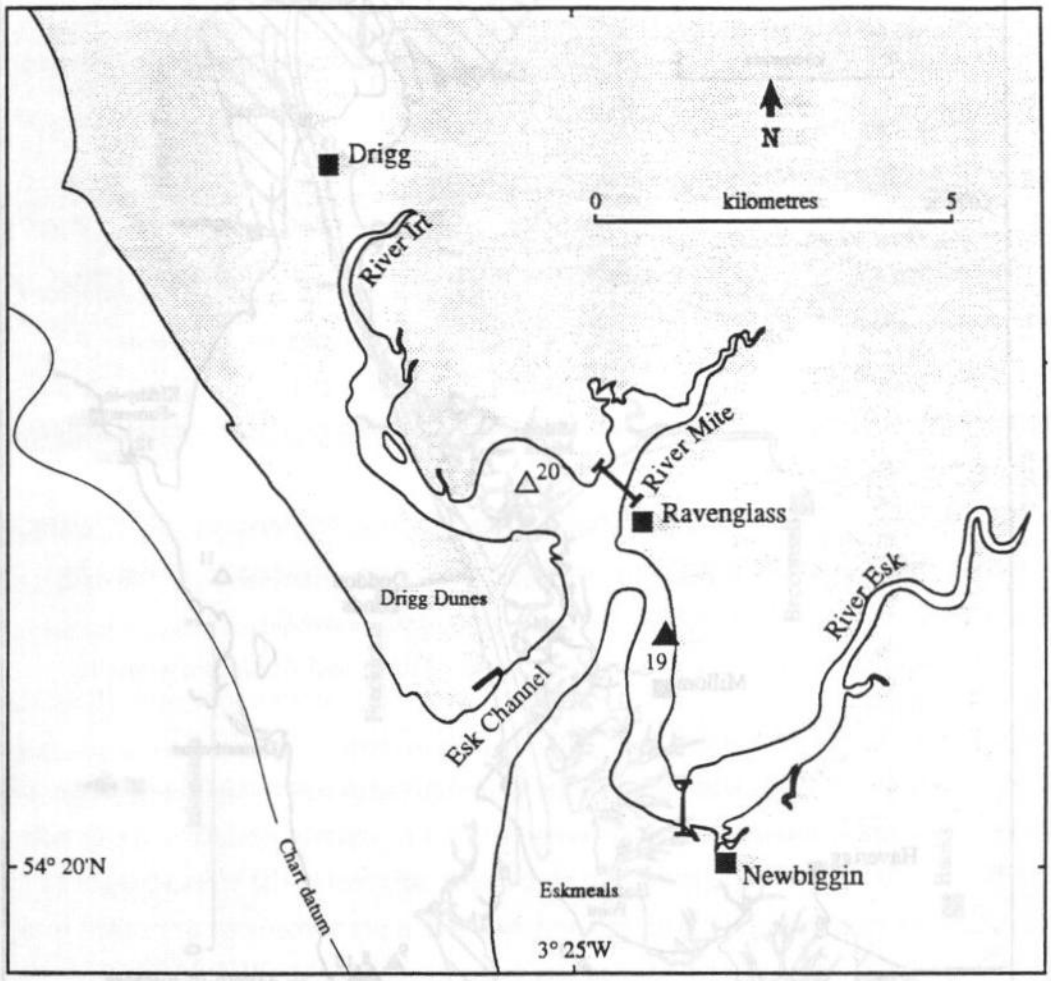


Figure 3 Location of sites surveyed by Covey & Davies (1989) in the Ravenglass system

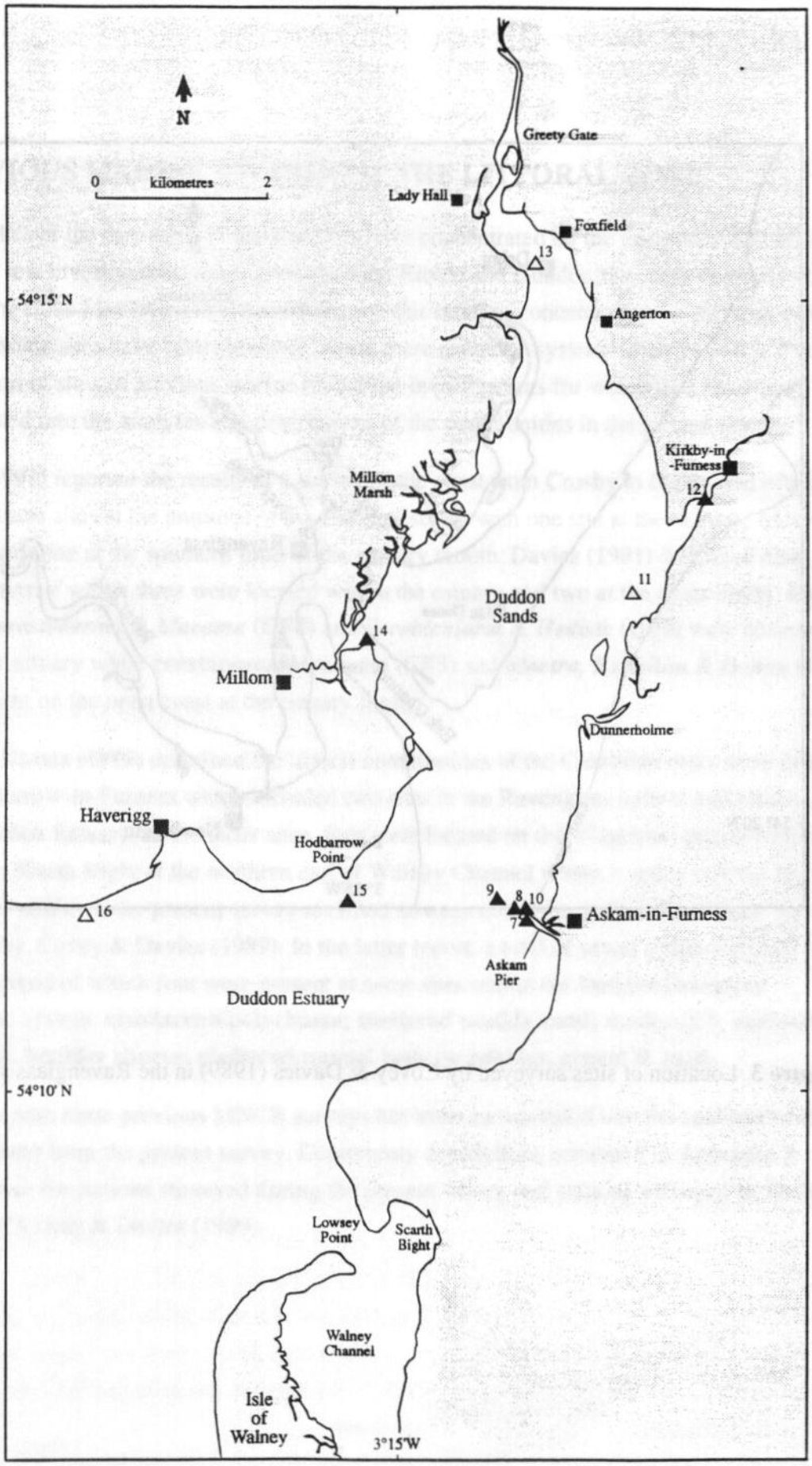


Figure 4 Location of sites surveyed by Covey & Davies (1989) in the Duddon Estuary

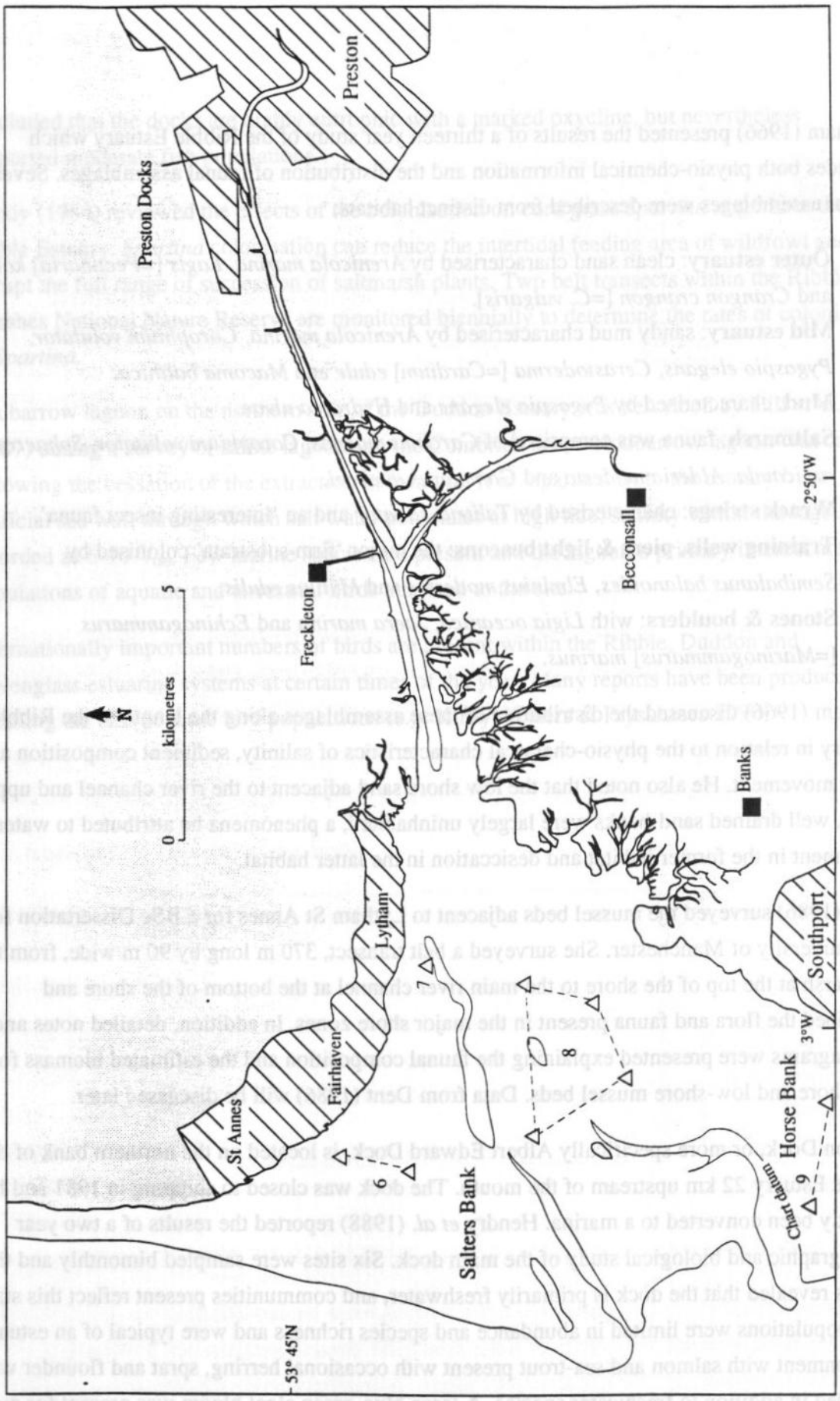


Figure 5 Location of sites surveyed by Davies (1991) in the Ribble Estuary

Popham (1966) presented the results of a thirteen year study of the Ribble Estuary which includes both physio-chemical information and the distribution of faunal assemblages. Seven faunal assemblages were described from distinct habitats:

Outer estuary: clean sand characterised by *Arenicola marina, Lagis* [=*Pectinaria*] *koreni,* and *Crangon crangon* [=*C. vulgaris*].
Mid estuary; sandy mud characterised by *Arenicola marina, Corophium volutator, Pygospio elegans, Cerastoderma* [=*Cardium*] *edule* and *Macoma balthica.*
Mud: characterised by *Pygospio elegans* and *Hydrobia ulvae.*
Saltmarsh: fauna was comprised of *Carcinus maenas, Corophium volutator, Sphaeroma rugicauda, Alderia modesta* and *Gammarus duebeni.*
Wrack strings: characterised by *Talitrus saltator* and an 'interesting insect fauna'.
Training walls, piers & light beacons: the major 'firm substrata' colonised by *Semibalanus balanoides*, *Elminius modestus* and *Mytilus edulis.*
Stones & boulders: with *Ligia oceanica, Jaera marina* and *Echinogammarus* [=*Marinogammarus*] *marinus.*

Popham (1966) discussed the distribution of these assemblages along the length of the Ribble Estuary in relation to the physio-chemical characteristics of salinity, sediment composition and water movement. He also noted that the low shore sand adjacent to the river channel and upper shore, well drained sand-banks were largely uninhabited, a phenomena he attributed to water movement in the former habitat and desiccation in the latter habitat.

Dent (1986) surveyed the mussel beds adjacent to Lytham St Annes for a BSc Dissertation for the University of Manchester. She surveyed a belt transect, 370 m long by 90 m wide, from the saltmarsh at the top of the shore to the main river channel at the bottom of the shore and described the flora and fauna present in the major shore zones. In addition, detailed notes and pie diagrams were presented explaining the faunal composition and the estimated biomass for mid-shore and low-shore mussel beds. Data from Dent (1986) will be discussed later.

Preston Dock, or more specifically Albert Edward Dock, is located on the northern bank of the Ribble Estuary 22 km upstream of the mouth. The dock was closed to shipping in 1981 and has recently been converted to a marina. Hendry *et al.* (1988) reported the results of a two year hydrographic and biological study of the main dock. Six sites were sampled bimonthly and the results revealed that the dock is primarily freshwater, and communities present reflect this status. Fish populations were limited in abundance and species richness and were typical of an estuarine environment with salmon and sea-trout present with occasional herring, sprat and flounder were recorded in addition to freshwater species. A large blue-green algal bloom was present for much of the year and Hendry *et al.* (1988) considered the dock to have a low conservation value. Conlon (1987) also described the physical environment and the fauna of Preston Docks and

concluded that the docks are highly eutrophic with a marked oxycline, but nevertheless supported moderate fish populations.

Doody (1984) reviewed the effects of the colonisation on cord grass *Spartina anglica* in the Ribble Estuary. *Spartina* colonisation can reduce the intertidal feeding area of wildfowl and disrupt the full range of succession of saltmarsh plants. Two belt transects within the Ribble Marshes National Nature Reserve are monitored biennially to determine the rates of colonisation of *Spartina.*

Hodbarrow lagoon on the northern side of the Duddon Estuary was described by Hill *et al.* (1987) during a survey of saline lagoons on the Cumbrian coast. Hodbarrow lagoon was created following the cessation of the extraction of iron ore. It is separated from the estuary by an artificial sea wall through which salt water percolates at high tide; salinity within the lagoon was recorded as 6-10 $^{o}/_{oo}$. Few marine species are present and the lagoon's primary interest are the populations of aquatic and terrestrial birds attracted to the site.

Internationally important numbers of birds are present within the Ribble, Duddon and Ravenglass estuarine systems at certain times of the year. Many reports have been produced detailing the size of these bird populations (*e.g.* Kirby, Waters & Prys-Jones 1990).

5 AIMS AND METHODS

5.1 Background

MNCR surveys aim to describe the range of habitats and the associated communities present within an area in order to assess their biological interest and marine nature conservation importance. These descriptions are based mainly on *in situ* survey using standard methods of recording. Sites are selected to survey typical and representative habitats and any unusual or uncommon habitats that may be present within the survey area. Habitats and communities are extensively photographed and a limited collection of specimens collected to provide a permanent record for the survey area. Results from the present survey will contribute information for a MNCR 'Theme Report' for the area Colwyn Bay to the Mull of Galloway.

Inspection of Ordnance Survey Maps (Nos: 96 & 102) and Admiralty Charts (Nos: 1931 & 1961) gave an indication of the distribution of the substrata types for the survey area. Sites were selected to cover a wide range of substrata subject to different environmental conditions in order to describe the range of habitats and associated communities present within the survey area. Where possible, sites were surveyed within and adjacent to existing Sites of Special Scientific Interest (SSSIs).

5.2 Survey methods

Plate 6 Sediment sampling in the Ribble Estuary. [MNCR slide N°: S38.1.11 Jon Davies]

The Ribble, Duddon and Ravenglass estuarine systems were surveyed during the period 11-17 July 1991. Sites were surveyed following standard MNCR methods (Hiscock 1990) and the information recorded onto MNCR recording forms. A description of each site was maintained on a 'Littoral/sublittoral site record' form which included details of the main physical features, a site profile and any conservation interest. Within each site, detailed biological records were

collected from each clearly distinguishable habitat. Habitats were selected to ensure records were collected for all the major biological zones and major substrata types present. Biological information was maintained on separate 'Littoral habitat form'(s). These biological records included a detailed description of the physical habitat features and a semi-quantitative assessment of all conspicuous species using MNCR abundance scales (Hiscock 1990). Height limits for each habitat were recorded above sea level and later converted to levels above chart datum. All heights in the present report refer to chart datum unless otherwise stated.

Sedimentary shores were surveyed for widely dispersed macrofauna by digging over an area of c. 1 m^2 to a depth of 30 cm noting the abundance of conspicuous species. Infaunal species were sampled by taking four 0.01 m^2 core samples which were washed over a 0.5 mm mesh sieve. Material retained on the sieve was preserved for subsequent identification. Material from all four cores were combined to ease laboratory analysis. A core sample was collected for granulometric analysis (see below).

Photographs of habitats, communities and species were taken at most sites to provide a permanent record of the area. Specimens were collected when *in situ* identification was not possible; a small collection of specimens has been retained as voucher material.

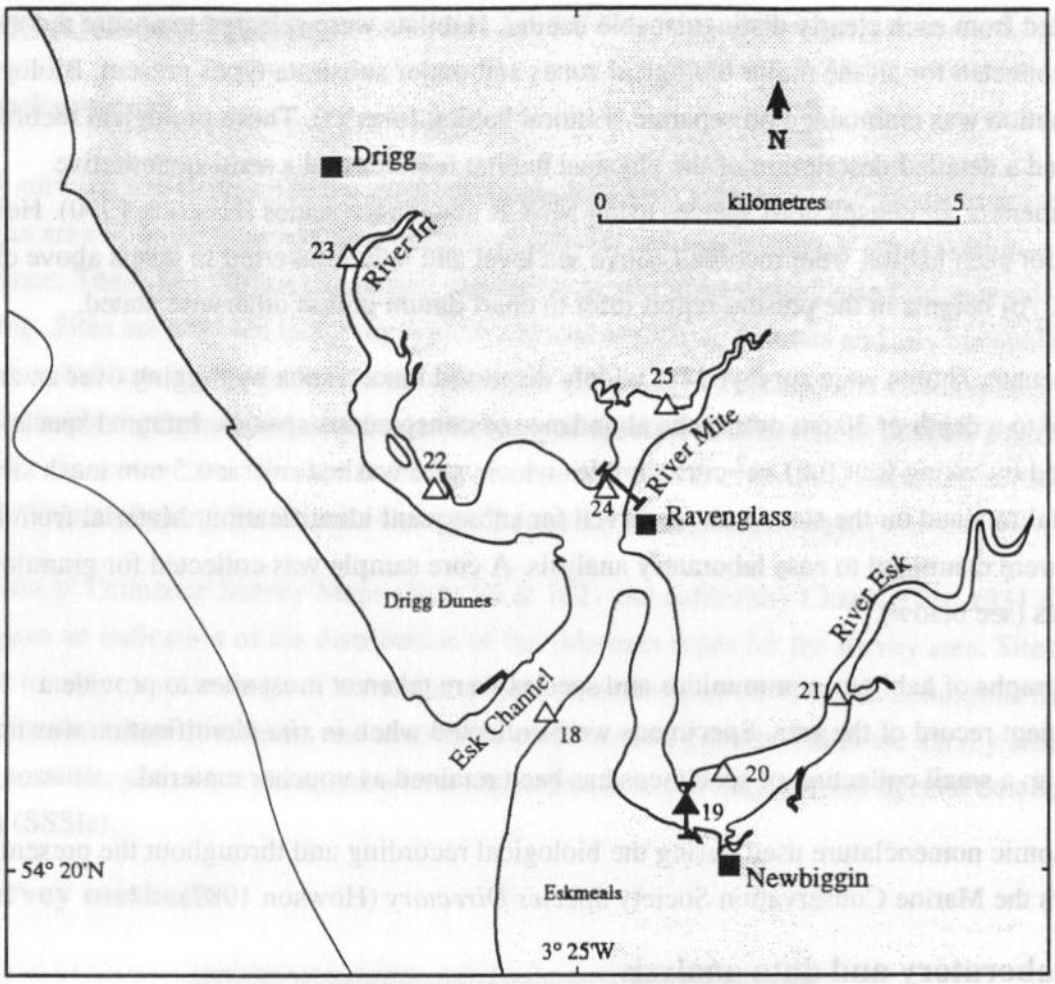
Taxonomic nomenclature used during the biological recording and throughout the present report follows the Marine Conservation Society *Species Directory* (Howson 1987).

5.3 Laboratory and data analysis

Specimens collected during the survey were identified in the laboratory and the results added to the recording forms. Identification of littoral sedimentary infauna was undertaken by Dr Peter Garwood (Identichaete, Newcastle) under contract to JNCC.

Sediment particle size distribution was determined to a standard granulometric scale (Wentworth 1922). Each sample was oven dried, weighed and puddled over a 63 µm sieve to remove the silt/clay fraction. All sediment retained on the sieve was re-dried, sieved through a standard series of Wentworth sieves and each fraction weighed. A percentage of the total weight was calculated for each sediment fraction to provide a grain size analysis to accompany the infaunal species data.

All site and habitat data were transferred to the MNCR computer database (Mills 1991) which can compile and sort site and habitat records by physical and biological features. To facilitate the identification of distinct assemblages of species ('communities') within the survey area, habitat data were subjected to the multivariate analytical procedure TWINSPAN (Hill 1979). TWINSPAN groupings do not always represent biologically meaningful communities particularly when dealing with stations with low species richness but high abundance. In these



cases, interpretation is required on physio-chemical habitat features. From the results of TWINSPAN, matrices of species records and physical habitat data were generated to facilitate description of the main habitat types, their associated communities and their common and characterising species (see Section 4 and Appendix 3).

Figure 6 Location of survey sites in the Ravenglass system

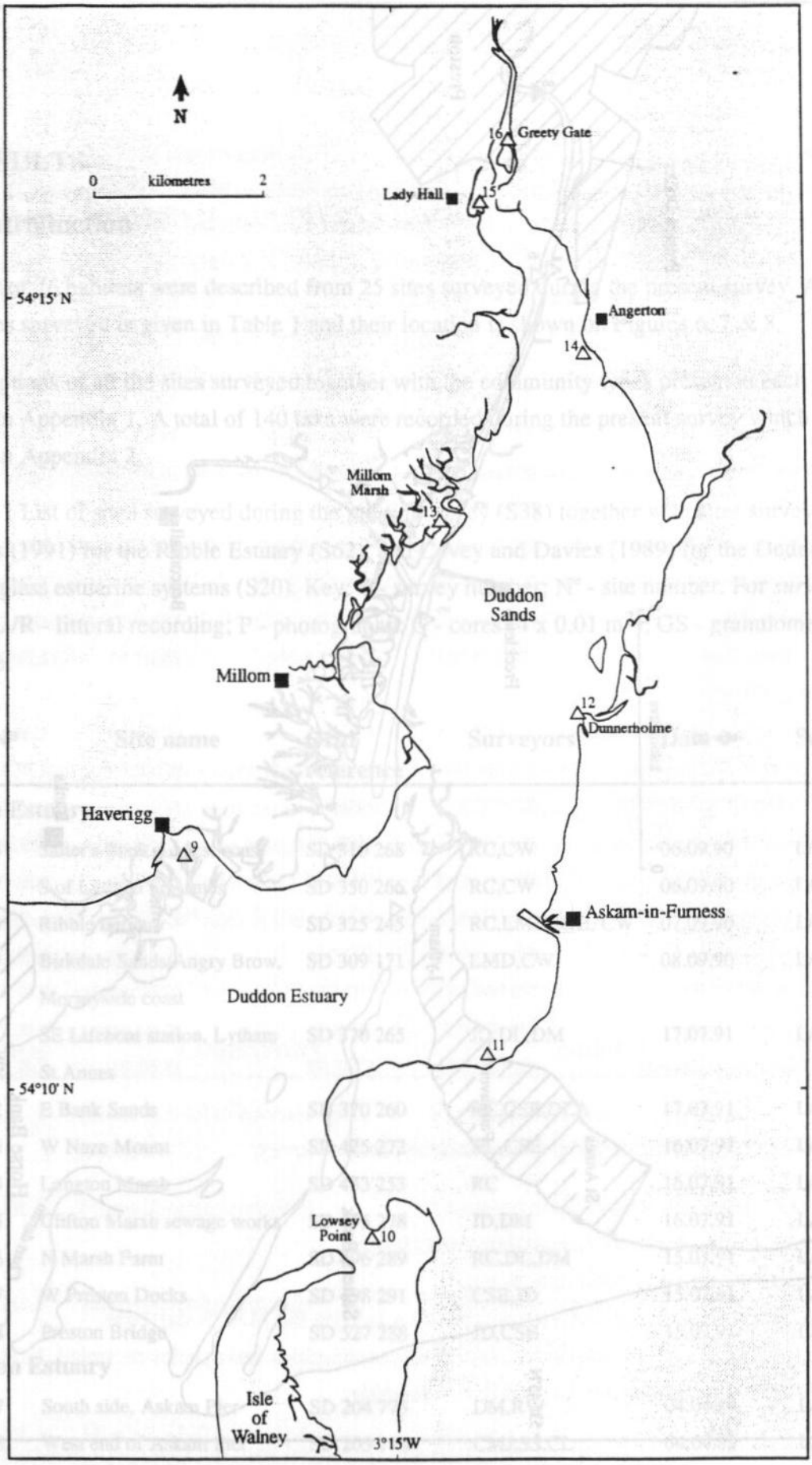


Figure 7 Location of survey sites in the Duddon Estuary

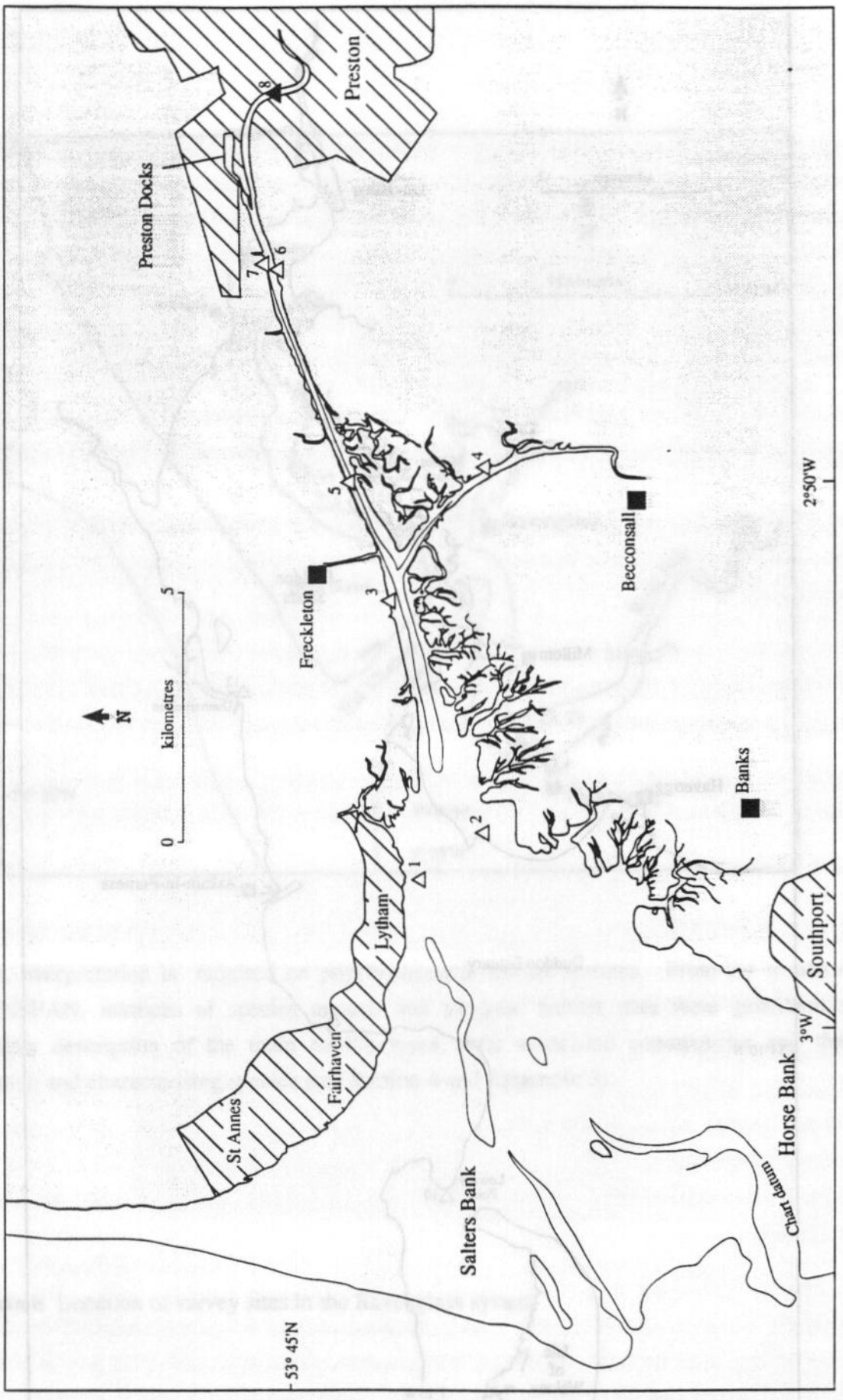


Figure 8 Location of survey sites in the Ribble Estuary

6 RESULTS

6.1 Introduction

A total of 76 habitats were described from 25 sites surveyed during the present survey. A list of the sites surveyed is given in Table 1 and their location is shown on Figures 6, 7 & 8.

Descriptions of all the sites surveyed together with the community types present at each site are listed in Appendix 1. A total of 140 taxa were recorded during the present survey which are listed in Appendix 2.

Table 1 List of sites surveyed during the present survey (S38) together with sites surveyed by Davies (1991) for the Ribble Estuary (S62), and Covey and Davies (1989) for the Duddon and Ravenglass estuarine systems (S20). Key: S - survey number; N° - site number. For *survey type*: Key: L /R - littoral recording; P - photography; C - cores (4 x 0.01 m^2); GS - granulometric sample.

S	N°	Site name	Grid reference	Surveyors	Date	Survey type
Ribble Estuary						
62	6	Salter's Bank, Lancs. coast	SD 310 268	RC,CW	06.09.90	L/R.C.GS
62	7	S of Lytham St Annes	SD 350 266	RC,CW	06.09.90	L/R.C.GS
62	8	Ribble Estuary	SD 325 245	RC,LMD,RHI, CW	07.09.90	L/R.P.C.GS
62	9	Birkdale Sands/Angry Brow, Merseyside coast	SD 309 171	LMD,CW	08.09.90	L/R.P.C.GS
38	1	SE Lifeboat station, Lytham St Annes	SD 370 265	JD,DL,DM	17.07.91	L/R.P.C.GS
38	2	E Bank Sands	SD 370 260	RC,CSE,DLA	17.07.91	L/R.P.C.GS
38	3	W Naze Mount	SD 425 272	DL,CSE	16.07.91	L/R.P.C.GS
38	4	Longton Marsh	SD 453 253	RC	16.07.91	L/R.P.C.GS
38	5	Clifton Marsh sewage works	SD 455 278	JD,DM	16.07.91	L/R.P.C.GS
38	6	N Marsh Farm	SD 496 289	RC,DL,DM	15.07.91	L/R.P.C.GS
38	7	W Preston Docks	SD 498 291	CSE,JD	15.07.91	L/R.C.GS
38	8	Preston Bridge	SD 527 288	JD,CSE	15.07.91	L/R
Duddon Estuary						
20	7	South side, Askam Pier	SD 204 775	DM,RW	04.04.89	L/R
20	8	West end of Askam Pier	SD 203 776	CMJ,SS,CL	04.04.89	L/R
20	9	Off Askam Pier	SD 200 778	CMJ,SS,CL	04.04.89	L/R
20	10	North side, Askam Pier	SD 204 776	RC,JD	04.04.89	L/R.P

20	11	Carl Cross	SD 215 814	DM,KH	06.04.89	L/R.C.P.GS
20	12	Sandside, Kirby-in-Furness	SD 226 826	KH,DM	06.04.89	L/R.C.P
20	13	West of Foxfield	SD 204 853	DWC,RW	06.04.89	L/R.C.P.GS
20	14	East of Salthouse, Millom	SD 186 808	CL,SS,CMJ	05.04.89	L/R
20	15	Hodbarrow Point	SD 184 775	DM,JD	06.04.89	L/R.P
				KH,DWC	06.04.89	
20	16	Bullstone Bed	SD 152 778	RC,RW	05.04.89	L/R.P.C.GS
38	9	SE Haverigg	SD 165 784	JD,DL	14.07.91	L/R.P.C.GS
38	10	Lowsey Point	SD 185 739	CSE,DL,DM	14.07.91	L/R.P.C.GS
38	11	NW Roanhead Farm	SD 199 760	JD,RC	14.07.91	L/R.P.C.GS
38	12	Dunnerholme	SD 210 800	RC,DL	13.07.91	L/R.P.C.GS
38	13	Millom Marsh	SD 195 825	CSE,RC,DM	14.07.91	L/R.C.GS
38	14	W Angerton	SD 210 840	JD,CSE,DM	13.07.91	L/R.P.C.GS
38	15	Lady Hall	SD 199 859	RC,DL	15.07.91	L/R.P.C.GS
38	16	Greety Gate	SD 213 867	CSE,JD,DM	15.07.91	L/R.C.GS
Ravenglass System						
20	19	River Esk, South Ravenglass	SD 087 955	CL,JD	07.04.89	L/R
20	20	West of Ravenglass	SD 078 966	DM,SS,CMJ	07.04.89	L/R.C.P.GS
38	18	Eskmeals Range	SD 078 950	CSE,DL	12.07.91	L/R.P.C.GS
38	19	Newbiggin Viaduct	SD 087 946	CSE,DM	12.07.91	L/R.P
38	20	NW Newbiggin	SD 082 945	DL,DM	13.07.91	L/R.C.GS
38	21	Hall Waberthwaite	SD 099 952	JD,DL	12.07.91	L/R.P.C.GS
38	22	W Saltcoats	SD 068 968	RC,DM	12.07.91	L/R.C.GS
38	23	NW Hall Carleton	SD 064 983	RC,BG	12.07.91	L/R.P.C.GS
38	24	Railway Bridge	SD 084 967	JD,BG	12.07.91	L/R.P.C.GS
38	25	Lower Mite Estuary	SD 086 972	CSE,JD	13.07.91	L/R.P.C.GS

The following end-products were produced by the present survey:

Volume 1: Survey report;
Volume 2: Conservation Assessment (confidential)
Volume 3: Completed field data sheets
Field, granulometric and infaunal sample data held on the MNCR database
Colour transparency photographs illustrating communities and species recorded, held by the MNCR and catalogued on the MNCR database:

Voucher specimens of animal species identified will be lodged with the Liverpool Museum.

In addition to the sites surveyed in the three estuarine systems, a site on the open coast at Tarn Bay was surveyed during the present study. Tarn Bay was surveyed by Covey & Davies (1989) who noted an extensive *Sabellaria alveolata* reef covering the mid shore. It was the intention of the present visit to investigate any changes to this reef. A detailed community description for the *S. alveolata* reef is presented in Covey & Davies (1989) and will not be repeated in the present report. Data collected by the current survey suggested the reef structure was similar to that recorded three years previous and there was no evidence of excessive physical damage due to human activities.

Detailed descriptions of each community are given in Appendix 3 and sedimentary community descriptions include the results of granulometric analyses. A total of ten communities have been described (Table 2) from the data collected during the present survey and incorporating data collected by Davies (1991) for the Ribble Estuary and Covey & Davies (1989) for the Duddon and Ravenglass systems. A general summary of the survey area incorporating these descriptions is given below.

Table 2 Community types described from the survey area based on data collected from the present survey combined with data collected by Covey & Davies (1989) and Davies (1991). Key: *Code* is a numeric value assigned for ease of reference and does not imply any ranked importance; *Community* is the main biotic characterising taxa; *Habitat* is a short summary of the physical environment; *Nº taxa* is the total number of taxa recorded from the stations assigned to that community type.

Code	Community	Habitat	Nº taxa
RDR 1	*Fucus spiralis/Enteromorpha* /barnacle	Sheltered to extremely sheltered, upper shore hard substrata	25
RDR 2	Fucoid/barnacle/mussel	Sheltered to extremely sheltered, mid-shore hard substrata	33
RDR 3	*Enteromorpha*/barnacle	Mid/low-shore boulders in low salinity subject to moderate tidal streams	13
RDR 4	*Mytilus edulis/Semibalanus balanoides*	Mixed stones on sediment subject to moderate tidal streams	30

RDR 5	Barnacle/mussel/littorinid	Sheltered pebbles with some small cobbles and gravel on sediment	27
RDR 6	*Hediste/Corophium*/green algae	Extremely sheltered stones on sediment subject to variable or low salinity	16
RDR 7	Crustacean/polychaete	Mobile, mid to low-shore, medium and fine sand	45
RDR 8	*Cerastoderma/Macoma/Pygospio*	Moderately exposed, mid-shore, medium-fine muddy sand	37
RDR 9	*Arenicola/Corophium/Hediste*	Very to extremely sheltered, mid-shore, fine sand subject to variable salinity	34
RDR 10	*Hediste/Corophium*/Oligochaete	Extremely sheltered estuarine mud subject to variable or low salinity	29

In summary, of the ten community types identified, six were hard substrata (mainly stones on sediment), and four were sedimentary communities. Sedimentary communities were distinguished on the basis of their biotic composition and on their sediment type. Figure 9 presents the results of the granulometric analyses and highlights the differences in sediment composition between the community types.

6.2 Distribution of habitats and communities

6.2.1 Introduction

For each community description in Appendix 3, a figure gives the location of stations where each community types was recorded within the survey area. These locations are put into context in the following descriptions of each estuary.

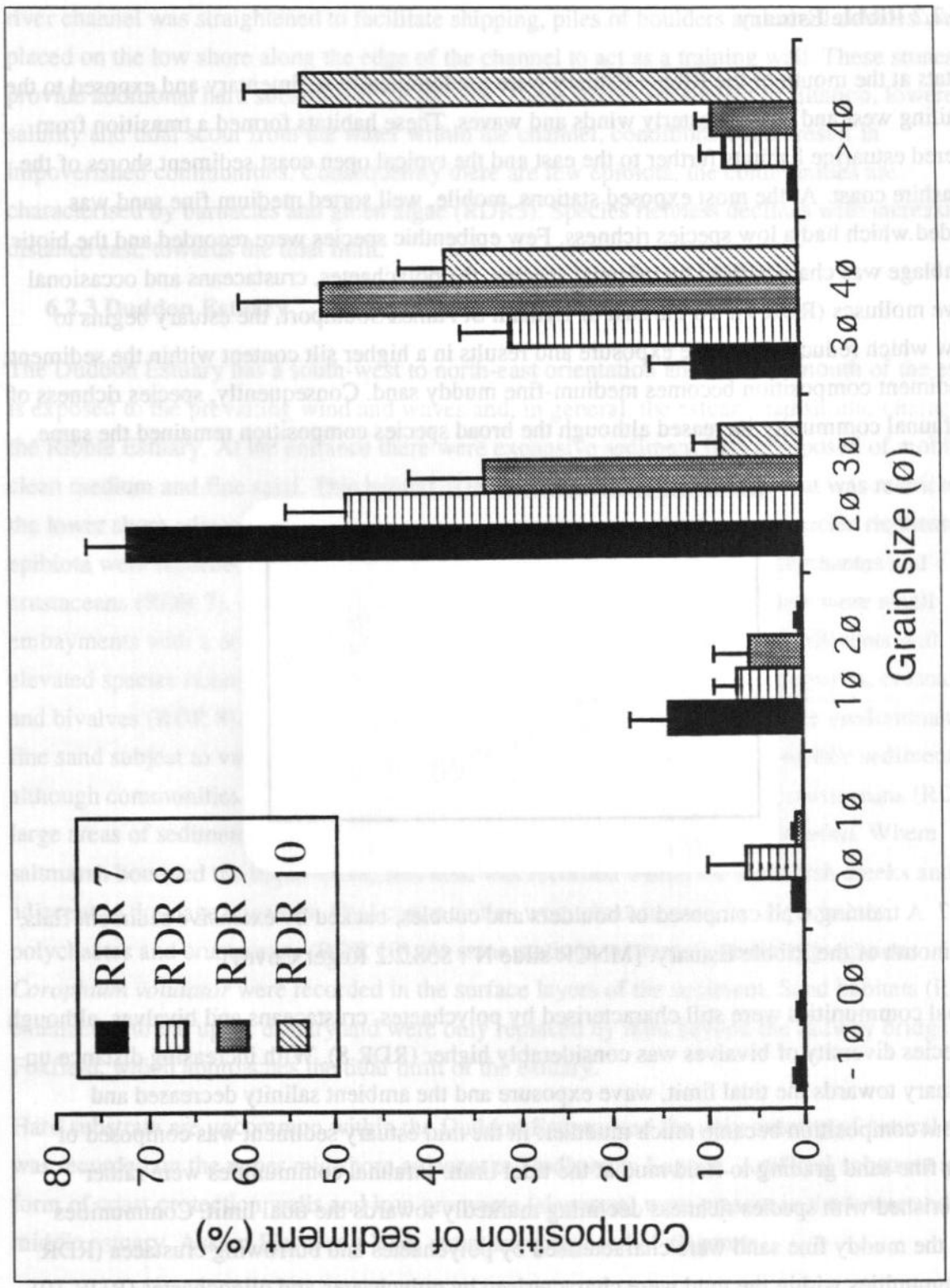


Figure 9 Grain size distribution for each of the four infaunal communities (RDR 7-10); data were from granulometric analyses of sediment samples. Data for all habitats for each community type were pooled and a mean percentage composition was determined for each grain size. Grain size is measured in units of Ø (Buchanan 1984) and the error bars represent ± 1 standard error.

6.2.2 Ribble Estuary

Habitats at the mouth of the Ribble Estuary were predominantly sedimentary and exposed to the prevailing west and south-westerly winds and waves. These habitats formed a transition from sheltered estuarine habitats further to the east and the typical open coast sediment shores of the Lancashire coast. At the most exposed stations, mobile, well sorted medium fine sand was recorded which had a low species richness. Few epibenthic species were recorded and the biotic assemblage was characterised by infaunal species: the polychaetes, crustaceans and occasional bivalve molluscs (RDR 7). To the east of Lytham St Annes/Southport, the estuary begins to narrow which reduces the wave exposure and results in a higher silt content within the sediment; the sediment composition becomes medium-fine muddy sand. Consequently, species richness of the infaunal community increased although the broad species composition remained the same.

Plate 7 A training wall composed of boulders and cobbles, backed by extensive sediment flats, at the mouth of the Ribble Estuary. [MNCR slide N°: S38.2.2 Roger Covey]

Infaunal communities were still characterised by polychaetes, crustaceans and bivalves, although the species diversity of bivalves was considerably higher (RDR 8). With increasing distance up the estuary towards the tidal limit, wave exposure and the ambient salinity decreased and sediment composition became much muddier: in the mid estuary sediment was composed of muddy fine sand grading to fluid mud at the tidal limit. Infaunal communities were rather impoverished with species richness declining markedly towards the tidal limit. Communities within the muddy fine sand were characterised by polychaetes and burrowing crustacea (RDR 9); communities within the mud were characterised by polychaetes and oligochaetes (RDR 10).

Habitats throughout the Ribble Estuary were predominantly sedimentary and natural hard substrata were rare. Near Lytham St Annes and within the Ribble Marshes NNR at the mouth of the estuary, natural aggregations of small stones and gravel were present, albeit restricted to a small area. Dense mussel beds were recorded on these stones (RDR 4; Dent 1986). When the

river channel was straightened to facilitate shipping, piles of boulders and small cobbles were placed on the low shore along the edge of the channel to act as a training wall. These stones provide additional hard substrata in the estuary. These stones are subject to siltation, lowered salinity and tidal scour from the water within the channel, conditions which result in impoverished communities. Consequently there are few epibiota, the communities are characterised by barnacles and green algae (RDR3). Species richness declines with increasing distance east, towards the tidal limit.

6.2.3 Duddon Estuary

The Duddon Estuary has a south-west to north-east orientation and thus the mouth of the estuary is exposed to the prevailing wind and waves and, in general, the estuary had similar character to the Ribble Estuary. At the entrance there were expansive sediment flats composed of mobile, clean medium and fine sand. This habitat extended into the middle estuary but was restricted to the lower shore adjacent to the main river channels. All stations had a low species richness: no epibiota were recorded and infaunal communities were characterised by polychaetes and crustaceans (RDR 7). At Haverigg and the entrance to Walney Channel, there were small embayments with a decreased wave exposure resulting in slightly muddier sediments with an elevated species richness. Infaunal communities were characterised by polychaetes, crustaceans and bivalves (RDR 8). Habitats in the lower and middle Duddon Estuary were predominantly fine sand subject to variable salinity. Species richness was higher than the mobile sediments although communities were nevertheless characterised by polychaetes and crustaceans (RDR 9); large areas of sediment had dense aggregations of the lugworm *Arenicola marina*. Where saltmarsh bounded the upper shore, soft mud was recorded within the saltmarsh creeks and adjacent to drainage channels. Mud communities were characterised by oligochaetes, polychaetes and crustaceans (RDR 10). At some stations, extremely dense aggregations of *Corophium volutator* were recorded in the surface layers of the sediment. Sand habitats (RDR 9) extended into the upper estuary and were only replaced by mud beyond the railway bridge at Foxfield, which approaches the tidal limit of the estuary.

Hard substrata are uncommon within the Duddon Estuary and the only outcrop of natural stone was recorded on the upper mid shore adjacent to Hodbarrow Lagoon. Artificial substrata in the form of coast protection walls and iron ore waste (slagcrete) were present in the lower and middle estuary. Askam Pier was a large structure composed of slagcrete.

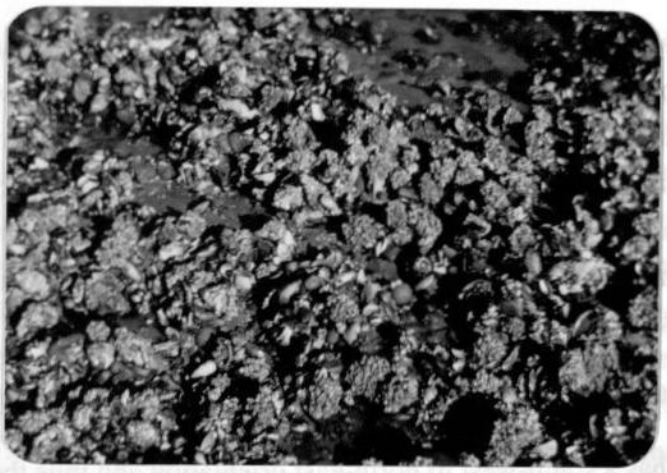


Plate 8 Agglomerations of small stones on sediment. Rock surfaces were covered with barnacles and mussels, with littorinid gastropods in the interstices between the stones. [MNCR slide N°: S38.10.4 Chris Emblow]

The communities present on the artificial substrata were similar to those at Hodbarrow although at all stations, species richness was low. Upper shore communities were characterised by fucoid and green algae with barnacles although the abundance of these taxa were low (RDR 1). Mid-shore communities were also characterised by fucoid algae and barnacles with small mussels in clumps and in cracks and fissures (RDR 2). On the mid and upper shore at Haverigg and at the entrance to Walney Channel, there were natural accumulations of small stones lying on the surface of the sediment. Barnacle covered the surface of these stones with large numbers of littorinid snails and small mussels in the interstices (RDR 5). At Hodbarrow, a similar habitat of stones on sediment was recorded on the bottom of a large pool, although the stones were covered with a dense population of small mussels, with barnacles covering the mussel-shell valves (RDR 4). In the upper Duddon Estuary, there were man-made piles of boulders which act as coast protection or foundations. These boulders were subject to low salinity conditions and moderate tidal flows. These stones had a sparse flora and fauna which were characterised by green filamentous algae and scattered barnacles (RDR 3).

6.2.4 Ravenglass system

The Ravenglass system comprises the River Esk, Irt and Mite which join near Ravenglass and exit to the open sea via the Esk Channel. Unlike the Ribble and the Duddon, only the Esk Channel is exposed to the prevailing wind and waves and the majority of the Ravenglass system is protected by large sand dune systems at Drigg and Eskmeals. Consequently, within the Esk Channel, habitats are composed of very mobile clean medium and fine sand. Due to the mobility of the sediment, infaunal communities were extremely impoverished with only occasional

crustacea and polychaetes present (RDR 7). Behind the dunes where the three rivers merge, there is an extensive sediment flat composed of fine sand which is mobile adjacent to the river channels. Infaunal communities were characterised by polychaetes and burrowing crustacea (RDR 9). In mid-shore areas away from the channels, sediment was slightly muddier with dense aggregations of *Arenicola marina* and *Corophium volutator*. In the upper mid-shore, large numbers of the burrowing beetle *Bembidium laterale* were found (Covey & Davies 1989). Sedimentary habitats differed between the three rivers.

Plate 9 Gravel on sand in the upper reaches on the River Esk, Ravenglass system. [MNCR slide N°: S38.21.14 Jon Davies]

In the River Esk, sand and sand with gravel predominated and extended into the upper reaches. Near Ravenglass, mobile sand banks composed of medium and fine sand were recorded on the low shore adjacent to the river channel. These habitats had a very low species richness and infaunal communities were characterised by crustaceans and occasional polychaetes (RDR 7). Further upstream, sediment became slightly muddier and was composed of fine sand with some silt subject to variable salinity. No epibiota were recorded and infaunal communities were characterised by polychaetes and burrowing crustaceans (RDR 9). Fine sand extended into the upper reaches of the River Esk towards the tidal limit although the species richness of the community declined; community composition tended towards an impoverished mud community (RDR 10). Soft mud was recorded in saltmarsh creeks adjacent to the upper shore (RDR 10).

At Ravenglass, sedimentary habitats within the River Mite were composed of fine sand subject to variable salinity. Infaunal communities were characterised by polychaetes and crustaceans (RDR 9) with a dense population of *Arenicola marina* present near the Railway Bridge. Upstream of this bridge, sediment became very muddy except immediately adjacent to the river channel for approximately 1 km which remained fine sand (RDR 9). Mid and upper shore habitats were soft mud subject to variable to low salinity. Infaunal communities were characterised by oligochaetes, burrowing crustaceans and polychaetes (RDR 10). Species richness declined with increasing distance upstream towards the tidal limit, presumably as a reflection of a gradual decline in ambient salinity.

The River Irt is bounded to the west by the Drigg sand-dune system and by grazing marsh to the east. Consequently, sand habitats extend upstream on the west bank, habitats on the east bank become more muddy. Sand habitats were composed of fine sand colonised by polychaetes and burrowing crustaceans (RDR 9), infaunal communities within the mud were characterised by oligochaetes and crustacea (RDR 10). In the lower part of the River Irt, mobile sand and shingle banks were present adjacent to the river channel. These banks were very mobile and consequently infaunal communities had a low species richness; communities in sand were characterised by crustaceans with occasional polychaetes (RDR 7). Shingle banks were more stable and infaunal communities had a higher species richness, mainly polychaetes with some filamentous green algae attached to the shingle (RDR 6).

Hard substrata are uncommon within Ravenglass estuary system and restricted to small areas of small stones on sediment, and artificial hard substrata predominantly bridge pilings. In the vicinity of Ravenglass there were agglomerations of stones on the sediment. In the lower Esk Estuary, these stones were consolidated by dense mussel beds (RDR 4) with abundant barnacles on the mussel valves and the stones. Sparse clumps of brown and red algae were recorded with littorinid snails in the interstices between the stones and mussels. Stones on sediment in the river channel and on mid-shore adjacent to the River Esk viaduct were subject to lowered salinity and colonised by green algae with polychaetes and burrowing crustaceans within the sediment (RDR 6). In the lower River Irt, patches of pebbles on sediment were colonised by barnacles and mussels with littorinid snails in the interstices (RDR 5). Stable hard substrata was restricted to the sandstone piers of the viaduct and railway bridge in the Rivers Esk and Mite respectively. 'Upper shore' communities were characterised by green and brown algae with occasional barnacles (RDR 1), 'mid-shore' communities had a similar species composition but with greater abundance of barnacles (RDR 2).

7 DISCUSSION

7.1 Comparison with previous studies

There have been few previous studies within the Ribble, Duddon and Ravenglass estuary systems. Covey & Davies (1989) described the Duddon and Ravenglass estuary systems, and Davies (1991) described the outer Ribble Estuary. Both surveys followed the same Marine Nature Conservation Review methodology as used during the present survey (Hiscock 1990). Data from these earlier surveys were incorporated into the analyses of the data collected by the present survey and therefore no further comparisons as necessary.

Popham (1966) reported the results of a detailed study of the Ribble Estuary and described seven main biotic assemblages (see Section 3 for a description). These assemblages are similar to the communities described during the present study although the Popham (1966) described many more species, a reflection of a more detailed, longer term study. Popham's 'outer estuary association' appears to be similar to a combination of the crustacean/polychaete (RDR 7) and the *Cerastoderma/Macoma/Pygospio* (RDR 8) communities described from the present study. A notable difference is that Popham (1966) recorded moderately high densities of the polychaete *Lagis koreni* and *Cerastoderma edule* in the sediment of Lytham St Annes. These records were not corroborated by Davies (1991) who concluded that these differences were possible attributable to different sampling strategies and/or variations in recruitment success. Popham (1966) described a 'sandy mud association' between Lytham St Annes and Fairhaven which was characterised by polychaetes, crustaceans and bivalve molluscs; the dominant species were *Arenicola marina, Corophium volutator, Pygospio elegans, Cerastoderma edule* and *Macoma balthica*. This association is very similar to community RDR 8 described from the present study. To the east of Fairhaven, Popham (1966) recorded a 'mud community' which was characterised by *Pygospio elegans* and *Hydrobia ulvae*. In the present study, a muddy fine sand community (RDR 9) was described for these middle areas of the estuary, and a mud community (RDR 10) for the upper estuary. It would appear that Popham's 'mud community' is a mixture of these two communities but tends towards the sand community. *Hydrobia ulvae* populations recorded during the present study had a low density in contrast to the results of Popham (1966). Covey & Davies (1989) reported a marked seasonal variation in the abundance of this species at Scarth Bight, Walney Channel, and therefore the apparent difference between the results of the present study and those of Popham (1966) may reflect similar seasonal variations.

Popham (1966) described a hard substrata community on 'training walls, piers and light beacons', characterised by *Semibalanus* (=*Balanus*) *balanoides, Elminius modestus* and *Mytilus edulis*, which had a similar biotic composition to community RDR 3 from the present study. During the present study, barnacle communities were characterised by *Elminius modestus* with a

lower abundance of *Semibalanus balanoides*. Popham (1966) recorded a higher species richness which is a reflection of a greater survey effort. Popham (1966) also described a 'stones and boulders community' characterised by isopod and amphipod crustaceans. A similar community was not described from the present study, all stones and boulder habitats were described within community RDR 3. Finally, Popham (1966) also described 'salt marsh' and 'wrack strings' communities but no equivalent communities were sampled during the present study.

Dent (1986) described the fauna present along a transect near Lytham which corresponded to site 7 of Davies (1991) who concluded that the data from the two studies were comparable. Interestingly, Dent (1986) recorded dense populations of *Hydrobia ulvae* which were not recorded by Davies (1991) or the present study (see above).

7.2 Comparison with other areas

In addition to the Ribble, Duddon and Esk estuary systems, a number of other major estuaries drain into the eastern basin of the Irish Sea including the Dee and the Mersey to the south, Solway Firth to the north, together with the rivers entering Morecambe Bay. The Dee, Mersey and Solway are considerably larger estuarine systems than those surveyed during the present study. Morecambe Bay was surveyed by the MNCR in 1991 and a report will be available shortly (Mills in prep.). Thus these other systems have a very different character to the Ribble, Duddon and Ravenglass systems. In addition to these differences in character, large volumes of data are available for these other estuaries and a meaningful comparison is impossible within the limits of the present report. A detailed comparison will be undertaken for the MNCR theme report for the coastal sector from Colwyn Bay to the Mull of Galloway.

8 CONCLUSIONS

The Ribble Duddon and Ravenglass estuary systems drain into the eastern basin of the Irish Sea. These estuaries have general west to east orientation which gives rise to a marked gradient of decreasing wave exposure with increasing distance east. In contrast, there is a salinity gradient of low salinity at the tidal limit in the east to near full salinity at the entrance of the estuary in the west. The Ribble Estuary has been extensively modified by man and receives a considerable anthropogenic input of waste material. In contrast, the Duddon and Ravenglass estuary systems are set in rural areas with little anthropogenic influence. Habitats within these estuarine are predominantly sedimentary with occasional small areas of small stones and shingle on the surface of the sediment.

Hard substrata are restricted to man-made structures such as coast protection, training walls and railway bridges. Consequently, total habitat diversity was low with only ten community types identified within the three estuarine systems. Communities on hard substrata had a low species richness and low abundance which was probably a consequence of low salinity, siltation and/or tidal scour. Sedimentary communities were characterised by infaunal species with few epibenthic species recorded. At the entrance to these estuaries, mobile medium and fine sand flats had a low species richness with occasional polychaetes and crustaceans. In the middle estuaries, sediment became muddier and species richness initially increased with infaunal communities characterised by polychaetes, burrowing crustaceans and bivalve molluscs. With increasing distance up the estuary towards the tidal limit, sediment changed to mud and the ambient salinity declined. Species richness of the infaunal community decreased, the communities were characterised by oligochaete worms and burrowing crustaceans. At the tidal limit, marine species richness declined to zero and freshwater species were recorded.

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APPENDIX 1

Description of the survey sites

Site descriptions, taken directly from the MNCR 'Littoral/Sublittoral Site Record' forms, are presented below. These descriptions were written by the surveyor(s) shortly after the site visit and therefore reflect their first impressions of the site. Site/community types (see Appendix 3) present at each site are included.

Site Number	Site Description	Communities present
Ribble Estuary		
62 6	Extensive sand flats north of Ribble entrance channel (marked by partially buried training wall). Impoverished sand with *Nephtys* sp., *Cerastoderma edule*, and on middle shore, *Macoma balthica*, with extensive drainage channel system.	RDR 7
62 7	Site located south of Lytham St Annes, surveyed from the upper shore to the lower shore inside a training wall of the river channel. Upper and mid shore composed of sandy mud leading to a sand flat in the lower shore: sandy mud holding varied fauna including *Scrobicularia plana, Hediste diversicolor* and *Cerastoderma edule*; low shore sand very impoverished. A boulder scar to east of the main survey line was dominated by *Mytilus edulis* and barnacles.	RDR 4 RDR 8

62 8	Southern half of large estuary, currently largest NNR in England. Very extensive 'mid-shore' sandbanks (c. 9000 ha), cut by creeks and drainage channels - sediment generally slightly muddy sand, but soft mud predominates near larger creeks. Sand is commercially extracted from the largest bank; cockles are collected and brown shrimp are caught by push net. Nature reserve status is based upon wintering wildfowl/waders. Sand contained many *Cerastoderma edule* and *Arenicola marina* with lots of dead shells and *Pectinaria* tubes. Mud contained polychaetes and bivalves despite being anaerobic below 4 cm. Fairly rich in invertebrates - probably more so than shown by limited number of sampling stations, judging by numbers of birds supported.	RDR 7 RDR 8
62 9	Extensive sediment shore on southern limit of Ribble Estuary - Angry Brow (divided from Birkdale Sands by a wide outflow channel) is part of Ribble Estuary. Upper mid-shore of muddy sand with abundant *Corophium* sp., lower mid-shore had *Acteon* sp. and sparse *Arenicola marina*. Low shore communities were quite diverse, with several species of bivalve (*Donax* sp., *Mactra* sp., *Spisula elliptica*, *Cerastoderma edule*), polychaetes and a single species of nemertean. Large wheeled vehicles work the shore for *Crangon* sp. and probably *Cerastoderma edule* as well, boiling the shrimps, caught in towed nets, on the way back up the shore. The heads and other discard are thrown onto the beach in heaps as the vehicle goes along.	RDR 7

38 1	Site was composed of extensive sediment flats leading to the main channel of Ribble. On the low shore a training wall of cobbles and boulders was present. 'Channel side' of the training wall, the sediment was mobile medium fine sand with a sparse infauna. The stones of the training wall had abundant *Elminius modestus* and *Enteromorpha* sp. with a covering of silt. Extensive sediment landward of wall was muddy sand with a soft surface layer. Infauna composed of *Macoma* sp. and polychaetes; *Hydrobia* sp. were common on the surface.	RDR 3 RDR 7 RDR 8
38 2	Site located on the south bank of Ribble Estuary, near the entrance. Very extensive saltmarsh led onto extensive mud flats and down to a training wall adjacent to the river. Training wall was composed of silty boulders with *Mytilus edulis*, *Elminius modestus* and *Fucus vesiculosus*. Three sediment habitats. Soft mud directly behind training wall with *Scrobicularia plana*, shell debris, and *Corophium* sp. in muddy sand.	RDR 9
38 3	Area of saltmarsh with steep mud slope with diatom film and *Hediste* sp. down to sandy bar in the river channel. Sand appeared mobile with no obvious infaunal species. Towards river channel boulders were covered with barnacles and filamentous green algae.	RDR 3 RDR 9 RDR 10
38 4	The River Asland is enclosed by saltmarsh in this area. The saltmarsh met the mud flats at a 1 m high vertical sediment bank. Mud flats, with underlying clay, slope steeply down to the main channel which was fringed by boulders.	RDR 3 RDR 4 RDR 10

38 5	Rather unsavoury site in the Ribble Estuary downstream of Clifton Marsh Sewage Farm. The upper shore area was flat composed of sandy mud, soft on top and very cohesive below. Extensive signs of bird feeding but no signs of marine life. Lower shore was more steeply sloping composed of boulders and cobbles, dumped to protect the bank from erosion. These were covered in green algae and a very few barnacles (*Elminius modestus*).	RDR 3 RDR 10
38 6	Site located in upper estuary channel between flood prevention walls backed by low lying pasture and industrial areas. Communities and habitats typical of habitats subject to low salinity in an upper estuary. Poor species richness in fine muddy sand with algal and diatom films.	RDR 3 RDR 4 RDR 9
38 7	Upper estuary, steep slope of very soft mud, very anoxic. No species obvious. Rubbish had been dumped on the top of the shore.	RDR 10
38 8	Site located beneath the A59 road bridge in the centre of Preston. Shore backed by a block wall. Narrow littoral zone - composed of cobbles and pebbles overlain with soft mud and areas of fluid mud up to 1 m deep. Impossible to collect a core sample; no marine fauna apparent: a couple of gastropods collected. Some rubbish dumped on the shore. A very unsavoury site.	RDR 8

Duddon Estuary

20 7	Exposed side of slagcrete pier	RDR 1 RDR 2
20 8	End of artificial slagcrete pier comprising a 'cliff face' which was undercut producing extensive overhangs in the upper and mid shore.	RDR 1
20 9	An exposed sandy shore off Askam Pier on south side of Duddon Estuary. Wave-washed sand community was present which was rather impoverished.	RDR 7

20 10	A pier of slagcrete; the north coast side is more sheltered, a steep rocky shore with representative species sediment shores at base of pier are relatively rich dominated by *Arenicola marina*.	RDR 1 RDR 2
20 11	Extensive sandy estuary site. Lower shore adjacent to channel of Duddon estuary composed of mobile sand with *Eurydice*/amphipod community. More stable upper shore levels between channels and adjacent to saltmarsh at Carl Cross was dominated by *Corophium* sp.	RDR 7 RDR 10
20 12	Narrow inlet with sandy mud shore bordered by grazed saltmarsh to the west, but with a tumble of angular boulders and cobbles as coastal protection to the north. The upper shore mid-platform terminates at an eroding mud cliff adjacent to the pier.	RDR 3 RDR 10
20 13	Upper part of Duddon Sand inlet, near limits of tidal waters. Wide plain of fine sand to east of main channel, backed by narrow band of saltmarsh and then a railway line and a road. Hard substrata under railway was also examined. Fauna very poor diversity near the channel, but with richer *Corophium* sp. community on upper shore. Tidal range at site only about 1 m. Sand plain was very uniform in texture with some wide drainage creeks across sand.	RDR 3 RDR 9
20 14	Extensive area of sheep-grazed saltmarsh with deep creeks. Upper shore creeks had abundant *Corophium* sp. and fine sand worm-tubes, grading down the shore to extensive sand flats across the estuary with some small *Arenicola marina* and *Macoma balthica*. Lots of very large, empty *Mya* sp. shells.	RDR 9 RDR 10

20 15	An exposed sand flat near mouth of Duddon Estuary. A sea wall and bedrock were present on the upper shore, with boulders, cobbles on sediment behind a large pool. Mid-low shore was comprised an extensive sand/flat (>100 m) well sorted, which was very mobile with dunes and ripples; an impoverished community was present- *Nephtys* sp. and Haustoriidae were the dominant taxa.	RDR 1 RDR 2 RDR 4 RDR 7
20 16	Wave washed sand flats at mouth of Duddon estuary backed by dunes. Sheltered to some extent by sand bars off-shore.	RDR 7
38 9	A sedimentary embayment at the mouth of the Duddon Estuary. Coast protection of large blocks formed the upper littoral limit. The upper shore was a pebble scar with mussels, barnacles and littorinids with sparse algae. Mid-shore areas were sandy mud with rich infaunal communities characterised by *Arenicola marina*, *Corophium* sp. and *Scrobicularia plana*. Small boats were moored on the shore. Across a small stream, the sediment became sandier with a similar community but with fewer *Corophium* sp. A bank of mobile sand led to the main river channel where the bank dropped steeply into the channel. The sediment was coarser and mobile with an impoverished infaunal community. A varied site.	RDR 5 RDR 7 RDR 8
38 10	Southern side of the Duddon Estuary at the southern end of Sandscale Haws in the entrance to Walney Channel. Extensive cobble/pebble beach down to the channel with an area of clean sand with *Arenicola marina* casts overlying gravel. A mussel bed was recorded within the cobbles which were covered by tall columnar *Elminius modestus*. Across a small channel was a very extensive, waved, mobile medium-sand with pools between the waves (small amounts of gravel in pools). Sand waves were rippled.	RDR 5 RDR 7 RDR 8

38 11	A broad sandy beach near the entrance of the Duddon Estuary. Broad sand flats extended to the southern Duddon channel. Adjacent to the channel, the sediment comprised medium/fine sand with sparse polychaete/crustacean infauna. Mid-shore areas were more muddy - muddy fine sand - with a dense *Arenicola marina* bed. Infaunal communities were relatively rich - *Macoma balthica, Cerastoderma edule, Corophium* sp. and polychaetes. Upper mid-shore had similar sediment type with clumps of tubes (juvenile. *Lanice*?) and *Mya* sp. (common). Infauna: *Macoma balthica* and *Arenicola marina.*	RDR 7 RDR 8
38 12	Station was located in the middle of large exposed sandy estuary backed by saltmarsh. Upper shore was composed of very mobile sand which graded to an area of more muddy sand with *Arenicola marina* next to the main channel. Some sand banks next to the main channel were composed of mobile 'aero' sand.	RDR 7 RDR 8
38 13	Site comprised sand flats which extended from saltmarsh to the east, area was cut by river channel. Areas of muddy sand with standing water were present. *Hydrobia* sp. were recorded on the surface with *Macoma balthica* within the sediment. Areas by channel had *Arenicola marina* and *Macoma balthica*, less standing water, and sub-surface layer of coarse sand.	RDR 9
38 14	Extensive flats of medium very mobile sand, on the south bank of Duddon estuary. Substrata were very similar throughout although species composition varied. Habitat 1 had abundant *Corophium* sp. and occasional *Macoma balthica* and *Hediste* sp. near main tidal channel. Habitat 2 had *Eurydice pulchra* with fewer *Corophium* sp. Habitat 3, was characterised by *Hydrobia* sp.	RDR 9

38 15	Earth embankment backing saltmarsh which graded into muddy fine sand adjacent to the main river channel. Sediment was fairly firm initially becoming liquid when trodden on. Sediment contained an impoverished infaunal community with only *Corophium* sp. obvious in core samples.	RDR 9
38 16	Site was located at the head of the Duddon Estuary just below the limit of tidal influence - short steep sandy mud bank with flocculent surface only 15-25 cm wide. A few *Corophium* sp. were present. Downstream was a fairly large sediment bank of sandy-mud, fairly firm compared to the other habitat. High bird activity, *i.e.* many footprints. *Corophium* sp. were occasional.	RDR 10

Ravenglass system

20 19	Extensive sand/mud bank on eastern shore of River Esk.	RDR 4
	Extensive mussel bed was present on the mid-shore.	RDR 6
	Pebbles and cobbles were recorded on the surface of the sediment and between mussel strings. A fish trap was present on the mid-shore: a sand bank has built up. A large freshwater flow gave rise to low salinity conditions.	RDR 7
20 20	Sheltered sandy estuary with saltmarsh on upper shore and a plain of muddy sand with some algal mat and standing water, colonised by small burrowing beetles and nematodes. Mid-shore habitats consisted of a sandy plain with deep creeks and numerous *Arenicola marina* with a few bivalves and *Eurydice pulchra*. Slightly further down the shore was a dense *Corophium* sp. population.	RDR 9

38 18	Southern bank of river channel where all three rivers of the Ravenglass system have joined together. Towards the sea, cobble scars with mobile sand, dominated by *Enteromorpha* sp. and *Semibalanus balanoides*. All sand along rest of the shore was very mobile medium-sand characterised by the absence of any obvious species. Towards the inner estuary areas of pebbles with *Fucus spiralis* and barnacles *Semibalanus balanoides* and *Elminius modestus* were present.	RDR 5 RDR 7
38 19	North bank beneath and downstream of the viaduct over the River Esk. Large area contained within curve of river was composed of coarse gravel with patches of sand and *Enteromorpha* sp. on the sand. Occasional *Fucus vesiculosus* on boulders. Inside of the curve area was composed of coarse tide-swept gravel on muddy sand. Areas of sandy/mud were present beneath the saltmarsh with *Corophium* sp. charactering the community. Lower shore area was composed of muddy sand with *Arenicola marina* casts. Bridge pillars offered the only hard substrata at this site. *Ascophyllum nodosum* zone had *Littorina littorea* and *Semibalanus balanoides.* *Enteromorpha* sp. zone had with *Elminius modestus* and *Fucus spiralis*.	RDR 1 RDR 2 RDR 6 RDR 9
38 20	Intertidal site in the middle Esk estuary, to the east of the Newbiggin (Eskmeals) viaduct. Adjacent to the main river Esk channel was an area of mobile medium sand with sand waves, which contained a high abundance of haustorid amphipods. Much of the intertidal was a softish muddy sand containing *Arenicola marina* with a moderately rich infauna including *Macoma balthica*, amphipods and polychaetes. Adjacent to the saltmarsh and in the saltmarsh creeks the sediment was soft mud dominated by *Corophium* sp.	RDR 7 RDR 9 RDR 10

38 21	An upper estuarine site on the Esk estuary. Extensive saltmarsh at the top of the shore had numerous deep muddy creeks. Infaunal communities were dominated by *Corophium* sp. Saltmarsh terminated with a short vertical drop (c. 1 m) on the upper shore within the river channels. Sediment was mainly muddy sand with mud content decreasing down the shore. Upper shore had distinct layering of leaf litter in sediment. Upper shore had *Salicornia* sp.with dense *Corophium* sp. and scattered *Hediste* sp.. Low shore sand was impoverished. Upstream where channel split, a gravel bank was present. Sparse infauna with occasional *Corophium* sp. and *Hediste* sp.; epibiota was *Enteromorpha/Ulva/Carcinus*.	RDR 6 RDR 9 RDR 10
38 22	Middle reaches of estuary with saltmarsh on one side and sand dunes (MOD use) on the other side. Littoral zone consisted of areas of shingle and pebbles interspersed with areas of muddy sand or, cleaner more mobile sand. Areas of sediment typically had dense populations of *Corophium* sp. and some *Hediste diversicolor*. One area of muddy sand also had *Macoma balthica*, and *Scrobicularia plana*. Harder shingle grounds with epifauna composed of *Semibalanus balanoides* and *Littorina littorea*.	RDR 5 RDR 6 RDR 9 RDR 10
38 23	Arm of estuary near limit of tidal influence. Saltmarsh dropped via a steep bank c. 1.5 m high to a short mud slope with occasional patches of shingle, which extended for c. 3 m to the main river channel which had considerable freshwater flow. A mud community was dominated by nereid polychaetes and *Corophium* sp. Shingle patches had gammarids, some *Enteromorpha* and some *Ulva* sp.	RDR 6 RDR 10

38 24	Site composed of the hard substrata of railway bridge and gravel/cobbles below plus sedimentary areas downstream. Site subject to salinity fluctuations from the river. Consequently a rather impoverished site. Sparse algae on hard substrata with occasional barnacles and common *Enteromorpha* sp.; some *Fucus ceranoides* on the stones in the channel. A sewage outfall was discharging adjacent to the bridge. Downstream, on the south side of the channel sediment was sandy with dense *Arenicola marina*. North side of channel was muddy with *Corophium* sp. South towards the village, sediment became muddy with dense *Corophium* sp. populations.	RDR 1 RDR 2 RDR 4 RDR 9
38 25	Site covers the inner part of the Mite estuary to the east of Ravenglass. River channel meanders across extensive littoral/supralittoral flats. Channel has steep sides - leading to flat, extensive saltmarsh with muddy creeks. Four stations were surveyed from west to east: sediment became muddier with increasing distance east; surface was soft but a clay layer was present c.15 cm below. Habitat 1 was upper-shore sediment grading into saltmarsh with dense *Hydrobia* sp. and *Corophium* sp. Habitat 2 was a mid-shore sediment flat with *Corophium* sp., *Hediste* sp. and bivalves. Habitat 3 was low shore estuarine mud with *Corophium* sp., *Hediste* sp. and *Macoma* sp. Habitat 4 was low shore muddy fine sand with *Corophium* and *Arenicola marina*. Mid-shore sediment flats had algal mats binding sediment together.	RDR 9 RDR 10

APPENDIX 2

List of all the taxa recorded within the Ribble, Duddon and Ravenglass estuarine systems.

All taxa recorded from the present survey (S38) are listed together with taxa recorded from the Ribble Estuary by Davies (1991) (S62) and the Duddon and Ravenglass Estuaries by Covey & Davies (1989) (S20). For each taxa, the site at which it was recorded within each survey are listed; site numbers follow those listed in Table 1. Taxa are listed according to Howson (1987), except for *Balanus balanoides* which is referred to the genus *Semibalanus*, and *Polydora cornuta* which was redefined by Blake & Maciolek (1987).

CNIDARIA

Laomedea flexuosa	S20: 15
Obelia longissima	S62: 6
Actinia equina	S20: 10; 15

NEMERTEA

Nemertea indet	S38: 2; 7; 9; 10; 11; 12; 16; 20
	S62: 8
Cerebratulus sp.	S62: 9

ANNELIDA

:POLYCHAETA

Polychaeta indet.	S20: 11;14
Pholoe inornata	S38: 11
Eteone longa	S20: 9; 15
	S38: 1; 2; 3; 9; 10; 11; 12; 15; 19; 22; 25
	S62: 7
Anaitides maculata	S20: 9
Glycera sp.	S20: 9
	S62: 8
Glycera tridactyla	S38: 22
Hediste diversicolor	S20: 11; 12; 13; 19; 20
	S38: 1; 2; 3; 6; 7; 9; 11; 12; 13; 14; 19; 20; 21; 22; 23; 24; 25
	S62: 7; 8
Neanthes virens	S20: 9
Nereis sp.	S20: 11

Nephtys sp.	S38: 1
	S62: 8
Nephtys cirrosa	S38: 9; 10; 11; 18; 20; 24
	S62: 6; 9
Nephtys hombergii	S20: 9; 15; 16
	S38: 1; 24
	S62: 6; 7; 8; 9
Lumbrineris gracilis	S20: 9
Scoloplos armiger	S38: 9; 11; 15
Polydora sp.	S20: 15
Polydora cornuta	S38: 2
Pygospio elegans	S38: 1; 2; 3; 4; 9; 10; 11; 12; 13; 14; 15; 19; 20; 21;
	22; 24; 25
	S62: 7; 8
Scolelepis squamata	S38: 10
	S62: 9
Spiophanes bombyx	S62: 6
Magelona filiformis	S38: 11
Magelona mirabilis	S62: 9
Capitella capitata	S20: 20
	S38: 1; 9; 10; 11; 12; 13; 16; 20; 21; 22; 24; 25
	S62: 9
Mediomastus fragilis	S38: 9
Arenicola marina	S20: 9; 14; 15; 19; 20
	S38: 9; 10; 11; 12; 13; 18; 19; 20; 21; 22; 24; 25
	S62: 8; 9
Owenia fusiformis	S62: 9
Lagis koreni	S62: 9
Lanice conchilega	S20: 19
	S38: 1; 10; 18
	S62: 9
Manayunkia aestuarina	S38: 2; 3; 4; 9; 13; 14; 20; 21; 22
Pomatoceros sp.	S20: 15

:OLIGOCHAETA

Oligochaeta indet.	S20: 13; 20
	S38: 5; 20
Tubifex costatus	S38: 2; 6; 7; 20; 21; 22; 23; 25
Tubificoides sp.	S20: 20
Tubificoides benedeni	S38: 1; 2; 3; 9; 10; 14; 15; 19; 20; 22; 25
	S62: 7
Tubificoides pseudogaster	S38: 1; 9; 25
	S62: 7
Enchytraeidae indet.	S38: 2; 4; 5; 6; 7; 9; 10; 11; 12; 13; 14; 16; 19; 20; 21; 22; 23; 25

CHELICERATA

Acari indet.	S38: 9
Halacaridae indet.	S38: 24

CRUSTACEA

:CIRRIPEDIA

Cirripedia indet. (juvenile)	S38: 3
Chthamalus montagui	S20: 15
Balanus balanoides	S20: 7; 8; 15; 19
	S38: 2; 18; 19; 22; 24
	S62: 6; 7
Balanus crenatus	S20: 15; 19
	S38: 2
	S62: 6; 7
Balanus improvisus	S38: 3; 6
Elminius modestus	S20: 7; 8; 10; 12; 15; 19
	S38: 1; 2; 5; 9; 10; 18; 19; 22; 24

: AMPHIPODA

Neomysis integer	S38: 16
Amphipoda indet.	S20: 10; 12; 13; 15
Pontocrates altamarinus	S62: 9
Urothoe elegans	S38: 9
Bathyporeia elegans	S62: 8
Bathyporeia pelagica	S20: 11; 13; 15; 20
	S38: 1; 9; 10
	S62: 6; 7; 8; 9

Bathyporeia pilosa	S38: 10; 12; 13; 14; 19; 20; 21
	S62: 7
Bathyporeia sarsi	S38: 10; 11; 16; 19; 20; 21
Haustoriidae indet.	S20: 9; 11
Haustorius arenarius	S20: 19
	S38: 20
Gammaridae indet.	S20: 7
	S38: 10; 14; 18; 23
	S62: 9
Echinogammarus marinus	S38: 24
Corophium sp.	S20: 11; 14; 19
	S38: 19; 21; 22; 24
Corophium arenarium	S38: 4; 11; 12; 13; 14; 20; 24
	S62: 8; 9
Corophium volutator	S20: 11; 12; 13; 20
	S38: 1; 2; 5; 9; 10; 13; 14; 15; 16; 19; 20; 21; 22; 23; 25
: ISOPODA	
Eurydice pulchra	S20: 9; 11; 13; 15; 19; 20
	S38: 1; 9; 12; 13; 14; 18; 20; 22
	S62: 9
Sphaeroma hookeri	S38: 16
Sphaeroma rugicauda	S20: 13
Ligia oceanica	S38: 18; 24
: DECAPODA	
Crangon crangon	S38: 9; 10; 22; 24
	S62: 9
Carcinus maenas	S20: 7; 13; 15
	S38: 1; 2; 6; 9; 10; 11; 15; 18; 19; 20; 21; 22; 24; 25
INSECTA	
Collembola indet.	S38: 4; 11; 23
Insecta indet.	S38: 16; 19; 20; 23
Petrobius maritimus	S20: 8
Bembidium laterale	S20: 20
Anurida maritima	S20: 7; 8; 12; 15

	S38: 19; 20; 24
MOLLUSCA	
: POLYPLACOPHORA	
Polyplacophora indet.	S20: 15
Lepidochitona cinereus	S38: 10; 18
: GASTROPODA	
Lymnaea peregra	S38: 8
Patella vulgata	S20: 15
Littorina littorea	S20: 7; 8; 10; 15; 19; 20
	S38: 9; 10; 18; 19; 22; 24
Littorina mariae	S20: 10; 15
Littorina obtusata	S20: 7
Littorina neglecta	S20: 15
	S38: 9
Littorina saxatilis	S20: 7; 10; 15; 19
	S38: 9; 10; 22
Hydrobia ulvae	S38: 1; 2; 9; 11; 12; 13; 14; 15; 24; 25
	S62: 7; 8
Nucella lapillus	S20: 15
Acteon tornatilis	S62: 9
: OPISTHOBRANCHIA	
Retusa obtusa	S38: 22
: PELECYPODA	
Mytilus edulis	S20: 7; 8; 10; 15; 19
	S38: 1; 2; 9; 10; 11; 18; 19; 22; 24
	S62: 6; 7
Modiolus indet. (juveniles)	S20: 10
Mysella bidentata	S38: 9
	S62: 6; 7; 9
Cerastoderma edule	S20: 19; 20
	S38: 1; 9; 11; 12; 22
	S62: 6; 7; 8; 9
Mactra stultorum	S62: 9
Spisula elliptica	S62: 8; 9
Macoma balthica	S20: 9; 11; 13; 14; 15; 20
	S38: 1; 2; 3; 5; 9; 10; 11; 12; 13; 14; 15; 19; 20; 21; 22; 24; 25

	S62: 6; 7; 8
Donax vittatus	S62: 9
Scrobicularia plana	S38: 2; 9; 21; 22; 25
	S62: 7; 8
Abra alba	S38: 11
Mya arenaria	S20: 19
	S38: 9; 11

BRYOZOA

Alcyonidium gelatinosum	S20: 10
Bowerbankia imbricata	S38: 22

ECHINODERMATA

Asterias rubens	S20: 15

OSTEICHTHYES

Ammodytes sp.	S20: 19
	S62: 8
Pomatoschistus sp.	S38: 10
Pleuronectiformes indet. (juveniles)	S20: 12

RHODOPHYCOTA

: BANGIALES

Porphyra sp.	S20: 7; 19
	S38: 18
Porphyra umbilicalis	S20: 15

: NEMALIALES

Audouinella sp.	S20: 7; 8; 15
	S38: 24
Gelidium sp.	S38: 24

: CRYPTONEMIALES

Dumontia contorta	S20: 15; 19

: HILDENBRANDIALES	
Hildenbrandia	S20: 8; 10
: CORALLINALES	
Corallinaceae indet.	S20: 15
Corallina officinalis	S20: 19
: GIGARTINALES	
Gracilaria verrucosa	S20: 19
Chondrus crispus	S20: 15; 19
	S38: 10; 19
Catenella caespitosa	S20: 7; 8; 10
	S38: 24
: CERAMIALES	
Ceramium sp.	S20: 15
	S38: 10
Polysiphonia sp.	S20: 10
	S38: 24
Rhodophycota indet.	S20: 7
(non-calcareous crusts)	S38: 19
CHRYSOPHYCOTA	
Diatoms - film	S38: 1; 3; 5; 6; 8
CHROMOPHYCOTA	
Ectocarpaceae indet.	S20: 15
	S38: 5; 8; 9
Ralfsia sp.	S20: 12
Ascophyllum nodosum	S20: 7; 10
	S38: 19; 24
Fucus indet. (sporelings)	S20: 10; 19
Fucus ceranoides	S38: 22; 24
Fucus spiralis	S20: 8; 10; 19
	S38: 9; 10; 18; 19; 24
Fucus vesiculosus	S20: 7; 10; 15; 19
	S38: 2; 10; 18; 19; 22; 24

Pelvetia canaliculata	S20: 7; 19
	S38: 9; 19; 24
Chromophycota indet. (crusts)	S20: 7
CHLOROPHYCOTA	
Chlorophycota indet.	S38: 1; 3; 4; 5; 6
Enteromorpha sp.	S20: 7; 8; 10; 12; 13; 15; 19; 20
	S38: 1; 2; 4; 5; 6; 8; 9; 10; 18; 19; 21; 22; 23; 24; 25
	S62: 6
Ulva sp.	S20: 8; 10; 12; 15
	S38: 19; 21; 22; 23; 24
Cladophora sp.	S38: 6; 10
Cladophora rupestris	S20: 7; 8; 15
Filamentous green algae	S38: 18
ANGIOSPERMAE	
Sueda maritima	S20: 19
Festuca rubra	S38: 25
Salicornia sp.	S38: 2; 9; 21
LICHENS	
Lichina pygmaea	S20: 15
Verrucaria maura	S20: 15
Verrucaria mucosa	S20: 8
	S38: 10
Total number of taxa recorded:	140

APPENDIX 3

Descriptions of each different habitat and its associated community recorded during the present survey are given below. Site and community classifications were developed from the groupings suggested by TWINSPAN analyses. Data from Davies (1991) and Covey & Davies (1989) have been incorporated into these analyses and the community descriptions in order to provide a more complete picture for the survey area. For rocky shores, the separate biological zones have been incorporated into descriptions of 'site types'. Sedimentary communities have been described in relation to height above chart datum and the composition of the sediment. A figure shows the recorded distribution of the site/community within the survey area. Where possible a plate illustrates the site and/or the community recorded. Each description has the following sections:

a. A title for the community type, which indicates the main characterising taxa or groups.
b. The key physical features of the habitat type including the zone and main substratum type and appropriate categories of wave exposure and tidal stream strength.
c. A site and habitat classification for the community according to MNCR terms. Where the community is present over a range of conditions the range within each category is indicated.
d. The distribution of the community within the area; the numbers are the site and habitat record numbers, *i.e.* 12.1 is site record 12 and habitat record 1. In a few cases habitat records may appear under more than one community description.
e. The known or expected extent of the community based on the information available on substrata, exposure to wave action and tidal streams.
f. A description of the community outlining the important physical and biological features, and any variations in the community structure at particular sites.
g. The biotic composition of the community. Taxa included are those which occurred at 25 % or more of the sites listed at (c). Where the description is derived from only one or two habitat records, the species included here are those recorded in abundances of 'Frequent' or higher. For each taxon, the range of its recorded abundance and the median abundance are shown. In addition, the total number of taxa recorded from all habitats and the habitat with the highest species richness are given.

The descriptions have been ordered from rock to sediment and then by decreasing wave exposure. In some cases, the community description is based on a small number of sites, and the addition of further information for similar habitats in the eastern basin of the Irish Sea may necessitate the modification, either by amalgamation or splitting, of the community types presented here.

COMMUNITY RDR 1: *Fucus spiralis/Enteromorpha*/barnacle

HABITAT: Sheltered to extremely sheltered, upper shore hard substrata

Classification

Situation:	Enclosed coast
Salinity:	Normal to variable
Wave Exposure:	Moderately exposed to extremely sheltered
Tidal Streams:	Moderately strong
Geology:	Hard
Zone/range:	Upper shore: littoral fringe and upper eulittoral
Substratum:	Bedrock and artificial (slagcrete)

Distribution

Present survey: 19.1, 24.1-2

Covey & Davies (1989): 7.1, 8.1, 10.1, 15.1

Extent

A restricted habitat only occurring at Askam Pier and Hodbarrow Point in the Duddon Estuary, and and the two railway bridges in the Ravenglass system.

Description

Stable hard substrata in the form of bedrock or large boulders was an uncommon habitat within the three estuarine systems. Naturally occurring rock was only recorded at Hodbarrow Point in the Duddon Estuary, and all other examples of this habitat were man-made in the form of sandstone blocks forming bridge piers in the Ravenglass system, and consolidated iron ore waste or 'slagcrete' at Askam Pier in the Duddon Estuary. Communities on these different habitat types could not be distinguished on the basis of their biotic composition and will therefore be described together. Wave exposure varied from moderately exposed in the Duddon Estuary to extremely sheltered in the Ravenglass system and all habitats were subjected to moderately strong tidal streams. At all sites, inclination of the habitat was very steep or even vertical.

Upper shore communities were characterised by algae, namely the green alga *Enteromorpha* sp., and the brown algae *Fucus spiralis* and *Pelvetia canaliculata.* Red algae were sparse and the species varying between sites: *Hildenbrandia* sp. and *Catenella caespitosa* were common at Askam Pier (sites 7, 8 & 10); *Audouinella* sp. was also present at site 10 and at site 24 in the Ravenglass system. Lichens *Verrucaria maura* and *Lichina pygmaea* were present at site 15, *Verrucaria mucosa* was recorded at site 8. No other species of lichen were recorded.

Animal communities were characterised by barnacles, mainly *Elminius modestus* with occasional *Semibalanus balanoides; Chthamalus montagui* was recorded at site 15. Few molluscs were recorded with *Littorina* sp. most common although in low abundance. Crustacea were rare with *Carcinus maenas* present at sites 19 & 24, *Ligia oceanica* present at the top of the shore at site 24.

In general, these habitats were impoverished although it is not possible to determine whether this is a reflection of their mainly anthropogenic origin or due to the prevailing environmental conditions.

Plate 10 Community RDR 1 on a pier of the railway viaduct across the River Esk, Ravenglass system. [MNCR slide N°: S38.19.11 Dave Mills]

Common and characterising taxa

Taxa	Frequency of occurrence		Abundance	
	No. of habitats (Total 7)	%	Range	Median
Balanus balanoides	3	43	R - O	O
Elminius modestus	5	71	R - C	F
Carcinus maenas	3	43	R - O	R
Littorina littorea	3	43	R - F	O
Audouinella sp.	3	43	R - A	O
Catenella caespitosa	3	43	O - C	F
Fucus spiralis	4	57	R - F	O
Pelvetia canaliculata	3	43	R - F	F
Enteromorpha sp.	6	86	O - C	C

Total number of taxa recorded: 25

Habitat with the highest species richness: 8.1 (13 taxa)

COMMUNITY RDR 2: Fucoid/barnacle/mussel

HABITAT: Sheltered to extremely sheltered, mid-shore hard substrata

Classification

Situation:	Enclosed coast
Salinity:	Normal to variable
Wave Exposure:	Moderately exposed to extremely sheltered
Tidal Streams:	Moderately strong
Geology:	Hard
Zone/range:	Mid-shore: mid to low eulittoral
Substratum:	Bedrock and artificial (slagcrete and sandstone blocks)

Distribution

Present survey: 19.2, 24.3
Covey & Davies (1989): 7.2-3, 10.2, 15.2

Extent

A restricted habitat only occurring at Askam Pier and Hodbarrow Point in the Duddon Estuary, and the two railway bridges in the Ravenglass system.

Description

Stable hard substrata in the form of bedrock or large boulders was an uncommon habitat within the three estuarine systems. Naturally occurring rock was only recorded at Hodbarrow Point in the Duddon Estuary and all other examples of this habitat were man-made in the form of sandstone blocks forming bridge piers in the Ravenglass system and consolidated iron ore waste or 'slagcrete' at Askam Pier in the Duddon Estuary. Communities on these different habitat types could not be distinguished on the basis of their biotic composition and will therefore be described together. Wave exposure varied from moderately exposed in the Duddon Estuary to extremely sheltered in the Ravenglass system and all habitats were subjected to moderately strong tidal streams. At some sites (48 %), inclination of the habitat was very steep or even vertical.

Mid-shore habitats were characterised by *Fucus vesiculosus* with occasional *Ascophyllum nodosum, Mytilus edulis* and barnacles: mainly *Elminius modestus* with *Semibalanus balanoides* additionally present at sites 7, 15, 19 & 24. Few other species of algae were present: *Enteromorpha* sp. were present at most sites and common at site 24; at site 7, red and brown encrusting algae were frequent with *Audouinella* common. In addition to the characterising

species listed above, faunal composition of these communities was varied and, in general, had a low species richness. *Littorina littorea* was present at all sites, *Littorina saxatilis* present only at sites in the Duddon Estuary (7, 10 & 15). At site 15, large 'pock holes', approximately 10-15 cm in diameter, were present which contained breeding aggregations of *Nucella lapillus*.

Plate 11 Mussels, barnacle and fucoid algae on mid-shore bedrock at Hodbarrow Point, Duddon Estuary. [MNCR slide N°: S20.15.5 Keith Hiscock]

Common and characterising taxa

Taxa	Frequency of occurrence		Abundance	
	No. of habitats (Total 6)	%	Range	Median
Balanus balanoides	4	67	O - A	O
Elminius modestus	6	100	R - S	O
Gammaridae	3	50	O - F	O
Carcinus maenas	3	50	R - C	O
Anurida maritima	4	67	R - C	O
Littorina littorea	6	100	R - C	O
Littorina saxatilis	4	67	R - C	O
Mytilus edulis	6	100	R - S	O
Audouinella sp.	3	50	R - A	O
Ascophyllum nodosum	5	83	O - F	O
Fucus vesiculosus	6	100	O - S	F
Enteromorpha sp.	4	67	R - C	O
Ulva sp.	3	50	R - O	O

Total number of taxa recorded: 33

Habitat with the highest species richness: 15.2 (18 taxa)

COMMUNITY RDR 3: *Enteromorpha*/Barnacle

HABITAT:Mid/low shore boulders in low salinity, subject to moderate tidal streams

Classification

Situation:	Enclosed coast
Salinity:	Variable-low
Wave Exposure:	Sheltered - ultra sheltered
Tidal Streams:	Moderately strong
Geology:	Hard
Zone/range:	Mid to low shore: mid eulittoral
Substratum:	Small boulders (39 %) and cobbles (31 %) on fine sand or mud (18 %)

Distribution

Present survey: 1.2, 3.3, 4.2, 5.2, 6.2, 8.1
Covey & Davies (1989): 12.2, 13.3

Extent

This habitat forms a mid to low shore training wall along the length of the Ribble Estuary from the mouth inland to Preston; tumbles of boulders were also recorded at two locations in the upper Duddon Estuary.

Description

When the Ribble channel was straightened to facilitate shipping movements, piles of stones were deposited on the mid to low shore to act as a training wall to maintain the channel. These boulders and cobbles, plus coastal defence walls, provide the main hard substrata habitats within the Ribble Estuary. In the outer estuary, these stones lie on, and generally have a covering of, fine muddy sand which is gradually replaced by soft mud in the inner estuary. All habitats are subject to low salinity and water borne pollution, mainly sewage. Water in the Ribble Channel has a high sediment load and, combined with the moderately strong tidal flows within the channel, subjects these habitats to high scour.

In the upper Duddon Estuary, hard substrata was also primarily boulders deposited on the shore either as foundations for man-made structures or as training walls. These boulders were subject to similar physical environmental conditions of low salinity and moderate tidal flows (cf. the Ribble Estuary).

Communities had a low species richness and were characterised by green algae, mainly *Enteromorpha* sp. and barnacles, mainly *Elminius modestus*. Sediment on the surface of the stones was bound together by a unicellular green and brown algal mat. At sites 5, 6 & 8, rock surfaces were covered with diatom film. *Mytilus edulis* were occasional at site 1 but not recorded at sites further east. Species richness declined with increasing distance up the Ribble Estuary, probably as a result of decreasing salinity; a predominantly outward flow of water which may restrict the supply of larvae, thereby reducing recruitment, to sites in the upper estuary.

Boulder habitats in the upper Duddon Estuary displayed a similar decline in species richness with increasing distance up the estuary. At site 12, boulders were colonised by green algae, mainly *Enteromorpha* sp., with occasional *Elminius modestus* and amphipod crustaceans. In contrast, site 13 was rather impoverished, boulders had a sparse covering of green algae and a very sparse fauna: juvenile amphipods and *Sphaeroma rugicauda* were recorded as rare.

Common and characterising taxa

Taxa	Frequency of occurrence		Abundance	
	No. of habitats (Total 8)	%	Range	Median
Elminius modestus	4	50	R - A	O
Chlorophycota indet. (green algal film)	5	63	O - C	F
Enteromorpha sp.	7	88	R - C	O

Total number of taxa recorded: 13

Habitat with the highest species richness: 6.2 (6 taxa)

COMMUNITY RDR 4: *Mytilus edulis/Semibalanus balanoides*

HABITAT:Mixed stones on sediment subject to moderate tidal streams

Classification

Situation:

Salinity: Normal to low

Wave Exposure: Moderately exposed to extremely sheltered

Tidal Streams: Moderately strong

Geology:

Zone/range: Mid to low shore: mid eulittoral

Substratum: Small boulders (20 %), cobbles (19 %) and pebbles (14 %) on fine sand (20 %) with gravel (8 %) and mud (4 %)

Distribution

Present survey: 4.2, 6.3, 24.4
Covey & Davies (1989): 15.3, 19.2, 19.4
Davies (1991): 7.4

Extent

This habitat was recorded at the mouth of the Ribble Estuary where it comprised boulder scars and stones of the training wall, at one site on the north-west side of the Duddon Estuary and in the lower part of the Esk Estuary in the Ravenglass system.

Description

Naturally occurring accumulations of stones (small boulders, cobbles and pebbles) lying on sediment were found in all three estuaries although this habitat was most extensive in the lower Esk Estuary. In addition, piles of boulders forming a training wall at the mouth of the Ribble Estuary had a similar biotic composition to the natural habitat. At all sites salinity was variable to low, and wave exposure varied from moderately exposed at the mouth of the Ribble, to extremely sheltered in the Ravenglass system.

The community was dominated by *Mytilus edulis* and barnacles, *Semibalanus balanoides* with *Balanus crenatus* (on the low shore). Barnacles were present both on the stones and on the mussel valves. Barnacle abundance was lowest in the Ravenglass system which may reflect the apparent lowered salinity at these sites. At sites 15 and 19, individual mussels were joined together to form clumps and chains which consolidated the stones on the sediment. In addition at site 19, the polychaetes *Arenicola marina, Lanice conchilega* and *Hediste diversicolor,* and the

bivalves *Mya arenaria* and *Cerastoderma edule* were recorded within the sediment between the stones and mussel aggregations.

Algae were sparse throughout all habitats, only *Enteromorpha* sp. and *Fucus vesiculosus* recorded in all three estuaries. In more sheltered sites, algal species richness increased but abundance remained low. At site 24, the habitat formed the base of the river channel and the estuarine alga *Fucus ceranoides* was frequent.

An intensive survey of the mussel beds at Lytham (Davies 1991; 7.4) over several months in late summer and autumn 1985 was reported by Dent (1986). Her methods included removal of mussels and surface cobbles to a depth of 20 cm, and consequently she recorded a wider range of organisms than the present study. In addition to the species noted earlier, Dent (1986) recorded an infauna which included the polychaetes *Pygospio elegans* and *Neanthes succinea,* the bivalves *Macoma balthica* and *Abra alba* and unidentified nematodes. Additional epibiota included *Elminius modestus* which were common or abundant, the gastropods *Littorina littorea, Littorina saxatilis* and *Hydrobia ulvae*, and the amphipod *Gammarus duebeni*. Most, if not all, of these species could be expected to be recorded in other examples of this habitat with more intensive survey effort.

In general, species richness declined with increasing wave exposure: the sites at the mouth of the Ribble Estuary were more impoverished than sites in the Duddon and Ravenglass systems.

Common and characterising taxa

Taxa	Frequency of occurrence		Abundance	
	No. of habitats (Total 7)	%	Range	Median
Balanus balanoides	7	100	O - C	F
Balanus crenatus	5	71	O - O	O
Elminius modestus	4	57	O - C	F
Littorina littorea	3	43	R - C	F
Mytilus edulis	7	100	F - S	C
Dumontia contorta	3	43	O - O	O
Chondrus crispus	3	43	O - F	O
Fucus vesiculosus	4	57	R - O	O
Enteromorpha sp.	5	71	R - O	O

Total number of taxa recorded: 30

Habitat with the highest species richness: 20.19.4 (17 taxa)

COMMUNITY RDR 5: Barnacle/mussel/littorinid

HABITAT:Sheltered pebbles with some small cobbles and gravel on sediment

Classification

Situation: Enclosed coast
Salinity: Variable
Wave Exposure: Sheltered (very sheltered at site 22)
Tidal Streams: Not known
Geology: Hard
Zone/range: Mid to upper shore: upper-mid eulittoral
Substratum: Pebbles (51 %) with some small cobbles (16 %) and gravel, some muddy medium-fine sand (19 %) in the interstices.

Distribution

Present survey: 9.1, 10.1, 10.3-4, 18.1, 18.3, 22.5

Extent

A habitat located in sheltered areas, generally restricted to the entrance of the Duddon and Ravenglass systems.

Description

Shingle scars were recorded in the Duddon Estuary at the entrance to Walney Channel and at Haverigg, in the entrance channel to the Ravenglass system, and in the lower reaches of the Irt Estuary. Due to their location, it is likely that these habitats will be subject to tidal flows although such flows were not recorded during the present survey due to state of the tide. Although located at the entrance to these estuarine systems, it is likely that these habitats will be subject to fluctuations in salinity. These scars were composed of pebbles with some small cobbles and gravel. Stones were embedded in sediment which was primarily sand at sites 10 & 18, with the silt content increasing at the more sheltered sites 9 & 22. Stones were considered to be relatively stable with some evidence of sand scour.

Marine communities present were animal dominated with occasional clumps of algae. Rock surfaces were dominated by barnacles, mainly *Elminius modestus* with *Semibalanus balanoides* present in the lower-shore parts of these habitats. At site 10, the barnacle populations were very dense resulting in individuals adopting a tall, columnar growth form. *Mytilus edulis* were present in small clumps between the stones and appeared to bind the stones together increasing the overall stability of the habitat. Gastropods were abundant within the interstices, the populations

dominated by *Littorina littorea* with *Littorina saxatilis* on the upper shore. At site 9, *Littorina neglecta* were recorded within empty barnacle tests. *Arenicola marina* casts and *Lanice conchilega* tubes were present between the stones, and *Cerastoderma edule* were recorded within sediment at the more sheltered site 22. Small gobies, *Pomatoschistus* sp. and shrimps, *Crangon crangon* were found in tiny pools between the stones in the lower shore of site 10. In general algae were sparse and only recorded as isolated clumps. *Pelvetia canaliculata* and *Fucus spiralis* were present on the upper shore, *Fucus vesiculosus* present in the mid-shore. *Chondrus crispus* and *Ceramium* sp. were recorded at site 10, *Porphyra* sp. were recorded at site 18. Where freshwater runoff was present, filamentous green algae were recorded.

Plate 12 Stones on sediment on the upper shore at Haverigg, Duddon Estuary. [MNCR slide N°: S38.9.7 Jon Davies]

Common and characterising taxa

Taxa	Frequency of occurrence		Abundance	
	No. of habitats (Total 7)	%	Range	Median
Arenicola marina	3	43	R - O	R
Balanus balanoides	3	43	O - F	F
Elminius modestus	6	86	O - S	F
Carcinus maenas	4	57	R - O	R
Littorina littorea	5	71	O - A	C
Littorina saxatilis	5	71	R - C	F
Mytilus edulis	5	71	R - F	F
Fucus spiralis	3	43	R - C	O
Fucus vesiculosus	3	43	R - O	R
Enteromorpha sp.	3	43	O - F	O

Total number of taxa recorded: 27

Habitat with the highest species richness: 10.4 (16 taxa)

COMMUNITY RDR 6: *Hediste/Corophium*/green algae

HABITAT:Extremely sheltered stones on sediment, subject to variable or low salinity

Classification

Situation:	Enclosed coast
Salinity:	Variable to low
Wave Exposure:	Extremely sheltered
Tidal Streams:	Moderately strong
Geology:	
Zone/range:	Upper to mid shore
Substratum:	Pebbles (28 %) with gravel (23 %) on sandy mud

Distribution

Present survey: 19.4-5, 21.4, 22.2, 23.2

Covey & Davies (1989): 19.1

Extent

Restricted to the edges of the river channels within the Ravenglass system, predominantly in the Esk Estuary.

Description

Shingle scars and banks were recorded along the edges of the river channels in the Ravenglass system. These habitats were composed on pebbles with gravel and rarely small cobbles (<1%) lying on sandy mud. Salinity was variable to low depending on the distance upstream, and the rate of tidal flows will be moderate, although not recorded due to the low tide. Stones were generally stable with some sediment adhering to their surface; it was considered likely that these habitats will be subject to sediment scour.

Epibenthic communities were characterised by algae, mainly *Enteromorpha* sp. and *Ulva* sp. with scattered clumps of *Fucus vesiculosus*; *Fucus ceranoides*, a species characteristic of low salinity conditions, was recorded at site 22. At site 19, habitat 5 was composed of fine sand bound together by dense filaments of *Enteromorpha* sp. forming a mat overlying pebbles and gravel. Barnacles, mainly *Semibalanus balanoides* with some *Elminius modestus* charactered epifaunal assemblages. The bryozoan, *Bowerbankia imbricata* was recorded at site 22, a species characteristic of variable to low salinity habitats. Within the sediment, infaunal communities were characterised by *Hediste diversicolor* and *Corophium volutator*.

Plate 13 Gravel on the surface of sediment in the lower River Esk; the green coloration to the surface of the substrata is the filamentous alga *Enteromorpha* sp.. [MNCR slide N°: S38.19.4 Dave Mills]

Species richness declined with increasing distance upstream: barnacles, *Mytilus edulis*, *Littorina littorea* and *Fucus vesiculosus* were recorded at sites 19 & 22, but not at the sites further upstream.

Common and characterising taxa

Taxa	Frequency of occurrence		Abundance	
	No. of habitats (Total 6)	%	Range	Median
Hediste diversicolor	3	50	R - F	F
Balanus balanoides	4	67	R - O	R
Elminius modestus	3	50	R - F	O
Corophium volutator	4	67	O - S	O
Carcinus maenas	4	67	P - R	R
Littorina littorea	3	50	R - O	O
Fucus vesiculosus	3	50	R - O	R
Enteromorpha sp.	5	83	O - A	O
Ulva sp.	3	50	R - O	O

Total number of taxa recorded: 16

Habitat with the highest species richness: 22.4 (12 taxa)

COMMUNITY RDR 7: Crustacean/polychaete

HABITAT:Mobile, mid to low shore, medium and fine sand

Classification

Situation:	Open to enclosed coast
Salinity:	Normal to variable
Wave Exposure:	Exposed to sheltered
Tidal Streams:	Moderately strong (for 37 % of records)
Geology:	Not applicable
Zone/range:	Low to mid shore
Substratum:	Medium (55 %) to fine (35 %) sand; mean grain size = 2.45 ± 0.08 Ø

Distribution

Present survey: 1.3, 9.4, 10.5, 11.3, 12.1, 18.2, 20.1
Covey & Davies (1989): 9.1, 11.3, 15.4, 16.1, 19.3
Davies (1991): 6.1, 6.2, 8.3, 9.1-3

Extent

Clean, mobile medium-fine sands were restricted to the outermost areas of the three estuaries, and adjacent to the main channels of within the estuarine systems.

Description

Extensive flats of moderately well sorted, medium fine sand characterise the mid to low shore transition areas between the Ribble, Duddon and Ravenglass estuarine systems and the open coast of the eastern basin of the Irish Sea. In the Ribble Estuary, this habitat was restricted to areas to the west of Lytham. For the Duddon Estuary, the habitat was restricted to outer-most areas and adjacent to the main channel in the middle estuary. In the Ravenglass system, mobile sands were present alongside the outermost joint channel and as sand banks adjacent to the main channel in the lower River Esk. The habitat was exposed to moderately exposed to prevailing wind and swell and composed of even, firm medium and fine sand (mean grain size of 2.45 ± 0.08 Ø) which was moderately well sorted (Inclusive graphic standard deviation = 0.53 ± 0.04). Within the estuaries, the habitat occurs in more sheltered conditions but adjacent to the main river channels and therefore subject to moderately strong tidal streams. Sediments will therefore be very mobile which is reflected in a low silt content (mean for Ø >4 = 0.89 %). At the outermost sites, salinity is likely to be near-normal but becoming more variable with increasing distance up the estuary.

Biotic assemblages recorded from these habitats were characterised by infaunal species, no epibenthic species were present. In general, infaunal communities had a low species richness and low biomass with the overall biotic composition very variable between stations. Low species richness is probably a reflection of the highly mobile nature of the sediment. Infaunal communities were characterised by the polychaete *Nephtys cirrosa,* the amphipod *Bathyporeia pelagic* and the isopod *Eurydice pulchra.* In addition, *Nephtys hombergii, Arenicola marina, Macoma balthica* and *Cerastoderma edule* were recorded at a slightly lower proportion of stations. Site 9 (Davies 1991) had the highest species richness, particularly for bivalve molluscs where 6 species were recorded; in addition the characterising species noted above, *Mysella bidentata, Mactra stultorum, Spisula elliptica* and *Dona vittatus* were recorded. Also at site 9, the opisthobranch *Acteon tornatilis* which feeds on *Lanice conchilega* and *Owenia fusiformis*, was recorded on the lower mid-shore. At site 19 (Covey & Davies 1989), the infaunal community recorded within a sand bank adjacent to the main river channel had abundant *Bathyporeia pilosa* and *Bathyporeia sarsi,* with *Corophium volutator* and *Anurida maritima* common; these latter species reflect a more estuarine character to the biotic composition. *Bathyporeia pilosa* is a more euryhaline species than its congener *Bathyporeia pelagica*, while *Bathyporeia sarsi* is uncommon within the Irish Sea (Hayward & Ryland 1990).

As indicated above, the biotic composition of stations assigned to this community type was somewhat variable. A variable biotic composition at a station with species characteristic of more than one community type indicates that the station probably forms a transition zone between two more 'pure' habitat types and the biotic composition therefore contains elements of the communities present in the 'pure' habitat. In particular, the community present at stations 6.1 & 6.2 (Davies 1991) are similar to community RDR 8, whilst station 9.1 (Covey & Davies 1989) is similar to community RDR 9.

Common and characterising taxa

Taxa	Frequency of occurrence		Abundance	
	No. of habitats (Total 19)	%	Range	Median
Nephtys cirrosa	8	42	P - A	P
Nephtys hombergii	5	26	P - P	P
Arenicola marina	7	37	P - C	O
Bathyporeia pelagica	8	42	P - A	C
Eurydice pulchra	10	53	P - A	P
Cerastoderma edule	6	32	P - O	R
Macoma balthica	7	37	P - C	F

Total number of taxa recorded: 45

Habitat with the highest species richness: 62.9.3 (16 taxa)

COMMUNITY RDR 8: *Cerastoderma/Macoma/Pygospio*

HABITAT:Moderately exposed, mid-shore, medium-fine muddy sand

Classification

Situation: Enclosed coast
Salinity: Normal to variable
Wave Exposure: Exposed to moderately exposed
Tidal Streams: Moderately strong to weak
Geology: Not applicable
Zone/range: Mid-shore
Substratum: Medium (28 %) - fine (47 %) sand with mud (23 %); mean grain size = 3.08 ± 0.14 Ø

Distribution

Present survey: 1.1, 9.2-3, 11.1-2, 12.2-3
Davies (1991): 7.1-2, 8.1-2, 8.4

Extent

Moderately exposed medium fine muddy sands were restricted to the mouth of the Ribble and Duddon Estuaries.

Description

At the entrance to both the Ribble and the Duddon Estuaries, there were extensive sediment flats composed of medium-fine sand with mud in the mid-shore zone. South-east of Lytham St Annes, Ribble Estuary, and south-east Haverigg, Duddon Estuary there were more sheltered embayments where the sediment had a surface covering of soft mud and fine sand, with a medium-fine sand forming a coarse layer below. This increased mud content was reflected in the granulometric results: muddier sites had 18-25 % sediment with >4Ø; the remaining sites had <10 % sediment >4Ø. Overall, the sediment surface was even and stable, the sediment itself was moderately well sorted (Inclusive graphic standard deviation = 0.83 ± 0.13).

Infaunal communities were characterised by the bivalves *Cerastoderma edule* and *Macoma balthica* and the polychaetes *Pygospio elegans* and *Hediste diversicolor*. In addition, *Eteone longa*, *Arenicola marina* and *Capitella capitata* were present at fewer sites but where present, they were recorded in very high abundances; *Capitella capitata* was present at muddier sites. At these muddier sites, namely 7 (Davies 1991) and 1 and 9 (present survey), the oligochaetes *Tubificoides* spp. and Enchytraeidae indet., and *Corophium volutator* were common or abundant

together with the bivalves *Mya arenaria* and *Scrobicularia plana*. At more exposed, sandier sites, infaunal communities were characterised by *Nephtys hombergii*, the amphipods *Bathyporeia* spp. and *Corophium arenarium* and the isopod *Eurydice pulchra* were also recorded; the bivalve *Abra alba* was common at the mid-shore station at site 11.

Overall stations where this community was recorded had a low species richness, stations with the highest species richness were the muddier stations which are probably transitional communities between the present and community RDR 9. In particular, *Cerastoderma edule* was not recorded at station 9.2 and the species composition was very similar to RDR 9. Station 9.2 has been assigned to the current community on the basis of granulometric composition of the sediment and the present of four bivalve species. When the current data set are analysed with data from the remainder of the eastern basin of the Irish Sea, it is likely that stations assigned to the current community will be reassigned to either more sandier or muddier communities.

Common and characterising species

Species	Frequency of occurrence		Abundance	
	No. of habitats (Total 12)	%	Range	Median
Nemertea indet.	6	50	P - P	P
Eteone longa	8	67	P - A	A
Hediste diversicolor	9	75	P - S	A
Nephtys hombergii	5	42	P - A	P
Scoloplos armiger	3	25	P - P	P
Pygospio elegans	12	100	P - S	A
Capitella capitata	7	58	C - S	C
Arenicola marina	8	67	P - S	C
Tubificoides benedeni	4	33	C - S	C
Tubificoides pseudogaster	4	33	C - C	C
Enchytraeidae indet.	4	33	C - C	C
Bathyporeia pilosa	3	25	P - A	P
Corophium arenarium	4	33	P - A	C
Corophium volutator	3	25	A - S	A
Carcinus maenas	3	25	P - S	S
Hydrobia ulvae	7	58	P - C	O
Mysella bidentata	3	25	P - P	P
Cerastoderma edule	11	92	P - A	A
Macoma balthica	12	100	C - S	C

Scrobicularia plana	4	33	P - A	O
Mya arenaria	3	25	O - C	F

Total number of taxa recorded: 37

Habitat with the highest species richness: 9.2 (38 taxa)

COMMUNITY RDR 9: *Arenicola/Corophium/Hediste*

HABITAT:Very to extremely sheltered, mid-shore, fine sand subject to variable salinity

Classification

Situation: Enclosed coast
Salinity: Variable to low
Wave Exposure: Extremely sheltered to sheltered
Tidal Streams: Very weak
Geology: Not applicable
Zone/range: Mid-shore
Substratum: Very fine sand with some medium sand (21 %) and silt (15 %); mean grain size = 3.06 ± 0.14 Ø

Distribution

Present survey: 2.3*, 3.2*, 6.1*, 10.2, 13.1-2, 14.1-3, 15.1*, 19.3*, 19.6, 20.2, 21.2-3, 22.1, 22.4, 24.5, 25.4.
Covey & Davies (1989): 13.1-2, 14.4*, 20.1*, 20.2, 20.3*
(* indicates a 'transitional' example - see description)

Extent

In the Ribble Estuary, fine sands were present in middle reaches although the communities present were 'transitional' (see below). Most expansive area of this community occurred in the mid section of the Duddon Estuary extending from the entrance to the Walney Channel in the south-east into the upper estuary at Lady Hall. A similar distribution was found in the Ravenglass system with this community characterising the mid and lower parts of all three rivers.

Description

Extensive flats of medium (21 % composition) and mainly fine sand (61 % composition) with a small silt fraction were characterised the mid and low-shore throughout the central part of the Duddon Estuary and the mid and lower reaches of the Rivers Esk, Irt and Mite in the Ravenglass system. A similar community was recorded in the middle part of the Ribble Estuary although the sediment had a much higher silt content. These areas are protected from the prevailing wind and swell by the sediment flats and off-shore banks to the west and therefore the wave exposure of these area areas is very to extremely sheltered. The sediment was moderately well sorted

(Inclusive graphic standard deviation = 0.52 ± 0.05) although the grain size distribution tended towards coarse skewness (Inclusive graphic skewness 0.9 ± 0.04). Examples of this community were often recorded adjacent to the river channels with the result that the sediment was more mobile and subject to variable to low salinity; ambient salinity will decline with increasing distance up the estuaries towards their tidal limit.

Plate 14 Extensive sediment flats composed of fine sand in the middle part of the Duddon Estuary. [MNCR slide N°: S38.11.6 Roger Covey]

When the data for fine sand habitats were analysed, two distinct species assemblages were identified. Upon further investigation it was apparent that one group was an impoverished example of the other with essentially the same characterising species. Granulometric analyses of the sediment from, and an inspection of the geographic location of, stations where this impoverished example occurred suggested that these stations were 'transitional' between fine sands and either medium-fine sands or estuarine muds. Therefore the following descriptions are based on the more species rich, 'pure' examples of this community.

Infaunal species assemblages were characterised by the polychaetes *Hediste diversicolor, Pygospio elegans, Capitella capitata* and *Arenicola marina*, unidentified Enchytraeidae, the amphipods *Corophium volutator* and *Bathyporeia pilosa* and the bivalve *Macoma balthica*. At sites where the sediment was sandier and/or more mobile, the isopod *Eurydice pulchra* was present in low abundance, and the amphipod *Corophium arenarium* was abundant. *Bathyporeia*

sarsi, a less common congener of *Bathyporeia pilosa*, was common at Lowsey Point, Duddon Estuary, and in particular, at three sites within the River Esk, Ravenglass system. At sites where the surface of the sediment was composed of a layer of silt, *Hydrobia ulvae* was common. *Manayunkia aestuarina,* a polychaete characteristic of lower salinity habitats, was recorded a stations adjacent to small creeks or channels.

In general the species composition of stations assigned to this community was variable, mainly as a consequence of the range of environmental conditions: variable to low salinity, sheltered to extremely sheltered wave exposure and sediment composition. Nevertheless, the common an characterising species outlined above were 'faithful' to this community type throughout. For transitional stations, the most apparent change was a decline in the number of polychaete species - only *Pygospio elegans* was common to transitional habitats - and crustacean species - only *Corophium volutator* was present - and an increase in the species richness and abundance of oligochaetes.

Common and characterising taxa

Only 'pure' stations are included in the following list:

Taxa	Frequency of occurrence		Abundance	
	No. of habitats	%	Range (Total 17)	Median
Hediste diversicolor	17	88	P - A	A
Pygospio elegans	12	71	P - S	C
Capitella capitata	10	59	P - A	C
Arenicola marina	10	59	R - S	S
Enchytraeidae indet.	9	53	P - A	C
Bathyporeia pilosa	9	53	P - S	C
Corophium arenarium	5	29	P - A	A
Corophium volutator	13	76	O - S	A
Eurydice pulchra	8	47	P - C	P
Macoma balthica	16	94	P - A	C

Total number of taxa recorded: 34

Habitat with the highest species richness: 22.4 (18 taxa)

COMMUNITY RDR 10: *Hediste/Corophium*/oligochaete

HABITAT:Extremely sheltered estuarine mud subject to variable or low salinity

Classification

Situation:	Enclosed coast
Salinity:	Variable to low
Wave Exposure:	Sheltered to extremely sheltered
Tidal Streams:	Moderately strong to very weak
Geology:	Not applicable
Zone/range:	Upper to mid-shore
Substratum:	Mud (71 %) with fine sand (26 %); median grain size = >4Ø

Distribution

Present survey: 2.1-2.2, 3.1, 4.1, 5.1, 7.1, 16.1-2, 20.3, 21.1, 22.3, 23.1, 25.1-3
Covey & Davies (1989): 11.1-2, 12.1, 14.1

Extent

Estuarine mud was recorded throughout the mid and upper Ribble Estuary, and restricted to the upper reaches of the Duddon Estuary and the Rivers Esk, Irt & Mite, Ravenglass system.

Description

Sediments in extremely sheltered areas were composed of mud (71 %) with fine sand (26 %), the median grain size exceeding 4Ø (it is not possible to calculate a mean grain size for sediments with a high silt fraction). These sediments were even, stable and well sorted with a soft surface layer; a sub-surface clay/mud layer was present at c. 17 % of sites. Mud habitats were common throughout the eastern-mid and upper parts of the Ribble Estuary, extending west to the Ribble Marshes NNR at the mouth where the wave exposure increased with a resultant increase in the sand fraction. In the Duddon and Ravenglass estuarine systems, mud habitats were restricted to the upper estuaries towards the tidal limit, or within upper-shore saltmarsh creeks of the mid-estuaries. As a consequence of their upper estuarine location, mud habitats were subject to variable, or mainly low salinity. Where located adjacent to river channels or creeks, these habitats will be subject to moderate water flow, especially on the ebb tide.

Infaunal species assemblages had a low species richness and were characterised by *Hediste diversicolor,* oligochaetes - *Tubifex costatus* and unidentified Enchytraeidae, and *Corophium volutator*. Oligochaetes were most abundant in the Ribble and Ravenglass estuarine systems,

possibly a reflection of the higher sand content for stations in the Duddon Estuary. *Macoma balthica* and *Manayunkia aestuarina* were common at stations in the middle region of the Ribble Estuary and in the River Esk, Ravenglass system. *Hydrobia ulvae* were super-abundant at station 25 in the River Esk but rare or absent at all other stations. Stations at site 2, located within the Ribble Marshes NNR, were more exposed and the sediment had a higher sand content which was reflected in a higher species richness and abundance. These stations are probably transitional between the present community type and community RDR 9.

Plate 15 Soft mud bordering saltmarsh in the upper River Irt, Ravenglass system. [MNCR slide N°: S38.23.4 Roger Covey]

Common and characterising species

Species	Frequency of occurrence		Abundance	
	No. of habitats (Total 19)	%	Range	Median
Hediste diversicolor	13	68	P - S	A
Pygospio elegans	6	32	P - A	P
Tubifex costatus	6	32	P - S	C
Enchytraeidae	9	47	P - S	C
Corophium volutator	12	63	P - S	A
Carcinus maenas	5	26	P - O	P
Macoma balthica	6	32	P - A	C

Total number of taxa recorded: 29

Habitat with the highest species richness: 20.3 (11 taxa)