JOINT NATURE CONSERVATION COMMITTEE

Marine Nature Conservation Review

Benthic marine ecosystems of Great Britain and the north-east Atlantic

edited by

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Part 2

Reviews within MNCR Coastal Sectors

Chapter 9: Bristol Channel and approaches (Cape Cornwall to Cwm yr Eglwys, Newport Bay) (MNCR Sector 9)*

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Synopsis

The coastline of the Bristol Channel and its approaches includes a great variety of different habitats and associated communities. These range from the distinctive biota of sandy surf beaches and nearshore areas in North Cornwall and the west coast of North Devon, through communities characteristic of the turbid waters, strong tidal streams and low salinity of the Bristol Channel and the Severn Estuary then northwards past the rocky coasts and offshore islands of Pembrokeshire characterised by open coast communities. Local features that result in the development of particular assemblages of species include the limestone rocks of the Gower, which attract species boring into the rock, the extensive rocky habitats in Milford Haven, and the Daucleddau with species and communities characteristic of ria conditions. Some of the communities of offshore islands are especially rich in species including rare species or ones at the northern limits of their distribution.

9.1 Introduction

Sector 9 'Bristol Channel and approaches' (Figure 9.1) encompasses the coast from Cape Cornwall to Cwm yr Eglwys in Pembrokeshire: an area of considerable contrast with very exposed rocky shores, high cliffs and exposed sandy beaches in the west, leading to extensive sand- and mud-flats subject to variable and low salinity and a huge tidal range in the upper Bristol Channel and Severn Estuary. North Cornwall, north Devon and west Wales are predominantly rural areas although dramatic scenery and extensive sandy beaches attract many visitors each year. South-east Wales and Avon are more industrialised, with a larger population and with four large ports in the upper Bristol Channel and Severn Estuary.

The Bristol Channel/Severn Estuary has the second largest tidal range in the world after the Bay of Fundy, Nova Scotia: 14 m during spring tides at Avonmouth. It has a catchment area comprising one sixth of the land area of England and Wales and the tidal river extends to Maismore Weir (Gloucester), 210 km east of Lundy. A combination of this huge tidal rise and fall, a large freshwater input, and the shape of the estuary, generate strong tidal streams which sweep along the Severn Estuary and Bristol Channel. Large mobile sandbanks have formed in areas away from the main tidal streams. A combination of the relatively narrow channel and the large tidal range provides potential for the generation of tidal power. Consequently, there have been a number of studies which have investigated the feasibility of building a barrage across the channel. All aspects of the development have been considered including the hydrography, the engineering, the ecology and the

* This review was completed from published sources of information on benthic habitats and communities as well as interviews with relevant workers undertaken up to 1991 and published in Davies (1991). It has been further revised to take account of major additional studies up to the end of 1994 by the author and up to the end of 1996 by the series editor. It does not include benthic survey information summarised for or published in the MNCR *Regional Reports* series or work now being undertaken to map biotopes in candidate Special Areas of Conservation. For information on conservation status and an analysis of rare and scarce seabed species, the reader is referred to the *Coastal Directories* series.

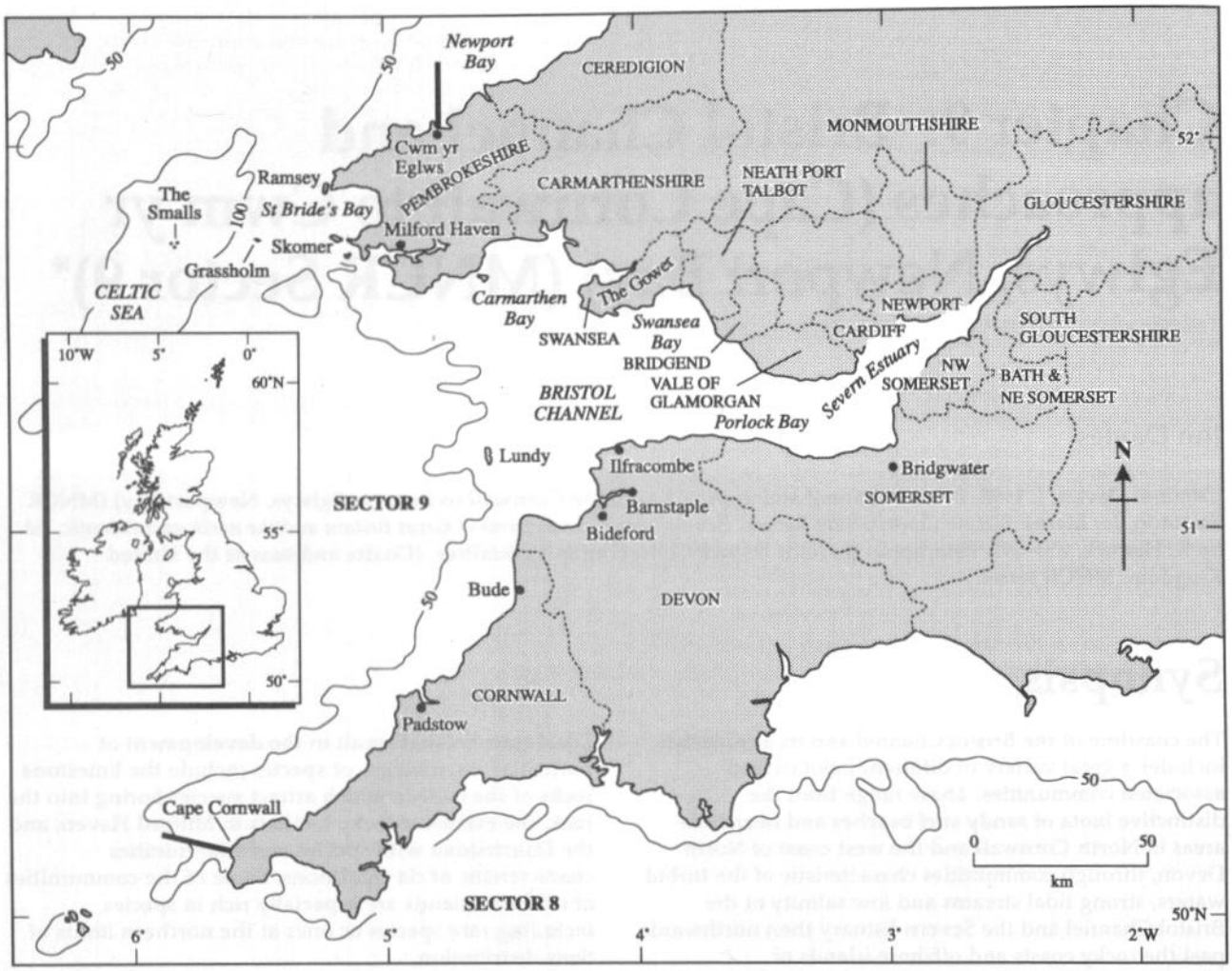

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Figure 9.1. Sector 9 showing location of places mentioned in the introduction.

implications for conservation. Feasibility studies intensified following the establishment of the Severn Tidal Power Group (STPG). STPG commissioned a number of marine biological investigations as a contribution to the feasibility studies which have significantly enhanced our understanding of the marine ecosystems within the Bristol Channel and Severn Estuary (Severn Tidal Power Group 1989).

Littoral ecosystems were investigated during the Nature Conservancy Council (NCC)-commissioned Intertidal Survey of Great Britain (Powell *et al.* 1978, 1979). Warwick & Davies (1977) reported the results of an intensive study of the sublittoral environment by the Institute for Marine and Environmental Research (IMER), now the Plymouth Marine Laboratory (PML). This benthic survey was part of a large multidisciplinary study undertaken by IMER during the period 1971–1981 which also included a detailed study on the distribution of plankton throughout the Bristol Channel and Severn Estuary (Williams & Collins 1985). Data were collected to study the geographical distribution and seasonal variability of plankton to construct a General Ecosystem Model (GEMBASE) for the Bristol Channel and Severn Estuary (Radford 1979, 1982; Radford & Joint 1980). Hartley (1979) described the offshore Mollusca of the Bristol Channel approaches. Nearshore sublittoral regions were surveyed and the communities present described during the South-West Britain Sublittoral Survey (SWBSS) (Hiscock 1981a), a project funded by the NCC. In the 1980s NCC commissioned a survey of harbours, rias and estuaries in southern Britain undertaken by the Field Studies Council (FSC) Oil Pollution Research Unit (Figure 9.2). The latter study considered the littoral and sublittoral environment and also included sites on the open coast adjacent to each marine inlet, but excluded the Severn Estuary.

A large population inhabits the catchment area for the Severn Estuary, resulting in considerable anthropogenic inputs to the marine environment. Welsh Water Authority (WWA) undertook many studies to monitor the effects of these inputs and published a review of the biology of the Severn Estuary, Swansea Bay and Milford Haven based on these studies (WWA 1982).

In recent years, conservation of estuaries has assumed considerable importance and a number of review studies have collated data on the estuarine resource. Davidson

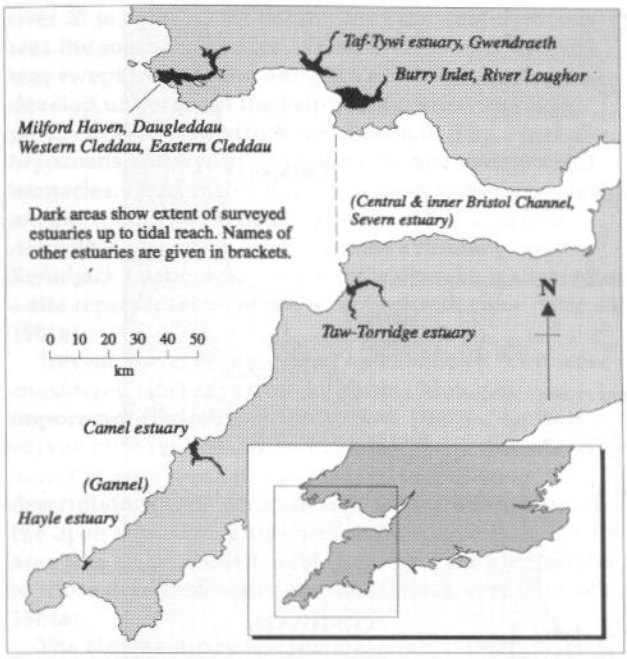

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Figure 9.2. Marine inlets in Sector 9 included in the survey of Harbours, Rias and Estuaries in Southern Britain.

et al. (1991) provided an overview of British estuaries, their wildlife, present conservation status, and human activities. Buck (1993) provided summaries of the physical characteristics, the wildlife features, human use, and conservation status of 15 estuaries in Sector 9. In parallel with these studies, the Countryside Council for Wales (CCW) completed its own estuaries review to determine the conservation status of Welsh estuaries (CCW 1993). The latter volume provided an overview of the geology, hydrography/oceanography, anthropogenic influences and the resource/planning framework for the Welsh coastline as a whole, followed by site-specific summaries for each estuary.

Estuarine fish are a resource often overlooked yet of considerable importance to the ecological and economic structure of an estuary. Kelley (1988) studied estuarine populations of sea bass *Dicentrarchus labrax*, and concluded that this species was under increased pressure from both angling and commercial fishing. More recently, the Joint Nature Conservation Committee commissioned a review of the status of estuarine fish in England and Wales (Potts & Swaby 1993a). This volume gave the results of a literature review for 22 estuaries and coastal areas in England and Wales including the Camel, Taw/Torridge and Severn estuaries in Sector 9. Data were presented on species diversity and the distribution of estuarine fish species. Potts & Swaby (1993a) considered low oxygen levels from high BOD (biochemical oxygen demand), possibly linked to the discharge of raw sewage, to be the most significant factor influencing the population status of estuarine fish. For each estuary, there is a summary of the benthic habitats present, data on fish populations, a summary of impacts, data on water quality status and a bibliography. A similar review (Potts & Swaby 1993b) produced accounts of marine and estuarine fish species of Wales.

Brackish-water habitats, and saline lagoons in particular, form a small yet highly significant part of the marine resource of Britain. These fragile, often ephemeral, habitats retain communities of high conservation value for the presence of a number of rare species. The lagoonal habitats of Cornwall were described by Little (1985). Bamber *et al.* (1992) described the ecology of brackish lagoons in Britain including information on their physical characteristics, the flora and fauna; some of the sites considered were located in Sector 9. They also presented the results of detailed analyses which aimed to contribute to the understanding of the parameters that define the lagoonal status and to classify the lagoons according to their biotic components. Bamber *et al.* (1992) highlighted areas requiring further investigation and offered guidelines for the conservation management of these lagoons. To assess the extent of the lagoon resource, English Nature reviewed the information available and produced a directory of saline lagoons in England (Smith & Laffoley 1992). This directory outlines the geophysical and biological status of lagoons but recognises that these data were highly variable due to different sampling regimes and inconsistent species identification. Data were summarised by geographical area, including south-west Britain, and English Nature intend to revise the directory when new data become available.

9.2 North Cornwall

North Cornwall (Figure 9.3) is famous for its high cliffs, sandy beaches and scenic appeal. Visitors are attracted to the extensive clean beaches at Bude and Newquay; the large breakers here are popular with surfers and wind-surfers alike. However, the extent of published marine biological information available for the area is rather sparse. The Cornish Biological Records Unit (CBRU) holds a coastal directory which is a major guide to the marine biological information for the region. Some of the major taxonomic groups were comprehensively described during the 19th century (for example, algae: Ralfs 1883–84; Mollusca: Tregelles 1896). Couch (1846) provided a detailed account of fish recorded around the Cornish coast based on personal observation and notes from fishermen and naturalists. *The Victoria history of the counties of England: Cornwall* (Page 1906) included papers on fish (Cunningham 1906), marine algae (Holmes 1906), marine invertebrates (Clark 1906), and crustaceans (Stebbing 1906). Each paper listed the species recorded in Cornwall and provided notes on their distribution. Turk (1983) compiled a historical record of conchology for Cornwall and described the

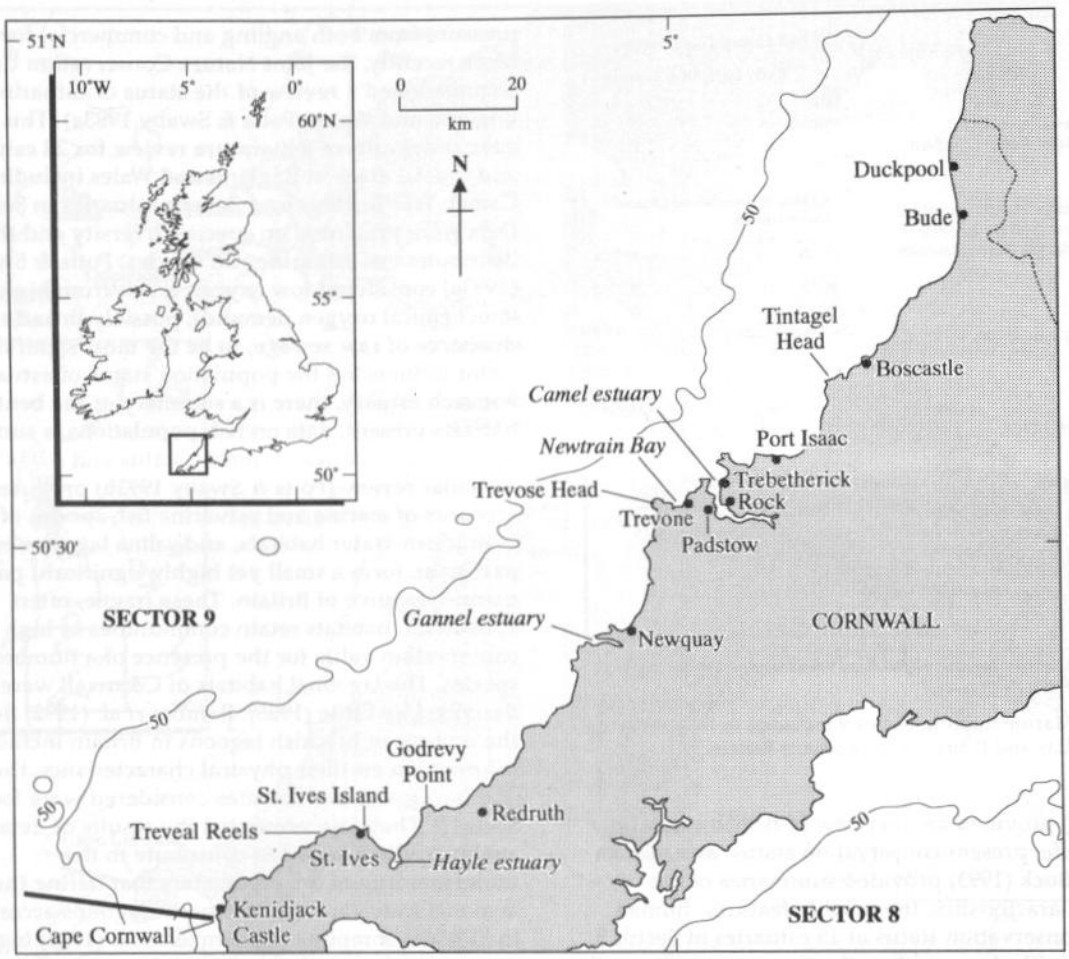

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Figure 9.3. North Cornwall, showing the location of places mentioned in the text.

shores and their molluscan fauna. Many shores were investigated by the Intertidal Survey Unit (Powell *et al.* 1978). These reports are the major sources of information on littoral communities. Sublittoral communities for parts of the area were described by the South-West Britain Sublittoral Survey (SWBSS) (Hiscock 1981a). Bennett (1984) produced a detailed report on coastal use and potential human impacts for the north Cornwall coast.

The major Cornish rivers drain to the south and thus there are few marine inlets on the north coast. Three inlets, the Hayle, Gannel and Camel estuaries are important for their southerly location and for sheltered habitats along an otherwise exposed coastline. Staff from the Marine Biological Association laboratory at Plymouth have studied these estuaries and, in addition, the CBRU at Redruth retains much unpublished information. Disposal of effluent, especially from the metal mining industry, has prompted a number of investigations into the bioaccumulation of heavy metals in the estuarine environment (Bryan & Hummerstone 1973). South-West Water Authority (now South West Water) monitor hydrographic features of the estuaries, especially in relation to sewage discharges and publish results in annual reports. These estuaries were surveyed by the FSC during the survey of Harbours, Rias and Estuaries in Southern Britain. The fragility of estuarine habitats along the north Cornwall coast was highlighted after the *Torrey Canyon* oil spill in 1968. A summary of the impact of the oil and the toxic dispersants used to combat the pollution was presented by Smith (1968).

From Cape Cornwall to St Ives, dramatic granite cliffs tower out of the sea. Many early naturalists visited the region and descriptions of single taxonomic groups were published around the turn of the century, for example, Mollusca: Marshall (1911); macroalgae: Ralfs (1882). A general description of the littoral zone was produced by the CBRU (Turk, unpublished). Cape Cornwall to St Ives is mainly exposed rocky shores with some deep pools on the low shore. These shores had typical barnacle and limpet-dominated mid-shores with fucoid covered low shores. Within the pools, the brown alga *Bifurcaria bifurcata* and the limpet *Patella aspersa* (now *Patella ulyssiponensis*) were unusually abundant (Powell *et al.* 1978).

Sublittoral habitats and communities were studied during the SWBSS (Hiscock 1981a). Extensive bedrock platforms were present with the kelp forest extending to

over 20 m below chart datum; the most abundant kelp was the southern species *Laminaria ochroleuca*. Bedrock was swept free of sand allowing a rich red algal turf to develop underneath the kelp plants. Below the kelp park, circalittoral bedrock was dominated by a turf of bryozoans and hydroids with encrusting sponges and barnacles. Dead-man's fingers *Alcyonium digitatum*, jewel anemones *Corynactis viridis* and the white anemone *Actinothoë sphyrodeta* were the most abundant species. Kenidjack Castle near Cape Cornwall was highlighted as a site representative of the west Cornwall coast (Hiscock 1981a).

Treveal Reefs, St Ives Island and Godrevy Point were considered sites of secondary marine biological importance (Powell *et al.* 1978). Turk (1972) described a survey of St Ives Island and gave an account of the island's history and natural history including descriptions of the maritime and terrestrial vegetation, the open rock shores and rockpools; a species list for the area was also included. Sublittoral habitats were similar to those described above for sites farther west (Hiscock 1981a).

The Hayle estuary is a shallow, predominantly sedimentary inlet with the distinction of being the most south-westerly marine inlet in Britain. It is adjacent to important bird migration routes and provides a strategic location for bird feeding and roosting sites. Conservation interest within the estuary centres on its ornithological importance, and most of the estuary is notified an SSSI. A sand-bar at the mouth narrows the main channel, creating treacherous currents. Export of copper and tin from the local mining industry established Hayle as the busiest port on the west Cornish coast. A large foundry and copper and tin smelters provided employment for the local population whilst a rail link to the main east-west railway ensured the development of the port. With the decline of the mining industry, the port of Hayle lost business and today is frequented only by pleasure craft and a few local fishing boats.

Few studies have described the marine biology of the Hayle estuary. Most of the biological information available has been generated by local naturalists; the Cornish Trust for Nature Conservation and the CBRU retain and hold many unpublished notes. The estuary was surveyed as part of the survey of Harbours, Rias and Estuaries in Southern Britain (Gill 1989) and five habitats and associated communities were identified within the estuary. All of the communities were considered of local conservation importance. Sedimentary habitats dominated the estuary; the principal hard substrata are provided by harbour walls and embankments. Intertidal sediment communities in the current-swept sandy beaches at the entrance to the estuary were poorly colonised with few species recorded. Within the enclosed parts of the estuary (the 'Pools'), infaunal diversity was low and estuarine species (the worm *Hediste diversicolor*, the amphipod *Corophium volutator* and the bivalve *Scrobicularia plana*) dominated the communities. Hard substrata habitats had a low diversity of rocky shore species.

Spectacular cliffs punctuated by sandy bays sweep northwards from Godrevy Point to Trevose Head, a long section of coast that includes the famous surfing beaches of Newquay and Perranporth and many disused metal mines. Newquay was formerly an important port and fishing village, and is now north Cornwall's premier resort town. Published marine biological information for littoral and sublittoral habitats between Godrevy Head and Trevose Head is sparse. Some early naturalists studied single taxonomic groups; for example Tregelles (1896) considered the Mollusca. The Intertidal Survey Unit visited four sites (Powell *et al.* 1978) and the CBRU conducted a general study of the littoral zone (Turk, unpublished).

At Trevone and Trebetherick, there are extensive rocky shores which were considered sites of primary marine biological importance (Powell *et al.* 1978); these sites are the most extensive rocky shores on the north Cornwall coast. Trevone was a special study site following the *Torrey Canyon* disaster in 1968 (Smith 1968). Newtrain Bay, Trevone has a series of irregular rocky reefs which support rich littoral communities. Mid-shore habitats were mussel/barnacle/limpet-dominated, the limpet *Patella aspersa* (now *Patella ulyssiponensis*) was particularly abundant. An unusual feature of the site was a zone of the brown alga *Cystoseira tamariscifolia* at low water. A population of the Mediterranean hermit crab *Clibanarius erythropus* was present but has not been seen following the oil pollution from the *Torrey Canyon*. Trebetherick Point lies at the southern end of a series of rocky reefs and has a typical mussel/barnacle/limpet-dominated mid-shore and algal-dominated low shore. In low-shore pools and gullies, the sublittoral alga *Desmarestia ligulata* and the rare sea-slug *Onchidella celtica* were present.

Sublittoral habitats and communities from East Trevose Head to Port Isaac were studied during the SWBSS (Hiscock 1978a). Sand is an important structuring force within sublittoral communities here. Most of the coast consisted of a flat sand plain or gentle slope extending into shallow water with rock outcrops and broken reefs; most rock surfaces had a covering of sediment. Off headlands, stable and often very broken bedrock extended into deeper water. Communities at the Bull, Trevose Head were different to those farther north. Rock surfaces were dominated by mussels *Mytilus edulis* and the red seasquirt *Dendrodoa grossularia*; large numbers of the spider crab *Maia squinado* were also recorded. At sites farther north, infralittoral bedrock supported a kelp community to only 3 m below chart datum, foliose algae only extending to about 13 m below chart datum. Restricted depth limits of the algae were attributed to the high levels of suspended sediment within the water column. Characterising species recorded on circalittoral rock included Ross 'coral' *Pentapora foliacea*, the sea squirt *Stolonica socialis* and the sea fan *Eunicella verrucosa*. At exposed sites, the organ-pipe hydroid *Tubularia indivisa* and the jewel anemone *Corynactis viridis* covered vertical rock surfaces. Few southern species were recorded from the region and included the anemone *Parazoanthus axinellae* which was present at only one site. Overall, species richness of these benthic communities was low considering the southerly location and the prevailing currents, and may be the result of the high sand load in the water.

Circalittoral communities at Kellan Head were considered to be the richest and most representative of the region surveyed (Hiscock 1978a).

The Camel estuary is the only major marine inlet on the north Cornwall coast. It is a predominantly shallow, sedimentary estuary which has considerable local nature conservation importance. It is designated an Area of Outstanding Natural Beauty, and there are five SSSIs and a bird sanctuary within the estuary. The estuary was considered to be a site of primary marine biological importance (Powell *et al.* 1978). Despite the Doom Bar sandbank at the mouth of the estuary, Padstow was formerly a thriving port. Trade declined as ships became larger, as the estuary became more difficult to navigate.

Marine investigations within the area include a study on the taxonomy of mussel populations at Rock. Here, a very sheltered site, pure populations of the common mussel *Mytilus edulis* occur alongside pure populations of the southern species *Mytilus galloprovincialis*. In contrast, a hybrid population occurs at Polzeath, an exposed site some 6–10 km north (Beaumont, Seed & Garcia-Martinez 1989). The FSC surveyed the estuary during the study of the Harbours, Rias and Estuaries in Southern Britain (Gill & Mercer 1989). Littoral and sublittoral habitats, communities and species were described and assessed as either of national, regional or local importance.

At the entrance to the Camel estuary, there were moderately exposed rocky shores with extensive rockpools on the low shore on the eastern side of the estuary. Extremely sheltered bedrock and boulder shores were dominated by the fucoid *Ascophyllum nodosum*; such sheltered communities are rarely encountered within the marine inlets of north Cornwall and north Devon. Predominantly sandy sediments had rich populations of polychaete worms especially the lugworm *Arenicola marina*. Dense beds of the cockle *Cerastoderma edule* were recorded from some areas. Muddier sediments were also dominated by polychaete worms, of which ragworm *Hediste diversicolor* was the most abundant species. In addition, the bivalve *Scrobicularia plana* and oligochaete worms were locally abundant. Sublittoral rock habitats at the mouth are subject to strong tidal streams. Dense growths of sponges, sea squirts, hydroids and anemones were found on steep bedrock and on gully walls. Notable species recorded included the small seasquirt *Pycnoclavella aurilucens* which nears its northern limit of distribution within the estuary, and four species of the nationally important genus of red algae *Pterosiphonia* (Gill & Mercer 1989).

North Cornwall, from Tintagel Head to the Devon border, includes some very famous landmarks. High Cliff towers over 200 m out of the sea and is the highest cliff in north Cornwall. Tintagel Head and its adjacent areas were very popular with early marine naturalists. Sublittoral habitats and communities were studied by the SWBSS (Maggs & Hiscock 1979). Nearshore sublittoral regions were composed of gently sloping bedrock, occasionally very broken, with boulders at some sites; rock surfaces had an even covering of sand. These habitats were dominated by algae although at some sites a kelp forest was absent. Rather surprisingly, circalittoral animal communities were rarely encountered. Infralittoral algal communities covered a very wide depth range (to 26 m below chart datum at Boscastle). Infralittoral communities were dominated by foliose red algae with *Dictyota dichotoma* and *Dictyopteris membranacea* abundant. A number of notable species of algae were recorded, for example the Mediterranean species *Choristocarpus tenellus*. Vertical and upward facing rock was dominated by bryozoans, sea squirts and sponges; erect sponges such as *Raspailia hispida* were common.

Duckpool, a small sheltered sandy bay near the Devon border, was considered to be a site of primary marine biological importance (Powell *et al.* 1978). Lower shore habitats have exceptionally fine colonies of the reef-building tubeworm *Sabellaria alveolata* (considered to be the finest in Britain by Cunningham *et al.* 1984). Long-term studies on the formation and duration of these reefs were reported by Wilson (1971).

9.3 Lundy

Lundy (Figure 9.4) is a small island lying 18 km off the north Devon coast. It measures just 5 km by 1.25 km and has 15 km of coastline ranging from very exposed to very sheltered from wave action. Most of the island is formed of granite with softer, more friable slate in the south-east corner, off the south coast and offshore of the north coast. Rock-type strongly influences the shores of the island: the majority of the coast comprises steep granite cliffs with inaccessible shores of well weathered granite boulders below. A breeding colony of grey seals *Halichoerus grypus* is present on the island.

The island was visited several times by Victorian naturalists and it is often named as the location of many rare species. Many aspects of the natural history of the island have been documented in the *Report of the Lundy Field Society* following the establishment of the Society in 1947. These include accounts of the marine ecology from work undertaken by Professor L.A. Harvey (Anon. 1948; Harvey 1950). Following a period when few studies were undertaken, the marine biology of the island was extensively studied during the 1970s and 1980s. From 1970 onwards, the *Reports of the Lundy Field Society* include species lists of all the major taxonomic groups recorded around the island; a list of algae was produced by Irvine *et al.* (1972). Studies of the marine biology of Lundy are summarised in Hiscock (1997). In 1973, the island became the first voluntary marine nature reserve in Britain and, in November 1986, Britain's first statutory Marine Nature Reserve. The management plan is published by English Nature (1993).

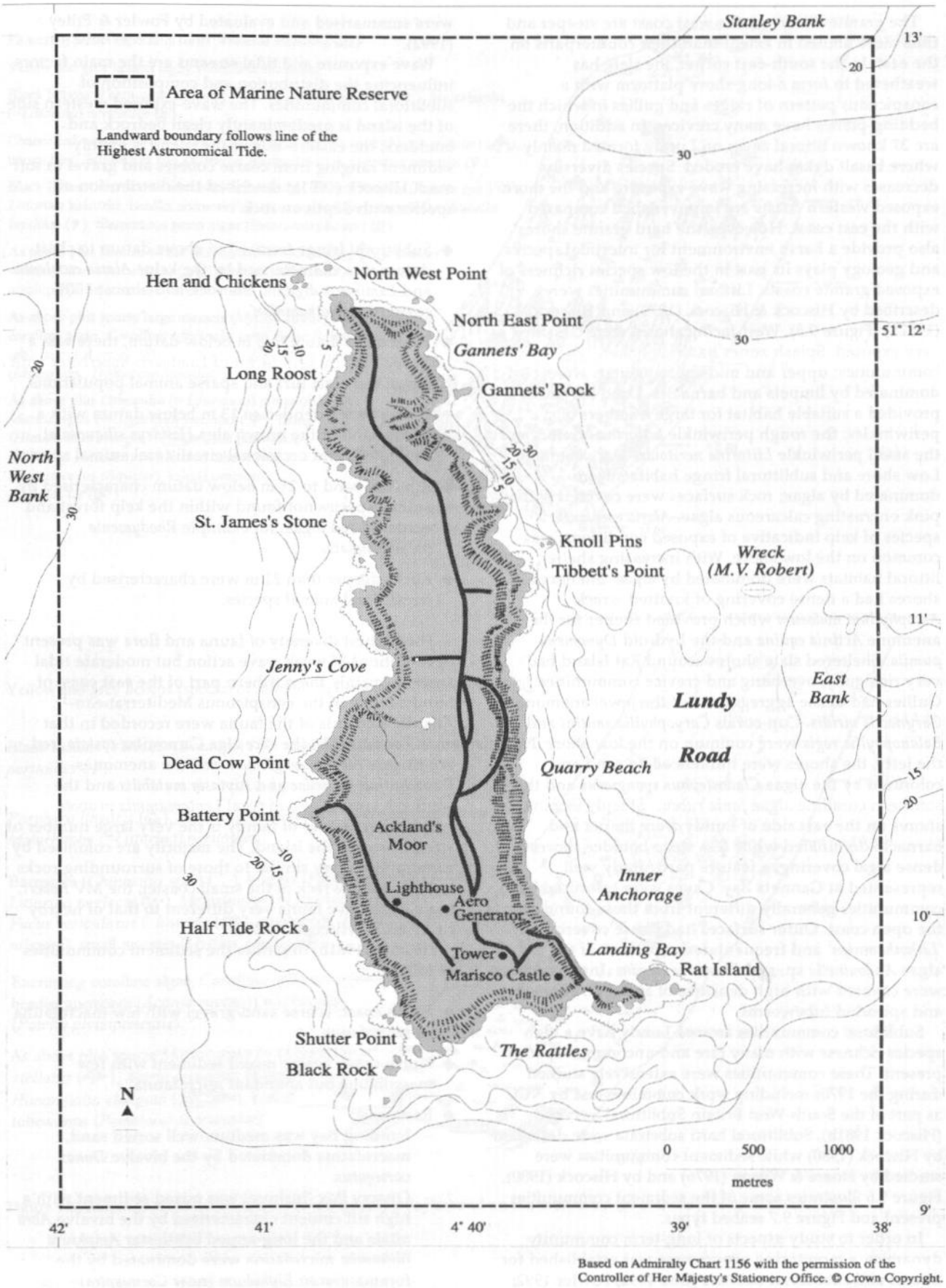

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Figure 9.4. Lundy, showing the boundaries of the Marine Nature Reserve.

The granite shores on the west coast are steeper and thus more limited in extent than their counterparts on the east. In the south-east corner, the slate has weathered to form a long shore platform with a conspicuous pattern of ridges and gullies in which the bedding-planes have many crevices. In addition, there are 37 known littoral caves on Lundy formed mainly where basalt dykes have eroded. Species diversity decreases with increasing wave exposure and the more exposed western coasts are impoverished compared with the east coast. However, the hard granite shores also provide a harsh environment for intertidal species and geology plays its part in the low species richness of exposed granite coasts. Littoral communities were described by Hiscock & Hiscock (1979) and Hiscock (1982a) (Figure 9.5). West-facing shores were classified as very exposed. Splash zones had rich lichen communities; upper and mid-shore habitats were dominated by limpets and barnacles. Dead barnacles provided a suitable habitat for large numbers of periwinkles; the rough periwinkle *Littorina saxatilis* and the small periwinkle *Littorina neritoides* were common. Low shore and sublittoral fringe habitats were dominated by algae; rock surfaces were covered with pink encrusting calcareous algae. *Alaria esculenta*, a species of kelp indicative of exposed conditions, was common on the low shore. With increasing shelter, littoral habitats were dominated by algae. Sheltered shores had a dense covering of knotted wrack *Ascophyllum nodosum* which provided shelter for the anemone *Actinia equina* and the hydroid *Dynamena pumila*. Sheltered slate shores around Rat Island had very rich gully, overhang and crevice communities. Gullies had dense aggregations of the jewel anemone *Corynactis viridis*. Cup-corals *Caryophyllia smithii* and *Balanophyllia regia* were common on the low shore. Near the jetty, the shores were influenced by sand and colonised by the algae *Cladostephus spongiosus* and the southern coralline algae *Jania rubens*. Steeply sloping shores on the east side of Lundy were limpet and barnacle-dominated while less steep boulder shores had dense algal covering, a feature particularly well represented at Gannets Bay. Caves were colonised by communities generally different from those found on the open coast. Outer surfaces had dense covering of '*Lithothamnion*' and frequent dense patches of the red algae *Audouinella* sp. and *Plumaria elegans*. Inner surfaces were covered with high densities of sponges, anemones and spirorbid tubeworms.

Sublittoral communities around Lundy have a high species richness with many rare and uncommon species present. These communities were extensively studied during the 1970s including work commissioned by NCC as part of the South-West Britain Sublittoral Survey (Hiscock 1981b). Sublittoral hard substrata were described by Hiscock (1980) while sediment communities were studied by Hoare & Wilson (1976) and by Hiscock (1980). Figure 9.6 illustrates some of the sediment communities present and Figure 9.7 seabed types.

In order to study aspects of long-term community dynamics, a monitoring programme was established for littoral and sublittoral habitats (Eno 1992; Fowler 1992; Hiscock 1984a, 1984b, 1994; Irving 1990). These studies were summarised and evaluated by Fowler & Pilley (1992).

Wave exposure and tidal streams are the main factors influencing the distribution and composition of sublittoral communities. The wave-exposed western side of the island is predominantly clean bedrock and boulders; the eastern side of the island is mainly sediment ranging from coarse cobbles and gravel to soft mud. Hiscock (1981a) described the distribution of species with depth on rock:

- Sublittoral fringe from +1 m above datum to chart datum was characterised by the kelps *Alaria esculenta* and *Laminaria digitata*, the rock had almost 100% cover of '*Lithothamnion*'.
- From chart datum to 8 m below datum, there was a closed canopy kelp forest of *Laminaria hyperborea* with a lush red algal turf and sparse animal populations.
- A kelp park extended to 13 m below datum with a dense band of the brown alga *Halidrys siliquosa* at some sites, and occasional circalittoral animal species.
- A mixed band to 21 m below datum characterised by animal species not found within the kelp forest and scattered red algae, for example *Rhodymenia pseudopalmata*.
- Rocks deeper than 21 m were characterised by circalittoral animal species.

The highest diversity of fauna and flora was present in conditions of weak wave action but moderate tidal streams, mainly the northern part of the east coast of Lundy. Many of the conspicuous Mediterranean–Atlantic elements of the fauna were recorded in that area. For example, the rare alga *Carpomitra costata*, red sea-fingers *Alcyonium glomeratum*, the anemones *Parazoanthus axinellae* and *Aiptasia mutabilis* and the southern species of cup coral *Leptopsammia pruvoti*.

A further feature of Lundy is the very large number of wrecks around the island. The majority are colonised by communities very similar to those of surrounding rocks but the intact wreck of the small coaster, the *MV Robert*, has a distinctive fauna very different to that of nearby rocky areas (Hiscock 1982b).

Hiscock (1981b) describes the sediment communities as follows:

- South coast: coarse sand/gravel with few macrofauna or microfauna.
- North coast: coarse mixed sediment with few macrofauna but abundant microfauna.
- East coast:
  - Landing Bay was medium well sorted sand, macrofauna dominated by the bivalve *Donax variegatus*.
  - Quarry Bay (inshore) was mixed sediment with a high silt content characterised by the bivalve *Abra nitida* and the long-armed brittlestar *Amphiura filiformis*; microfauna were dominated by the foramaniferan *Elphidium* (now *Cornuspira*) *selseyense*.

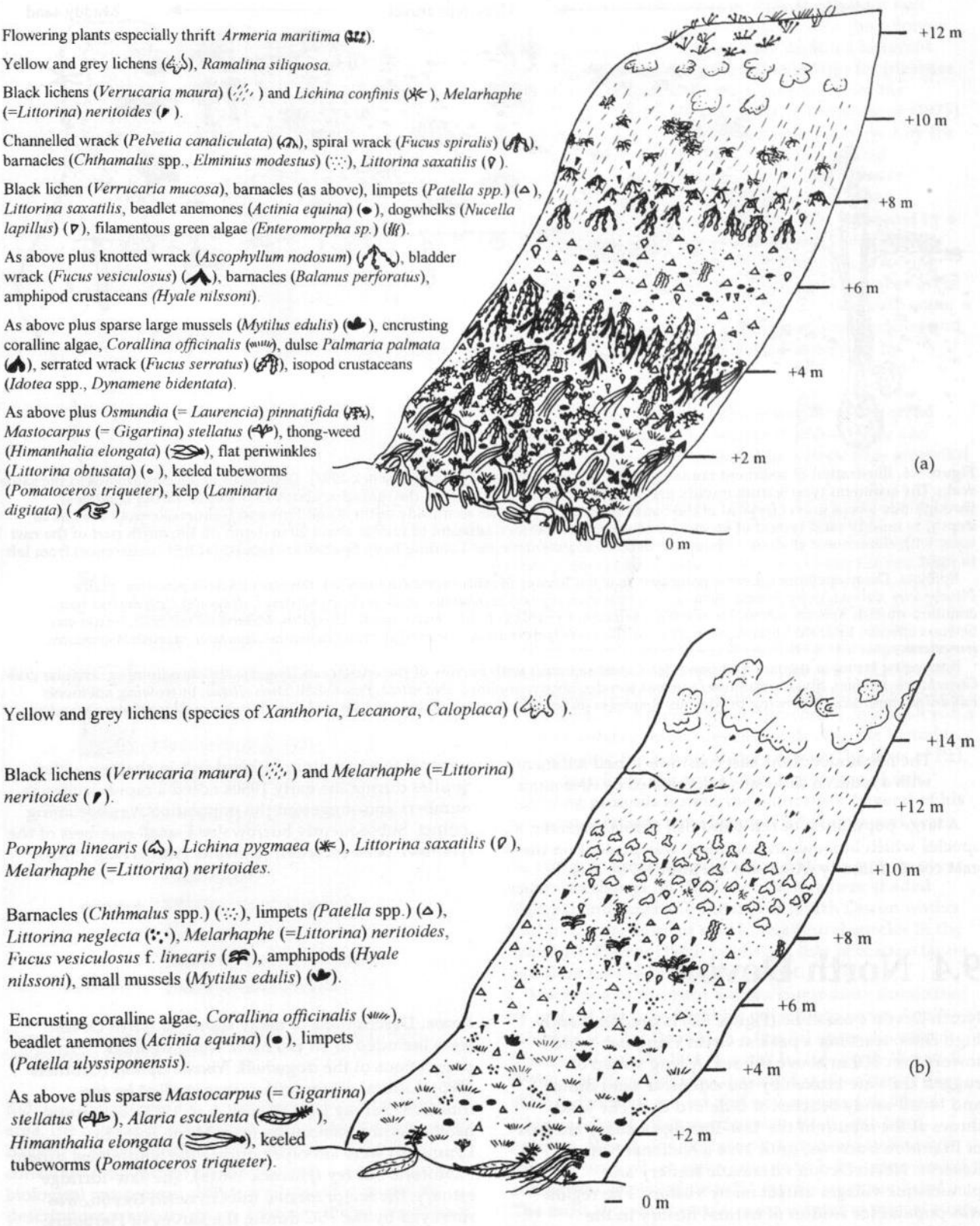

Figure 9.5. Zonation of intertidal species in the Landing Bay (a) and on the west coast (b) at Lundy. From Hiscock (1997).

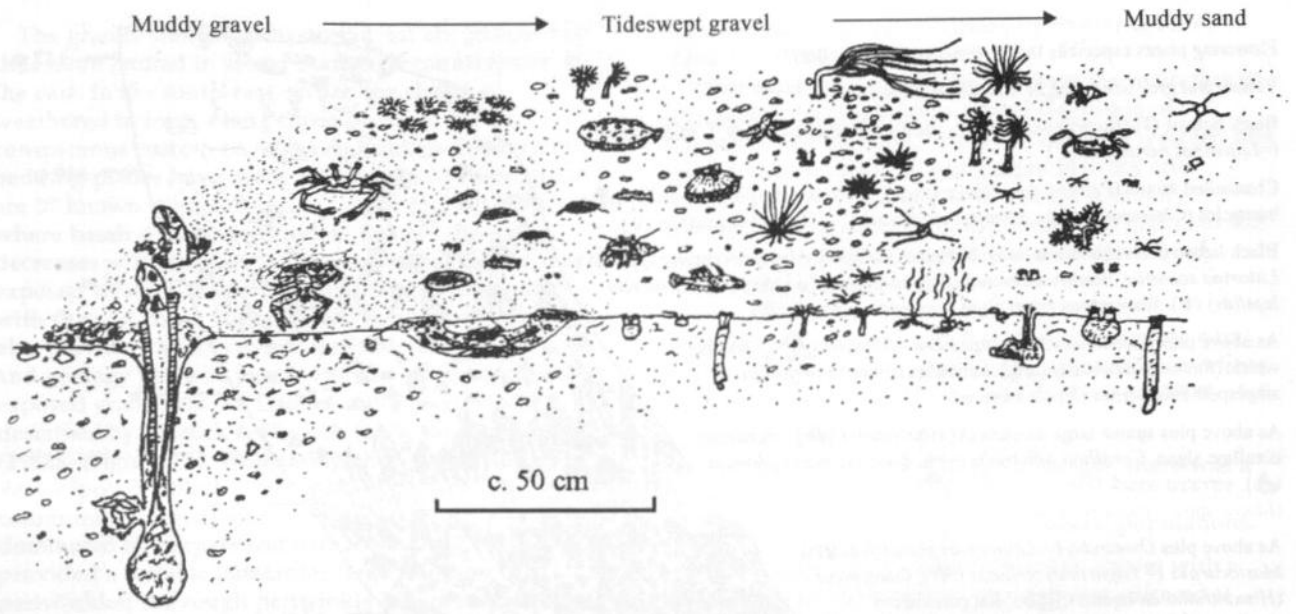

Figure 9.6. Illustration of sediment fauna from the east coast of Lundy (from Hiscock 1997). Depictions of species are not to the same scale. The sediment type is from muddy gravel overlain by mud (typical of the seabed at about 15 m depth off the Quarries) through tide-swept gravel (typical of the banks built-up against the south side of the Knoll Pins and Gannets Rock at 20 to 30 m depth) to muddy sand typical of areas near to rocks (for instance adjacent to rock at about 20 m depth on the north part of the east coast with elements of shallow – about 6 m depth – sediments in the Landing Bay). Species are named (at first occurrence) from left to right.

Epibiota. Daisy anemones (*Cereus peduculatus*), squat lobster *Munida rugosa* (in burrow), fan worm *Sabella pavonina*, plaice *Pleuronectes platessa*, goby *Pomatachistus* sp., hermit crab *Pagurus bernhardus*, scallop *Pecten maximus*, dragonet *Callionymus lyra*, common starfish *Asterias rubens*, burrowing anemones *Cerianthus lloydii, Halcampoides elongatus, Mesacmaea mitchelli*, brittle star *Ophiura ophiura*, hydroid *Corymorpha nutans*, brittle star *Ophiura albida*, swimming crab *Liocarcinus depurator*, starfish *Astropecten irregularis*.

Burrowing fauna in section. Red band fish *Cepola rubescens* with burrow of the crustacean *Upogebia stellata* adjoining, angular crab *Goneplax rhomboides*, bivalve mollusc *Lucinoma borealis*, bivalve mollusc *Abra nitida*, razor shell *Ensis siliqua*, burrowing anemone *Edwardsia claparedii*, burrowing brittlestars *Amphiura filiformis*, sea potato *Echinocardium cordatum*, bivalve mollusc *Arctica islandica*.

– The remainder of the east coast was mixed sediment with a reduced silt content dominated by *Abra nitida*.

A large population of red-band fish *Cepola rubescens*, a species which burrows in sediment, was present on the east coast of Lundy (Atkinson & Pullin 1976). It is unusual to encounter red-band fish in shallow water. Studies during the early 1980s noted a rapid decline in numbers and suggested the population was becoming extinct. Subsequently burrows and small numbers of the fish have been recorded (Howard 1988; Irving 1990).

9.4 North Devon

North Devon's coastline (Figure 9.8) is predominantly high cliffs, reaching a peak at Great Hangman which towers over 300 m above the sea. A long sweep of rugged cliffs are broken by the extensive sand dunes and broad sandy beaches of Bideford Bay. The sand dunes at the mouth of the Taw-Torridge estuary are part of Braunton Burrows, until 1996 a National Nature Reserve. North Devon's dramatic scenery and picturesque villages attract many visitors. The region was popular for studies of natural history in the mid-19th century. Naturalists such as Phillip Henry Gosse and Charles Kingsley worked there and wrote classic accounts of these coasts conveying their enthusiasm in texts such as *A naturalist's rambles on the Devonshire coast* (Gosse 1853). The marine flora of Devon was described by Parke (1952) in the volume *Flora of Devon*. Descriptions of many shores of north Devon were included in an extensive study on local populations of the dogwhelk *Nucella lapillus* (Crothers 1985). Littoral communities were studied by the Intertidal Survey Unit (Powell *et al.* 1978); sublittoral habitats and communities from Morte Point to Lynmouth were surveyed during the South-West Britain Sublittoral Survey (Hiscock 1981a). The Taw-Torridge estuary, the major marine inlet in north Devon, was surveyed by the FSC during the survey of Harbours, Rias and Estuaries in Southern Britain (Little 1989).

From the Devon–Cornwall border, lofty cliffs sweep north then east into Bideford/Barnstaple Bay. Rocky shores at Hartland Quay were considered of marine biological importance (Powell *et al.* 1978). Descriptions of habitats and associated communities within

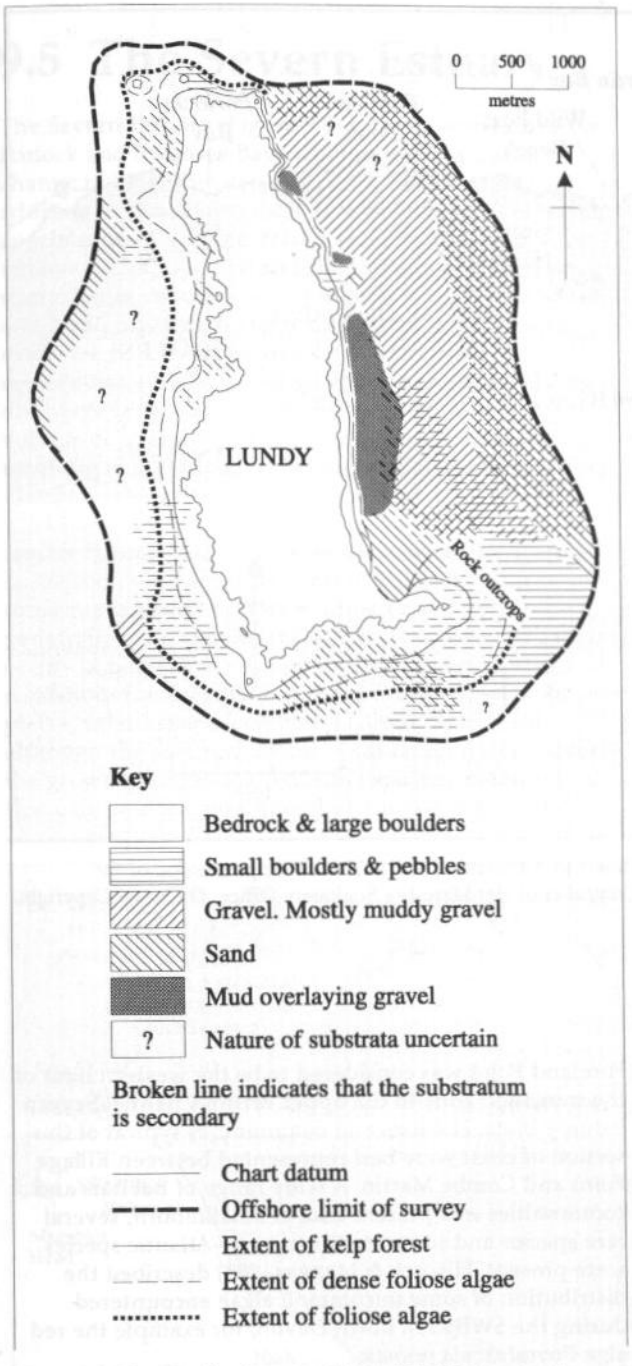

Figure 9.7. The distribution of sublittoral habitats around Lundy (from Hiscock 1981b).

Bideford/Barnstaple Bay are rather scarce. Within the area, the cliffs at Westward Ho!, Braunton Burrows and Baggy Point are notified SSSIs. Powell *et al.* (1978) considered the rocky shores at Croyde a site of marine biological importance, although detailed community descriptions were not given. Hiscock (1981a) considered the sublittoral communities present to have a "strong regional characteristic with sparse algal communities and rocks in many areas dominated by mussels".

The Taw-Torridge estuary complex is a broad sedimentary estuary extending some distance inland, terminating in a series of muddy creeks. Bideford and Barnstaple were both major ports in the days of sail; strong trading links were established with the colonies of North America. Both ports have declined in recent times and now provide sheltered moorings for pleasure craft. Bioaccumulation of heavy metals within the sediments was studied by Bryan & Hummerstone (1973). Marine habitats and communities were surveyed by the FSC (Little 1989) and 11 habitats and associated communities were described. Shores in the lower estuary were considered very good examples of moderately exposed broken rocky shores colonised by a wide variety of algae and animals particularly in the rockpools. Sediment shores were described as having generally low diversity. Areas of sublittoral seabed were restricted to narrow current-swept channels with some extensive hard substrata including bedrock, cobbles and shell or pebbles in gravel colonised especially by hydroids, sponges, sea anemones, erect bryozoans, barnacles and mussels. Sublittoral sediments had a restricted fauna of species characteristic of disturbed conditions, including the worms *Nephtys cirrosa* and *Lanice conchilega* and the amphipods *Haustorius arenarius* and *Bathyporeia sarsi*.

No information is published for the extensive sandy bays with their rock outcrops at Saunton and Woolacombe but the beaches are known to include rocky shore communities adjacent to sand characterised by solitary and small colonies of the honeycomb worm *Sabellaria alveolata* and by the barnacle *Balanus perforatus*. The coarse sandy beaches are colonised by species characteristic of mobile sand including the isopod *Eurydice pulchra* and cirratulid polychaetes (K. Hiscock, unpublished). At Morte Point, the coastline sweeps east and adopts a northern aspect. Ilfracombe, north Devon's premier holiday resort, developed during the Victorian era following the arrival of the railway. The texts of P.H. Gosse describing the area present an image of rich collecting grounds for marine naturalists. Several of his favoured locations have been revisited in recent years, revealing the continued presence of a rich littoral fauna (K. Hiscock, unpublished). Many of these species occur under overhangs on the lower shore where shaded (damp) conditions and the turbid North Devon waters lead to the presence of many circalittoral species in the intertidal. Palmer (1946) published lists of marine fauna and flora for the Ilfracombe district.

The fauna of the hard bottom community dominated by reefs of the tube-building polychaete worm *Sabellaria spinulosa* at a depth of 41 m a few kilometres north of Ilfracombe was studied in detail by George & Warwick (1985). *Sabellaria spinulosa* occurred in densities of over 3,000 individuals per m^2 and was accompanied by a wide variety of other species associated with hard bottoms. Ninety-four species were recorded although they are ones which were capable of being enumerated and several expected colonial species were not listed. The most abundant species were subject to special study of biomass and productivity.

The coastline from Combe Martin to beyond the Devon–Somerset border forms the seaward boundary of the Exmoor National Park. Holme & Nichols (1976) described the rocky shore habitats and communities within the National Park. The Exmoor coastline is

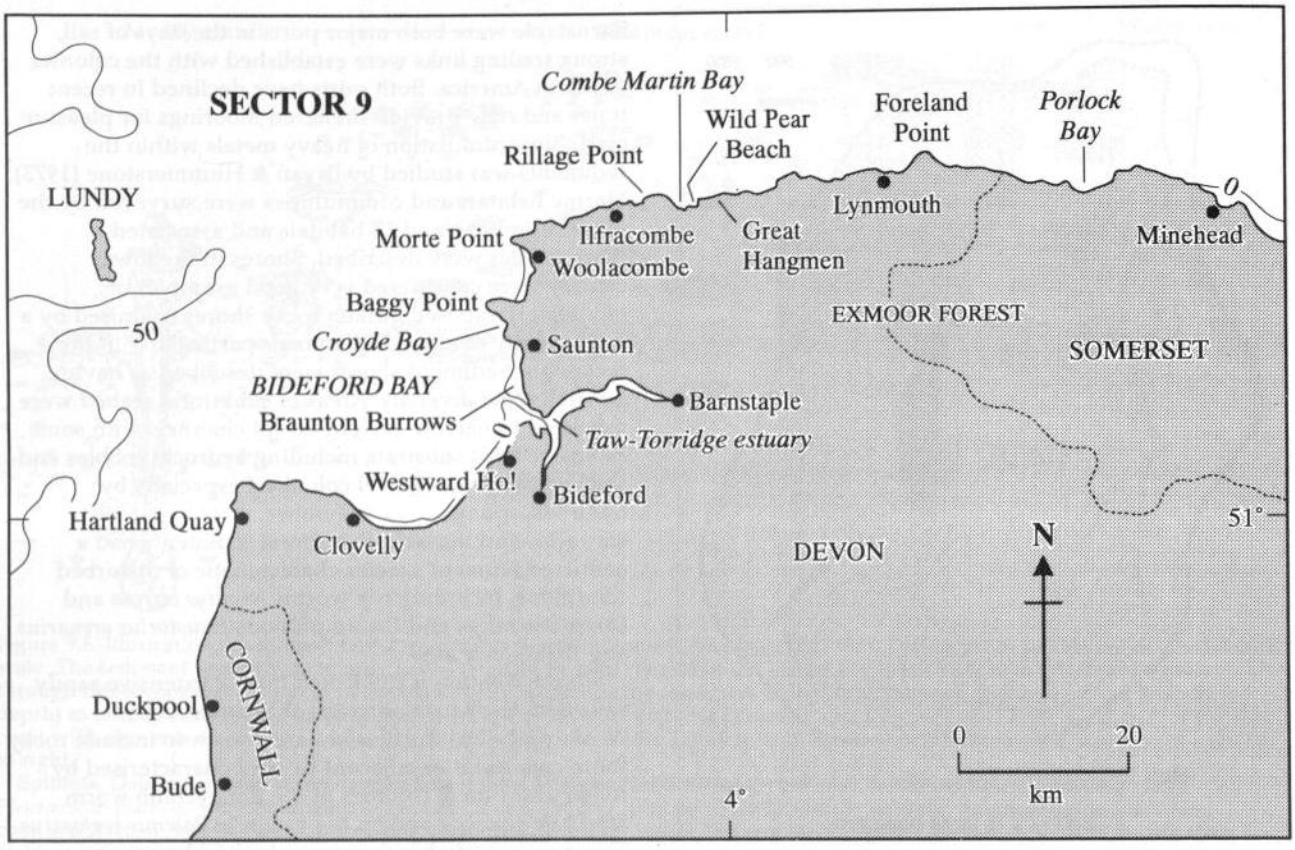

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Figure 9.8. North Devon, showing places mentioned in the text.

predominantly boulder shores with occasional rocky reefs and some stretches of sand. Moderate to severe wave action reduces boulder stability which in turn reduces species richness within littoral communities. One site within the Devon part of the survey, Wild Pear Beach, was considered of medium species richness. Mid-shore habitats were dominated by barnacles and limpets with sparse algal cover. The bladderless form of bladder wrack *Fucus vesiculosus* var. *evesiculosus* was present on more exposed shores. Pools and overhangs were covered with encrusting sponges, mainly the breadcrumb sponge *Halichondria panicea* and the orange sponge *Hymeniacidon perleve*. Two species of interest were the uncommon anemone *Actinia fragacea* and the honeycomb worm *Sabellaria alveolata*. Powell *et al.* (1978) also considered Wild Pear Beach a site of marine biological importance, although no descriptions of the habitats and associated communities were provided.

Sublittoral habitats and communities of the North Devon coast were investigated during the SWBSS and the results summarised in the final report (Hiscock 1981a). Communities present had a similar species composition from west to east and a similar downward extent of the main subzones. A wide variety of species were present although few characteristically west coast or Mediterranean–Atlantic species were recorded. Foreland Point was considered to be the western limit of the transition zone to the upper Bristol Channel/Severn Estuary biota. Habitats and communities typical of this section of coast were best represented between Rillage Point and Combe Martin. A wide range of habitats and communities was present and, at Smallmouth, several rare species and some Mediterranean–Atlantic species were present. Hiscock & Maggs (1984) described the distribution of some uncommon algae encountered during the SWBSS in north Devon; for example the red alga *Pterosiphonia pennata*.

Expansion of the construction industry has precipitated a large increase in demand for aggregate. One of the major sources of aggregate is the marine environment and large areas of the outer Bristol Channel are suitable for aggregate extraction. Baldock (1991) reported the results of a review of available data on fisheries activity and a basic benthic survey for an area off the coast of north Devon where a licence was sought for aggregate extraction. Eight stations were sampled and 74 taxa were identified. These were considered to form a *Modiolus* community (*sensu* Warwick & Davies 1977), a widespread community within the Bristol Channel. Bottom trawls captured 14 species of fish with poor cod *Trisopterus minutus* the most abundant species.

9.5 The Severn Estuary

The Severn Estuary (Figure 9.9) extends eastwards from Porlock and Swansea Bays where there is a distinct change in biota (Boyden *et al.* 1977; Hiscock 1981a). In addition to the Severn itself, five major rivers enter this area: the Avon and the Parrett enter on the south shore while the Usk, the Wye and the Taff enter on the north shore. Large conurbations at Bristol, Portishead, Cardiff and Newport, and the large amount of industry and extensive port facilities associated with these conurbations, leads to a large volume of effluent being discharged into the marine environment. A very large volume of fresh water enters the Severn Estuary, resulting in a gradual decline in salinity with increasing distance eastwards. In addition, a large tidal range combined with the funnelling effect of the estuary creates strong tidal streams which suspend or retain in suspension very large amounts of sediment with consequent effects on water turbidity and light penetration throughout the system. 'Liquid mud', which occurs in parts of the estuary, provides very difficult conditions for the colonisation of benthic species. In places, tidal streams maintain bedrock clear of silt, although the scouring action of silt-laden water reduces the growth of epifauna. Thus the marine communities that exist in the upper Bristol Channel and Severn Estuary are very different from those of almost all other estuaries in Britain, including some characteristic of estuarine conditions and some highly impoverished examples of biotopes.

The Severn Estuary has long been recognised as an area of considerable nature conservation importance. Both biological and geological features are notified as SSSIs, for example the limestone outcrops of Brean Down and the Holm Islands. Allen (1990) described the geology of the Severn Estuary and presented diagrams explaining the hard geology and the overlying sediments. In addition, changes in the geomorphology were discussed in relation to changes in sea-level in recent (geological) time. Extensive mudflats at Berrow, Gwent Levels and the upper Severn Estuary have rich infaunal communities that support internationally important populations of wading birds. In recognition of the high conservation importance, the entire Severn Estuary was notified an SSSI in 1988.

A series of studies describing the fauna of rocky promontories of the Bristol Channel and Severn Estuary was published in the *Proceedings of the Bristol Naturalists' Society* under the general heading *Studies on the biology of the Bristol Channel*. In that series, the littoral fauna and flora of the southern shores were described

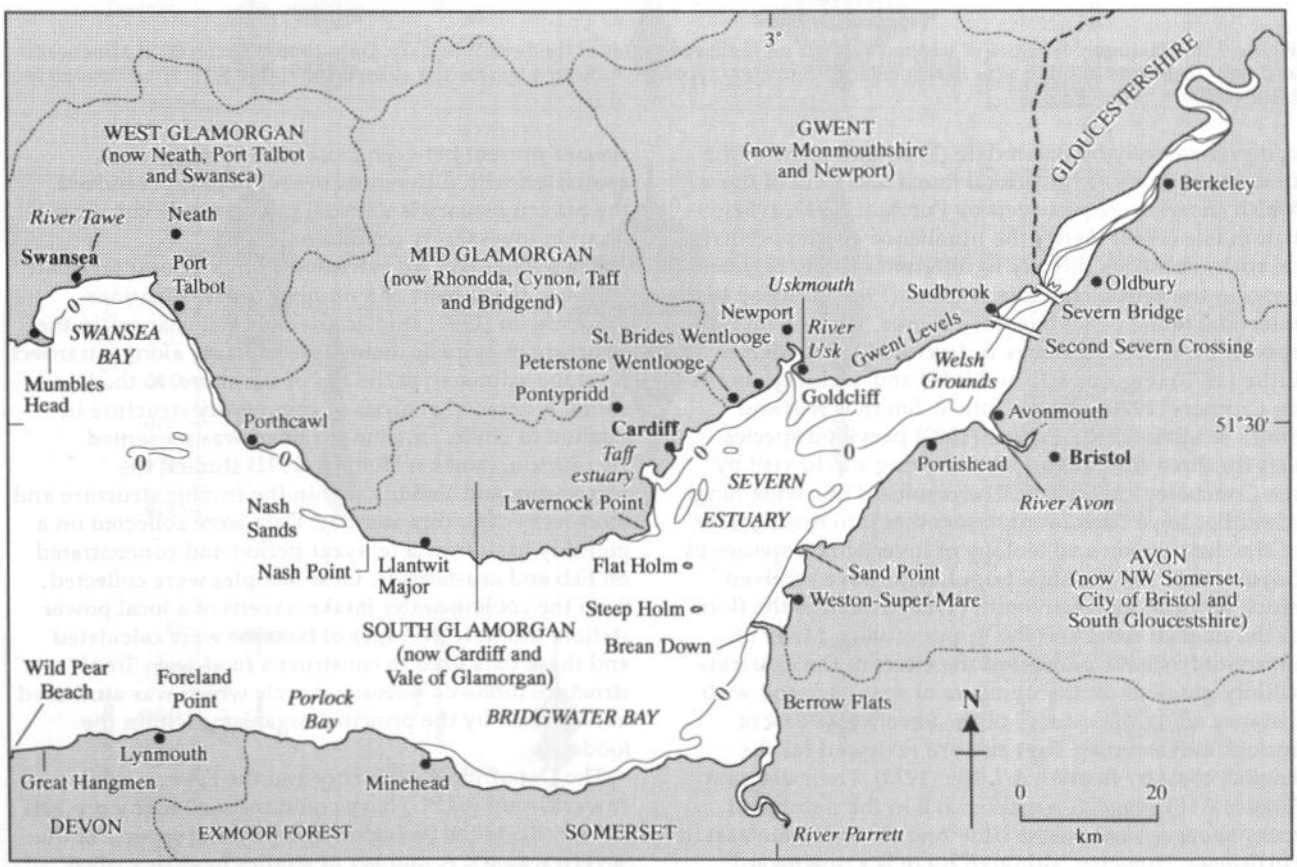

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Figure 9.9. The Severn Estuary, showing places mentioned in the text.

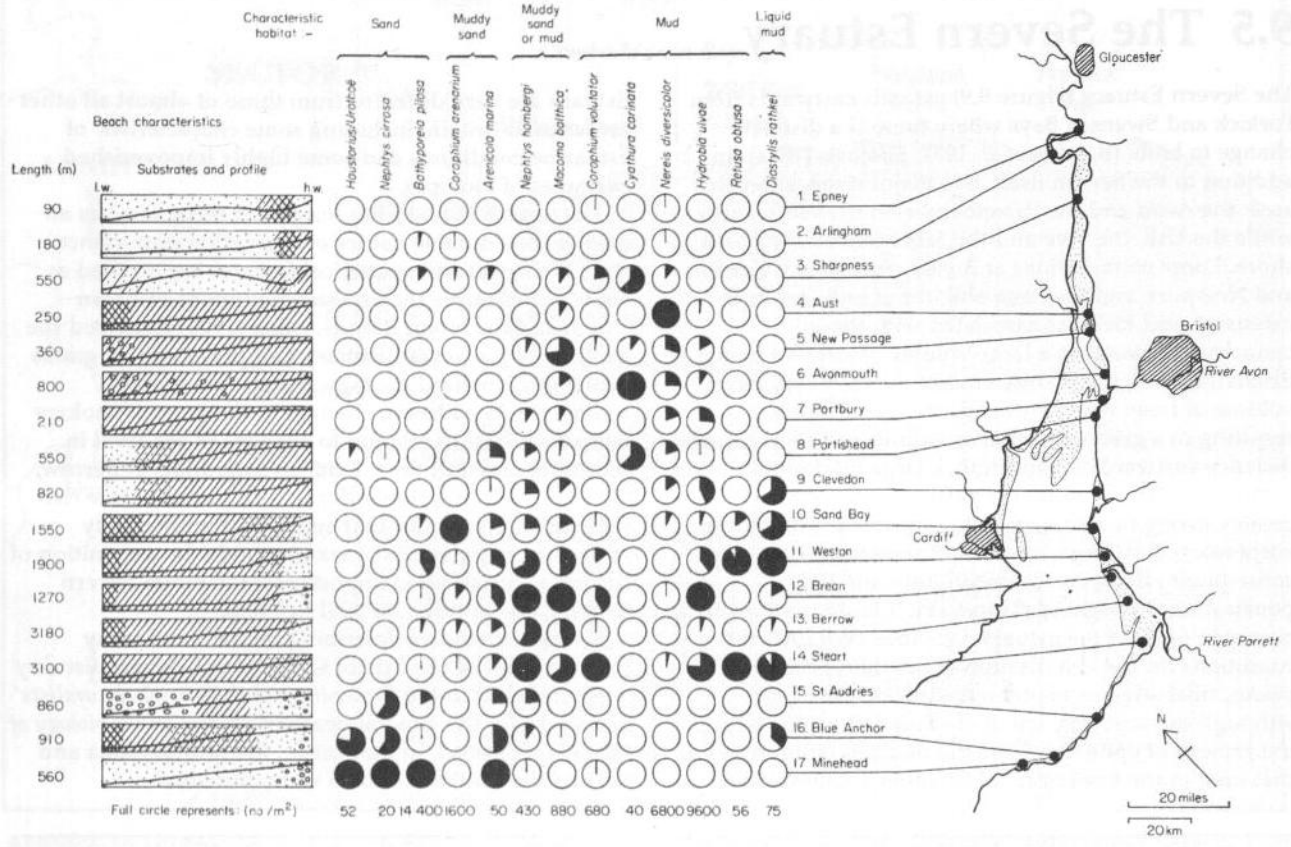

Figure 9.10. Maximum densities of selected animals on sediment shores of the Severn Estuary. Only *Urothoë* occurred at Minehead and only *Haustorius* at other sites in that column. Sediment types are indicated by shading as keyed in Figure 9.11. From Boyden & Little (1973).

comprehensively by Bassindale (1941) and some of the first descriptions of the littoral fauna and flora of the Welsh shores were provided by Purchon (1947, 1951). Bassindale (1943) relates the number of species occurring on rocky substrata directly to different salinity regimes. Later in the series, Haderlie & Clark (1959) describe the intertidal fauna of sedimentary shores. The zonation of species on sediment shores is described by Boyden & Little (1973) (Figures 9.10 and 9.11) and on rocky shores by Crothers (1976) and by Little & Smith (1980) and Smith & Little (1980). Palmer (1992) provided species lists for three sites at Porlock following a field visit by the Conchological Society. The results of this wide range of studies have been brought together into descriptions of the distribution and biology of invertebrate species by Boyden *et al.* (1977). Algal populations have received much less attention but Smith (1980) describes the flora of the English coast and the upper estuary. Many of these studies have addressed the effect of the estuarine salinity gradient on the numbers of species found with distance along the estuary of the Severn (i.e. east of Porlock and Swansea Bay) and are reviewed for the English coast by Boyden & Little (1973). Their diagram (Figure 9.10) suggests a marked fall in the number of rocky shore species east of Blue Anchor and again east of Portishead. However, although there is a downward trend in the number of sediment shore species from west to east (with few species occurring beyond Sharpness), differences in composition and number of species present between locations are much more associated with differences in sediment type. Indeed, the Severn Estuary is unusual in that sandy substrata occur in low salinity conditions.

Bridgwater Bay, an extensive area of littoral sandflats, has been the subject of a number of investigations. Oppenheim (1991) studied the seasonal changes in the structure of epipelic diatom assemblages along a transect from the saltmarsh at the top of the shore, to the low shore. A detailed analysis of community structure in relation to environmental variables was presented. Henderson, James & Holmes (1992) studied the seasonality and stability within the trophic structure and food-webs of Bridgwater Bay. Data were collected on a monthly basis over a ten-year period and concentrated on fish and crustaceans; these samples were collected from the cooling-water intake screens of a local power station. Monthly averages of biomass were calculated and these data used to construct a food-web. Trophic structure followed a seasonal cycle which was attributed to migration by the principal organisms within the food-web.

The Department of Energy and the Severn Tidal Power Group (STPG) have commissioned many projects to investigate the biological and physical aspects of the Severn Estuary. A number of studies have described littoral and sublittoral habitats and their associated communities; the results of these studies and descriptions of the communities identified were

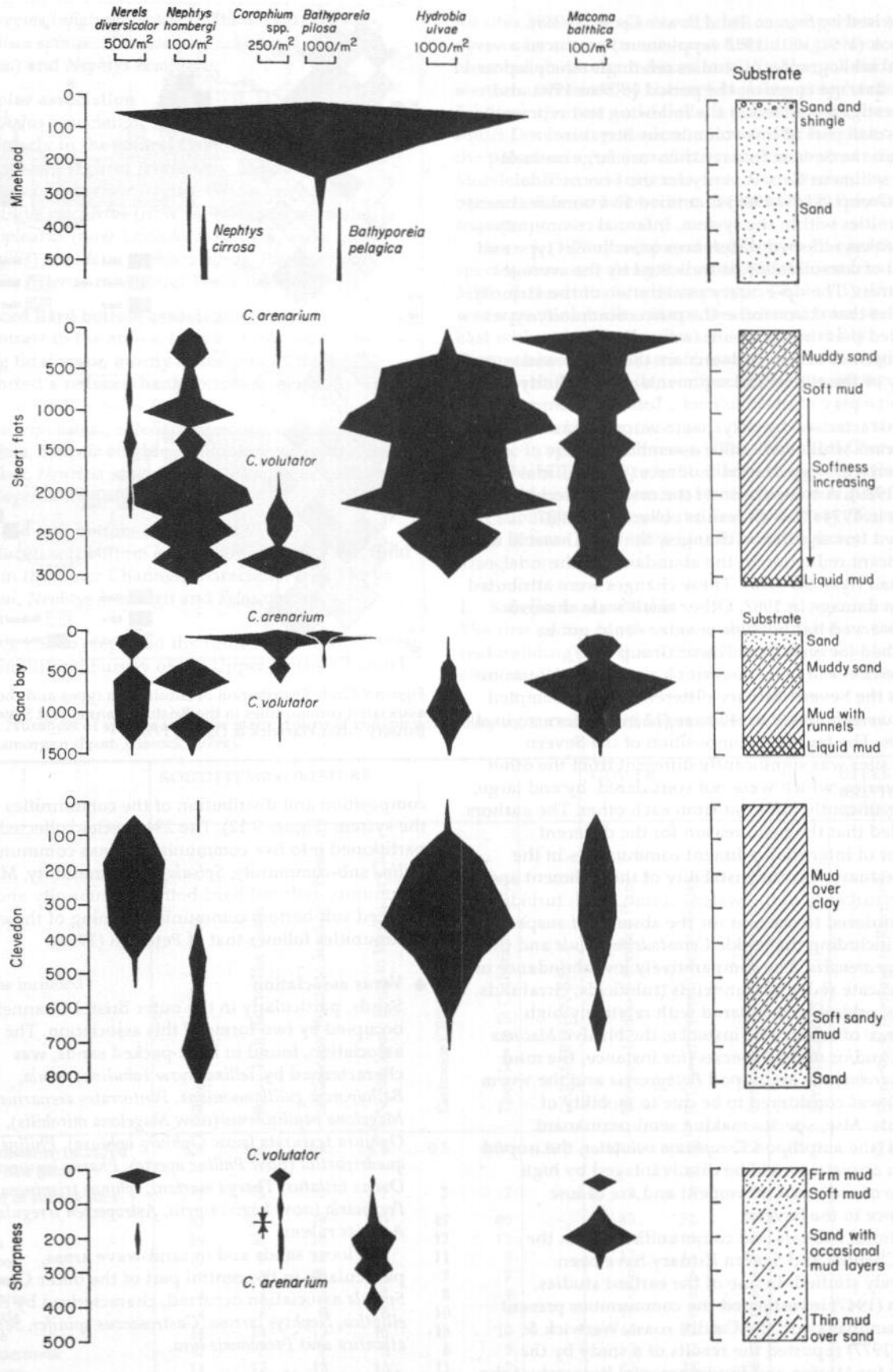

Figure 9.11. Distribution and abundance of selected animals on some muddy and sandy shores of the Severn Estuary. Shading is the same as for Figure 9.10. From Boyden & Little (1973).

summarised by Severn Tidal Power Group (1989). Holbrook (1991, with 1992 supplement) produced a very detailed bibliography of studies relating to the proposed Severn Barrage covering the period 1909 to 1990, and the investigations cited in the following text represent only a small part of this voluminous literature.

Within the Severn Estuary there are large areas of littoral sediment flats. A study for the Severn Tidal Power Group (STPG 1989) identified 13 littoral sediment communities within the system. Infaunal community composition reflected differences in sediment type and its level of consolidation as indicated by the average shear stress. The up-estuary penetration of the majority of species that characterise the main community types suggested that the dominant factors limiting the distribution of benthic infauna are the nature and stability of the superficial sediments while salinity appears to play a subsidiary role. Infaunal communities were characterised by polychaete worms and amphipod crustaceans while epibenthic assemblages were characterised by gastropod molluscs (Severn Tidal Power Group 1989). A comparison of the results collected by surveys in 1974–77 with results collected in 1987 produced few significant changes; the most notable was a significant reduction in the abundance of the mud-snail *Hydrobia ulvae*. These changes were attributed to storm damage in 1987. Other small-scale changes were observed but possible reasons could not be established (Severn Tidal Power Group 1989).

Warwick *et al.* (1991) undertook a study to determine "Why is the Severn Estuary different?". They sampled macroinvertebrates from 40 sites (12 in the Severn) in six estuaries. The faunistic composition of the Severn estuary sites was significantly different from the other five estuaries, which were not considered, by and large, to be significantly different from each other. The authors concluded that the main reason for the different character of intertidal sediment communities in the Severn estuary was the instability of the sediment and the high turbidity of the water column. High turbidity was considered to account for the absence of suspension feeders including the cockle *Cerastoderma edule* and the clam *Mya arenaria*. The comparatively low abundance of small delicate sedentary annelids (tubificids, cirratulids, spionids, orbiniids) compared with relatively high abundance of robust (for instance, the bivalve *Macoma balthica*) and/or mobile species (for instance, the mud snail *Hydrobia*, the amphipod *Bathyporeia* and the worm *Nephtys*) was considered to be due to mobility of sediments. Also, species making semi-permanant burrows (the amphipod *Corophium volutator*, the isopod *Cyathura carinata*) would be disadvantaged by high amounts of sediment movement and are of low abundance in the Severn.

Sublittoral habitats and communities within the Bristol Channel and Severn Estuary have been extensively studied. In one of the earliest studies, Purchon (1947) investigated the communities present within sandbanks off the Cardiff coast. Warwick & Davies (1977) reported the results of a study by the Institute for Marine and Environmental Research of the Bristol Channel and Severn Estuary. Some 155 stations were sampled; the results provided information on the

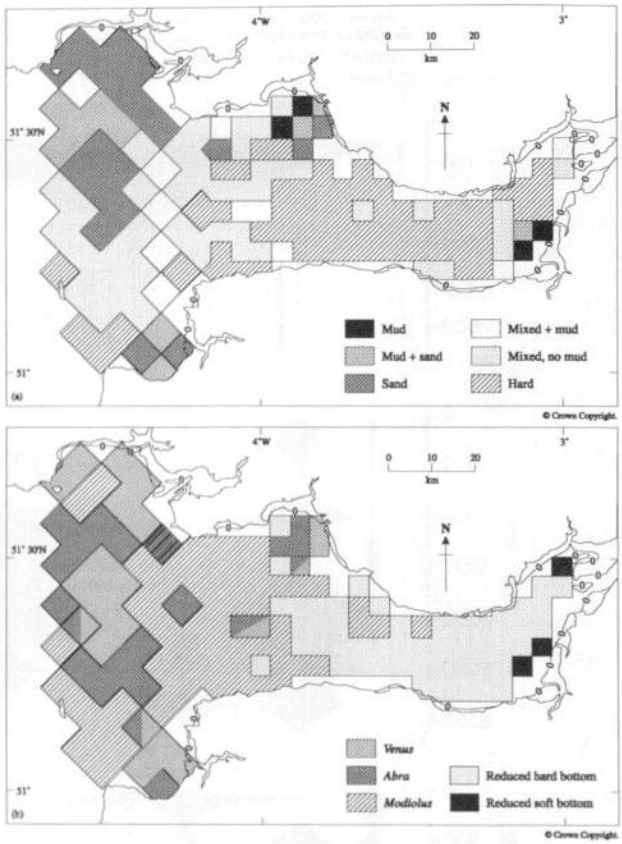

Figure 9.12a/b. Distribution of substratum types and their associated communities in the Bristol Channel and Severn Estuary (after Warwick & Davies 1977).

composition and distribution of the communities within the system (Figure 9.12). The 294 species collected were partitioned into five communities: *Venus* community, *Tellina* sub-community, *Spisula* sub-community, *Modiolus* community, reduced hard-bottom community and a reduced soft-bottom community. Naming of these communities follows that of Petersen (1914):

- ***Venus* association**
  Sands, particularly in the outer Bristol Channel, were occupied by two forms of this association. The *Tellina* association, found in hard-packed sands, was characterised by *Tellina* (now *Fabulina*) *fabula*, *Bathyporeia guilliamsoniana*, *Pontocrates arenarius*, *Magelona papillicornis* (now *Magelona mirabilis*), *Ophiura texturata* (now *Ophiura ophiura*), *Philine quadripartita* (now *Philine aperta*), *Pharus legumen*, *Donax vittatus*, *Tharyx marioni*, *Iphinoe trispinosa*, *Pectinaria* (now *Lagis*) *koreni*, *Astropecten irregularis* and *Asterias rubens*.

  On loose sands and in sand-wave areas, particularly in the central part of the outer Channel, a *Spisula* association occurred, characterised by *Spisula elliptica*, *Nephtys cirrosa*, *Gastrosaccus spinifer*, *Sepiola atlantica* and *Paradoneis lyra*.

- ***Abra* association**
  Muddy bottoms in the outer Channel were occupied by an *Abra* association, characterised by *Abra alba*,

Scalibregma inflatum, Pectinaria (now *Lagis*) *koreni, Ampelisca spinipes, Nucula turgida* (now *Nucula nitidosa*) and *Nephtys hombergii.*

◆ ***Modiolus* association**
A *Modiolus* association was found on hard bottoms, particularly in the central Channel. Characterising species were *Pagurus bernhardus, Lepidonotus squamatus, Ophiothrix fragilis, Pisidia longicornis, Eurystheus maculatus* (now *Gammaropsis maculata*), *Lepidopleurus* (now *Leptochiton*) *asellus, Syllis* (now *Typosyllis*) *armillaris, Ophiura albida, Psammechinus miliaris, Asterias rubens* and *Ebalia tuberosa.*

◆ **Reduced hard bottom association**
In contrast to the above, hard bottoms subject to strong tidal scour, mostly in the inner Channel, supported a reduced hard bottom association, characterised by *Syllis* (now *Typosyllis*) *armillaris, Eulalia tripunctata, Sabellaria alveolata, Sabellaria spinulosa, Sphenia binghami, Unciola crenatipalma, Janira maculosa, Henricia sanguinolenta, Gammarus zaddachi* and *Sagartia troglodytes.*

◆ **Reduced soft bottom association**
A reduced soft bottom association was found in fluid mud in the inner Channel, characterised by *Tharyx marioni, Nephtys hombergii* and *Peloscolex* sp.

Hiscock (1979a) reported the results of the South-West Britain Sublittoral Survey of the Upper Bristol Channel. All sites had a low species richness in comparison to open coast areas of south-west Britain. Algae were only recorded above chart datum level. Stable rock surfaces were characterised by the reef-building polychaetes *Sabellaria alveolata* and *Sabellaria spinulosa* with the sea squirt *Dendrodoa grossularia,* mussels *Mytilus edulis* and the polychaete *Polydora ciliata* common at some sites. Mobile or scoured substrata were characterised by the barnacle *Balanus balanus* and the tubeworm *Pomatoceros triqueter.*

Hiscock (1979a) compared the number of conspicuous species observed along the south Wales coast from Milford Haven to South Glamorgan (Table 9.1). There was a gradual decline in species richness from west to east with a sharp reduction across Swansea Bay. Communities to the east of Swansea Bay were highly impoverished. A similar comparison of sites along the Somerset coast revealed a similar trend but with no sharp discontinuity. Hiscock (1979a) considered the decline in species richness within the Bristol Channel and Severn Estuary to be similar to that observed when moving from the open coast to enclosed marine inlets.

A sublittoral survey of the Severn Estuary (Severn Tidal Power Group 1989) identified ten species associations:

1. ***Sabellaria* association**
The first group consisted of sites dominated by the reef-building polychaete *Sabellaria* (mainly *Sabellaria alveolata*, though *Sabellaria spinulosa* was also recorded).

Table 9.1. Numbers of species from the main groups of conspicuous rocky sublittoral organisms present from Milford Haven to South Glamorgan (From Hiscock 1979a).

	SOUTH PEMBROKESHIRE							GOWER				UPPER BRISTOL CHANNEL
Coastline included	Sheep Island to Crow Rock	Pen-y-Holt Bay to The Castle	St Gowans Shoals to Stackpole Head	N. Stackpole Head to Westmoor Cliff	Eastmoor Cliff to West Beacon Point	The Flats to St Catherines Island	CARMARTHEN BAY	Worms Head to S. Oxwich Point	E. Oxwich Point to Seven Slades	Off Caswell Bay to Mumbles Head	SWANSEA BAY	Fairy Rock, Portcawl to Reynards Cave, Llantwit Major
Linear distance included west to east (km)	4.5	6.6	3.9	4.4	9.5	4.5*	22.5	12.9	6.9	5.2	19.3	12.1
Number of survey sites	7	8	7	7	7	7		7	7	7		6
Algae	57	60	49	50	49	40		45	52	19		17
Porifera	19	20	18	17	17	13		16	15	11		5
Hydrozoa	11	9	12	12	11	9		12	14	10		8
Anthozoa	7	8	10	6	7	7		9	6	6		5
Polychaeta	4	4	4	7	8	4		7	6	6		6
Decapoda	4	6	9	8	10	9		10	8	6		2
Bryozoa	14	14	13	16	18	10		10	12	12		10
Echinodermata	7	7	7	6	8	5		2	2	2		3
Ascidiacea	11	12	13	13	11	7		13	14	10		2
Total number of species	134	140	136	136	139	104		124	129	82		58

*South to north

This association covered the greatest area of the subtidal region and contained the richest assemblage of species (up to 25 per sample). *Sabellaria* spp. occurred at most stations not covered with a layer of sediment, its range extending landward of Avonmouth.

The substratum at these stations was poorly sorted with a predominance of gravel and sands, giving a bimodal distribution of grain-size. Moderate amounts of fine material were present. The sediment was collected from between cobbles and pebbles, and the sites were therefore logged as hard bottom from visual inspection. In addition to *Sabellaria* spp., the fauna was characterised by the polychaetes *Eulalia tripunctata*, *Typosyllis armillaris*, *Melinna cristata* and *Golfingia vulgaris*. There was some indication that subdivisions of the association exist. Sites near Cardiff, abutting areas of sediment, were characterised by the polychaete *Mediomastus fragilis*, possibly because of the presence of fine sediment in the interstices of the reef. West of Bridgwater Bay areas of cobbles among pebbles or gravel were thinly colonised by *Sabellaria* sp., without consolidation into a reef. Stenohaline species, including the gastropod *Tricolia pullus*, occurred only at stations west of Lavernock Point. While this may correlate with the salinity gradient along the estuary, lack of suitable substrata was suggested to be a more likely limit to upstream penetration of this species.

2. ***Sabellaria/Exogone* (gravels) association**

The second group represents an extension of the '*Sabellaria*' association, but was distinguished by the presence of the polychaete *Exogone naidina*. The bivalve *Nucula turgida* (now *Nucula nitidosa*) was also present. The sediment at such stations consisted predominantly (>80%) of gravel with little fine material present. They were located at the western end of areas of lag gravel off the southern shore and at a few sites on the northern shore.

3. ***Nephtys/Tharyx* (reduced soft sediments) association**

At two extensive areas, one in Bridgwater Bay and the other off Wentlooge flats, the sediment consisted of soft, settled mud (with some coarse material). These habitats extended into the intertidal and were characterised by the polychaetes *Nephtys hombergii* and *Tharyx marioni*, the oligochaete *Tubificoides amplivasatus* and the crustacean *Diastylis rathkei typica*.

4. ***Macoma/Hydrobia* polychaete (intertidal mud) association**

The fourth association occurred mainly in the intertidal region, but with one station among offshore gravels. The characteristic species were the bivalve *Macoma balthica*, the snail *Hydrobia ulvae*, the oligochaete *Tubificoides benedeni* and the polychaetes *Nephtys hombergii*, *Streblospio shrubsolii*, *Pygospio elegans* and, especially on the upper shore, *Nereis* (now *Hediste*) *diversicolor*. The transition zone between this and association 3 contained species common to both. The sediments of these two associations were very similar, namely silt/clay (though that of association 4 lacked coarse sand), and the difference between them apparently arose from the difference in vertical elevation. This allowed the mud at stations in Group 3 to drain and consolidate at low tide. The presence of benthic microalgae in intertidal sediments may also enhance their stabilisation as a consequence of the production of mucus by the algae.

5. ***Macoma/Hydrobia*/amphipod association**

Group 5 consisted of stations found on the borders of mud and sand areas on the Welsh Grounds, Berrow Flats, the mouth of the River Usk and Sand Point. These were characterised by *Macoma balthica*, *Hydrobia ulvae*, the amphipods *Bathyporeia pelagica*, *Bathyporeia pilosa* and *Haustorius arenarius*, the polychaete *Nephtys cirrosa* and the crustacean *Cumopsis goodsiri*. The sediments at these stations were predominantly fine sand, with some medium sand and little silt/clay.

6. ***Capitella/Mesopodopsis* association**

The stations comprising Group 6 occurred in the upper estuary, partly in the subtidal region (at the inner end of Newport Deep and in the main channel off Avonmouth) and partly bordering intertidal mud on the Welsh Grounds (where they receive freshwater runoff). The sediment was essentially sandy, medium-fine and poorly sorted, with about 20% silt/clay. The fauna contained species considered characteristic of disturbed conditions, including the polychaete *Capitella capitata* and the mysid *Mesopodopsis slabberi*. This impoverished fauna, usually containing fewer than five species and few individuals per sample, was associated with areas of high bed stress.

7. ***Gammarus*/medium-fine sand association**

The stations in this group were characterised by the amphipod *Gammarus salinus*, associated with poorly sorted medium-fine sand containing less coarse sand than Group 6 stations, and about 20% silt/clay.

8. ***Mesopodopsis*/medium-fine sand association**

Group 8 stations were characterised by *Mesopodopsis slabberi* and consisted of well sorted medium sand with less than 2% silt/clay. Again, the presence of these species suggested a mobile, unstable substrata.

9. ***Eurydice* (mobile fine sand) association**

Stations in this group were also associated with areas of high bed stress. These contained well sorted medium sand with more than 4% silt/clay, and were located at the edges of well sorted sandbanks. They were characterised by the mobile isopod *Eurydice pulchra*.

10. ***Nephtys cirrosa* (mobile fine sand) association**

The final group of stations was defined by the presence of the polychaete *Nephtys cirrosa*. The stations were located in the west of the study area, subtidally inshore of Nash Sands and on mobile outer parts of the Welsh and English Grounds. The sediment consisted of fine/very fine sand which was moderately well sorted and contained more than 10% fine material.

Many of the communities within this area are typical of other British estuaries. In contrast to other estuaries, the tide-swept hard substrata in turbid water results in the formation of extensive sublittoral reefs of the tube-building polychaete *Sabellaria alveolata*, a feature

unique to the Severn Estuary. These reefs also provide hard substrata for the attachment of other invertebrate species. Strong tidal streams have resulted in the formation of large sandbanks dominated by a *Spisula* sub-community (Tyler & Shackley 1980). Further sampling undertaken at a large number of stations in the Severn Estuary and Bristol Channel (Mettam, Conneely & White 1994) revealed eight groupings of macrobenthic fauna. Samples were faunistically impoverished, especially in sublittoral areas, but greater species richness was associated with reefs of *Sabellaria alveolata* which extended well into the estuary.

Four large water-cooled electricity generating stations are sited within the inner and upper Severn Estuary at Hinkley Point, Berkley, Oldbury and Uskmouth. Cooling-water intake screens are a valuable source for the collection of pelagic marine organisms and facilitate the study of their population ecology. Based on data from these intake screens, fish population ecology within the estuary has been well documented (for a review see Claridge, Potter & Hardisty 1986). Henderson (1989) described the inshore fish communities of Britain based on captures from 12 coastal power stations including the four listed above. Of 118 species of fish captured, 77 species were recorded at Hinkley Point, 71 species at Berkley, 75 species at Oldbury, and 35 species at Uskmouth. Holmes & Henderson (1990) reported that 1989 had been an exceptional year for recruitment to the populations of five fish species: bass *Dicentrachus labrax*, twaite shad *Alosa fallax fallax*, red mullet *Mullus surmuletus*, herring *Clupea harengus* and Norway pout *Trisopterus esmarkii*; and for the swimming crab *Liocarcinus holsatus*. Relatively high sea water temperatures during the 1988–89 winter and the following spring were considered the most likely explanation for this phenomenon.

Another feature of considerable marine conservation importance within the Severn Estuary is the large populations of anadromous fish (fish that breed in rivers but go to sea to feed for most of their lives) and catadromous eels *Anguilla anguilla* (which live in freshwater but breed in the sea); elvers (juvenile eels) support a commercial fishery. Especially important are the two rare species of shad, the twaite shad *Alosa fallax fallax* and the allis shad *Alosa alosa*. Claridge & Gardner (1978) studied the growth and movements of the twaite shad and concluded that this species had a large healthy population within the Severn Estuary. In contrast, the allis shad was found to be rare and the decline in numbers of this species was attributed to the recent construction of navigation weirs within local rivers (Claridge & Gardner 1978). Aprahamian (1988) investigated the population ecology of the twaite shad.

Proposals to construct a tidal barrage across the Bristol Channel and Severn Estuary focused attention on the need to obtain a baseline knowledge of this ecosystem in order that the full impact on nature conservation may be fully assessed. Bolt *et al.* (1989) discussed the implications of barrage development on the nature conservation importance of the Bristol Channel and Severn Estuary and suggested that any such developments would significantly reduce the conservation interest within the area. In particular, populations of anadromous fish would be severely affected by any tidal barrage construction.

Saltwater incursion to the upper Severn Estuary combined with considerable human development along the coast has created a number of small brackish ponds and lagoons. Sheader & Sheader (1987) undertook a lagoon survey of Avon and Gloucestershire. Preliminary investigations found eight sites which appeared to match the criteria for lagoon status but subsequent detailed survey reduced this to two sites at Portishead. Information was provided on the physical characteristics and the biotic composition of these two lagoons.

During the late 1970s and early 1980s the WWA undertook a series of benthic investigations of the rivers Wye, Usk and Taff, mainly in connection with effluent discharges. Wharfe *et al.* (1979) studied the macrofaunal distribution of the Usk and Wye estuaries. Samples were collected at 1 km intervals along each estuary and the macrofaunal assemblages enumerated. Data analysis revealed three distinct site groups in the Usk, and two groups in the Wye. Davies & Wade (1985) surveyed the intertidal fauna within sedimentary habitats of the lower Usk estuary in relation to an outfall from a local steel works. Fourteen stations were sampled within 1.3 km of the outfall and 17 taxa were recorded, with the polychaete *Hediste diversicolor* and the bivalve *Macoma balthica* the most widespread taxa.

Morrisey & Sait (1988) described the sublittoral ecology of the Avon, Wye and Usk estuaries during a study that contributed to the Severn Barrage Project. Habitats present within these rivers were almost exclusively soft sediment with some coarse stony areas. The fauna present were similar to soft sediment areas of the Severn Estuary. Communities were dominated by the bivalve *Macoma balthica*, ragworm *Hediste diversicolor*, the burrowing amphipod *Corophium volutator* and oligochaete worms; maximum densities recorded were higher than in the adjacent Severn Estuary. Within each river, the distributions of the dominant species show variations related to environmental stress. At upstream sites, oligochaete worms were dominant; farther downstream, *Hediste* sp. and *Corophium* sp. were dominant while at the lower shore sites, *Macoma* sp. were the most abundant species recorded.

The WWA completed a series of investigations of the Severn Estuary within its jurisdiction. Jones & Jones (1983) sampled 32 stations on 6 ha of intertidal sediment around the outfall from Ashton Paper Mill, located on the north shore of the estuary 5 km downstream of the Severn Bridge. A total of 17 taxa was recorded, with invertebrate density ranging between 1,580–32,000 m^{-2}. Of these 17 taxa, the oligochaetes *Tubifex costatus* and Enchytraeidae, the polychaetes *Nereis* (now *Hediste*) *diversicolor* and *Pygospio elegans* and the bivalve *Macoma balthica* were most common. Davies & Jones (1982) sampled 51 stations between the Severn Bridge and Cardiff during a pilot study of the intertidal and subtidal benthic macroinvertebrates of soft sediment habitats. Most of the samples were collected from mud habitats, except in the vicinity of Goldcliffe where the substrata were more variable, and 34 taxa were identified. In general, subtidal sites were numerically dominated by tubificid oligochaetes and sedentary polychaetes, while

intertidal sites were dominated by the mud-snail *Hydrobia ulvae*. Jones & Davies (1983) reported the results of a more extensive study of the environmental factors influencing the distribution of soft sediment macroinvertebrates between Sudbrook (5 km downstream of the Severn Bridge) and Lavernock Point. They sampled 246 stations, revealing 62 taxa, which were attributed to three main invertebrate assemblages, although 57% of the sites did not have any major features of community structure. Perhaps the most comprehensive study by the WWA was the Usk Coastal Waters Study, which was a detailed investigation between 1981 to 1984 of dilution, toxicity and a benthic ecological study for the coastal waters between the Wye and Usk estuaries (WWA 1985b, 1985c). Broom *et al.* (1991) reported the results of the benthic study which sampled 244 intertidal and marginally subtidal sedimentary stations between Sudbrook and Nash Point in relation to the discharges from a paper mill, a steel works and an organic chemical plant. The results were intended to provide baseline information against which future decisions on discharge consents could be taken. Ten faunal assemblages were identified and were characterised by polychaete worms, bivalve molluscs and amphipod crustaceans. Analysis of physio-chemical data in conjunction with the faunal analyses revealed physio-chemical characteristics that may explain the composition of these ten biotic assemblages.

Rees (1940) published the results of a preliminary study of a mudflat near Cardiff: ten stations were sampled from low to high water. Mettam (1983) re-surveyed the area to consider the impact, if any, of sewage outfalls constructed during the intervening time. There appeared to be little change 40 years on from the study by Rees (1940), although the spread of the polychaete *Streblospio shrubsolii* along the Wentlooge Flats may reflect the tidal movement of raw sewage. An area near Rhumney Great Wharfe, Cardiff has been claimed using Schleswig-Holstein poldering technique, and White & Mettam (1989) completed a qualitative and quantitative study of the mudflat behind the enclosure. Results of the study were compared with the results of Boyden *et al.* (1977) and Mettam (1983) and the faunal association present was considered to be a transitional stage between a sandflat and saltmarsh fauna.

A number of major sewage outfalls are located between Newport and Cardiff. The WWA (1984) studied the impact of the Rhymney Valley, Ystraddyfodwg, Pontypridd and Cardiff East trunk sewers on the benthic macroinvertebrate fauna of adjacent sedimentary habitats. Sixty-six sites were sampled between Newport and Cardiff. There was no evidence that the effluent discharge affected the distribution of invertebrate species: community composition at these stations was considered to be similar to the communities present at other sites in the upper Severn Estuary. Davies (1985) undertook a biological impact assessment of the Western Valley Trunk Sewer on the benthic fauna of the nearshore Severn Estuary. This sewer discharged to the west of Newport, and a grid of 50 stations around the outfall were sampled using a grab. Sediment particle-size analysis showed that these stations were mainly poorly sorted fine mud. Few species were present, with an average of only four taxa per station. Multivariate statistical analysis classified the taxa into four species groups, and the sites into four site groups. Shore height was considered to be the principal factor determining the distribution of taxa.

The Taff estuary was surveyed by the WWA (1985a). Twenty-six stations were sampled, mainly in Cardiff Bay with six stations upstream. Twenty-four species were identified and grouped into three faunal assemblages:

- **A mudflat community either side of the main channel**
  A community dominated by the polychaete worms *Hediste diversicolor* and *Streblospio shrubsolii*, the bivalve *Macoma balthica*, the mud-snail *Hydrobia ulvae* and the oligochaete worm *Tubificoides benedeni*.
- **Channel community in or adjacent to the main channel**
  Community composition was similar to above but with reduced abundance.
- **Upper estuary community**
  A community dominated by oligochaete worms *Tubifex costatus* and the amphipod *Gammarus zaddachi*.

Physio-chemical analysis suggested that sediment particle size distribution influenced the biotic composition of these assemblages, but salinity was the primary factor controlling the spatial distribution of each assemblage.

Rocky shores from Nash Point to Lavernock Point were surveyed by the WWA (1976) who concluded that Nash Point occupies a critical position in the Severn Estuary. Species such as the gastropods *Littorina* (now *Melarhaphe*) *neritoides* and the kelp *Laminaria digitata* were scarce to the east of Nash Point. At that time (1976), sewage discharges were thought to be a contributory factor to this decline in species distribution. A number of other studies have included the shores of Glamorgan when considering the wider area of Swansea Bay, and so are discussed later.

9.6 South-west Wales

9.6.1 Introduction

South-west Wales (Figure 9.13) encompasses the coast from the mouth of the Tawe estuary at Swansea to Cwm yr Eglwys in Newport Bay, Pembrokeshire. The area includes a wide range of coastal habitats from the sheltered sandy shores of west Swansea Bay to the very exposed rocky coast of Pembrokeshire. The coastline extends for over 400 km, with only a small part subject to urban or industrial development. The Pembrokeshire Coast National Park, the only predominantly maritime

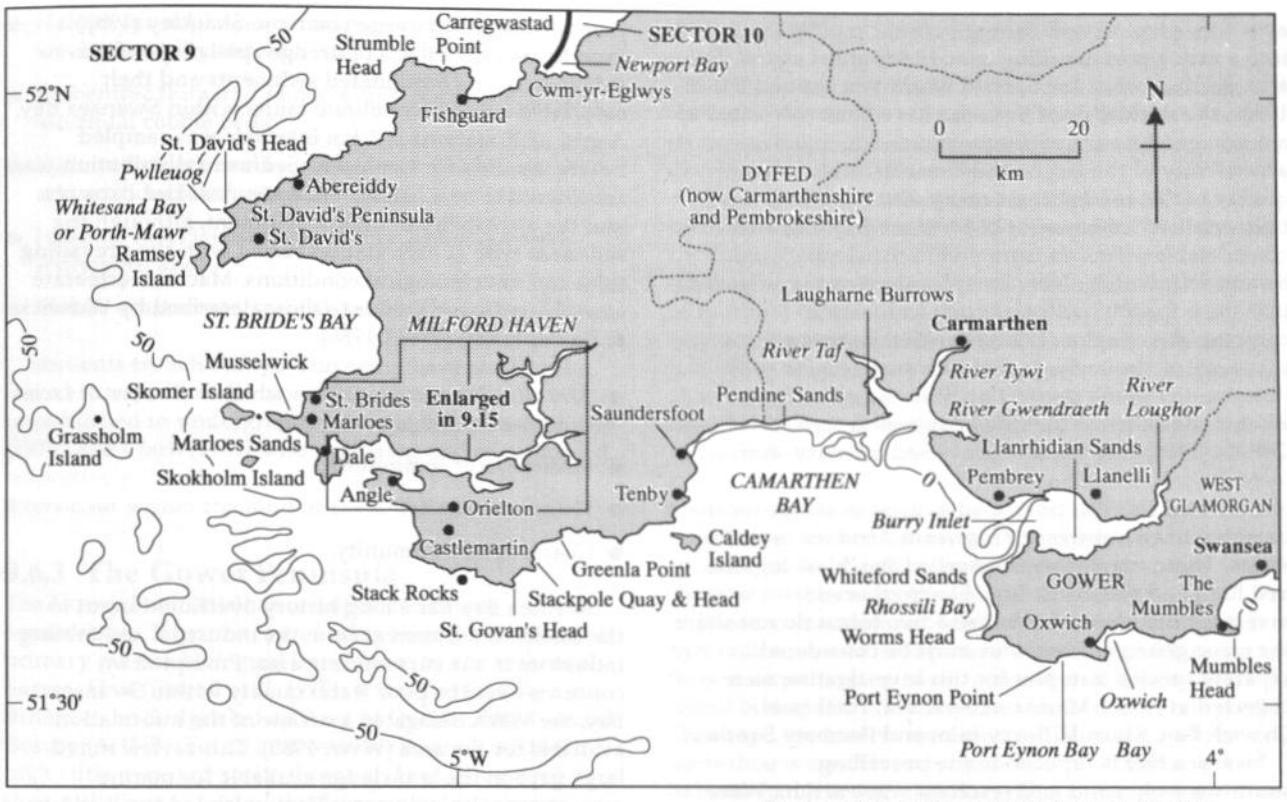

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Figure 9.13. South-west Wales, showing places mentioned in the text.

national park in England and Wales, covers some of the most spectacular coastal scenery in Wales including stacks, natural arches, offshore islands and towering cliffs. Milford Haven, a drowned river valley or ria, extends inland, taking near fully saline water many kilometres from the open sea. The Haven is possibly the finest natural harbour in Britain and today is a major centre for the oil industry.

Proliferation of heavy industry and mining during the Industrial Revolution centred on the main rivers and estuaries. These industries needed water for washing and cooling and an easy method of disposal for their effluent. Effluent discharge in particular has had a severe impact on the marine inlets of south Wales. Within the estuaries, extensive areas of littoral sediment formerly supported large shellfish fisheries although a combination of pollution and over-fishing has led to their decline in the past 30 years. Nevertheless, these inlets have a high conservation value and many areas have been notified SSSIs. Conservation interest centres on the large number of birds attracted to the sediment flats.

West Wales has a long history of marine biological investigations. In Victorian times, Tenby attracted many great naturalists including T.H. Huxley and Dr Samuel Wilberforce (see Chatfield 1979). Gosse (1856) published a book titled *Tenby: A sea-side holiday* which contains descriptions of animals and plants found on the local shores. In recent times, the establishment of Swansea University, the Field Studies Council field centres at Dale Fort and Orielton and the Oil Pollution Research Unit (OPRU) at Pembroke has generated considerable marine biological information for south-west Wales.

The Intertidal Survey Unit visited many shores in the region to assess their marine biological importance (Powell *et al.* 1979). Sublittoral habitats and communities were investigated by the South-West Britain Sublittoral Survey (SWBSS) (Hiscock 1981a). Major marine inlets were surveyed by the Field Studies Council during the survey of Harbours, Rias and Estuaries in Southern Britain. Skomer, one of the Pembrokeshire islands, displays many of the habitats and communities typical of the region. In recognition of this importance, the island was declared Wales' first Voluntary Marine Nature Reserve in 1976 and was designated a statutory Marine Nature Reserve (MNR) in 1990, the second MNR in Britain.

9.6.2 Swansea Bay

Swansea Bay marks the transition from the Severn Estuary to the Bristol Channel and is largely composed of muddy sand, which extends from Port Talbot to Mumbles. Margam Sands on the east side of the Bay is a long sandy beach backed by a large steel works. Swansea expanded rapidly after the Industrial Revolution. A plentiful supply of cheap coal and nearby deposits of copper led to smelting works being built

above the city. A small fishing harbour rapidly expanded into a major port handling over 10,000 ships a year. The area declined after the Second World War but since the 1980s, the docklands of Swansea have been converted to a marina and luxury accommodation. The relative accessibility of the large sandy beaches and the scenic quality of the coast attracts many visitors. The industrialised embayment of Swansea Bay attracted considerable attention from pollution scientists and Swansea University have completed many investigations into the impact of pollutants on local marine communities. Naylor (1972) provided an extensive summary of the zoology of the Swansea region with notes on the fauna present on different shore types. Work undertaken in Swansea Bay was described in Collins (1980) and the infauna of sedimentary shores were described by Shackley (1981). Cadman & Nelson-Smith (1990) published genetic evidence for the presence of two species of lugworm *Arenicola* in south Wales. These two forms were called the 'blow lug' (or 'red lug') and the 'black lug'. Electrophoretic investigations showed that these two forms do not share the same gene pool and thus must be considered separate species. Samples for this investigation were collected at Jersey Marine in Swansea, Porthcawl, Oxwich Bay, Rhossili, Burry Inlet and Pembrey Sands.

Swansea Bay is exposed to the prevailing south-westerly wind and resultant wave action. Wave action increases the mobility of the sediment which reduces species richness and biomass in the communities present. Rocky shore communities were investigated by Nelson-Smith (1974) who classified the communities present as limpet/barnacle-dominated moderately exposed shores. In the following year the WWA (1975) completed an intensive survey of the rocky shores of Mid Glamorgan which included 17 transects in Swansea Bay and further transects in between Nash Point and Lavernock Point to the east. Intertidal sediments at eight stations between Baglan and Ogmore on the eastern side of Swansea Bay were surveyed by the WWA in 1976 (WWA 1976). Shackley (1981) completed a more intensive study of intertidal sediments at 11 stations between Worms Head and Dunraven Bay, near Nash Point. Three areas were defined by their wave exposure: south Gower to Mumbles was exposed; Swansea Bay to Aberavon was sheltered; and the eastern coastline to Dunraven Bay was semi-exposed. Within the sediments, the fauna reflected the wave exposure with mainly cirolanid and haustoriid crustacea in exposed sediments, and rich bivalve and sedentary polychaetes in sheltered sediments.

Sublittoral communities in Swansea Bay were studied during a survey of the Bristol Channel by the Institute of Marine Environmental Research, Plymouth (Warwick & Davies 1977; Warwick 1984). Warwick & George (1980) estimated energy flow through the sedimentary communities by regular sampling of a single station. The community present was classified as an *Abra alba* community although in terms of biomass, the bivalves *Spisula elliptica* and *Nucula turgida* (now *Nucula nitidosa*) were the most abundant. Brittlestars, mainly *Ophiura ophiura*, and the polychaete worms *Nephtys hombergii* and *Ampharete acutifrons* were common. Shackley (1982) investigated the effects of dredge spoil disposal on sublittoral non-consolidated sediments and their associated macroinvertebrate fauna within Swansea Bay. A grid of 20 stations at 1 km intervals was sampled nearly monthly for two years. Sediment distribution was considered to be a balance between near-bed currents and the availability of mobile sediment, although the sediment type at each station varied with the prevailing tidal and meteorological conditions. Macroinvertebrate assemblages were similar to those described by Warwick & Davies (1977) (WWA 1986):

- *Abra alba* community, within which a number of facies could be identified;
- *Modiolus*/reef community;
- *Venus* community;
- Coarse sand community.

Swansea Bay has a long history of effluent input to the marine environment from the industrial and mining industries in the surrounding area. Prompted by concerns over the poor water quality within Swansea Bay, the WWA instigated a review of the information available for the area (WWA 1983). This review noted large gaps in the knowledge available for marine ecosystems within Swansea Bay which led the WWA to initiate a comprehensive programme to gather information on the physical, chemical and biological environment. A 1 km^2 modular grid comprising 272 stations was sampled with a 0.1 m^2 Day grab. Of these stations, 89 were located on hard ground with adequate faunal samples taken from the remaining 176 stations. An interim report on the benthic infaunal study was produced in 1986 (WWA 1986) followed by the final report on the whole Swansea Bay monitoring project in 1988 (Conneely 1988). Benthic infaunal assemblages were considered similar to those described by Warwick & Davies (1977) with the *Abra abra* community and the *Nucula turgida* (now *Nucula nitidosa*) and *Nephtys hombergii* community the most common.

Neath estuary complex has considerable terrestrial nature conservation importance for its wetland habitats, although few investigations have considered the marine environment. A basic description of marine habitats was provided by the Nature Conservancy Council (1977) in a review of terrestrial conservation, and the WWA (1980) surveyed the seabed in the vicinity of the Neath sewage outfall.

The Tawe estuary is a small, stratified estuary where the salt-wedge penetrates 5 km upstream, although the estuary is tidal for a further 2 km. It has been substantially modified by port developments and land-claim, so that the lower estuary is now canalised for most of its extent. Dyrynda (1991) studied the estuary in connection with a proposal to construct a barrage which would impound the lower estuary. This study provided a detailed description of the physical, chemical and biological characteristics of the estuary. Five ecological sub-systems were identified to which 98 species were attributed:

- Halophytic angiosperm community of the upper levels of muddy shores;
- Epibenthic flora and fauna within subtidal and low intertidal cobble beds;
- Epibenthic flora and fauna on large stable boulders and artificial hard substrata;
- Infaunal invertebrate community within cohesive sediments, and
- Mobile crustaceans and fish within the water column.

Students from Swansea University have studied the Tawe estuary although most of this information remains unpublished in undergraduate theses, for example Eagle (1970) and Clark (1981) who evaluated and re-evaluated respectively the distribution of *Nereis* (now *Hediste*) *diversicolor* within the mud of the lower estuary.

9.6.3 The Gower Peninsula

The Gower Peninsula has considerable nature conservation importance and was considered an area of primary marine biological importance by the Intertidal Survey Unit (Powell *et al.* 1979); it was the first area in Britain to be designated an Area of Outstanding Natural Beauty (AONB). South and west coasts are a mixture of high cliffs, exposed rocky shores and sandy bays while the north coast is part of the Burry Inlet, a sheltered sedimentary estuary. Most of the peninsula comprises folded Carboniferous limestone with the present coastline cutting across the limestone beds to give a variety of cliff formations. In the bottom of the folds, some of the Millstone Grit shales overlying the limestone have been retained. These rocks are softer and have been eroded by the sea to form the sandy bays of Oxwich and Port Eynon. Erosion has created a series of coastal caves, important for their fossils. The shores of the Gower attract marine biologists, student field courses and amateur naturalists from far afield.

A literature review of the littoral flora and fauna of the Gower Peninsula was produced by Freytag (1977). In general, rocky shores had limpet/barnacle-dominated mid-shores and a rich algal dominated low shore. Rich rockpool communities were recorded at most sites. Naylor (1972) documented the littoral fauna of the Gower. Wilkinson (1982) listed the algae recorded from eight shores around the Gower following a visit of the British Phycological Society. Some 41 species recorded were not listed in the previous authoritative list for the County of Glamorgan (Rees 1936).

Oxwich Bay, a National Nature Reserve, is a large, moderately exposed sandy bay. The littoral zone is characterised by a rich '*Echinocardium-siliqua*' community (Bishop & Holme 1980). High densities of the heart urchin *Echinocardium cordatum* and the razor shell *Ensis siliqua* were recorded on the low shores. Shallow sublittoral habitats had a rather impoverished '*Spisula*' community which is replaced farther offshore with a '*Syndosmya*' (now *Abra*) community (Tyler 1977). Shores around the Gower have long been exploited by shellfish collectors and bait-diggers. Recently stocks have declined and these deleterious activities were the subject of impact studies (Cryer, Whittle & Williams 1987; Wege 1987; Liddiard *et al.* 1989). Rhossili Bay, an extensive sandy beach, is exposed to the full force of the prevailing westerly winds. Worms Head affords some shelter to the southern end of the bay allowing a moderately rich '*Echinocardium-siliqua*' community to develop (Bishop & Holme 1980).

Sublittoral habitats and communities were investigated during the SWBSS (Hiscock 1979b; Hiscock, Cartlidge & Hiscock 1980). Compared with the open coast areas of south-west Britain, the algal-dominated infralittoral fringe was very compressed. Kelp *Laminaria hyperborea* extended from +1 m above chart datum to or just below chart datum while the lower limit of foliose algae was just 3 m below chart datum. These restricted algal limits are a reflection of the high turbidity of the water. Sublittoral habitats were mainly horizontal or gently sloping bedrock, extensive areas were covered by mussels *Mytilus edulis* and by the tube-building polychaete *Sabellaria spinulosa*. Vertical and overhanging surfaces had particularly rich animal communities characterised by erect bryozoans such as *Bugula turbinata*, colonial seasquirts such as *Botryllus schlosseri*, hydroids such as *Kirchenpaueria pinnata* and dead-man's fingers *Alcyonium digitatum*. A number of species were found boring into the limestone, for example the sponge *Cliona* sp., the bivalve mollusc *Hiatella arctica* and the horseshoe worm *Phoronis hippocrepia*. Sedimentary habitats had a sparse epibiota which included the burrowing anemone *Cereus pedunculatus*, the sand-mason worm *Lanice conchilega* and the gastropod *Nassarius reticulatus* (now *Hinia reticulata*).

9.6.4 The Burry Inlet

The mouth of the River Loughor forms the Burry Inlet, a small, shallow, sedimentary estuary with strong tidal streams and frequently shifting sandbanks. Sandflats at the mouth have rich infaunal communities and the estuary is famous for its cockle *Cerastoderma edule* fishery, the third largest in Britain. Annual landings for 1987 totalled 65,163 cwt (3,310 t) (Moore 1989). The fishery has declined in recent years probably through a mixture of over-fishing and predation by oystercatchers *Haematopus ostralegus* (Swarbrick 1984; Franklin 1977). The cockle populations have since suffered a viral infection which has further reduced numbers. Whiteford, on the western side, is a National Nature Reserve which attracts internationally important numbers of waders and wildfowl. Whiteford Sands were considered a site of primary marine biological interest for a well developed *Tellina* community (Bishop & Holme 1980). The Burry Inlet is notified an SSSI for its ornithological interest.

Effluent discharges from the steel plant at Tostre in Llanelli and sewage from local communities were investigated by Poopetch (1980). A symposium considering the problems experienced by small estuaries used the Burry Inlet as its primary example (Nelson-Smith & Bridges 1977). The estuary was surveyed by the FSC during the survey of Harbours, Rias and Estuaries in Southern Britain, and the report also summarised previous marine biological investigations within the Inlet (Moore 1989).

Thirteen littoral and two sublittoral habitats were identified from the FSC survey (Moore 1989). Littoral habitats were predominantly sedimentary and hard substrata were limited. Whiteford Scar, a stable mussel-scar composed of boulders, cobbles and pebbles dominated by mussels *Mytilus edulis*, had rich low-shore algal communities. Extensive areas of moderately stable, fine and very fine sand in the middle and lower estuary were characterised by bivalve molluscs and polychaete worms. These areas are cockle *Cerastoderma edule* beds and were considered of regional, or possibly national, importance. Sedimentary communities throughout the lower estuary had rich infaunal communities and the area to the west of Llanrhidian Sands is one of only a few recorded locations in Britain for the polychaete *Ophelia bicornis* (A.S.Y. Mackie pers. comm.). Sublittoral areas were sedimentary and are restricted to the centres of the main channels. At the mouth of the estuary, these sublittoral sediments were mobile medium-fine sand habitats and had an impoverished faunal assemblage. Farther up the estuary, the mud content of the sediment increased with a corresponding increase in species richness. In the upper estuary above Loughor, where salinity is always low and usually below 20‰, the polychaete worm *Hediste diversicolor* together with oligochaete worms were abundant with much lower abundances of the bivalve *Scrobicularia plana*, the worm *Etone longa*, the amphipod *Corophium volutator*, the mud snail *Hydrobia ulvae* and the shore crab *Carcinus maenas*.

Historically, cockle fishing on Llanrhidian Sands was by hand but more recently, tractor-towed cockle harvesting has begun. Rostron (1993) investigated the impact of tractor-towed cockle harvesting on benthic habitats of Llanrhidian Sands. Two areas were sampled from October to April to cover pre- and post-harvesting activities, and the initial recovery phase. Dredging led to a significant reduction in the number of species which continued for two weeks post-dredging. Population recovery rates varied between species although seasonal environmental factors could have contributed to the lack of recovery of some species. Rostron (1993) concluded that tractor-towed cockle harvesting would adversely affect benthic infaunal communities.

9.6.5 Carmarthen Bay

Carmarthen Bay, a large, shallow, sandy bay with unusually well sorted sediment, is fully exposed to the prevailing south-westerly winds. Broad sandy beaches are very popular with tourists and the populations of the surrounding towns and villages swell considerably during the summer months. The eastern half of the bay has broad sandy beaches, including Pendine Sands, a 10-km stretch of firm sand, dissected by a series of wide river estuaries. In contrast, the western half has spectacular cliff scenery with very busy tourist resorts in the sandy bays.

Carmarthen is near the tidal limit of the River Tywi, one of the 'Three Rivers' system in Carmarthenshire. The River Gwendraeth and River Taf join the River Tywi to enter the eastern part of Carmarthen Bay. The Taf and Tywi are typical coastal plain estuaries while the Gwendraeth is a bar-built estuary formed by the north-westerly movement of sand from the Pembrey coast dune system. Tidal flows within the system are high with a distorted wave symmetry producing a longer ebb than flow. Conservation interest within the system centres on the large populations of birds feeding on the sediment flats exposed at low tide. Laugharne Burrows SSSI at the mouth of the 'Three Rivers' is the largest sand dune system in west Wales. On the eastern side of the mouth, Pembrey Coast SSSI has one of the best examples of ungrazed western saltmarsh in Britain (Mercer 1989).

Extensive sediment flats at the mouth of the system support a large cockle and mussel fishery. Swarbrick (1984) discussed the shell-fisheries of the 'Three Rivers' and suggested potential future shell-fisheries and mariculture operations for the area. Under consideration are the native species *Venerupis decussata* (now *Tapes decussatus*), *Mya arenaria* and the whelk *Buccinum undatum*, and the introduced species *Tapes semidecussata* (Manila clam) and *Crassostrea gigas* (Pacific oyster). Recently, shellfish stocks have been threatened by increased bait-digging within the area. Cadman (1989) investigated the impact of this bait-digging and noted significant damage and slow recovery of infaunal communities to their pre-bait-digging state.

Marine habitats and communities within the 'Three Rivers' system have been less extensively studied than the Burry Inlet. The system was surveyed by the FSC during the survey of Harbours, Rias and Estuaries in Southern Britain, and the report also summarised the information presented by earlier investigators (Mercer 1989). A total of seven littoral communities were identified. At the mouth of the 'Three Rivers', the mobile fine sands supported a community characterised by the bivalves *Macoma balthica* and *Angulus tenuis* and the polychaete *Nepthys* sp. Upper shore sandflat communities were characterised by the bivalves *Cerastoderma edule* and *Macoma balthica*, the polychaetes *Hediste diversicolor* and *Nephtys* spp., the amphipod *Bathyporeia sarsi* and the mud snail *Hydrobia ulvae*. Species richness was generally low and habitats and associated communities were considered of local conservation importance. Mussel *Mytilus edulis* beds on muddy sand and stones, and sandflats with extensive cockle *Cerastoderma edule* beds, had a more diverse fauna and were considered of regional conservation importance. Upper estuarine muds supported a low diversity assemblage of oligochaetes and the ragworm *Hediste diversicolor*.

Shores in the Saundersfoot region were considered to be sites of primary marine biological importance (Powell *et al.* 1979). Pendine had a rich '*Echinocardium–siliqua*' community and large populations of the opisthobranch *Acteon tornatilis* in a '*Tellina*' community on the low shore. Sediment shores farther west around Saundersfoot had well developed '*Echinocardium–siliqua*' communities with abundant bivalve molluscs such as *Donax vittatus* and *Tellina* (now *Angulus*) *tenuis*. Offshore benthic communities within Carmarthen Bay were classified as a '*Venus*' community (Warwick, George & Davies 1978).

Caldey Island lies across the prevailing winds. The south-west shores are very exposed while the north-east shores are sheltered. Powell *et al.* (1979) included a brief

description of littoral habitats. Sheltered shores were dominated by mussels *Mytilus edulis* with a prominent zone of the red alga *Palmaria palmata* on the low shore. Exposed shores were characterised by barnacles and mussels with encrusting red algae on the low shore. Warren & George (1988) surveyed four sites around Caldey Island and noted that despite considerable visitor pressure, the shores appeared undisturbed. Rich marine communities were recorded from a limestone shore at the north-west tip of the island. Along the south Pembrokeshire coast, there were a number of sheltered overhang and cave communities with interesting cryptofaunal organisms. Rock-boring species such as the bivalve *Hiatella arctica* provide holes which attract species such as the anemone *Sagartia elegans*, hydroids and the sponge *Cliona* sp. (Powell *et al.* 1979).

9.6.6 South Pembrokeshire (Tenby to Milford Haven)

The south Pembrokeshire coast from Tenby to the mouth of Milford Haven comprises very exposed or exposed rocky shores with some sediment shores present within the many small bays. The Castlemartin Peninsula has a series of limestone cliffs which run its entire length. Constant pounding by the prevailing wind and waves has created a variety of interesting geological formations. Stack Rocks, an isolated group of limestone stacks, supports large seabird colonies, whilst the nearby Devil's Cauldron, formerly a blow-hole, is now a natural arch. These high cliffs form part of a military firing range which leads to large sections of the shoreline having restricted public access. The coast forms part of the Pembrokeshire National Park and large sections are notified SSSIs. The biology of this exposed coastline was first described by Evans (1949) and was considered an area of primary marine biological importance by Powell *et al.* (1979). It has some of the finest examples of rocky shore communities in Wales. Stackpole Quay had well developed splash zone lichen communities. St Govan's Chapel Cove has large eroded boulders with large numbers of the periwinkles *Littorina saxatilis* and *Littorina* (now *Melarhaphe*) *neritoides* within pits and crevices. Low-shore pools were dominated by algae, the coralline alga *Corallina officinalis* and Irish moss *Chondrus crispus* were abundant. West of St Govan's Chapel Cove there is a large rock platform which had rich littoral communities. Low-shore habitats were characterised by diverse red algal communities, pools had abundant limpets and anemones such as *Bunodactis verrucosa*; overhangs had elephant's ear sponge *Pachymatisma johnstonia*. Farther west, shores become very steep and had excellent examples of steep rocky shore zonation patterns (Powell *et al.* 1979).

Sublittoral habitats and communities were investigated during the SWBSS (Cartlidge & Hiscock 1979) and Stackpole Head to Greenala Point were considered to be an area of "outstanding scientific interest" (Hiscock 1981a). Communities were similar along the whole length of the coast although some species were locally abundant and species richness declined with increasing distance east. A wide variety of habitats was present and the communities included a

Figure 9.14. Limestone rock broken open to show the rock-boring community. Species illustrated include: 1. *Scrupocellaria* sp., 2. *Scypha compressa*, 3. *Aiptasia mutabilis*, 4. *Dendrodoa grossularia*, 5. *Flustra foliacea*, 6. *Hiatella arctica*, 7. *Polymastia* sp., 8. *Ophiothrix fragilis*, 9. *Pisidia longicornis*, 10. *Amphilectus fucorum*, 11. *Phoronis hippocrepia*, 12. *Cliona celata*, 13. *Alcyonidium diaphanum*, 14. *Bugula plumosa*, 15. *Haliclona* sp., 16. *Verruca stroemia* and 17. *Dilsea carnosa*. Original drawing by Chris Childs. Re-drawn from Cartlidge & Hiscock 1979 by Sue Scott.

diverse assemblage of species on limestone and sandstone rock. Communities of animals boring into limestone (Figure 9.14) were particularly well represented and included the bivalve *Hiatella arctica*, the sponge *Cliona* sp. and the phoronid worm *Phoronis hippocrepia*. Extensive flat limestone reefs off Stackpole Head had very rich animal communities dominated by mussels *Mytilus edulis*, sea squirts such as *Molgula manhattensis*, *Stolonica socialis*, *Distomus variolosus* and the rare *Pycnoclavella aurilucens*, erect bryozoans such as *Flustra foliacea*, featherstars *Antedon bifida* and brittlestars *Ophiothrix fragilis*. Several rare or previously unrecorded species were found during the SWBSS including the alga *Rhodymenia colax-botryoidea* (Cartlidge & Hiscock 1979). Animal communities on extensive areas of flat limestone off Stackpole Head were very rich and provided an excellent example of patchiness on apparently homogeneous rocky sublittoral habitats. Stackpole area had a very high density of *Aiptasia mutabilis*, and rich sedimentary communities with dense populations of the hearturchin *Echinocardium cordatum* and razor-clams *Ensis* sp. (J. Moore pers. comm.).

West Angle, located on the exposed west coast of the Castlemartin Peninsula, comprises steep cliffs of Lower Devonian sandstone and Carboniferous limestone dissected by coves and pocket beaches. These shores have long been recognised for their significant marine biological importance. Jones & Williams (1966) documented algae for the area while the fauna of sedimentary shores was described by Withers (1977). Shore platforms called Little and Great Furzenip and the rocky shores of West Angle Bay were of most interest (Powell *et al.* 1979). The shore platforms had well developed zonation patterns and particularly well developed algal communities within rockpools. The pocket beach of West Angle Bay has a wide intertidal

zone of clean fine sand. Withers (1977) classified the community present as a representative crustacean-polychaete community; polychaete worms were the most abundant taxa. Rocky ridges rise steeply from the sand on the south and north sides of the Bay. Well developed algal communities dominate these rock habitats. West Angle Bay is the type locality for a small cushion-star *Asterina phylactica* (Emson & Crump 1979).

9.6.7 Milford Haven and the Daucleddau

Milford Haven and the Daucleddau estuary (Figure 9.15) is one the best examples of a ria system in Britain. Milford Haven is the seaward portion of ria formed by the drowning of the Daucleddau and its tributaries, of which the largest are the Eastern and Western Cleddau, the Carew and Cresswell Rivers and Pembroke River. The area under tidal influence covers over 110 km of coastline and a wide variety of habitats and communities are represented. A westerly location led to its development as a port; there are records dating back to the 13th century of the Haven being used as a port. The history of Milford Haven and the surrounding area was summarised by John (1976). Since the 1960s, Milford Haven has become an important centre for the oil industry with four oil refineries, an oil terminal and a power station built in the area. In 1967, the tanker *Chryssi P. Goulandris* spilt over 250 tonnes of crude oil in Milford Haven. Following this incident, the FSC's Oil Pollution Research Unit (OPRU) was established to investigate the impact of oil and refinery effluent on marine communities. Many studies undertaken to investigate oil pollution and its effect on marine communities have centred on Milford Haven and were summarised and reviewed in Little & Hiscock (1987) and Dicks (1989).

Milford Haven was once famous for its native oyster *Ostrea edulis* fishery, with shellfish exported from the area from before 1600 until about 1866 (George 1964), although the industry declined because of rapid dock developments. In recent years, the rearing of the Pacific oyster *Crassostrea gigas* has been established upstream of the Cleddau Bridge.

Milford Haven has attracted naturalists for many years and the marine environment in particular has been thoroughly described. Steep rocky shores extending from above high water to the lowest shore occur throughout Milford Haven and the Daucleddau providing contrasts in wave exposure from the open coast to the extreme shelter of the upper reaches. Shores of mixed sediments occur in bays in the outer Haven but extensive muddy shores are restricted to the creeks or 'pills'. In the sublittoral, there are extensive rocky areas including bedrock, boulder and cobble substrata. Sediments range from tide-swept gravels (including slipper limpet *Crepidula fornicata* shell-gravel) to muddy sands with mud present mainly in the creeks. A comprehensive review of previous investigations within

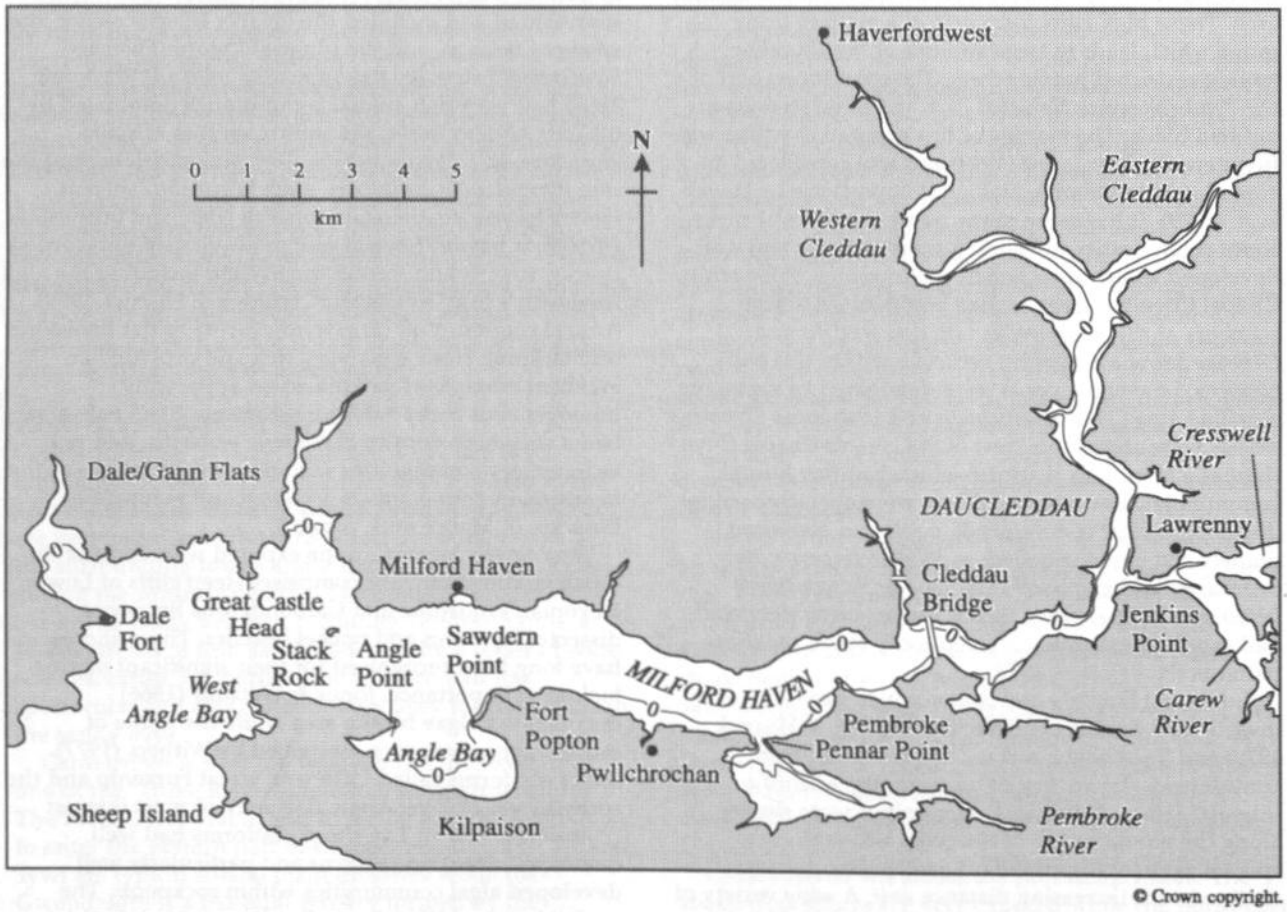

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Figure 9.15. Milford Haven and the Daucleddau showing places mentioned in the text.

Milford Haven was presented by Little & Hiscock (1987) and in the various papers listed in Dicks (1989).

In 1991 Dyfed County Council organised a conference to consider how pollution may affect the Milford Haven waterway. Following this conference a small steering group was established to consider the need for increased environmental monitoring of Milford Haven, consisting of representatives from agencies and authorities with an interest in the waterway. This group, the Milford Haven Environmental Monitoring Steering Group, commissioned a study titled *A review of the current state of environmental knowledge of the Milford Haven Waterway* (Hobbs & Morgan 1992). In 1992 the steering group published its final conclusions and recommendations which stated that a programme of work would be initiated to fill gaps in the knowledge and establish an ongoing monitoring programme for the Milford Haven Waterway. To implement this programme, the steering group would be established on a permanent basis with the 'mission statement' of:

> ... the maintenance and enhancement of a rich and diverse marine environment within the Milford Haven Waterway will be recognised by all those organisations operating on the Haven as a key element in their environmental policy objectives. In this respect, the primacy of sustaining the rich and diverse marine environment of the Milford Haven Waterway should be established and agreed as a responsibility for all those organisations operating in the Haven.

There were three basic parts to the review: a description of the physical environment and the flora and fauna; a review of man's use and impact on the Milford Haven Waterway; and a summary of the research and monitoring studies undertaken within the area. Hobbs & Morgan (1992a, 1992b) presented a comprehensive report covering all these aspects and include excellent descriptions of the physical and biological environment. They presented a summary table which lists 55 baseline and project-based studies completed within Milford Haven. The following account is only a brief summary of some of these studies; Hobbs & Morgan (1992a, 1992b) should be consulted for a more complete description of Milford Haven.

Milford Haven was extensively studied by the Intertidal Survey Unit (Powell *et al.* 1979) who noted the marine conservation importance of a number of sites (see below). Many studies have described the distribution and abundance of rocky intertidal organisms (Evans 1949; Moyse & Nelson-Smith 1963). Crapp (1971) re-surveyed 22 of the original 30 transects established by Moyse & Nelson-Smith (1963). Following the establishment of OPRU, rocky shore sites became part of an integrated study to monitor the effects of oil pollution. Little & Hiscock (1989) reviewed rocky shore monitoring within Milford Haven and described changes in abundance of barnacles, the top-shell *Monodonta lineata* and the dogwhelk *Nucella lapillus*. There appeared no general deterioration in the rocky shores communities throughout the period 1960–1982. Littoral sedimentary communities from five sites in western Milford Haven were described by Crapp, Withers & Sullivan (1971) who noted that some sites were subject to exploitation by bait-collectors. Morris (1985), during a benthic and physiochemical study of the Daucleddau, examined macrofaunal communities at 31 sites.

Sublittoral habitats and their associated communities have also been studied in considerable detail. During 1978 and 1979, 30 sites were surveyed by the SWBSS and the results summarised by Hiscock (1981a). Milford Haven and the Daucleddau were surveyed as part of the survey of Harbours, Rias and Estuaries in Southern Britain (Little & Hiscock 1987). Sublittoral rock habitats were investigated by Case (1981) and further discussed by Nelson-Smith & Case (1984). Sublittoral sedimentary habitats have been extensively surveyed in connection with studies considering the impact of oil pollution on benthic communities. Three large surveys were commissioned by the Institute of Petroleum to study the distribution of benthic macrofauna in Milford Haven (Addy 1976, 1979; Rostron, Little & Howells 1986). A total of 135 sites were surveyed; Figure 9.16 shows the sampling stations and the distribution of sediments within Milford Haven. Five major zones were apparent:

I Poorly sorted sediments in Dale Roads in which widespread species were *Chaetozone ?setosa, Notomastus latericeus, Lumbrinereis gracilis, Spio filiformis, Abra alba, Lucinoma borealis, Harpinia antennaria* and maldanid polychaetes. Other characteristic species were *Phascolion strombi, Arabell trocolor* and *Amphiura filiformis.*

II Coarse pebbly sediments across the entrance to Milford Haven with a wide variety of species many of which were exclusive to this zone. Poorly sorted sediments were characterised by the ascidian *Dendrodoa grossularia*, the horseshoe worm *Phoronis ?muelleri*, the tubeworm *Pomatoceros triqueter* and a variety of errant syllid and polynoid polychaetes. Other frequently recorded species were *Astarte triangularis* and *Arabella iricolor.* Within this zone, bays not exposed to strong tidal streams had well sorted fine sands characterised by the worms *Spio filicornis, Spiophanes bombyx, Magelona papillicornis, Magelona filiformis* and lesser numbers of *Magelona alleni, Myriochele oculata* and the brittlestar *Amphiura filiformis.*

III Zone III occupied the outer Haven but very similar communities were also present farther east along the Haven and this area was described as Zone IIIA. Several different communities occurred in this zone reflecting the complex distribution of sediments. The dominant species in shallow poorly sorted sediments in the north-west of Zone III were common throughout the Haven and included *Lumbrinereis gracilis, Chaetozone ?setosa* and *Notomastus latericeus.* In deeper water, other regularly recorded species included *Mellina palmata, Abra alba, Nucula nucleus, Ampharete lindstroemi* and maldanid polychaetes. Sandy sediments near to the south shore in Zone III held a distinctive community consisting largely of *Harpinia antennina, Lanice conchilega, Eumida sanguinea, Abra alba* and maldanid polychaetes. Major species in Zone IIIA were *Lumbrinereis gracilis, Chaetozone ?setosa*

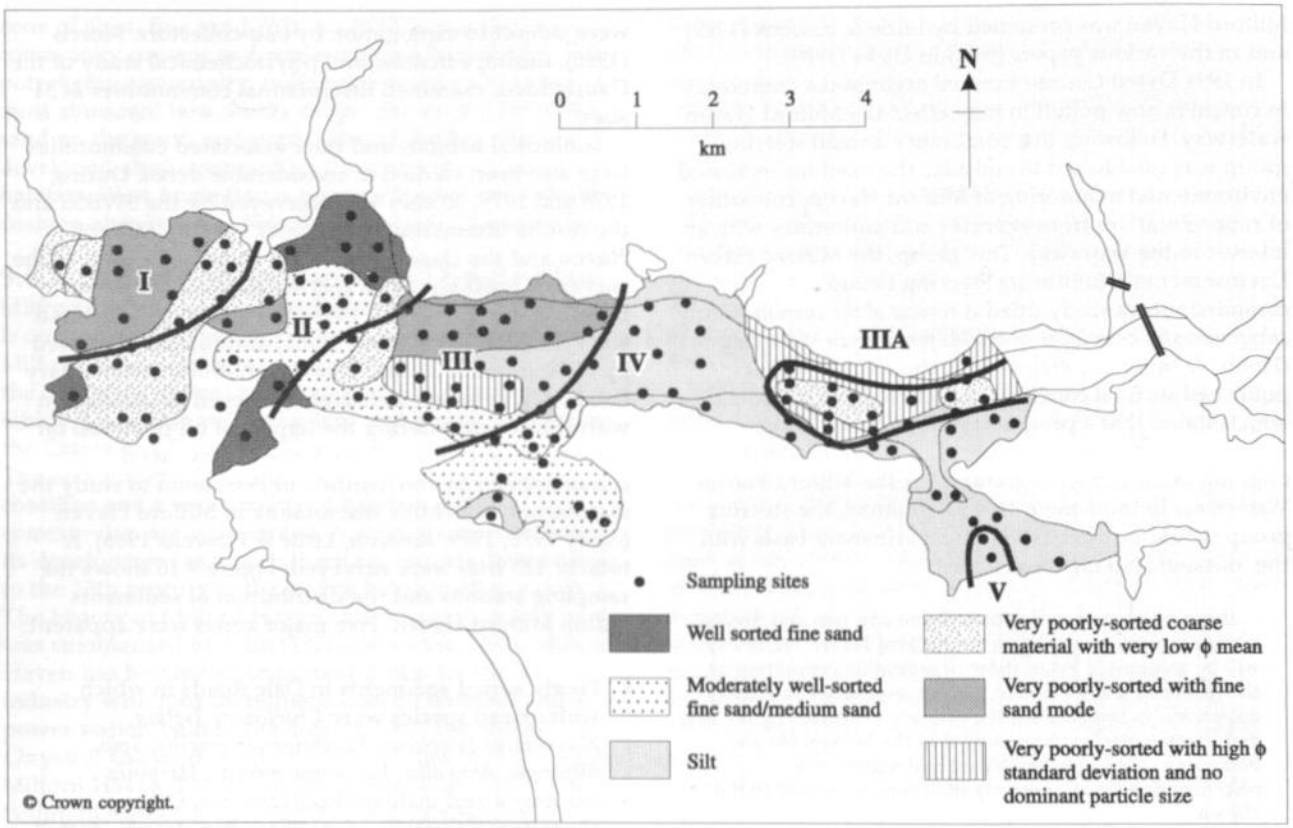

Figure 9.16. The distribution of sediments, sample sites and zones in Milford Haven (from Rostron, Little & Howells 1986).

and *Notomastus latericeus* with *Melinna palmata* present at shallow stations and *Cirriformia tentaculata* abundant at deeper stations.

IV Sediments in the central Haven east of Angle Bay and off the town of Milford Haven were predominantly of mud and many of the species recorded from other areas of the Haven were absent or present in low numbers. Species showing a preference for finer sediments were *Mellina palmata, Amphelisca brevicornis, Nepthys hombergii* and possibly *Thyasira flexuosa*. In intertidal areas, *Nepthys hombergii* and *Melinna palmata* were dominant.

V This zone was a small area of littoral mudflat in which dominant taxa included oligochaetes, mainly *Tubificoides benedeni, Pygospio elegans, Heteromastus filiformis, Hydrobia ulvae, Scoloplos armiger* and nematodes.

Powell *et al.* (1979) highlighted a number of sites that were considered to have significant marine biological importance, including the Angle Peninsula which forms the southern shore of lower Milford Haven. Angle Bay comprises a large area of predominantly muddy fine sand sheltered from wave action. Within the bay the habitats present range from bedrock outcrops to sandy shores to muddy shores. The communities within the sediment were considered to be particularly rich, with two distinct sediment communities identified. Sandy areas at Kilpaison were dominated by polychaetes with low densities of bivalves; the burrowing brittlestar *Acrocnida* (now *Amphiura*) *brachiata* was present. The community present was classified as a '*Pullastra*' community.

In muddier areas, the lugworm *Arenicola marina* was abundant and was the characterising species for the community. Kilpaison has been much disturbed by bait-diggers but the low shore has probably retained its value. Large beds of seagrass *Zostera noltii* and *Zostera angustifolia* are present in Angle Bay and have been the subject of a series of investigations into the effects of oil and dispersants on marine communities (for review see Howard, Baker & Hiscock 1989). Both oil and dispersants appear to reduce *Zostera* growth and can cause a discoloration of the leaves.

Rocky shores at Angle Point were one of the sites selected for a long-term monitoring programme established in 1961 (Woodman, Little & Dicks 1983). The shore is moderately exposed and has representative rocky shore habitats and associated communities. Shores within Angle Bay, especially at Sawdern Point, are regularly studied by staff and students from the local FSC centre at Orielton.

A number of studies have investigated the shores at Pwllcrochan. Sediment communities present are representative for the Milford Haven area. The Intertidal Survey Unit considered the area to have a particularly well developed '*Scrobicularia*' community and the site forms the eastern limit of a site considered of primary marine biological importance (Powell *et al.* 1979). The

Central Electricity Generating Board surveyed the area in relation to the local power station outfalls (Coughlan 1969). Unfortunately there is no recent published information available to determine whether the site has retained its marine biological interest.

Pembroke River, a predominantly muddy embayment which has suffered considerable pollution, was investigated by Rostron, Little & Howells (1986) and Rostron (1983). Littoral flats are composed of fine silt, a substratum suitable for deposit-feeding organisms. Marine communities present were dominated by capitellid and cirratulid polychaete worms, taxa characteristic of disturbed and/or polluted environments.

The sediments were colonised by seagrasses *Zostera noltii* and *Zostera angustifolia*. In the lower estuary, the communities present were characteristic of fully saline water and were dominated by the polychaete *Nephtys hombergii*. Near the mouth the unusual phoronid worm, *Phoronis muelleri*, was recorded as abundant. Nationally, *Phoronis muelleri* has a patchy distribution, although where it appears it is locally abundant. In the upper reaches where the salinity is lower, the communities were characterised by ragworm *Hediste diversicolor*. Pembroke River was considered to have high species diversity in comparison with other estuarine areas in the British Isles (Rostron, Little & Howells 1986).

A number of studies investigated the rocky shores in the region of Pennar Point and the channel from Pennar Gut into Milford Haven. The shore at Pennar Point has a permanent rocky shore transect which has been studied since 1961 (Woodman, Little & Dicks 1983). Pennar Point was a representative rocky shore with a wide range of littoral species. The shore includes the sheltered water forms of the sponges *Hymeniacidon perleve*, *Halichondria panicea*, and *Halichondria bowerbanki* and is one of the few localities in the area where live specimens of the oyster *Ostrea edulis* occur.

Littoral habitats at Pennar Gut/Pennar Mouth were classified as regionally important for the sheltered bedrock and stable boulders (Little & Hiscock 1987). Hard substrata had a rich biota with some rarely encountered species. In the sublittoral environment, the algal communities included the non-native species *Solieria chordalis* as well as rarely recorded species including *Stenogramme interrupta* and *Gigartina teedii* (Hiscock & Maggs 1984).

West and East Cleddau Rivers combine to form the Daucleddau, the inner part of Milford Haven. This section of the waterway was considered a site of primary marine biological importance for its characteristic estuarine biota (Powell *et al.* 1979). Shores of the Daucleddau are generally rocky while shores of the West and East Cleddau tend to be mainly soft mud and gravel. Where the channel narrows, tidal streams increase and the shores become steeper. Penetration of open coast species decreases within a short distance up the estuary. Only about half of the common littoral species have been recorded beyond Lawrenny. As salinity decreases, the Australasian barnacle *Elminius modestus* replaces the common barnacle *Balanus balanoides*. *Balanus improvisus*, a nationally important estuarine species of barnacle, has been recorded in the upper Cleddau (Furman *et al.* 1989). *Fucus ceranoides*, a brackish-water algae, becomes abundant farther upstream.

Jenkins Point has very sheltered bedrock and stable boulders in the lower shore which were dominated by the sea squirt *Dendrodoa grossularia* and the sublittoral fringe had a rich biotic assemblage (Little & Hiscock 1987). Sediment shores at Lawrenny had a rich polychaete community (Powell *et al.* 1979). Both studies noted the unusually high abundance of eels *Anguilla anguilla* under boulders in the narrows. Sublittoral habitats were composed of cobbles and pebbles subject to strong tidal streams, a habitat considered of regional conservation importance by Little & Hiscock (1987). Rocky shores at Lawrenny Ferry have been monitored since 1961 (Woodman, Little & Dicks 1983) and were of interest because the area is within the transition zone from fully marine to brackish conditions; many marine species attain their upper distributional limit in this area (Figure 9.17).

Sublittoral sediment communities throughout the estuary were surveyed by Rostron (1983), who attributed recent faunal changes to organic enrichment and oil pollution. The biota has a strong southern influence with many species reaching their northern distributional limit within the region.

Milford Haven and the estuaries of the Rivers Cleddau were extensively surveyed by the FSC during the NCC's Harbours, Rias and Estuaries survey. A number of habitats and communities were considered of considerable marine biological importance (Little & Hiscock 1987).

Maerl beds were recorded near Stack Rock and large populations of seagrass *Zostera marina* on shallow sublittoral sand or mud. The maerl beds were scattered and broken but had a greater variety of associated algal species than the more dense beds in the Fal estuary (Cornwall) (Little & Hiscock 1987). Within the inner Milford Haven and the Daucleddau, wave-sheltered bedrock and boulder habitats exposed to moderate tidal streams were considered of national conservation importance. Algal communities were limited to shallow habitats but animal communities included a high abundance of a small range of species characteristic of ria communities. Communities present in Daucleddau were considered to be the best-developed and most extensive examples of their type in south-west Britain (Little & Hiscock 1987). Rock surfaces were covered with the sea squirts *Dendrodoa grossularia* and *Clavelina lepadiformis* and massive piped forms of the sponges *Halichondria panicea*, *Halichondria bowerbankii* and *Amphilectus fucorum*. In addition many species of hydroid, anemone, bryozoan and fish were recorded.

The intensity of study within Milford Haven has led to the discovery of many important species either new to Britain or species attaining their biogeographical limits within the area. For example the algae *Solieria chordalis* and *Grateloupia doryphora* were first recorded in Milford Haven (Little & Hiscock 1987); *Gymnogongrus griffithsiae* and *Griffithsia devoniensis* attain their northern limit of distribution within Milford Haven.

On the north side of Milford Haven, a number of studies have considered the impact of oil refinery

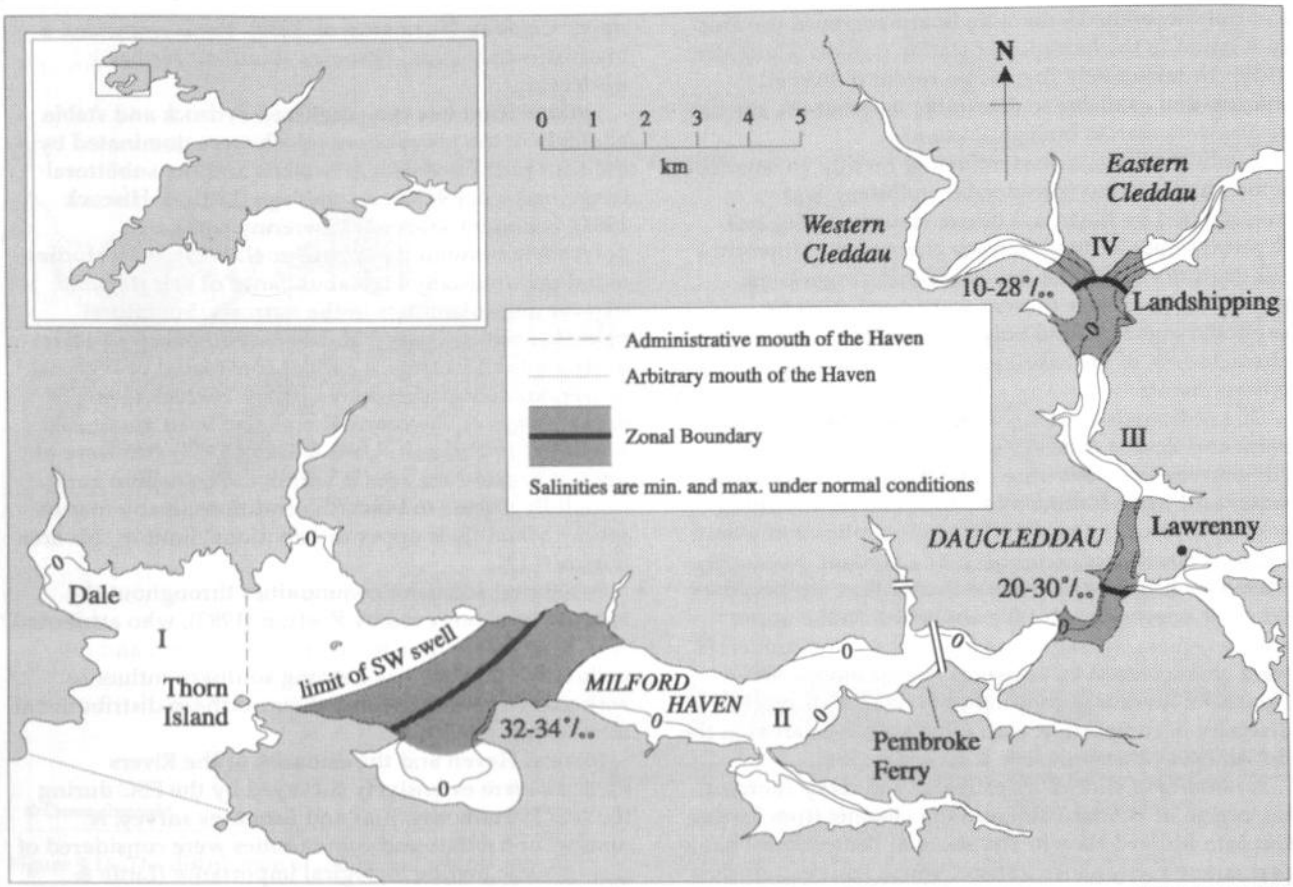

Figure 9.17. Zonal boundaries within Milford Haven and the Daucleddau. *Zone I*: oceanic-marine, sandy substrata; *zone II*: marine-polyhaline, mixed substrata; *zone III*; marine-mesohaline, rocky substrata; *zone IV*: polyhaline-mesohaline, muddy substrata. (Re-drawn from Nelson-Smith 1965.)

effluent on marine epifaunal communities on the Esso and Amoco jetties and on the extensive seagrass *Zostera marina* bed between the jetties. Flora and fauna on the jetties were investigated by Hiscock & Cartlidge (1980), Hiscock, Cartlidge & Little (1981) and Hiscock, Rostron & Little (1982). Howard, Baker & Hiscock (1989) described investigations of oil refinery effluent on the *Zostera* beds and presented information on the composition of infaunal communities, described previous mapping exercises, and compared the *Zostera* epibiota with other areas.

Extensive areas of littoral sediment at Dale/Gann Flats were described by Bassindale & Clark (1960) and were considered a site of primary marine biological importance (Bishop & Holme 1980). The flats are an internationally important site for wildfowl. In recognition of this importance, the flats are notified an SSSI. Bishop & Holme (1980) identified '*Arenicola*' and '*Pullastra*' communities on the flats. Over 40 species of polychaete and 30 species of mollusc have been recorded from this site. Species of interest were the sipunculid *Golfingia elongatum*, the priapulid *Priapulus caudatus* and the anemone *Peachia hastata* (now *Peachia cylindrica*). Dale Sands were characterised by a moderately developed '*Echinocardium–siliqua*' community which had limited species richness but high biomass. The Gann Flat was re-surveyed in 1988 by Edwards, Garwood & Kendall (1992). They recorded 111 species of which 60 were polychaetes, 14 bivalve molluscs, and 12 amphipod crustacea. Four distinct assemblages were identified determined by the interaction of tidal level, freshwater influence and sediment type. Compared with the work of Bassindale and Clark in 1958–1959, there had been a decline in the abundance of the polychaetes *Magalomma vesiculosum*, *Sabella pavonina* and *Arenicola marina* and a dramatic increase in the abundance of *Neanthes virens*. Referring to a study undertaken by Dr R. Warwick of a broad range of estuaries in south-west Britain, the authors note that the fauna of the Gann Flat was clearly different from that of the other 40 sites investigated and that the area must be seen as having a high conservation value.

Milford Haven was significantly affected by the *Sea Empress* oil spill in February 1996 and a large number of studies of the ecological impact of this spill, which will include general descriptions of habitats and communities, are in preparation.

9.6.8 The Dale and Marloes Peninsulas and St Brides Bay

The Dale/Marloes Peninsula is a very exposed, largely rocky coast within the Pembrokeshire National Park. The rock is sandstone with a number of important geological formations; for example, the sandstone columns the

Three Chimneys. The area has been investigated in some detail by the FSC's Dale Fort Field Centre. Information on the fauna of the region is contained within the *Dale Fort Marine Fauna* (Crothers 1966). Rocky shores in Milford Haven, around the Marloes peninsula and on Skomer are subject to widely different degrees of wave action and Ballantine (1961) used them to develop an exposure scale for rocky shores which has been widely used and adapted for different geographical areas (Figure 9.18). Very exposed sand beaches apparently devoid of macrofauna are found at Marloes and Musselwick. The Marloes peninsula was considered to have primary marine biological interest (Powell *et al.* 1979). Great Castle Head, Westdale Bay, Marloes Sands and Rocks, Musselwick and St Brides Haven were considered the most representative sites within the area.

Sublittoral habitats and the associated communities of the Dale/Marloes peninsula were first described by Hunnam (1976) and later by the SWBSS (Hiscock 1980). Sublittoral communities of southern St Brides Bay were considered unusual for the number of species of echinoderm encountered. These included the sea cucumbers *Neopentadactyla mixta* and *Cucumaria* (now *Aslia*) *lefevrei*, the featherstar *Antedon bifida* and the common urchin *Echinus esculentus*. A wide variety of species was present including some of Mediterranean–Atlantic origin. The bryozoan *Cellepora pumicosa* and the hydroid *Aglaophenia pluma* were

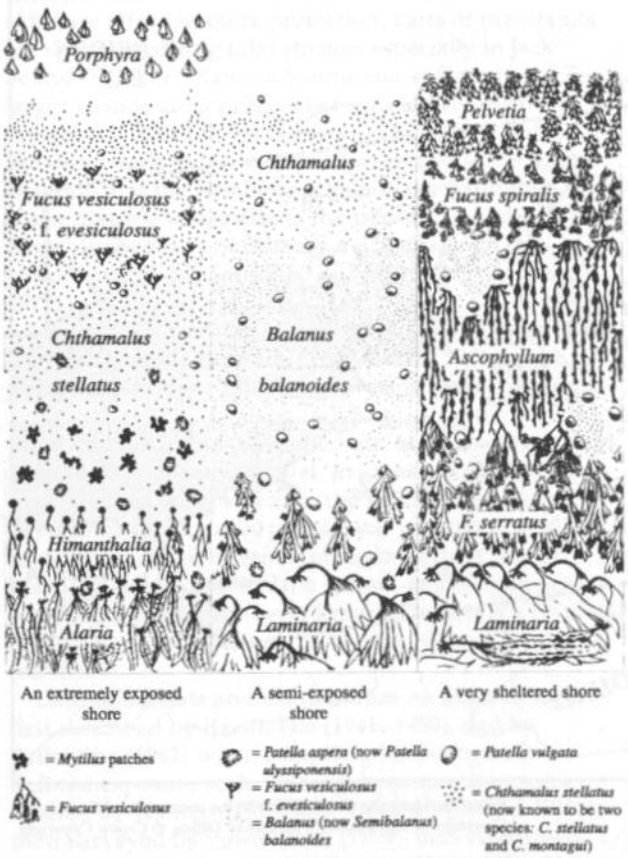

Figure 9.18. Diagrammatic representation of communities present on 'extremely exposed', 'semi-exposed' and 'very sheltered' rocky shores in Pembrokeshire (from Ballantine 1961).

characteristic species in shallow water. Part of the peninsula forms the south-east boundary of the Skomer Marine Nature Reserve (see below).

A long sweep of sand, St Brides Bay, leads to the rocky shores of St David's Peninsula. High cliffs exposed to the full force of the Atlantic weather are punctuated by small coves and narrow inlets, a coastline similar to north Cornwall. The coast at St David's was considered to have primary marine biological importance (Powell *et al.* 1979). St David's Head appears to form a northern boundary for the distribution of many species. Porthselau, a small cove at the south end of Whitesand Bay, was considered a site of importance. Slightly sheltered littoral communities were dominated by barnacles, limpets and fucoid algae. Well developed rockpool communities had dense mats of algae. The site appears to be the northern limit of the top-shell *Monodonta lineata* (Powell *et al.* 1979). Whitesand Bay, an exposed sandy bay, was characterised by a crustacean-polychaete community. At Pwlleuog, the rare brown alga *Waerniella lucifuga* was found in an upper shore cave (Cartlidge & Hiscock 1980).

9.6.9 North Pembrokeshire (St David's to Fishguard Bay)

The north Pembrokeshire coast is mainly high cliffs renowned for their diverse maritime vegetation and important seabird colonies. Fishguard is a busy fishing port and a main ferry terminal for services to Ireland. Cwm yr Eglwys, at the limit of Sector 9, was once a thriving port but was destroyed during the Great Storm of 1859. Sublittoral habitats and the associated communities of the north Pembrokeshire coast were investigated by the SWBSS (Cartlidge & Hiscock 1980). Sublittoral habitats were predominantly rock with sheltered sites to the east of Strumble Head having a covering of mud and silt. A number of southern species attain their northern limit of distribution within the area including the sponges *Thymosia guernei* and *Axinella polypoides*, the sea fan *Eunicella verrucosa* and the sea squirt *Pycnoclavella aurilucens*. Hunnam & Brown (1975) described the sublittoral nudibranch molluscs of the Pembrokeshire coast.

Abereiddy Quarry is a rather unusual habitat. It is a disused slate quarry 66 m across and 24 m deep, flooded with sea water. It is unique within the south-west and only one other similar habitat occurs in Britain, at Easdale Quarry, Argyll. Abereiddy Quarry is extremely sheltered from the prevailing wave action and the communities present are very different from the adjacent open coast (Hiscock & Hoare 1975). A number of interesting features were noted:

- a sharp discontinuity in the vertical distribution of species on rock, which is correlated with the depth of a thermocline and associated oxycline in summer;
- the absence of a kelp forest; only a thin line of kelp was found at or just below low water;
- large numbers of the sponges *Tethya aurantium*, *Suberites carnosa* and *Hymeniacidon sanguinea*, the

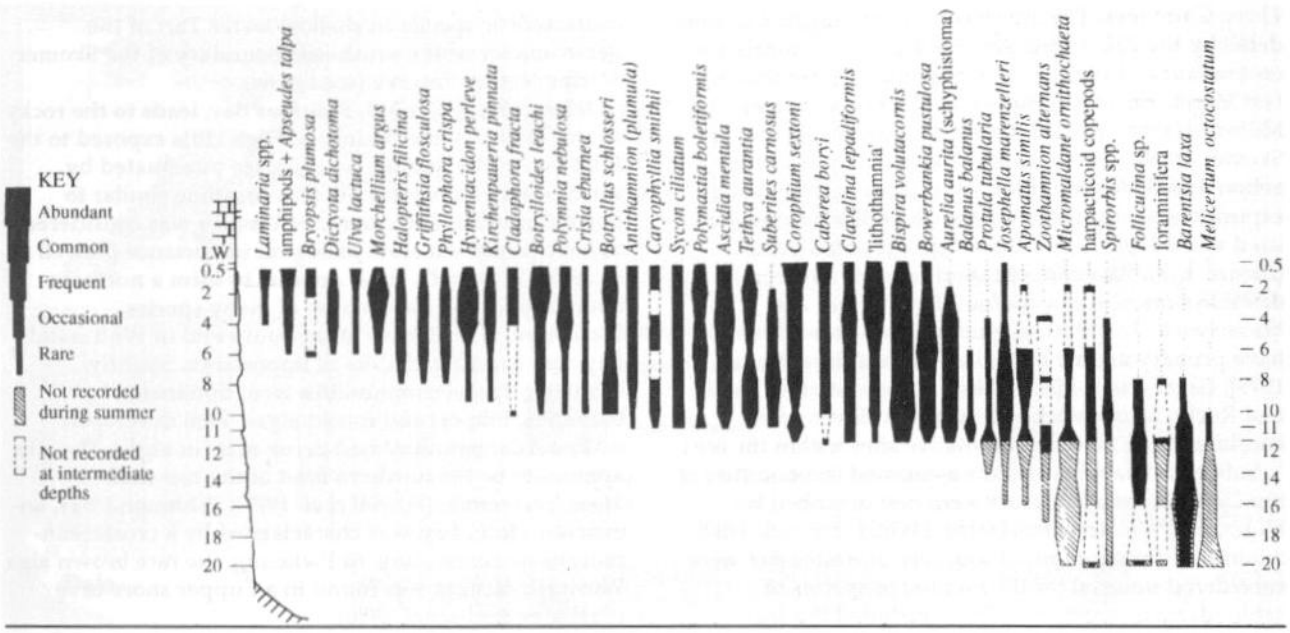

Figure 9.19. Vertical zonation of species recorded at 2 m depth intervals on a vertical rockface in Abereiddy Quarry. The sharp discontinuity at about 11 m is caused by a thermocline and associated oxycline present in summer. From Hiscock & Hoare (1975).

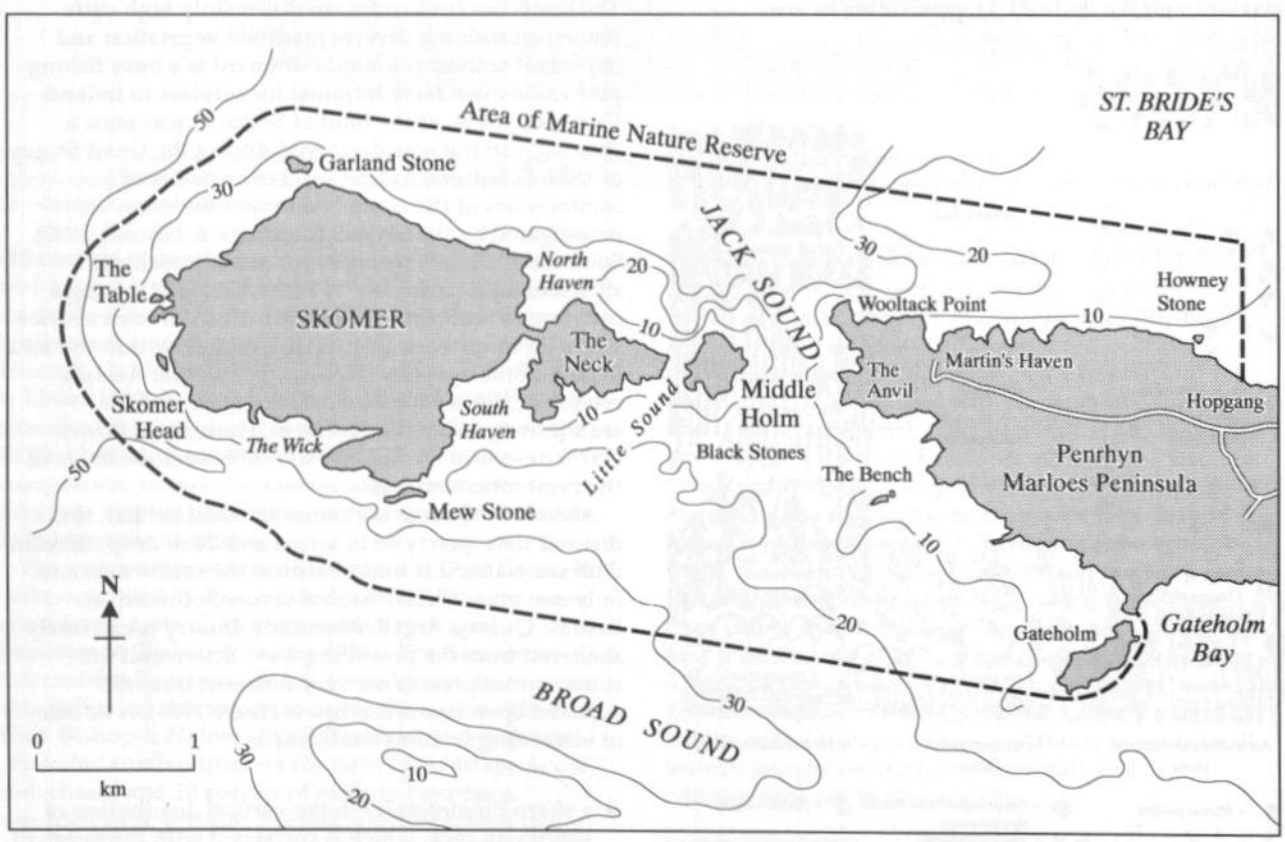

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Figure 9.20. Skomer Marine Nature Reserve.

sabellid worm *Bispira volutacornis* and solitary sea squirts such as *Ascidia mentula* were present;

- the presence below the thermocline/oxycline of large amounts of species rarely found on the open coast, including the entoproct *Barentsia laxa/elongata*, the ciliate *Folliculina* sp. and the hydroid *Melicertum octocostatum*;
- the presence of large numbers of fish;
- the absence of many species that were abundant on the adjacent open coast, for example the sea squirt *Molgula manhattensis*;
- the absence of many species of anthozoan for example dead-man's fingers *Alcyonium digitatum* and the jewel anemone *Corynactis viridis*.

Abereiddy Quarry is notified a SSSI in recognition of its marine biological interest.

9.7 Pembrokeshire islands: Skomer, Grassholm, Skokholm and Ramsey

The Pembrokeshire offshore islands have long been recognised as sites of significant biological and conservation importance. The islands are important seabird colonies and breeding sites for grey seals *Halichoerus grypus*. All the islands are notified SSSIs, and Grassholm, with its large gannetry, and Ramsey are owned by the Royal Society for the Protection of Birds. Their south-westerly location creates a strong southern element in the marine biota; many species recorded here are unrecorded farther north in Britain. The western side of the islands are very exposed to the prevailing wind-driven waves and swell; the northern and eastern sides are afforded more protection. Parts of the islands are swept by strong tidal streams especially in Jack Sound (Skomer), Ramsey Sound and at Grassholm. The larger islands are a prime site for local fishermen and are famous for their lobster *Homarus gammarus*, crawfish *Palinurus elephas* and scallops. Spectacular scenery, the isolation and the rich biota attract many naturalists, scuba divers and tourists to the islands. The islands were recognised as sites of primary marine biological importance by the Intertidal Survey Unit (Powell *et al.* 1979).

Skomer (Figure 9.20) is exposed to the full force of the prevailing winds from the open Atlantic Ocean; the nearest land mass to the south-west is Brazil. Skomer is approximately 3.2 km long, 2.1 km wide at the widest point and has a total coastal length of 15 km. It is a flat plateau 60 m above sea-level. Evidence from Skomer suggests man was present in the Bronze Age, and a population of up to 200 people was present in the Iron Age. Skomer is an internationally important seabird breeding colony and has the second-largest grey seal pupping area in south-west Britain. Skomer is a National Nature Reserve (NNR) and a Marine Nature Reserve (MNR).

Littoral habitats and communities on Skomer were first described by Bassindale (1946, 1950), and by Ballantine (1961) when compiling his biologically defined exposure scale. The algal communities were studied by Thomas (1953) and Jones & Williams (1966), then surveyed by Powell *et al.* (1979), and extensively described by Bunker, Iball & Crump (1983). Littoral zones were considered to have the following key features:

- the presence of classic examples of extremely exposed shores;
- an exceptionally wide variety of habitats and communities;
- a number of unusual microhabitats within a small geographic area.

Fifteen littoral habitats and associated communities were identified by Bunker, Iball & Crump (1983):

- **Boulder shores facing north**: Characteristic sheltered shore communities dominated by fucoid algae, namely *Pelvetia canaliculata, Fucus spiralis, Fucus vesiculosus, Ascophyllum nodosum* and *Fucus serratus*.
- **Boulder shores facing south-east**: Rich sublittoral fringe habitats with the small urchin *Psammechinus miliaris* and the cup-corals *Caryophyllia smithii* and *Balanophyllia regia*.
- **Boulder shores facing south-west**: Boulder shores with good growths of the elephant's ear sponge *Pachymatisma johnstonia*.
- **Boulder shores with sand**: Rich algal communities including the exposed variety of bladder wrack *Fucus vesiculosus* var. *linearis*.
- **Sloping bedrock shores facing south-east**: Fucoid-dominated shores with well developed splash zone lichen communities.
- **Sloping bedrock facing south-west**: Rich sublittoral fringe community with kelp and encrusting red algae, limpet-barnacle-dominated mid-shore. Shores characteristic of extreme exposure.
- **Sloping bedrock shores facing north-west**
- **Sloping bedrock shores facing south-east**: Sheltered open coast shores dominated by algae.
- **Vertical bedrock shores facing south-west**: Barnacle dominated mid-shore with lush growths of thong weed *Himanthalia elongata*.

- **Vertical bedrock facing north:** Barnacle-dominated mid-shore with *Balanus* (now *Semibalanus*) *balanoides* below mid-tide-level, *Chthamalus stellatus* above mid-tide-level. Red algal-dominated low shore.
- **Narrow inlets with vertical sides:** Similar to vertical shores although extensive growths of the black lichen *Lichina pygmaea* present on the upper shore.
- **Areas of wave surge:** Lush red algal communities on the low shore with the kelp *Alaria esculenta*. Animal communities dominated by erect bryozoans, encrusting sponges, tubeworms and barnacles. A number of species uncommon in littoral area were present, for example the organ-pipe hydroid *Tubularia indivisa*.
- **Littoral caves**
- **Rockpools**
- **Crevices**

The latter habitats were not fully investigated and little community information was available. Crump (1993) repeated the 1982 transects ten years later but unfortunately detailed comparisons were not possible because the original transects could not be exactly relocated. In general, zonation patterns in 1992 were considered to be similar to the original survey. Permanent transect marks were established to ensure exact relocation in future years.

Many diving studies have been undertaken around Skomer: Hunnam (1976) and Hiscock (1980, 1981a, 1983) completed diving surveys; Earll (1979) studied the urchin *Echinus esculentus*; and scallops were studied by Jones (1980) and Bunker (1983). Sublittoral habitats and communities were described during the South-West Britain Sublittoral Survey and during the preparation of the management plan for the then proposed Marine Nature Reserve (Hiscock & Bunker 1984). A review of the marine biological information was compiled by Bunker & Hiscock (1987). Sublittoral habitat and community diversity mirrors that encountered in littoral zones for variety and extent. A comprehensive description is not possible here. Bunker & Hiscock (1987) identified the following communities and assessed their marine nature conservation importance:

- Undisturbed bedrock and large boulders: national;
- Communities on disturbed bedrock and boulders: regional;
- Medium and small boulders, stones and pebbles: regional;
- Communities on wrecks: regional;
- Sheltered sediments: regional.

Undisturbed bedrock communities were of greatest interest. A very wide range of communities representative of all sublittoral zones were present within small areas. Of particular interest were the circalittoral animal communities subject to water movement within Broad Sound. There were well developed communities of erect sponges including species such as *Raspailia hispida*, *Axinella polypoides* and *Axinella infundibuliformis*. In addition the nationally important sponge *Thymosia guernei* was recorded here. A number of south-western species were present, including the sea fan *Eunicella verrucosa* plus its nudibranch predator *Tritonia odhneri*, red sea-fingers *Alcyonium glomeratum*, the colourful sea-slug *Okenia elegans* and the cup-coral *Balanophyllia regia*. Infralittoral algal communities were considered particularly well developed and included dense populations of the regionally important south-western species *Drachiella spectabilis*. Also recorded were a number of other algal species considered to be of marine biological importance. These included an internationally important parasitic red alga *Rhodymeniacolax* sp.

The infaunal communities of sublittoral sediments in Skomer MNR were surveyed by Rostron (1994). Although the sediments were rich in both species and individuals, the overall distribution of species showed no distinct pattern, and no meaningful classification could be defined. However, subtle differences between sampling stations were apparent, and distributional patterns of some individual species could be attributed to sediment type.

In order to obtain information on species distribution and population dynamics, a monitoring programme was established in 1982 (Bullimore 1987); this should ensure any potentially damaging impacts are quickly recognised. Skomer MNR now has two full-time wardens and one seasonal warden, who monitor the usage of the reserve by divers, fishermen and tourists (Bullimore 1989), in addition to sublittoral biological monitoring. Physio-chemical monitoring instruments have been installed within the MNR to gather data on the physical environment to complement the biological monitoring. Recommendations for monitoring of algal populations at Skomer were given by Scott (1994).

In 1994, the MNCR undertook a sublittoral survey of The Smalls, a group of reefs some 26 km due west of Skomer.

Skokholm was included with Skomer and the Marloes Peninsula as a site of primary marine biological importance (Powell *et al.* 1979). Well developed rockpool communities were identified at West Tump, Grassholm. Grassholm and Skokholm have very good examples of very exposed rocky shores; the kelp *Alaria esculenta*, characteristic of very exposed conditions, was abundant on the lower shore. Sublittoral habitats and associated communities of Grassholm were surveyed by Hiscock (1980a); brief notes on Skokholm were presented in Hiscock (1981a). Communities present on Grassholm were typical of exposed bedrock habitats; infralittoral communities were dominated by algae while circalittoral communities were dominated by animals. Skokholm has a wide range of habitats and associated communities although diversity is not as high as that recorded from the adjacent island of Skomer (Hiscock 1981a). Brooke (1990) described the natural history of Skokholm concentrating on the marine ornithological interest with only brief comments on the marine littoral biota.

Stanbury (1974) undertook a mark/recapture study on the populations of the top-shell *Monodonta lineata* and found that individuals of the species could live for up to 15 years.

Sublittoral habitats and communities of Ramsey and the offshore rocks to the west (Bishops and Clerks) were described by Hiscock (1978b). Substrata were predominantly clean stable rocks although extensive areas of sand were present off the west coast at Aber Mawr. Strong tidal streams (up to 6 knots (3 m s^{-1})) sweep around the islands and are the primary structuring force of the marine communities present on rock surfaces. Communities were characterised by sessile filter-feeding taxa such as sponges, hydroids, bryozoans and ascidians. Several species of algae and animals at or near the northern limit of their distribution were recorded including the red algae *Radicilingua thysanorhizans*, whose previously recorded northern limit was at Lundy, and the sea squirt *Stolonica socialis* (Hiscock 1978b). Ramsey Sound was considered to be an area of "outstanding scientific interest" by Hiscock (1981a). Very strong tidal streams in the centre of the sound lead to a characteristic community not encountered elsewhere in south-west Britain and similar to communities in the Menai Strait (north Wales) and Strangford Lough Narrows (Northern Ireland). The MNCR team undertook further surveys of the Bishops and Clerks in 1995.

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Chapter 10: Cardigan Bay and north Wales (Cwm-yr-Eglwys, Newport Bay to Rhôs-on-Sea) (MNCR Sector 10)*

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Synopsis

The coastline from north Pembrokeshire to the north coast of Wales east to the Great Orme includes extensive sandy beaches and sublittoral sediments as well as rocky coasts. The sarns in Cardigan Bay are long spits of shallow hard substratum habitats colonised by emphemeral communities of algae and animals. The offshore sediments of Cardigan Bay hold communities characteristic of sands and muds with coarser substrata near to the sarns and where tidal streams are strong. Examples of open coast tide-exposed biotopes are well developed around Bardsey and the nearby coast and include caves at St Tudwal's Islands. Rock surfaces generally extend to only shallow depths along the north coast of the Lleyn Peninsula but, offshore, strong tidal streams sweep extensive areas of hard substratum composed of pebbles and cobbles with asociated infauna and epifaunal communities. The island of Anglesey is separated from the mainland of North Wales by the Menai Strait and, here, very strong tidal streams lead to the presence of characteristic communities dominated by sponges and hydroids. Communities along the rocky coast of Anglesey show a transition from those of the open west coast to those of the shelter and high turbidity of the east basin of the Irish Sea. The sheltered harbour at Holyhead includes mud habitats colonised by sea pens *Virgularia mirabilis* whilst the nearby Inland Sea has extensive sediment flats exposed to a peculiar tidal regime. To the east of Anglesey, extensive sand flats occur along the coast broken by the limestone headland of the Great Orme.

10.1 Introduction

Sector 10 (Figures 10.1 and 10.5) has a wide variety of coastal types. The shores of Cardigan Bay south of the Dyfi estuary are predominantly of boulders and bedrock backed by low cliffs. North of the Dyfi, sandy shores are more common, frequently backed by sand dunes, as at Morfa Harlech and Morfa Dyffryn. These shores are exposed to westerly winds, but the shallow water of Cardigan Bay reduces the effect of wave action. Shingle and sandy shores feature prominently on the southern coastline of the Lleyn Peninsula. The western and northern coastline of the peninsula is rocky with low cliffs. The south-west coast of Anglesey contains sandy estuaries, saltmarshes and sand dunes, including the important calcareous dune system of Newborough Warren. Much of the north and west coasts are rocky, with high cliffs in the vicinity of Holyhead. Carboniferous limestone outcrops on the north-east coast, while the east coast is also predominantly rocky, but there are also areas of sandy shore in Dulas Bay, Lligwy Bay and in Red Wharf Bay (see Figure 10.5). The Menai Strait, which separates Anglesey from the Welsh mainland, is a geologically complex feature, formed

* This review was completed from published and, where available, unpublished sources of information on benthic habitats and communities including the results of interviews with relevant workers undertaken up to 1991. That work was published in Mills (1991). The review has been further revised to take account of major additional studies up to the end of 1994 by the author and up to the end of 1996 by the series editor. It does not include benthic survey information summarised for or published in the MNCR *Regional Reports* series or work now being undertaken to describe and map biotopes in candidate Special Areas of Conservation. For information on conservation status and an analysis of rare and scarce seabed species, the reader is referred to the *Coastal Directories* series.

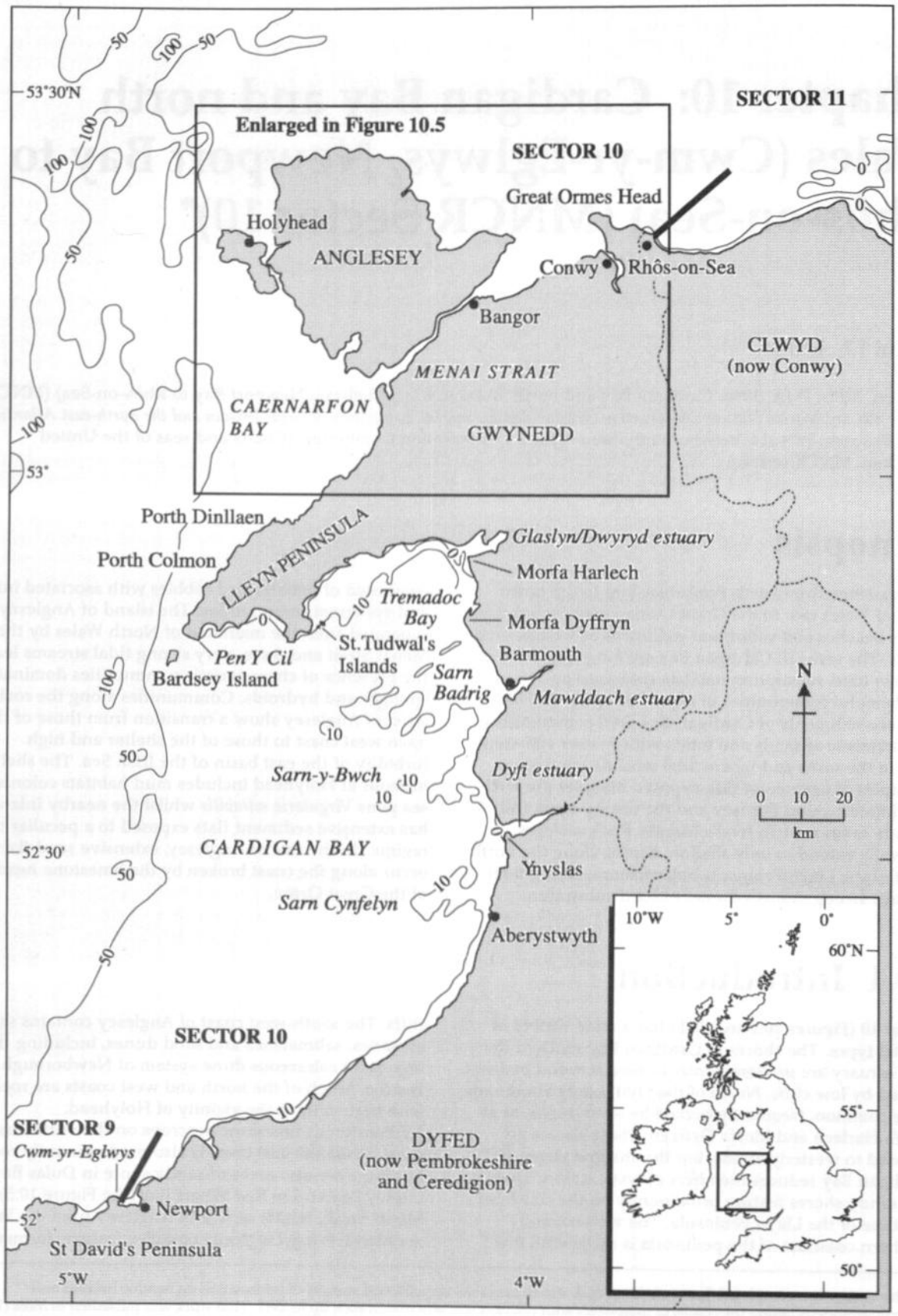

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Figure 10.1. MNCR Sector 10, showing places mentioned in the text.

from the unification of two glacially deepened valleys. The Strait gives rise to particularly unusual habitats, created by extreme shelter from wave action and exposure to strong tidal streams. Great Ormes Head and Little Ormes Head are outcrops of Carboniferous limestone similar to those on north-east Anglesey.

Much of the coastline in Sector 10 is relatively unspoilt and undeveloped, particularly in comparison to Liverpool Bay, to the north-east. Because the coastal hinterland of this sector is predominantly rural in character, it receives a relatively restricted pollution load, although agricultural and sewage discharges have a localised effect (Huckbody *et al.* 1992). The area is popular for tourism and recreation, centred on Snowdonia National Park and traditional seaside resorts. The only major commercial port in Sector 10 is at Holyhead on Anglesey. However, one area of environmental concern in this sector which has recently assumed prominence is the development of an offshore oil and gas industry in the Irish Sea.

Sector 10 has many features of conservation interest. Two locations have been proposed as Marine Nature Reserves: the Menai Strait and adjacent areas, and Bardsey Island with part of the Lleyn Peninsula (Nature Conservancy Council 1982). Parts of the coast of Cardigan Bay, the Lleyn Peninsula and stretches of the Anglesey coast have been designated as Heritage Coast, and much of Anglesey and the Lleyn Peninsula has been designated as Areas of Outstanding Natural Beauty (Huckbody *et al.* 1992). The Ceredigion coast between Aberporth and Newquay is Britain's first Marine Heritage Coast, extending into the inshore waters of Cardigan Bay. The Lleyn Peninsula is also of considerable geological conservation interest (Huckbody *et al.* 1992). Great Ormes Head and Little Ormes Head are recognised as of particular conservation importance for their maritime vegetation and geology.

Marine research in the area has fluctuated in intensity since the Liverpool Marine Biological Committee maintained a field station on Puffin Island at the northern end of the Menai Strait from 1887–1891. The activities of the station were short-lived, as the Committee moved the focus of its activities to Port Erin on the Isle of Man (Herdman 1920). Much of the current academic research effort in the area is based at the Marine Laboratory of the University College of North Wales at Menai Bridge, and at the University College of Wales at Aberystwyth. The Ministry of Agriculture, Fisheries and Food (now as the Centre for Environment, Fisheries and Aquaculture Science) carries out research into fisheries, shellfish cultivation, the nursery grounds of commercial fish species and the impacts of mobile fishing gear from its laboratory at Conwy.

The Irish Sea Study Group was formed in 1985 to focus attention on the environmental health of the Irish Sea. The Irish Sea Study Group (ISSG) carried out an environmental review of the Irish Sea (Shaw 1990). The results of this review were reported at a major conference held on the Isle of Man in 1990. Four specialist reports were produced covering the topics of nature conservation, waste inputs and pollution, exploitable living resources and planning, development and management (ISSG 1990a, 1990b; Norton & Geffen 1990; Smith & Geffen 1990). As part of the report on nature conservation, Mackie (1990) reviewed the state of current knowledge, and mapped the distribution of sediment types and offshore benthic communities in the Irish Sea (see Part 1 of this volume). The report on waste inputs and pollution (ISSG 1990b) drew an immediate critical response from Greenpeace and other non-governmental organisations for the report's advocacy for an environmental protection policy based upon the 'assimilative capacity' of the environment. Greenpeace presented a case for an alternative philosophy based on the 'precautionary principle' and on reducing waste inputs through the adoption of 'clean production' (Johnston & Simmonds 1990). A further Irish Sea symposium was held at Chester in 1991 (Jones & Norgain 1991). More specialised symposia have considered the effects of climate change (Irish Sea Forum 1992a), marine viruses (Irish Sea Forum 1992b) and fisheries management (Irish Sea Forum/Marine Forum 1993). Two environmental appraisals were commissioned by Hamilton Oil, describing Caernarfon and Cardigan Bays (Huckbody *et al.* 1992), and the coast of north Wales and north-west England (Taylor & Parker 1993). Chatfield (1979) provides a bibliography of marine molluscan studies in Wales relevant to this area. Estuaries were described by Buck (1993) and the Countryside Council for Wales (1993). Marine and estuarine fish species were described by Potts & Swaby (1993). Most recently, Mackie, Oliver & Rees (1995) have described and mapped the distribution of sediment benthos species, benthic assemblages and features characterising those assemblages including species richness and diversity (species abundance-richness measures) for the southern Irish Sea. The Countryside Council for Wales commenced a phase 1 survey of intertidal areas in 1995 and the MNCR is undertaking littoral and sublittoral surveys of this coastal sector during the period 1995 to 1997.

10.2 Cardigan Bay

10.2.1 Introduction

The oceanography of Cardigan Bay, the area enclosed by the St David's and Lleyn Peninsulas, is described by Bowers (1991) and the geology by Dobson & Whittington (1987). Sedimentological features are described by Caston (1966) and Dobson, Evans & James (1971). In the outer part of Cardigan Bay there are extensive sand banks aligned in the direction of tidal streams (Bowers 1991). An unusual feature of Cardigan Bay is the presence of shallow boulder reefs derived from glacial moraines, known as 'Sarns'.

Marine biological studies in Cardigan Bay have been carried out predominantly by staff and students based at the University College of Wales at Aberystwyth since the

beginning of the 20th century. There have been two main periods of research activity. Prior to 1950, the studies undertaken were to describe the ecology of the rocky open coast (Walton 1913; Lewis 1936; David 1941; Evans 1947), the infauna of the Dyfi estuary (Beanland 1926, 1940) and sublittoral benthic infauna (Laurie & Watkin 1922). The second phase of activity commenced around 1970 focusing on the autecology of common estuarine or open coast littoral species. A very large number of theses and papers have resulted and are summarised in an unpublished bibliography (Fish 1991). However, they are not included here unless they describe aspects of benthic ecology related to community structure and biology.

There are no major fishing ports in Cardigan Bay but many small boats work out of the minor ports along this coast. Although the herring *Clupea harengus* fishery was historically important, the lobster *Homarus gammarus* fishery is now the major fishery in Cardigan Bay. Cardigan Bay is the site of an ongoing experimental lobster stock enhancement programme by the North Western and North Wales Sea Fisheries Committee, in which larval lobsters are grown on prior to relase into suitable lobster habitat (Cook, Fish & Sankey 1989; Sankey 1991). There is also a fishery for scallops, with rays, dogfish and sole making up the bulk of the fish landings (Huckbody *et al.* 1992).

10.2.2 Intertidal areas

Descriptions of the rocky shores and their animal and plant communities were provided by Evans (1947) who was particularly interested in the zonation patterns of littoral species and in the concept of 'critical heights' marking the dividing line between zones. He recorded the algae and fauna from 25 sites to the north and south of Aberystwyth, and described '*Littorina*', 'balanoid' and 'laminarian' zones at different heights on the shore. He also examined the effects of rock configuration on the distribution of species, recording the brown alga *Ascophyllum nodosum* on rock platforms, where the effects of wave action were locally attenuated by the low gradient. More recent information describing littoral marine communities at sites in Cardigan Bay has been extremely limited. Five shores in the south of the Bay were surveyed by the Scottish Marine Biological Association/Marine Biological Association Intertidal Survey Unit (Powell *et al.* 1979) for the NCC. Cunningham *et al.* (1984) described the distribution of the polychaete *Sabellaria alveolata* around Britain (reefs formed from the tubes of this species are a characteristic feature of shores in Cardigan Bay), and provided descriptions for two shore sites in Cardigan Bay, at Mochras (Shell Island at the north end of Morfa Dyffryn) and from Llwyngwril (south-west of Barmouth). Site descriptions for a few further sites can also be gleaned from autecological studies (e.g. Aboul-Dahab 1990).

10.2.3 Estuaries

Within Cardigan Bay, there are three principal estuaries, the Dyfi, Mawddach (Barmouth) and the Glaslyn/Dwyryd system. The estuarine sediments are predominantly sandy, and contain a fauna of low diversity and productivity (Buck 1993; E.I.S. Rees pers. comm.). Beanland (1940) identified two principal infaunal communities in the Dyfi estuary, a '*Corophium* community', and a '*Macoma* community', the latter divided into '*Macoma/Bathyporeia*' and '*Macoma/Cerastoderma*' subcommunities. Mills (1978) studied the distribution of *Corophium volutator* and *Corophium arenarium* at four locations within the Dyfi estuary. He observed little overlap in the distributions of the two species; *Corophium arenarium* was present in the outer estuary stations in slightly silty sands, and *Corophium volutator* in muddier sediments in the inner estuary, subject to lower salinity and wider salinity fluctuations. The beach at Ynyslas, at the mouth of the Dyfi estuary, has been studied particularly intensively by students from University College Aberystwyth (Fish 1991). Mollusc species from this location are listed in Smith (1991). Several autecological studies also compared faunal distributions at Ynyslas with those from an adjacent open coast site (Fish 1969, Preece 1970). There does not appear to be any published information on the Mawddach estuary, but the estuary is considered to be of limited marine biological interest (E.I.S. Rees pers. comm.). The benthos of the Glaslyn/Dwyryd estuary system was extensively surveyed by Cook & Rees (1978). Two trends were apparent in the distribution of fauna, dependent on gradients in salinity and sediment stability. The fauna of the lower estuary was dominated by characteristic sand beach species such as the amphipods *Bathyporeia* spp., *Haustorius arenarius* and the bivalve *Angulus tenuis*. The transition areas between open sandflats and saltmarsh were muddier and richer with the amphipod *Corophium volutator*, and the bivalves *Mya arenaria* and *Scrobicularia plana*.

10.2.4 Sublittoral hard substrata: The Sarns

The fauna and flora of the rocky sublittoral has received little attention. The fauna of kelp holdfasts was investigated by Scarratt (1961) and Moore (1978). Most studies have been carried out on The Sarns which are very shallow features (maximum depth approximately 10 m below chart datum), of roughly linear shape, which appear to be composed entirely of boulders, cobbles and pebbles with various grades of sediments mixed in. Sarn Badrig (St Patrick's Causeway), in particular, is a very impressive topographical feature, and breaks the surface at low water at intervals along its length up to 17 km offshore. The Sarns are very exposed to wave action from the south-west. Because of this wave exposure, some of the substratum may be mobile during storms. In addition to wave exposure, the Sarns obstruct tidal currents causing turbulent flows particularly on the shallow reef crests during spring tides (Hiscock 1986).

Sarn Badrig, Sarn-y-Bwch and Sarn Cynfelin were surveyed by Hiscock (1985, 1986). The dynamic nature of the environment at these exposed sites, had a considerable effect on the species and communities present. She recorded distinctive communities dominated by ephemeral algae from the sublittoral fringe on the reef crests (for instance, Figure 10.2). In slightly deeper water dense foliose algae dominated all hard substrata with few animals present. Between 4 and

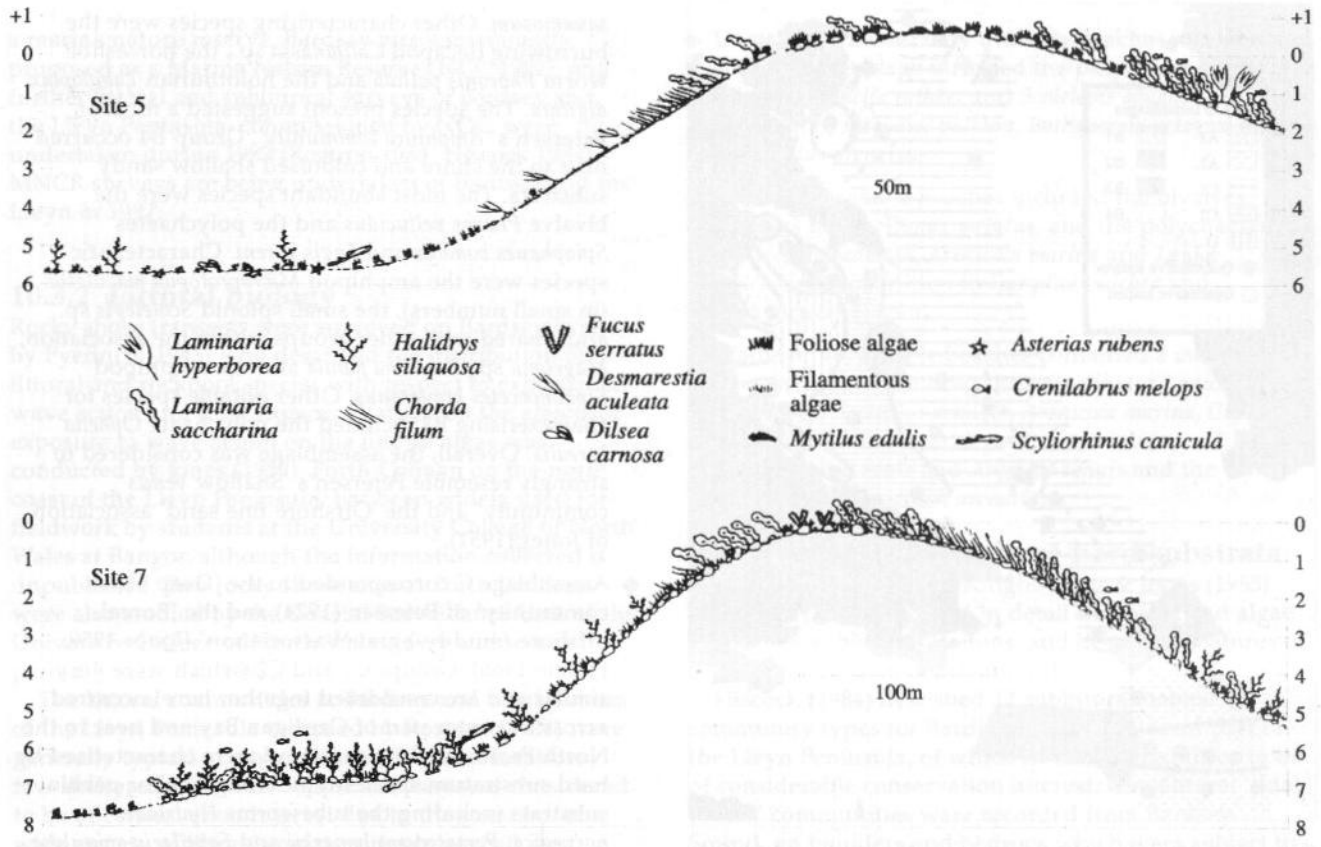

Figure 10.2. Section through two sites on Sarn Badrig, showing the principal substrata and species. The vertical scale showing depth in metres relative to chart datum (broken line) is greatly exaggerated. (From Hiscock 1986.)

9 m *Halidrys siliquosa* forests covered extensive areas, attached to boulders and cobbles in sediment. In deeper water (over 10 m) off the ends of the reef, animal communities with a wide variety of species were present on tide-swept boulders. Recently, sublittoral surveys were carried out by volunteer divers as part of the Marine Conservation Society's 'Seasearch' project funded by JNCC (Bunker 1993).

10.2.5 Sublittoral sediments

The sublittoral benthic infauna of Cardigan Bay is also comparatively poorly known. In one of the first quantitative studies of sublittoral sediments in British waters, Laurie & Watkin (1922) used a grab to sample the sublittoral biota of 'the Gutter', an area of seabed to the south-west of Aberystwyth. A further survey of 'the Gutter' and other areas in Cardigan and Caernarfon Bays was carried out during 1991 (Huckbody *et al.* 1992). Additional molluscan species were recorded by Cotton (1930, in Chatfield 1979) from dead shells washed up at Shell Island. Inshore areas of Cardigan Bay have been recently sampled as part of a wider benthic survey of the Irish Sea by the National Museum of Wales (Mackie 1990, Mackie, Oliver & Rees 1995). Four main assemblages and seven groups within them were identified from Cardigan Bay (Figure 10.4).

- Assemblage A was present in the Celtic Deep and was characterised by 12 exclusive species, mostly small polychaetes.

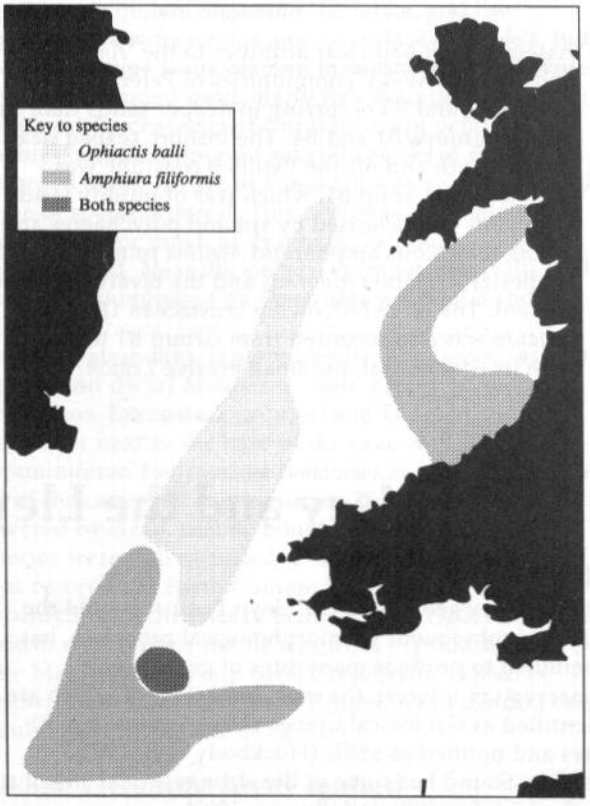

Figure 10.3. One of the maps of species distributions (for two species of brittle stars) in the southern Irish Sea from the BioMôr report (Mackie, Oliver & Rees 1995) (re-drawn).

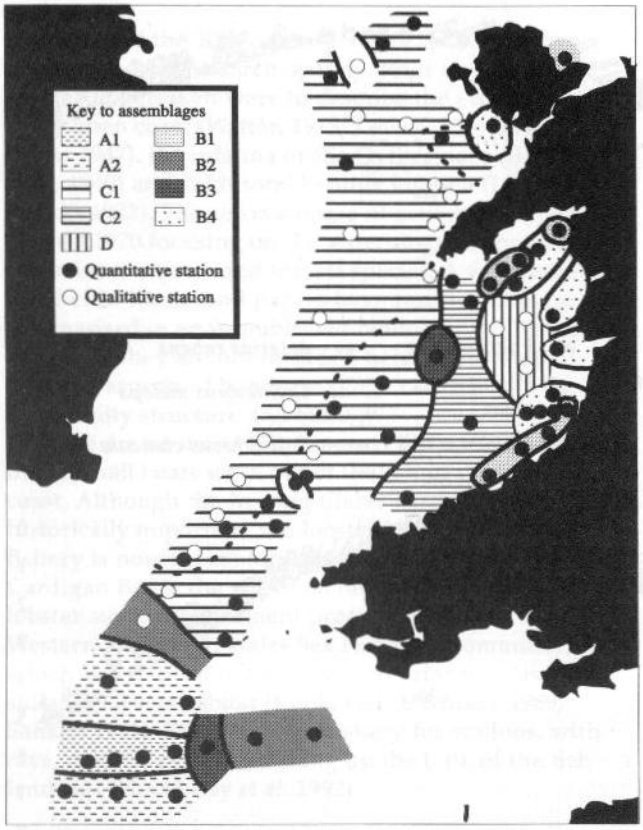

Figure 10.4. Macrofaunal assemblages in the southern Irish Sea as determined by Czekanowski classification. Redrawn and interpreted from Mackie, Oliver & Rees (1995). Assemblages are described in the text.

- Assemblage B had clear affinities to the '*Amphiura*' and 'shallow *Venus*' communities of Petersen with groups B2 and B3 occurring in deeper sands than the inshore groups B1 and B4. The inshore seabed near Aberystwyth and off the Pwllheli coastline was colonised by Group B1, which was of muddy sand sediments characterised by spionid polychaetes and by the tubicolous ampharetid *Mellina palmata* with the brittlestar *Amphiura filiformis* and the bivalve *Abra alba* present. The large burrowing crustacean *Upogebia deltaura* was also recorded from Group B1 together with its commensal, the small bivalve *Lepton squamosum*. Other characterising species were the burrowing decapod *Callianassa* sp., the horseshoe worm *Phoronis pallida* and the holothurian *Labidoplax digitata*. The species present suggested a form of Petersen's '*Amphiura community*'. Group B4 occurred near to the shore and colonised shallow sandy substrata. The most abundant species were the bivalve *Phaxas pellucidus* and the polychaetes *Spiophanes bombyx* and *Lagis koreni*. Characteristic species were the amphipod *Microprotopus maculatus* (in small numbers), the small spionid *Scolelepis* sp. and, shared with other groups within the association, *Magelona* sp., *Fabulina fabula* and the amphipod *Siphonoecetes kroyeranus*. Other notable species for characterising B4 included the polychaete *Ophelia borealis*. Overall, the assemblage was considered to strongly resemble Petersen's 'Shallow *Venus* community' and the 'Offshore fine sand' association of Jones (1951).
- Assemblage C corresponded to the 'Deep *Venus* community' of Petersen (1924) and the 'Boreal offshore (muddy-) gravel association' (Jones 1950; Holme 1966). Groups C1 and C2 (which were very similar and are considered together here) occurred across the outer part of Cardigan Bay and near to the North Pembrokeshire coast and were characterised by hard substratum species typical of gravel or pebble substrata including the tubeworms *Hydroides norvegica*, *Pomatoceros lamarkii* and *Sabellaria spinulosa* and the ascidian *Dendrodoa grossularia*. Infaunal species characteristic of this assemblage were tubicolous ampharetids and the small amphipod *Guernea coalita*. The spionids *Aonides paucibranchiata* and *Laonice bahusiensis*, the sabellid *Chone* sp., the amphipod *Unicola planipes* and the molluscs *Astarte sulcata* and *Spisula elliptica* were considered partial indicators.
- Assemblage D was present in the central shallow areas of Cardigan Bay on stony habitats and was poorly defined. General indicator species were considered to be the hesionid polychaetes *Kefersteinia cirrata* and *Syllidia armata*, the gastropods *Pusilla inconspicua* and *Partulida spiralis*, the bivalve *Tapes rhomboides*, the amphipod *Gittana sarsi* and the decapod *Eurynome* sp.

10.3 Bardsey and the Lleyn Peninsula

10.3.1 Introduction

The complex geology of the Lleyn Peninsula, and the effect of subsequent geomorphological processes, has combined to produce many sites of geological conservation interest, the most important of which are identified as Geological Conservation Review (GCR) sites and notified as SSSIs (Huckbody *et al.* 1992). Bardsey Sound has some of the strongest tidal streams in the Irish Sea (Elliott & Bowers 1992).

The intertidal marine biota of the Lleyn Peninsula has been extensively studied, mainly by staff and students from the University College of North Wales, Bangor. However, much of this information is unpublished. Crisp & Knight-Jones (1955) suggested that the Lleyn Peninsula represented a discontinuity in the distribution of many species, and the northern limit in the Irish Sea for some species with a south-western distribution. During 1977 littoral and sublittoral surveys of Bardsey Island were undertaken by the University College of North Wales under contract to NCC (Hoare & Jones 1981). In the report of these surveys Hoare & Jones (1981) put forward a case for the adoption of Bardsey as

a marine nature reserve. Bardsey was subsequently proposed as a Marine Nature Reserve (NCC 1982), and further littoral and sublittoral surveys of Bardsey and the Lleyn Peninsula, commissioned by NCC, were undertaken during 1983 (Rostron 1984; Hiscock 1984). MNCR surveys are being undertaken of Bardsey and the Lleyn in 1997.

10.3.2 Littoral biology

Rocky shore transects were surveyed on Bardsey Island by Pyefinch (1943) who described the distribution of littoral and rockpool species with respect to exposure to wave action and tidal streams. A study on the effects of exposure to wave action on the littoral algae was conducted by Jones (1959). Porth Colman on the north coast of the Lleyn Peninsula, has been widely used for fieldwork by students at the University College of North Wales at Bangor, although the information collected is unpublished. Two rocky shore sites at Porth Dinllaen were also studied by the Coastal Surveillance Unit of the University College of North Wales, over a nine-year period (Jones *et al.* 1983).

The littoral communities at Bardsey and nearby areas of the Lleyn Peninsula recorded by Rostron (1984) were generally typical of wave and tide-exposed locations; few sheltered sites were found. Bardsey was considered to be of conservation interest due to the presence of a wide variety of littoral communities in a small area, including good examples of exposed rocky shore communities, and for the presence of rare algal species. Rostron (1984) described the habitats within a cave on St Tudwal's Island, which she considered as of high conservation interest. The cave was some 40 m long and 10 m high. In the inner cave the ascidian *Dendrodoa grossularia* covered the rock surfaces to 6 m above chart datum. Associated with *Dendrodoa* were the sponges *Clathrina coriacea* and *Stelletta grubii* (normally a sublittoral species), the hydroid *Dynamena pumila*, a gelatinous bryozoan, and the anemones *Actinia equina*, *Sagartia elegans* and *Corynactis viridis*. The barnacle *Semibalanus balanoides* dominated the middle cave, where the vertical extent of *Dendrodoa* was reduced to 2 m above chart datum. Near the cave entrance the fauna was similar to that of the adjacent open coast.

Allen *et al.* (1983) recorded the fauna of beaches on the Lleyn Peninsula and Anglesey, subject to varying degrees of exposure to wave action, with the aim of developing a biological scale for sediment stability. This scale was intended for use in engineering applications for predicting the wave-induced stresses on structures in the littoral zone. To assess sediment stability, the authors made repeat visits to the shores, and produced accurate shore profiles at each visit. From the changes in shore profiles, they were able to derive a 'stability index' (mean change in height per month) for each beach. They were then able to recognise four broad faunal assemblages characteristic of levels of sediment stability.

- Very unstable beaches containing a low-diversity species assemblage characterised by the isopod *Eurydice pulchra* and the amphipods *Bathyporeia pelagica* and *Haustorius arenarius*.
- Unstable or moderately unstable beaches, where the species assemblage included the polychaetes *Paraonis fulgrens*, *Ophelia rathkei* and *Scolelepis squamata* in addition to *Eurydice pulchra*, *Bathyporeia pelagica* and *Haustorius arenarius*.
- Moderately stable beaches included the bivalves *Angulus tenuis*, *Donax vittatus*, and the polychaetes *Scolelepis squamata*, *Arenicola marina* and *Lanice conchilega*, in addition to *Eurydice pulchra* and *Bathyporeia pelagica*.
- Stable or very stable beaches contained a more diverse fauna including the polychaetes *Lanice conchilega*, *Scoloplos armiger*, *Arenicola marina*, *Clymene oerstedii* and *Pygospio elegans*, the bivalves *Cerastoderma edule* and *Angulus tenuis* and the amphipod *Corophium arenarium*.

10.3.3 Sublittoral inshore hard substrata

In an early diving study, Knight-Jones & Jones (1955) and Jones (1955) recorded in detail the fauna and algae from three sublittoral stations, and described features of their zonation with depth at Bardsey.

Hiscock (1984) described 17 sublittoral habitat or community types for Bardsey and the adjacent part of the Lleyn Peninsula, of which he considered three to be of considerable conservation interest. Circalittoral 'tidal sound' communities were recorded from Bardsey Sound, on boulders and bedrock which were subject to strong tidal streams. These communities were dominated by species which are characteristic of such situations, including the hydroid *Tubularia indivisa*, the dead-man's fingers *Alcyonium digitatum*, and the anemones *Sagartia elegans* and *Actinothoë sphyrodeta*, but the habitat type is uncommon in southern Britain. The area also included particularly rich examples of communities characteristic of tide-swept pebbles and cobbles, which supported several species of rarely recorded algae. A cave at Pen-y-Cil was also considered to be of special interest. This cave was completely submerged for much of its length, extending through the headland. Near the eastern entrance, the walls of the cave were dominated by *Dendrodoa grossularia* and *Clathrina coriacea*. Further into the cave these species were less abundant, replaced by the anemones *Sagartia elegans* and dwarf *Metridium senile*, erect hydroids and bryozoans. Encrusting sponges and Didemnidae were dominant near to the base of the cave wall. The foraminiferan *Haliphysema tumanowiczi* was common in all of the cave wall communities. The cave floor was covered by clean, mobile boulders. Several notable species were also recorded. The alga *Cruoriopsis hauckii* was recorded at Porth Colmon. This species was also recorded from the Isles of Scilly during 1983, but the last British record prior to this was from Plymouth in 1896. The Mediterranean cup coral *Caryophyllia inornatus*, known from few locations in Britain, was recorded on boulders from one site at Bardsey.

10.3.4 Offshore level seabed

Exploratory oil drilling was carried out during November and December 1992, at a site some 9.5 km north of Braich y Pwll, the headland at the tip of the

Lleyn Peninsula. Prior to the commencement of drilling in this environmentally sensitive area, studies were conducted on the benthos and tidal streams at the proposed drilling location (Rees 1992; Elliott & Bowers 1992). Follow-up sampling was undertaken in May 1993 (Rees *et al.* 1993). The substratum in this area was composed of tide-swept cobbles and pebbles embedded in a sediment matrix, which was too hard to sample quantitatively using grabs, and, at 60 m, was beyond SCUBA diving depth. Consequently, acoustic methods were used to record variations in substratum, and the biota was surveyed using seabed photography, supplemented by dredge samples and a few successful grabs (Rees 1992). A 'Deep *Venus* (Hard) community' (*sensu* Mackie 1990 and Huckbody *et al.* 1992) was found in tide-swept areas including the drilling location, where the seabed contains appreciable quantities of pebbles and cobbles. Within the study area, the biota varied primarily in the densities of the brittlestar *Ophiothrix fragilis*, from dense beds to scattered individuals, and in the density of epifauna, which was impoverished in pebbly areas but was richer where the substratum contained appreciable numbers of larger cobbles and boulders. Epifauna species were predominantly encrusting Bryozoa, barnacles, tubeworms, hydroids, ascidians and sponges. A few notable species were also recorded including the urchin *Echinus elegans*, the hermit crab *Cestopagurus timidus*, the crab *Eurynome spinosa* and the 'southern' bryozoan *Plagioecia sarnensis*. The community recorded also had features in common with the tide-swept boulder/cobble communities recorded by Hiscock (1984).

Off the northern part of the Lleyn Peninsula the sediment communities have been little studied but some data is available for Caernarfon Bay (E.I.S. Rees pers. comm.). Benthic surveys of the southern Irish Sea by the National Museum of Wales also sampled from stations in Caernarfon Bay (Mackie 1990; Huckbody *et al.* 1992); the results of these surveys are yet to be published (Mackie, Oliver & Rees 1995).

10.4 Anglesey

10.4.1 Open coast areas for the whole island

Figure 10.5 shows the island of Anglesey and the mainland adjacent to the Menai Strait. Locations on the coast of Anglesey have been extensively studied by staff and students from the University College of North Wales, Bangor including work published in MSc and PhD theses not all of which are described here. A general account of the natural history and marine biology of Anglesey is contained in Jones (1990) which updates the earlier account of Jones (1968). For rocky shores, the Coastal Surveillance Unit conducted detailed studies over a period of nine years to examine the temporal variation within rocky littoral communities at a large number of sites on Anglesey, the adjacent mainland, and two sites on the Lleyn peninsula (Jones *et al.* 1983). Other publications which describe the rocky shore flora and fauna of Anglesey include Lewis (1953) and Davey (1953).

Studies of sublittoral hard substrata around Anglesey are comparatively few. Smith (1967) examined the effects of exposure to wave action on the sublittoral algal communities at three sites. Hiscock (1976) recorded the fauna of the rocky sublittoral of 32 sites around Anglesey using abundance scales. He identified characteristic populations from the west, north, and east coasts, and the Menai Strait. West coast populations were typified by dense bryozoan cover with polyclinid tunicates, the hydroid *Nemertesia antennina* and the crinoid *Antedon bifida* with the dead-man's fingers *Alcyonium digitatum*, the massive form of the sponge *Cliona celata* and the anemone *Actinothoë sphyrodeta*. On the north coast *Antedon bifida* and the brittlestar *Ophiothrix fragilis* were present in dense beds, with the sponges *Polymastia* spp. and *Suberites carnosus*. On the east coast *Alcyonium digitatum* and the anemone *Metridium senile* dominated. Many rock surfaces in this area were muddy, with tubes of the polychaete *Polydora*. The distribution of species was found to be related primarily to geographical location around Anglesey and water quality, and secondly to the degree of exposure to wave action and the strength of tidal streams.

Published information on intertidal sediment communities around Anglesey is limited and described for different parts of the coast below. The fauna of five beaches on Anglesey was described by Allen *et al.* (1983) in their study of the effects of sediment stability on beach fauna described above.

Information on offshore communities is scarce. The 'best estimate' of the distribution of offshore communities was given in Huckbody *et al.* (1992, derived from Mackie 1990). In the study published by Mackie, Oliver & Rees (1995), inshore areas of south-west Anglesey and off the east coast correspond to Group B4 (see description above) living in sand. Offshore of the west coast, Group C1 on muddy gravel continues from offshore areas of Cardigan Bay. Much of this paucity of information is due to the hard nature of the substrata to the north and west of Anglesey, which cannot be sampled effectively using grabs. Experimental studies of the effects of beam trawling undertaken about 15 km off the north-east coast of Anglesey (Kaiser & Spencer 1996) provide descriptions of the benthos on coarse muddy shell sand and more mobile muddy sands. Two different assemblages were present; one dominated by amphipods of the genus *Urothoe* and *Ampelisca* and the other by Spionidae, *Glycera* spp., *Aonides* spp., Terebellidae and *Moerella* spp.

10.4.2 West coast

Jones & Demetropoulos (1968) examined the effects of wave action on algal communities at Porth Trecastell, and a recent series of papers described the experimental

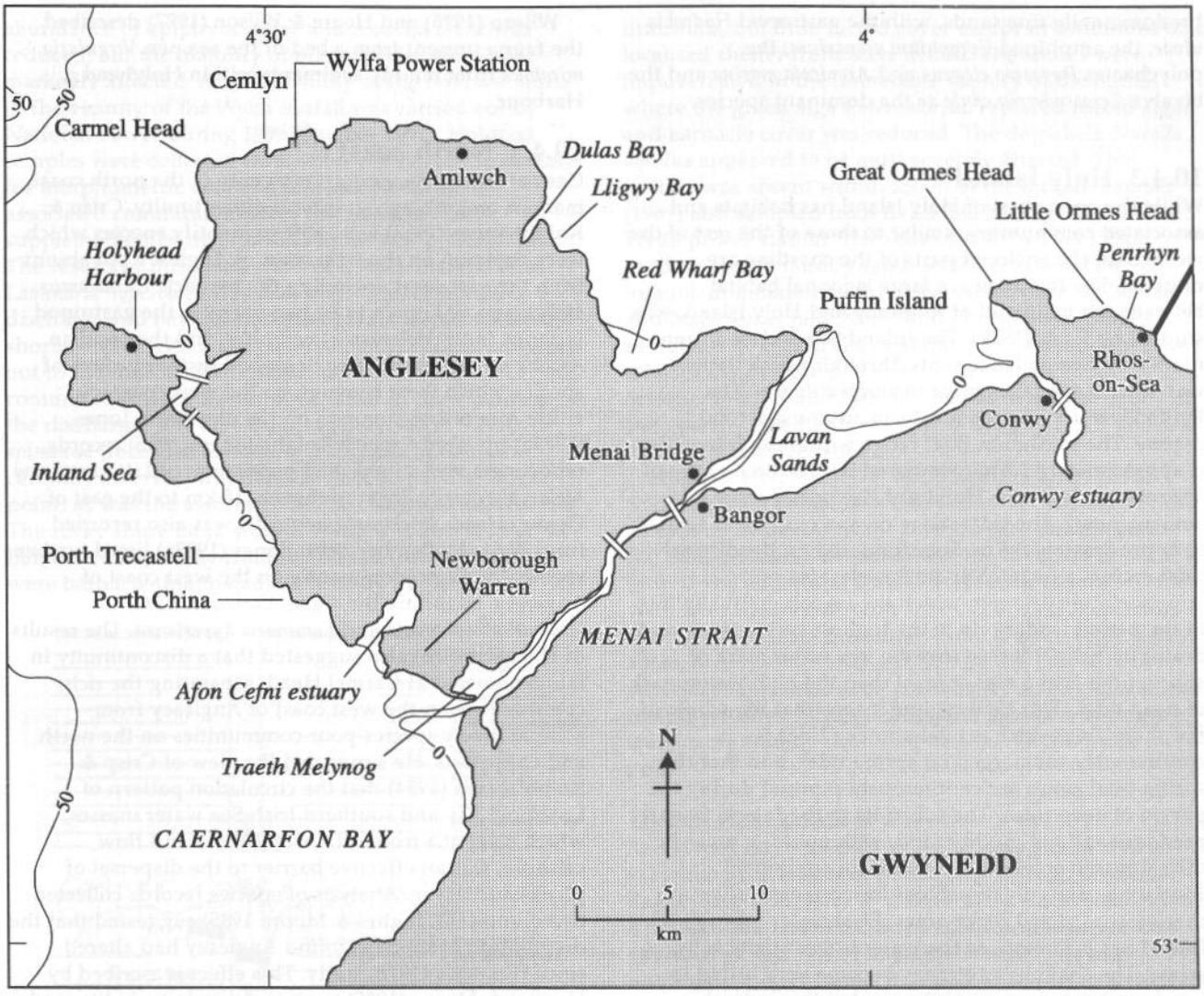

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Figure 10.5. Anglesey and the Menai Strait, showing places mentioned in the text.

manipulation of dogwhelk *Nucella lapillus* populations on wave-exposed and sheltered shores at Ynys Llanddwyn (Burrows & Hughes 1989, 1990, 1991; Hughes & Burrows 1990, 1991). Kensler (1965) and Kensler & Crisp (1965) recorded crevice fauna at Porth China. They described the tidal zonation of crevice-dwelling species, and the zonation within crevices and classified crevice fauna into permanent crevice-dwellers, temporary crevice-dwellers, and 'accidental' crevice-dwellers. He further sub-divided permanent crevice-dwelling species into obligatory and facultative inhabitants, and the temporary forms into juvenile forms of organisms which live elsewhere as adults, and foragers which used the crevices for feeding. Crevice-dwelling species were found to have a generally low resistance to desiccation. Permanent crevice-dwellers were more susceptible to desiccation than temporary crevice-dwellers.

Crisp & Mwaiseje (1989) examined the phytal animal associations living on the algae *Corallina officinalis* and *Cladophora rupestris* from Anglesey, Tremadoc Bay, the Menai Strait, and from two locations in south-west Ireland. The tubiculous polychaete *Spirorbis corallinae* was found encrusting the fronds of *Corallina*, often at very high densities. The polychaete *Hediste diversicolor*, the amphipod *Stenothoe monoculoides* and the bivalve *Musculus discors* were found exclusively on *Corallina*. The amphipod *Caprella linearis*, the gastropods *Rissoa parva*, *Rissoella opalina* and the ophiuroid *Amphipholis squamata* were more commonly recorded on *Corallina* than on *Cladophora*. The diversity of phytal organisms on *Cladophora* was poor in comparison to that from *Corallina*, and only the isopod *Idotea granulosa* and the amphipod *Amphithoe rubricata* were more abundant on *Cladophora*. Few spirorbids were found on *Cladophora*; these were mainly *Spirorbis pagenstecheri*. There were some geographical trends, the amphipods *Hyale* spp. were more common on the open coasts of Anglesey and south-west Ireland, whereas pycnogonids and *Caprella linearis* were more common in the tide-swept Menai Strait.

The Afon Cefni estuary was surveyed by Rees & Walker (1976a). Sediments within the estuary were

predominantly fine sands, with the gastropod *Hydrobia ulvae*, the amphipod *Corophium arenarium*, the polychaetes *Pygospio elegans* and *Arenicola marina* and the bivalve *Cerastoderma edule* as the dominant species.

10.4.3 Holy Island

While the open coast of Holy Island has habitats and associated communities similar to those of the rest of the west coast, the enclosed parts of the coastline are unusual. The Inland Sea, a large lagoonal habitat between the mainland of Anglesey and Holy Island, was studied by Jones (1978). The Inland Sea is closed from the sea by two embankments, through which limited water exchange takes place through culverts. The limited water exchange results in an unusual tidal regime. The maximum tidal range within the Inland Sea is approximately 1.2 m (compared with at tidal range of approximately 5 m in Holyhead Bay outside the embankment). The tidal range on any one tide is limited to approximately 0.6 m. Superimposed on the diurnal tidal cycle is a fortnightly tidal cycle, also of approximately 0.6 m, in which the lagoon gradually fills in the period leading up to the highest spring tides, and drains on neap tides, so that the low water mark of spring tides is at a higher level than the high water mark of neap tides. This tidal regime means that the whole of the shore area which is tidal on neap tides is continuously submerged on spring tides, and that the spring tidal zones are continuously exposed during the period of neap tides. The substrata in the Inland Sea are predominantly of muddy sand, with muddier areas in the saltmarsh creeks. Hard substrata are limited, consisting primarily of pebbles in sediments, although there are restricted rocky areas. Freshwater input to the Inland Sea is limited, so the water is essentially fully saline. The shallow water may become very turbid in windy weather. Jones (1978) recorded the vertical zonation of the fauna and flora on seven transects in the Inland Sea, covering a range of substratum types. He recorded a compressed intertidal zonation on hard substrata. The spring tidal range was characterised by littoral fringe communities, predominantly lichens, with the brown alga *Pelvetia canaliculata*, the gastropod *Littorina saxatilis* and the barnacles *Balanus balanoides* and *Elminius modestus* present above low water springs. The eulittoral and sublittoral fringe zones were compressed into the neap tidal range. The seagrass *Zostera nana* was present on intertidal sediment flats in the neap tidal range, while *Zostera marina* was only recorded below low water neaps. The infauna also showed a marked tidal zonation. The amphipod *Corophium* sp. and the polychaetes *Nereis* (now *Hediste*) *diversicolor* and *Scoloplos armiger* were present through much of the tidal range, but a high proportion of the species recorded, including the lugworm *Arenicola marina* and the bivalves *Mya arenaria* and *Cerastoderma edule*, were not found above high water neaps. A further group of species including the polychaetes *Ampharete grubei* and *Tharyx marioni* were found at or below the low water neap level. Further studies of the Inland Sea have been carried out prompted by proposals for an additional causeway (E.I.S. Rees pers. comm.).

Wilson (1975) and Hoare & Wilson (1977) described the fauna present from a bed of the sea pen *Virgularia mirabilis* from muddy sediments within Holyhead Harbour.

10.4.4 North coast

Carmel Head, the western extremity of the north coast, marks a major biogeographical discontinuity. Crisp & Knight-Jones (1955) were able to identify species which were common on the west coast of Anglesey but absent from the east coast, including the barnacle *Chthalamus stellatus* (now known to be two species), the gastropod *Littorina* (now *Melarhaphe*) *neritoides*, and the ascidian *Ascidia mentula*. They also described further groups of species which were common on the west coast and either rare or less common on the east coast. Jones (1983a) updated Crisp & Knight-Jones' (1955) records, reporting a well-established population of *Littorina* (now *Melaraphe*) *neritoides* at Amlwych, 15 km to the east of Carmel Head. (*Melaraphe neritoides* was also recorded from Wylfa by Bamber 1989). Jones (1983a) listed further species found predominantly on the west coast of Anglesey, including the algae *Alaria esculenta*, *Himanthalia elongata* and *Laminaria hyperborea*. The results of Hiscock (1976) also suggested that a discontinuity in fauna occurred at Carmel Head, separating the rich communities on the west coast of Anglesey from comparatively species-poor communities on the north and east coasts. He supported the view of Crisp & Knight-Jones (1954) that the circulation pattern of Liverpool Bay and southern Irish Sea water masses, which meet at a front off Carmel Head and flow offshore, was an effective barrier to the dispersal of planktonic larvae. Analysis of species records collected by volunteers (Hughes & Moore 1985) suggested that the distribution of species around Anglesey had altered since Hiscock's (1976) study. This effect is ascribed by Hughes & Moore (1985) to an increase in turbidity, and an increase in the extent of areas affected by Liverpool Bay water-masses.

The lagoon at Cemlyn is maintained by a weir which is only overtopped on spring tides. Sediments are predominantly muddy and salinity is very variable. Jones (1978) recorded a relatively low diversity biota including the polychaete *Nereis* (now *Hediste*) *diversicolor*, the amphipod *Corophium* sp., the gastropod *Hydrobia ulvae*, mysids and the green alga *Enteromorpha* sp. The seagrass *Ruppia* sp. was present in the Tyn Llan pool, which is separated from the main lagoon by a culvert. This lagoon was also surveyed by Barnes (1987) who considered it to be exceptional, one of the top five or six most important lagoonal sites in Britain. He recorded 21 invertebrate species, including three specialist lagoonal species, the gastropod *Hydrobia ventrosa*, the bryozoan *Conopeum seurati* and the hydroid *Laomedia loveni*. The spit enclosing the lagoon is also of geomorphological and maritime botanical interest.

Creak (1974) sampled the fauna from the holdfasts of the kelp *Laminaria hyperborea* from transects in the vicinity of a thermal effluent at Wylfa nuclear power station. His results showed that the ascidian *Sidnyum turbinatum* and the amphipod *Jassa falcata* were absent from the immediate vicinity of the outfall, and that the

abundance of epiphytic algae and *Antedon bifida* was reduced, but the majority of other species were not markedly affected. A further study of the holdfast fauna in the vicinity of the Wylfa outfall was carried out by National Power during 1989 (Bamber 1991). Holdfast samples were collected from within 400 m of the outfall, for morphometric analysis, and analysis of their associated communities. This information was supplemented by diver observations and photography. The results of this study showed a more marked effect. *Laminaria hyperborea* was absent within 100 m of the discharge and beyond this zone plants were smaller and shorter-lived, with an impoverished holdfast community out to 250 m from the outfall. Sublittoral bedrock communities were also impoverished in the vicinity of the discharge. The tube-building polychaete *Sabellaria spinulosa* [recorded as *Sabellaria alveolata* but almost certainly an error] was densest close to the discharge point, as was the associated species *Nicomanche personata*. The rocky shore biota around Wylfa was also studied by Bamber (1989). Away from the outfall the rocky shores were barnacle-dominated, with many limpets and littorinids, but little fucoid cover except in conditions of localised shelter from wave action. The shores were impoverished in the immediate vicinity of the outfall where the green alga *Enteromorpha* replaced fucoid algae and barnacle cover was reduced. The dogwhelk *Nucella lapillus* appeared to be most severely affected. This species was absent within 250 m of the outfall. Bamber (1989) also sampled from five small beaches near to the Wylfa power station. The sediment at two sites was predominantly muddy sand, which contained an infauna dominated by the polychaetes *Capitella capitata* and *Malacocerus fuliginosus*, and oligochaetes. Sandy sediments at a third site contained a less abundant fauna which included the polychaetes *Lanice conchilega*, *Scoloplos armiger* and *Spio martinensis*, while the fauna of the gravelly sediments present at the other two sites was extremely impoverished.

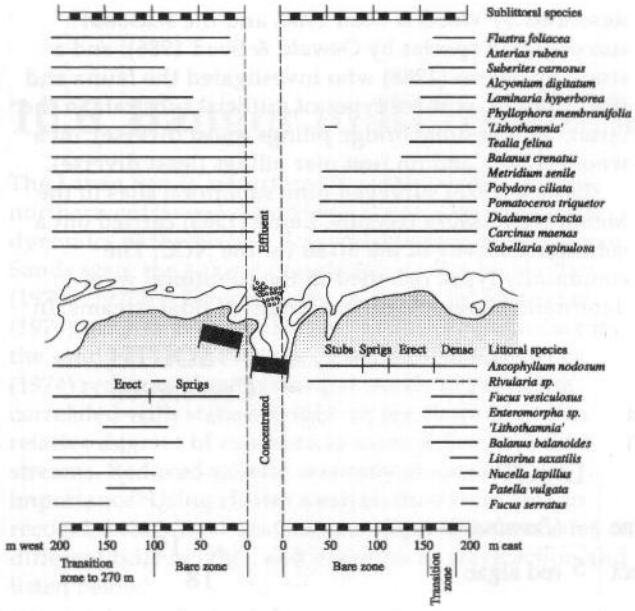

Figure 10.6. The distribution of conspicuous littoral and sublittoral species with distance away from the outfall from a bromine extraction plant at Porth Offereiad, near Amlwych, Anglesey in 1973. (Re-drawn from Hoare & Hiscock 1974.)

Hoare & Hiscock (1974) examined the effects of an acidic effluent containing free halogens discharged from a bromine extraction plant at Amlwych. The effects of the effluent works were marked; the diversity of both littoral and sublittoral species was much reduced in the vicinity of the outfall, with species richness increasing with distance from the outfall point (Figure 10.6). Red algae, the crinoid *Antedon bifida* and the limpet *Helicon pellucidum* appeared to be particularly sensitive, whereas the polychaetes *Polydora ciliata* and *Sabellaria spinulosa* were exceptionally abundant near to the discharge point.

10.4.5 East coast

Red Wharf Bay was used as a reference site in studies examining the effects of pollution at sites in Liverpool Bay (Hoare 1975; Rees & Walker 1983). Rees, Nicolaidou & Laskaridou (1977) recorded sublittoral invertebrates stranded at Red Wharf Bay after storms. The most numerous species found stranded were the bivalves *Abra alba*, *Spisula subtruncata*, *Mactra corallina*, the brittlestar *Ophiura texturata* and the dead-man's fingers *Alcyonium digitatum*. The communities in sublittoral sediments in Red Wharf Bay have been sampled extensively by UCNW and are described in an MSc thesis (Moore 1983).

Some of the earliest records of marine fauna from this area were collected during the period of activity of the Liverpool Marine Biological Committee field station on Puffin Island and were published by Harvey-Gibson, Knight & Coburn (1913) and Herdman (1920). Caves on the north of the island were considered to be of special interest.

10.5 Menai Strait

The Menai Strait (Figure 10.5) is a long channel in which the residual flow of water is from north-east to south-west and which includes extensive intertidal sediment or mixed substratum flats at both ends but a very narrow rocky channel in the middle. The Strait is used for navigation, and for sailing and other recreational activities. There are cockle fisheries, mussel fisheries and oyster cultivation. The Menai Strait, already a voluntary marine conservation area, was identified by the Nature Conservancy Council as a potential Marine Nature Reserve (MNR), and a consultation document was issued (NCC 1988). The boundary of the proposed MNR is shown in Figure 10.7. Although the majority of consultees were broadly in favour of the idea of a reserve, local opposition led to protracted negotiations to resolve objections to the plan, followed by the publication of a revised consultative document and management plan by the Countryside

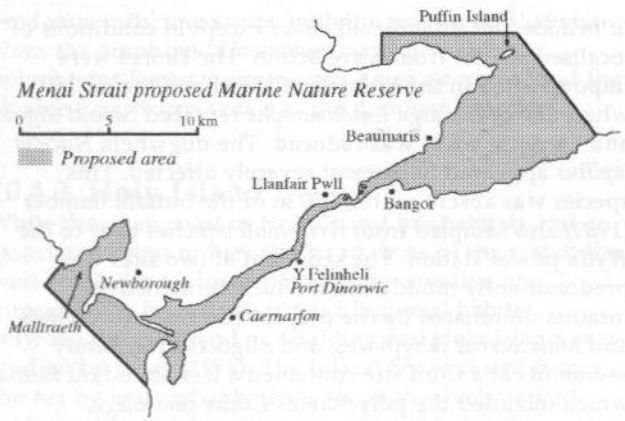

Figure 10.7. Menai Strait pMNR boundary (re-drawn from CCW 1992).

Council for Wales (CCW 1992). The proposed MNR boundary (Figure 10.7) encompasses the whole of the Menai Strait, and the waters and shores adjacent to its two mouths, including Traeth Lafan (Lavan Sands), the Cefni estuary, Traeth Melynog and the Foryd estuary. The MNR proposals led the then NCC to commission studies to describe the biological interest of the Strait (Jones 1983b, Lumb 1983) and of activities which might affect the conservation interest of the area (e.g. Oliver, Mackie & Trew 1986). A literature review of the Menai Strait, with an annotated bibliography of material held by the Wolfston Library (University College of North Wales, Bangor), was prepared by Young [1992].

A report detailing the biological interest of the littoral zone of the Menai Strait, based on past records and new survey work, was produced by Jones (1983b). He concluded that the region of the Strait between the bridges was of extremely high scientific interest, with the north-east end of the Strait to Puffin Island also worthy of inclusion into a marine nature reserve on ecological grounds. Oliver, Mackie & Trew (1986) produced detailed species lists for the Mollusca and Polychaeta at several littoral sites in the Straits. Bait-digging was assessed as a potentially damaging impact by Coates (1983) and Olive (1987, 1993). Olive (1993) found that the exploited population of the large bait-worm *Nereis* (now *Neanthes*) *virens* was present at low densities but that individuals were generally large and that only a relatively small proportion bred in one year. Since this species is semelparous (i.e. individuals breed only once in their lifetime), the low proportion of individuals in breeding condition suggested that individuals in this population are long-lived, and hence the population was very vulnerable to over-exploitation. Further studies in the littoral habitats within the Strait include a series of papers on the ecology of the epiphytic communities on the fucoid alga *Fucus serratus* (the communities recorded from these studies are described by Wood & Seed 1980, and the seasonal succession of species by Oswald & Seed 1986); and a study by Bavins (1988) who investigated the fauna and flora present on three types of artificial substrata in the Strait, on limestone bridge pilings (most diverse), on a wooden jetty, and on iron pier pilings (least diverse).

Hiscock (1976) surveyed nine sublittoral sites in the Menai Strait. More recently, Lumb (1983) carried out a sublittoral survey of the Strait for the NCC. The community types recorded in the sublittoral were determined largely by the strength of tidal streams. In

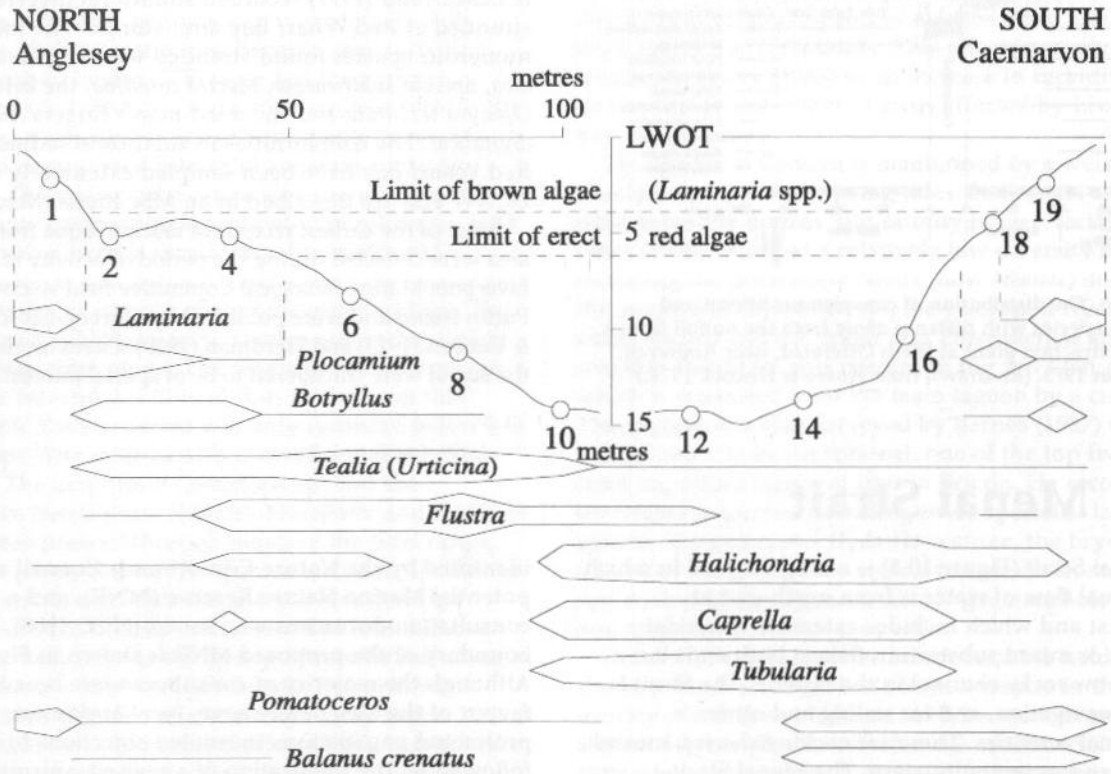

Figure 10.8. Section across the Menai Strait along the telegraph cable transect, showing the distribution of common plant and animal species with depth. (From Knight-Jones & Nelson-Smith 1977.)

areas with the highest tidal stream velocities, bedrock and boulders were dominated by the barnacle *Balanus crenatus* and a thin encrusting cover of the sponge *Halichondria panicea*. At slightly lower tidal stream velocities, *Halichondria panicea* and the hydroid *Tubularia indivisa* dominated the communities. In areas with moderate tidal streams, three principal assemblages of species were recognisable, characterised respectively by the bryozoan *Flustra foliacea*, the sponge *Haliclona oculata* and the anemone *Metridium senile* in conjunction with the dead-man's fingers *Alcyonium digitatum*. Within the Strait there were few areas sheltered from the effects of tidal streams.

A sublittoral transect following a telegraph cable across the central Strait, adjacent to the suspension bridge, has been the subject of several studies. The transect was first surveyed in 1957 (Knight-Jones, Jones & Lucas 1957; Knight-Jones & Nelson-Smith 1977: Figure 10.8) and has been resurveyed subsequently (Hoare & Peattie 1979). Other surveys on this transect have concentrated on the fauna associated with the sponge *Halichondria panicea* (Cooper 1976; Peattie & Hoare 1981). A second transect was subsequently established at Pwll Fanog (2.5 km west of the original transect) for comparative studies (Jones *et al.* 1981; Wood 1981).

The University College of North Wales have made routine measurements of water turbidity in the Menai Strait from the pier at Menai Bridge since 1961. From these measurements, and from other circumstantial evidence, it has been suggested that the Menai Strait has become more turbid in recent years by Lumb (1990). He used the turbidity data to calculate predicted critical light level depths for the kelp *Laminaria digitata* and for epilithic red foliose algae. These predicted depth limits were compared with the observed distribution of algae with depth on the telegraph cable transect, which was recorded annually from 1983 to 1988, during September of each year. The observed lower limit of the algae corresponded closely to the predicted levels, with a time-lag of one year.

At the southern entrance to the Menai Strait, surveys were carried out at Traeth Melynog (Rees & Walker 1976b). The fauna recorded was considered typical of a sheltered sand beach containing the cockle *Cerastoderma edule*, the amphipods *Bathyporeia pilosa* and *Corophium arenarium* and the polychaete *Scoloplos armiger*.

10.6 Bangor to Rhôs-on-Sea

The Lavan Sands are extensive sediment flats at the northern entrance to the Menai Strait. The population dynamics of the bivalve *Scrobicularia plana* on the Lavan Sands were the subject of detailed studies by Hughes (1970a, 1970b). The flats were surveyed by Eagle *et al.* (1974) prior to the construction of an oil pipeline across the sands. From the results of ordination, Eagle *et al.* (1974) recognised two principal trends in their data, correlated with station height on the shore and with relative degrees of exposure to wave action and tidal streams. Reduced salinity was only of localised importance. Using cluster analysis they were able to recognise six faunal associations characteristic of sites at different tidal heights, and exposure to wave action and listed below.

- 'Association A', dominated by the polychaetes *Heteromastus filiformis* and *Cirratulus* sp., the oligochaete *Peloscolex benedini* (now *Tubificoides benedii*), the amphipod *Corophium volutator* and unidentified nematodes, was recorded from sheltered muddy sites on Bangor Flats.
- 'Association B' was recorded from four upper shore muddy sites, and was dominated by the gastropod *Hydrobia ulvae*, the polychaetes *Pygospio elegans* and *Hediste diversicolor* with *Corophium arenarium*, *Peloscolex benedini* (now *Tubificoides benedii*) and *Scrobicularia plana*.
- 'Association C' was recorded from the remainder of the muddy sites, and contained a similar fauna, dominated by *Peloscolex benedini* (now *Tubificoides benedii*), *Corophium arenarium*, *Scrobicularia plana*, *Corophium volutator* and the bivalve *Macoma balthica*.
- 'Association D' was transitional between the upper shore, muddy sites and lower shore sandy sites, dominated by the polychaete *Scoloplos armiger*, *Cerastoderma edule* and *Arenicola marina* with *Corophium arenarium*, *Hydrobia ulvae* and the amphipod *Bathyporeia sarsi*.
- 'Association E', containing *Bathyporeia sarsi*, *Pygospio elegans* and *Scoloplos armiger*, was recorded from large areas of clean, fine sand.
- 'Association F' was recorded from all tidal levels on the shore, in coarser sediments on the more exposed, outer areas of the flats. This association was characterised by *Bathyporeia sarsi*, the polychaete *Nephtys cirrosa* and the bivalve *Angulus tenuis*.

The effects of the pipeline construction, and post-disturbance recolonisation, were subsequently described by Rees (1978). The pipe was laid in a trench dug by excavators. The spoil from the trenching was then used to bury the pipe. The trenching severely disturbed a narrow zone, but a zone some 50 m wide on each side of the pipeline was also disturbed by the passage of vehicles. The tracked vehicles damaged and exposed shallow-burrowing species such as the bivalves *Cerastoderma edule* and *Macoma balthica*, which were then preyed upon by birds. Deeper-dwelling species were apparently less affected; casts of the lugworm *Arenicola marina* and feeding-marks made by the bivalve *Scrobicularia plana* were both observed in the vehicle tracks. During the construction period, the disturbed zone was continually re-populated by mobile organisms, such as the gastropod *Hydrobia ulvae*. Post-disturbance recolonisation was rapid. Several species, including the

polychaetes *Arenicola marina, Eteone longa* and *Scoloplos armiger* were recruited preferentially to the disturbed area. However, the numbers of the relatively long-lived *Scrobicularia plana* were markedly depressed, without signs of obvious recruitment several years after the pipeline operations had been completed.

A more recent development which may have a deleterious impact on the fauna of the Traeth Lafan, has been the introduction of hydraulic dredging into the cockle fishery. NCC commissioned studies to assess the potential nature conservation implications of hydraulic cockle dredging. Moore (1990, 1991) carried out experimental dredging on the Lavan Sands and on the Blackshaw Flats in the Solway Firth. The fauna recorded from the experimental site on the Lavan Sands prior to dredging was similar to that recorded by Eagle *et al.* (1974), numerically dominated by the amphipod *Corophium arenarium*, with the bivalves *Macoma balthica* and *Cerastoderma edule*, and the polychaetes *Arenicola marina, Scoloplos armiger, Aricidea minuta* and *Pygospio elegans*. Immediately after dredging, the number of taxa recorded was reduced from 27 to 20, and the number of individuals of most species was reduced by more than half. Only *Pygospio elegans* appeared to be unaffected. However, recovery from the effects of dredging was rapid, and few differences between dredged and control sites were detectable one week after dredging. However, the results of this small-scale experimental dredging may not reflect the situation in extensively dredged areas, as the impacted areas could be speedily recolonised from unaffected populations which were present within metres of the dredge track.

To investigate the effects of the commercial fishery on the Lavan Sands, Moore (1991) subsequently carried out a second study comparing the fauna present in intensively dredged areas, and in a 'control' area which was subject to little or no dredging. Although the study was inconclusive, *Macoma balthica, Pygospio elegans* and the target species *Cerastoderma edule* were all significantly reduced in the study area. Moore (1991) also reported studies by the North Western and North Wales Sea Fisheries Committee, who reported severe erosion effects in areas on the Lavan Sands, where dredging pressure was intense.

The fauna and flora of the Conwy estuary were surveyed by MSc students of the University College of North Wales and the distribution patterns of benthic invertebrates described (Thorburn & Rees 1976). Heavy metals, derived from seepage of water through mine workings, were identified as a potential problem for oyster culture in the estuary (Elderfield, Thornton & Webb 1971).

The construction of the A55 Conwy tunnel involved major engineering works in the Conwy estuary. Biological, water quality and fisheries surveys were carried out in the estuary and in Conwy Bay under contract to the Welsh Office, but the data from these surveys is yet to be released (E.I.S. Rees pers. comm.). The estuary has also been proposed as a potential site for the construction of a tidal energy generating barrage, following a desk study comparing the tidal energy generating potential of small estuaries on the west coast of England and Wales (Binnie & Partners 1987). The desk study concluded that the Conwy estuary was one of the most likely sites for such a scheme. A more detailed feasibility study was subsequently carried out which concluded that the construction of the barrage was technically and economically feasible (Matthews 1988; TH Technology 1990).

Surprisingly, considering the terrestrial conservation interest of the area, there have been no published studies describing the marine biological interest of either Great Ormes Head or Little Ormes Head. The shore at Great Ormes Head was described briefly in Taylor & Parker (1993). Bedrock extends down into the subtidal and supports a standard moderately exposed rocky shore community with abundant mussels in places. Wilson (1977a, 1977b) described the shore at Penrhyn Bay. Particular features of interest were intertidal peat beds from which the boring bivalves *Barnea candida* and *Zirfaea crispata* were recorded, and rockpools on a limestone boulder in which the horse mussel *Modiolus modiolus* was found on repeat visits over a 50-year period. Wilson (1977b) also recorded the disappearance of the tube-building polychaete *Sabellaria alveolata* from the shore at Rhôs-on-Sea.

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