Joint Nature Conservation Committee
Monkstone House
City Road
Peterborough PE1 1JY

Marine Nature Conservation Review

LITTORAL SURVEY OF THE INNER SOLWAY FIRTH AND ADDITIONAL SITES IN DUMFRIES AND GALLOWAY

Roger Covey & Chris S. Emblow
September 1992 33.

Field survey team:

Dumfries and Galloway
Roger Covey
L. Mark Davies
Chris Emblow
Joanne Ward

Inner Solway
Roger Covey
L. Mark Davies
Chris Emblow
N. Clare Eno
Dan Laffoley
Joanne Ward

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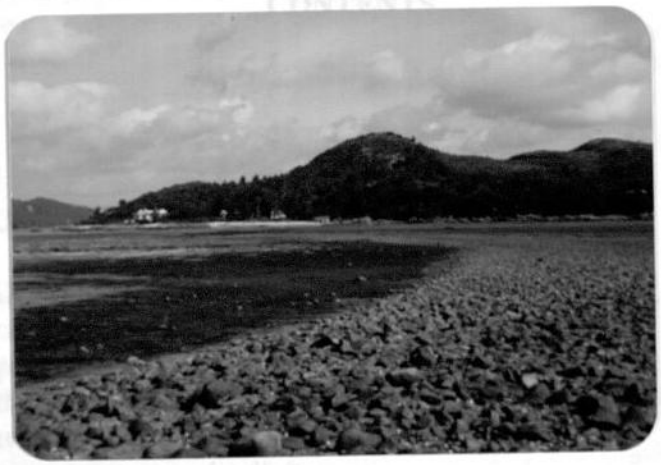

FRONTISPIECE

Plate 1 Upper shore boulder causeway with adjacent lower shore *Zostera* beds. Rough Island causeway flats, inner Solway (S286.23.10. L. Mark Davies)

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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

Marine Nature Conservation Review

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SYNOPSIS

The inner Solway is an area of predominantly sedimentary substrata, with large expanses of mobile sediment and constantly migrating river channels extending from the Rivers Esk and Eden which enter the Firth at its head around Rockcliffe Marsh. Within the inner Solway, hard substratum is limited in extent to scoured boulder scars in the south of the area and some true rocky shores fringing the sediment flats to the west of Southerness Point.

The coastline of the middle and upper reaches of the estuary is largely linear, with only Moricambe, the River Nith and the Rough Firth/Auchencairn Bay complex providing any variation. The west side of Auchencairn Bay marks the end of the sedimentary shores, giving way to predominantly rocky shoreline more characteristic of the north shore of the outer Solway. The rocky coastline is only interrupted by large areas of sediment in Kirkcudbright Bay, Fleet Bay and Wigtown Bay. From Burrow Head the coastline swings north-west into the vast Luce Bay which extends to the Mull of Galloway. The bay is backed by Luce Sands, over 8 km long, and by Torrs Warren, a broad area of sand dunes.

In June 1991 survey work was completed on the north coast of the Solway Firth between Luce Sands and Mullock Bay following the recommendations in Covey (1990). The inner Solway from Maryport to Balcarry Point was surveyed in August 1991. Both surveys contributed to MNCR work in the north-east basin of the Irish Sea.

On the north coast of the outer Solway, seventeen littoral sites were surveyed and 83 habitats recorded. In the inner Solway, 28 littoral sites were surveyed and 91 habitats recorded. Using records collected on both surveys, six hard substrata, five mixed substrata and four soft substrata habitat/community types were described. Variations of the rocky shore communities were described from wave exposed/open coast sites and wave sheltered/enclosed coast sites. Two facies of one sediment community were also identified. The rocky sites were predominantly barnacle and fucoid dominated with extensive mussel beds on the lower shores at some sites. At the more exposed sites *Chthalamus montagui* was predominant as band on the upper shore with *Balanus balanoides* and *Fucus vesiculosus* on the lower shore. More sheltered sites were characterised by *Pelvetia canaliculata* on the upper shore and *Ascophyllum nodosum* on the lower shore. Boulder scar communities on mixed substrata were described according to the stability of the substrata and the amount of sedimentary material binding the larger material together thus providing a matrix for polychaetes etc. to colonise. Soft substratum habitats and communities were split broadly into two groups; enclosed coast estuarine fine sands and muds, and open coast fine sands. Within these two groups, finer divisions were recognised on the basis of salinity and wave exposure, which affected the sediment composition, the species present and their abundance.

Marine Nature Conservation Review

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1 INTRODUCTION

The inner Solway is an area of predominantly sedimentary substrata, with large expanses of mobile sediment and constantly migrating river channels extending from the Rivers Esk and Eden which enter the Firth at its head around Rockcliffe Marsh. Much of the land bordering the inner Solway is used for agriculture, with a large amount of the fringing land used as pasture. Only the Whitehaven and Maryport area have substantial industrial development. In the 18th and 19th centuries, great industrial advances took place as the coastal coal fields of the north-west Cumbrian coast were exploited, and blast furnaces poured out iron products. Whitehaven, Workington and Maryport developed their ports along with shipbuilding, and traded with Europe, Ireland and America as well as with other British ports. Whitehaven became Britain's second port to London by the 18th Century. Although Maryport, as an important harbour, dates back to Roman times, the modern history of the town as a port began in the 18th Century, when a local landowner obtained an Act of Parliament to create a new town and port. The harbour prospered and expanded, and by 1867 some 3,000 vessels a year were using the port. In terms of volume of trade, Maryport now assumed national importance, and this was recognised by the construction of the coastal defence battery half a mile to the north of the harbour entrance. Technological change and shifts in trade patterns led to a rapid decline of the port. The last locally registered ship to use the harbour departed in 1952.

Along the north coast of the outer Solway, industrialisation is minimal and urban development does not infringe on the naturalness of the coastline. The area is a popular holiday destination with numerous caravan sites and camping facilities. From Burrow Head the coastline swings north-west into the vast Luce Bay which extends to the Mull of Galloway. At the head of the bay, Luce Sands extend over 8 km, and are backed by Torrs Warren, a broad area of sand dunes. Luce Bay is used by the Ministry of Defence (MOD) as a missile and bomb testing range, and access to the sands and dunes is limited. Nearly 10 km of coast east of Kirkcudbright is also MOD property.

Within the inner Solway, hard substratum is limited in extent, with scoured boulder scars in the south of the area and some true rocky shores fringing the sediment flats west of Southerness Point. Further west, near the head of the Firth, only limited hard substratum occurs, ranging from stable shingle to viaduct stonework.

The east side of Auchencairn Bay on the north coast of the Solway marks the transition from the sedimentary shores, to a predominantly rocky shoreline more characteristic of the outer Solway. The rocky coastline is interspersed with large areas of sediment in the Kirkcudbright Bay, Fleet Bay and Wigtown Bay.

The area of survey included the outer, middle and upper estuarine reaches of the Solway Firth, as defined by Perkins (1978). He defines the limits of the Solway by a line drawn from the Mull of Galloway to Hodbarrow Point, Cumbria. The coastline of the middle and upper reaches of the estuary is largely linear, with only Moricambe, the River Nith and the Rough Firth/Auchencairn Bay complex providing any variation.

2 PHYSICAL CONDITIONS

2.1 Geology

For the most part the solid geology of the survey area is of little relevance to the marine biology, since the basal rocks are covered by boulder clay, transported marine sands or peat deposits. Much of the hard substratum is derived from weathered boulder clays from glacial moraines and drumlins.

Calciferous sandstone rocks outcrop above the sediment along the north coast from Southerness Point westwards, with steep cliffs present at Port o' Warren. Auchencairn Bay represents an area where these calciferous sandstones have been breached and the bays are cut back into the Criffel granite. There are also traces of fossil cliffs and raised beach deposits, for example behind Caerlaverock, where the lowland, fringing the marshes, is formed from raised beach material. Steers (1973) states that the moat of Caerlaverock Castle was filled with seawater in the thirteenth and fourteenth centuries, though it is now well inland. The form of the marsh in this area indicates a drift in sediment to the east. The first diversion of the Lochar Water was the result of a shingle spit, in raised beach times, which formed near the Castle corner; and this natural process continues. The Lochar accounts for some erosion near its mouth. Much work has been carried out studying the rates of erosion and deposition of saltmarsh in the Solway and this is summarised in Section 4.

The majority of the Mull of Galloway is composed of Silurian sedimentary rocks. There are local variations particulary north-east of Auchencairn Bay where a large granite batholith intrudes, and to the west of Auchencairn Bay where a band of Carboniferous limestone runs along the coast. Throughout the region there are smaller coastal exposures of the igneous rock porphyrite. The sedimentary rock formations found between Gipsy Point and Mullock Bay are particulary interesting. The bedding plains have been rotated through 90° forming regular angular blocks.

The geology changes to the west of Glenluce. Ordovician sedimentary rock outcrops to a point just east of the centre of Luce Sands. Further to the west, until Sandhead, the low lying Rhins of Galloway, once sea covered, are composed of Permian breccias, sandstones and mudstones. South of Sandhead the Silurian sandstones are again present.

2.2 Topography

The majority of the inner Solway area consists of littoral sediment flats, dissected by river channels from the main freshwater inflows of the Rivers Eden, Esk, Nith; the Rivers Wampool and Waver which enter Moricambe Bay, and the Urr Water which enters the Rough

Firth. These channels are constantly changing position, a situation which causes some confusion as the England-Scotland border follows the centre of the main channel of the Solway.

The extent of the intertidal zone varies according to the proximity of the main channel to the banks, but in general the width of the shores is in excess of 500 m.

Most shores are bounded by saltmarsh or salted grazing, with very few areas backed by sea defences or urban areas.

The shores on the open coast of the northern outer Solway are predominantly bouldery, with areas of outcropping folded bedrock. Within Kirkcudbright Bay, Fleet Bay, Wigtown Bay and Luce Bay the substrata are sedimentary. The more exposed sedimentary shores are mobile medium and fine sands, and the comparatively sheltered areas fine sand, mud and silt. Perkins (1978) details the hydrology and sediment transport of the Solway Firth. He states that the sediments are derived from the Irish Sea and are easily transported into the Firth. However, local hydrological factors result in the deposition of the finer sediments in the bays and estuaries to the west of Southerness Point.

The littoral width of the outer Solway coast is variable. Typically the short, steep, predominantly rocky shores have a horizontal extent of 10-100 m between high and low water. The sediment flats of Luce Bay and Wigtown Sands have a littoral extent of some 2-3 km.

Shore backing in the outer Solway is generally low, with the exception of moderate cliffs on the Mull of Galloway and Gipsy Point. In most areas the upper shore blends into a narrow band of rough grassland of scrub, being backed by agricultural land, primarily used for dairying. Exceptions to this occur at Luce Bay, where the sands are backed by an extensive sand dune system; Wigtown Bay, where some areas are backed by saltmarsh vegetation; and Ravenshall Point where the shore is backed by moderate cliffs with maritime oak woodland.

2.3 Bathymetry and tidal heights

Inshore waters in the survey area are predominantly less than 10 m deep, and mostly shallower than 5 m. Deeper water occurs in the main channels, with depths of up to 17 m off Maryport Roads and in the central channel midway between Allonby and Sandyhills. Towards the head of the Solway the river channels are less than 2 m deep.

In the outer Solway the water is generally less than 20 m. The 20 m isobath is within 2 km of the shore only at the Mull of Galloway and Burrow Head. Elsewhere it is up to 20 km from the shore.

The tidal range in the western part of the survey area (Port William, Isle of Whithorn, Garlieston) is around 6.0 m; further east (Hestan Islet, Southerness Point, Workington) the range is around 7.5 m. Data are not available for the inner Solway, but are likely to be similar.

2.4 Wave exposure and tidal streams

The Solway Firth faces west and is open to the prevailing winds. However, due to the shallow offshore waters and the reduction in width towards the head of the Firth, most shores can be considered moderately exposed or sheltered. South of Grune Point, and on the open coast west of Southerness Point, shores are more exposed.

Most of the north coast of the outer Solway has a southerly aspect although the eastern shores of the bays are exposed to the prevailing winds. A combination of the shallow offshore water and the shelter from the Isle of Man and Ireland reduces wave exposure on the open coast and the shores are moderately exposed to exposed. Shores in the upper reaches of Kirkcudbright Bay and Fleet Bay are very sheltered.

2.5 Sea temperature and salinity

Due to the enclosed and shallow nature of the inner Solway Firth, the temperature varies greatly from summer to winter. Surface water temperatures vary from around 5 °C in winter to in excess of 15 °C in summer. Bottom temperatures vary from 5 °C to 12 °C (Data from Lee & Ramster 1981).

In the outer Firth the water temperature is more stable. Surface water varies from around 6.5 °C, in the winter but does not exceed 14.5 °C in the summer. Mean bottom temperatures do not drop below 8 °C in the winter or exceed 12 °C in the summer.

A gradient of declining salinity occurs in the Solway, such that fully saline water occurs in the outer Solway. Localised areas of reduced salinity do occur around freshwater inputs and at the heads of inlets, such as the River Cree, Water of Fleet and the River Dee at Kirkcudbright. A range of 15 to 32 $^{o}/_{oo}$ was recorded in the Southerness/Dubmill area (Perkins 1977). No data are available for the extreme upper part of the Solway, but variable salinity is likely to occur due to freshwater run-off at times of high rainfall.

3 PREVIOUS STUDIES OF THE LITTORAL BIOTA AND WATER QUALITY

A large volume of data exists on the littoral biota of the Cumbrian shores of the survey area, due to the work carried out by Dr E.J. Perkins for the Cumbrian Sea Fisheries Committee. Much of this work is reported in the Consultant's Reports to the Cumbrian Sea Fisheries Committee (Perkins 1973-1985). Site related data is summarised on a site by site basis along with other studies in Appendix 2. Perkins (1973) in particular provides descriptions for many sites throughout the Solway.

For the north coast of the inner Solway, the Solway River Purification Board has carried out a series of biological and trace metal surveys covering the area east of Southerness Point. The biological data from the latest of these surveys (Rendall 1990) is included in Appendix 2, and the results have been taken into account in summarising habitats and communities for this survey.

Marshall (1962) describes the morphology of the upper Solway saltmarshes, with a comprehensive report on the rates of erosion and accretion taking place in saltmarshes from Moricambe Bay to Caerlaverock. Most marshes were composed of around 90% fine sand with varying fractions of coarse sand, silt and clay. Differences in the thixotropic nature of the sediments were not explained by the sediment characteristics, but were believed to be due to the water content, which was higher in Moricambe Bay where the most thixotropic sediments occurred. At the time of this paper it appeared that the rate of erosion along the Solway marshlands exceeded the rate of accretion. Moricambe Bay was infilling, but over the estuary as a whole the reverse was felt to be true.

Polderman and Polderman-Hall (1980) also report on saltmarsh communities in the Solway as part of a larger study of algal communities in Scottish saltmarshes. They describe the marshes at Auchencairn Bay, and Glencaple in the present survey area. Auchencairn Bay had a clear zonation, with an extensive lower marsh vegetation of *Juncus maritimus* with a combination of *Fucus spiralis*, *Chaetomorpha linum*, and *Catenella caespitosa*. Glencaple consisted of predominantly terrestrial and freshwater algae.

Perkins (1985) describes the zonation of the algae *Pelvetia canaliculata*, *Fucus vesiculosus*, *F. spiralis*, and *Ascophyllum nodosum* within the Urr Estuary and Rough Firth. Samples were taken from a number of stations up the estuary to detect changes in growth and reproductive ability with changing salinity and wave exposure. *Fucus spiralis* appeared to show little change in length with varying wave exposure. However it apparently showed a gradual reduction in mean frond length with decreasing salinity. In contrast, both *F. vesiculosus* and *A. nodosum* initially derived benefit from the increasing shelter provided by the estuary. Maximum frond length for *F. vesiculosus* was achieved at Kippford, and decreased further up the estuary under the influence of decreasing salinity. No further evidence in respect of reproductive ability was found beyond that described by Williams, Perkins and Gorman (1965) who showed that receptacle development of *Pelvetia canaliculata*, *Fucus spiralis*, *F.vesiculosus*, and *Ascophyllum nodosum* proceeded to the mature state at all stations up the Urr estuary (the same stations used by Perkins in his 1985 study). They also showed that position in the estuary had an influence on the duration of the period when mature receptacles are present.

Studies of turbidity and suspended solid loading of the inner and outer Solway Firth waters are described by Perkins (1977). Dividing the inner and outer Solway with a line from Southerness Point to Dubmill Point, Perkins found that water clarity (measured by the mean depth of disappearance of a 30 cm diameter Secchi Disc) was much lower in the inner Solway than the outer Solway (D = 0.6 m and D = 2.2 m respectively). Similarly the suspended solid loading of the inner Solway waters was higher than those of the outer Solway, with 90% of the inner Solway surface water samples having a suspended solid load of $\leq$ 170 mg/l while 90% of samples for the outer Solway surface waters had a loading of $\leq$ 45 mg/l. Surface waters in both cases were found to have a lower sediment load than bottom waters. Further sampling showed that a zone of higher turbidity extended for around 50-100 m from the waters edge, which is likely to have an effect on littoral and shallow sublittoral biota.

A recent impact on parts of the Solway has been the use of powerful suction dredgers in the collection of certain bivalve species, notably *Cerastoderma edule*. Perkins (1988) described

the effect of these dredgers on the sedimentary biota of Auchencairn Bay during 1988 when the use of this equipment became common in the Solway. He concluded that the use of suction dredgers in Auchencairn Bay led to a loss of *Zostera marina* and a decline in the numbers of *Cerastoderma edule* and *Macoma balthica* from the dredged grounds. Additionally Perkins noted a destabilisation of sediments and a loss of finer material from areas which had been dredged.

Further studies on the impact of suction dredging are reported by Moore (1990) for Blackshaw Flats in the Solway, in comparison with Lavan Sands in North Wales. This study found no significant impact of suction dredging on either the sediment characteristics or the infaunal species (held by a 0.5 mm sieve). The only species which appeared to be adversely affected by suction dredging was the mud snail *Hydrobia ulvae*. Since this is a surface feeder it was suggested as unsurprising that it suffered under the disturbance, but that recolonisation was rapid if sufficient populations occurred nearby. The nature conservation implications of hydraulic cockle dredging were discussed and it was concluded that sheltered, silted areas were more susceptible to erosion and the infauna affected by disturbance than comparable areas of relatively mobile sediment. Since this was the result of small scale experimental dredging, recolonisation from adjacent undredged areas could easily occur. This is unlikely to be the case when large areas of sediment are commercially dredged.

Wilkinson (1975) described the intertidal algae from the Urr estuary, River Dee estuary, Water of Fleet estuary and one site from Brighouse Bay. In the upper Urr estuary four sites were described from a range of muddy and rocky substrata at Kippford, Palnackie, Buittle Bridge and near The Port. Five sites in the Dee estuary were described in the upper estuary and one in the middle reaches at Shoulder Craig. Five sites were described in the Water of Fleet estuary, from Fleet Bridge, the limit of tidal influence, to Mossyard Bay in the outer estuary. The sites covered a variety of substrata from muddy banks to rock. Wilkinson (1980) described the intertidal algae at further sites in the outer Solway estuary at Garlieston Harbour, Eggerness Point and on the Bladnoch estuary, in Wigtown Bay, and other sites west of the Mull of Galloway outside of the current survey area.

The hydrology of the inner and outer Solway Firth are described in two reports (Perkins and Williams 1966, Perkins 1978). The former describes the hydrology and sediment transport in relation to the accumulation of radioactivity in sediments and biota, while the latter divides the Solway into distinct hydrographic units for the purposes of conservation management. Perkins (1978) considers the Solway to consist of those waters east of a line from the Mull of Galloway to Hodbarrow Point (Cumbria). He described a gradient of declining salinity from 33-35 $^{o}/_{oo}$ in the outer region to a range of 15-31 $^{o}/_{oo}$ east of a line from Southerness Point to Dubmill Point. This area was considered to be well in the mid-estuary region. In dividing the area into hydrographic units, Perkins suggests a major division into the inner and outer Firth, with three further divisions of the inner Solway Firth and seven of the outer Firth:

Inner Solway Firth	The river Nith estuary and associated banks enclosed by a line from Southerness Point to Powfoot (i.e. including Blackshaw sands);
	The part of the inner Solway east of the old viaduct (Herdhill to Seafield);

Moricambe and Grune Point;

Outer Solway Firth — Kirkcudbright Bay and the Auchencairn Bay/Rough Firth complex;

Castlehill Point to Southerness Point (including Sandyhills Bay, Southwick Merse and Barnhourie Sands);

The Cumbrian coast north from St Bees Head to Dubmill Point, including Allonby Bay, Workington Bank, Three Fathoms Bank, Two Feet Bank, Robin Rigg and Dumroof Bank.

Other suggested areas outside the current survey area are not included here.

A broad review of the marine flora and fauna of the Solway Firth area is given by Perkins (1973), where he briefly describes five sites in Luce Bay, one site on the Isle of Whithorn, seven sites in the River Cree estuary, eight sites in the River Fleet estuary and thirteen sites in the River Dee estuary, progressing as far east as Abbey Burnfoot, before dealing with sites in Auchencairn Bay. The location of these sites is shown in Figure 3, and the results are reviewed in Appendix 2. Much of Perkins (1973) work is based on the results obtained during routine sampling on the distribution of radioactivity within the Solway Firth. The results of this study are given by Perkins and Williams (1966) in which they conclude that mechanisms of silt transport and associated radioactivity in the Solway Firth are due primarily to the differential velocities of flood and ebb tides caused by the shape of the Firth. The distribution of radionulides showed a strong correlation with the silt distribution. Maximum deposition occurred in Balcary Bay and Carsethorn, with secondary deposition at the head of the shore, in the the silty inner areas of estuaries and sheltered bays, and along the margins of creeks. Areas of minimum activity had sediments with a low silt content, such as open bays with a south-westerly exposure, island banks and the exposed mouths of estuaries.

In 1987 Perkins carried out a study for the Nature Conservancy Council into the effects of recreational activity and the collection of winkles *Littorina littorea* in the Kirkcudbright coast Site of Special Scientific Interest (SSSI). He concluded that an increase in recreational pressure on the shores has had little influence on the biota, the shores at Brighouse Bay and Ardwall Island having a high diversity of biota. However, a long period of marked erosion had occurred on the backing duneland of Brighouse Bay. By 1980 this ceased and Perkins reported that accretion was then taking place. On the subject of winkle picking, Perkins concluded that fears of overfishing appeared to be groundless. Although compared with Mullock Bay and Gipsy Point (known sites of exploitation in the area of the firing range) winkles at Ardwall and Brighouse appeared to be smaller and of poorer quality, Perkins suggests that this offers a reason why winkle picking is more intense on the shores below the firing range.

The ecology of scar grounds (areas of glacially derived boulders and cobbles) in the Solway Firth is discussed by Perkins (1986). In this study he describes stages of settlement and community development on scar areas inundated frequently by sand, and the development of more stable communities on more permanent features. The scar grounds are compared with bound shingle habitats in a range of other areas, from Loch Fyne to Hastings, on the Sussex

coast. Scar grounds are shown to be a very rich habitat with a biomass of some 10 to 100 times that of comparable areas of sandy substrata.

Eleftheriou and McIntyre (1976) carried out a study of the sandy beaches of Scotland and included one site at Sandhead, in Luce Bay (site location is shown in Figure 3). They describe the shore as composed of stones and coarse gravel, becoming fine well sorted sand below mean high water (neap tides). They recorded 32 species in the sediment, predominantly polychaete species. Crustaceans were poorly represented, only *Bathyporeia pilosa* being present in moderate densities. The dominant mollusc on the shore was *Angulus tenuis* though *Cerastoderma edule* was also recorded.

In 1989 the MNCR surveyed eighteen sites along the Dumfries and Galloway coast between East Tarbet, on the Mull of Galloway, and Rascarrel Bay near Auchencairn Bay (Covey (1990). 9 littoral hard substrata communities and 4 littoral sediment communities were described and 209 taxa were identified from 72 habitat records. Recommendations were made that further sites needed to be surveyed to provide a comprehensive description of the habitats and communities in this area.

4 HUMAN INFLUENCES

4.1 Water Quality

Water quality in the survey area is generally good. Rivers entering the inner Solway are of class 1 water quality, except for Kirtle Water (entering the Solway by Gretna) and Lochar Water (entering just east of Caerlaverock) which were class 2 (NCC Estuaries Review data). Most inputs of pollutants occur from discharges directly to the marine environment, particularly on the industrial coast of west Cumbria, which has historically been a site of pollution input.

Coal mining spoil has been dumped on the Cumbrian shores for the past 250 years, commencing with the Saltom Pit which began operation in 1729. The only contemporary input of this material was made from a conveyor belt at the top of the cliff at Barrowmouth, just south of Whitehaven. In calm weather Perkins (1981) describes the spoil accumulating to form a cone, reaching to make contact with the conveyor belt. During more turbulent conditions this cone was levelled onto the true shore, covering it to some depth. The material is then transported northwards by wave action, towards and beyond Whitehaven. Comparatively minute amounts pass south-westwards to St Bees Head. Perkins (1981) states that the whole of the upper shore above mid tide level receives, and is affected by, this material, which exerts a considerable abrasive influence on the rocks and biota to the north-east of Barrowmouth.

The dumping of coal waste to the shore from Haig Pit ceased in 1988, but Perkins (1990) suggests that the presence of coal waste in the marine sediments of the Solway will continue to affect the biota and the sedimentology for many years to come.

Other dumping related to the coal mining industry included the discharge of liquid wastes consisting of mine or adit water, washery waste, spoil heap run-off and miscellaneous

discharges from the bath house etc. Perkins (1981) described the water flowing from the adit as of variable quality, volume and duration of flow. The colour ranged from clear to a very strong rusty red, which on occasions discoloured the margin of the sea from Saltom Pit to Whitehaven Harbour. On the shores below the adit, rocks and boulders were coated with Fe_2O_3 deposited from the outflow. Such effluents are normally acidic, and pH's from 3.2 to 7.0 have been recorded. Coal washery effluent was released beside the National Coal Board solid waste tip at Barrowmouth, but from 1977 had been released at high water just to the south of the minewater adit (Perkins 1981). Suspended solid concentrations of up to 155,000 mg/l were recorded. The supernatant liquor had a mean phenol concentration of 1.9 mg/l (North West Water Authority 1976).

During 1985 production and the dumping of coal waste from this pit ceased, leading to a lowering of the beach level and a colonisation of the exposed boulders by the algae *Enteromorpha linza*, *Ulothrix* sp. and *Porphyra umbilicalis*, the winkle *Littorina littorea* and mussels *Mytilus edulis* (Perkins 1986).

The current major discharge from the west Cumbrian coast is that from the Marchon works of Albright and Wilson, where sulphuric acid, phosphoric acid, tripolyphosphate, alkyl benzene sulphonic acid, powder and liquid household and toiletry detergents are produced. Effluent from the Marchon works is released 2.6 km south-west of Whitehaven. Previously effluent spilled over cliffs, though since 1973 it has been diverted through an adit to discharge on the upper shore. Efforts to extend the pipeline to low water failed due to the instability of the shore caused by mine waste. This effluent on average discharges the following quantities annually: phosphate 18,615 tonnes, detergent 930 tonnes, cadmium 27.92 tonnes, fluoride 18,615 and solids 1,116,900 (figures from Johnston and Simmonds 1990). Perkins (1981) found no evidence for either an increase in the sulphate concentration or a distortion in the SO_4^{++}:Cl^- ratio in the receiving waters of Saltom Bay. He did note the development of a small delta formed by the deposition of solids. However he noted that the sublittoral fauna of Saltom Bay appeared to be typical of similar sediments elsewhere. Perkins made few comments on the littoral fauna, apart from noting the ability of barnacles *Elminius modestus* and *Balanus balanoides* and the green alga *Enteromorpha* sp. to live on rocks bathed by seawater having fluoride concentrations ranging from 2.1 to 40 ppm and a local pH which, at times, may fall below 6.0.

Although Albright and Wilson release the largest volume of effluent on this part of the Cumbrian coast, Perkins (1981) describes a range of other effluent discharges on the basis of data from North West Water Authority (1976). These include contaminants from Whitehaven Harbour, occurring as a result accidental spillages of oil and refuse, and Whitehaven town sewers, which discharges at the lower shore just west of Whitehaven town.

In an annual report to the Cumbria Sea Fisheries Committee, Perkins (1986) describes the occurrence of particulate pollutants in water samples from the Solway. One litre samples of seawater were suction filtered and the number of particles of various origins remaining on the filter disc were counted. This showed that the most common particles were wood fragments from the Thames Board Mills at Siddick. However, a rise in the presence of synthetic fibres, courlene fibres and paint fragments was noted between 1975 and 1986. No obvious source of these materials emerged, but it was postulated that the increase in synthetic and courlene fibres could result from the increased use of automatic washing machines.

Water quality in the outer Solway is good with little heavy industry and low population density. Sewage is discharged from population centres for example from effluent pipes in Garlieston Bay and a similar discharge at Sandhead. However the discharges and their effects have not been given the same degree of scrutiny as those on the west Cumbrian coast.

Plate 2 Drifts of empty cockle shells on midshore muddy fine sand flats left by hydraulic suction dredgers. Blackshaw Bank, inner Solway (S286.18.5. Roger Covey)

4.2 Fisheries

Fisheries along the Solway Firth are extensively described by Dr Eric Perkins in Consultant's Reports to the Cumbrian Sea Fisheries Committee (Perkins 1977-1985). The dominant species commercially fished are the brown shrimp, *Crangon crangon* and the thornback ray, *Raja batis*. Additionally there is an established fishery for the cockle, *Cerastoderma edule* which has recently increased in intensity following the introduction of suction dredgers to the area.

The largest proportion of fishery effort takes place around the outer sections of the Solway. The area offshore from Gipsy Point to the Mull of Galloway and northwards are noted by Lee & Ramster (1981) as the main inshore fishing grounds. However, towards the head of the inner Solway, on the Scottish shores, are a number of stake nets, many of which are used for commercial fishing of salmon.

Although not commercially important, an element of opportunistic collection of shellfish occurs on the scars around Silloth, Allonby and Maryport. This takes place largely at times of low spring tides, when crabs and the occasional lobster are found amongst the boulders of the lower shore. Bait digging also occurs on many shores in the survey area.

The outer Solway coast, with its popularity as a holiday destination, is a popular area for sea anglers. Boats operate out of several of the smaller ports, including Kirkcudbright and the Isle of Whithorn

4.3 Port/harbour facilities

Within the inner Solway port and harbour facilities are extremely limited. The only commercial ports are located at Whitehaven, Workington, Maryport and Silloth. Some smaller boats also use Annan, though with recent siltation, its importance as a fishing port has declined considerably.

Locally owned, leisure craft are moored around the Solway, for example the Urr estuary at Kippford, or beached in areas of saltmarsh convenient to their owners. The only commercial marina is situated at Maryport, in a converted dock.

Kirkcudbright and the Isle of Whithorn are the two larger ports on the outer Solway coast although they do not have extensive harbour facilities. Kirkcudbright is used as a base for scallop dredgers, fishing on the grounds to the north of the Isle of Man, and hydraulic cockle dredgers when operating on the inner Solway grounds.

4.4 Recreation

Leisure and recreational use of the inner Solway is very limited, as there are few facilities. Maryport and Silloth are the main tourist centres on the southern shores, and Annan and Dumfries are the major centres on the north coast. The coastline west of Southerness Point is more popular with tourists. Tourist caravan parks and holiday chalets occur at Southerness Point, Kippford and Sandyhills, where the main bathing beach of the north shore is situated. Adjacent camping facilities ensure its continued popularity.

The outer Solway coast has numerous sites for caravanning and camping although other facilities are limited. Kirkcudbright is the main tourist centre.

5 ESTABLISHED NATURE CONSERVATION IMPORTANCE

The predominant nature conservation interest of the inner Solway is ornithological, with the whole inner Solway area designated a SSSI, and a number of reserves owned or managed by the RSPB, Wildfowl Trust and Cumbria Wildlife Trust. The Upper Solway Flats and marshes are also designated as wetlands of international importance under the Ramsar convention, and are a Special Protection Area (SPA).

The Upper Solway Flats and Marshes SSSI extends from around a line from Dubmill Point to Southerness Point, up to and including Rockcliffe Marsh. It includes the whole estuary, from above high water. The site was designated for its botanical, geological, marine botanical, marine biological and ornithological interest and is also a proposed Special Protection Area (SPA).

Within the Upper Solway Flats and Marshes, the Rockcliffe Marsh SSSI has been designated for its marine botanical and ornithological interest. The marshes are managed by Cumbria Wildlife Trust, though owned by Castletown Estate.

Table 1. Coastal SSSIs in the Solway Firth with cited interest

Site name	Cited interest
Inner Solway (Waterfoot to Sarkfoot)	Ornithological
Priestside Bank	Ornithological
Kirkconnell Merse	Marine botanical, Ornithological
Carse Bay	Marine biological (rich invertebrate communities), Ornithological
Southerness Coast	Botanical, Geological, Marine botanical, Ornithological
Auchencairn Bay	Botanical, Marine botanical, Ornithological
Rerrick Cliffs	Botanical, Entomological
Torrs to Mason Walk	Botanical, Entomological, Geological
Borgue coast	Geological
Ravenshall Wood	Botanical, Marine botanical
Cree Estuary	Botanical
Torrs Warren-Luce Sands	Botanical, Geological, Ornithological
Mull of Galloway	Botanical, Ornithological

On the northern side of the Firth is Caerlaverock National Nature Reserve, also a SSSI, and administered by Scotish Natural Heritage. This reserve was designated in 1957 and covers the six miles of coastline from the River Nith to Lochar Water, though negotiations are underway to extend the reserve eastwards towards Powfoot. The area covered is from the upper limit of saltmarsh out over the foreshore to extreme low water of spring tides. The prime importance of the site is for overwintering barnacle geese, which spend the period October to March on the Solway Firth, mainly at Caerlaverock. Natterjack toads are also present in shallow pools fringing the saltmarsh.

Sites of Special Scientific Interest within the survey area and their cited interest are listed in Table 1. All extend down to Mean Low Water.

6. METHODS

6.1 Introduction

During 1991 as part of survey effort in the MNCR sector R11 (Colwyn Bay to the Mull of Galloway) two surveys were undertaken along the coastline between Maryport and the Mull of Galloway. In June 1991, following recommendations in Covey (1990) for additional site coverage along the north coast of the outer Solway, survey effort was concentrated between Luce Sands and Mullock Bay. During August the work continued on the area between Maryport on the Cumbrian coast and Balcarry Point. The data obtained from both surveys have been analysed together to give an increased sample size providing an overall, more significant description of the Solway Firth.

6.2 Aims and site selection

The aims of the surveys were to provide descriptions of the littoral habitats and associated communities of conspicuous species on the coast of the Solway Firth and to make an assessment of the biological interest and nature conservation importance of the area in terms of sites, habitats and species. Survey sites were selected with this general aim in mind, but targeted towards sites within SSSIs, sites identified as of interest by English Nature and Nature Conservancy Council for Scotland regional staff, and in areas where little existing data was available. The results of this survey will contribute towards the MNCR Theme Report on the Liverpool Bay and the Solway Firth area.

To reduce the amount of time spent travelling to and from sites on early morning and late evening tides, the team of surveyors was based in local accommodation. For the six days of the first survey the team was based in Newton Stewart, Kirkcudbright and Garlieston and for the seven days of the second survey in Maryport, Silloth, Kirkbride, Powfoot and Kippford.

Examination of Admiralty charts and Ordnance Survey maps of the area gave an indication of the distribution of substratum types, general topography and the range of exposure to wave action and tidal streams. This, together with reviews of previous marine biological studies in the area enabled sites to be selected to cover the widest possible range of habitat types.

6.3 Recording

The procedures adopted for survey work and the recording forms used are those defined for MNCR surveys (Hiscock 1990). The aim was to record the number and abundance of conspicuous species within distinct habitats at different heights within the littoral zone. It is important to emphasise that this approach aims to identify the range of habitats present within a site and is therefore not a transect approach. This allowed the surveyors to concentrate on any rare or unusual habitats rather than generating multiple descriptions of similar habitats.

For each site, a description was made of the main features of physical, biological and conservation interest. The physical and biological characteristics of each habitat were noted, with the relative abundances of all conspicuous species estimated using abundance scales developed for the MNCR (Hiscock 1990).

Shores which were predominantly sedimentary, were surveyed for widely dispersed macrofauna by digging over an area of 1 m^2, to a depth of 0.3 m and recording the presence of conspicuous species with an estimate of their abundance. Such epifaunal species as were present were also recorded, with specimens of both infauna and epifauna being collected and preserved for later laboratory identification where necessary. Smaller infaunal species were sampled by taking four core samples, each of 0.01 m^2, which were washed over a 0.5 mm mesh sieve. Material retained on the sieve was preserved using saline formalin with eosin stain for later identification in the laboratory. A core sample was taken at each site for granulometric analysis.

6.4 Laboratory analysis

All the fauna in the sedimentary samples collected by coring were sorted from the sediment. Identification was carried out where possible to genus or species, and absolute abundances of taxa in the cores were corrected to numbers per square metre prior to conversion to MNCR relative abundance categories on the recording forms. Identification of infauna was carried out by Identichaet and the Field Studies Council Research Centre.

Each granulometric sample was oven dried to a constant weight, weighed to exactly 50 g or 100 g and left to soak over night in a solution of sodium hexametaphosphate (33 gl^{-1}) to aid particle dispersion. Each sample was then wet sieved through a 63 µm sieve to remove any silt/clay fraction. The remaining sample was redried to a constant weight, sieved through a standard series of Wentworth sieves and each fraction weighed. The percentage composition of each fraction was derived to provided standard sediment statistics to accompany the data from the infaunal samples. Granulometric analysis for the inner Solway samples was carried out by the Field Studies Council Research Centre and for the outer Solway by MNCR staff.

6.5 Data analysis

All data was entered onto the MNCR computer database (Mills 1991), which allowed comparison of subsets of the data according to biological or physical features. TWINSPAN analysis (Hill 1979) of the species data aided the separation of the habitat records into broad groupings which formed the basis for descriptions of the communities present in the survey area. The communities identified were assigned identification codes (prefixed by ISDG) which are unique to this survey report. It should be noted that TWINSPAN analysis did not always produce biologically meaningful divisions in the data, particularly when dealing with stations with few species records. The TWINSPAN groupings were therefore modified in the light of information not taken into account by the analysis, such as details of substratum composition and stability.

6.6 Photography

Photographs were taken during the survey to illustrate sites, habitats, communities and species. Photographs were taken using Olympus SLR cameras with 28 mm wide angle, and 50 mm macro lenses onto Kodachrome 64 ASA colour slide film. Olympus T32 flash guns were used when light conditions were poor.

Photographic details were entered onto the MNCR computer database, enabling the production of slide labels showing details of survey, site and photographer, and additional labels showing the photograph title. Each photograph entered to the database is keyworded to enable retrieval of slides showing particular subjects in the future.

7. RESULTS

7.1 Introduction

During the present survey 46 sites were described and 174 habitat records completed. From these records 6 hard substratum, 4 mixed substratum and 4 sedimentary communities have been described. A total of 256 taxa were recorded.

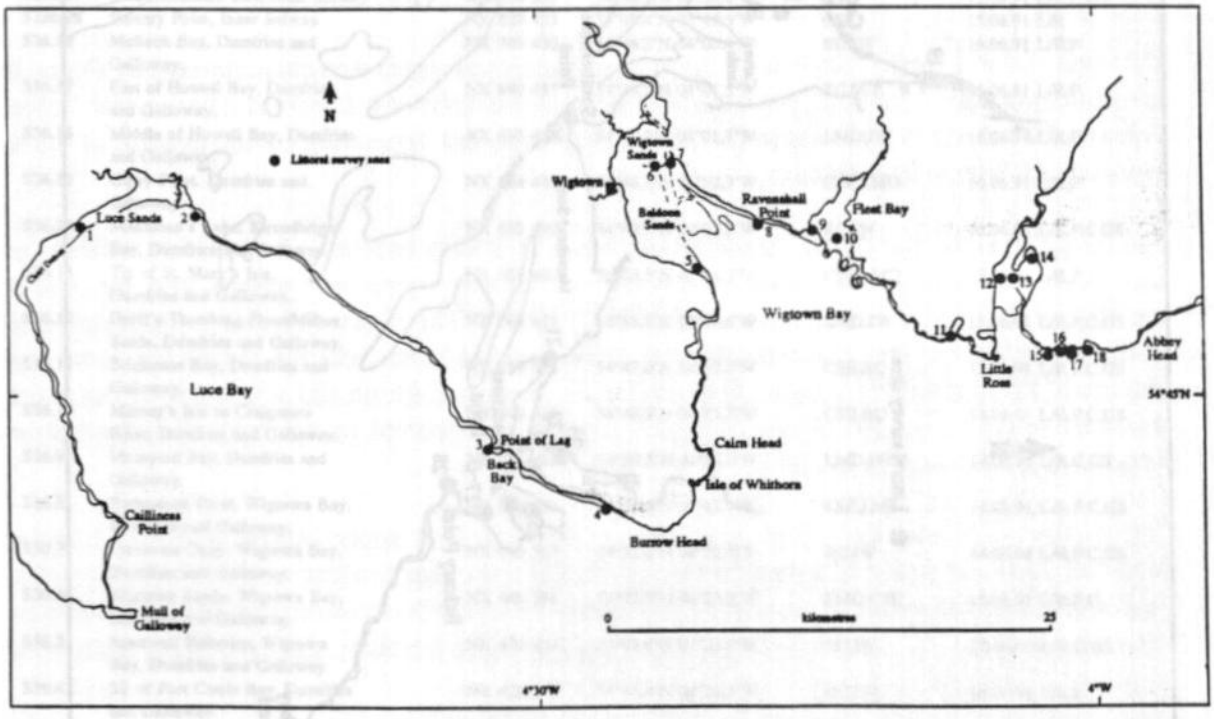

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Figure 1 Locations of sites surveyed during the Dumfries and Galloway survey

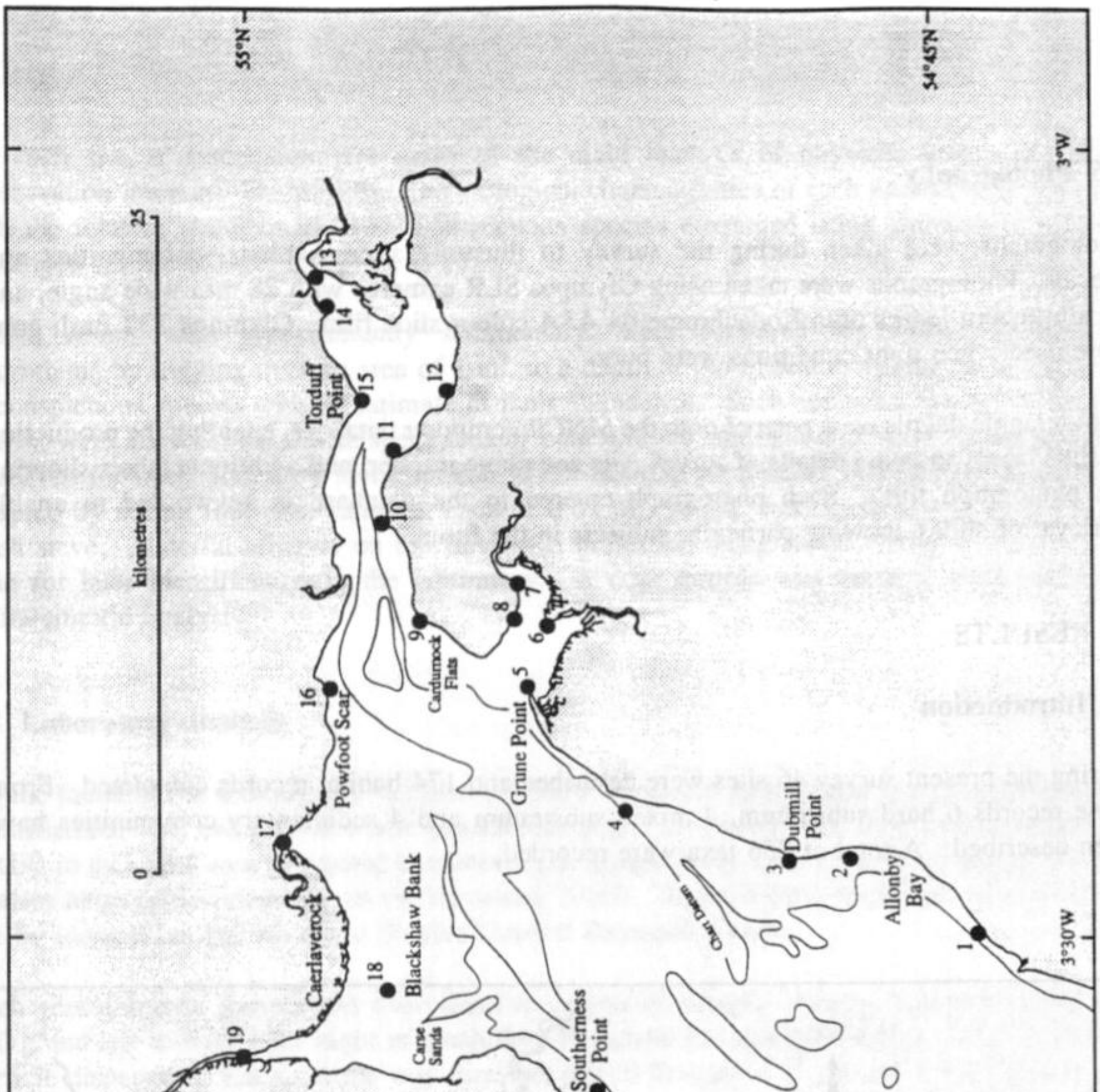

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Figure 2 Locations of sites surveyed during the inner Solway survey

Table 2. Sites surveyed by the present surveys.

Key:

L/R	Littoral recording	P	Photography
C	Core samples (infauna)	GS	Granulometry sample
S286	Inner Solway survey	S36	Dumfries and Galloway survey

No.	Site name	Grid ref.	Latitude & longitude	Surveyors	Date	Survey type
S286.1	NW Brown Rigg, Inner Solway.	NY 053 395	54°44.4'N 03°28.2'W	RC,JW	09.08.91	L/R.C.GS
S286.2	Allonby Scar, Inner Solway.	NY 075 430	54°46.4'N 03°26.2'W	CSE,CE,DA	09.08.91	L/R.P.C.GS
S286.3	Dubmill Scar, Inner Solway.	NY 073 450	54°47.4'N 03°26.5'W	RC,JW	10.08.91	L/P.C.GS
S286.4	Silloth Lighthouse, Lees Scar, Inner Solway.	NY 095 529	54°51.7'N 03°24.6'W	CSE,DA,CE	10.08.91	L/R.P.C.GS
S286.5	Grune Point, Inner Solway.	NY 145 568	54°53.9'N 03°20.0'W	CSE,CE,JW	10.08.91	L/R.P.C.GS
S286.6	NE Border, Inner Solway.	NY 179 555	54°53.2'N 03°16.8'W	RC,DA	10.08.91	L/C.GS
S286.7	W Anthorn, Inner Solway.	NY 186 572	54°54.1'N 03°16.1'W	CE,CSE	11.08.91	L/R.P.C.GS
S286.8	Longdyke Scar, Inner Solway.	NY 179 577	54°54.4'N 03°16.8'W	RC,DA	11.08.91	L/R.C.GS
S286.9	Cardurnock Flats, Inner Solway.	NY 170 615	54°56.4'N 03°17.7'W	RC,CE	11.08.91	L/R.P.C.GS
S286.10	Herdhill Scar, Inner Solway.	NY 213 628	54°57.2'N 03°13.7'W	CSE,DA,JW	11.08.91	L/R.P.C.GS
S286.11	Port Carlisle, Inner Solway.	NY 244 620	54°56.8'N 03°10.8'W	CSE,CE,JW	12.08.91	L/R.P.C.GS
S286.12	Drumburgh, Inner Solway.	NY 268 603	54°55.9'N 03°08.5'W	CE,CSE,JW	12.08.91	L/R.P.C.GS
S286.13	NW Rockcliffe Marsh, Inner Solway	NY 316 655	54°58.7'N 03°04.1'W	RC,DA	12.08.91	L/R.P.C.GS
S286.14	Redkirk Point, Inner Solway.	NY 302 651	54°58.5'N 03°05.4'W	CE,LMD	12.08.91	L/R.P.C.GS
S286.15	Torduff Point, Inner Solway.	NY 265 637	54°57.7'N 03°08.8'W	RC,CSE	12.08.91	L/R.P
S286.16	Powfoot Scar, Inner Solway.	NY 145 651	54°58.3'N 03°20.1'W	LMD,CSE,JW	13.08.91	L/R.P.C.GS
S286.17	Stanhope, Inner Solway.	NY 084 673	54°59.5'N 03°25.9'W	LMD	13.08.91	L/R.P
S286.18	Blackshaw Bank, Inner Solway.	NY 022 637	54°57.4'N 03°31.6'W	RC,CE	13.08.91	L/R.P.C.GS
S286.19	Glencaple, Inner Solway.	NX 994 685	55°00.0'N 03°34.3'W	RC,CE	13.08.91	L/R.P.C.GS
S286.20	Southerness Point, Inner Solway	NX 977 543	54°52.3'N 03°35.6'W	CSE,CE,JW	13.08.91	L/R.P
S286.21	Port O' Warren, Inner Solway.	NX 879 534	54°51.7'N 03°44.8'W	LMD,RC	13.08.91	L/R.P.C.GS
S286.22	Port Donnel Beach, Inner Solway	NX 845 538	54°51.9'N 03°47.9'W	CE	14.08.91	L/R.P
S286.23	Rough Island Causway Flats, Inner Solway.	NX 844 535	54°51.7'N 03°48.0'W	CE,LMD,JW	14.08.91	L/R.P.C.GS
S286.24	White Horse Bay, Inner Solway.	NX 839 525	54°51.2'N 03°48.5'W	RC,CSE	14.08.91	L/R.P.C.GS
S286.25	SW Orchardton Bay, Inner Solway	NX 820 523	54°51.0'N 03°50.2'W	RC,CE	15.08.91	L/R.C.GS
S286.26	Torr Point, Inner Solway.	NX 823 517	54°50.7'N 03°49.9'W	RC,CE	15.08.91	L/R
S286.27	W Auchencairn Bay, Inner Solway	NX 814 507	54°50.2'N 03°50.8'W	CSE	15.08.91	L/R.C.GS
S286.28	Balcary Point, Inner Solway.	NX 829 493	54°49.4'N 03°49.3'W	CSE	15.08.91	L/R
S36.18	Mullock Bay, Dumfries and Galloway.	NX 709 436	54°46.2'N 04°00.4'W	RC,JW	16.06.91	L/R.P
S36.17	East of Howell Bay, Dumfries and Galloway.	NX 699 437	54°46.2'N 04°01.3'W	RC,CSE	16.06.91	L/R.P
S36.16	Middle of Howell Bay, Dumfries and Galloway.	NX 695 437	54°46.2'N 04°01.7'W	LMD,JW	16.06.91	L/R.P
S36.15	Gipsy Point, Dumfries and Galloway.	NX 684 436	54°46.1'N 04°02.7'W	CSE,LMD	16.06.91	L/R.P
S36.14	Manxman's Lake, Kircudbright Bay, Dumfries and Galloway.	NX 680 490	54°49.1'N 04°03.2'W	RC,JW	15.06.91	L/R.P.C.GS
S36.13	Tip of St. Mary's Isle, Dumfries and Galloway.	NX 668 480	54°48.5'N 04°04.3'W	CSE,LMD	15.06.91	L/R.P
S36.12	Devil's Thrashing Floor/Milton Sands, Dumfries and Galloway.	NX 665 475	54°48.2'N 04°04.6'W	LMD,JW	15.06.91	L/R.P.C.GS
S36.11	Brighouse Bay, Dumfries and Galloway.	NX 633 453	54°47.0'N 04°07.5'W	CSE,RC	15.06.91	L/R.P.C.GS
S36.10	Murray's Isle to Craigmore Point, Dumfries and Galloway.	NX 568 510	54°49.9'N 04°13.7'W	CSE,RC	14.06.91	L/R.P.C.GS
S36.9	Mossyard Bay, Dumfries and Galloway.	NX 555 516	54°50.2'N 04°15.0'W	LMD,JW	14.06.91	L/R.C.GS
S36.8	Ravenshall Point, Wigtown Bay, Dumfries and Galloway.	NX 524 523	54°50.6'N 04°17.9'W	CSE,LMD	14.06.91	L/R.P.C.GS
S36.7	Creetown Quay, Wigtown Bay, Dumfries and Galloway.	NX 473 563	54°52.6'N 04°22.8'W	RC,JW	14.06.91	L/R.P.C.GS
S36.6	Wigtown Sands, Wigtown Bay, Dumfries and Galloway.	NX 468 560	54°52.5'N 04°23.2'W	LMD,CSE	13.06.91	L/R.P.C
S36.5	Innerwell Fisheries, Wigtown Bay, Dumfries and Galloway.	NX 479 494	54°48.9'N 04°22.0'W	RC,JW	13.06.91	L/R.C.GS
S36.4	SE of Port Castle Bay, Dumfries and Galloway.	NX 428 356	54°41.4'N 04°26.3'W	RC,JW	18.06.91	L/R.P
S36.3	Point of Lagg, Luce Bay, Dumfries and Galloway.	NX 362 395	54°43.4'N 04°32.6'W	LMD,CSE	18.06.91	L/R.P
S36.2	Crow's Nest, Luce Bay, Dumfries and Galloway.	NX 203 533	54°50.5'N 04°47.9'W	LMD,JW,RC, CSE	17.06.91	L/R.C.GS
S36.1	Centre of Luce Sands, Luce Bay, Dumfries and Galloway.	NX 127 526	54°49.9'N 04°54.9'W	CSE,RC	17.06.91	L/R.P.C.GS

7.2 Hard substratum habitats and communities

Six hard substrata communities were identified from the surveys and are described in Table 3. Communities are generally described from biological zones occurring down the shore. However, where rocky shores did occur in wave exposed and wave sheltered locations the subsequent variations in the community structure are described.

Communities are described in detail in Appendix 3, where maps of their distribution are also given.

The communities described here occurred on the predominantly bedrock and large boulder shores. Although at some sites additional substrata was present it was not thought to alter the community structure considerably. The communities are broadly descriptions of the biological zones occurring down a rocky shore from the supralittoral fringe to the sublittoral fringe. Where differences did occur in the community from shore to shore, within the same biological zone, variations are split according to the situation of the community (open coast or sheltered coast) and exposure to wave action. Bedrock and large boulder habitats occurred mainly in the outer Solway west of Southerness Point and along the Dumfries and Galloway coast, limited within the inner Solway to the artificial bridge supports at Herdhill Scar.

The supralittoral fringe was characterised throughout the survey area by the lichens *Verrucaria maura*, *Calloplaca marina*, *Xanthoria parietina* and *Lecanora atra*. No noticeable variations occurred in the community structure with exposure to wave action, although the vertical extent of the lichen zone was greater at more exposed sites.

The upper littoral fringe community throughout the survey areas was characterised by *Pelvetia canaliculata*, *Fucus spiralis*, periwinkles *Littorina saxatilis* and *Littorina littorea* and lichen *Verrucaria maura*. Variations in the community occurred depending on the amount of wave exposure the site was subject to.

The community on the upper littoral fringe/upper eulittoral bedrock and boulders, subject to high wave exposure, was characterised by the lichen *Verrucaria maura* and the rough periwinkle *Littorina saxatilis* (community ISDG H2.1). The algae, *Pelvetia canaliculata* and *Fucus spiralis* were less common than on more sheltered sites and the top of the zone was frequently dominated by a band of *Chthalamus montagui* which did not occur at the more sheltered sites. The red algae *Catenella caespitosa* occurred in crevices with the limpet *Patella vulgata* on the open rock.

Community ISDG H2.2 on the enclosed/sheltered sites of upper littoral fringe and upper eulittoral bedrock was dominated by the algae *Pelvetia canaliculata* and/or *Fucus spiralis*. The introduced Australasian barnacle *Elminius modestus* was occasional on the rock surfaces not covered by algae, with *Enteromorpha* sp. occurring at the more sheltered sites. *Catenella caespitosa* was rare to common in the crevices.

The lower eulittoral bedrock was characterised by community ISDG H3. This community was characterised by barnacles, fucoids and the dogwhelk *Nucella lapillus*. *Balanus balanoides* and *Elminius modestus* were the dominant barnacles. Variations in community

structure did occur depending on the wave exposure.

Table 3. Summary of hard substratum habitats and communities identified.

Community	Description	Distribution
ISDG H1	Supralittoral fringe bedrock and boulders	Inner Solway: 20.1, 21.1, 22.1, 24.2, 26.1, 28.1 Dumfries and Galloway: 4.1, 8.1, 10.1, 11.1, 12.1, 12.2, 15.1, 16.1 17.1
ISDG H2.1	Upper eulittoral-littoral fringe bedrock and boulders at open coast/wave exposed sites	Inner Solway: 20.2 21.2, 21.3, 28.2 Dumfries and Galloway: 2.1, 3.1 4.2, 8.2, 15.2, 16.2, 17.2, 18.1, 18.2
ISDG H2.2	Upper eulittoral-littoral fringe bedrock and boulders at enclosed coast/wave sheltered sites	Inner Solway: 10.2, 10.3, 22.2, 24.3, 26.2 Dumfries and Galloway: 5.1, 7.1, 10.2, 11.2, 12.3, 13.1
ISDG H3.1	Mid-shore bedrock and boulders at open coast/wave exposed sites	Inner Solway: 20.3, 21.4, 28.3, 28.4 Dumfries and Galloway: 4.3, 8.3, 11.3, 15.3, 15.4, 16.3, 17.3, 18.3
ISDG H3.2	Mid-shore bedrock and boulders at enclosed coast/sheltered sites	Inner Solway: 10.4, 20.5, 22.3, 22.4 24.4 26.3 Dumfries and Galloway: 6.2, 7.3, 9.2, 9.3, 9.4, 10.3, 10.4, 12.4, 13.2, 13.3
ISDG H4	Lower eulittoral moderately exposed to exposed bedrock and boulders	Inner Solway: 28.5 Dumfries and Galloway: 2.4, 3.4, 4.4, 16.5, 17.4, 18.4
ISDG H5	Mid and lower eulittoral rockpools	Dumfries and Galloway: 3.3, 13.4, 16.4
ISDG H6	Sublittoral fringe bedrock and boulders	Dumfries and Galloway: 3.5, 11.5, 15.5, 16.6, 18.5

Variation 1 of community ISDG H3 occurred at the open coast/exposed sites. The community, was dominated by barnacles on the steep and vertical rock faces, with the green algae *Ulva* sp. and *Enteromorpha* sp. more abundant on the horizontal and flatter areas of rock. Other characteristic species were the edible mussel *Mytilus edulis*, *Fucus vesiculosus* and *Ascophyllum nodosum*. *Mytilus* was particulary common on the shores which were adjacent to areas of sediment and on the vertical bedrock at Gipsy Point (Dumfries and Galloway site 15). Coralline crusts and *Corallina officinalis* were common in rockpools.

The more sheltered sites on the enclosed coast (community ISDG H3.2) was also characterised by the barnacle *Balanus balanoides* although the fucoid algae *Ascophyllum nodosum* and *Fucus vesiculosus* were more dominant than variation 1 of the community. *Mytilus edulis* was also much more abundant. *Fucus serratus* was noted at the lower extremes of the zone but red algae were conspicuous by their absence, except for *Polysiphonia lanosa* and *Chondrus crispus* which occurred at several sites in rockpools.

Community ISDG H4 was present on lower eulittoral bedrock and stable boulders, moderately exposed or exposed to wave action and subject to very weak or weak tidal streams. This community is characterised by the fucoid *Fucus serratus*, *Balanus balanoides*, *Nucella lapillus* and *Patella vulgata*. *Palmaria palmata*, *Mastocarpus stellatus* and *Lomentaria articulata*, and green algae, *Enteromorpha* sp. occurred on the less exposed rock faces and between the boulders. Coralline crusts covered the bedrock and boulders under the fucoids and in rockpools. At three sites, where the hard substrata was adjacent to lower shore sediment (Inner Solway (28.5); Dumfries and Galloway (11.4), (18.4)) tubes of the polychaete *Sabellaria alveolata* were found. The crusts were badly eroded and live animals were recorded from one site only. Towards the lower end of the zone *Laminaria digitata* was recorded.

Rockpools occurred in the eulittoral on several shores (community ISDG H5) although only recorded as separate habitats from three sites. At two of the sites the pools were formed in depressions in bedrock. At the Point of Lagg (Dumfries and Galloway site 3) a pool was created in a depression in the boulder shore. A clay layer underlying the boulders retained the water. The community was predominantly algal dominated with *Corallina officinalis*, *Chondrus crispus* and *Ceramium rubrum*, and brown algae *Ascophyllum nodosum* and *Fucus serratus* conspicuous. The pool at Point of Lagg had a particulary dense growth of red algae with coralline crusts on the rock surfaces. The dominant animals were the littorinids, *Littorina obtusata* and *Littorina saxatilis* and the topshell *Gibbula* sp. The beadlet anemone *Actinia equina* was also recorded.

In the inner Solway many of the rocky shores gave way to sediment flats on the lower shore. Consequently sublittoral fringe communities were limited to the open coast of Dumfries and Galloway, where sites were moderately exposed or exposed to wave action. Community ISDG H6 is characterised by *Laminaria hyperborea*, *Laminaria saccharina* and *Alaria esculenta* with the barnacles, *Balanus balanoides* and *B.crenatus*, and coralline crusts covering the rock surfaces. The red algae *Palmaria palmata*, *Mastocarpus stellatus* and *Chondrus crispus* occurred amongst the kelp with the sponge *Halichondria panicea* in the crevices and underboulders. *Fucus serratus* was present in the upper part of the zone.

7.3 Mixed substratum habitats and communities

Five mixed substratum communities were identified during the surveys, as shown in Table 4. Communities were broadly divided by the substratum type, and the presence of sediment in the interstitial spaces of the larger substratum material. The exception was the low shore *Sabellaria* reef community.

Communities are described in detail in Appendix 3, where maps of their distribution are also given.

Table 4. Summary of mixed substratum habitats and communities identified.

Community	Description	Distribution
ISDG M1	Clean boulders and cobbles on the open coast.	Inner Solway: 16.1, 20.4, 23.1 Dumfries and Galloway: 2.2, 7.2, 11.4, 12.5, 16.7
ISDG M2	Open coast cobbles exposures with *Mytilus edulis*.	Inner Solway: 2.3, 2.4, 3.2, 4.4 Dumfries and Galloway: 2.3
ISDG M3	Poorly sorted cobbles and pebbles on mud.	Inner Solway: 5.4, 8.1, 8.2, 15.1
ISDG M4	Mid and lower eulittoral boulders and cobbles	Inner Solway: 2.2, 14.1, 16.2, 17.2, 19.2, 20.6, 24.5
ISDG M5	Lower shore *Sabellaria alveolata* reefs on boulders and cobbles.	Inner Solway: 1.3, 3.3

For the purpose of this description, mixed substrata were classified as material such as boulders, cobbles and pebbles etc. which supported a range of epifaunal and infaunal species. The dominance of epifauna versus infauna is reflected in the division into five habitat types, four of them defined largely on the amount of sedimentary material binding the larger material and providing a matrix for sedimentary infauna to colonise.

Clean boulders and cobbles had very little sedimentary material, and as such were characterised by epifaunal species such as barnacles, littorinids and brown algae. This habitat type largely occurred in areas of moderate wave exposure.

On the open coast, a similar habitat type occurred, but the community was characterised by the edible mussel *Mytilus edulis*. The matrix of mussels encouraged the settlement and retention of sediment, which along with the muddy 'pseudofaeces' from the mussels allowed species such as lugworm *Arenicola marina* and sandmason worm *Lanice conchilega* to colonise. A range of epifaunal species was still present, but the presence of algae was limited.

In very sheltered areas of the enclosed coast of the inner Solway poorly sorted muddy cobbles and pebbles became mixed with deposited mud. On such a habitat a mixture of infaunal species such as *Hediste diversicolor*, *Corophium volutator*, *Arenicola marina* and *Macoma balthica* occurred with epifaunal species *Littorina littorea*, *Littorina saxatilis* and *Balanus balanoides*.

The fourth mixed habitat was recorded from the mid and lower eulittoral on both open and enclosed coasts. Species diversity was generally low, with characterising species being *Elminius modestus*, *Balanus crenatus*, *Mytilus edulis* and *Enteromorpha* sp.

The final mixed habitat was recorded from the open coast of Cumbria and the south of the inner Solway. The mixed substrata was colonised by the reef building polychaete *Sabellaria alveolata* which stabilised the cobbles and pebbles and provided suitable substrata for algae and the sponge *Halichondria panicea*. The reefs were much more developed than the crusts of *Sabellaria* found on the north coast of the Solway (community ISDG H4).

7.4 Soft substratum habitats and communities

Seven soft substratum communities were identified during the surveys, as shown in Table 5. Communities were broadly divided by the degree of shelter from wave action, and the salinity of the water.

Communities are described in detail in Appendix 3, where maps of their distribution are also given.

Soft substratum habitats and communities were split broadly into two groups; enclosed coast estuarine fine sands and muds, and open coast fine sands. Within these two groups, finer divisions were recognised on the basis of salinity and wave exposure, which affected the sediment composition and species presence/abundance.

Towards the head of the Solway Firth, and in the shelter of the enclosed estuaries of the outer Solway, sediments were typically muds and silts, with varying degrees of fine sand. The major community type of these areas was a sheltered mud and fine sand community, with abundant *Corophium volutator*, *Hydrobia ulvae*, and *Macoma balthica*. Variations (facies) of this community were noted where salinity became more variable or reduced. In muddy areas the community became characterised by nematoda, with *Pygospio elegans* also becoming more abundant. In areas with more fine sand associated with the muds, the bivalve *Scrobicularia plana* became more common and characterised the facies.

Facies 1 of the sheltered mud and fine sand community differed from the main community type in having an abundance of nematodes and the polychaete worm *Pygospio elegans*. This facies was largely present at the top of shores, where fluctuations in salinity occur due to surface drainage from the adjacent saltmarsh. Other species present in this facies were broadly similar to those of the main community type, with *Corophium volutator*, *Macoma balthica* and *Hediste diversicolor* regularly found.

Table 5. Summary of soft substratum habitats and communities identified.

Community	Description	Distribution
ISDG S1	Sheltered mud and fine sands with *Corophium*, *Hydrobia* and *Macoma*.	Inner Solway: 4.1, 5.2, 5.3, 7.2, 8.3, 9.2, 9.3, 10.5, 11.2, 14.3, 16.3, 16.4, 18.3, 21.5, 27.2 Dumfries and Galloway: 6.3, 7.4
ISDG S1.1	Variable salinity mud with *Pygospio elegans* and Nematoda.	Inner Solway: 5.1, 6.1, 6.2, 7.1, 9.1, 10.1, 11.1, 13.1, 14.2, 17.1, 18.1, 18.2, 19.1
ISDG S1.2	Mud and fine sands with *Pygospio*, *Corophium*, and *Scrobicularia*.	Inner Solway: 2.1, 12.1, 23.2, 24.1, 24.6, 25.1, 27.1 Dumfries and Galloway: 5.3, 6.1, 6.4, 9.1, 14.1, 14.2
ISDG S2	Fine sands with very fine sands	Inner Solway: 1.1, 1.4, 3.1, 4.2, 4.3, 23.3, 25.2
ISDG S3	Open coast fine sands with rich infauna.	Inner Solway: 2.5 Dumfries and Galloway: 1.2, 1.3, 2.5, 8.5, 9.5, 10.5, 11.6, 12.6
ISDG S4	Barren upper shore fine sand.	Dumfries and Galloway: 1.1

Facies 2 of the sheltered mud and fine sand community differed from the main community type and facies F1 by the presence of the bivalve *Scrobicularia plana* in addition to *Hediste diversicolor*, *Corophium volutator*, and *Macoma balthica*. Also recorded from three examples of this community was the angiosperm *Zostera nana*.

Between the sheltered mud and exposed fine sand communities, a transitional community occurred; a fine and very fine sand community. This community type was described from the open coast south of Moricambe, and the broad inlet of Auchencairn Bay. Sediment in these areas was composed of fine and very fine sands with around 10% silt content. The sediment of these areas was well, or moderately well sorted, with a symmetrical, or slightly fine skewed grain size distribution curve. Typical species in these areas were the polychaetes *Nephtys* spp., *Scoloplos armiger*, and *Arenicola marina*, with the amphipod *Bathyporiea pelagica*, a species typical of fine sands which remain wet during low tide periods.

On the open coast, fine sands were the predominant substratum, indicative of the effect of the shallow offshore areas in reducing wave exposure. The fauna of these sediments was generally rich, with a wide range of polychaete, amphipod, echinoderm and mollusc species recorded from the open coast fine sand community as a whole. By far the richest example was found on the lower shore in the centre of Luce Bay. Here was a rich fauna with

abundant heart urchins *Echinocardium cordatum*, and numerous bivalves *Donax vittatus*, *Fabulina fabula* and *Chamelea gallina*. Characterising species for the open coast fine sand community were the polychaete species *Nephtys cirrosa*, *Arenicola marina* and *Lanice conchilega* and the amphipod *Bathyporeia pelagica*.

A barren sand community was only described from the upper shore in the centre of Luce Bay, though it is likely to be more widespread than this survey indicates. In Luce Bay the fine sand sampled at the top of the shore was above the zone of water retention, where water drains freely from the sediment during low tide periods. The sediment was virtually barren, with only three species recorded.

8. DISCUSSION

8.1 Comparison with previous marine biological studies

Where comparable sites have been surveyed there is close agreement between our data and previous work. Results from sites for which previous survey data does not exist compared favourably with results from sites in similar physiographic locations.

Previous studies on the hard substrata have been carried out by Perkins (1973) and Wilkinson (1975, 1980). Perkins gives brief descriptions of several sites also surveyed on the current surveys. Site descriptions are comparable although the shortage of species data in Perkins (1973) does not allow close comparison. Wilkinson (1975, 1980) lists marine algae from hard substrata and sediment sites which compare well with algae found on the current survey. However no other biological or habitat data is given.

Sedimentary data, in terms of species presence and substratum type, are closely in agreement with the results of Rendall (1990) for the inner Solway. Similar to our results, the species *Pygospio elegans*, *Corophium volutator* and *Macoma balthica* were virtually ubiquitous in fine sands and muds, whilst other species such as *Eteone* sp., *Nereis* (=*Hediste*) sp., *Capitella capitata* and *Hydrobia ulvae* were also widely occurring.

Brief site descriptions of were previous work has been undertaken are given in Appendix 2.

8.2 Recommendations for future work

The vast expanses of mobile sediment in the inner Solway restricted the number of samples that could be taken because of the distances required to travel from one station to another. More detailed sampling would demonstrate the transition from estuarine mud to open coast fine sediments.

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APPENDIX 1

Summary of site descriptions. Sites are listed from Maryport anti-clockwise around the coast.

Inner Solway

286.1 North West of Brown Rigg. **NY 053395**

An upper shore shingle ridge led down to an area of muddy fine sand with patches of dense *Arenicola marina* (habitat 1). This finished at an extensive mussel scar on soft muddy sand with some small boulders and cobbles (habitat 2). Below this was an area of boulders with reefs of *Sabellaria alveolata* (habitat 3), which finished at a lower shore sand flat (habitat 4).

286.2 Allonby Scar. **NY 075430**

An open coast site, consisting of predominantly sediment shore with occasional mussel beds and rocky scars on the mid to lower shore. Shore backed by pebble beach colonised in upper areas by typical strandline plants. Communities and habitats recorded were typical for the area and displayed low species diversity but high abundance of 1 or 2 species. Five habitats were recorded: upper shore firm sand; cobbles and pebbles with *Enteromorpha*; midshore cobbles and boulders; mussel scar on sediment with boulders, and; medium/fine lower shore sand.

286.3 Dubmill Scar. **NY 073450**

A seawall, protecting the road, led to an upper shore shingle ridge, held in place by groynes. This ended at an upper shore flat of muddy fine sand with sparse *Arenicola marina* (habitat 1). The midshore was dominated by a mussel scar on fine sand with some boulders and cobbles (habitat 2). The lower shore was a *Sabellaria* reef with abundant *Halichondria panicea* (habitat 3).

286.4 Silloth Lighthouse, Lees Scar. **NY 095529**

The site consisted of extensive sand flats, which were cut by a drainage channel. On the lower shore was a lighthouse, set on concrete blocks on a cobble scar. This area was encrusted with *Mytilus* with some sediment in which were *Lanice*. Four habitats were recorded: upper shore sand with standing water, dominated by *Arenicola marina* and *Macoma balthica*; soft sand by the side of the drainage channel, with few *Arenicola* and juvenile *Macoma*; midshore sand with sparse infauna, and a lower shore mussel scar.

286.5 Grune Point. **NY 145568**

This site extended from the end of the shingle/grassland spit on the south side of Moricambe, eastwards towards Grune Point Scar. A shingle upper shore led down to *Corophium* dominated mud (habitat 1) and into a large drainage creek with an area of sandy mud beside (habitat 2). The opposite bank was of fine sand and some silt with *Arenicola* (habitat 3), extending eastwards to a boulder scar with many dead *Mytilus* shells (habitat 4). The edges

of the scar were scoured by sand, restricting settlement. Some large boulders had juvenile *E. modestus*, *Porphyra* and *Enteromorpha*.

286.6 North East of Border. **NY 179555**

This site was at the head of a large inlet, Moricambe, backed by saltmarsh. The area was dominated by extensive flats of muddy fine sand, thixotropic in places. Adjacent to the saltmarsh (habitat 1) the dominant organism was *Corophium volutator*, further out into the centre of the inlet (though not much lower relative to chart datum) was an area of *Arenicola* dominated sand, with *Macoma* (habitat 2).

286.7 South West of Anthorn. **NY 186572**

This site was the sediment bank of River Wampool channel. Bordered by heavily eroding saltmarsh, a muddy bank with dense *Corophium*, *Hydrobia* and *Macoma* community (habitat 1) led to a lower shore comprising sandier sediment with *Arenicola* (habitat 2), and fewer *Corophium* and *Macoma* than the muddy banks.

286.8 Longdyke Scar. **NY 179577**

A thin strip of backing saltmarsh ended at the upper shore of pebbles on muddy fine sand with littorinids and barnacles (habitat 1). The middle shore was a mussel scar with pebbles and underlying fine sand (habitat 2). This ended near low water with flats of thixotropic muddy fine sand with *Arenicola* and *Macoma* (habitat 3).

286.9 Cardurnock Flats. **NY 170615**

Extensive flats of muddy fine sand, generally with standing water. Backed by saltmarsh, there was a gradual transition from upper shore *Corophium* dominated community (habitat 1), through an area dominated by *Arenicola* (habitat 2), to lower shore flats with *Macoma balthica* (habitat 3). The whole area was fairly mobile and rippled.

286.10 Herdhill Scar. **NY 213628**

This site was located in the upper Solway estuary beside the remains of the viaduct on the southern shore. Six habitats were studied: upper shore muddy fine sand with *Corophium volutator*; a narrow upper littoral fringe of filamentous green algae on the old viaduct stonework; a *Fucus spiralis* zone on the old viaduct stonework; *Fucus vesiculosus* and *Ascophyllum nodosum* on viaduct stonework; lower shore impoverished muddy sand, and; a lower shore scar of boulders, cobbles and patches of fine muddy sand.

286.11 Port Carlisle. **NY 244620**

This site, on the south side of the Solway Firth east of Bowness on Solway, was backed by saltmarsh. Near the top of the shore muddy sand was dominated by *Corophium* with patchy distribution of *Hydrobia* (habitat 1). The rest of the site consisted of extensive sandy flats (habitat 2) with *Macoma balthica*, *Arenicola marina*, juvenile *Mya* and *Cerastoderma* with

occasional *Hediste*.

286.12 Drumburgh. **NY 268603**

Sediment shore at the bottom of saltmarsh creek. Very mobile fine sand apparently bereft of infauna (habitat 1). Sandy banks of saltmarsh creek contained *Corophium* but were rapidly eroding.

286.13 North West of Rockcliffe Marsh. **NY 316655**

Extensive flats of fine sand with some mud, covered by standing water. Backed by extensive area of saltmarsh and grazed maritime grassland, also cut for turf.

286.14 Redkirk Point. **NY 302651**

Redkirk Point was backed by saltmarsh, however to the east there was practically no intertidal below the saltmarsh, which was directly adjacent to the channel. To the west there were extensive sand flats. A narrow band of rocky shore (habitat 1) just below the saltmarsh gave way to fine muddy sand dominated by *Corophium* (habitat 2) leading down to a creek flowing into the main channel. Beyond the creek were extensive sand flats containing *Macoma* (habitat 3).

286.15 Torduff Point. **NY 265637**

A bedrock and cobble scar with *Fucus spiralis* and *Enteromorpha*. The whole scar was heavily silted with fine sand and mud. *Corophium* and *Hediste* were present in the sediment under boulders. The whole site was characterised by low species richness and abundance.

286.16 Powfoot Scar. **NY 145651**

An upper shore cobble scar (habitat 1) with occasional large boulders was surrounded by a rich sediment of fine sand dominated by polychaetes and bivalves (habitat 3). On cobbles to the west was a fish trap with *Fucus spiralis* (habitat 2). The muddy fine sand on the lower shore (habitat 4) was characterised by a lack of obvious infaunal species.

286.17 Stanhope. **NY 084673**

Site (examined briefly) where Lochar Water enters the main firth across Blackshaw Bank. Below the saltmarsh the sediment appeared a fairly uniform rippled muddy fine sand, with large numbers of *Corophium* burrows (habitat 1), but no *Arenicola* mounds. Further out into the mouth of the inlet there was a band of cobbles with *Enteromorpha* (habitat 2).

286.18 Blackshaw Bank. **NY 022637**

Extremely extensive sand flat off Caerlaverock NNR. Inshore was a fairly narrow strip of saltmarsh. The top of the shore was composed of muddy fine sand dominated by *Corophium* and some *Hydrobia* (habitat 1). Further down the shore was a dense polychaete settlement

with *Macoma*, *Arenicola* and diatom surface film (habitat 2). The lowest station sampled contained *Cerastoderma*, *Macoma* and *Nephtys* (habitat 3).

286.19 Glencaple. **NX 994685**

On the eastern tidal bank of the River Nith. A narrow band of salt marsh fringed the river, below which was muddy fine sand. On the upper shore this was colonised by *Corophium volutator* and *Hediste diversicolor* (habitat 1). Lower on the shore the sediment was covered by cobbles. The only conspicuous fauna were *Enteromorpha* and *Elminius modestus* (habitat 2).

286.20 Southerness Point. **NX 977543**

A complex rocky shore on an exposed headland on the north Solway shore. Bedrock outcrops, perpendicular to a line down the shore were interspersed with sediments, and boulders, and cobbles with sand between. Either side of the rock were extensive sandy flats (not surveyed). The upper shore lichen zone (habitat 1) was fairly narrow with a *Pelvetia* and *Fucus spiralis* zone (habitat 2) below. Below this was the *Fucus spiralis* and *Ascophyllum nodosum* zone (habitat 3), with a barnacle dominated boulder area in the midshore (habitat 4). Lower shore bedrock was dominated by *Mytilus* with patches of *Lanice conchilega* (habitat 5). Boulders also in the lower shore were dominated by barnacles with *Lanice* and *Mytilus* (habitat 6). The whole shore was modified by scour, which altered the distribution of the zones. *Ascophyllum* in habitat 3 was only found in the sheltered areas. Small clumps of *Sabellaria* occurred in habitat 5.

286.21 Port O' Warren. **NX 879534**

The site was a rocky sandstone point dropping to an extensive sand flat. Rugged bedrock extended from above the supralittoral to the lower midshore and held large gullies and crevices, the former with mobile pebbles and cobbles as a floor. The upper shore had a moderately rich assemblage of lichens (habitat 1), leading to zones of *Pelvetia* (habitat 2) and *Fucus spiralis* (habitat 3). Below these the topography was extremely varied due to the gullies and small cliff faces, so that the eulittoral (habitat 4) contained areas dominated by filamentous green and red algae and *Catenella caespitosa* in the gullies, areas of *Ascophyllum nodosum* and *Fucus vesiculosus* on areas of gradually sloping rock, and large areas dominated by *Elminius modestus*, *Semibalanus* and clumps of *Mytilus* (on vertical faces). Below the bedrock was a sediment plain (habitat 5) of slightly soft, rippled muddy sand, with little infauna except *Arenicola*. A generally interesting and varied site, particularly for the survey area.

286.22 Port Donnel Beach. **NX 845538**

A rocky shore above sediment flats near Rough Island. A rich lichen zone on bedrock (habitat 1) led down to *Pelvetia canaliculata* and *Fucus spiralis*, on bedrock and boulders (habitat 2). Below this were midshore bedrock and boulders, dominated by *Ascophyllum* (habitat 3), and *Fucus vesiculosus* dominated bedrock, boulders and cobbles with sediment scour (habitat 4).

286.23 Rough Island Causeway and Flats. **NX 844535**

This site consisted of a boulder and cobble causeway, leading to Rough Island and sediment flats to either side. Three distinct habitats occurred: causeway of boulders and cobbles with *Elminius modestus*, and *Littorina saxatilis*; a *Zostera* bed on muddy shelly sand close to the causeway; and a flat of muddy fine sand with *Cerastoderma* further away from the causeway.

286.24 White Horse Bay. **NX 839525**

A small sheltered bay at the head of a peninsula on the western side of Rough Firth. Sediment in the main was *Scrobicularia* dominated mud (habitat 1). A rocky headland on the south side of the bay had a well developed lichen zone (habitat 2), then typical rocky shore fucoid dominated communities (habitats 3 and 4), ending in a lower shore mudflat (habitat 5) with an area of silted boulders (habitat 6). A varied site in a beautiful location giving intrinsic appeal.

286.25 South West of Orchardton Bay. **NX 820523**

Orchardton Bay is an extensive sandy embayment on the eastern side of Auchencairn Bay, split from the main area of Auchencairn Bay by the peninsula of Torr Point. The inner part of the bay, between Girvellan Point and Torr Hill was of soft muddy sand, with *Scrobicularia* and *Zostera noltii* (habitat 1). The outer area was an extensive flat of muddy fine sand with *Cerastoderma edule* (habitat 2).

286.26 Torr Point. **NX 823517**

The end of the point was characterised by wave exposed rocky shore communities, with a lichen zone (habitat 1), upper shore *Pelvetia* zone (habitat 2) and midshore *Mytilus* dominated bedrock (habitat 3) leading down to a sand flat at lower midshore. On the north-eastern side of the point, more sheltered communities occurred, though these were not surveyed.

286.27 West side of Auchencairn Bay. **NX 814507**

This site covered the western edge of the extensive fine sand flats of Auchencairn Bay. Near the west shore, muddy fine sand (habitat 1) was dominated by *Corophium* with *Macoma*, *Scrobicularia*, and *Hediste*. Out from the shore extensive *Zostera* beds occurred (habitat 2). These consisted of *Zostera nana*, with *Zostera marina* in small clumps further out on the flats. A subsurface clay layer was present in both habitats. Near the shore were piles of cockle shells with *Spartina*.

286.28 Balcarry Point. **NX 829493**

A fairly steep rocky shore with gullies and fissures, near the mouth of Auchencairn Bay on the western side. An extensive lichen zone on the upper shore (habitat 1) led down to a *Pelvetia* zone (habitat 2) with abundant *Verrucaria mucosa*. Below this was an extensive *Patella*/barnacle dominated zone (habitat 3) with *Mytilus* and occasional *Sabellaria*

hummocks. This gave way to a narrow band of *Fucus vesiculosus* (habitat 4) and *Fucus serratus* (habitat 5) on the lower shore with *Halichondria* and bryozoan crusts under boulders.

36.18 Mullock Bay **NX 709436**

A rocky headland on western end of a broad boulder bay. Access to the site is strictly controlled by the MOD who use the area as a firing range. Rugged vertical bedrock covered all the zones, though the lichen zone was not extensive in the location surveyed. Zones were generally dominated by barnacles on higher exposed steps, *Chthalamus montagui* (Habitat 2) and *Balanus balanoides* (Habitats 3 and 4), with algal domination on the flatter areas.

36.17 East of Howell Bay **NX 699437**

The east side of a rocky bay with limited access due to the area being an MOD firing range. The shore was unusual, vertically bedded rock lying perpendicular to the line of the shore, such that ribs of rock ran down from high to low water. The rocks formed numerous gullies and small pools. The bedrock was largely barnacle dominated, with some fucoids and other red algae on the lower shore.

36.16 Middle of Howell Bay **NX 695437**

Gradually inclined rock platform extending in excess of 100 m into the middle of bay, with a boulder beach to west. The bedrock was extremely rugged, with rock strata dipping slightly, producing ridges and furrows running up shore. The fauna and flora was typical of upward facing wave exposed bedrock, dominated by *Semibalanus balanoides* in midshore, with scattered fucoids, and *Laminaria digitata* in sublittoral fringe. The boulders had a very impoverished version of the same communities, and were clearly quite mobile in stormy weather, being smooth, rounded and often uncolonised by barnacles or algae. Some shallow pools were present in the furrows higher up the shore. Zones were generally not well defined and blended into one another because of the varying inclinations and aspects of the rock platform.

36.15 Gipsy Point **NX 648436**

A rugged, chiefly steep and vertical bedrock shore, on MOD property. Exposed to the south-west prevailing winds, the shore was barnacle dominated, with a band of *Chthamalus montagui* above a band of *Semibalanus balanoides*. The lower eulittoral also contained *Mytilus edulis*, *Palmaria palmata*, *Patella ulyssiponensis*, *Nucella lapillus* and small red algae. The sublittoral fringe held *Alaria esculenta* and *Laminaria digitata*. Away from the point there was a little more shelter and *Pelvetia* occurred on the upper shore (not surveyed fully).

36.14 Manxman's Lake, Kircudbright Bay **NX 680490**

The site was at the head of deeply incut embayment/estuary, with little freshwater inflow. The soft mud nearer the shore gave way to muddy fine sand with a dense bed of *Zostera nana*. The softer mud around the edges was dominated by *Corophium* sp., *Scrobicularia plana* and *Macoma balthica*.

36.13 Tip of St. Mary's Isle **NX 668480**

Rock outcrops to the south of St. Marys Isle in Kircudbright Bay. The rock was mussel dominated with high siltation. Rockpools occurred nearer the top of the shore which was dominated by *Ascophyllum nodosum*. There was a small but limited *Pelvetia* zone. The rock outcropped from muddy sand which was not surveyed.

36.12 Devil's Thrashing Floor/Milton Sands **NX 665487**

An extensive sand flat in a sheltered embayment, backed by rocky shores. The sediment was muddy, fine sand or fine sand with a silt veneer, with *Arenicola marina* and *Fabulina fabula*. Pools with small boulders supported *Enteromorpha*. The rocky shore extended from the supralittoral to the mid/lower eulittoral, and was fucoid dominated. Boulder patches on the sand flat were dominated by *Mytilus* and *Semibalanus*. All the hard substrata supported a smaller variety of life than expected, possibly due to the silt load in the water and/or fresh water runoff.

36.11 Brighouse Bay **NX 635455**

Brighouse is an enclosed bay to the west of Kirkcudbright Bay. The site was on the west side of the bay near the entrance. A fucoid dominated bedrock and boulder shore extending from the supralittoral to the sublittoral fringe with an extensive sediment plain of ripple sand with *Arenicola* casts. Patches of peat/clay were exposed through sediment with piddock holes and shells but no live animals.

36.10 Murray's Isle to Craigmore Point **NX 568510**

Eastern shore of water of Fleet estuary. Between the offshore Murray's Isle and Craigmore Point was an extensive rippled, firm sand plain with *Arenicola* and *Echinocardium*. Murray's Isle and Craigmore Point had typical gradients from lichen zone to lower mid shore with *Mytilus edulis*. In addition *Sabellaria alveolata* crusts were present on Craigmore Point but were small and highly eroded.

36.9 Mossyard Bay, Western side of Fleet Bay **NX 555516**

Upper/mid shore of bedrock with pockets of sediment characterised by *Scrobicularia*. There was some freshwater runoff over the shore and this area was fucoid dominated with *Fucus ceranoides*. The rest of the bedrock was dominated by *Mytilus* and *Semibalanus*. Below the bedrock a sediment plain extended to the river channel, the sediment was fine sand with a layer of underlying coarse sand beneath. Sparse infauna with *Arenicola* and *Lanice*. Very silty bedrock outcropped from the sediment plain and was dominated by *Mytilus edulis*.

36.8 Ravenshall Point, Wigtown Bay **NX 524523**

North-west side of Wigtown Bay. A large outcrop of rock with a distinct lichen zone, lichen/littorinid zone and barnacle zone down to boulder shore covered with barnacles and mussels. At the base of the boulders was a rippled fine sand plain with occasional *Lanice*.

36.7 Creetown Quay, Wigtown Bay **NX 473563**

A quay and sediment/boulder shore on the east side of the Cree estuary. A sandy beach led to an area of mixed cobbles and pebbles with sand, which graded to boulders and cobbles. The lower shore was a flat of muddy, fine sand with little infauna. The quayside was dominated by *Ascophyllum.*

36.6 Wigtown Sands, Wigtown Bay **NX 458560**

Extensive mud/sand flats in inner part of Wigtown Bay, backed by well developed grazed saltmarsh and cut by numerous deep channels. The upper parts of the flats were muddy sand/mud with extremely abundant *Scrobicularia plana* and *Hydrobia ulvae*. The midshore was similar (more sand content) with *Arenicola* and *Macoma*. The lowershore, on the edges of the main channel, was very firm, shelly sand which was anaerobic from surface, with little signs of bioturbation. A breakwater flanked one channel, made of boulders, dominated by fucoids and barnacles.

36.5 Innerwell Fisheries, Wigtown Bay **NX 479494**

North-east facing bay with patches of shingle and outcrops of bedrock in the upper shore. The midshore of boulders and cobbles with coarse sand was dominated by *Fucus vesiculosus* and *Ascophyllum nodosum*. The lower shore was a very soft mud flat with little infauna.

36.4 South East of Port Castle Bay **NX 428356**

A wave exposed bedrock shore, rugged, fissured and creviced particularly in upper and mid eulittoral due to vertically bedded strata running perpendicular to the shore. The upper shore *Pelvetia* zone led down to the barnacle dominated mid and lower eulittoral with some algal clumps. Rock pools contained coralline algae and the kelps *Laminaria digitata* and *Alaria esculenta.*

36.3 Point of Lagg, Luce Bay **NX 362395**

A shore on east coast of Luce Bay of boulders and large cobbles with a large tidal pool in the midshore. Areas of hard boulder clay were exposed where the boulders were sparse. The upper shore was dominated by *Verrucaria maura* and *Pelvetia*. The midshore, with the tidal pool, was dominated with algae and the exposed rocks where dominated by *Semibalanus balanoides*. The lower eulittoral was characterised by *Fucus serratus* and *Balanus crenatus*, and the sublittoral fringe by *Laminaria digitata* and *Alaria*.

36.2 Crow's Nest, Luce Bay **NX 203533**

A small embayment to the east of Luce Sands, comprising of boulders down to the low shore, then clean, fine sand with freshwater runoff (including the outfall from the public toilets) influencing much of site. The upper shore had sparse *Pelvetia* and *Fucus spiralis* and the midshore was characterised by fairly dense *Ascophyllum*. The lower shore (widest band) was dominated by *Mytilus edulis* with *Fucus vesiculosus*, although the low shore sand was fairly

depauperate, with sparse *Arenicola marina* and *Lanice conchilega*. One area of shore had low mounds of *Sabellaria alveolata*, although only a small percentage appeared alive. Most were rounded off, lacking entrance holes, and covered in an *Audouinella*/polychaete turf. Tourist facilities and a launching slip were present.

36.1 Centre of Luce Sands, Luce Bay NX 127526

The site was in the centre of the bay backed by extensive sand dunes. The whole bay was an expanse of fine sand. The lower shore was dominated by *Echinocardium* and *Donax*. *Arenicola* was abundant in the middle shore with a sparse epifauna on the upper shore.

APPENDIX 2

Summary of site descriptions from previous studies

For convenience, sites are numbered in geographic order starting north of St Bees Head and progressing northwards around the Solway to Auchencairn Bay. These numbers do not relate to site numbers in the original reference. References for the data are given after the site name, along with national grid reference for the site location. Site location maps are given at the end of the appendix.

1 False Head (Perkins 1981) **NX 949152**

A small sandy bay sheltered by the false head of St Bees. The bay contained a small sandy shore which to the north and south was replaced by boulders.

2 Boulder field south of The Pavement (Perkins 1981) **NX 956155**

Perkins described five sites which were morphologically similar between The pavement and the steeper rocky cliffs of the mass of north St Bees Head. The land above extreme high water fell from an earth cliff onto the boulder field which extended to the lower shore. There was a narrow strip of sand at extreme low water.

3 Rock Pavement (Perkins 1981) **NX 958159**

A rock pavement running approximately north-east to south-west, which sloped gently down the shore. In the north-west the pavement fell sheer to a boulder field which extended to low water.

4 Landslip (Perkins 1981) **NX 959160**

Boulders extended from the steep-faced foot of the tailings from the former gypsum mine, themselves now covered by a stabilised spoil heap. Some loss of material to the shore occurred in severe gales.

5 Rock outcrop (Perkins 1981) **NX 959161**

This outcrop and the massive fall between it and the cliff presented a substantial barrier to passage along the shore except at the time of low water during spring tides. From this level the seaward face of the outcrop rose sheer to a height of around 6 m above sand level. From here it extended some 50 m across the shore towards the base of the cliff. South-west of the outcrop the shore was choked with boulders down to the lower shore where a narrow strip of sand was exposed during low spring tides. In severe storms a considerable movement of these boulders occurred, removing colonising organisms.

6 NCB Barrowmouth (Ladysmith) Tip (Perkins 1981) **NX 960162**

The whole of this shore was affected by the tipping of colliery waste from the conveyor at the cliff top. At the highest shore levels the green alga extended along the shore to the south side of the cone of coal waste. At the low water mark a zone of high boulders began and extended south-west to the rock outcrop. The number of boulders and the height they stood above the shore was dependant on the volume of waste being tipped and the state of the weather.

7 Clifftop drains (Perkins 1981) **Site centre NX 962165**

At times when the input of coal mining waste was high, Perkins described the shore from extreme high water to mid shore as being composed of coal waste, with only the top of the occasional boulder to be seen. Near to low water the boulders stood sufficiently high to allow colonisation. When inputs of coal mining waste were reduced, the material was carried away to the north-east by longshore drift and a well developed boulder field emerged across the whole shore. Boulders previously buried under coal waste then stood about 2 m above shore level and were colonised by the green alga *Ulothrix*.

8 Old Boiler (Perkins 1981) **NX 962165**

Like preceding stations the upper and midshore at this site was primarily composed of coal waste. The lower shore was composed of large boulders.

9 NCB Tipway (Perkins 1981) **NX 963170**

An extensive upper and midshore composed of coal mining waste. Lower shore characterised by substantial rock slabs and boulders, the former considerably abraded.

10 Rock slabs (north of Saltom Pit) (Perkins 1981) **NX 963174**

An area of mainly smooth, largely bare rock with occasional shallow pools and some deep cracks between the larger rock areas. The slabs, extending about 50 m along and down the beach were situated in the upper mid-shore. Down the shore, and further to the west, separated from the slabs by a stretch of shingle stood a rock outcrop similar to Tom Hurd (14). On its seaward and south-western side it graded into rock slabs on the lower shore. The rock outcrop was creviced and some of the vertical faces were inaccessible to direct examination.

11 Saltom Pit (Perkins 1981) **NX 964174**

Beneath the retaining wall of the pit there was and extensive upper and mid shore, primarily composed of coal mining waste. At levels below this low lying rock slabs and boulders were available for colonisation. The whole of this site was very vulnerable to abrasion by coal waste.

12 Rocks below the adit (Perkins 1981) **NX 965177**

An area of low flat rock, more or less continuous at the lower shore levels replaced by large boulders and variable amounts of coarse sand and fine shale at upper levels. Rocks of the mid and lower shore were stained a rusty colour due to deposition of Fe_2O_3 from mine drainage. From 1977 onwards this shore also received the flow of colliery washing waste which deposited fine solids at all levels. Although there would appear to be direct effects on the biota from these effluents, Perkins points out that substantial areas of the flat rock are comprised of mudstone, which is a poor surface for colonisation by epibenthic organisms.

13 Sewer surge shaft (Perkins 1981) **NX 965179**

An upper shore of boulders, coal waste and shingle gave way to a more predominantly boulder strewn shore at mid-tide level. The lower shore was composed of low flat rock strata which extended north-east towards the Hurd Rocks and south-west towards the rock slabs. At the low shore level there was a break in the rock for the passage of the sewer.

14 Hurd Rocks (Perkins 1981) **NX 966183**

A large rocky outcrop just south of Whitehaven Harbour, separated from it by a fine shingle upper shore. Numerous small pools and crevices in its surface, especially near the southern and seaward facing edges.

15 Whitehaven Harbour (Perkins 1981) **NX 968185**

The walls of the outer harbour were protected from the worst of the turbulent conditions and therefore gave an indication of the range of flora and fauna which might be expected in the absence of the abrasive material carried by longshore drift. The walls were near vertical, with gaps in the masonry resembling crevices in the rock and providing opportunities for colonisation.

16 Whitehaven Docks (Hill, Cameron and Hawkins 1987) **NX 970185**

This was a large dock basin with moorings for commercial ships, fishing boats and leisure craft. The inlet channel was short and fringed by mudflats. Only *Enteromorpha* sp. and *Porphyra linearis* were noted.

17 North Beach, Whitehaven (Perkins 1981) **NX 972187**

At about the level of mean high water a steep upper shore gave way to sands which extended to below low water springs. The sands were contaminated by fine coal to varying degrees and the beach face slope was composed predominantly of material of industrial origin. The shore received waste input from two pipes. Further to the north a now disused gantry dumped coal waste onto the shore. The sands extended north to Redness Point, where they became narrow and were present only as a fringe at extreme low water.

18 Redness Point (Perkins 1981) **NX 972193**

This was an area of rock separated from the sea wall by a band of unconsolidated shingle and coarse industrial waste. At the highest levels a large slagcrete residue and two stone towers were present, suggesting that at some time in the past substantial deposits of slag were made. The substantial area of rock in the mid shore was interrupted by gullies and rockpools. Patches of slagcrete, some very ferruginous, occurred amongst the rocks, which had eroded in places exposing the shale and mudstone beneath. This mudstone was very slippery and poorly colonised, though in places pholad burrows were present, which may be of geological rather than contemporary in origin. near extreme low water the edge of the rocks gave way to boulders, which were succeeded by sand. To the south-west mussels were abundant, but in the north-east these were replaced by barnacles. Although red, fucoid and laminarian algae were present none achieved dominance, and the laminarians were only present in rockpools.

19 Parton (Perkins 1981) **NX 977206**

A substantial area of rock, separated from the supralittoral by a band of shingle and industrial waste remnants. The rocks were sparsely colonised by fucoid algae, with *Fucus spiralis*, *Fucus vesiculosus* and *Fucus serratus* present. *Pelvetia canaliculata* was absent. *Ascophyllum nodosum* was common to abundant, though at lower levels on the shore the plants were reduced to strap-like remnants, due Perkins suggests to the exposed nature of the site and grazing by the periwinkle *Littorina littorea*. The rock mass was crossed by gullies and pools and gave way to broken stony ground in the north-east. From mid tide level to extreme low water both the bedrock and the broken stony ground gave way to sands overlaying rock slabs. These sands contained up to 70% industrial waste, principally coal and

shale.

20 Lowca (Perkins 1977, 1981) **NX 978215**

Immediately to the north-east of Distington Beck the substratum consisted of unconsolidated industrial waste. Further to the north-east this shingle was confined to the upper shore only by longshore drift. At lower levels the shingle was consolidated and colonised by biota. Still further north-east, the upper and mid shore comprised of a rocky outcrop and boulders, giving way to a rocky ledge at low water, which dropped vertically at extreme low water to sands.

The biota in this area was rich, particularly in the rock outcrop and boulder field which stretched north-east towards Cunning Point, and was characterised by an abundance of fucoid algae. Laminarians colonised rocks at extreme low water near Lowca, but were prevented from colonising further north by the sand.

21 Cunning Point (Perkins 1981) **NX 978229**

The point was characterised by high rock outcrops succeeded by rock slabs at lower levels and towards mean low water. In the bays on either side and around the point, boulders were very compacted with sediment. To the north-east of the point the rocks being bathed by acid mine drainage had a rusty hue, and here the biota was impoverished. While an abundant biota including fucoid algae was recorded here, it was rather less flourishing than that living nearer to Lowca Point.

22 Harrington (Perkins 1981) **NX 985246**

This shore was composed principally of boulders embedded in a sandy, stony substratum, and rock slabs with pools at mid and lower shore levels. This gave way to sand with isolated stony outcrops near extreme low water. The shore was characterised by a rich biota including fucoid and laminarian algae. At low water of spring tides the shore was the site of extensive searching for crabs and lobsters by local fishermen.

23 Workington Docks (Hill, Cameron & Hawkins 1987) **NX 990295**

This was a large and active dock basin with lock gates closing it off from the inlet channel. Only *Enteromorpha* sp. and *Porphyra linearis* were noted.

24 Northside, Workington (Perkins 1977) **NX 986300**

The top of this shore was characterised by large 'slagcrete' outcrops which reared up from the mid-tide level to a height well above mean high water of spring tides. These outcrops were colonised by a varied biota including the algae *Ulva lactuca*, *Enteromorpha* sp., *Cladophora rupestris*, *Fucus vesiculosus*, *Ascophyllum nodosum*, *Porphyra umbilicalis*, *Rhodochorton floridulum* [*Audouinella floridulum*] and *Mastocarpus stellatus*, and the molluscs *Patella* sp., *Littorina littorea*, *Littorina saxatilis* and *Mytilus edulis*. Below the slagcrete the shore was one of mobile sand, with *Arenicola marina* and *Lanice conchilega*. To the south of the sewer pipe which ran across the shore, an area of bound shingle was present, colonised by *Mytilus edulis*, *Littorina littorea* and occasional *Fucus spiralis*.

25 Maryport Docks (Hill, Cameron & Hawkins 1987) **NY 030365**

Maryport harbour contained two dock basins, only one of which was in use, having two lock gates. The disused dock was open to the inlet channel which was long and had extensive

mudflats. Species diversity was low with only *Enteromorpha* sp. and *Porphyra linearis* noted.

26 Dubmill Point (Perkins 1973) **NY 076462**
To the south of the point was the boulder strewn Dubmill Scar, while to the north intermittent scars were present in the sand. At the head of the shore at Dubmill Point, there were coast defence works (sea wall and groynes) with shingle substratum. Material collected by the groynes indicated a weak north-easterly longshore drift.

27 Mawbray (Perkins 1973) **NY 080469**
Well developed dunes gave way to a sandy shore which showed considerable mobility.

28 Stinking Crag (perkins 1973) **NY 084480**
Dune substratum, colonised by marram grass at the head of the shore gave way to the top of a shingle slope which was succeeded by sand flats sloping gently to the bed of the Solway. Scar grounds occurred widely in the sands of the shore, though considerable movements of sand cause the fauna to be impoverished.

29 Beckfoot (Perkins 1973) **NY 090493**
See Stinking Crag above

30 Lee's Scar (Perkins 1973) **NY 101524**
Well developed dunes gave way to a sandy shore marked by bars, including a high one towards mean low water. This ground, along with Beckfoot and Stinking Crag was regarded as the best feeding for fish on the south side of the Solway.

31 Silloth Dock Basin (Hill, Cameron & Hawkins 1987) **NY 105535**
A small active dock basin with lock gates connecting it with the inlet channel. The inlet channel was short with mudflats on either side. Species diversity was low, with only *Enteromorpha* spp. and *Porphyra linearis* noted.

32 Silloth (Perkins 1973) **NY 106536**
A shingle beach crossed by groynes which gave evidence of a weak north-easterly longshore drift. *Fucus spiralis* and *Fucus vesiculosus* were present.

33 East Cote, Silloth (Perkins 1973) **NY 116551**
This shore was much affected by sea defence work, with a concrete sea wall and wooden groynes. It was essentially a shore of shingle and bound shingle, with some sand at low water mark. The groynes were sparsely colonised by the algae *Fucus spiralis* and *Fucus vesiculosus*. *Porphyra* sp. occurred on stones around the low water mark.

34 Grune Point (Perkins 1973) **NY 140570**
Grune Point was undergoing erosion at the time of Perkins study. At approximately the level of high water neaps, the shingle gave way both on the Moricambe and Solway shores to muddy sand, while on the north-west side and from the tip of Grune Point, the soil grade increased in size towards the channel.

35 Skinburness Marsh (Perkins 1973) **NY 135551 to NY 150565**

An extensive area of terraced marsh, marked by creek and pan development, terminated in an accretion edge which was colonised and showed rapid signs of development. From the accretion edge sandy flats extended down to the stony bed of the Waver at Tickhill Scar.

36 Calvo Marsh (Perkins 1973) **NY 167542 to NY 175556**

An extensive terraced grass marsh, crossed by creeks terminated at an erosion step. Below the erosion edge a vast area of clean fine sand extended to the channel of the Waver.

37 Winding Banks, Raby Cote (Perkins 1973) **NY 169523**

At the southern end of the marshes stretching to Skinburness a narrow terraced grass marsh ended in a steep fluvial erosion edge which formed the bank of the River Waver.

38 Salt Cote Marsh (Perkins 1973) **NY 184533 to NY 177532**

A terraced grass marsh crossed by creeks and having pan development. Marked erosion edges occurred, enhanced by the channel of the Waver, which ran alongside the marsh. Sand was found to have quicksand properties in some areas.

39 Anthorn (Perkins 1973) **NY 192581**

A narrow terraced grass marsh adjacent to the road led to a shore of muddy sand which sloped down to the bound shingle bed of the River Wampool. On the further side of the Wampool an extensive bank of fine sand was present. Stones on the Anthorn shore were colonised by the algae *Ulva lactuca* and *Fucus spiralis*.

40 Cardurnock (Perkins 1973) **NY 169588**

A wide, gently sloping terraced grass marsh led on to the extensive sand flats which sloped down to the Silloth Channel.

41 Biglands House (Perkins 1973) **NY 208619**

A terraced grass marsh was bound on the eastern side by the old Solway viaduct, and was terminated by an erosion edge, which Perkins reports had changed to an accretion edge in 1964. Below the erosion/accretion edge the shore became progressively less muddy, sloping gently down to the Solway Channel.

42 Bowness, Pottery House (Perkins 1973) **NY 218625**

A terraced grass marsh, bounded on the western side by the old Solway viaduct, led down to a long sloping shore of sand, becoming progressively less silty towards the Solway channel. Perkins reports considerable erosion of sand from this area in the period 1964-1968. At the northern end of the viaduct embankment there was colonisation by the algae *Fucus vesiculosus*, *Fucus spiralis* and *Ascophyllum nodosum*.

43 Port Carlisle (Perkins 1973) **NY 242673**

Saltmarsh grass ended at a deep erosion step which was succeeded by a shore of muddy sand. A jumble of stone from a ruined harbour was colonised by the algae *Fucus spiralis*, *Fucus vesiculosus*, and *Fucus ceranoides*. Below this was an expanse of fine sand to the Solway Channel.

44 Westfield (Perkins 1973) **NY 252612**
A terraced grass marsh, adjacent to the road, terminated in a deep erosion edge with hummocks of grass below. This was succeeded by a shore of muddy sand and pebbles which in turn was succeeded by sand sloping down to the bed of the Esk Channel.

45 Easton (Perkins 1973) **NY 275597**
A grass marsh terminated in a steep erosion edge which led to the stony bed of the River Eden.

46 Moss-Band Hall Marsh (Perkins 1973) **NY 334651**
Saltmarsh grass with a steep fluvial erosion edge fringed by sand lay above the stony bed of the Esk.

47 Sark Marsh (Perkins 1973) **NY 323664**
An extensive saltmarsh, undergoing accretion and development, fell away to muddy sand in the mouth of the Sark and in the Esk to coarse sand, succeeded by an area of coarse sand, stones and rubbish which finally led to the stony bed of the Esk. The area of sand and stone in the Esk was much scoured by the tide.

48 Old Gretna (Perkins 1973) **NY 317661**
A narrow saltmarsh was succeeded by a narrow shore of muddy sand leading down to the stony bed of the Esk.

49 Redkirk Point (Perkins 1973) **NY 302651**
Bedrock, backed by saltmarsh, both of which were undergoing extensive erosion at the time of Perkins' study.

50 Brow Houses (Perkins 1973) **NY 282650**
A grass marsh, developed on a base of shingle, terminated in an erosion edge and was succeeded by a narrow shore of muddy sand which gave way to fine sand near the Esk channel. To the west a shingle bank formed the base of a stake net. Stones of the shore were colonised by the algae *Ulva lactuca* and *Fucus spiralis*.

51 Torduff Point (Perkins 1973) **NY 266638**
An earthen cliff at Torduff Point gave way to a grassy bank on the east and west. The upper shore of stone, rock and coarse sand was succeeded by a zone of muddy sand which in turn was succeeded by coarser sand towards the middle of the Solway. The alga *Fucus ceranoides* was present on the rocks of the point.

52 Dornock Brow (Perkins 1973) **NY 239651**
A grass marsh developed on shingle, to the east the shore was of shingle alone. The developing edge of the saltmarsh consisted of *Puccinellia* hummocks; stones protruding in this zone were colonised by *Fucus spiralis*. Below this was a zone of muddy sand which gave way to fine sand towards the middle of the Solway.

53 Dornockbrow (Rendall 1990) **Station 11.1 NY 239649** **Station 11.2 NY 239648**
TWINSPAN analysis by Rendall placed both stations in the same group, consisting of very fine sand with a median grain size around 80 μm and between 19% and 27% silt content.

Station 11.1 had 12820 individuals in sixteen taxa, station 11.2 22495 individuals in thirteen taxa. The species present were broadly similar at both stations, with numerical abundance of *Pygospio elegans*, *Corophium volutator* and *Corophium* sp. at both stations, and additionally high abundances of *Hydrobia ulvae*, *Macoma balthica* and Tellinaceae at station 11.2

54 Whinnyrig (Rendall 1990) **Stations 10.1 and 10.2 NY 212647**

Both stations were of very fine sand, median grain size 82-85 μm with 18-22% silt content. These stations were placed in separate groups by TWINSPAN analysis.

55 Seafield (Perkins 1973) **NY 203648**

This shore was bounded on the east by the northern end of the old Solway viaduct. The upper shore marsh terminated in an erosion step. The stone work of the viaduct was colonised by the algae *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum*, and *Fucus vesiculosus*.

56 Annan Waterfoot (Perkins 1973) **NY 196646**

Saltmarsh terminated in an erosion step. A short steep bank of mud led to the stony bank of the Annan. The alga *Fucus spiralis* colonised the sewer outfall.

57 Newbie (Rendall 1990) **Station 9.1 NY 174645 Station NY 174644**

These stations were on very fine sand, median grain size 99.4 μm (9.1) and 84.6 μm (9.2) with 21.2% and 17.7% silt content respectively. The fauna of the sites was similar, with sixteen taxa and 6973 individuals at 9.1 and seventeen taxa and 6884 individuals at 9.2. TWINSPAN analysis by Rendall put both stations into the same group. Although a similar range of species was present at both stations, the relative abundances varied. *Pygospio elegans* and *Corophium volutator* were most abundant at station 9.1, and *Macoma balthica*, Cardiidae and Tellinaceae being more abundant at 9.2.

Station 10.1 had 18822 individuals in 16 taxa, 10.2 had 44920 individuals in 15 taxa. Both stations were numerically dominated by a small range of species, chiefly *Pygospio elegans* and *Polydora ligni*, (both most abundant at station 10.2) *Corophium volutator*, *Corophium* sp., *Macoma balthica*, Cardiidae and Nemertines.

58 Newbie shore (Perkins 1973) **Rifle Range NY 164651**
Newbie Mains NY 173646
Barnkirk Point NY 196643

The shore was primarily one of stones towards the head, with deposits of finer material towards low water mark, though in places the stones extended to the channel. Intense scouring of the scar ground to the east of Newbie Mains was clearly due to tidal action. There was no evidence anywhere for the direct effects of wave action or for the action of longshore drift. To the west of Barnkirk Point deposition of land derived sediments sometimes occurred. During 1962 stumps of a submerged forest were observed in the region of tidal scour between Newbie Villa and Barnkirk Point. Colonisation of the shores by the algae *Pelvetia canaliculata*, *Fucus spiralis*, and *Fucus vesiculosus* occurred widely, though not abundantly. *Fucus ceranoides* occurred at Barnkirk Point.

59 Powfoot (Perkins 1973) **NY 147654**

From 1961 to 1964 Perkins reports the shore as being a ragged development of saltmarsh, coarse red sand and shingle. Between then and 1973 vast amounts of sand were deposited on the shore, obliterating the Powfoot Channel. This sand deposition almost submerged the wooden paddling pool, killing the *Fucus spiralis* and *Mytilus* colonising the structure (compare this with the results of the present survey). The saltmarsh 'hummock' zone was colonised by *Enteromorpha*, *Fucus spiralis*, and *Pelvetia canaliculata*.

60 Powfoot (Rendall 1990) **Station 1.1 NY 148654 Station 1.2 NY 148653**

Both stations were composed of very fine sand, though station 1.2 had a higher proportion of silt (30%) and a finer median particle size (76.4 μm as opposed to 116 μm at 1.1). Station 1.1 was numerically dominated by juvenile Tellinaceae and Cardiidae, with additionally high numbers of *Macoma balthica*, *Hydrobia ulvae*, *Pygospio elegans*, and *Corophium volutator*. Station 1.2 lacked the high numbers of bivalves found in 1.1, with only low numbers of *Macoma balthica*. The fauna in general was impoverished compared with 1.1 with a similar range of species all at reduced numbers except for *Corophium volutator*, which was equally abundant at each station. The amphipod *Bathyporeia pilosa* was present at station 1.2 but absent from 1.1

61 Howgarth (Perkins 1973) **NY 140652**

A narrow eroding merse led to a wide expanse of sand flats which sloped to the Powfoot Channel.

62 Ladyhall (Perkins 1973) **NY 097661**

A wide saltmarsh terminated in an erosion step and led to muddy sand sloping down to Lochar Water at the north-west end of Priestside Bank.

63 Brow Well (Perkins 1973) **NY 084673**

In 1964 Perkins reports a wide saltmarsh terminated at an erosion step, beyond which a short flat of muddy sand sloped gently to the stony bed of the Lochar Water. By 1968 a considerable deposition of fine sand had filled and shifted the Lochar Channel, and an accretion edge with *Puccinellia* hummocks had developed.

64 Castlewood (Rendall 1990) **Station 3.1 NY 022646 Station 3.3 NY 022645**

Both stations were composed of very fine sand, though 3.3 had a higher percentage of silt (43.2%) and a slighty smaller median particle size. Under TWINSPAN analysis these stations were grouped together with 1.1 and 1.2, and similar to 1.1 and 1.2 the station nearer the top of the shore was the richer in both number of individuals and number of taxa. Station 3.1 was numerically dominated by the bivalve *Macoma balthica*, the amphipod *Corophium volutator* and the polychaetes *Pygospio elegans* and *Hediste* (=*Nereis*) sp. Station 3.2 had lower numbers of a similar range of species, though *Corophium volutator* was much more abundant, and nematodes were also recorded in greater numbers.

65 Kennethbank (Rendall 1990) **Stations 4.1 and 4.2 NY 000668**

These two stations were very similar, composed of very fine sand with a median particle size of 84 um and around 14% silt content.

In spite of the similarities in sediment characteristics the two stations showed differences in their biota and were grouped separately by TWINSPAN analysis. Station 4.1 had 59 individuals from eight taxa, whilst station 4.2 had 225 individuals in ten taxa. The major difference appeared to be the increased number of *Corophium volutator* at 4.2, coupled with a small increase in the numbers of the polychaetes *Manayunkia aestuarina* and *Enchytraeidae*.

66 Kennethbank, Caerlaverock (Perkins 1973) **NX 998675**

Phragmites swamp gave way to saltmarsh which terminated in an erosion step. This was succeeded by a flat of muddy sand which ran down to the bed of the Nith.

67 Glencaple (Perkins 1973) **NX 994685**

A narrow grass marsh terminated at an erosion step, below which a narrow sand shore ran down to the stony bed of the Nith.

68 Airds Point (Rendall 1990) **Stations 4.6 and 4.7 NX 993662**

Station 4.6 was composed of silt/clay with a median grain size of <63 um and a 55.8% silt content. These stations were grouped separately by TWINSPAN analysis. Both stations had ten taxa recorded, station 4.6 with 9458 individuals and station 4.7 with more at 16591. The range of species recorded was similar at each station, though numbers varied. The polychaete *Manayunkia aestuarina* was abundant at 4.6, but only present in low numbers at 4.7, however *Enchytraeidae* were more abundant at 4.7, along with nematodes.

69 Overton (Rendall 1990) **Stations 4.9 and 4.10 NX 992640**

Station 4.9 was of very fine sand, median grain size 75.6 um with 32.1% silt content whilst 4.10 was of fine sand, median grain size 158 um, with 4.7% silt content. Station 4.9 had 871 individuals in fifteen taxa, whilst 4.10 had only 131 individuals in twelve taxa. The two stations were placed in different groups by TWINSPAN analysis.

Station 4.9 was richer for all species groups collected except for *Capitella capitata*, which was more abundant at 4.10, and *Arenicola marina*, which was absent from 4.9 and represented by only one individual at 4.10. Other characteristic species included *Macoma balthica*, *Pygospio elegans*, *Nephtys* sp. and *Hediste* (=*Nereis*) sp.

70 Burnfoot (Perkins 1973) **NX 989637**

A narrow grass marsh led to a narrow low gradient shore of fine sand which terminated in a steep, deep drop to the bed of the west channel of the Nith. To the north, at the point, rocks at the head of the shore were colonised by the algae *Pelvetia canaliculata* and *Fucus spiralis*.

71 Drumburn (Perkins 1973) **NX 984620**

A narrow grass marsh led to a wide low gradient shore of fine sand, terminated in a steep drop to the bed of the west channel of the Nith.

72 Carsethorn (Perkins 1973) **NX 982600**

Carse Bay faces north-east. A stone and coarse sand upper shore was backed by saltmarsh.

73 Carsethorn (Rendall 1990) **Stations 5.1, 5.2 and 5.3 centre NX 996597**

All stations were placed in the same grouping by TWINSPAN analysis. This group was characterised by very fine sand, median grain size around 77 um with around 5% silt content. Species diversity and number of individuals increased down the shore (from stations 5.1 to 5.3) with 21 taxa and 8209 individuals at 5.1, nineteen taxa and 8113 individuals at 5.2 and sixteen taxa and 6328 individuals at 5.3.

The dominant species at all stations were *Pygospio elegans*, *Capitella capitata*, *Tubifex costatus*, *Tubificoides benedenii*, *Enchytraeidae*, *Corophium volutator*, *Macoma balthica*, and nematodes. Many of these species are characteristic of sites of organic enrichment, and these stations all showed around 5% loss on ignition, confirming a high proportion of organic material in the sediment.

74 Arbigland (Rendall 1990) **Stations 6.1, 6.2 and 6.3, centre NX 998572**

TWINSPAN analysis grouped stations 6.1 and 6.2 together, separate from 6.3. Stations 6.1 and 6.2 were of very fine sand, with a median grain size of 96 um and 86 um respectively, and both having around 9% silt content.

Station 6.3 was composed of fine sand with a median grain size of 128 um and 4.9% silt content.

Stations 6.1 and 6.2 both had seventeen taxa, with 146 and 231 individuals respectively. Station 6.3, on fine sand, was richer with 21 taxa and 168 individuals. The fauna of the stations was similar, with low numbers of *Corophium volutator*, *Macoma balthica* and *Pygospio elegans*, all most abundant at 6.1. Species such as *Nephtys cirrosa*, *Spio martinensis*, *Capitella capitata* and *Bathyporiea pilosa* became more abundant from 6.1 to 6.3, progressing down the shore.

75 Powillimont (Perkins 1973) **NX 991565**

At the northern end of Gillfoot Bay, cliffs and a rocky or shingly upper shore gave way in the *Fucus spiralis* zone to fine sand. This site represented a transition between the exposed shores of Southerness Point and the sheltered shore of Carsthorne.

76 Southerness Point (Perkins 1973) **NX 977542**

An area of wave exposed rock reefs and sand. The rock was colonised by the algae *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum* (with *Polysiphonia lanosa*), *Fucus vesiculosus* and *Fucus serratus*. Southerness Point marks the eastern limit in the Solway Firth of the polychaete *Sabellaria* sp.

77 Mersehead Sands (Perkins 1973) **NX 968545**

Sand dunes ended in a deep erosion edge on to a steep slope of coarse sand forming the upper shore. Below this the shore was composed of fine sand extending down to the Barnhourie Channel.

78 Southwick Merse (Perkins 1973) **NX 916559**

An expanse of saltmarsh, showing all stages of saltmarsh zonation. In the burn meandering across the marsh rocks were colonised by the algae *Pelvetia canaliculata* and *Fucus spiralis*.

79 Port O' Warren (Perkins 1973) **NX 878534**

Cliffs 45 m high fell sheer to the *Fucus vesiculosus* zone where muddy sand reached up to the base of the cliffs; *Pelvetia canaliculata* and *Porphyra* sp. were also present. In caves and fissures at the base of the cliffs coarse sand collected and reefs of the polychaete worm *Sabellaria* sp. developed.

80 Craig Roan (Perkins 1973) **NX 878534**

A rocky islet to the east of Castehill Point, the site of a mussel bed. *Fucus spiralis* was present.

81 Spring Stones (Rough Island) (Perkins 1973) **NX 845529**

A collection of rocks at the southern end of Rough Island, and the site of a mussel fishery. Cockles also occerred in workable numbers at this site. *Fucus spiralis* and *Fucus vesiculosus* were present.

82 Rockcliffe (Perkins 1973) **NX 850533**

Rocks were colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum*, (with *Polysiphonia lanosa*) and *Fucus vesiculosus*. Below which were flats of muddy sand.

83 Rough Firth (Perkins 1973) **NX 840541**

A grass bank gave way to a grass bank which led to a rocky outcrop colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum* and *Fucus vesiculosus*. Below the *Fucus vesiculosus* zone extensive mud flats with *Zostera* gave way eventually to the shelly bottom of the Urr Water channel.

84 Kipford Post Office (Perkins 1973) **NX 837549**

An upper shore of stones rocks and ragged salt marsh led to a stony beach colonised by *Pelvetia canaliculata* and *Fucus spiralis*. Below this was a mud slope to the stony bottom of the Urr Water. Where stones or rock outcrops protruded above the mud, colonisation by *Ascophyllum nodosum* and *Fucus vesiculosus* occurred.

85 Kippford (Wilkinson 1975) **NX 837550**

A varied site with rock, mud, boulders and wooden pilings recorded. Ten species of algae recorded, including *Blidingia* spp., *Enteromorpha* spp., *Monostroma oxyspermum*, *Rhizoclonium riparium*, *Elachista fucicola*, *Polysiphonia lanosa* and *Porphyra umbilicalis*.

86 Kippford Merse (Perkins 1973) **NX 832555**

A wide area of salt marsh led to a slight slope of muddy sand which in turn gave way to the stony bed of the Urr Water.

87 Craigbrex (Perkins 1973) **NX 836564**

A jetty of granite rubble , colonised by the algae *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus*, and *Ascophyllum nodosum* led directly down to the Urr Water. To the north and south the intertidal was predominantly a muddy bank.

88 Palnackie (Wilkinson 1975) **NX 822569**

Rock, boulders and mud were present at this site. Eight species of algae were recorded,

including *Blidingia* spp., *Enteromorpha intestinalis*, *Rhizoclonium riparium*, *Fucus ceranoides*, *F.spiralis*, *F.vesiculosus* and *Pelvetia canaliculata*.

89 Garden Reach (Perkins 1973) **NX 822574**
Saltmarsh was separated by an erosion step from the steeply sloping bank of mud which fell to the stony bed of the Urr Water. The stones in the bed of the channel were colonised by *Fucus ceranoides*.

90 near The Port (Wilkinson 1975) **NX 832603**
Only mud was present at this site. Only two species of algae were recrded from this site, *Phormidium* sp. and *Vaucheria* sp.

91 Buittle Bridge (Perkins 1973, Wilkinson 1975) **NX 823606**
The tidal limit of the Urr Water. No development of shore. Grass banks led directly to a low vertical muddy bank at the waters edge. Little tidal range. Five species of algae were recorded, *Cladophora glomerata*, *Oedogonium* sp., *Phormidium* sp., *Vaucheria* sp. and *Euglena* sp.

92 South Glen (Perkins 1973) **NX 832557**
A steep muddy and stony bank fell to the stony bed of the Urr Water. Stones were colonised by the algae *Pelvetia canaliculata*, *Fucus spiralis* and *Ascophyllum nodosum*.

93 Glen Isle Marsh (Perkins 1973) **NX 834549**
On the eastern side, saltmarsh gave way to a zone of bare mud which soon fell steeply to the stony bed of the Urr. To the south, the saltmarsh led to an area of mud flats. Stones lying in the surface of the saltmarsh were colonised by *Pelvetia canaliculata* and *Fucus spiralis*. The rock of Glen Isle, which bordered the marsh, was colonised by a thin indistinct band of *Pelvetia canaliculata*.

94 Glen Black Stone (Perkins 1973) **NX 832447**
A rocky outcrop projecting into the Urr Water. The more gently sloping upper levels of the rock led to steeper surfaces near the main channel. Upper levels were silted and colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum*, and *Fucus vesiculosus*.

95 Glen Bay (Perkins 1973) **NX 830548**
This south facing bay between Glen Isle and the Almorness peninsula was characterised by saltmarsh at its head, with rocky arms to either side. On the rocks above the muddy sand colonised by *Spartina townsendii* the algae *Pelvetia canaliculata* and *Fucus spiralis* occurred, though near to the head of the bay only the former was present.

96 Horse Isles Bay (White Horse Bay) (Perkins 1973) **NX 837525**
A north facing bay with saltmarsh present at the head and eastern sides of the bay. Sedimentary material was deposited below the marsh, particularly in the eastern side of the bay there was protection from the tidal streams and predominant south-westerly wave action. Colonisation by *Fucus spiralis* occurred.

97 Hestan Rack (Perkins 1973) **NX 838505**
A bound shingle area extending north from the northern end of Hestan Island as a causeway to Almorness Point. This was the site of an extensive mussel bed, with *Fucus spiralis* and *Fucus vesiculosus*.

98 Girvellan Point (Perkins 1973) **NX 820525**
The tip of a rocky peninsula in Orchardton Bay was colonised by the algae *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum* (with *Polysiphonia lanosa*). Muddy sands in the centre of the bay were colonised by *Zostera*.

99 Red Haven (Perkins 1973) **NX 816517**
A small south-easterly facing bay on the Torr Hill peninsula. Two rocky arms colonised by the algae *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus*, and *Ascophyllum nodosum* enclosed a sandy beach, with coarse sand on the upper beach and muddy sand lower on the shore. To the west of Red Haven, and across Auchencairn Lane a cockle bed occurred.

100 North Lodge (Perkins 1973) **NX 813508**
A sea wall at the roadside gave way to a gently sloping shore of rock, stones and bound shingle colonised by *Pelvetia canaliculata*, and *Fucus spiralis*. This gave way to muddy sand which towards the centre of the bay was colonised by *Zostera*.

101 Cottage (Perkins 1973) **NX 817505**
A rocky upper shore colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum* gave way to muddy sand which was colonised by *Zostera* in the more central part of Auchencairn Bay.

102 Balcarry Bay (Perkins 1973) **NX 821493**
This bay faces north-east, having and upper shore of shingle while the jaws of the bay were rocky. The shingle underwent a transition from bound shingle to muddy sand which extended to the base of the rocks colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum*. *Fucus serratus* and *Porphyra* sp. occurred on the south side of the bay. On the northern side, *Zostera* occurred below the bound shingle and rocks.

103 Balcarry Point (Perkins 1973) **NX 829493**
A steep, exposed rocky shore at the south-western entrance to Auchencairn Bay. Coarse sand occurred at extreme low water. The rocks were colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus*, *Fucus serratus*, *Ascophyllum nodosum*, and *Porphyra* sp. Some *Sabellaria* was present on the lower shore.

104 Abbey Burnfoot (Perkins 1973) **NX 742445**
A stony upper shore gave way to exposed barnacle encrusted rocks. The rocks were colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum*, *Porphyra* sp. and *Chorda filum*, while in the more sheltered mouth of Abbey Burn *Fucus ceranoides* was also present.

105 The Lake (Perkins 1973) **NX 681473**
A rocky stony upper shore was succeeded by muddy sand. The upper rocks were barren but

at a lower level were colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *F.vesiculosus*, *F.ceranoides* and *Ascophyllum nodosum*.

106 Black Murray Plantation (Perkins 1973) **NX 685492**
A narrow band of saltmarsh gave way to the muddy sand flat of Manxman's Lake at an erosion step. Stones, where present, were colonised by *Pelvetia canaliculata*, *Fucus spiralis*, and *F.ceranoides*.

107 St Mary's Isle (Perkins 1973) **NX 677486**
A jumble of rocks colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *F.vesiculosus* and *Ascophyllum nodosum* gave way to a shore of muddy sand.

108 Kirkcudbright (Wilkinson 1975) **NX 686516**
Ten algal species were recorded, six chlorophytes, two phaeophytes, one xanthophyte and one euglenophyte. Species included *Blidingia* spp., *Enteromorpha intestinalis*, *Fucus ceranoides*, *Vaucheria* spp., and *Euglena* spp.

109 Low Boreland (Perkins 1973) **NX 690522**
A large erosion step led to a steeply sloping mud bank, falling rapidly to the stony bed of the Dee. Stones in the bed of the estuary were colonised by *Fucus ceranoides*.

110 Tongland Bridge (Perkins 1973) **NX 691534**
A grassy supralittoral gave way to a stony shore which at lower levels was colonised by *Fucus ceranoides* and some *F.spiralis*.

111 Kirkcudbright (Wilkinson 1975) **NX 686537**
Nine species of algae were recorded, five chlorophytes, one myxophyte, one bacillariophyte, one xanthophyte and one euglenophyte. Species included *Blidingia* spp., *Enteromorpha intestinalis*, *Phormidium* sp., *Melosira moniliformis*, *Vaucheria* sp. and *Euglena* sp.

112 Low Bridge of Tarff (Wilkinson 1975) **NX 685541**
Six species of algae recorded, four chlorophytes, one myxophyte, and one xanthophyte. Species recorded include *Blidingia* spp., *Enteromorpha intestinalis*, *Phormidium* sp., and *Vaucheria* sp.

113 Glenald (Wilkinson 1975) **NX 686542**
A muddy bank with four species of algae recorded, two chlorophytes, one myxophyte and one xanthophyte. Species recorded were *Blidingia minima*, *Ulothrix subflaccida*, *Phormidium* sp., and *Vaucheria* sp.

114 near Kirkchrist (Wilkinson 1975) **NX 675513**
Fifteen algal species were recorded, eight chlorophytes, five phaeophytes, one rhodophyte and one xanthophyte. Species included were *Blidingia* spp., *Enteromorpha intestinalis*, *Ulothrix* spp., *Ascophyllum nodosum*, *Fucus spiralis*, *F.vesiculosus*, *Pelvetia canaliculata*.

115 Kirkchrist (Perkins 1973) **NX 676514**
Saltmarsh backed by grass verge fell steeply by an erosion step to a mud bank, sloping

steeply to the stony bed of the Dee. Stones, where present, were colonised by *Ascophyllum nodosum* and *Fucus ceranoides*.

116 River Dee, opposite yacht club (Perkins 1973) **NX 674510**
Saltmarsh terminated at an erosion step, below which mud fell steeply to the stony bed of the Dee. Stones where present were colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus*, *Fucus ceranoides* and *Ascophyllum nodosum*.

117 Gibb Hill Point (Perkins 1973) **NX 672508**
A saltmarsh gave way at an erosion step to an almost level mud flat changing rapidly to a steep mud slope leading to the stony bottom of the Dee. Stones where present were colonised by *Pelvetia canaliculata*, *Fucus vesiculosus* and *Porphyra* sp.

118 Seaward Cottage (Perkins 1973) **NX 665493**
An eroded road verge gave way to an upper shore of shingle with *Puccinellia*, *Limonium* and *Armeria maritima* at mid levels and *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum* and *Fucus vesiculosus*. A mud flat with *Enteromorpha* sp. succeeded this, giving way to the stony bottom of the Dee channel.

119 Nun Mill (Perkins 1973) **NX 663490**
A steep rocky upper shore colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus*, *Fucus serratus* and *Ascophyllum nodosum*, gave way at about mid tide level to level shore of fine thixotropic sand. Rock outcrops in the sand were colonised by *Fucus vesiculosus* and *Porphyra* sp.

120 Shoulder Craig (Wilkinson 1975) **NX 663490**
24 algal species recorded, eight chlorophytes, six phaeophytes, nine rhodophytes and one Bacillariophyte. Included were *Blidingia marginata*, *Cladophora rupestris*, *Enteromorpha intestinalis*, *Ulva lactuca*, *Ulothrix* spp., *Ascophyllum nodosum*, *Fucus serratus*, *Fucus spiralis*, and *Fucus vesiculosus*, *Pelvetia canaliculata*.

121 Ross Bay (Perkins 1973) **NX 650445**
Facing east, with marsh on the south side and rocky shore to the north, the bay was predominantly of muddy sand. Algal communities present depended on the degree of sediment deposition. Rocks free from sedniment were colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum*.

122 Brighouse Bay (Perkins 1973) **NX 635455**
Facing south-west, a grass bank leads directly to the medium sand of the shore. The sides of the bay were rocky with *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum* and *Fucus vesiculosus*. Considerable erosion occurs due to visitor pressure.

123 Brighouse Bay (Wilkinson 1975) **NX 635450**
42 species of algae recorded, twelve species of Chlorophyceae, ten species of Phaeophyceae, sixteen species of Rhodophyceae, three Myxophyceae and one Xanthophyceae. The list includes *Blidingia* spp., *Cladophora* spp., *Enteromorpha intestinalis*, *Ulva lactuca*, *Ascophyllum nodosum*, *Fucus ceranoides*, *Fucus serratus*, *Fucus spiralis*, *Fucus vesiculosus*.

124 Ardwall Island shore (Perkins 1973) **NX 575498**
Rocky upper shore with *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus*, *Fucus serratus* and *Ascophyllum nodosum* giving way to a lower shore of sand. Opposite Ardwall Island itself a shingle beach separated rock and sand. This shingle showed typical features of a beach exposed to appreciable wave action and as such was a rare feature of the Solway.

125 Carrick shore (Perkins 1973) **NX 578511**
Rocky upper shore colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum*. Below the *Fucus vesiculosus* zone the shore was sandy.

126 Airds Bay (Perkins 1973) **NX 576521**
Sandy beach of medium coarse sediment. Adjacent to saltmarsh a more steeply sloping zone of coarser sand levelled out into a sand flat, colonised at the highest levels by *Zostera*. Rock promontories bounded the bay, colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum*.

127 Cardoness castle (Perkins 1973) **NX 592553**
At this site the Fleet was contained within dykes. The bank of the dyke fell sharply to the stony bed of the Fleet, colonised by *Fucus ceranoides*.

128 Cardoness Castle (Wilkinson 1975) **NX 592553**
Boulders and mud. six species of algae were recorded, four chlorophytes, one phaeophyte and one euglenophyte. Species included *Blidingia* spp., *Monostroma oxyspermum*, *Ulothrix pseudoflacca*, *Fucus ceranoides*,and *Euglena* sp.

129 Fleet Water (Perkins 1973) **NX 595557 NX 595560**
Marine influences much reduced. Slight development of marsh, freshwater rather than marine in character, succeeded by a zone of muddy stones, the transition to the stony bed of the Fleet. *Fucus ceranoides* was present on rock in the bed of the Fleet and on an old wharf to the south.

130 Alder Pool (Wilkinson 1975) **NX 595559**
Rock. Five algal species were recorded, four chlorophytes and one phaeophyte. Species recorded include *Blidingia* spp., *Ulothrix pseudoflacca*, and *Fucus ceranoides*.

131 Fleet Bridge (Wilkinson 1975) **NX 598562**
Muddy bank. Four species of algae were recorded, three chlorophytes, and one xanthophyte. Species included *Rhizoclonium riparium*, *Ulothrix* spp., and *Vaucheria* sp.

132 Skyreburn Bay (Wilkinson 1975) **NX 575545**
Rock, boulders and sand. Eleven algal species were recorded, five chlorophytes, three phaeophytes, two rhodophytes and one xanthophyte. Species included *Blidingia* spp., *Enteromorpha intestinalis*, *Ulva lactuca*, *Fucus spiralis*, *Pelvetia canaliculata*, and *Vaucheria* sp.

133 Skyreburn Bay (Perkins 1973) **NX 577545**
Tussocky marsh and shingle present near Skyre Burn. To the east rocky promontories with

sandy bays were developed. Rocky promontories were colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum* , whilst backing sedimentary shores *Spartina* and *Salicornia* occurred on muddy sand. This then dropped in a short, more steeply sloping bank to the stony bed of the Fleet.

134 Mossyard Bay (Wilkinson 1975) **NX 552518**
Rocks and sand. 41 species of algae were recorded, sixteen chlorophytes, nine phaeophytes, thirteen rhodophytes, two myxophytes and one bacillariophyte. Species included *Blidingia* spp., *Chaetomorpha linum*, *Cladophora* spp., *Enteromorpha intestinalis*, *Ulothrix* spp., *Ascophyllum nodosum*, *Fucus ceranoides*, *Fucus spiralis*, *Fucus vesiculosus*, *Halidrys siliquosa*, *Pelvetia canaliculata*.

135 Auchenlarie (Perkins 1973) **NX 538520**
Moderately exposed rocky shore strewn with boulders, numerous gullies. Dense encrustation of barnacles. Algae reduced on the upper shore. *Pelvetia canaliculata*, *Fucus spiralis*, *Corallina* sp. *Chondrus crispus* and *Mastocarpus stellatus* present.

136 Ravenshall Point (Perkins 1973) **NX 523522**
Exposed shore strewn with barnacle encrusted boulders. Algal populations impoverished with primarily *Pelvetia canaliculata* and *Fucus spiralis*. Some *Ascophyllum nodosum*, *Fucus vesiculosus*, and *Laminaria* sp. occurred. Some shingle was present at the top of the shore. Increased deposition of fine sediment was noticed on a subsequent visit.

137 Carsluith (Perkins 1973) **NX 484548**
Upper shore of shingle and saltmarsh. *Pelvetia canaliculata*, and *Fucus spiralis* occurred in zones where coarse sand and mud occurred in layers. Below this *Ascophyllum nodosum*, and *Fucus vesiculosus* were attached to stones surrounded by soft mud.

138 Cassencarrie (Perkins 1973) **NX 472578**
Shingle and muddy sand. A roadside grass bank dropped steeply to saltmarsh and shingle. This narrow zone gave way to a wider level zone of muddy sand which later sloped to the stony bottom of the Cree. To the south stones were colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum*.

139 Spital (Perkins 1973) **NX 465603**
The northern limit of an extensive saltmarsh was succeeded by marked erosion steps to a short steep bank of muddy sand which fell to the stony bed of the Cree. The algae *Pelvetia canaliculata*, *Fucus spiralis* and *Fucus vesiculosus* occurred on a rock outcrop.

140 Cree viaduct (Perkins 1973) **NX 435635**
Short steep muddy bank of the Cree. An erosion step was present.

141 Shore south of Creetown granite works (Perkins 1973) **NX 475562**
The northern limit of the shore was bounded by a rubble quay of the granite works. To the east a grass bank gave way to a shingle upper shore then to a shore of muddy sand. Intense rubbish deposition. A stony spit was colonised by *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum*.

142 Bladnoch estuary (Wilkinson 1980) **NX 421542**
The shore consisted of a muddy river bank with some stone from walling. Four species of algae were recorded, two *Vaucheria* sp., *Phormidium corium* and *Rhizoclonium riparium.*

143 Eggerness Point (Wilkinson 1980) **NX 4946**
The shore consisted of gently sloping rocky ledges, more steeply sloping rock, with shallow and deep rockpools and areas of boulders. A total of 98 species of algae were recorded.

144 Garlieston Harbour (Wilkinson 1980) **NX 4746 NX 4846**
This area consisted of rock outcrops in sand, shingle, harbour walls with some freshwater inflow at places on the shore. Only five species of algae were recorded, two species of *Blidingia, Chlorochytrium willei, Enteromorpha intestinalis* and *Rhizoclonium riparium.*

145 Isle of Whithorn (Perkins 1973) **NX 478362**
An exposed rocky shore outside the harbour with numerous gullies. Colonised by *Pelvetia canaliculata, Fucus spiralis, Fucus vesiculosus, Fucus serratus, Ascophyllum nodosum, Mastocarpus stellata, Laminaria saccharina* and *Halidrys siliquosa.*

146 Auchenmalg Bay (Perkins 1973) **NX 243516**
Shingle upper shore giving way to large barnacle encrusted boulders. *Pelvetia canaliculata, Fucus spiralis* and *Fucus vesiculosus* were present.

147 Philip and Mary (Perkins 1973) **NX 328456**
Sandy shore with some bar development. To the north a spit of rocks was colonised by *Fucus spiralis, Fucus vesiculosus, Fucus serratus, Ascophyllum nodosum,* and *Mastocarpus stellata* (*Gigartina stellata*). Heavy deposition of algae occurs due to the hydrography of the area.

148 Balcarry (Perkins 1973) **NX 198555**
Cliff-backed shingle upper shore, succeeded by sand. A stone and shingle spit ran across the shore. The base of the cliff was colonised by *Pelvetia canaliculata, Fucus spiralis* and *F.vesiculosus,* which in addition to *Porphyra* sp. and *Ulva lactuca* colonised the bound shingle.

149 Sandhead (Eleftheriou and McIntyre 1976) **NX 1050**
The upper foreshore consisted of stones and coarse gravel, becoming sandy below MHWN. 32 faunal species were recorded. Sediment communities were polychaete dominated, *Bathyporeia pilosa* was the only common crustacean, *Tellina tenuis* was the most important mollusc.

150 Sandhead (Perkins 1973) **NX 098495**
Extreme upper shore of shingle, grading into a sandy shore. To the south of the village a bound shingle shore occurred which was colonised by *Fucus spiralis, Fucus vesiculosus,* and *Porphyra* sp. Freshwater input in one area encouraged *Fucus ceranoides, Ulva lactuca* and *Enteromorpha* spp.

151 Maryport, Drummore (Perkins 1973) **NX 143344**

Steeply sloping sandy upper shore with upward facing mid shore sand flat. Bounded by rocks to north and south, at mean low water sand gave way to boulders densely colonised by fucoid algae. Species recorded include *Ulva lactuca*, *Pelvetia canaliculata*, *Fucus spiralis*, *Fucus vesiculosus*, *Fucus serratus*, *Chorda filum*, *Laminaria digitata*, *Ascophyllum nodosum*, and *Polysiphonia lanosa*.

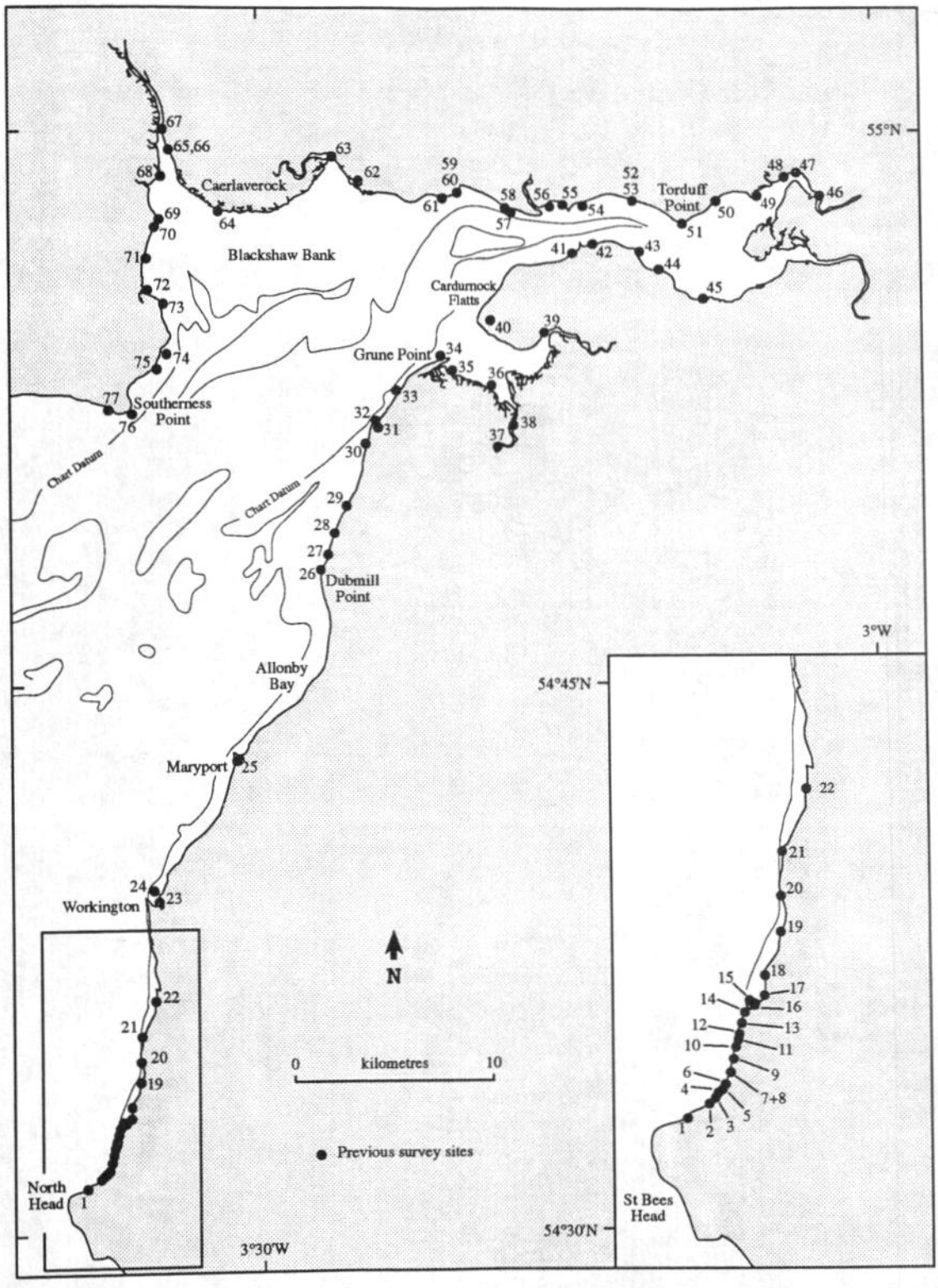

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Figure 3a Locations of sites studied by previous workers

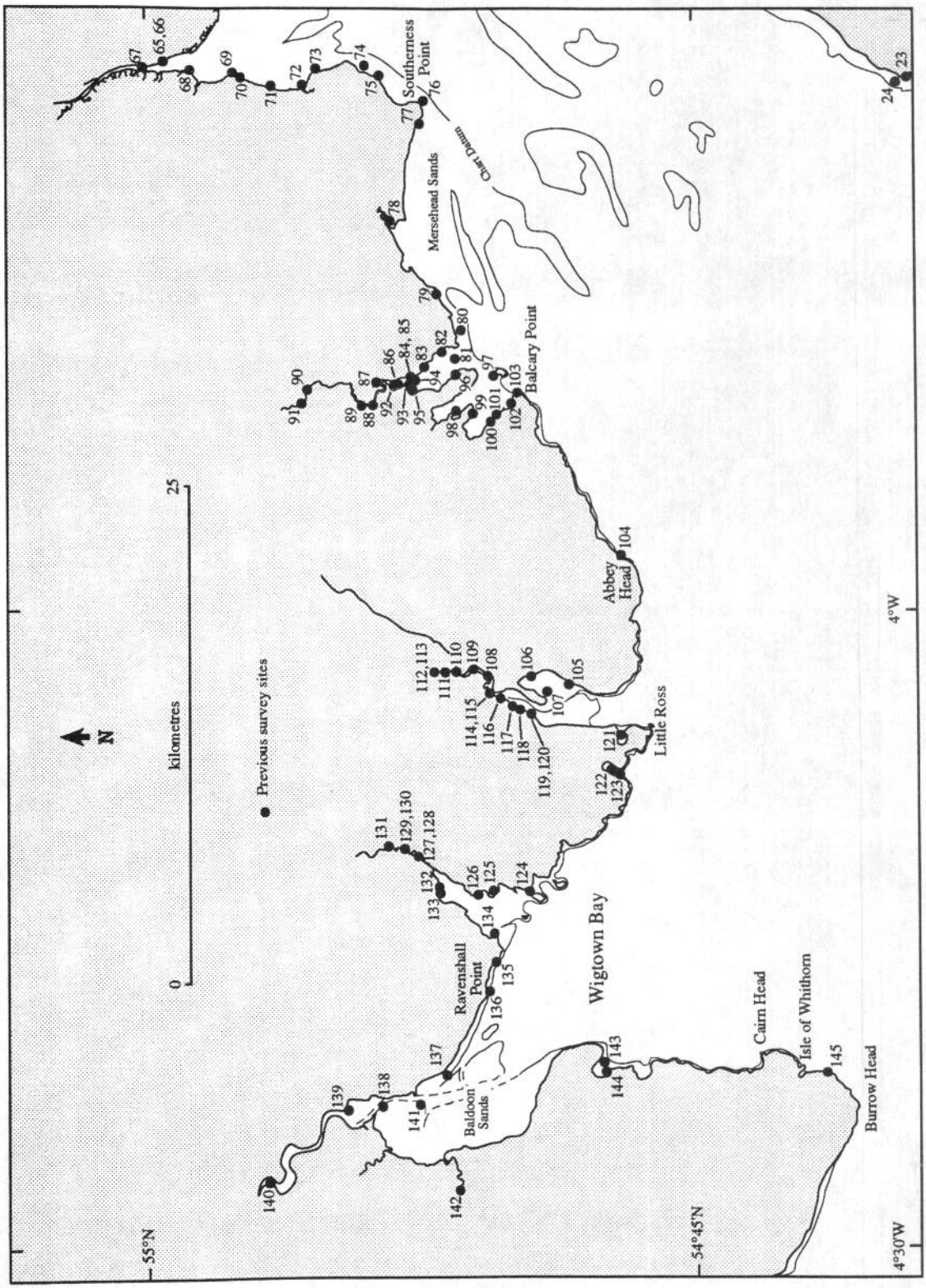

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Figure 3b Locations of sites studied by previous workers

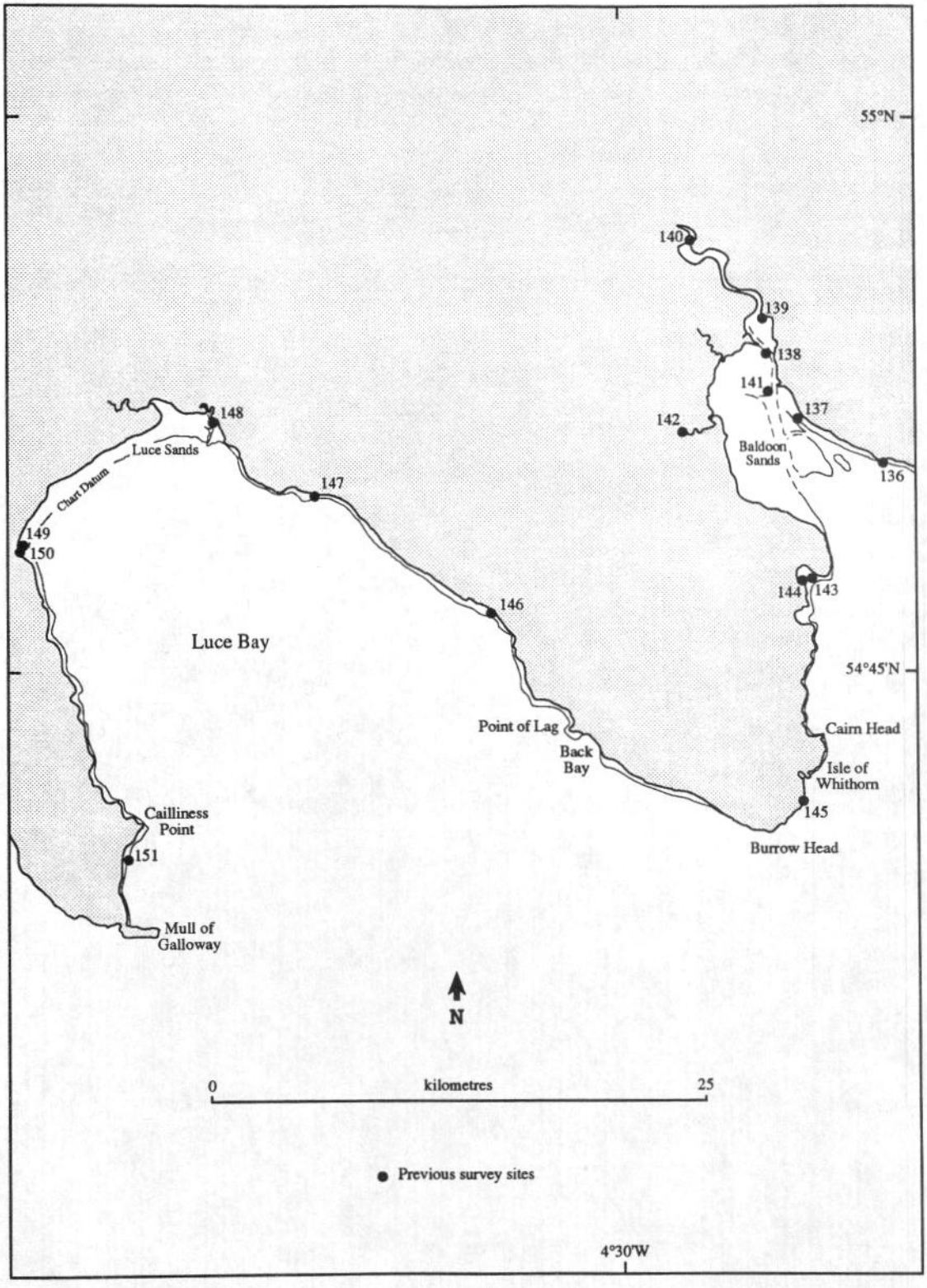

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Figure 3c Locations of sites studied by previous workers

Appendix 3

Description of habitats and communities identified in the survey

A detailed description of each community recorded during the survey is given below. In many cases the description is based on a single site, and the addition of further information from similar habitats from other surveys may necessitate the modification of the community types presented here. Each community description comprises the following sections:

(i) A title for the community, which indicates the main characterising species or features of the community. The community types are numbered consecutively with a prefix ISDG denoting the survey. These numbers do not relate to numbers given to community descriptions in other MNCR survey reports.

(ii) A classification of site and habitat features for the community according to MNCR terms. Where the community is present over a range of conditions the range within each classification category is indicated.

(iii) The distribution of the community in the present survey area. The numbers are the site and habitat numbers which correspond with the database records, i.e. 22.1 is site record 22 and habitat record 1.

(iv) The known or expected extent of the community.

(v) A description of the community, including important physical and biological features, and variations in community structure at particular sites.

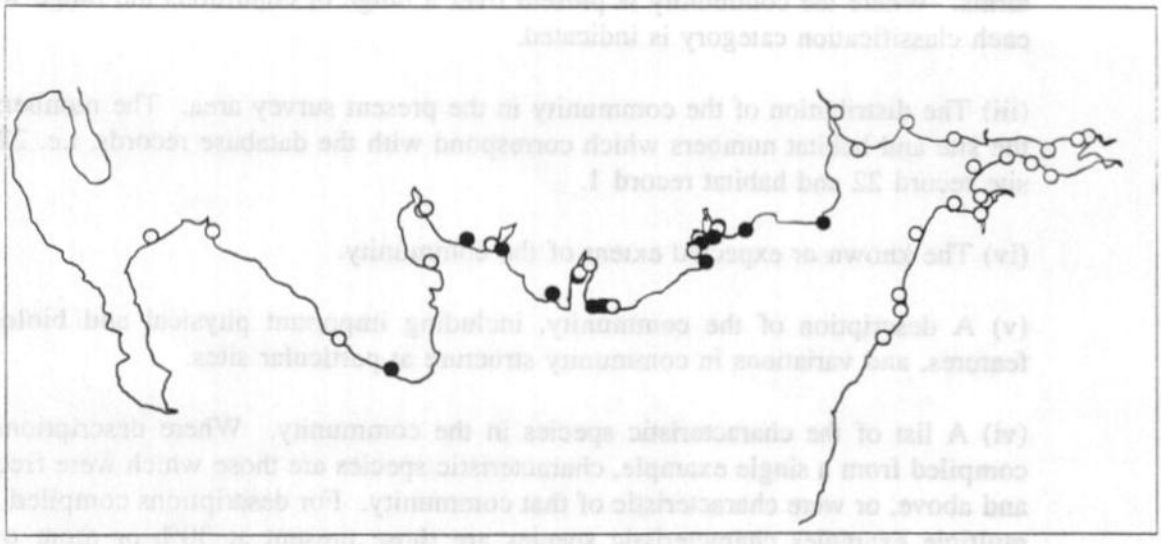
(vi) A list of the characteristic species in the community. Where descriptions are compiled from a single example, characteristic species are those which were frequent and above, or were characteristic of that community. For descriptions compiled from multiple examples characteristic species are those present at 30% or more of the records, present at common or more at any example, or are thought to be characteristic of the community.

COMMUNITY ISDG H1 Supralittoral fringe bedrock and boulders

Classification

Situation:	Enclosed and open coast
Salinity:	Normal/variable
Wave exposure:	Very sheltered to exposed
Tidal streams:	Very weak to moderate
Geology:	Hard - igneous, sandstone, slate Medium - limestone
Zone/range:	Supralittoral fringe; 10 - 11 m acd (36.15.1)
Substratum:	Bedrock and boulders
Modifiers:	Inclination vertical (286.22.1)

Distribution



INNER SOLWAY:

Southerness Point (20.1)
Port O'Warren (21.1)
Port Donnel Beach (22.1)
White Horse Bay (24.2)
Torr Point (26.1)
Balcarry Point (28.1)

DUMFRIES AND GALLOWAY:

SE of Port Castle Bay (4.1)
Ravenshall Point (8.1)
Murray's Isle to Craigmore Point (10.1)
Brighouse Bay (11.1)
Devil's Thrashing Floor/Milton Sands (12.1), (12.2) - both incomplete records
Gipsy Point (15.1)
Middle of Howell Bay (16.1) - incomplete record
East of Howell Bay (17.1)

Extent

Likely to be widespread throughout the survey area.

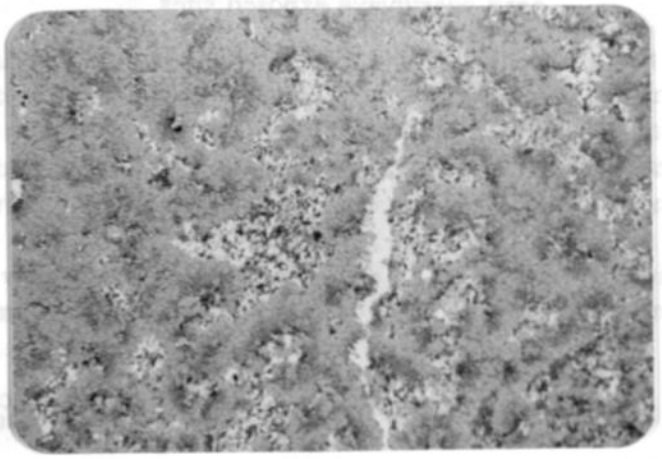


Plate 3 Dense *Xanthoria parientina* on supralittoral bedrock. White Horse Bay, Inner Solway Picture width approximately 50 cm. (S286.24.16, Chris Emblow)

Description

This community was widespread throughout the inner Solway and Dumfries and Galloway where there was stable hard substrata in the supralittoral fringe. The extent of the community was dependent on the wave exposure. The more exposed shores particulary at Ravenshall Point (Dumfries and Galloway 8.1) the zone was fairly extensive and extending 10 - 20 m acd.

The community is characterised by lichens particulary *Verrucaria maura*, *Caloplaca marina*, *Xanthoria parietina* and *Lecanora atra*

Common and characteristic species

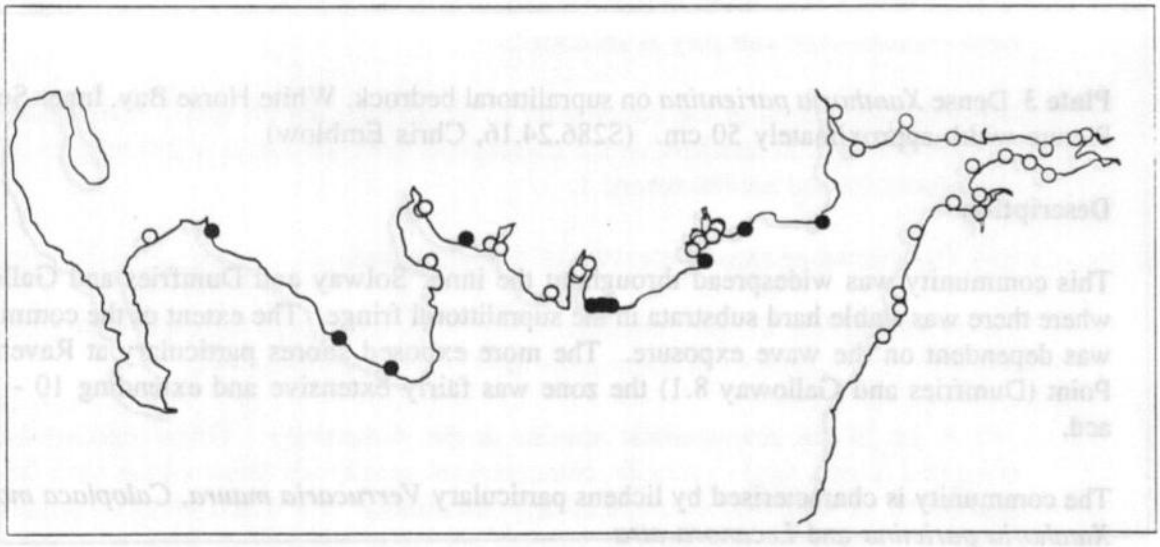
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 15)	%	Range	Median
Caloplaca marina	11	73	P - C	F
Lecanora atra	5	33	F - A	C
Ramalina sp.	8	53	R - A	F
Verrucaria maura	13	87	O - C	F
Xanthoria parietina	9	60	P - A	F
Grey lichens	8	53	O - C	F

COMMUNITY ISDG H2.1 Upper eulittoral-littoral fringe bedrock and boulders at open coast/wave exposed sites

Classification

Situation:	Open coast
Salinity:	Normal/variable
Wave exposure:	Moderately exposed to exposed
Tidal streams:	Very weak to moderate
Geology:	Hard - igneous, sandstone, friable
	Medium - limestone
Zone/range:	Upper littoral fringe to upper eulittoral
Substratum:	Predominantly bedrock and boulders with some cobbles and pebbles.

Distribution



INNER SOLWAY:

Southerness Point (20.2)
Port O'Warren (21.2), (21.3)
Balcarry Point (28.2)

DUMFRIES AND GALLOWAY:

Crow's Nest (2.1)
Point of Lagg (3.1)
SE of Port Castle Bay (4.2)
Ravenshall Point (8.2)
Gipsy Point (15.2)
Middle of Howell Bay (16.2)
East of Howell Bay (17.2)
Mullock Bay (18.1),(18.2)

Extent

Likely to be widespread throughout the outer Solway on the more wave exposed/open coast sites.

Description

The upper littoral fringe/upper eulittoral bedrock and boulder sites subject to high wave exposure were characterised by the lichen *Verrucaria maura*, and the algae *Pelvetia canaliculata* and rough periwinkle *Littorina saxatilis*. The top of the zone was frequently dominated by a band of *Chthalamus montagui*. The crevices and less exposed rock faces were colonised with *Catenella caespitosa* with frequent *Patella vulgata* on the open rock.

This community was extremely variable in species dominance and biomass of each species and the total biomass, although the composition of the species present was constant.

Common and characteristic species

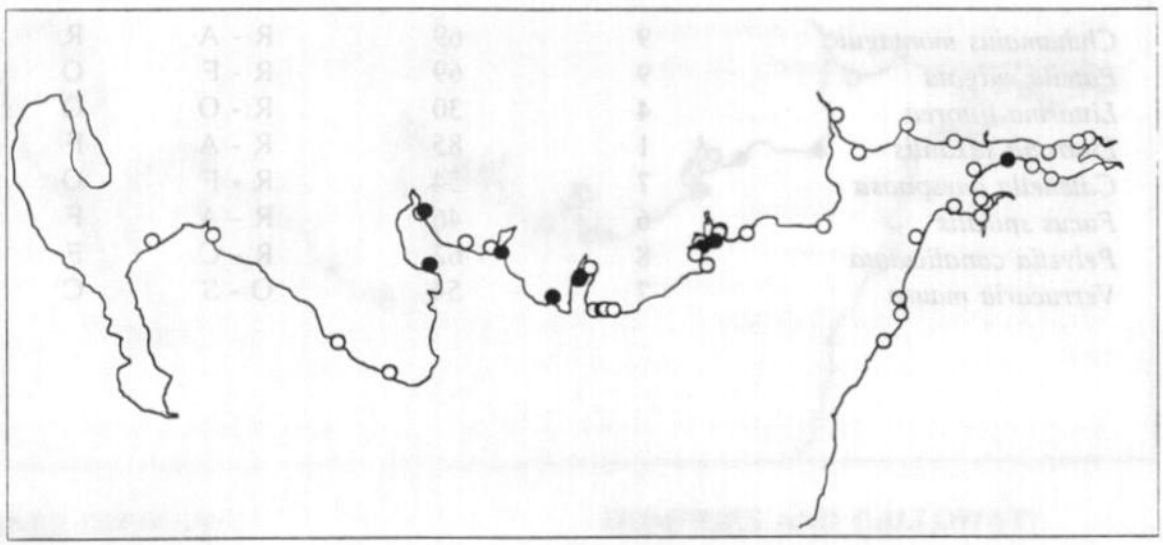
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 14)	%	Range	Median
Chthamalus montagui	9	69	R - A	R
Patella vulgata	9	69	R - F	O
Littorina littorea	4	30	R - O	O
Littorina saxatilis	1	85	R - A	F
Catenella caespitosa	7	54	R - F	O
Fucus spiralis	6	46	R - A	F
Pelvetia canaliculata	8	62	R - C	F
Verrucaria maura	7	54	O - S	C

COMMUNITY ISDG H2.2 Upper eulittoral-littoral fringe bedrock and boulders at enclosed coast/wave sheltered sites

Classification

Situation:	Enclosed coast
Salinity:	Normal/variable
Wave exposure:	Very sheltered to moderately exposed
Tidal streams:	Very weak (uncertain)
Geology:	Hard - igneous, slate
Zone/range:	Upper littoral fringe to upper eulittoral
Substratum:	Predominantly bedrock and boulders with some cobbles and pebbles. At one site (inner Solway 10) the substratum was 100% stonework (quay).

Distribution



INNER SOLWAY:

Herdhill Scar (10.2, 10.3)
Port Donnel Beach (22.2)
White Horse Bay (24.3)
Torr Point (26.2)

DUMFRIES AND GALLOWAY:

Innerwell Fisheries (5.1)
Creetown Quay (7.1)
Murray's Isle to Craigmore Point (10.2)
Brighouse Bay (11.2)
Devil's Thrashing Floor/Milton Sands (12.3)
Tip of St Mary's Isle (13.1)

Extent

Likely to be widespread throughout the survey area where the coast is sheltered from wave

action.

Description

The sheltered enclosed sites of upper littoral fringe and upper eulittoral bedrock were dominated by *Pelvetia canaliculata* and/or *Fucus spiralis*. The Australasian barnacle *Elminius modestus* was occasional on the rock surfaces not covered by algae. *Enteromorpha* sp. was occasional at the more sheltered sites. *Catenella caespitosa* was rare to common in the crevices.

Common and characteristic species

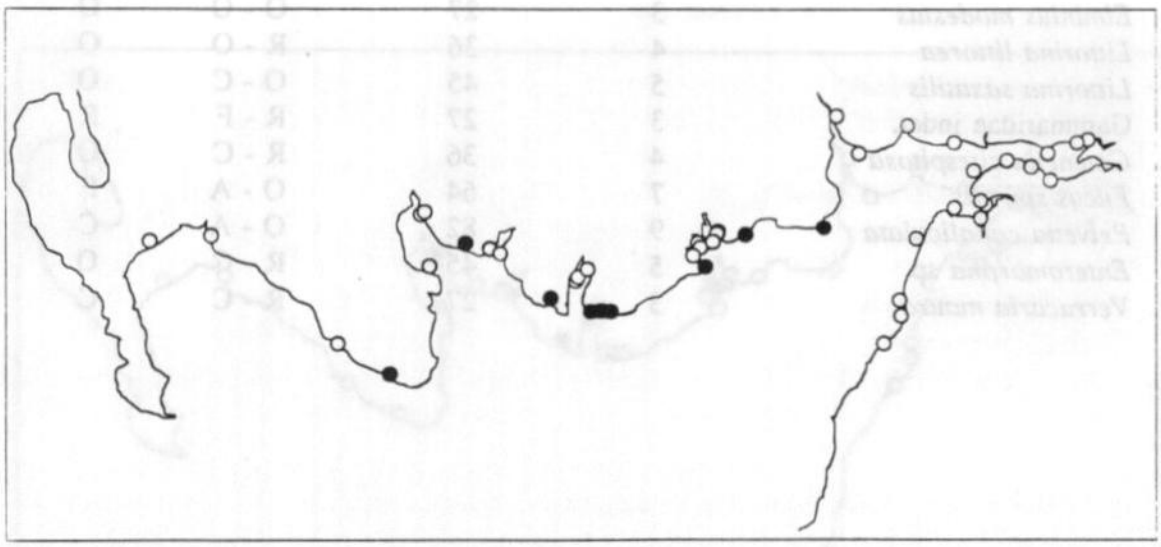
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 11)	%	Range	Median
Elminius modestus	3	27	O - O	O
Littorina littorea	4	36	R - O	O
Littorina saxatilis	5	45	O - C	O
Gammaridae indet.	3	27	R - F	R
Catenella caespitosa	4	36	R - C	O
Fucus spiralis	7	64	O - A	F
Pelvetia canaliculata	9	82	O - A	C
Enteromorpha sp.	5	45	R - C	O
Verrucaria maura	3	27	R - C	C

COMMUNITY ISDG H3.1 Mid-shore bedrock and boulders at open coast/wave exposed sites

Classification

Situation:	Open coast and enclosed coast
Salinity:	Normal
Wave exposure:	Moderately exposed to exposed
Tidal streams:	Very weak to weak (uncertain)
Geology:	Hard - igneous, slate
	Medium - limestone
	Friable
Zone/range:	Eulittoral; 1 - 8 m acd (Dumfries and Galloway site 15)
Substratum:	100% bedrock

Distribution



INNER SOLWAY:

Southerness Point (20.3)
Port O' Warren (21.4)
Balcarry Point (28.3, 28.4)

DUMFRIES AND GALLOWAY:

SE of Port Castle Bay (4.3)
Ravenshall Point (8.3)
Brighouse Bay (11.3)
Gipsy Point (15.3, 15.4)
Middle of Howell Bay (16.3)
East of Howell Bay (17.3)
Mullock Bay (18.3)

Extent

Likely to be widespread in the survey area especially along the outer Solway coast on the more wave exposed/open coast sites.

Plate 4 Zonation in the mid/upper shore , Ravenshall Point, Wigtown Bay, Dumfries and Galloway (S36.8.2. Chris Emblow)

Plate 5 Fucoid and barnacle characterised middle shore, Port O' Warren, inner Solway Picture width approximately 3 m. (S286.21.8. L. Mark Davies)

Description

All the sites at which this community was found were exclusively bedrock and were exposed or moderately exposed to wave action. The rock was dominated by the barnacle *Balanus balanoides* with the Australasian barnacle *Elminius modestus* rare to common. Amongst the barnacles the predatory dogwhelk *Nucella lapillus* was frequent. Other characteristic species

included the edible mussel *Mytilus edulis* which was rare to common particulary at the sites were the bedrock gave way to sand and on the vertical rock at Gipsy Point. Two species of fucoid algae were found particulary *Fucus vesiculosus*, with *Ascophyllum nodosum* rare to frequent on the more sheltered rock faces. *Corallina officinalis* and coralline crusts were representative of the red algae occurring in rockpools. Barnacles dominated the steep and vertical rock with *Ulva* sp. and *Enteromorpha* sp. characteristic of the horizontal and flatter areas.

Common and characteristic species

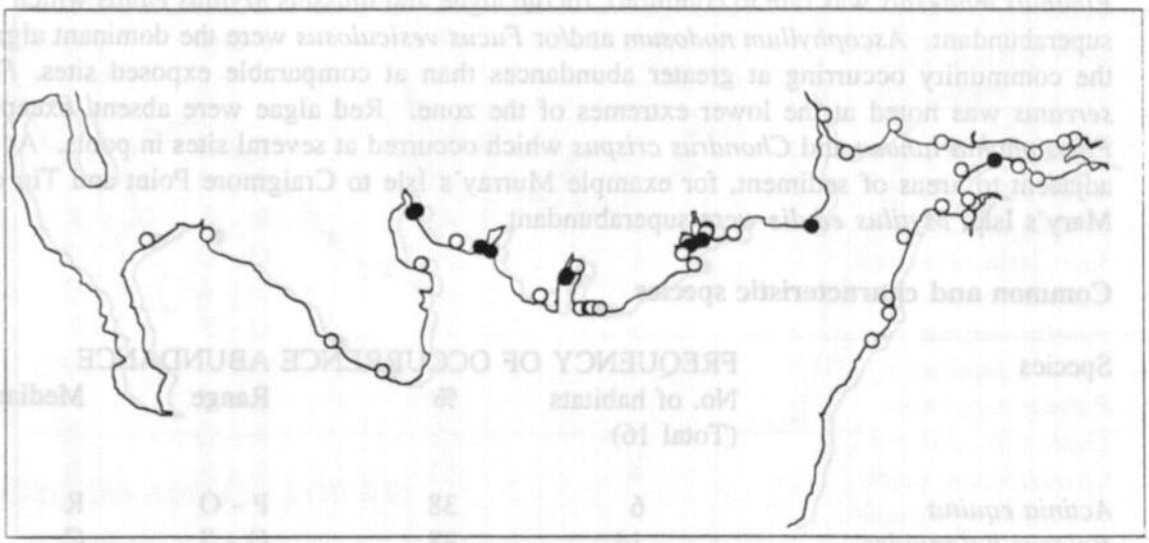
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 12)	%	Range	Median
Actinia equina	7	58	R - O	R
Balanus balanoides	12	100	F - S	A
Elminius modestus	8	67	R - C	O
Carcinus maenas	5	42	R - O	R
Anurida maitima	4	33	P - F	R
Patella vulgata	8	67	R - A	F
Littorina littorea	7	58	R - A	O
Nucella lapillus	11	92	R - F	F
Mytilus edulis	8	67	R - C	O
Palmaria palmata	4	33	R - F	R
Corallinaceae indet.	8	67	R - O	R
Corallina officinalis	7	58	R - O	R
Mastocarpus stellatus	5	42	R - O	R
Catenella caespitosa	4	33	R - O	R
Ceramium sp.	6	50	R - O	R
Laurencia pinnatifida	4	33	R - F	O
Ascophyllum nodosum	5	42	R - F	F
Fucus vesiculosus	7	58	R - C	F
Enteromorpha sp.	9	75	R - F	R
Ulva sp.	10	83	R - O	R
Cladophora sp.	4	33	R - R	R

COMMUNITY ISDG H3.2 Mid-shore bedrock and boulders at enclosed coast/ sheltered sites

Classification

Situation:	Enclosed coast
Salinity:	Normal to variable (unknown)
Wave exposure:	Very sheltered to sheltered
Tidal streams:	Very weak to moderate (uncertain)
Geology:	Hard - igneous
Zone/range:	Eulittoral
Substratum:	Predominantly bedrock and boulders although some sites had a small percentage of cobbles, pebbles, gravel sand and mud. At one site (inner Solway 10) the substratum was 100% stonework.

Distribution



INNER SOLWAY:

Herdhill Scar (10.4)
Southerness Point (20.5)
Port Donnell Beach (22.3, 22.4)
White Horse Bay (24.4)
Torr Point (26.3)

DUMFRIES AND GALLOWAY:

Wigtown Sands (6.2)
Creetown Quay (7.3)
Mossyard Bay (9.2 - incomplete record, 9.3, 9.4)
Murray's Isle to Craigmore Point (10.3, 10.4)
Devil's Thrashing Floor/Milton Sands (12.4)
Tip of St Mary's Isle (13.2 - incomplete record, 13.3)

Extent

Likely to be widespread throughout the survey area where the coast is sheltered from wave action.

Description

All the sites with this community were predominantly bedrock or boulders. At some sites the substrata was slightly varied where in addition to the bedrock and boulders there was a small percentage of cobbles and pebbles. At Wigtown Sands there were small patches of sand and mud between the boulders although the general community structure appeared unaffected. All the sites were in enclosed inlets or bays with little direct exposure to wave action and were classed as very sheltered or sheltered. Wigtown Sands was adjacent to the Bladnock river and possibly subject to variations in salinity although this again does not appear to affect the general community structure.

The community is characterised by barnacles, particulary *Balanus balanoides* (although *Elminius modestus* was rare to common), fucoid algae and mussels *Mytilus edulis* which were superabundant. *Ascophyllum nodosum* and/or *Fucus vesiculosus* were the dominant algae of the community occurring at greater abundances than at comparable exposed sites. *Fucus serratus* was noted at the lower extremes of the zone. Red algae were absent, except for *Polysiphonia lanosa* and *Chondrus crispus* which occurred at several sites in pools. At sites adjacent to areas of sediment, for example Murray's Isle to Craigmore Point and Tip of St Mary's Isle, *Mytilus edulis* were superabundant.

Common and characteristic species

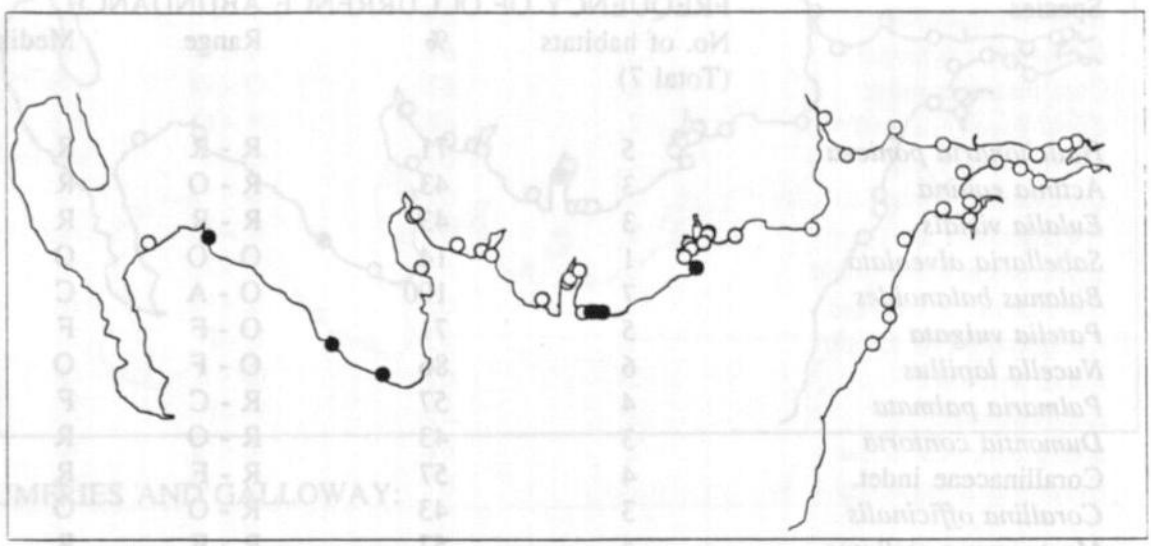
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 16)	%	Range	Median
Actinia equina	6	38	P - O	R
Balanus balanoides	14	88	O - S	C
Elminius modestus	5	31	R - C	O
Carcinus maenas	10	63	P - O	R
Littorina littorea	11	73	P - F	F
Nucella lapillus	9	56	P - O	O
Mytilus edulis	15	94	O - S	F
Chondrus crispus	5	33	P - O	R
Polysiphonia lanosa	7	44	R - F	O
Ascophyllum nodosum	14	88	R - S	C
Fucus vesiculosus	14	88	R - A	O

COMMUNITY ISDG H4 Lower eulittoral moderately exposed to exposed bedrock and boulders

Classification

Situation:	Enclosed and open coast
Salinity:	Variable to normal
Wave exposure:	Moderately exposed to exposed
Tidal streams:	Very weak to weak
Geology:	Hard - igneous, slate, friable Medium - limestone
Zone/range:	Lower eulittoral
Substratum:	Predominantly bedrock, boulders with some cobbles, pebbles and gravel between

Distribution



INNER SOLWAY:

Balcarry Point (28.5)

DUMFRIES AND GALLOWAY:

Crow's Nest (2.4)
Point of Lagg (3.4)
SE of Port Castle Bay (4.4)
Middle of Howell Bay (16.5)
East of Howell Bay (17.4)
Mullock Bay (18.4)

Extent

Unlikely to occur in the inner Solway and limited to the open coast of the outer Solway, where it is likely to be widespread.

Description

This community was present on bedrock and stable boulders on the lower shore. At some sites the boulders had patches of pebbles and gravel between them. All the sites were moderately exposed or exposed to wave action and subject to very weak or weak tidal streams.

This community is characterised by the fucoid algae *Fucus serratus*, *Balanus balanoides*, *Nucella lapillus* and *Patella vulgata*. The red algae, *Palmaria palmata*, *Mastocarpus stellatus* and *Lomentaria articulata*, and green algae, *Enteromorpha* occurred between the boulders and on the less exposed rock faces. Coralline crusts occurred on the bedrock and boulders under the fucoids and in rockpools. At three sites where the hard substrata was adjacent to lower shore sediment (inner Solway (28.5); Dumfries and Galloway (11.4), (18.4)) tubes of the polychaete *Sabellaria alveolata* were found. The reefs were badly eroded and live animals were recorded from one site only. Towards the lower end of the zone *Laminaria digitata* was recorded.

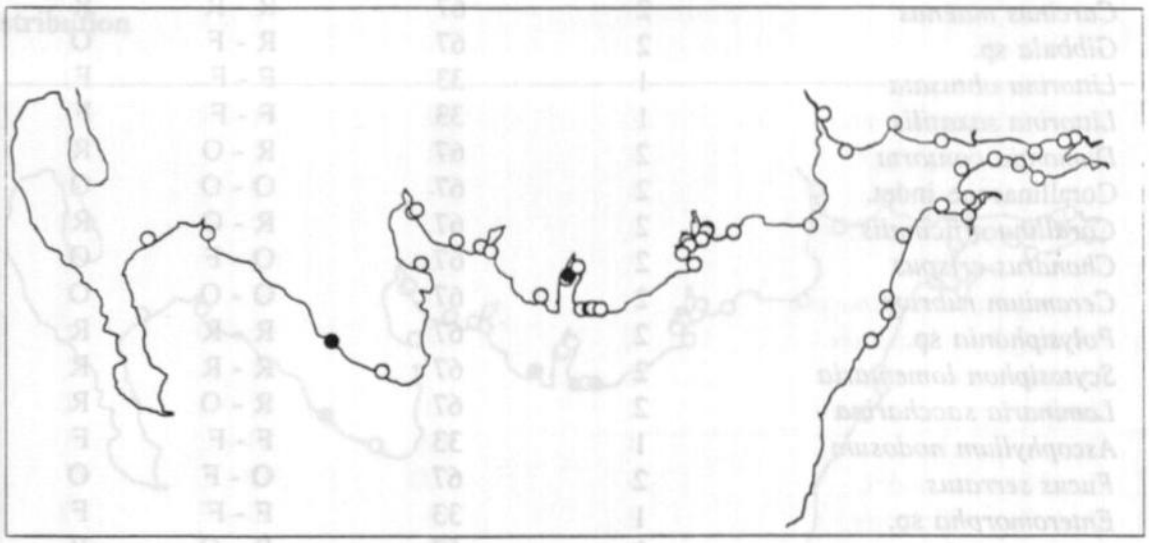
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 7)	%	Range	Median
Halichondria panicea	5	71	R - R	R
Actinia equina	3	43	R - O	R
Eulalia viridis	3	43	R - R	R
Sabellaria alveolata	1	14	O - O	O
Balanus balanoides	7	100	O - A	C
Patella vulgata	5	71	O - F	F
Nucella lapillus	6	86	O - F	O
Palmaria palmata	4	57	R - C	F
Dumontia contorta	3	43	R - O	R
Corallinaceae indet.	4	57	R - F	R
Corallina officinalis	3	43	R - O	O
Mastocarpus stellatus	4	57	R - F	R
Ceramium sp.	3	43	O - F	O
Laurencia pinnatifida	4	57	O - F	O
Laminaria digitata	3	43	R - O	R
Fucus serratus	7	100	F - C	F
Enteromorpha sp.	5	71	O - C	F
Ulva sp.	5	71	R - O	O

COMMUNITY ISDG H5 Mid and lower eulittoral rockpools

Classification

Situation:	Enclosed and open coast
Salinity:	Normal
Wave exposure:	Sheltered to exposed
Tidal streams:	Very weak
Geology:	Hard
Zone/range:	Eulittoral
Substratum:	Bedrock and boulders

Distribution



DUMFRIES AND GALLOWAY:

Point of Lagg (3.3)
Tip of St Mary's Isle (13.4) - incomplete record
Middle of Howell Bay (16.4)

Extent

Unlikely to be widespread in the inner Solway although possibly common along the outer Solway in the midshore.

Description

Rockpools in the eulittoral. At two of the sites the pools were formed in depressions in bedrock. At the Point of Lagg the pool was created in a depression in the boulder shore, with an underlying clay layer retaining the water.

Species composition was predominantly algal dominated with the red algae *Corallina officinalis*, *Chondrus crispus* and *Ceramium rubrum*, and brown algae *Ascophyllum nodosum* and *Fucus serratus*. The pool at Point of Lagg had a particulary dense growth of red algae. Coralline crusts occurred on the rock surfaces. The dominant animals were the littorinids *Littorina obtusata* and *Littorina saxatilis* and *Gibbula* sp. The beadlet anemone *Actinia equina* was present in low abundance in all of the pools.

Common and characteristic species

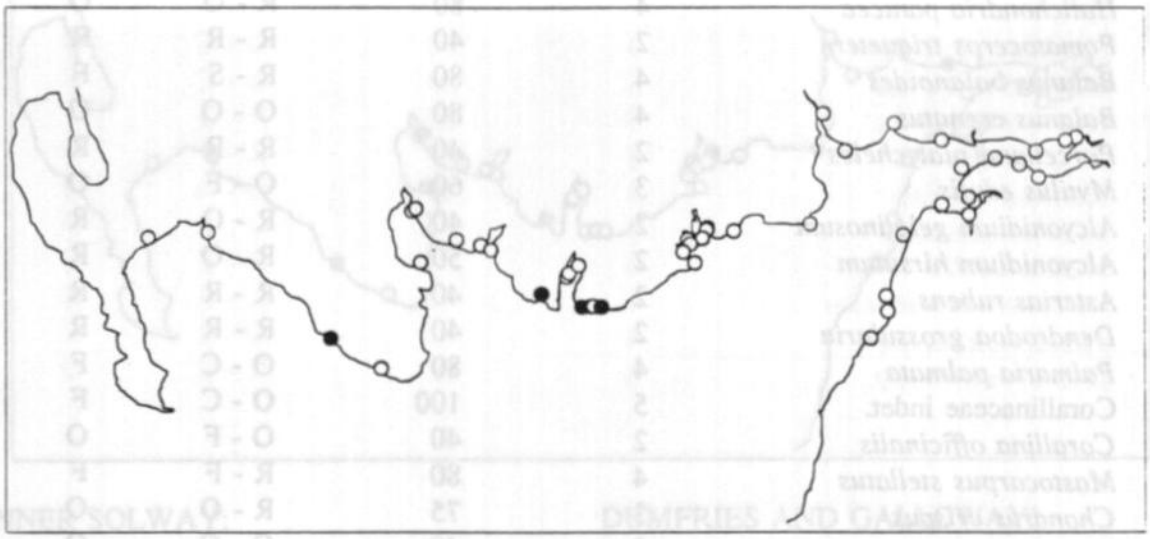
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 3)	%	Range	Median
Actinia equina	3	100	R- R	R
Carcinus maenas	2	67	R - R	R
Gibbula sp.	2	67	R - F	O
Littorina obtusata	1	33	F - F	F
Littorina saxatilis	1	33	F - F	F
Dumontia contorta	2	67	R - O	R
Corallinaceae indet.	2	67	O - O	O
Corallina officinalis	2	67	R - O	R
Chondrus crispus	2	67	O - F	O
Ceramium rubrum	2	67	O - O	O
Polysiphonia sp.	2	67	R - R	R
Scytosiphon lomentaria	2	67	R - R	R
Laminaria saccharina	2	67	R - O	R
Ascophyllum nodosum	1	33	F - F	F
Fucus serratus	2	67	O - F	O
Enteromorpha sp.	1	33	F - F	F
Spongomorpha arcta	2	67	R - O	R
Cladophora rupestris	2	67	O - O	O

COMMUNITY ISDG H6 Sublittoral fringe bedrock and boulders

Classification

Situation:	Enclosed and open coast
Salinity:	Normal
Wave exposure:	Moderately exposed to exposed
Tidal streams:	Very weak to weak
Geology:	Hard - slate, friable Medium
Zone/range:	Sublittoral fringe
Substratum:	Predominantly bedrock, boulders with some cobbles, pebbles and gravel between.

Distribution



DUMFRIES AND GALLOWAY:

Point of Lagg (3.5)
Brighouse Bay (11.5) - incomplete record
Gipsy Point (15.5)
Middle of Howell Bay (16.6) - incomplete record
Mullock Bay (18.5)

Extent

Likely to be occur at open coast and enclosed coast sites with sublittoral fringe hard substrata along the outer Solway coast.

Description

Present on extreme lower shore bedrock and boulders in the outer Solway and Dumfries and

Galloway. All the sites were moderately exposed or exposed to wave action and very weak or weak tidal streams.

Characteristic species are the kelps *Laminaria hyperborea*, *Laminaria saccharina* and *Alaria esculenta*. The barnacles *Balanus balanoides* and *Balanus crenatus* were superabundant to common. Coralline crusts covered the rock surfaces along with the red algae *Palmaria palmata*, *Mastocarpus stellatus* and *Chondrus crispus* occasional to frequent amongst the kelp. The sponge *Halichondria panicea* was occasional in the crevices and underboulders. *Fucus serratus* was present in the upper part of the zone.

Common and characteristic species

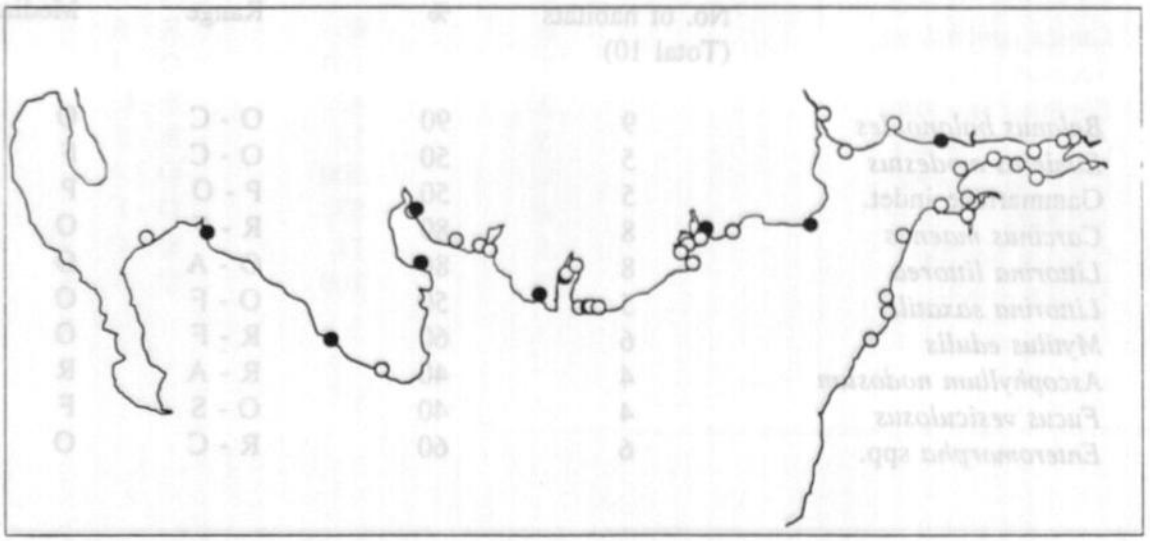
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 5)	%	Range	Median
Halichondria panicea	4	80	R - O	O
Pomatoceros triqueter	2	40	R - R	R
Balanus balanoides	4	80	R - S	F
Balanus crenatus	4	80	O - O	O
Porcellana platycheles	2	40	R - R	R
Mytilus edulis	3	60	O - F	O
Alcyonidium gelatinosum	2	40	R - O	R
Alcyonidium hirsutum	2	50	R - O	R
Asterias rubens	2	40	R - R	R
Dendrodoa grossularia	2	40	R - R	R
Palmaria palmata	4	80	O - C	F
Corallinaceae indet.	5	100	O - C	F
Corallina officinalis	2	40	O - F	O
Mastocarpus stellatus	4	80	R - F	F
Chondrus crispus	3	75	R - O	O
Ceramium sp.	2	40	O - O	O
Laminaria digitata	5	100	O - A	F
Laminaria saccharina	2	40	R - F	R
Alaria esculenta	3	60	F - F	F
Fucus serratus	2	40	O - C	O
Ulva sp.	2	40	R - R	R

COMMUNITY ISDG M1 Clean boulders and cobbles on the open coast.

Classification

Situation:	Open coast/enclosed coast
Salinity:	Normal to variable
Wave exposure:	Exposed to very sheltered
Tidal streams:	Moderate to nil
Geology:	Hard - igneous, sandstone
Zone/range:	Eulittoral
Substratum:	Boulders and cobbles with little or no sand and mud

Distribution



INNER SOLWAY:

Powfoot Scar (16.1)
Southerness Point (20.4)
Rough Island Causeway (23.1)

DUMFRIES AND GALLOWAY:

Crow's Nest, Luce Bay (2.2)
Point of Lagg (3.2)
Innerwell Fishery (5.2)
Creetown Quay (7.2)
Brighouse Bay (11.4)
Devil's Thrashing Floor (12.5)
Middle of Howell Bay (16.7)

Extent

Likely to be widespread in the survey area

Description

This community occurred on mixture of clean boulders, cobbles and pebbles which did not

rest on sediment. The substratum type varied from 50% boulders and 50% cobbles at Brighouse Bay, to 40% pebbles and 20% cobbles with some gravel at Powfoot Scar. Wave exposure at the sites where this community was described varied from exposed at Southerness Point, to very sheltered at Rough Island Causeway and Innerwell Fishery. Exposure within these limits appeared not to substantially affect the community, which was characterised by a limited range of epifaunal species. Chief amongst these were the barnacles *Balanus balanoides*, and *Elminius modestus*, the littorinids *Littorina saxatilis* and *Littorina littorea*, and occasional mussels *Mytilus edulis* and green algae *Enteromorpha* spp. Also present in varying abundances at three of the examples were the brown algae *Ascophyllum nodosum* and *Fucus vesiculosus*.

Common and characteristic species

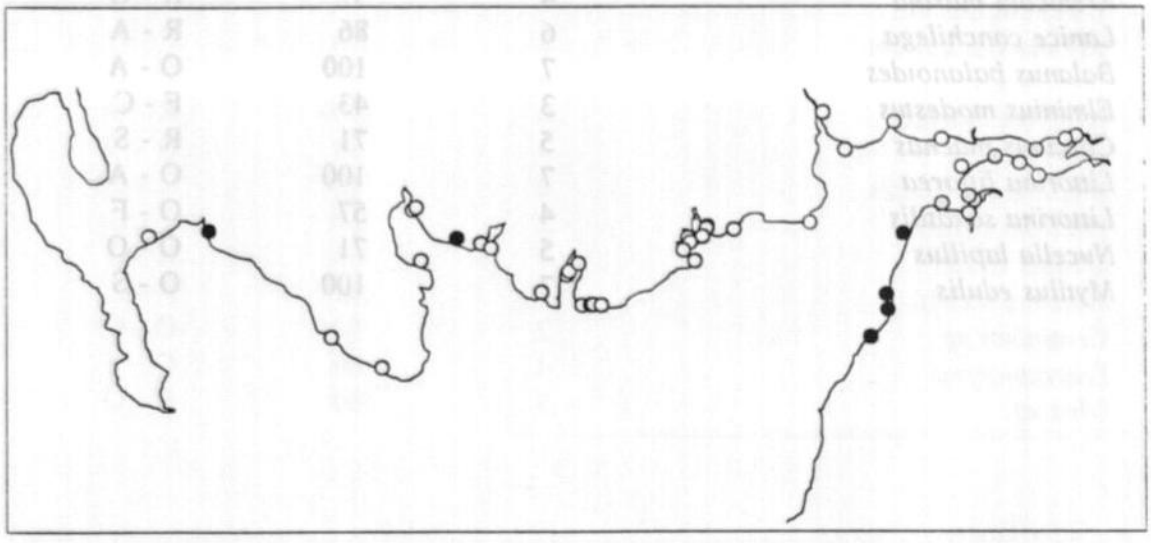
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 10)	%	Range	Median
Balanus balanoides	9	90	O - C	O
Elminius modestus	5	50	O - C	F
Gammaridae indet.	5	50	P - O	P
Carcinus maenas	8	80	R - F	O
Littorina littorea	8	80	O - A	O
Littorina saxatilis	5	50	O - F	O
Mytilus edulis	6	60	R - F	O
Ascophyllum nodosum	4	40	R - A	R
Fucus vesiculosus	4	40	O - S	F
Enteromorpha spp.	6	60	R - C	O

COMMUNITY ISDG M2 Open coast cobble exposures with *Mytilus edulis*

Classification

Situation:	Enclosed and open coast
Salinity:	Normal
Wave exposure:	Exposed to moderately exposed
Tidal streams:	nil
Geology:	Hard - igneous
Zone/range:	Eulittoral
Substratum:	Boulders, cobbles, pebbles, sand and gravel

Distribution



INNER SOLWAY:

NW of Brown Rigg (1.2)
Allonby Scar (2.3, 2.4)
Dubmill Scar (3.2)
Silloth Lighthouse (4.4)

DUMFRIES AND GALLOWAY:

Crow's Nest (2.3)
Ravenshall Point (8.4)

Extent

Widespread on many of the rocky scars in the Solway, though more characteristic of the Cumbrian than the Dumfries and Galloway coast.

Description

This community was typically found on mussel scars, where a mixture of cobbles and sediment with *Mytilus edulis* occurred. Due to the sediment trapped by the mussels and the deposition of pseudofaeces, infaunal species were able to colonise the habitat.

Characterising species were the mussel *Mytilus edulis*, with the barnacles *Balanus balanoides* and *Elminius modestus* finding settlement sites on the mussel shells and larger cobbles and pebbles. The edible periwinkle *Littorina littorea* was found at all examples, ranging from abundant to occasional. Between the mussels, in the associated sediment were occasional lugworms *Arenicola marina* and occasional sandmason worms *Lanice conchilega*.

Common and characteristic species

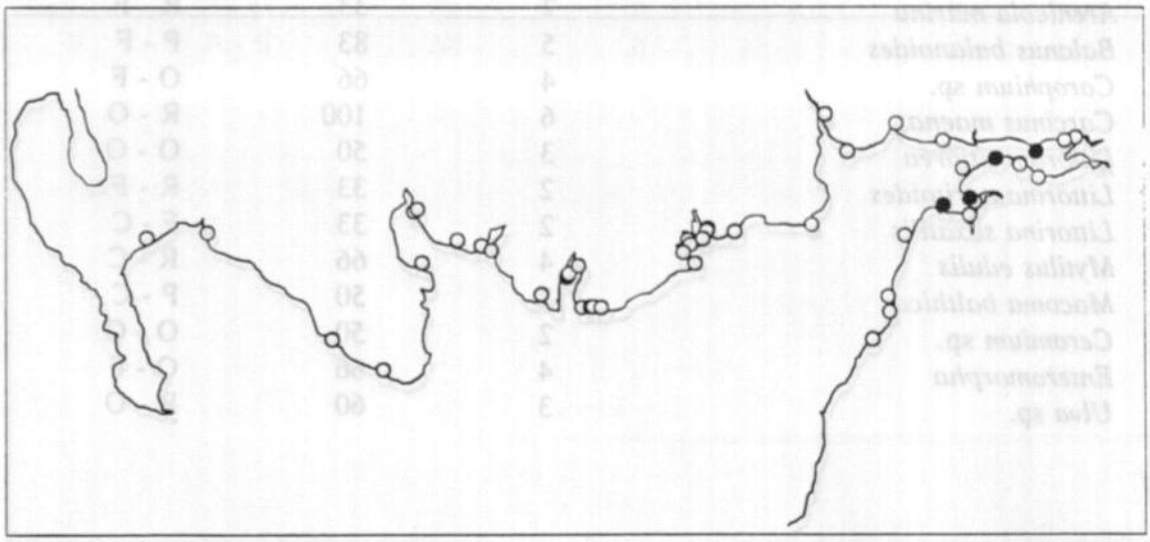
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 7)	%	Range	Median
Actinia equina	3	43	R - R	R
Arenicola marina	4	57	R - O	R
Lanice conchilega	6	86	R - A	O
Balanus balanoides	7	100	O - A	F
Elminius modestus	3	43	F - C	C
Carcinus maenas	5	71	R - S	O
Littorina littorea	7	100	O - A	O
Littorina saxatilis	4	57	O - F	O
Nucella lapillus	5	71	O - O	O
Mytilus edulis	7	100	O - S	A

COMMUNITY ISDG M3 Poorly sorted cobbles and pebbles on mud

Classification

Situation:	Enclosed coast
Salinity:	Normal
Wave exposure:	Moderately exposed to very sheltered
Tidal streams:	moderate to nil
Geology:	Hard - friable, mudstone
Zone/range:	Eulittoral
Substratum:	Boulders, cobbles and pebbles with mud and sand.

Distribution



INNER SOLWAY:

Grune Point (5.4)
Longdyke Scar (8.1, 8.2)
Herdhill Scar (10.6)
Torduff Point (15.1)

DUMFRIES AND GALLOWAY:

Devil's Thrashing Floor/Milton Sands (12.7)

Extent

Small areas of this habitat are likely to occur throughout sheltered areas of the inner Solway.

Description

This community occurred on poorly sorted mixtures of cobbles and pebbles on sand, gravel and mud. All examples came from enclosed coast sites, where sheltered conditions are likely to encourage the settlement of finer particulate material in the interstices between the larger pebbles and cobbles.

Although the salinity was recorded as normal at all examples, the ubiquitous presence of the polychaete *Hediste diversicolor*, the amphipod *Corophium volutator* and the bivalve *Macoma balthica*, would indicate that salinity is more likely to be variable or low. Other characterising species include the barnacle *Balanus balanoides*, the crab *Carcinus maenas* and the green alga *Ulva* sp. In contrast to other mixed substratum habitats, the Australasian barnacle *Elminius modestus* was rarely recorded, being noted only in one example.

Common and characteristic species

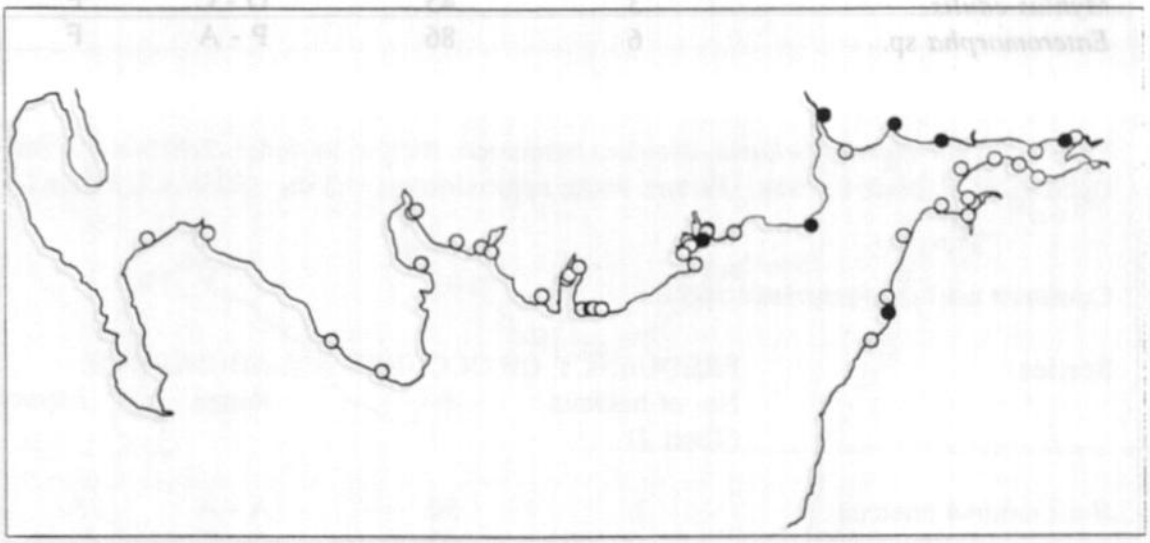
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 6)	%	Range	Median
Hediste diversicolor	5	83	R - C	F
Arenicola marina	2	33	R - F	R
Balanus balanoides	5	83	P - F	F
Corophium sp.	4	66	O - F	O
Carcinus maenas	6	100	R - O	O
Littorina littorea	3	50	O - O	O
Littorina neritoides	2	33	R - F	R
Littorina saxatilis	2	33	F - C	F
Mytilus edulis	4	66	R - C	O
Macoma balthica	2	50	P - C	P
Ceramium sp.	2	50	O - C	O
Enteromorpha	4	66	O - F	O
Ulva sp.	3	60	R - O	O

COMMUNITY ISDG M4 Mid and lower eulittoral boulders and cobbles

Classification

Situation:	Open coast and enclosed coast
Salinity:	Normal to low
Wave exposure:	Exposed to extremely sheltered
Tidal streams:	Moderate to weak
Geology:	Hard - igneous
Zone/range:	Mid and lower eulittoral
Substratum:	Boulders and cobbles

Distribution



INNER SOLWAY:

Allonby Scar (2.2)
Redkirk Point (14.1)
Powfoot Scar (16.2)
Stanhope (17.2)
Glencaple (19.2)
Southerness Point (20.6)
White Horse Bay (24.5)

Extent

Likely to be widespread on the lower shore of many of the boulder scars of the Cumbrian coast.

Description

This community was found on boulders, cobbles and pebbles in the mid and lower eulittoral.

Species diversity was low, with only the barnacle *Elminius modestus*, the crab *Carcinus maenas* and the green alga *Enteromorpha* being characteristic. In contrast to other mixed substratum sites the native barnacle *Balanus balanoides* was not widely recorded, being noted as present at only one site. In its place was the Australasian barnacle *Elminius modestus*.

Common and characteristic species

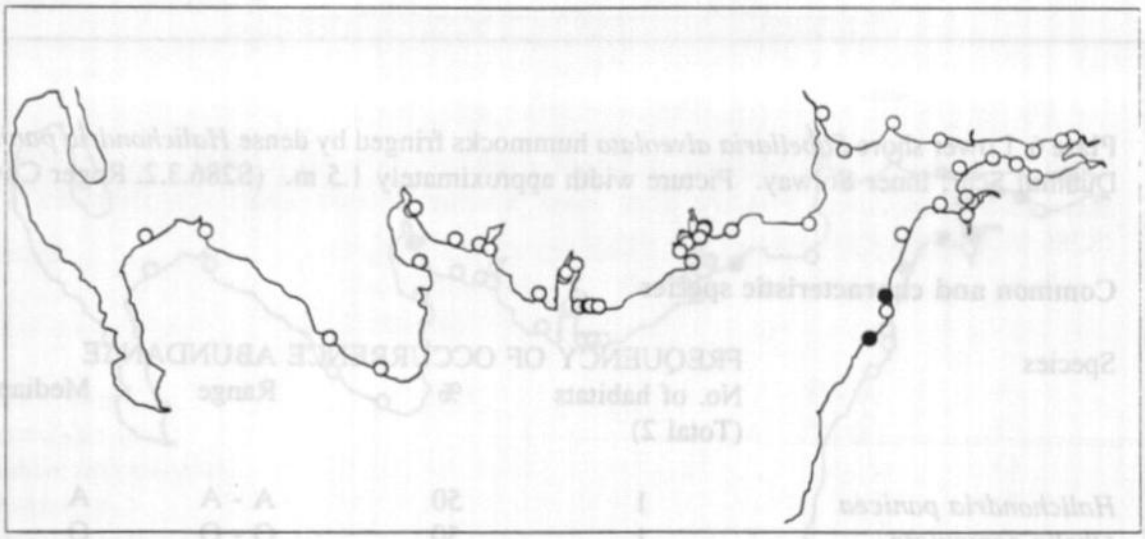
Species	FREQUENCY OF OCCURRENCE			ABUNDANCE
	No. of habitats (total 7)	%	Range	Median
Balanus crenatus	3	43	O - C	O
Elminius modestus	5	71	O - F	O
Carcinus maenas	4	57	P - F	R
Mytilus edulis	3	43	O - C	F
Enteromorpha sp.	6	86	P - A	F

COMMUNITY ISDG M5 Lower shore *Sabellaria alveolata* reefs

Classification

Situation:	Open coast
Salinity:	Normal
Wave exposure:	Exposed
Tidal streams:	Uncertain
Geology:	Hard
Zone/range:	Lower eulittoral
Substratum:	Mixed boulders, cobbles, pebbles and sand

Distribution



INNER SOLWAY:

NW of Brown Rigg (1.3)
Dubmill Scar (3.3)

Extent

Small reefs occur along the boulder scars of the Cumbrian coast of the Solway although less extensive areas occur on the north coast of the Solway.

Description

This community was present at sites which were exposed to wave action on the open coast but subject to only weak tidal streams. The reefs were on mixed substrata of small boulders, cobbles and pebbles with sand. The tops of the *Sabellaria alveolata* reefs had a covering of algae particulary *Ceramium* sp., *Polysiphonia* sp., *Palmaria palmata*, *Ulva* sp. and *Enteromorpha* sp. The areas of hard substrata had *Balanus balanoides* and *Nucella lapillus* with the sponge *Halichondria panicea* abundant on low lying boulders.

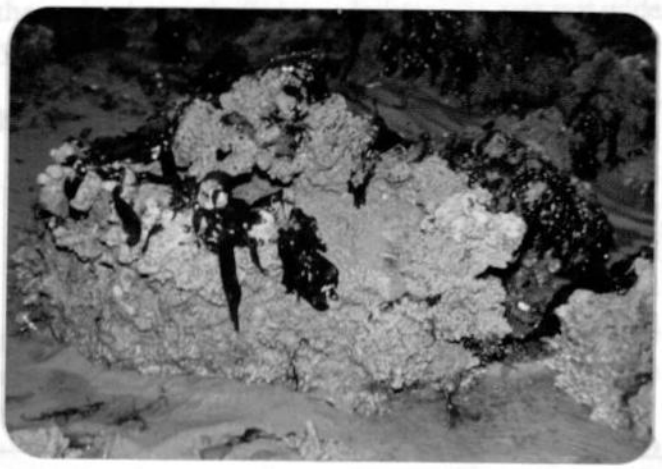


Plate 6 Lower shore *Sabellaria alveolata* hummocks fringed by dense *Halichondria panicea*. Dubmill Scar, Inner Solway. Picture width approximately 1.5 m. (S286.3.2. Roger Covey)

Common and characteristic species

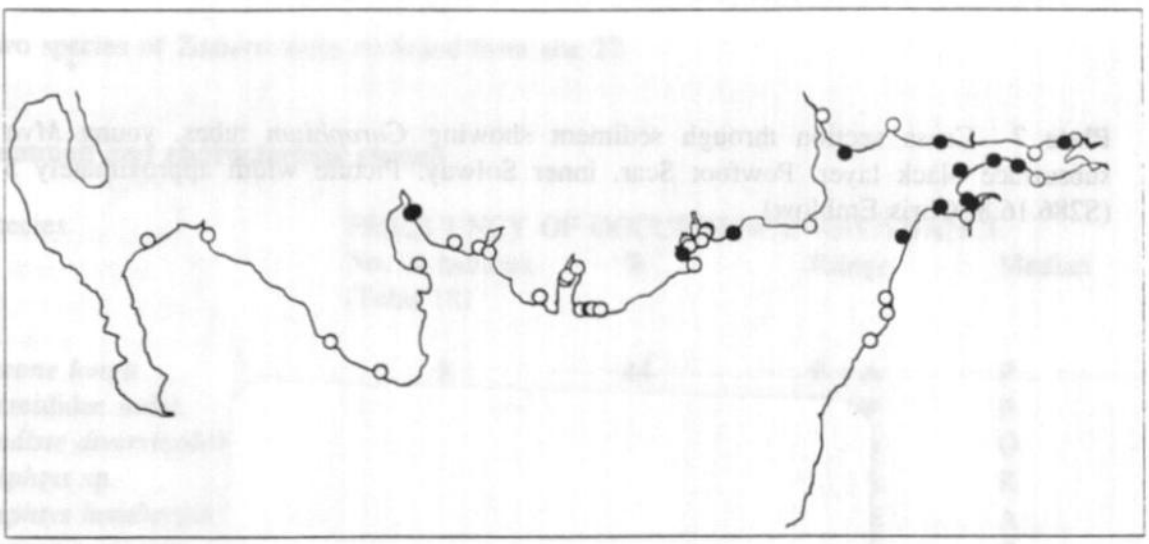
Species	FREQUENCY OF OCCURRENCE No. of habitats (Total 2)	%	ABUNDANCE Range	Median
Halichondria panicea	1	50	A - A	A
Obelia geniculata	1	50	O - O	O
Sabellaria alveolata	2	100	C - C	C
Balanus balanoides	2	100	O - F	F
Patella vulgata	1	50	O - O	O
Littorina littorea	2	100	R - O	O
Nucella lapillus	2	100	O - O	O
Palmaria palmata	1	50	C - C	C
Mastocarpus stellatus	1	50	O - O	O
Ceramium sp.	2	100	O - O	O
Polysiphonia sp.	2	100	O - O	O
Cladostephus spongiosus	1	50	O - O	O
Laminaria digitata	1	50	O - O	O
Fucus serratus	1	50	O - O	O
Enteromorpha	1	50	O - O	O
Ulva sp.	2	100	O - F	F
Bryopsis plumosa	1	50	F - F	F

COMMUNITY ISDG S1 Sheltered mud and fine sands with *Corophium*, *Hydrobia*, and *Macoma*.

Classification

Situation:	Enclosed coast (4.1 & 21.5 open coast)
Salinity:	Normal to variable (low)
Wave exposure:	Moderately exposed to very sheltered
Tidal streams:	-
Geology:	-
Zone/range:	Midshore
Substratum:	Muddy fine sands

Distribution



INNER SOLWAY:

Silloth Lighthouse (4.1)
Grune Point (5.2; 5.3)
W Anthorn (7.2)
Longdyke Scar (8.3)
Cardurnock Flats (9.2; 9.3)
Herdhill Scar (10.5)
Port Carlisle (11.2)
Redkirk Point (14.3)
Powfoot Scar (16.3; 16.4)
Blackshaw Bank (18.3)
Port O' Warren (21.5)
W Auchencairn Bay (27.2)

DUMFRIES AND GALLOWAY:

Wigtown Sands (6.3)
Creetown Quay (7.4)

Plate 7 Cross section through sediment showing *Corophium* tubes, young *Mya* and subsurface black layer. Powfoot Scar, inner Solway. Picture width approximately 5 cm. (S286.16.8. Chris Emblow)

Plate 8 Extensive flats of rippled muddy fine sand, Cardurnock Flats, inner Solway (S286.9.2. Roger Covey)

Extent

Likely to be widespread on mid and lower shores of much of the inner Solway and sheltered associated estuaries of the outer Solway.

Description

This habitat was generally composed of sediment with a very high content of very fine sand with some mud and silt. The basic community type is present over most of the sedimentary areas of the inner Solway, with other areas being characterised by facies of this community, varying due to their salinity regime and higher silt content of the sediment. Characterising species were *Macoma balthica*, ranging from present to abundant at seventeen of the eighteen examples (median abundance common); *Corophium volutator*, at fourteen habitats ranging from present to abundant; *Hydrobia ulvae* at thirteen habitats, ranging from present to abundant. *Arenicola marina* was present in 67% of the records.

Two species of *Zostera* were recorded from site 27.

Common and characteristic species

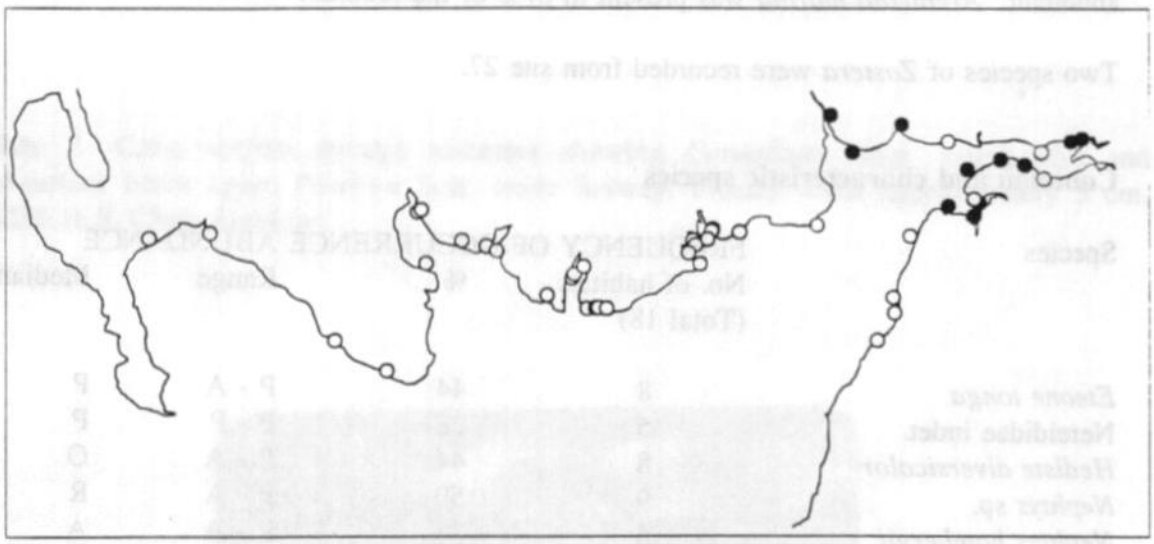
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 18)	%	Range	Median
Eteone longa	8	44	P - A	P
Nereididae indet.	5	28	P - P	P
Hediste diversicolor	8	44	P - A	O
Nephtys sp.	9	50	P - A	R
Nephtys hombergii	6	33	P - A	A
Pygospio elegans	8	44	P - A	C
Capitella sp.	8	44	P - C	P
Arenicola marina	12	67	P - S	F
Bathyporeia pilosa	9	50	P - A	P
Corophium volutator	15	83	P - A	P
Crangon crangon	6	33	P - P	P
Hydrobia ulvae	13	72	P - A	C
Cerastoderma edule	7	39	P - A	F
Macoma balthica	17	94	P - A	C

COMMUNITY ISDG S1.1 Variable salinity mud with *Pygospio elegans* and Nematoda

Classification

Situation:	Enclosed coast
Salinity:	Normal to variable (low)
Wave exposure:	Extremely sheltered to sheltered
Tidal streams:	nil
Geology:	-
Zone/range:	Upper shore to midshore
Substratum:	Fine sandy muds; median grain size <.0884 mm

Distribution



INNER SOLWAY:

Grune Point (5.1)
NE Border (6.1; 6.2)
W Anthorn (7.1)
Cardurnock Flats (9.1)
Herdhill Scar (10.1)
Port Carlisle (11.1)
NW Rockcliffe Marsh (13.1)
Redkirk Point (14.2)
Stanhope (17.1)
Blackshaw Bank (18.1; 18.2)
Glencaple (19.1)

Extent

This community is likely to be widespread over the upper shore of the inner Solway Firth.

Description

This community occurred exclusively in the inner Solway on sediments with a median grain size of less than 84 um, i.e. predominantly mud with small amounts of fine sand. Most examples described were from the upper or mid shore, where salinity is likely to be variable or low due to freshwater input.

Characteristic taxa included Nematoda and *Pygospio elegans*, ranging from present to superabundant at twelve of the thirteen examples, both having a median abundance of common; and *Corophium volutator*, ranging from common to superabundant, with a median abundance of superabundant, recorded from all of the thirteen examples of this community.

Other conspicuous species included *Eteone longa*, *Hediste diversicolor*, *Hydrobia ulvae*, and *Macoma balthica*.

Common and characteristic species

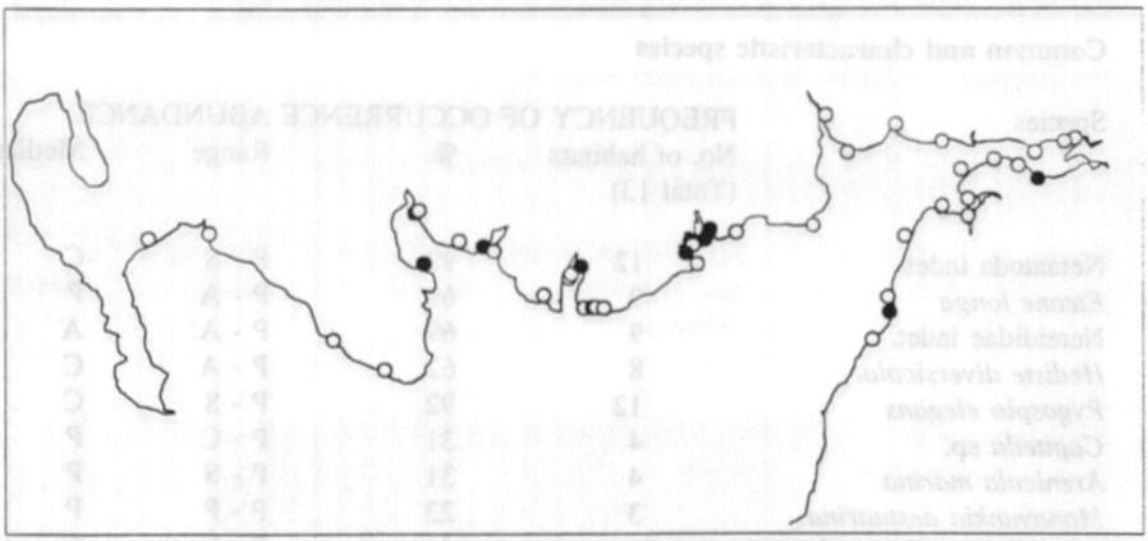
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 13)	%	Range	Median
Nematoda indet.	12	92	P - S	C
Eteone longa	9	69	P - A	P
Nereididae indet.	9	69	P - A	A
Hediste diversicolor	8	62	P - A	C
Pygospio elegans	12	92	P - S	C
Capitella sp.	4	31	P - C	P
Arenicola marina	4	31	P - S	P
Manayunkia aestuarina	3	23	P - P	P
Oligochaeta indet.	6	46	P - C	C
Bathyporeia pilosa	7	54	C - A	A
Corophium volutator	13	100	C - S	S
Carcinus maenas	3	23	P - O	R
Hydrobia ulvae	8	62	P - A	C
Macoma balthica	10	77	C - A	A

COMMUNITY ISDG S1.2 Mud and fine sands with *Pygospio, Corophium* and *Scrobicularia*

Classification

Situation:	Enclosed and open coast
Salinity:	Normal and variable
Wave exposure:	Very sheltered to sheltered
Tidal streams:	Nil to moderate
Geology:	-
Zone/range:	-
Substratum:	Fine sandy muds

Distribution



INNER SOLWAY:

Allonby Scar (2.1)
Drumburgh (12.1)
Rough Island causeway flats (23.2)
White Horse Bay (24.1; 24.6)
SW Orchardton Bay (25.1)
W Auchencairn Bay (27.1)

DUMFRIES AND GALLOWAY:

Innerwell Fisheries (5.3)
Wigtown Sands (6.1; 6.4)
Mossyard Bay (9.1)
Manxman's Lake (14.1; 14.2)

Extent

Likely to be widespread over much of the inner Solway and estuaries of the outer Solway.

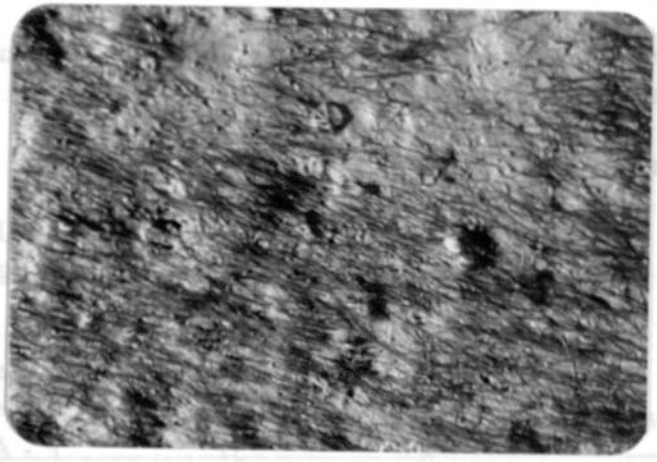


Plate 9 *Zostera nana* with *Hydrobia ulvae* on the lower shore. Rough Island causeway flats. inner Solway. Picture width approximately 1 m. (S286.23.4 L. Mark Davies)

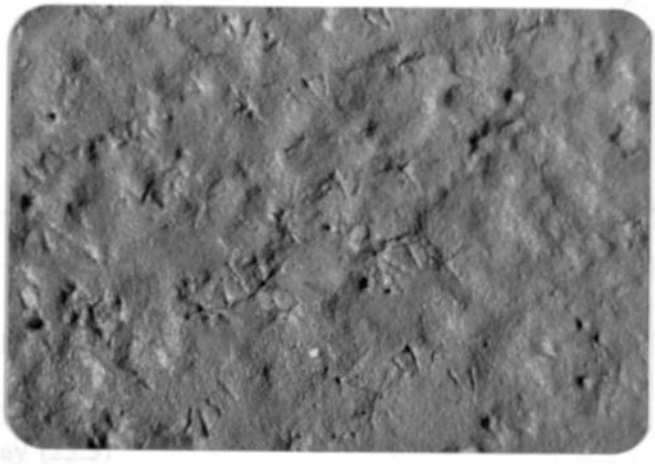


Plate 10 Upper shore mud with siphon marks from *Scrobicularia plana*. White Horse Bay, inner Solway. Picture width approximately 50 cm. (S286.24.10 Roger Covey)

Description

This facies of the sheltered muddy fine sands community was found predominantly in enclosed coast areas with a high silt content and fluctuating salinity. Particularly characteristic were the annelids *Tubificoides benedeni*, *Hediste diversicolor*, and *Pygospio elegans*; and the bivalves *Macoma balthica* and *Scrobicularia plana*. Habitat 12.1 from the inner Solway was slightly atypical, since it was beside a curve in the main Solway channel.

where increased current speeds removed most of the mud component leaving 79% fine sand. All other sites had between 45 and 90% mud content.

The seagrass *Zostera nana* was recorded from three examples of this habitat, in Auchencairn Bay, and Manxman's Lake, Kirkcudbright.

Common and characteristic species

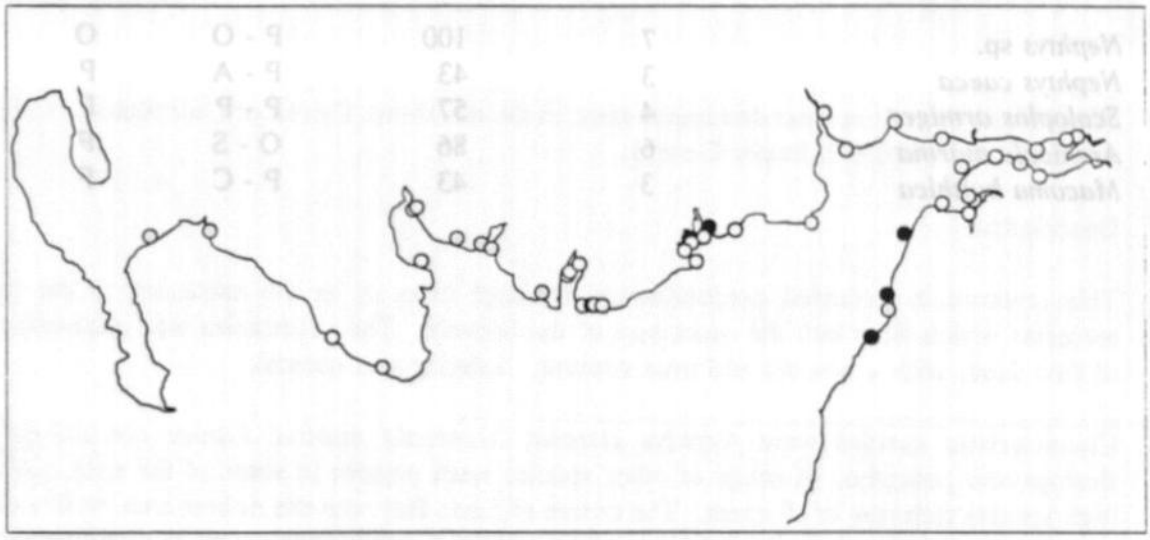
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 13)	%	Range	Median
Eteone longa	5	38	P - A	P
Hediste diversicolor	7	54	P - A	A
Nephtys hombergii	4	31	P - A	P
Pygospio elegans	12	92	P - A	P
Arenicola marina	5	38	P - F	O
Tubificoides benedeni	9	69	C - S	A
Corophium volutator	11	85	C - S	C
Carcinus maenas	5	38	P - F	P
Hydrobia ulvae	8	62	P - A	C
Macoma balthica	9	69	P - A	C
Scrobicularia plana	7	54	F - A	C

COMMUNITY ISDG S2 Fine sands with very fine sands

Classification

Situation:	Open coast
Salinity:	Normal
Wave exposure:	Exposed
Tidal streams:	Nil
Geology:	-
Zone/range:	-
Substratum:	Fine sand

Distribution



INNER SOLWAY:

NW of Brown Rigg (1.1: 1.4)
Dubmill Scar (3.1)
Silloth Lighthouse (4.2; 4.3)
Rough Island Causeway (23.3)
SW Orchardton Bay (25.2)

Extent

Likely to be common on the open coast of much of more open coast of the Solway south of Moricambe.

Description

Sites with fine sand community on the open coast were situated on the south coast of the Solway, south of Moricambe, where the Solway becomes wider and the coast receives less shelter due to its more westerly aspect.

In many ways this community represents a transition between the enclosed coast muddy sediments of the inner Solway and estuaries, and the medium and fine grained sands of the exposed open coast.

Characteristic species were *Scoloplos armiger*, typical of muddy fine sand, *Nephtys* spp., and *Arenicola marina*. The genus *Bathyporeia* was represented by three species; *Bathyporeia elegans*, *Bathyporeia pelagica*, and *Bathyporeia sarsi*. These species are all typical of fine sands which remain wet during low tide periods.

Common and characteristic species

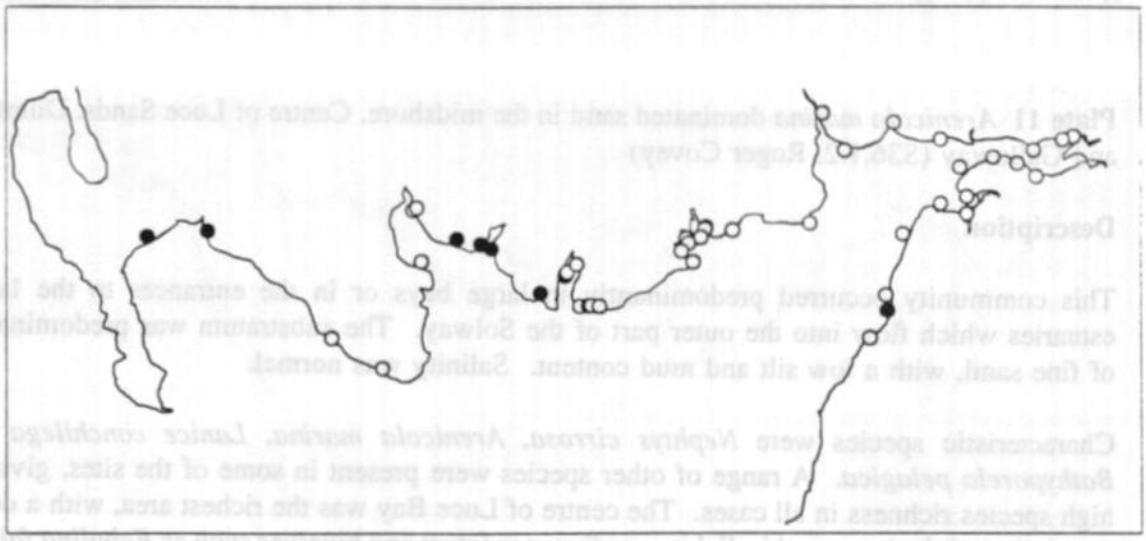
Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 7)	%	Range	Median
Nephtys sp.	7	100	P - O	O
Nephtys caeca	3	43	P - A	P
Scoloplos armiger	4	57	P - P	P
Arenicola marina	6	86	O - S	F
Macoma balthica	3	43	P - C	F

COMMUNITY ISDG S3 Open coast fine sands with a rich infauna.

Classification

Situation:	Enclosed and open coast
Salinity:	Normal
Wave exposure:	Sheltered, moderately exposed and exposed
Tidal streams:	Very weak or uncertain
Geology:	-
Zone/range:	
Substratum:	Fine sands

Distribution



INNER SOLWAY:

Allonby Scar (2.5)

DUMFRIES AND GALLOWAY:

Centre of Luce Sands (1.2: 1.3)
Crow's Nest, Luce Bay (2.5)
Ravenshall Point (8.5)
Mossyard Bay (9.5)
Murray's Isle to Craigmore Point (10.5)
Brighouse Bay (11.6)
Devil's Thrashing floor/Milton sands (12.6)

Extent

Likely to occur in the semi-exposed mouths of many of the estuaries which flow into the Solway and in embayments.

Plate 11 *Arenicola marina* dominated sand in the midshore. Centre of Luce Sands, Dumfries and Galloway (S36.1.2. Roger Covey)

Description

This community occurred predominantly in large bays or in the entrances to the larger estuaries which flow into the outer part of the Solway. The substratum was predominantly of fine sand, with a low silt and mud content. Salinity was normal.

Characteristic species were *Nephtys cirrosa*, *Arenicola marina*, *Lanice conchilega* and *Bathyporeia pelagica*. A range of other species were present in some of the sites, giving a high species richness in all cases. The centre of Luce Bay was the richest area, with a dense population of the heart urchin *Echinocardium cordatum* and bivalves such as *Fabulina fabula*, *Donax vittatus* and *Chamelea gallina*.

Common and characteristic species

Species	FREQUENCY OF OCCURRENCE		ABUNDANCE	
	No. of habitats (Total 9)	%	Range	Median
Nemertea indet.	3	33	P - P	P
Sigalion mathildae	4	44	P - P	P
Nephtys sp.	4	44	P - R	R
Nephtys cirrosa	6	67	P - A	A
Nephtys hombergii	3	33	P - P	P
Scoloplos armiger	4	44	P - C	P
Pygospio elegans	4	44	P - C	P
Spio martinensis	4	44	P - P	P
Spiophanes bombyx	4	44	P - P	P

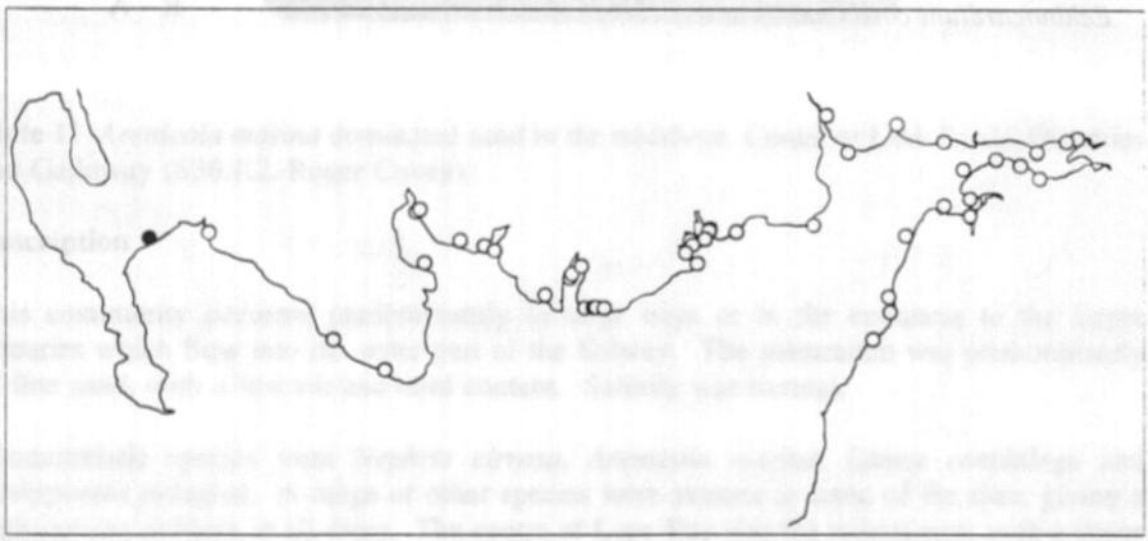
Magelona mirabilis	4	44	P - C	P
Capitella capitata	3	33	P - P	P
Arenicola marina	8	89	F - A	F
Owenia fusiformis	3	33	P - O	P
Lanice conchilega	7	78	R - C	F
Tubificoides benedeni	3	33	P - P	P
Bathyporeia pelagica	6	67	P - C	P
Cumopsis goodsiri	4	44	P - P	P
Pseudocuma longicornis	3	33	P - C	C
Crangon crangon	3	33	P - P	P
Ensis sp.	2	22	P - R	P
Angulus tenuis	4	44	P - C	P
Fabulina fabula	4	44	P - O	R
Echinocardium cordatum	2	22	R - A	R

COMMUNITY ISDG S4 Barren upper shore fine sand

Classification

Situation:	Open coast
Salinity:	Normal
Wave exposure:	Exposed
Tidal streams:	Nil
Geology:	-
Zone/range:	Upper shore
Substratum:	Fine sand

Distribution



DUMFRIES AND GALLOWAY:

Centre of Luce Sands (1.1)

Extent

Unlikely to be widespread outside Luce Bay

Description

At the top of the shore at the centre of Luce Bay fine sand was mobile and with a low silt content. This sediment was likely to be above the zone of water retention and was virtually barren, with only six species recorded.

Common and characteristic species

Species	ABUNDANCE
Nemertea indet	P
Pygospio elegans	P
Pseudocuma longicornis	P
Scolelepis squamata	C
Eurydice pulchra	P
Bathyporeia pelagica	P

APPENDIX 4

List of taxa recorded during survey

The site number is given for each species or taxa recorded during the surveys. Sites from the Dumfries and Galloway survey are prefixed by S36, those from the Inner Solway Survey are prefixed by S286. Taxa are listed according to Howson (1987), excepting *Balanus balanoides* which is assigned to the genus *Semibalanus*.

PORIFERA

Scypha ciliata	S36: 3
Halichondria panicea	S36: 3; 4; 11; 15; 16; 17; 18
	S286: 3; 28
Hymeniacidon perleve	S36: 3; 4; 17

CNIDARIA :HYDROZOA

Hydrozoa indet.	S286: 24; 28
Abietinaria abietina	S286: 5
Dynamena pumila	S36: 15
Hydrallmania falcata	S286: 1
Obelia sp.	S36: 8; 9; 17
	S286: 20
Obelia bidentata	S286: 10
Obelia geniculata	S36: 8; 12; 13
	S286: 3; 4; 16; 22

: ANTHOZOA

Actinia equina	S36: 2; 3; 4; 8; 9; 10; 13; 15; 16; 17; 18
	S286: 2; 21; 22; 26; 28
Actinia fragacea	S36: 11
Urticina felina	S36: 17; 18
Sagartia elegans	S286: 28
Cereus pedunculatus	S286: 20; 22

NEMERTEA

Nemertea indet.	S36: 1; 2
Cephalothricidae indet.	S36: 9
Tubulanus polymorphus	S36: 5
Cerebratulus sp.	S286: 5; 6; 8; 11; 24

NEMATODA

Nemertoda indet.	S286: 1; 5; 6; 7; 9; 10; 11; 13; 14; 18; 19; 24

ANNELIDA : POLYCHAETA

Polychaeta indet.	S36: 2; 12

	S286: 23
Harmothoe sp.	S36: 10
Harmothoe marphysae	S286: 2
Sigalion mathildae	S36: 1; 2; 9
	S286: 2
Eteone sp.	S286: 10
Eteone longa	S36: 5; 6; 10; 14
	S286: 2; 4; 5; 6; 7; 8; 9; 10; 11; 12; 14; 16; 18; 24
Eulalia viridis	S36: 4; 15; 16; 17
Glycera tridactyla	S36: 7
Nereididae indet.	S286: 4; 5; 6; 7; 8; 10; 11; 13; 14; 18; 19; 27
Hediste diversicolor	S36: 6; 14
	S286: 2; 4; 5; 6; 7; 8; 9; 10; 11; 13; 14; 15; 16; 18; 19; 24; 25; 27
Nephtys sp.	S36: 2; 6; 7; 8; 11; 12
	S286: 1; 2; 3; 4; 11; 14; 16; 18; 21; 23; 25
Nephtys caeca	S286: 1; 2; 4
Nephtys cirrosa	S36: 1; 2; 7; 8; 10; 11
Nephtys hombergii	S36: 1; 5; 6; 7; 12
	S286: 2; 4; 8; 18; 25; 27
Orbinia sp.	S36: 10
Scoloplos armiger	S36: 1; 8; 10; 12
	S286: 1; 2; 4; 25
Aricidea minuta	S36: 12
Levinsenia gracilis	S286: 3; 4
Spionidae indet.	S286: 4
Malacoceros tetracerus	S286: 2
Polydora ligni	S286: 16; 27
Pygospio elegans	S36: 1; 5; 6; 7; 8; 10; 12; 14
	S286: 2; 4; 5; 6; 7; 9; 10; 11; 12; 13; 14; 16; 18; 19; 21; 23; 24; 25; 27
Scolelepis sp.	S286: 2
Scolelepis squamata	S36: 1; 10
	S286: 3
Spio decorata	S36: 2
Spio martinensis	S36: 1; 9; 12
Spiophanes bombyx	S36: 1; 2; 8; 12
Magelona sp.	S36: 2
Magelona filiformis	S36: 9; 12
Magelona mirabilis	S36: 1; 8; 10; 11
	S286: 1
Tharyx marioni	S36: 5
Capitella sp.	S286: 1; 2; 4; 5; 6; 7; 8; 11; 16; 18; 21; 24
Capitella capitata	S36: 2; 6; 9; 10; 14
Heteromastus filiformis	S36: 5
Arenicola marina	S36: 1; 2; 6; 7; 8; 9; 10; 11; 12; 14
	S286: 1; 2; 3; 4; 5; 6; 7; 8; 9; 11; 16; 21; 23; 24; 25; 27

Maldanidae indet.	S286: 25
Owenia fusiformis	S36: 8; 10; 12
Lagis koreni	S36: 10; 12; 14
Sabellaria alveolata	S36: 11
	S286: 1; 3; 20; 28
Ampharete sp.	S286: 24
Ampharete grubei	S286: 2; 23
Terebellidae indet.	S286: 22
Eupolymnia nebulosa	S286: 26
Lanice conchilega	S36: 1; 2; 7; 8; 9; 10; 11; 13
	S286: 2; 3; 4; 20; 22
Manayunkia aestuarina	S36: 5; 6; 14
	S286: 5; 7; 11
Pomatoceros lamarcki	S36: 17
Pomatoceros triqueter	S36: 3; 10; 11; 15
	S286: 4; 28
Spirorbidae indet.	S36: 3; 4; 11
Spirorbis sp.	S36: 17
Spirorbis corallinae	S36: 3
Spirorbis spirorbis	S36: 3

:OLIGOCHAETA

Oligochaeta indet.	S286: 6; 7; 8; 10; 11; 14; 27
Tubifex costatus	S36: 14
Tubificoides benedeni	S36: 5; 6; 7; 9; 11; 12; 14
	S286: 1; 2; 5; 8; 19; 24; 25; 27
Tubificoides pseudogaster	S36: 14
Monopylephorus rubroniveus	S286: 24
Enchytraeidae indet.	S36: 14

CHELICERATA

Acari indet.	S286: 21; 22; 23

CRUSTACEA :CIRRIPEDIA

Chthamalus montagui	S36: 2; 4; 8; 11; 15; 16; 17; 18
	S286: 21
Chthamalus stellatus	S36: 8
Balanus sp.	S36: 12
Balanus balanoides	S36: 2; 3; 4; 6; 7; 8; 9; 10; 11; 12; 13; 15; 16; 17; 18
	S286: 1; 2; 3; 4; 8; 10; 15; 16; 20; 21; 22; 23; 24; 26; 28
Balanus crenatus	S36: 2; 3; 6; 7; 8; 10; 11; 12; 13; 15; 18
	S286: 16; 20; 24; 28
Elminius modestus	S36: 2; 3; 8; 10; 11; 12; 13; 15
	S286: 2; 4; 5; 10; 16; 19; 20; 21; 22; 23; 24; 28

CRUSTACEA :MYSIDA

Mysidae indet.	S286: 16
Leptomysis gracilis	S36: 14

:AMPHIPODA

Amphipoda indet.	S36: 2; 5; 11; 13
	S286: 24
Pontocrates arenarius	S36: 1
	S286: 1
Talitridae indet.	S36: 3
Orchestia mediterranea	S286: 27
Atylus swammerdami	S286: 1
Bathyporeia sp.	S286: 1; 2; 9
Bathyporeia elegans	S286: 1; 2; 3
Bathyporeia pelagica	S36: 1; 2; 8; 11
	S286: 1; 2; 4; 9
Bathyporeia pilosa	S286: 6; 7; 8; 9; 10; 11; 12; 13; 14; 16; 18; 21; 24
Bathyporeia sarsi	S36: 1
	S286: 1; 18
Haustorius arenarius	S286: 3
Gammaridae indet.	S36: 2; 3; 5; 6; 7; 10; 12; 14
	S286: 2; 4; 5; 10; 14; 16; 20; 21; 22; 23
Echinogammarus obtusatus	S286: 2
Gammarus sp.	S286: 28
Gammarus salinus	S286: 2
Corophium sp.	S36: 6; 9
	S286: 2; 4; 5; 6; 7; 8; 9; 10; 11; 13; 14; 15; 16; 17
Corophium volutator	S36: 5; 6; 7; 14
	S286: 2; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 16; 18; 19; 21; 24; 25; 27

:ISOPODA

Isopoda indet.	S36: 2
Eurydice pulchra	S36: 1
	S286: 4; 9
Idotea sp.	S36: 15
Idotea pelagica	S286: 27
Ligia oceanica	S36: 8; 15; 16
Cumopsis goodsiri	S36: 1; 8; 9; 11
Bodotria pulchella	S286: 2
Pseudocuma longicornis	S36: 1; 8

:DECAPODA

Caridea indet.	S286: 12; 27
Palaemon elegans	S36: 3; 12
Pandalus montagui	S36: 10
Crangon crangon	S36: 1; 6; 7; 12; 14

	S286: 1; 2; 7; 16; 27
Pagurus bernhardus	S36: 3; 8; 10
	S286: 1; 2; 5
Porcellana platycheles	S36: 3; 11; 17
Cancer pagurus	S36: 11
Liocarcinus puber	S36: 3
Carcinus maenas	S36: 2; 3; 5; 6; 7; 8; 9; 11; 12; 13; 15; 16; 17
	S286: 2; 4; 5; 7; 8; 10; 12; 14; 15; 16; 18; 20; 21; 22; 23; 24; 25; 26; 27; 28
INSECTA	
Insecta indet.	S36: 2
Anurida maritima	S36: 3; 8; 15
	S286: 20; 21; 23; 26
MOLLUSCA :POLYPLACOPHORA	
Lepidochitona cinereus	S36: 2
	S286: 2
Tectura testudinalis	S36: 2
:GASTROPODA	
Patella sp.	S36: 15
Patella ulyssiponensis	S36: 4; 10; 16; 17; 18
Patella vulgata	S36: 2; 3; 4; 5; 8; 9; 10; 11; 12; 16; 17; 18
	S286: 1; 3; 21; 24; 26; 28
Margarites undulata	S36: 2
Monodonta lineata	S36: 16
Gibbula cineraria	S36: 3; 16
Gibbula umbilicalis	S36: 3; 16
Littorina littorea	S36: 2; 3; 4; 5; 7; 8; 9; 10; 11; 13; 16; 17; 18
	S286: 1; 2; 3; 4; 8; 10; 16; 20; 21; 22; 23; 24; 26; 28
Littorina neritoides	S286: 8
Littorina mariae	S36: 2; 4
	S286: 21
Littorina obtusata	S36: 3; 10
Littorina neglecta	S36: 15; 16
Littorina saxatilis	S36: 2; 3; 4; 5; 7; 8; 10; 11; 15; 16; 17; 18
	S286: 2; 4; 8; 16; 20; 21; 22; 23; 24; 26; 27
Hydrobia sp.	S286: 5
Hydrobia ulvae	S36: 5; 6; 7; 14
	S286: 4; 5; 6; 7; 8; 9; 10; 11; 16; 18; 21; 23; 24; 25; 27
Nucella lapillus	S36: 2; 3; 4; 8; 9; 10; 11; 13; 15; 16; 17; 18
	S286: 1; 3; 4; 21; 22; 24; 26; 28
Buccinum undatum	S286: 2
:OPISTOBRANCHIA	
Dendronotus frondosus	S36: 16

:PELECYPODA

Pelecypoda indet.	S36: 12
Mytilidae indet.	S286: 4
Mytilus edulis	S36: 2; 5; 6; 7; 9; 10; 11; 12; 13; 15; 16; 18
	S286: 1; 2; 3; 4; 5; 8; 10; 16; 20; 21; 22; 23; 24; 26; 28
Anomia ephippium	S36: 17
Cerastoderma edule	S36: 5; 14
	S286: 4; 5; 9; 11; 13; 16; 18; 23; 25; 27
Ensis sp.	S36: 10; 12
Angulus tenuis	S36: 2; 8; 12
	S286: 2
Fabulina fabula	S36: 1; 8; 10
	S286: 2
Macoma balthica	S36: 5; 6; 7; 10; 14
	S286: 2; 4; 5; 6; 7; 8; 9; 11; 12; 13; 14; 16; 18; 19; 21; 23; 24; 25; 27
Donax vittatus	S36: 1
Scrobicularia plana	S36: 6; 9; 14
	S286: 23; 24; 25
Abra nitida	S36: 12
Chamelea gallina	S36: 1
Mya arenaria	S286: 11; 16; 18; 21

BRYOZOA

Bryozoa indet.	S36: 5; 11; 12
	S286: 16; 20; 28
Alcyonidium gelatinosum	S36: 15; 18
Alcyonidium hirsutum	S36: 15; 16
Membranipora membranacea	S36: 11
Flustra foliacea	S286: 4
Bryozoa crusts indet	S36: 12

ECHINODERMATA :ASTEROIDEA

Asterias rubens	S36: 3; 11; 18
	S286: 16; 20; 28

:OPHIUROIDEA

Ophiothrix fragilis	S36: 3

:ECHINOIDEA

Echinocardium cordatum	S36: 1; 10

TUNICATA

Diplosoma sp.	S36: 3
Ascidiella scabra	S286: 1
Ascidia mentula	S36: 11

	S286: 24; 26; 28
Xanthoria sp.	S36: 17
Xanthoria parietina	S36: 8; 10; 11; 12
	S286: 20; 21; 22; 24; 26; 28
Grey lichens	S36: 8; 11; 15; 16; 17
	S286: 20; 22; 24; 26; 28

Total number of taxa 256

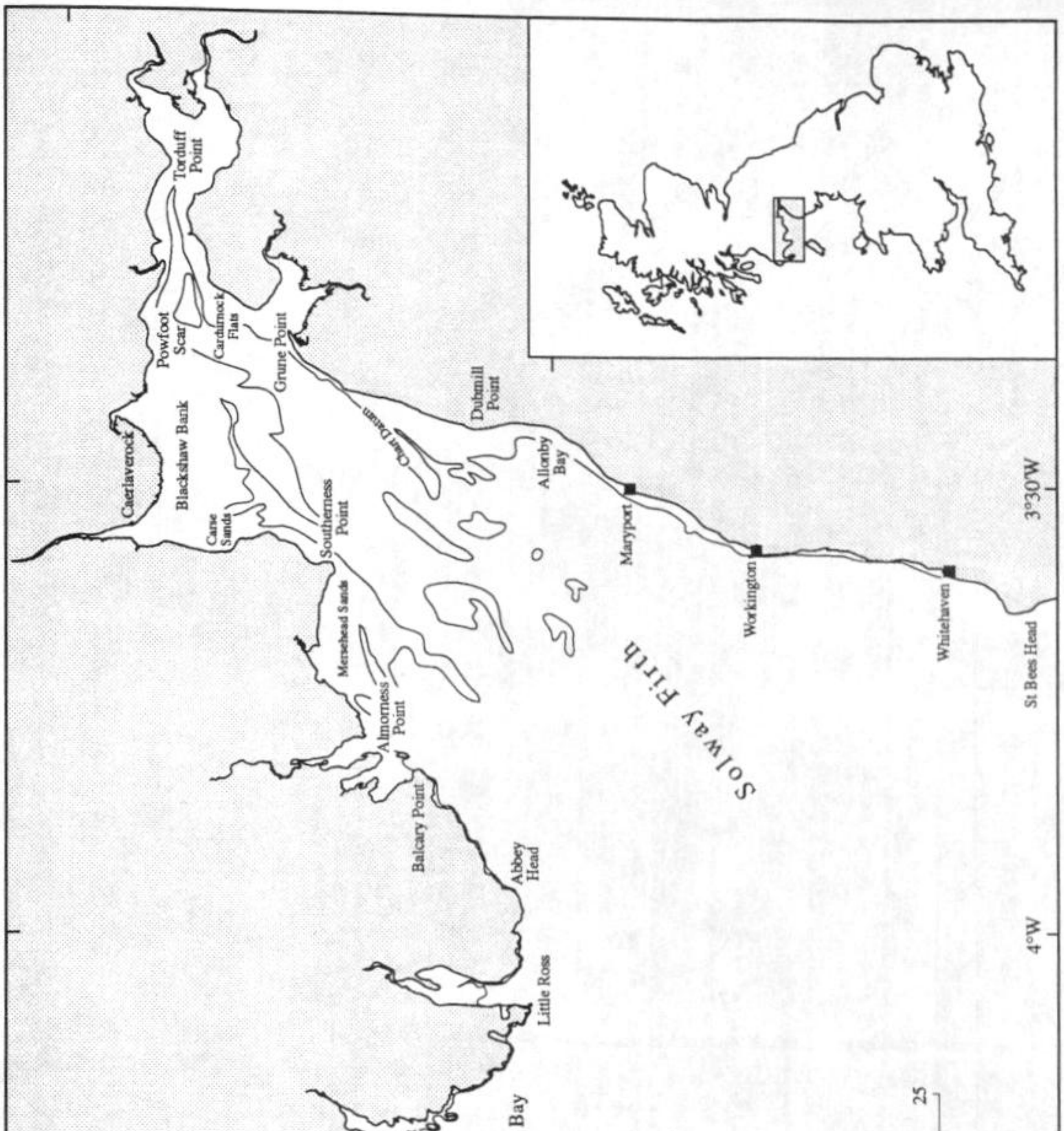


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Figure 6 Location of places mentioned in the text