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 6: Eastern England (Bridlington to Folkestone) (MNCR Sector 6)*

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Synopsis

Most of the coastline of eastern England is sedimentary in nature and includes marine species characteristic of shallow North Sea habitats. Estuarine habitats are extensive and include those of The Wash and the several small and large estuaries in Suffolk and Essex and the Thames Estuary. This sector includes the greatest concentration and some of the best examples of shingle lagoons in Britain. Also, the chalk coasts include communities not found on other substrata and are best developed in the south-east at locations where coastal defences have not been built.

6.1 Introduction

This sector of the coast of England, Bridlington to Folkestone (Figures 6.1 and 6.2), contrasts with the adjacent north-east and south-east coasts, being predominantly sedimentary in nature. Furthermore, the coast is affected by many active coastal processes resulting in a changing coastline. For instance, estimates suggest that the coast south of Bridlington to the Humber is eroded by as much as 2 m per year (J. Pethick pers. comm.); farther south, in Suffolk, the estimated maximum rate of erosion at Southwold has been as high as 13.5 m per year (Sunamura 1992).

The only coastal outcrops of bedrock in eastern England are the greensand shores of Hunstanton and the chalk/flint shores of Norfolk and Kent. The chalk shores are an important and rare habitat within both the British Isles and north-west Europe. Their extent in Great Britain is shown in Figure 6.2.

This section of the coast occupies the southern bight of the North Sea, which characteristically has a shallow shelving seabed, mainly sedimentary in nature, and which is marked by very turbid water. Furthermore, the shallow depths of the southern North Sea and its proximity to the continent result in greater extremes of sea temperatures than are generally found elsewhere on the open coast of the British Isles. The low sea temperatures, around 5 °C in winter, generally high turbidity and lack of hard substrata are important factors which reduce the diversity of the fauna and flora in this region.

The nature of this generally low-lying sedimentary coastline has resulted in the formation of a number of saline coastal lagoons. A directory of saline lagoons and lagoon-like habitats (Smith & Laffoley 1992) considered 29 lagoonal and lagoon-like habitats worthy of conservation in England. Of those recommended for conservation, 12 of the lagoons and two of the lagoon-like habitats fall within the east coast area, predominantly in Suffolk.

The southern North Sea supports rich fishing grounds, which are served by the main fishing ports at Grimsby and Lowestoft, and are monitored by the Ministry of Agriculture, Fisheries and Food (MAFF), based at Lowestoft, and Eastern Sea Fisheries Committee. In addition there are inshore fisheries for crabs *Cancer pagurus* (MAFF 1967) and lobsters *Homarus gammarus* (Howard 1980) and the Thames estuary and Wash are among the most important fishing grounds in Britain for shrimp *Crangon crangon* (Mistakidis 1957;

* 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 Covey (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.

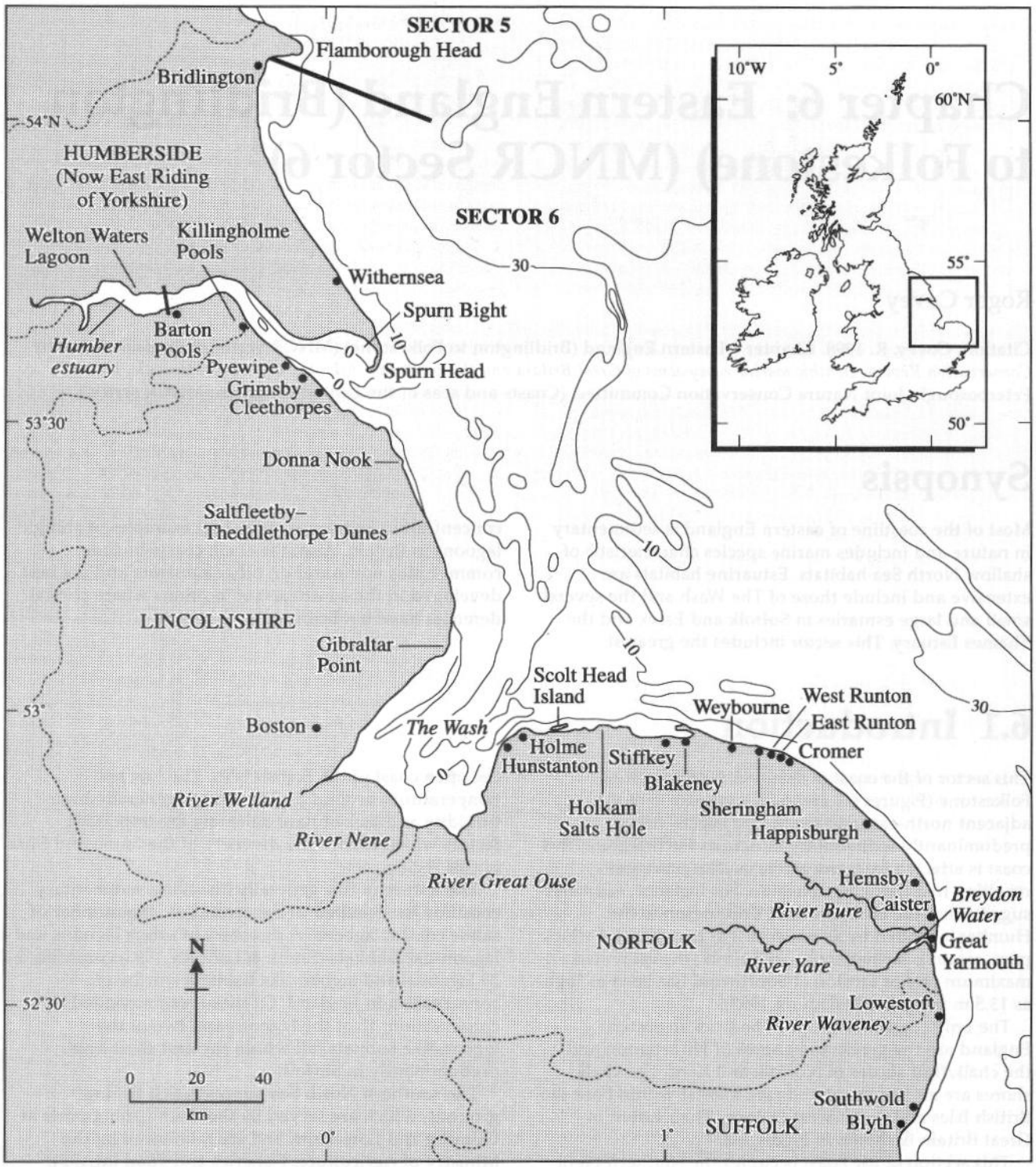

Figure 6.1. The northern part of MNCR Sector 6 showing the location of places mentioned in the text.

Warren 1973) and cockle *Cerastoderma edule* (Franklin 1972). The fisheries of the Wash were reviewed by Aldous (1987), who reported that the area accounted for 80–90% of UK shrimp, 70% of the UK mussel *Mytilus edulis* and 35% of the UK cockle landings. The Wash is also important as a nursery area for cod *Gadus morhua*, plaice *Pleuronectes platessa* and sole *Solea solea*. Many of the sedimentary shores in the area are extensively used for bait digging by both amateur fishermen and professional bait collectors. A review of the activities of

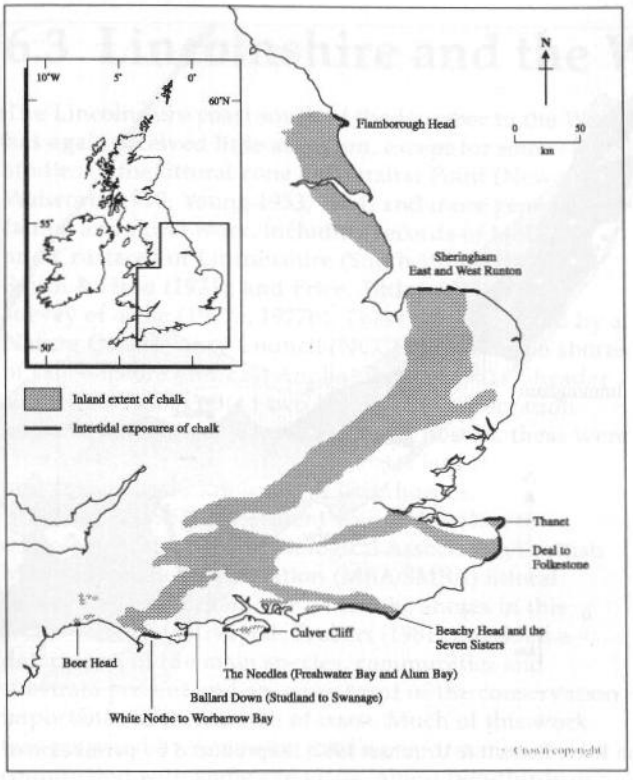

Figure 6.2. The distribution of coastal chalk exposures in Great Britain.

bait diggers, problems and solutions was provided by Fowler (1992).

The dense human population of the south-east of England has produced considerable pressures on much of the coast from industrial, domestic and recreational use. Many of the estuaries are occupied by large conurbations which place a heavy reliance on the estuary for the discharge of industrial and domestic effluent. Some of these estuaries are developed as ports. A review of threats to UK estuaries, focusing on many on the east coast, was given by Cadbury (1987). The open coast is also intensively developed in places with a number of recreational centres. Additionally, the high degree of coastal erosion in the region has led to considerable efforts to prevent further loss of land through extensive coastal defences with consequent modifications to the natural shoreline.

Ecological studies within the region have concentrated mainly on the estuaries and marine inlets where human pressures have necessitated a greater understanding of the environment. Work has been predominantly in the littoral zone; the sublittoral remains largely unknown except for isolated studies. Distributional reviews for algae (Norton 1985) and for Mollusca (Seaward 1990) include records for the area. Killeen (1994) provided an update on mollusc recording in the southern part of Sector 6. Offshore, much work has been carried out studying benthic communities in the southern North Sea. Work carried out in this area was reviewed by Mitchell (1987a) and more recently in the *Directory of the North Sea Coastal Margin* (Doody, Johnston & Smith 1993).

During 1992 and 1993 survey work by the MNCR focused on the estuaries between the Wash, and the Swale (Kent). Survey work in 1992 included the Orford Ness system, Deben estuary, Orwell and Stour estuaries, Hamford Water, and the Colne and Blackwater estuaries, and in 1993 the Swale, Medway, and north Norfolk.

6.2 Bridlington to the Humber estuary

The coast from Bridlington to the Humber estuary has been studied only poorly. Petch (1904, 1907) provided some early records of the littoral fauna at Withernsea and the surrounding area, while Philip (1936) described the seagrass *Zostera* and *Ruppia* communities at Spurn Head. More recently, Murray *et al.* (1980) gave details of seabed types off the mouth of the Humber in an assessment of sludge dumping in this area. The macrobenthos was typical of Jones' (1950) 'boreal offshore gravel association', and of the *Modiolus* epifauna in particular, with horse mussels *Modiolus modiolus*, brittlestars *Ophiothrix fragilis* and the bryozoan *Flustra foliacea* characterising the fauna.

The River Humber has the largest catchment area in Britain (20% of the land surface of England). Marine studies within the estuary have been co-ordinated through the Hull Advisory Group and Humber Estuary Committee, with work undertaken mainly by the University of Hull, and now encompassed by its Institute of Estuarine and Coastal Studies, and its Humber Observatory, and the Anglian, Severn-Trent and Yorkshire Regions of the Environment Agency (formerly the National Rivers Authority, and previously Anglian, Severn Trent and Yorkshire Water Authorities and Lincolnshire and Yorkshire River Authorities). This work has been highlighted in a number of symposia and reviews (for example Jones 1973; Jones & Boatman 1976; Natural Environment Research Council 1979; Gameson 1982; Edwards, Freestone & Urquhart 1987) which described the physical, chemical and biological nature of the estuary, and discussed industrial and other pressures on the Humber.

A biological survey of the Humber, reported by Hinton-Clifton (1964), provided details of the commoner species distributed along the southern shores. Subsequently, more detailed investigations were initiated by the Yorkshire and Lincolnshire River Authorities along both north and south banks (Jones 1973). The polychaete worm *Nereis* (now *Hediste*) *diversicolor*, the bivalve *Macoma balthica*, the amphipod *Corophium volutator* and oligochaetes were the most abundant and widespread species, and species diversity was found to increase from west (7 species/station) seawards to east (40 species/station). Littoral monitoring has continued on a regular basis since these early studies and was extended to include a larger number of

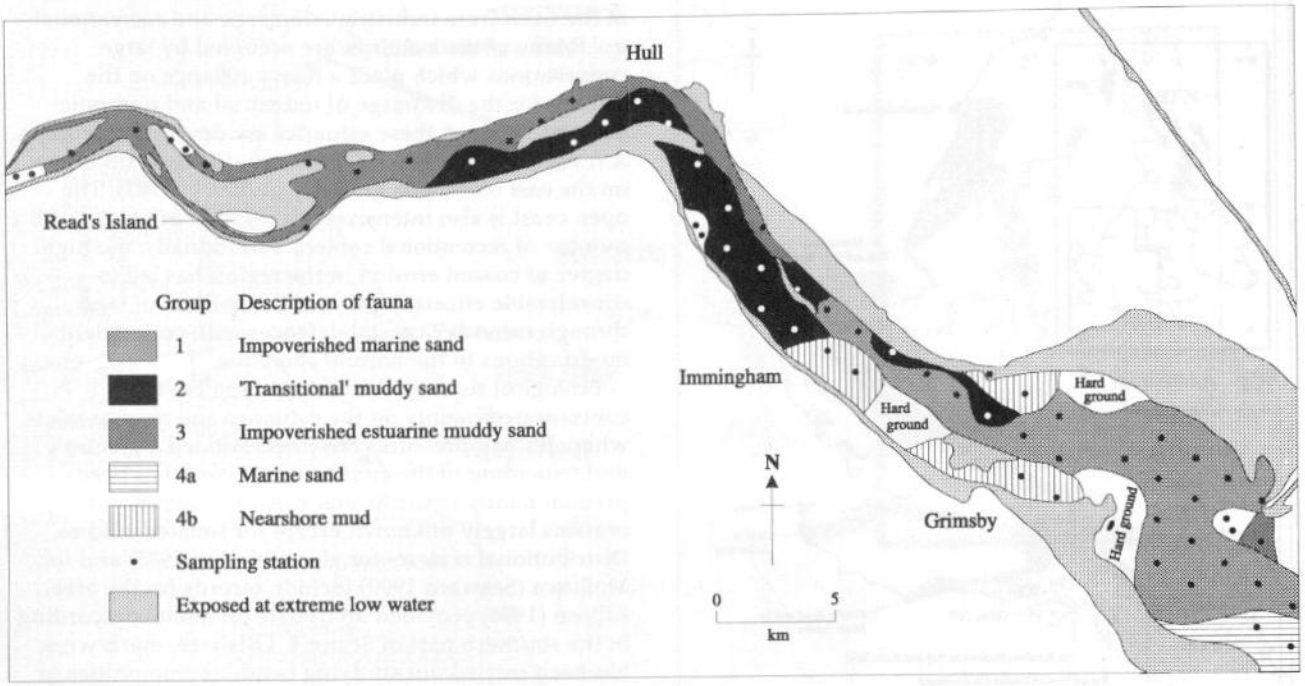

Figure 6.3. Faunal associations of the Humber estuary (re-drawn from Rees, Barnett & Urquhart 1982). Reproduced by permission of the Humber Estuary Committee.

stations in the tidal reaches of the tributaries to the Humber (Rees, Barnett & Urquhart 1982; Barnett 1984). A recent change in the biota of the estuary was the disappearance of *Corophium volutator* since Barnett reported in 1984 (A.J. Bates pers. comm.).

Little was known of the biology of the sublittoral zone of the Humber until the mid-1970s. The distribution of sediment types was described by the Natural Environment Research Council (1979). Yorkshire and Anglian Water Authorities began benthic surveys in the mid-1970s. A grid sampling programme at 70 sites undertaken at five-year intervals is supplemented by annual sampling along the length of the estuary (Anglian Water 1986a; Barr 1987; Edwards, Freestone & Urquhart 1987). Rees, Barnett & Urquhart (1982) described five main community types from these benthic surveys:

- Impoverished marine sand, influenced by tidal action and characterised by *Nephtys* spp., Mysidae, *Spio filicornis* and *Spiophanes bombyx*.
- 'Transitional' muddy sand, influenced by tidal current action, with *Capitella capitata*, *Polydora* sp., Mysidae, Gammaridae, and *Nephtys* spp.
- Impoverished estuarine muddy sand, influenced by tidal current action. Sparse fauna, distinguished from transitional muddy sand by the absence of polychaetes.
- Marine sand, containing a rich fauna in areas which were presumed to be less exposed than those of impoverished marine sand in the main channel. Characteristic species include *Spiophanes bombyx* and *Spio filicornis*.
- Nearshore mud, with a rich mud fauna including *Polydora* sp. and *Pygospio elegans*.

The distribution of these communities is shown in Figure 6.3.

Biological monitoring is used to assess water quality in the Humber, and the results are presented in the reports of the Humber Estuary Committee. In addition to regular monitoring, the water authorities have responded to major pollution incidents such as the oil spill from the *Sivand* in 1983, by monitoring their effect on the infauna (Yorkshire Water Authority 1983, 1984; Hemsley-Flint 1985). Another study (Newell *et al.* 1983; Newell, Newell & Trett 1984) concentrated on the effects of industrial effluent discharge in the vicinity of Pyewipe mudflats near Grimsby. The main bird feeding grounds on the lower shore of this area were shown to support a significantly richer infaunal community compared with surrounding sediments. Such communities attract large numbers of wildfowl, pink-footed geese and waders, for which the Humber is noted to be of conservation importance (Mitchell & Ungley 1979).

Other studies in the Humber include work on the fouling biota of navigation buoys (Hemsley-Flint 1976), a study of the ecology of the mudflats at Spurn Bight (Key 1983), algae on the southern shore (Price, Tittley & Honey 1977a, 1977b) and Sheader & Sheader's (1985, 1986) survey of coastal lagoons. The latter surveys suggested that two lagoons on the north shore (Welton Waters Central Lagoon), and three on the south shore (Barton Pool and Killingholme Pools), were of conservation interest.

6.3 Lincolnshire and the Wash

The Lincolnshire coast south of the Humber to the Wash has again received little attention, except for some studies of the littoral zone at Gibraltar Point (Newan & Walworth 1919; Young 1953, 1954) and more general faunal and floral work, including records of Mollusca and Crustacea of Lincolnshire (Smith 1919a, 1919b); Smith & Hind (1921); and Price, Tittley & Honey's survey of algae (1977a, 1977b). These were followed by a Nature Conservancy Council (NCC) review of the shores of Lincolnshire and East Anglia (Probert 1981). Sheader & Sheader (1986) noted two lagoons of conservation importance between Cleethorpes and Boston; these were Humberstone Fitties and Northcoates lagoons, approximately 10 km south of Cleethorpes.

Probert's (1981) assessment was undertaken to complement the Marine Biological Association/Scottish Marine Biological Association (MBA/SMBA) littoral survey of Great Britain, for which the shores in this sector were not surveyed. Probert (1981) provided a description of the main species, communities and substrata present and an assessment of the conservation importance of this stretch of coast. Much of this work was prepared by reviewing existing information, in conjunction with some site visits. About two-thirds of the coast of Lincolnshire is notified as a Site of Special Scientific Interest (Davies *et al.* 1990). Pyewipe and Cleethorpes coast is cited for its rich infaunal communities, saltmarsh vegetation and ornithological importance. The North Lincolnshire Coast and Saltfleetby to Theddlethorpe Dunes SSSI is of importance for its sand dune slack system, but has no cited marine interest. Gibraltar Point is cited for botanical, entomological, marine botanical (saltmarsh/sand dune) and ornithological interest; no mention is made of marine interest. The grey seal *Halichoerus grypus* colony at Donna Nook is unusual in that it is not associated with rock. The whole of the Wash is notified as an SSSI for its international ornithological importance in addition to its rich infaunal communities, important shellfish stocks and its importance as a nursery area for flatfish. It is also a Special Protection Area (SPA), a Ramsar site, and partly an Area of Outstanding Natural Beauty. The conservation strategy for the Wash was discussed by Schofield *et al.* (1992). A sustainable management strategy for the Wash is in preparation (Wash Estuary Strategy Group 1994).

An assessment of the ecological consequences of land-claim and a proposed water storage scheme in the Wash was given by the Natural Environment Research Council (NERC) (1969), and a response to such threats was given by the NCC (1976). Studies carried out as a result of the planned water storage scheme were reviewed by Mitchell (1987b). Ecological studies for the NERC assessment included surveys of the invertebrate and algal communities of the littoral zone, particularly in the context of a food resource for birds, and similar studies have continued (for example, Gray 1977, 1978; Jones (1975) (a study of food availability for turnstones); Goss-Custard & Jones (1976) (on the diets of redshank and curlew); Reading & McGrorty (1978) (on variations in the burying depths of the bivalve *Macoma balthica*); McGrorty & Reading (1984) (on the rate of infill and colonisation by invertebrates of borrow pits created during feasibility studies for the Wash reservoir). This latter study described the complete infilling of a 458,000 m^3 borrow pit by sedimentation over 3.5 years. Initially, poorly sorted unconsolidated anaerobic sediments accumulated, with up to 5 cm of liquid mud at the surface. This rapid infilling was thought to be the reason for the paucity of fauna in the pit until it was completely infilled. After two years, the predominant fraction was fine sand. Only the polychaete *Nephtys hombergii* became established before the pit was completely infilled, after which the other pre-excavation, dominant species returned (bivalves, the polychaete *Pygospio elegans* and the gastropod *Hydrobia ulvae*). The borrow pit after complete infill had higher densities of bird food species than before excavation, but was rarely visited by birds.

Studies of Wash birds and invertebrates were commissioned by the Department of the Environment and undertaken by the Institute of Terrestrial Ecology. The work arose out of a package of projects proposed by NCC to address the complex of questions on predicting the effects of proposed land-claim in the Wash. The project surveyed bird and invertebrate distributions. The west side of the Wash was surveyed in October 1985 and the south and east sides in October 1986. A total of 172 sites along 23 transects were sampled for invertebrate macrofauna species and 116 species were identified. The report (Goss-Custard *et al.* 1988) includes maps of the distribution and abundance of species known to be eaten by birds.

A conference in 1987 discussed the main environmental and ecological features and problems of the Wash (Doody & Barnett 1987). The imbalance in knowledge between the littoral and sublittoral zones of the Wash was partially redressed by Dipper (1983) and again in a more comprehensive survey by NCC in 1985 and 1986 (Fowler 1987). Dipper, Irving & Fowler (1989), in a later report of the 1985 and 1986 surveys, recorded five main community types within the Wash on predominantly sedimentary substrata. These were:

- a brittlestar *Ophiura albida* community on fine sand and silt, with dense *Ophiura albida* (up to 1,500 m^2) as well as the echinoderms *Ophiura texturata, Asterias rubens, Crossaster papposus, Psammechinus miliaris,* the anemone *Sagartia troglodytes,* the crustacea *Crangon crangon, Pandulus montagui* and the polychaete *Lanice conchilega;*
- a fanworm *Sabella pavonina* community, present at two sites, on fine sand overlying a sticky clay mud. *Sabella* tubes provided a substratum for thick growths of the hydroid *Obelia dichotoma* and the bryozoan *Flustra foliacea*. The anemone *Sagartia troglodytes* was abundant in the mud between the *Sabella* tubes;
- muddy sand with shell gravel and pebbles, which provided attachment points for hydroids, Bryozoa

(especially *Flustra*) and pieces of *Alcyonium digitatum*. Other prominent species included *Sagartia troglodytes*, *Lanice conchilega* and occasional *Ophiura albida*;

- sand, rippled with occasional empty shells and virtually no epifauna;
- soft mud, with common lugworm *Arenicola* casts.

Dipper, Irving & Fowler (1989) also noted the virtual absence of an infralittoral (algal-dominated) zone, owing to high turbidity.

The benthos of the Rivers Great Ouse and Nene were monitored over a two-year period for Anglian Water (Dyer & Grist 1986, 1987) and were found to be dominated by oligochaetes, including *Tubificoides diazi*, a species new to Britain. Although both the Great Ouse and Nene were tidal well inland it was found that salinity rapidly decreased with distance from the Wash, such that salt water intrusion did not take place upstream of Wisbech on the Nene, and Denver Sluice on the Great Ouse. The estuaries were shown to be divided into three main zones; the inner and middle sections having a low number of species and individuals, which increased in the outer section. The Rivers Welland and Witham are now also monitored by Anglian Water (M. Best pers. comm.). A major review of monitoring in the Wash, including a report of the NRA's 1991 subtidal benthic survey and a comprehensive bibliography, was produced by the National Rivers Authority Anglian Region (1994).

Reports on the Wash fisheries were given by Johnson (1970), Warren (1973) and Gould *et al.* (1986). Aldous (1987) reviewed fisheries in the Wash, and commented on the disappearance of oysters *Ostrea edulis* in the early part of the twentieth century.

Irving (1987) examined the lagoons between Boston Haven and the River Nene as part of NCC's survey of coastal lagoons. Two were considered worthy of further attention: Wyberton Marsh pond, on account of its range of fauna and flora which included the three-spined stickleback *Gasterosteus aculeatus*, the molluscs *Macoma balthica* and *Hydrobia ventrosa*, and the seagrass *Ruppia cirrhosa*; and Lawyer's Farm Pool due to the presence of the rare lagoonal amphipod *Gammarus insensibilis*. However, Barnes (1988), in an overview of the lagoons in Britain, did not rate the lagoons of this area as especially noteworthy in a national context.

Until the outbreak of phocine distemper virus in the late 1980s, the common seal *Phoca vitulina* population of the Wash was regarded as one of the largest and most dense concentrations of this species anywhere in the world (Thompson & Hiby 1990). Until 1973 there was an annual hunt of seal pups for their skins. Following the cessation of this hunt, the population in the Wash grew steadily at around 3.4% per annum until 1988. There was a sudden decline of around 50% between 1988 and 1989, undoubtedly as a result of the outbreak of phocine distemper virus (Thompson & Hiby 1990). Research on the diet of grey seal *Halichoerus grypus* populations around the Lincolnshire coast was reported by Prime & Hammond (1990). They found by counting otoliths in seal faeces that 56% of the diet was composed of sandeel species (Ammodytidae), cod *Gadus morhua* and sole *Solea solea*, with a further 22% accounted for by dab *Limanda limanda*, flounder *Platychthys flesus* and plaice *Pleuronectes platessa*.

Offshore between the Humber and North Norfolk are extensive areas exploited for aggregates. Studies of the environmental impact of gravel and sand extraction have provided considerable amounts of information on the fauna present but little is published. However, studies undertaken by MAFF (Kenny & Rees 1996) describe both undisturbed and dredged areas predominantly of fine sand with gravel sand approximately 40 km east of the Lincolnshire coast and 15 km north of the Norfolk coast. Communities there were characterised by epifaunal species living on or among the gravel (the sea squirt *Dendrodoa grosularia* and barnacle *Balanus crenatus* with lesser quantities of the worm *Sabellaria spinulosa*, the crab *Pisidia longicornis* and the slipper limpet *Crepidula fornicata*) and by a variety of amphipods and worms living in the sediment. Diver observations also revealed clumps of horse mussels *Modiolus modiolus*.

6.4 East Anglia

Much of the open coast of East Anglia had received little attention before Probert's (1981) overview of the shores, although many of the estuaries had been examined in some detail.

In the late 19th and early 20th centuries, there were several faunistic and floristic studies, with most attention paid to the algae, molluscs and fish. These included: algae (Batters 1894; Bloomfield 1908; Chapman 1937); Actiniaria (Collings 1938); Polychaeta (Morley 1941); Crustacea (Anon. 1934; Morley 1934); Mollusca (Anon. 1938); Bryozoa (Anon. 1937), and fish (Collings 1933). More recently Dr R. Hamond provided a detailed account of the marine fauna of Norfolk in a series of papers (e.g. Hamond 1957, 1963a, l963b, 1966, 1967, 1968a, 1968b, 1971a, 1971b, 1972, 1973a, 1973b; Hamond & Williams 1977). These mainly review the distribution of certain groups around the Norfolk and Suffolk coast, with additional notes on taxonomy. Hughes & Quinn (1983) and Quinn (1982) gave additions to the Suffolk fauna, and the algae of Essex were listed by Milligan (1965).

Much of Hamond's work was based on collections made at Blakeney, on the north Norfolk coast, in an area much used in recent years for field studies, and which is of high conservation interest. Previous work around Blakeney included early ecological studies on marine algae in saltmarshes (Baker 1912; Baker & Bohling 1916), further examination of algae (Cotton 1929), and of Crustacea (Hart 1930). The invertebrate fauna of nearby Scolt Head Island was reviewed by Serventy (1960), who

distinguished the fauna of the main channels from that on the littoral mudflats and in the marsh pools. Barnes *et al.* (1976) examined the meiofauna in the saltmarsh sediments around the island.

Frid (1988) and Frid & James (1989) also studied saltmarsh fauna at Stiffkey, north Norfolk, observing factors affecting spatial distribution of invertebrate fauna, whilst Cherrill & James (1985) examined a large number of saltmarsh habitats between Boston and Aldeburgh in their investigation of habitat preferences of mud snails (Hydrobiidae).

The importance of the north Norfolk coast between Holme and Weybourne for its range of sedimentary and coastal habitats in an ornithological context was recognised in its designation as a Ramsar and SPA site. Virtually the whole length of this coast is notified as an SSSI, with a chain of National and Local Nature Reserves, Norfolk Wildlife Trust reserves, RSPB reserves and National Trust properties.

To the east of Blakeney, mainly between Sheringham and West Runton, but also at East Runton and Cromer, lie isolated stretches of chalk bedrock that extend from the shore into the sublittoral. They represent the only appreciable area of natural hard substrata on the coast of East Anglia. The area was surveyed by the British Museum (Natural History) (George *et al.* 1988) as part of NCC's assessment of the chalk shores in England, following work by Anglian Water (AWA) (1986b), in which the conservation importance of this area was taken into account in the plans to site a sewage outfall between Cromer and Sheringham. Frid (1987) undertook a brief survey in the area using diving, and George & Platt (1988) surveyed the area for Anglian Water with particular reference to the crab fishery. Further work for Anglian Water Services relating to the commisioning of a new sewage outfall at West Runton was reported by George *et al.* (1992). Their report described the results of intertidal and subtidal monitoring at a number of sites to the east and west of the proposed pipeline location, over the years 1989, 1990 and 1991. Monitoring continues with most recent surveys in 1996 (J.D. George pers. comm.). The fluctuations in benthos present on shallow-water cobble habitats is described by George *et al.* (1995). That paper describes the presence of over 380 species of macroinvertebrates recorded from 14 sites dominated by polychaetes, with hydroids, pycnogonids, amphipods, decapods, bryozoans and ascidians well represented. This work showed that there was a substantial change in species composition, particularly of mobile epifauna and infauna, at the monitoring sites from year-to-year.

Anglian Water also studied the effect of the sewage outfall at Caister (Anglian Water 1984), with sublittoral benthic sampling between Hemsby and the mouth of the Yare before (Anglian Water 1984) and after (Anglian Water 1987) the outfall came into operation. They also carried out a comparative study off Lowestoft Harbour in 1986 around an existing outfall (G. Phillips pers. comm.). Early records in the Great Yarmouth district include Patterson's (1903) notes on Mollusca, and Gurney's (1907) records of lower Crustacea in the tidal reaches of the Rivers Bure, Yare and Waveney. The enclosed estuarine system of Breydon Water was the subject of a littoral survey by Anglian Water (Johnson 1988). Species diversity was found to be low, owing to the uniformity of habitat type, predominantly estuarine mud.

The open coast of Suffolk, and in particular the sublittoral zone, has attracted little attention except for benthic studies off Southwold and at Sizewell Power Station.

Bamber & Coughlan (1980) provided details of sublittoral communities in the vicinity of Sizewell Power Station, which were sampled by dredge and grab. Six communities were described, three of which were numerically dense and discrete, the others being sparse and possibly overlapping. A distribution map of these communities is given in Figure 6.4.

The communities described are listed below:

- *Nucula* community, in sandy muds. Dominant species were *Nucula turgida, Nephtys hombergii, Spiophanes bombyx, Mysella bidentata, Macoma balthica* and *Abra nitida.*
- *Polymnia* community, in muddy sands. Dominant species were *Polymnia* (= *Eupolymnia*) *nebulosa, Magelona papillicornis, Perioculoides longimanus, Nephtys* spp., and *Spiophanes bombyx.*
- *Phoronis* cf. *muelleri* community, on sand. The presence of *Phoronis* and hydroids gave the sand stability such that the other characterising species were epifaunal, including eight species of hydroids and bryozoans, five species of pycnogonid, predominantly *Nymphon brevirostre* and *Anoplodactylus petiolatus.*
- Amphipoda community, in coarse sediment. This was an indistinct community, though both the amphipod *Urothoe elegans* and the polychaete *Nerinides cantabra* were restricted to coarse inshore sediments to the south of the power station.
- *Scalibregma* community. This was an indistinct community of sandy inshore areas, having less than 70 individuals per m^2, dominated by *Scalibregma inflatum.*
- *Nephtys* community, species-poor on muddy sand and offshore areas. Dominated by *Nephtys hombergii.*

More recently, Bamber & Batten (1989) carried out benthic surveys offshore in the same area describing a seabed predominantly of coarse sand dominated by the polychaete *Spiophanes bombyx*, with other less widespread communities including an impoverished sandbank system dominated by haustoriid amphipods, and a bare coralline crag with a diverse *Phoronis* community. The littoral zone was described as azoic coarse gravel.

An assessment of the effects of dredging on the seabed (Millner, Dickson & Rolfe 1977) gave an indication of the main species and bottom types off Southwold in Suffolk. Other marine biological studies undertaken at Sizewell include records of fish (Turnpenny & Utting 1987) and shrimps (Whitehouse 1986), and a study of the saline lagoons of the area by Bamber (1989).

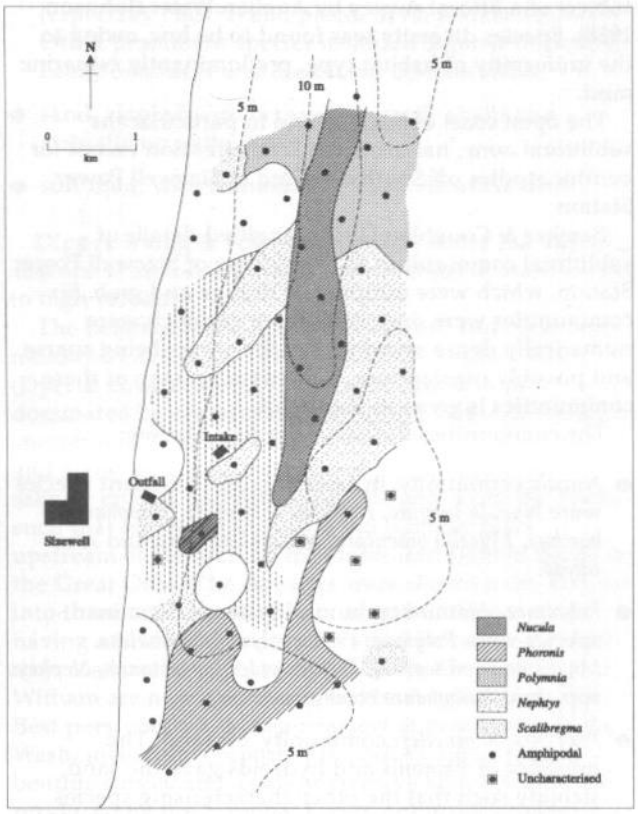

Figure 6.4. Macrofaunal communities in the vicinity of Sizewell Power Station. (Re-drawn from Bamber & Coughlan 1980.) (Reproduced by permission of National Power.)

South of Sizewell (Figure 6.5), the coast is indented by a series of estuaries, including the Thames, many of which have extensive mudflats and saltmarshes, and are of high ornithological interest. The littoral sediments on this stretch of coast were examined by Kay & Knights (1975) and by Boorman & Ranwell (1977), the latter in response to proposals for an airport at Maplin Sands. Kay & Knights (1975) identified four main community types, dominated by *Mytilus*, *Hydrobia ulvae*, *Cerastoderma edule*, or mixed fauna, with the *Mytilus* communities being the most rich and diverse. Boorman & Ranwell (1977) provided a map of the saltmarsh, reclaimed saltmarsh and littoral flats, and gave estimates for the areas of *Zostera* and *Enteromorpha* and for the quantity of macroinvertebrates available as a food resource for birds. Maplin is the largest area of continuous littoral flats on the British coast.

The estuaries have been the subject of a number of studies and reviews, and were included in an NCC review (Davidson *et al.* 1991). Suffolk Wildlife Trust carried out a review of the estuaries from the Blyth to the Stour (Beardall, Dryden & Holzer 1988). Information on human activities and pressures was given, together with an account of the geology, history and terrestrial natural history of each estuary. Limited information was given on their marine biology. As part of the National Rivers Authority Regional Estuaries Survey in 1990, intertidal benthic sampling was undertaken at 67 sites on 11 estuaries in Suffolk and Essex (Dyer, Grist & Smith 1991). This survey programme concentrated on comprehensive sampling in those estuaries which had previously been only sparsely surveyed, with fewer sampling sites in estuaries for which recent data was available.

The intertidal invertebrate fauna of the Orwell estuary was surveyed in 1986 (Beardall, Gooch & Pilcher 1990) to investigate changes since the survey by Kay & Knights (1975). Twenty-four transects were sampled up the estuary, from which 32 taxa were identified, consisting mainly of annelid worms, molluscs and arthropods. In comparison with Kay & Knight's (1975) study, Beardall, Gooch & Pilcher (1990) found the fauna to be dominated by annelids, rather than the molluscan domination noted in the 1975 study. A range of possible causes for the change were suggested, including increased effluent discharge from the Cliff Quay sewage works, hydrographic changes owing to the construction of Felixstowe Port's Trinity terminal, increased boat movements and size of vessels using Felixstowe and Ipswich ports, and the increased channel dredging to accommodate such vessels. It was also suggested that the use of tributyltin (TBT) antifouling paints may have affected mollusc populations more adversely than the annelids. With the cessation of the use of TBT paints on pleasure craft, future studies may reveal a reverse in the trend, and a return to mollusc-dominated communities.

Further survey work in the intertidal and subtidal zones of the Orwell estuary by the National Rivers Authority, Anglian Region, was reported by Baxter (1989). In common with Beardall, Gooch & Pilcher (1990), Baxter found the intertidal benthos of the estuary to be dominated by polychaetes and oligochaetes, with the exception of one site (Downham Reach) which was mollusc-dominated. Subtidally, 75 taxa were recorded, of which over half were polychaetes, with 16 species of crustacean and nine species of mollusc. Most of the variation in species richness in the subtidal sites was shown to be due to polychaetes.

The Orwell estuary joins the Stour estuary near its mouth, in the vicinity of Felixstowe and Harwich Ports. The Stour has been the subject of studies, both in its own right, and as part of joint studies of both the Stour and Orwell estuaries. Whitehead (1911) provided early dredging records from both the Stour and the Orwell Rivers. The mudflat infauna of the Stour estuary was the subject of a study by Bull, Honeyman & Knott (1960), and more recently was surveyed by Mann (1985), and Eastern Sea Fisheries Joint Committee (1990). The subtidal benthos of the Stour estuary was the subject of a survey by Anglian Water in 1989 (M. Johnson pers. comm.). Intertidal surveys by Anglian Water in the Stour show a similar change from mollusc- to annelid-dominated communities to that found in the Orwell. Infauna was characterised by annelids, with three polychaete species, *Eteone longa*, *Nereis* (now *Hediste*) *diversicolor*, and *Tharyx marioni*, occurring at over 50% of the survey sites. An intertidal rock platform, the Harwich Stone Band, is present at the entrance to the Stour. The sea-walls, breakwater, rock platform and associated boulder and other hard substratum surfaces provide a wide variety of habitats with associated rich variety of species for this coastline described by Tittley

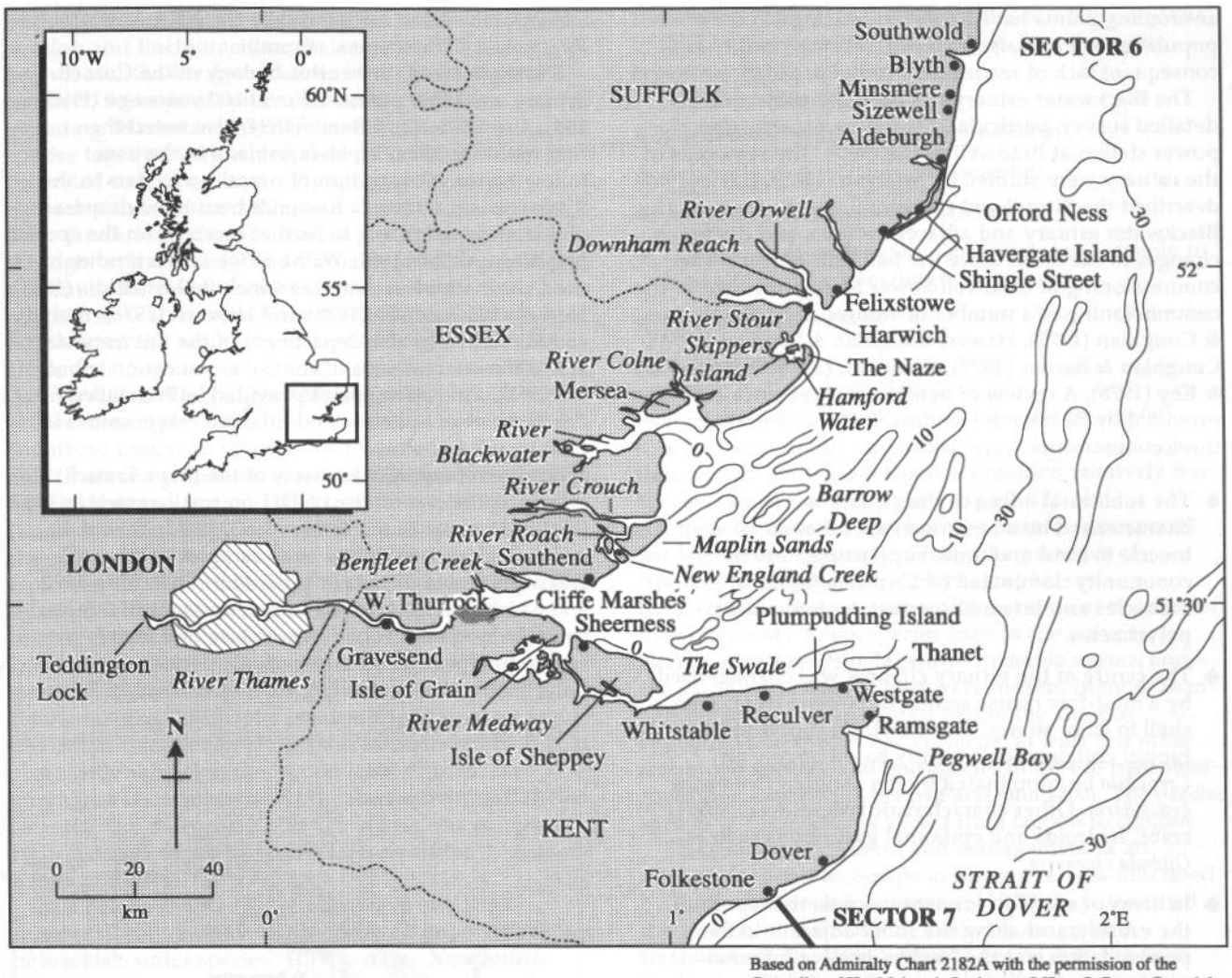

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Figure 6.5. The southern part of MNCR Sector 6 showing place names mentioned in the text.

(1982, 1986) and Tittley *et al.* (1989). The Stone Band was considered an interesting and important habitat by Tittley *et al.* (1989) since it represents the only hard natural rocky outcrop on the east coast between Kent and Norfolk available for colonisation.

South of the mouth of the Stour and Orwell estuaries is the convoluted coastline of Hamford Water, an enclosed estuarine system designated an SPA for its ornithological importance. Little data exists for the littoral biota of this area. The biology of Skippers Island near the Naze was discussed by Nisbet (1960), and further information was provided by Dyer, Grist & Smith (1991). Littoral and sublittoral surveys of Hamford Water were carried out in 1992 by the Marine Nature Conservation Review (Hill, Emblow & Northen 1996).

Many of the Essex estuaries have a long history of oyster cultivation, with numerous papers on their biology and the ecology of native and introduced pests. Mistakidis (1951) described the biota of areas with a history of mariculture in the rivers Crouch, Roach and Blackwater. Many areas of seabed in these estuaries were covered in a cultch of dead cockle shells, resulting in a changed substratum from the naturally occurring mud. At the time of the study (1951), the grounds were not intensively fished, and the fauna reflected this fact. The climax community on uncultivated grounds in the Crouch and Roach was dominated by the introduced species *Crepidula fornicata*, whereas on uncultivated grounds in the Blackwater, the climax community was dominated by *Crepidula fornicata* with the ascidians *Ascidiella aspersa* and *Ciona intestinalis*. On cultivated well-stocked grounds where *Crepidula* was present the equilibrium between this species and the oysters needed to be maintained by frequent dredging. A study by Hancock (1955) on the feeding behaviour of starfish on the Essex oyster beds found the starfish *Asterias rubens* to be associated with *Crepidula fornicata*. It was concluded that *Asterias* was not a serious predator of oysters as its preferred prey items were *Mytilus edulis*, *Crepidula fornicata* and even *Urosalpinx cinerea*, which were more serious threats to oyster cultivation. Gibbs, Spencer & Pascoe (1991) proved that tributyltin (TBT)

antifouling paints have had a devastating effect on populations of *Urosalpinx cinerea*, causing sterility and consequent lack of recruitment to the population.

The Blackwater estuary has been the subject of detailed survey, particularly since the construction of a power station at Bradwell in the 1960s. The seaweeds of the estuary were studied by Milligan (1965). Davis (1967) described the littoral and sublittoral marine fauna of the Blackwater estuary and adjacent waters, and discusses changes in the fauna since the late 19th century. The commissioning of Bradwell Power Station resulted in the commissioning of a number of studies, including Barnes & Coughlan (1972), Hawes, Coughlan & Spencer (1974), Coughlan & Barnes (1977), Coughlan (1978), Whitehouse & Key (1978). A review of benthic surveys since 1960 was provided by Bamber & Henderson (1981). In this review, three communities were described from the 1960 data:

- The sublittoral edges of the estuary were characterised by a heterogenous substrate of shell breccia in sand and mud, supporting a mixed community dominated by *Crepidula fornicata*, barnacles and infaunal species, predominantly polychaetes.
- The centre of the estuary channel was characterised by a mud-free coarse sediment ranging from clean shell to large stones. This substrate supported a typical epifaunal community based largely on *Crepidula* but dominated by the ascidian *Dendrodoa grossularia*. Other characteristic species were spider crabs, hydroids and epifaunal gastropods such as *Gibbula cineraria*.
- In areas of muddy sediment towards the mouth of the estuary, and along the shore adjacent to the power station was the *Nephtys*-bivalve infaunal community. The fauna was represented by typical infaunal species, mainly polychaetes (particularly *Nephtys* spp.) lamellibranch molluscs (*Abra alba* and *Macoma balthica*) and amphipods.

Bamber & Henderson (1981) followed the distribution of these communities using data from succeeding surveys (Figure 6.6). In 1965 the only change was a replacement of the *Nephtys*-bivalve infaunal community adjacent to the power station with the *Crepidula*-polychaete mixed community. By 1970 the infaunal community was no longer found in that area. The most likely cause of this change was thought to be a change in the sediment structure resulting from scour at the cooling-water outfall, though sediment instability had also been reported by Barnes & Coughlan (1972), and the habitat may have been under stress from fishing waste dumping subsequent to barrier wall construction. More recently, littoral survey work was carried out by Anglian Water (Harbott, King & Ripton 1985).

The River Colne which opens into the Blackwater estuary was first examined by Sorby (1897) and was included in some of the Bradwell surveys. Littoral survey work on the Colne and Blackwater estuaries was carried out by the Marine Nature Conservation Review in 1992 (Hill, Emblow & Northen 1996); sublittoral surveys have been carried out by the NRA Anglian Region (M. Johnson pers. comm.).

Descriptions of the benthic biology of the Crouch estuary were first published over 100 years ago (Fitch 1891; Crouch 1892). Crouch (1894) also noted the non-native species *Crepidula fornicata* in the area following the introduction of American oysters to the River Crouch. *Crepidula* has since become widespread and abundant, leading to further research on the species (e.g. Chipperfield 1951; Walne 1956). Other studies in the Crouch and Roach systems include Mistakidis (1951); Newell (1964); MAFF (1975) and Howard (1976). A study commissioned by the Department of the Environment to assess the effectiveness of control measures on tributyl tin (TBT) anti-fouling paint provided both detailed descriptions of epifauna and infaunal communities in the Crouch and showed evidence of increased benthic species diversity in the estuary of the River Crouch following the ban on use of TBT on small vessels in 1987 (Waldock, Matthiessen & Rees 1993; Waldock *et al.* in press; Rees *et al.* in press). Grab samples of infaunal species revealed 37 taxa in 1987, 46 in 1988, 55 in 1990 and 63 in 1991. Occurrence and abundance of infaunal species along the Crouch was determined mainly by sediment type. The most abundant species were the polychaetes *Nephtys hombergii, Scoloplos armiger, Tharyx*

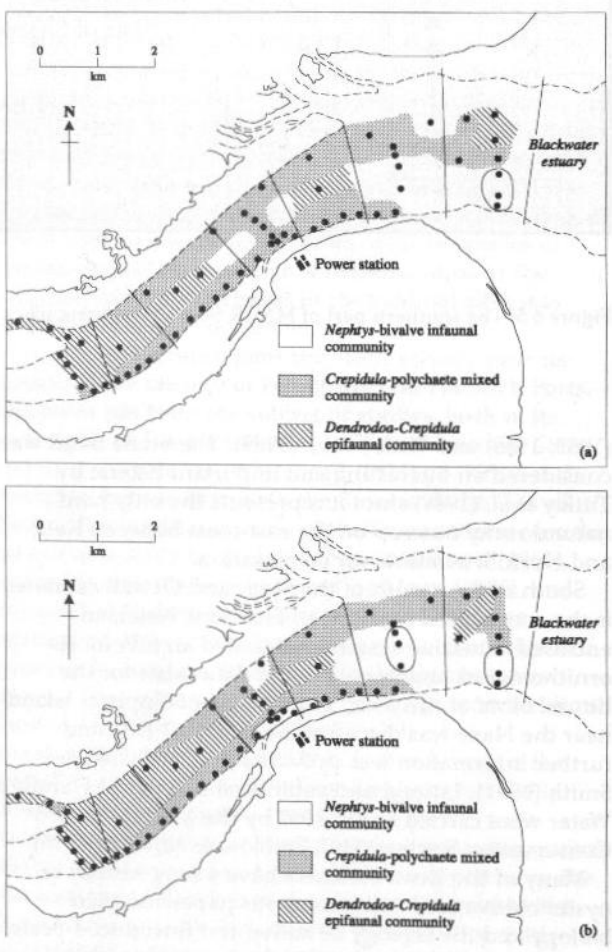

Figure 6.6. Benthic communities in the Blackwater estuary, 1970 (a) and 1960 (b). (Re-drawn from Bamber & Henderson 1981.) (Reproduced by permission of National Power.)

marioni, Cossura longocirrata, the oligochaetes *Tubificoides benedeni* and Enchytraeidae, the amphipod *Caprella linearis*, and the bivalves *Macoma balthica* and *Mysella bidentata*. Surveys of epibenthos sampled 69 taxa, including 18 crustaceans, nine molluscs and 20 fish species together with widespread occurrence of taxa not separated to species, especially sponges, hydroids, barnacles and ascidians. Numerically abundant species were the shrimps *Crangon crangon* and *Pandalus montagui* throughout the estuary and *Crepidula fornicata* especially present in the middle reaches. Other common and ubiquitous species were the armed bullhead *Agonus cataphractus*, the sand goby *Pomatoschistus minutus*, the shore crab *Carcinus maenas* and the common starfish *Asterias rubens*. The bullrout *Myoxocephalus scorpius* was present especially in the upper reaches. Ascidians were common in the middle and upper reaches of the estuary and *Dendrodoa grossularia* is specifically mentioned. Sandy shores were dominated in 1987 by oligochaetes (Enchytraeidae, *Tubificoides benedeni* and tubificids) and the polychaete *Tharyx marioni*, with *Neanthes diversicolor*. However, in 1988, numbers of Enchytraeidae, *Tubificoides benedeni* and tubificids had declined. Samples from muddy shores revealed fewer species than in sandy substrata with the most abundant being *Nereis diversicolor, Streblospio shrubsolii, Tharyx marioni*, Enchytraeidae, *Tubificoides benedeni, Hydrobia ulvae* and *Macoma balthica*. Rocky shores were dominated by fucoid algae with barnacles, the isopod *Jaera albifrons*, the amphipod *Hyale nilssoni* and the flat periwinkle *Littorina obtusata*. The periwinkle *Littorina littorea* was scarcely recorded and appears to have been significantly reduced in abundance by TBT.

East Anglia is noted for the presence of a large number of saline lagoons, which are an important refuge of brackish-water species. The anemone *Nematostella vectensis* and several rare brackish-water amphipods were included in the invertebrate Red Data Book (Bratton 1991). Williams (1973) drew attention to the rarity of anemones *Nematostella vectensis* and *Haliplanella lineata* and the vulnerability of their habitat. There are detailed studies of New England Creek (Howes 1939), Shingle Street (Barnes & Heath 1980), Holkham Salts Hole (Hunt 1971; Williams & Beale 1977), Havergate Island (Mason 1986) and a number of other lagoons (Williams 1972, 1976); several of them brought together in a description and classification of East Anglian lagoons by Barnes (1985) as part of NCC's review of this threatened habitat. In this review the surviving lagoons of East Anglia were classified into six physiographic types:

- pits located within shingle formations;
- depressions in reclaimed saltmarshes;
- ponded back streams or small rivers;
- shallow pools with a clay substratum immediately to landwards of barrier shingle ridges;
- former estuaries; and
- relict systems.

Four macroalgal, nine angiosperm and 44 animal species were recorded from the lagoons of East Anglia, though each individual lagoon contained relatively few species (mean number eight; range 2–17). No correlations were evident between numbers of species per lagoon and lagoonal salinity, the presence of fringing macrophytes, the physiographic or hydrographic characteristics of the system or the area of the water body. Some species such as the polychaete *Hediste diversicolor*, the lugworm *Arenicola marina*, and the amphipod *Idotea chelipes* were present in more than half the lagoons, and at least half of the lagoons contained one species of *Corophium*, at least one other amphipod species, and one species of mysid, hydrobiid gastropod, burrowing bivalve and small fish. The precise species in these groups varied from lagoon to lagoon.

The process of creation and management of an artificial lagoon, the Scrape at Minsmere, was described by Burgess, Hirons & Sorensen (1992). They described the process of maintaining a salinity range from freshwater in the West Scrape to brackish in the East Scrape and Southern Pools, and the management required to keep the system in ideal condition for breeding waterbirds. Results showed that invertebrate densities reach a peak around two to five years after creation of a lagoon, when nutrient levels are higher and aquatic predators are not yet established. After five years, numbers decline, with a consequent effect on bird densities. It is suggested that to manage the system for maximum waterfowl densities it may be necessary to drain artificial lagoons on a three- to five-year rotation, possibly even allowing a period for vegetation to recolonise, before re-flooding.

6.5 Thames and Medway estuaries

The Thames estuary has suffered severe pollution from industrial and domestic effluent since the 19th century, resulting in a peak around the 1950s when large stretches of the Thames were completely deoxygenated (Gameson & Wheeler 1977). A major effort to restore the Thames has resulted in the return of fish to these once depleted stretches (Wheeler 1969; Gameson & Wheeler 1977). Thames Water initiated some qualitative survey work to help monitor improvements in the estuary and to assess the effect of sewage sludge dumping in the Barrow Deep area (Cockburn 1976) where benthic monitoring has continued (M. Andrews pers. comm.). Talbot *et al.* (1982) reported on the effects of the latter; improvements in the macrofauna of the estuary were discussed by Andrews & Rickard (1980) and Andrews *et al.* (1982). Fish stocks continue to be monitored at the intake screens at West Thurrock power station (D. Rickard pers. comm.) and this site provided data to test

the effect of increased discharge following a sewage workers' strike on the fauna of the area (Sedgwick & Arthur 1976). Thames Water undertook benthic surveys at 15 sites out to Southend in 1989 (D. Tinsley pers. comm.). Since the division of Thames Water Authority in 1989, the NRA Thames Region instigated the Thames Estuary Benthic Programme. This entailed sampling 28 littoral and sublittoral sites from Teddington Weir, the limit of tidal influence, out to Sea Reach No. 2 Buoy, in the mouth of the Thames south of Shoeburyness. Samples were taken quarterly, using cores, kick samples or Day grab (Attrill *et al.* 1996). A conference, *Thames estuary, environment and ecology*, in 1992 formed the basis of a conference volume (Atrill & Trett in prep.).

The work reported by Attrill *et al.* (1996) identifies a "biodiversity hot-spot" situated off Canvey Island where over 200 invertebrate species from a sample area of 4.4 m^2 taken over the years 1989–92 were recorded. Biomass was also high. Species present were predominantly Nematoda, Crustacea, Polychaeta and Mollusca. Those macrofauna species with highest abundance which may represent a typical high diversity estuarine fauna were (of those which could be enumerated) the sea anemone *Sagartia troglodytes*, the polychaete worms *Sabella pavonina*, *Capitellides giardi* and *Sabellaria spinulosa*, the amphipod *Caprella linearis* and the bivalve *Petricola pholadiformis*. Additionally, species which could not be enumerated but which were present included hydroids (for instance, *Sertularia cupressina*), barnacles (for instance, *Balanus improvisus*) and Bryozoa (for instance, *Electra pilosa*).

Clarke, Bayes & Durdin (1991) reviewed the threats facing the greater Thames estuary, including the Colne and Blackwater estuaries and the Medway and Swale estuaries. They described the piecemeal destruction of intertidal habitats due to reclamation, and highlighted a number of current case studies.

Tittley & Price (1977a) and Tittley (1985a) described the algae of the Thames. Tittley & Price (1977b) divided the tidal Thames into four sections; marine, estuarine, brackish, and tidal freshwater. Within these divisions, they described the algal communities present on river walls, on mussel, shingle and shell banks (occurring only in the marine section), on floating structures, and saltmarshes. Each of these habitats had a distinct assemblage of algae, with green algae characterising the upper reaches, and brown algae only occurring on hard substrata in the estuarine and marine sections. The distribution of seagrass *Zostera* in the outer Thames was described by Wyer, Boorman & Waters (1977).

South Benfleet Creek on the north bank of the Thames was described by Gee (1961) with particular reference to the distribution of *Corophium volutator* and *Corophium arenarium*. The ornithological interest of the littoral sand and mudflats was discussed in Nall's (1976) conservation assessment of the outer Thames.

The Rivers Medway and Swale discharge into the outer Thames estuary with important wetlands at the mouth of the Medway and a National Nature Reserve in the Swale area, together with other nature reserves. Detailed studies of the littoral and sublittoral fauna of the Medway include those of Arnott & Skinner (1977); Levell (1973); Wharfe (1977a, 1977b) and Wildish (1970). Clarke & Tittley (1980) carried out a botanical survey of the Swale National Nature Reserve and include a list of algae of the area. Baker (1974) provided data on the biology of the sea walls in the Medway, while Millner (1980), Dines & Wharfe (1985) and Wharfe, Dines & Bird (1986) considered the problems of paper mill waste discharge in the area. The existence of Kingsnorth power station on the Medway has also led to some benthic studies (e.g. Langford 1983; Bamber & Spencer 1984; Bamber 1985). The Swale and outer Medway were the subject of an MNCR survey in 1993.

Lagoons in north Kent between Gravesend and Whitstable were surveyed by Sheader & Sheader (1988). None of the eight lagoon systems was natural in origin, falling into three categories: dammed sea inlets/creeks, old drainage dykes behind sea walls, and flooded clay/gravel pits. Lagoons at Minster and Cliffe Marshes were both large, species-rich sites, supporting typical lagoonal species. The rare lagoonal amphipod *Gammarus insensibilis* was recorded at Sheerness, its only recent record from the Thames estuary. A further survey of the flooded clay-pits at Cliffe (Sheader & Sheader 1993) found that the northern lagoons had a higher salinity, a relatively rich and diverse biota, and greater conservation importance, than the southern lagoons at this site.

6.6 Whitstable to Folkestone

To the east of the Swale, collections made at Whitstable, where the University of London ran a field station, led to the production of faunal lists for the area (for example Newell 1954; El Maghraby & Perkins 1955; Gibbs 1965), and to other studies (such as Chapman & Newell 1949). The area was formerly noted for its oyster *Ostrea edulis* fishery, for which Sheail (1986) gave an account of its history and demise. Plumpudding Island Lagoon near Reculver was noted for its diverse lagoonal fauna and flora and was recommended for protection by Sheader & Sheader (1987). Rocky shores at Whitstable were described by Tittley *et al.* (1989). These included sea walls, pilings, mussel beds and hard Eocene clay reefs at extreme low water level.

The remaining part of the Kent coast from Whitstable to Folkestone was included in a conservation assessment by Arnott *et al.* (1978). This broad-scale survey concentrated on major features of the coast and littoral habitats. The report recognised Pegwell Bay and the Long Rock at Whitstable as having shores of interest. However, this stretch of the coast is most noted for its chalk cliffs, for which the first description of the algal flora was given by Anand (1937), following detailed studies at Westgate and farther west at Beachy Head.

Table 6.1. Chalk shore algal communities identified by Anand (1937).

Belt	Exposed cliff surface	Tunnels	Caves	Embankments
Endoderma	45 cm-high belt at upper limit of spray zone. Dominant plant was *Endoderma perforans*, now described by Tittley (1985b) as *Pseudendoclonium submarinum*	Belt as described for exposed cliff surface over the roofs of tunnels.	As for tunnels.	Combined into *Pleurocarpa-Endoderma* belt.
Chrysophyceae	Divided into five community types: (i) *Chrysotila stipitata* (ii) Chrysophyceae – *Endoderma – Lyngbya* (iii) *Schizothrix fritschii* (iv) *Calothrix* (v) *Rivularia atra*	Divided into two community types: (i) *Ectocarpus* (ii) *Pilinia maritima*	Divided into two community types: (i) Chrysophyceae – *Endoderma – Lyngbya* (ii) *Gloeothece* – Chrysophyceae – *Ectocarpus*	
Enteromorpha	Band 70 cm high, just above high water mark.	One community: (i) *Pseudulvella applanata*	Divided into two community types: (i) *Ectocarpus – Holmesii* (ii) *Phormidium ambiguum*	Slightly greater height than on open faces due to increased spray from wave action.
Fucus	Divided into seven community types: (i) *Fucus* (ii) *Enteromorpha intestinalis* (iii) *Rhizoclonium – Vaucheria* (v) Chalk-boring algae (vi) *Ralfsia verrucosa* (vii) *Gelidium – Polysiphonia*	Divided into two community types: (i) *Polysiphonia – Ulva* (ii) Chalk-boring algae	Divided into four community types: (i) *Fucus* (ii) *Rhizoclonium – Vaucheria* (iii) Chalk-boring algae (iv) *Gelidium pusillum* Three communities are also described here from the back of caves, which do not fit into the four main belts: (i) *Rhodochorton rothii* (ii) *Lyngbya – Phormidium* (iii) *Chroococcus calcicola*	Divided into two community types: (i) *Cladophora rupestris* (ii) *Pleurocapsa – Plectonema – Calothrix*

Anand recognised four clear belts: on exposed cliff surfaces, in tunnels, in caves and on embankments; namely those of *Fucus*, *Enteromorpha*, Chrysophyceae and *Endoderma* (= *Epicladia perforans*, now recognised by Tittley (1985b) as being a form of *Pseudendoclonium submarinum*, a species known from caves). These belts were further split into separate communities, as summarised in Table 6.1

The algae of Kent have since been examined on a wider scale by Tittley and Price (e.g. Price & Tittley 1972; Tittley & Price 1977a, 1978; Tittley, Fletcher & Price 1985) and concern over the conservation of these chalk habitats and their associated algal communities has been raised (Tittley 1985c), and subsequently recognised in the notification of SSSIs and in public inquiries where coastal defence works have been proposed (Fowler & Tittley 1993).

The chalk coasts of Thanet have been recognised as being distinct from any others in Britain. Fowler & Tittley (1993) in a review of the nature conservation importance of British coastal chalk habitats, considered Thanet of international importance as "the best example of chalk cliffs and algal communities in Britain and perhaps Europe, and additionally important as the type locality for the genus and species described by Anand (1937) and the site of this pioneering work on chalk cliff ecology".

Development proposals at Ramsgate Harbour necessitated environmental studies in Pegwell Bay by Bennett (1985) and Environmental Resources Limited (1986). Habitat loss with particular threat to the algal communities on the chalk cliffs was emphasised by these studies. The impact of hovercraft in the bay was assessed by McGrorty *et al.* (1976).

The chalk cliffs between Dover and Folkestone were the subject of further detailed survey, following plans for the construction of the Channel Tunnel (Institute of Offshore Engineering 1985; Tittley *et al.* 1986; Fincham & George 1986; Fincham *et al.* 1987; George & Fincham 1989). The effect of spoil dumping from the excavation of the Channel Tunnel raised concern, especially at some of the richest sites such as Shakespeare Cliff and Copt Point which are within a notified SSSI. The macro-invertebrate communities of chalk shores described by George & Fincham (1989) included 194 taxa and were characterised by the presence of boring species such as piddocks and the polychaete *Polydora ciliata*. The sublittoral zone in the region of the Tunnel is also of

conservation importance, owing to the limited areas of sublittoral chalk in Britain and the relative richness of communities in this area (Wood & Wood 1986). Sublittoral exposures of chalk and greensand bedrock and boulders were described as supporting a rich biota (Wood & Wood 1986). Shallower upward-facing surfaces were colonised by the kelps *Laminaria digitata* and *Laminaria saccharina*, with some filamentous and foliose red algae. However, in some cases, outcrops were dominated by silty mats of the spionid worm *Polydora* sp. Deeper areas, farther offshore where current action was stronger, were dominated by the sponge *Halichondria panicea*, with a range of bryozoan and hydroid species forming a low turf. A silted mat of the ascidian *Molgula manhattensis*, covering many horizontal surfaces was noted at many locations. Monitoring sites have been established in both the littoral and sublittoral zones to continue assessment of the effects of the Channel Tunnel construction (Wood 1987, 1989a, 1989b, 1991). The biota of non-chalk shores in the region of Folkestone was described by Tittley *et al.* (1989). Copt Point appears to be a rich site with communities present which do not occur on nearby chalk shores.

6.7 Acknowledgements

Many people contributed their time in drawing attention to published data and by discussing ongoing and unpublished studies. Special acknowledgement is due to the following for their contribution to this chapter of the present volume or the MNCR Occasional report (Covey 1991) which preceded it: M. Andrews, A.J. Bates, Dr M. Best, Dr S. Bolt, Dr M. Elliott, Dr R. Hamond, M. Johnson, Professor J. Pethick, G. Phillips, Dr H. Rees, D. Rickard, D. Tinsley.

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Chapter 7: Eastern Channel (Folkestone to Durlston Head) (MNCR Sector 7)*

Roger Covey

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Synopsis

The coastline of the eastern English Channel is predominantly of rock or shingle. Extensive intertidal chalk platforms occur to the east of the coastal sector dominated by algae or scoured by mobile flints and other substrata. The lower parts of these shores and adjacent subtidal areas are colonised by species boring into the rocks especially the worm *Polydora ciliata*, piddocks and phoronid worms. Algae extend to a few metres below low water level below which rocks are colonised by sponges, erect bryozoans and ascidians. Intertidal sediments are rare and sublittoral sediment communities are poorly recorded on this part of the coastline. Extensive areas of pebbles and cobbles occur in tide-swept areas off the coast often consolidated by the tube-building worm *Sabellaria spinulosa* and the ascidian *Dendrodoa grossularia* and providing a substratum for a wide variety of epifauna species. To the west of Selsey Bill, the Solent system, which includes the Southampton Water and several smaller estuaries that feed into it as well as extensive shallow harbours of Langstone, Chichester and Portsmouth, has a wide range of estuarine habitats. Several lagoons also occur along this coastline including ones harbouring rare species. The Solent area has been colonised by a large number of non-native species which constitute a significant proportion of the communities present in some areas. West of the Solent, Christchurch Harbour has a restricted range of brackish communities while Poole Harbour has extensive sediment flats colonised by high biomass but low diversity communities with tidal channels colonised by extensive peacock worm *Sabella pavonina* colonies with associated species.

7.1 Introduction

The coast from Folkestone to Durlston Head (Figure 7.1) includes the transition between the east coast, with its relatively restricted diversity of habitats and species, to the more diverse south-west coast flora and fauna, with the Solent area separating the eastern and western parts of the English Channel. This is an open stretch of coast, largely uninterrupted with the exception of the major estuary of Southampton Water in the Solent system and the important natural harbours of Chichester, Langstone, Portsmouth and Poole, plus a small number of lesser inlets. There are many saline lagoons and ponds along this stretch of coast. Extensive sedimentary coastlines occur, in contrast with the predominantly rocky nature of the coast farther west, and there is a generally shallow sloping seabed. Much of the coast is densely urban, with considerable lengths of the shore modified by coastal defences.

Marked biogeographic changes occur between the eastern and western ends of the English Channel, illustrated from large-scale surveys of common shore species (Crisp & Southward 1958) (for instance, Figure 7.3) and of benthic communities (Holme 1961, 1966; Cabioch *et al.* 1977) (see Part 1, Figures 22 and 23). Changes in physical conditions along the Channel, most notably temperature and substratum, give rise to a boundary in the Solent/Isle of Wight area where many littoral and sublittoral species with a southern distribution reach their eastern limit. Tittley & Price

* 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 Covey (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.

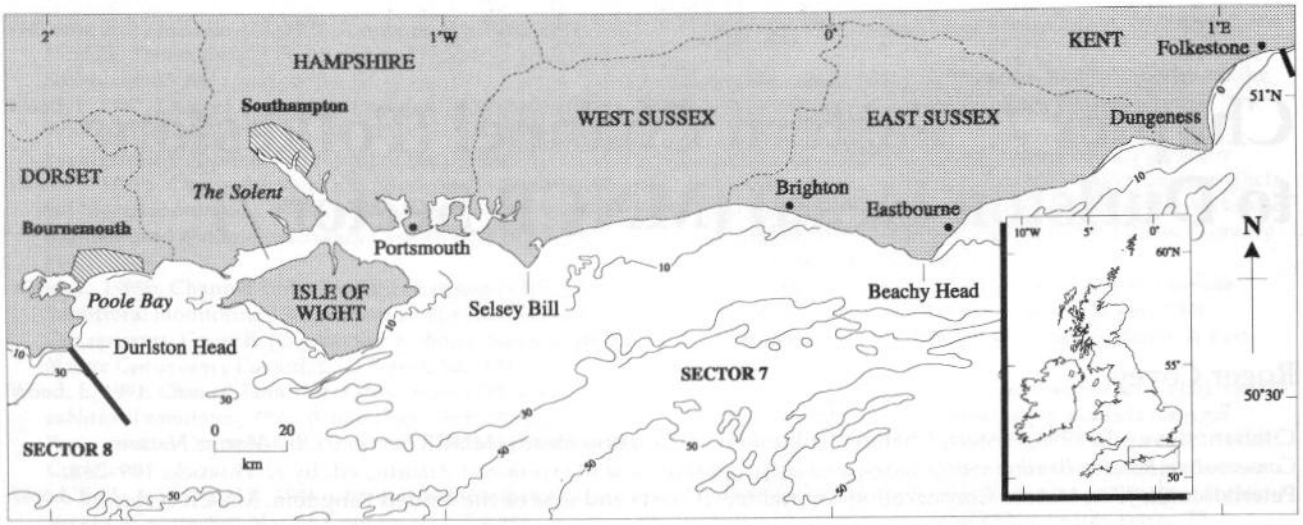

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Figure 7.1. MNCR Sector 7.

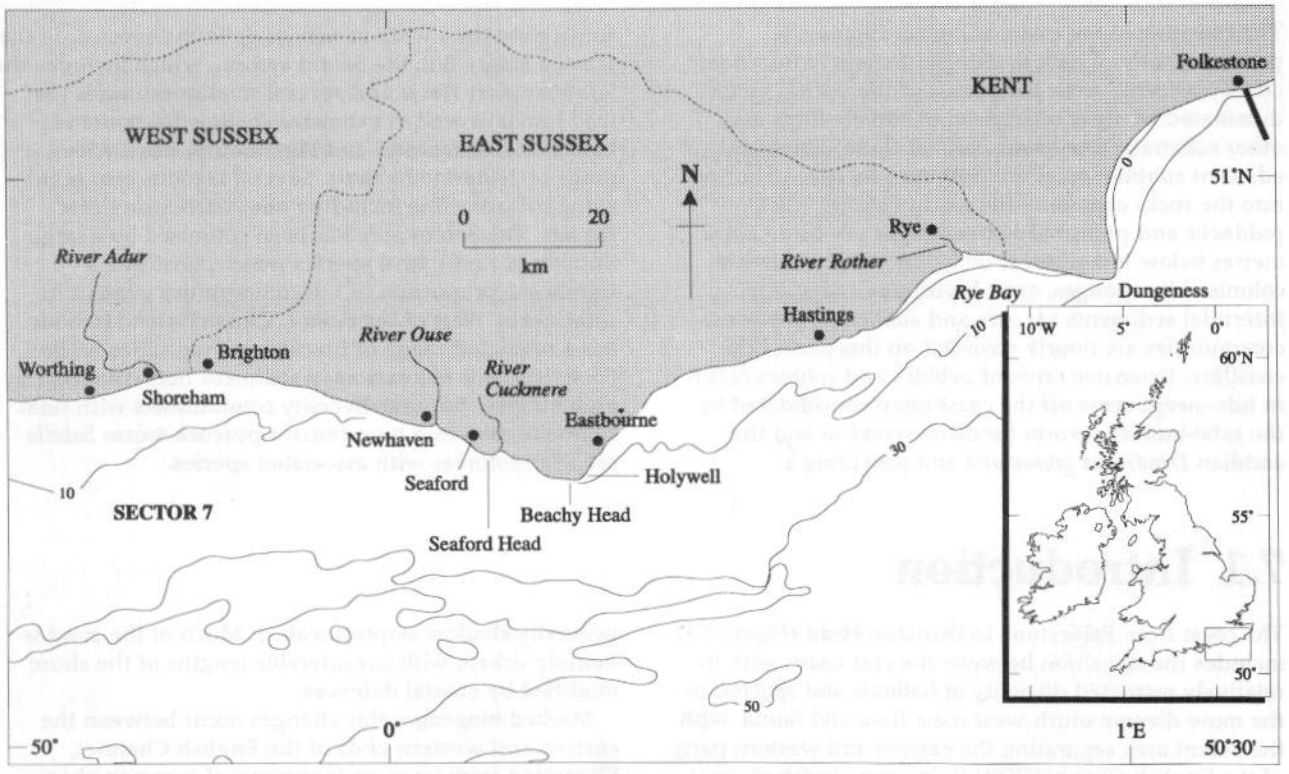

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Figure 7.2. The eastern Channel (eastern part), showing the location of places mentioned in the text.

(1978) discussed algal distribution on the French and English coasts of the eastern end of the Channel and found a similar biogeographic boundary, but suggested an area of change rather than the sharp discontinuity described by Crisp & Southward (1958). Tittley & Price's (1978) area extended from Cherbourg and the Isle of Wight in the west to South Foreland and Cap Gris-Nez in the east. The most notable differences between the floras of the English and French coasts occurred in the lower littoral and infralittoral fringe, where certain species of southern warmer water affinity were more frequent and luxuriant on the French side.

Some studies include descriptions of locations along this coastal sector. For example, Tittley *et al.* (1986) described the communities of chalk and greensand shores and Tittley *et al.* (1989) the communities of non-chalk rocky shores in south-eastern England, Light (1990) produced a provisional atlas of marine Mollusca

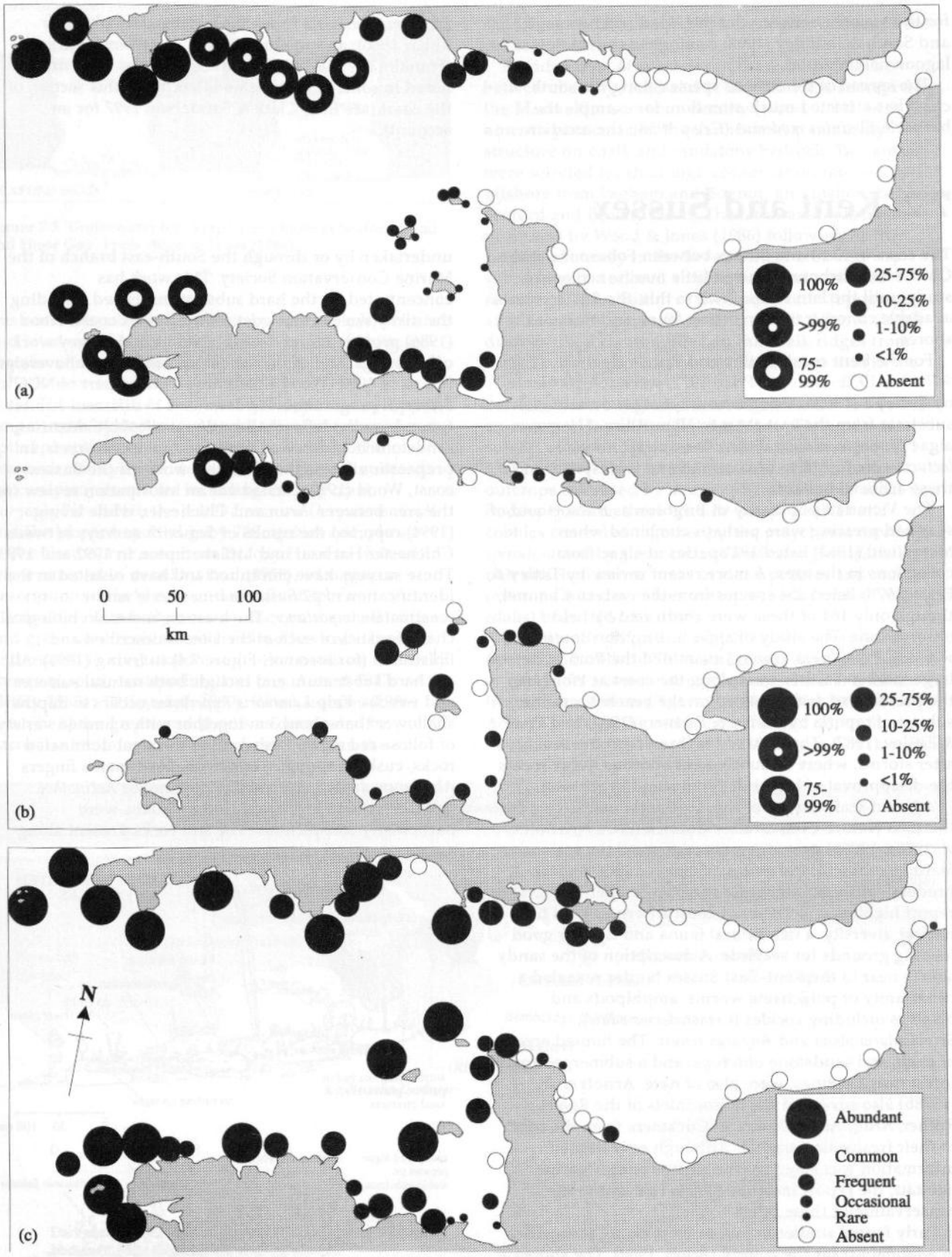

Figure 7.3. The distribution of some rocky shore species along the English Channel coast across Sectors 7 and 8. (a) confined exclusively to the western part of the Channel (*Chthamalus stellatus* [now known to be two species] shown as a percentage of populations of *Chthamalus* and *Balanus* [now *Semibalanus*] *balanoides*); (b) common in the west and rare in the east (*Hemioniscus balani*, shown as percentage infection of *Balanus* [now *Semibalanus*] *balanoides*); (c) present in the eastern basin on the French side of the Channel only (*Littorina* [now *Melarhaphe*] *neritoides*). From Crisp & Southward (1958).

for the sea area between Beachy Head and Swanage, and Smith & Laffoley (1992) catalogued the saline lagoon habitats.

The spread of introduced species along the south coast has attracted much attention, for example the barnacle *Elminius modestus* (Crisp 1958); the ascidian *Styela mammiculata* (now *Styela clava*) (Houghton & Millar 1960); and the brown alga *Sargassum muticum* (Franklin 1979). Many introduced species were first noted in some of the marine inlets along this section of the coast (see Eno, Clark & Sanderson 1997 for an account).

7.2 Kent and Sussex

The coast of Kent and Sussex between Folkestone and Chichester Harbour attracted little marine ecological study until the late 1970s. Prior to this, the few accounts available concentrated on listing fauna and flora of the shores.

For the Kent coast, Tittley and Price's algal lists (Price & Tittley 1972; Tittley & Price 1977) were complemented by Tittley's (1985a, 1986) account of algae on artificial substrata from the east coast to Hampshire. The green algae *Blidingia minima*, *Enteromorpha* spp. and *Ulva lactuca* were found to be common and widespread in these artificial habitats.

The Victorian popularity of Brighton as a resort and of seaweed pressing were perhaps combined when Merryfield (1863) listed 192 species of algae from collections in the area. A more recent review by Tittley & Price (1978) listed 254 species from the eastern Channel, though only 154 of these were confirmed by field observations. The study of algae at Brighton continues, where J. Price (pers. comm.) examined the flora in its large marina. Farther west along the coast at Worthing, the presence of drift seaweed on the beaches was the subject of reports by Binnie & Partners (1987) and Price & Tittley (1987). The seaweed is thrown on the beach after storms, where its subsequent odorous decay meets the disapproval of local inhabitants and beach users.

A broad-scale survey of the Kent and Sussex coast for the then Nature Conservancy Council (NCC) (Arnott *et al.* 1978a, 1978b) provides a description of the main features of the littoral and maritime habitats on this predominantly uninterrupted stretch of open coast. The report highlights stretches of coast where there is high habitat diversity, a rich littoral fauna and flora or good feeding grounds for seabirds. A description of the sandy shores near to the Kent–East Sussex border revealed a community of polychaete worms, amphipods and bivalves including cockles (*Cerastoderma edule*), *Scrobicularia plana* and *Angulus tenuis*. The limited areas of chalk and sandstone outcrops, and a submerged fossil forest near Hastings, were also of note. Arnott *et al.* (1978b) also surveyed the minor inlets of the Rivers Rother, Arun, Adur, Ouse and Cuckmere from the coast to their freshwater reaches. Although only limited information was given for the marine and estuarine habitats, the report includes details relevant to the conservation of these inlets.

Early faunal studies in Sussex were brought together in a faunal list for the county (Anon. 1960). The shores at Hastings were examined by Ticehurst (1961), Booth (1966) and Tittley *et al.* (1989), while Ventham (1990, 1992) produced detailed lists of the shore fauna at Brighton. A great deal of observational work has been undertaken by or through the South-east branch of the Marine Conservation Society. This work has concentrated on the hard substratum seabed including the many wrecks that exist off the Sussex coast. Wood (1986) provided brief details of sublittoral survey work off Hastings; and of the sandstone reefs of the Sovereign Shoals in 1989 (Wood 1990) carried out as part of NCC's *Seasearch* programme. He described 15 different habitat types, broadly defined as sand/gravel/cobble mixtures, sandstone boulders and sandstone rock slabs/reefs. In preparation for further *Seasearch* work off the Sussex coast, Wood (1992) carried out an information review for the area between Arun and Chichester, while Irving (1994) reported the results of *Seasearch* surveys between Chichester Harbour and Littlehampton in 1992 and 1993. These surveys have continued and have resulted in the identification of 12 *Sussex marine sites of nature conservation importance*. The location and main biological characteristics of each of the sites is described and illustrated (for instance, Figure 7.4) in Irving (1996). All are hard substratum and include both natural surfaces and wrecks. Kelp *Laminaria hyperborea* occurs in depths shallower than about 3 m together with a limited variety of foliose red algae. Deeper than the algal dominated rocks, cushion sponges, hydroids, dead-man's fingers *Alcyonium digitatum*, sandalled anemones *Actinothoë sphyrodeta*, erect bryozoans and ascidians were particularly conspicuous. The soft rocks present along

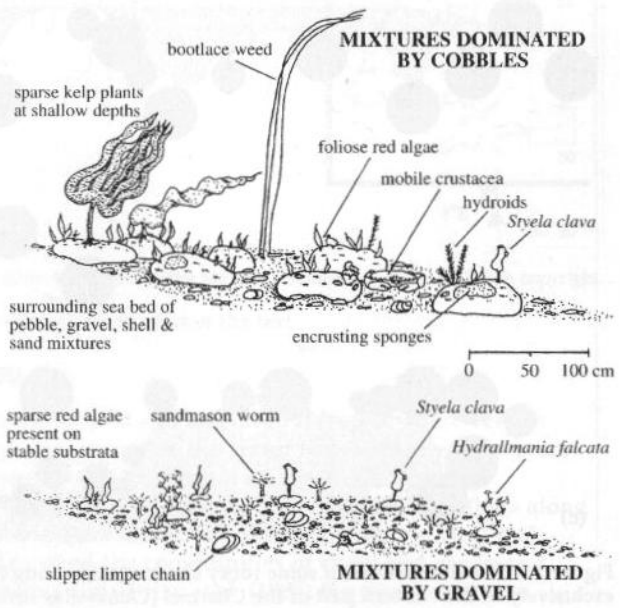

Figure 7.4. Communities on hard and sedimentary substrata at Shelley Rocks south-east of Bognor Regis. From Irving (1996).

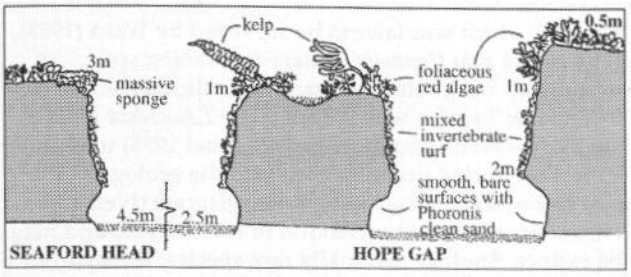

Figure 7.5. Underwater topography and biota at Seaford Head and Hope Gap. From Wood & Jones (1986).

this coast are colonised by boring worms *Polydora ciliata* and bivalves, *Hiatella arctica*, *Barnea candida* and *Pholas dactylus* and by the horseshoe worm *Phoronis hippocrepia*. Pollack, wrasse and two-spot gobies were common over reefs. The non-native species *Crepidula fornicata* (slipper limpet) and *Styela clava* (an ascidian) were conspicuous epifauna species on mixed coarse sediments. The *Seasearch* surveys provide several most easterly records for conspicuous species including the cup coral *Caryophyllia smithii*, the jewel anemone *Corynactis viridis*, and the leopard spotted goby *Thorogobius ephippiatus*.

The Eastbourne area from Beachy Head to Holywell was examined in detail by Paul (1958), who gave a description of the shores and details of species distribution within the area. Studies on the chalk cliffs and greensand reefs at Beachy Head have also been undertaken in conjunction with other work on the rocky shores of south-eastern England (e.g. Anand 1937; Tittley 1985a; Tittley *et al.* 1989). Wood & Jones (1986) describe these greensand shores as dominated by barnacles and mussels. Areas of clay between the sandstone were colonised by very high densities of the piddock *Barnea candida*.

A wide range of substrata in the sublittoral zone between Beachy Head and Selsey Bill were surveyed by the Marine Conservation Society (Wood 1984), with notes in particular on the variation in community structure on chalk and sandstone bedrock. Two areas were selected for their high conservation interest: offshore from Pagham and Bognor; and inshore between Seaford and Beachy Head. The latter area was again promoted by Wood & Jones (1986) following further sublittoral survey in the Seven Sisters area and was subsequently declared a voluntary marine nature reserve. An illustration of the underwater topography and biota is shown in Figure 7.5. Wood & Jones (1986) distinguished communities on the chalk ridges from those on the sedimentary, cobble and clay sites in the area and also describe a further seven littoral sites between Eastbourne and Seaford Head. Off Selsey Bill, an unusual clay cliff called the Mixon Hole was the subject of an Underwater Conservation Year project (Ackers 1977). Further offshore still, shallow rock outcrops colonised by dense ephemeral algae occur and, in deeper water, there are tide-swept pebbles and cobbles cemented together by the polychaete *Sabellaria spinulosa* and by the ascidian *Dendrodoa grossularia* with a rich attached fauna, areas of clean pebbles and rock outcrops and clay ridges with patches of mussel (*Mytilus edulis*) beds (Hiscock 1985).

Between Brighton and Worthing, the River Adur opens at Shoreham. This estuary was surveyed by NCC as part of its assessment of Harbours, Rias and Estuaries in southern Britain (Figure 7.6) (Johnston 1989). The Adur is perhaps the most natural of the minor Sussex inlets surveyed by Arnott *et al.* (1978b), and has a variety

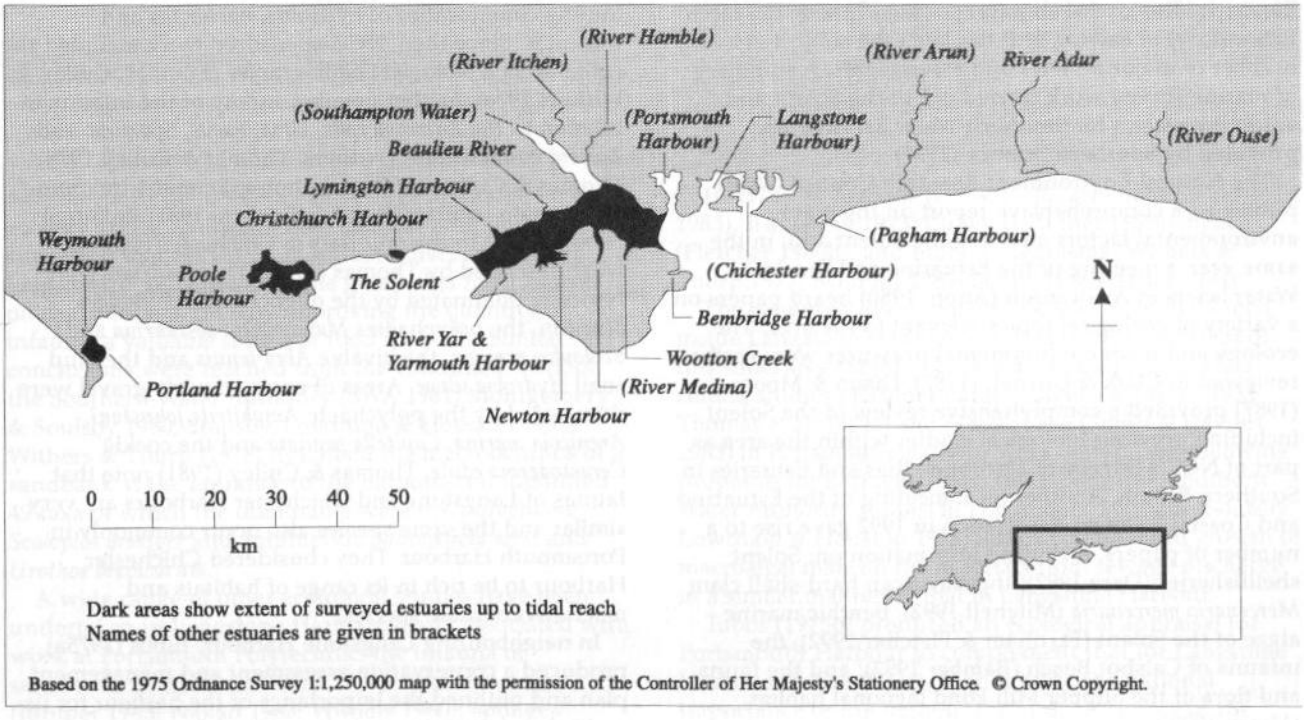

Figure 7.6. Marine inlets along the south coast of England, including those surveyed (not in brackets) by the Harbours, Rias and Estuaries Survey.

of sedimentary habitats, including rich bird feeding grounds in an RSPB reserve (Porter 1980). The sites surveyed by Johnston (1989) were within the western arm of the estuary and revealed a varied fauna with high densities of the worm *Hediste diversicolor* and of the bivalve *Scrobicularia plana* at some locations.

Information on the natural history of Pagham Harbour, a local nature reserve and SSSI, was drawn together by Rayner (1975). The harbour consists mainly of saltmarsh and littoral mudflat, contains a variety of habitats and detailed accounts are given of the algae, lichens, invertebrates and fish. The 'Inner Mulberry Harbour' at Pagham was surveyed by Cuncliffe (1981).

The coastal lagoons from east Sussex and Kent were studied by Sheader & Sheader (1985, 1987) as part of NCC's national assessment of this rare habitat. The lagoons in Sussex had previously attracted attention as early as the 1920s, when Thorpe (1927) examined a number in this area. Ellis (1932) investigated the dykes and lagoons in the Adur estuary at Shoreham, paying particular attention to the habitats of *Hydrobia* spp. in the area. Included in Ellis's work was Widewater Lagoon, which was later to be surveyed by Ward (1983), who found that *Capitella capitata* and *Tubifex* sp. dominated the 17 sites he examined. Also present in Widewater Lagoon was the anemone *Edwardsia ivelli*, a species previously undescribed (Manuel 1975) until its collection during investigations into the ecology of the brackish-water cockle *Cerastoderma glaucum* (Ivell 1979). However, it has not been found in recent years and may be extinct. Another nationally rare species, the hydroid *Clavopsella navis*, also occurs in Widewater Lagoon. Other lagoons in the sector harbouring rare species are Birdham Pool (the lagoonal sand-shrimp *Gammarus insensibilis*) and Pagham Lagoon (the starlet sea anemone *Nematostella vectensis*). Information on saline lagoons and lagoon-like habitats was drawn together in a directory by Smith & Laffoley (1992).

Irving (1987) compiled information from various sources to list Hampshire's principal coastal sites of conservation importance. A considerable portion of the county's coastline is of interest, particularly for its saltmarsh, bird life and geomorphological formations, and is protected by a variety of designations.

7.3 The Solent system

The Solent system extends from Selsey Bill in the east to Hurst Point in the west and is enclosed by the Isle of Wight (Figure 7.7). The Solent system includes Southampton Water and the natural harbours of Chichester, Langstone and Portsmouth. The area has attracted considerable interest in its biology from the University of Southampton, Portsmouth Polytechnic (now the University of Portsmouth), Southern Water Authority, the Esso Oil Company and the Central Electricity Research Laboratories (now Fawley Research Laboratory) at Fawley, and has been the subject of a number of major reviews and assessments. A summary of marine survey work carried out in the Solent and adjoining waters for Southern Water Services was provided by Southern Science (1991).

The Natural Environment Research Council (1980) published a comprehensive report on the main environmental factors affecting the Solent and, in the same year, a meeting of the Estuarine and Brackish Water Sciences Association (Anon. 1980) heard papers on a variety of ecological topics relevant to the area. The ecology and main environmental pressures were further reviewed in Clark & Gurnell (1987). Dixon & Moore (1987) provided a comprehensive review of the Solent including previous biological studies within the area as part of NCC's Survey of Harbours, Rias and Estuaries in Southern Britain. Another local meeting of the Estuarine and Coastal Sciences Association in 1992 gave rise to a number of papers, including information on: Solent shellfisheries (Dare 1992); the American hard-shell clam *Mercenaria mercenaria* (Mitchell 1992); benthic marine algae of the Solent (Farnham & Fletcher 1992); the infauna of Calshot Beach (Bamber 1992); and the fauna and flora of the Slipper Mill Pond lagoonal habitat (Thorp 1992).

Dixon & Moore (1987) carried out a survey in the outer parts of the Solent, which had received less attention than the more sheltered body of Southampton Water itself and the three natural harbours to the east, which are notified Sites of Special Scientific Interest, and of considerable ornithological importance. The most easterly of these inlets, Chichester Harbour, was the subject of detailed ecological survey by Stubbings & Houghton (1964) who paid particular attention to the fouling communities of hydroids, barnacles and tunicates. Since then, NCC-sponsored work included the collation of a biological bibliography (Thomas, Culley & Withers 1978), further detailed survey of the infauna in relation to the *Enteromorpha*, *Ulva*, *Fucus*, *Spartina*, and *Zostera* communities (Withers, Thomas & Culley 1978; Thomas & Culley 1981) and photogrammetric mapping of the main habitats (Budd & Coulson 1981). Infaunal communities in the mudflats of Chichester Harbour were described by Thomas (1986). The mudflats were typically dominated by the oligochaete *Tubificoides benedeni*, the polychaetes *Manayunkia aestuarina* and *Scoloplos armiger*, the bivalve *Abra tenuis* and the mud snail *Hydrobia ulvae*. Areas of coarse muddy gravel were dominated by the polychaete *Amphitrite johnstoni*, *Arenicola marina*, *Capitella capitata* and the cockle *Cerastoderma edule*. Thomas & Culley (1981) note that faunas of Langstone and Chichester Harbours are very similar and the same species also occur commonly in Portsmouth Harbour. They considered Chichester Harbour to be rich in its range of habitats and macroinvertebrate species.

In neighbouring Langstone Harbour, Tubbs (1975a) produced a conservation assessment and management plan and outlined the importance of the harbour for its seabird and wader populations. The following year, Portsmouth Polytechnic (1976) prepared a detailed

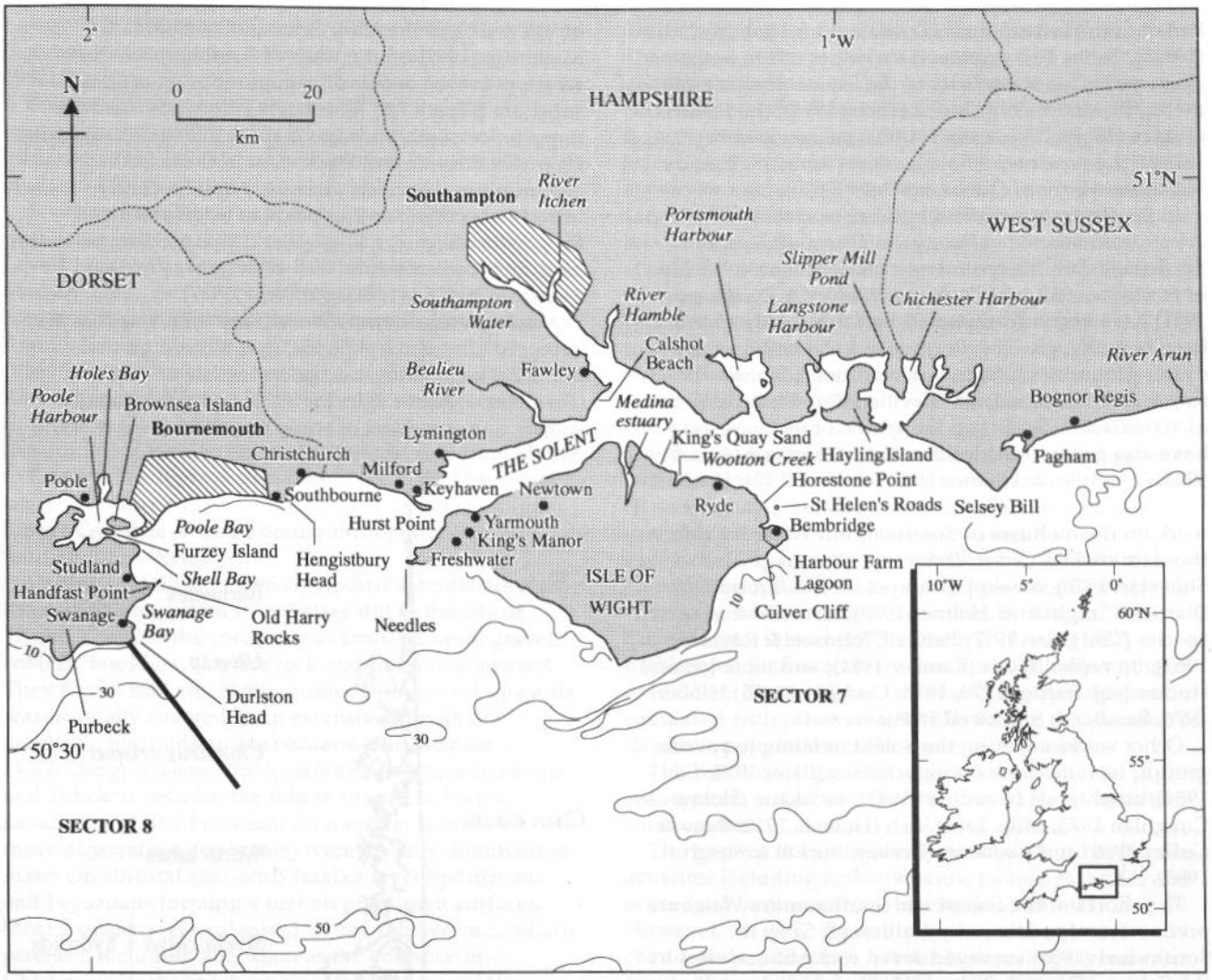

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Figure 7.7. The eastern Channel (western part), showing the location of places mentioned in the text.

assessment of the influence of sewage discharge on the ecology and amenities of the Harbour. This study suggested that reduction in effluent discharge might help control the growth of the green alga *Enteromorpha* on the mudflats, thereby improving the quantity of infauna, a valuable source of food for birds. Similar conclusions were reached from the continued work of the Southern Water Authority (SWA 1981; Montgomery & Soulsby 1980; Soulsby, Lowthion & Houston 1982). Withers & Thorp (1978) described the macrobenthos of a sandbank at the entrance to the harbour and identified 49 taxa of which the dominants were the polychaete *Scoloplos armiger* and amphipods *Bathyporeia sarsi* and *Urothoe brevicornis*.

A wide range of other ecological studies have been undertaken in Langstone Harbour, many associated with work at Portsmouth Polytechnic: the infauna of sandbanks (Withers & Thorp 1978); littoral infauna (Juniper 1963; Foolad 1983; Withers 1980); sponges (Juniper & Steele 1969; Stone 1969, 1970; Alexander 1969; Frith 1976); bryozoans (Crew 1970); ascidians (Middleton 1983); fish (Reay 1973; Culley & Palmer 1978); algae (Fletcher 1980b); and fouling organisms (Withers & Thorp 1977; Schmidt 1983; Schmidt & Warner 1984).

The proposed development of a marina in the Kench, inside Langstone Harbour, resulted in an assessment of this small area (Smith, Haynes & Thomas 1986), while similar studies of Tipner Lakes (Haynes & Joyner 1983, Thomas *et al.* 1989a) and Haslar Lake (Smith & Haynes 1985) in Portsmouth Harbour were undertaken following proposals for barrages across their entrances. Southern Water Authority studies in Portsmouth Harbour (Soulsby, Lowthion & Houston 1978) indicated enhanced growth of macroalgal mats on the mudflats from sewage discharge in a similar manner to that in Langstone Harbour.

Tubbs (1975b) produced an ecological appraisal for Portsmouth Harbour to complement that for Langstone Harbour (Tubbs 1975a), highlighting the national importance of the harbour for birds. A survey of the macroinvertebrate fauna of Stanshaw Lake, in the east of

Portsmouth Harbour, was carried out by Thomas *et al.* (1989b). Tubbs also produced a number of conservation assessments for other parts of the Solent (for example the north-west Solent shores (Tubbs 1973), the Medina estuary (Tubbs 1975c), the Hamble estuary (Tubbs 1975d), the north-west Solent coast (Tubbs 1979) and Newtown Harbour (Tubbs & White 1977)).

In Southampton Water a number of studies have arisen from interest in the oyster *Ostrea edulis* and hard-shell clam *Mercenaria mercenaria* fisheries. Reviews of the oyster fishery (e.g. Key 1972; Key & Davidson 1981) have been accompanied by work on the species itself (e.g. Waugh 1964; Rodhouse 1979) and on the oyster grounds (e.g. Barnes, Coughlan & Holmes 1973; Key & Davidson 1981; de Turville 1978). The non-native *Mercenaria mercenaria* and the effects of its harvesting have also generated considerable interest (e.g. Ansell 1963; Coughlan & Holmes 1972; Mitchell 1974; Romeril 1979; Walker 1985; Sheader 1986; Cox 1991). Further work on the molluscs of Southampton Water include those on cockles *Cerastoderma* spp. (Barnes 1973; Shoostari 1978), on slipper-limpet *Crepidula fornicata* (Barnes, Coughlan & Holmes 1973), on wood-boring species (Coughlan 1977; Pannell, Johnson & Raymont 1962), on cephalopods (Bamber 1981); and more general studies (e.g. Barnes 1970, 1973; Coughlan 1981; Hibbert 1976; Bamber & Stockwell 1988).

Other works covering the Solent, relating to specific groups, include those on polychaetes (Esser 1972; Ede 1984), amphipods (Goodhart 1941), ascidians (Holmes & Coughlan 1975; Mills 1984), fish (Holmes 1978; Reay & Culley 1980) and plankton (Leakey, Burkill & Sleigh 1993).

The shores of the Solent and Southampton Water are predominantly sedimentary, although Crisp & Southward (1958) surveyed seven rocky littoral sites in the Solent. Holme & Bishop (1980) visited about 30 sites (all sedimentary shores) within the area and assigned each to the five main community types encountered:

- Crustacean – Polychaete;
- *Lanice;*
- *Arenicola;*
- *Venerupis pullastra;*
- *Scrobicularia.*

The sites of highest conservation interest fell within already notified SSSIs (Bishop & Holme 1980). More specific and detailed examination of the shores in the area were undertaken at: Royal Pier, Southampton (Lauriston 1977); Lymington-Keyhaven (Waters 1977; Lydon 1988; Cooper [1987]; Johnston 1989); Itchen estuary (Irving 1983); Fawley (Bamber & Stockwell 1988); and Fawley saltmarshes (Dicks & Iball 1981). The latter recorded the recovery of the cord grass *Spartina* following the reduction in oil refinery effluent. Barnes (1971a) gave a list of fauna recorded from the shores of Southampton Water, and Barnes (1971b) described the distribution of Mollusca there.

Sublittoral studies include those by Warner (1984) on a wreck in Ryde Bay; by Collins & Mallinson (1983a, 1984) on the wreck of the *Mary Rose*; and by Collins & Mallinson (1987) on the walls of Southampton docks, which provided details of communities on artificial substrata (Figure 7.8). This latter survey revealed the importance of the introduced species *Elminius modestus*, *Hydroides ozoensis* and *Styela clava* in these fouling communities. *Hydroides ozoensis*, a quite recently introduced polychaete, appears to be displacing *Ficopomatus enigmaticus*, another introduced worm in this area, and its distribution and ecology was further discussed by Ede (1984) and West (1987).

A conspicuous non-native introduction was that of 'japweed' *Sargassum muticum*, first noticed on the intertidal reefs at Bembridge on the Isle of Wight in 1973 (Farnham, Fletcher & Irvine 1973) and subsequently subject to a great deal of study (e.g. Withers *et al.* 1975;

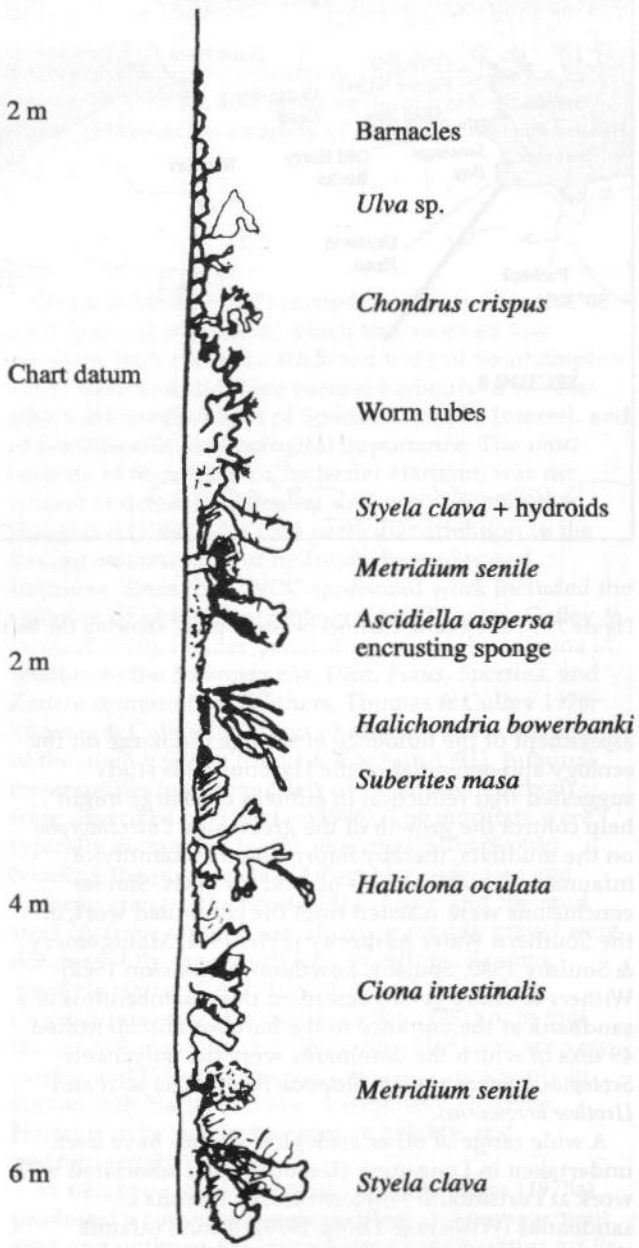

Figure 7.8. Vertical profile of a dock wall in Southampton Docks (from Collins & Mallinson 1987).

Lewey 1976; Fletcher & Fletcher 1975a, 1975b; Gray 1978; Fletcher 1980a; Critchley 1981; Portsmouth Polytechnic 1982).

Southern Water Authority carried out a series of studies on the sublittoral benthos of a number of estuaries in the Solent system (Soulsby, Lowthion & Houston 1981).

Southampton Water has been extensively surveyed by grab sampling (e.g. Barnes, Coughlan & Holmes 1973; Levell 1979, 1985; Oyenekan 1980; Houston, Lowthion & Soulsby 1983). Levell (1979) described the main benthic communities in Southampton Water noting numerical domination by the cirratulid *Caulleriella* sp. with an underlying community consisting of *Melinna palmata*, *Abra nitida* and *Nepthys hombergii* with variations in different regions of the estuary. *Cerastoderma edule* was the dominant bivalve on the south-west side from Hythe to Fawley. The highest densities of the clam *Mercenaria mercenaria* were found on the opposite side. The slipper limpet *Crepidula fornicata* occurs throughout Southampton Water.

Collins & Mallinson (1983b) studied subtidal areas in the east Solent system from Selsey Bill to the Isle of Wight. They list the conspicuous fauna of sand, gravel, cobbles, boulders, clay bedrock and limestone bedrock. They found that any stable surface from gravel upwards was normally covered in an extensive growth of ascidians, hydroids and bryozoans. The ascidian *Dendrodoa grossularia*, the hydroids *Nemertesia antennina* and *Tubularia indivisa*, the foliose bryozoan *Flustra foliacea*, the fleshy bryozoan *Alcyonidium gelatinosum* (now *Alcyonidium diaphanum*) were visually dominant at many circalittoral sites with smaller erect hydrozoans and bryozoans forming a turf on prominent surfaces. Most surfaces were colonised by the tubeworm *Sabellaria pavonona* including a location at the entrance to Chichester Harbour where a continuous mat of the worm held together an otherwise sandy seabed. Exposed clay and limestone outcrops were extensively bored by the bivalves *Pholas dactylus* and *Barnea* sp. respectively.

Dixon & Moore (1987) reviewed the information describing marine habitats and communities in the Solent and undertook a programme of sampling to help fill gaps in information. Intertidal work was concentrated on the rocky areas of the Solent coast of the Isle of Wight and subtidal work in the western Solent. All of the rocky shores surveyed were algal dominated, mainly by fucoids and *Audouinella* sp. Rockpools were dominated by *Sargassum muticum*, fucoids and filamentous green algae. The most widespread animal species were the barnacle *Semibalanus balanoides* and the periwinkle *Littorina littorea*, and faunal diversity was considered to be low. The seabed of the western Solent included a low diversity of habitats and a predominance of current-scoured pebbly sediments. Species typical of stony sediments included the algae *Griffithsia flosculosa*, *Hypoglossum woodwardii*, *Gracilaria verrucosa*, *Polysiphonia nigrescens*, encrusting Rhodophycota, ectocarpoids and *Sargassum muticum* with a higher diversity and more luxuriant growth on shallow boulders. Most of the attached epifaunal species were ubiquitous and occurred wherever hard substrata were available. Characteristic species were the barnacle *Balanus crenatus*, the tubeworms *Pomatoceros triqueter* and *Pomatoceros lamarckii*, the ascidian *Dendrodoa grossularia* and the sponge *Halichondria panicea*. The epifauna on stable boulders was dominated by the hydroid *Tubularia indivisa* and by the massive form of *Halichondria panicea* with the foliose bryozoan *Flustra foliacea* and the hydroid *Hydrallmania falcata* also present. The slipper limpet *Crepidula fornicata* was dominant on sediments everywhere apart from on mobile sand. The subtidal animal communities observed by Dixon & Moore (1987) were very similar to those described by Barnes, Coughlan & Holmes (1973). Dixon & Moore (1987) highlighted Stanswood Bay and the north side of the west Solent for its higher richness of algae and fauna compared with other areas on the Solent, and because of its native population of the oyster *Ostrea edulis*.

The Beaulieu River, although an extensive inlet of the sea, appears not to have been surveyed for its benthic communities.

The estuary at Lymington is greatly altered by human activities including embankments, moorings, jetties and is dredged to maintain the navigation channel. However, the now disused salt pans and adjacent channels are a brackish habitat harbouring several rare lagoonal species (Sheader & Sheader 1985). They include Eight Acre Pond, excavated from old salt pans in 1957 and containing four rare lagoonal species. Sampling has been undertaken by Waters (1977) and by Goodhart (1941) who undertook detailed work on the Amphipoda of the Afon Water at Keyhaven to the west of Lymington describing the occurrence of 41 species. Holme & Bishop (1980) describe the shore at Pennington to the west of Lymington where anaerobic muddy sand was dominated by species of *Nereis* (presumably including the species now known as *Hediste diversicolor*) and *Nephthys*. The inlet was described by Johnston (1989), who found the fauna to be impoverished along the lower littoral. Information on the sublittoral biology of the Lymington river is limited although Holme & Bishop mention that the outer estuary is the type locality for the acorn worm *Saccoglossus horstii*.

7.4 The Isle of Wight

The shores of the Isle of Wight are reasonably well known. Morey (1909) provided a checklist of species for the island, whilst Kain (1958) described a range of shores, with particular emphasis on the algae. The littoral chalk communities were encompassed in the British Museum (Natural History) survey of these habitats (Tittley 1988). The littoral infaunal communities of the Medina estuary were discussed by Withers

(1979b), whilst Tubbs provided estuary conservation management assessments for the Medina (Tubbs 1975c), Newtown Harbour (Tubbs & White 1977) and the Yar (Waters & Tubbs 1977). Sites on the Isle of Wight were surveyed during the NCC-commissioned littoral survey of Great Britain and described by Holme & Bishop (1980). The benthos of lagoon or lagoon-like habitats of the Isle of Wight were described by Sheader & Sheader (1988). The Yar, together with Newtown Harbour, Wootton Creek and Bembridge Harbours were the subject of NCC-commissioned Survey of Harbours, Rias and Estuaries in southern Britain (Howard, Moore & Dixon 1988; Johnston 1989).

The Yar was described in Johnston (1989) as including habitats typical of south coast inlets but with rich communities in the upper reaches north of King's Manor where current-swept cobbles occurred colonised especially by a rich and diverse fauna of sponges, anemones and ascidians including the rarely recorded sponge *Suberites massa*.

Newton Harbour includes extensive fringing mudflats and sublittoral channels. The flats are almost entirely of sediment and therefore epibiota was sparse although the winkle *Littorina littorea* and the slipper limpet *Crepidula fornicata* were present in significant numbers (Howard, Moore & Dixon 1988). Sediment samples were dominated numerically by polychaetes and oligochaetes and contained few crustaceans or molluscs and the following three main shore types were identified (Howard, Dixon & Moore 1988):

- Sheltered coastal mixed sediments of fine sandy mud with sparse fauna and flora including occasional plants of *Enteromorpha* sp. and *Fucus vesiculosus*, occasional *Arenicola marina* and patchily abundant *Littorina littorea* near the entrance to the harbour.
- Sheltered estuarine fine sediments in the central region of the harbour colonised most abundantly by the polychaete worms *Tharyx marioni* and *Ampharete finmarchica* and tubificid oligochaete worms. The amphipod *Corophium volutator* was abundant in places.
- Extremely sheltered estuarine fine sediment at the innermost reaches of tidal creeks had, in addition to the polychaetes and oligochaetes mentioned above, high densities of the polychaete *Streblospio shrubsolii*.

The subtidal habitats in channels were predominantly of tide-swept cobbles and pebbles colonised by red foliose algae and by the brown seaweed *Sargassum muticum*. Animals dominated some hard substrata and included species typically found in estuarine conditions (for instance, the fan worm *Sabella pavonina*, the bryozoan *Amathia pruvoti* and the sea squirt *Dendrodoa grossularia*. Oysters, *Ostrea edulis*, were also present.

The old saltings on the edge of saltmarsh in Newton Harbour support a diverse fauna and flora including the only site of the Isle of Wight where the alga *Chaetomorpha linum* and the amphipod *Gammarus insensibilis*, a nationally important species, were found (Sheader & Sheader 1988). The shores on the north-east side of the Isle of Wight at King's Quay Sands, Wootton Creek and Ryde Sands were described by Bishop & Holme (1980) and by Johnston (1989). The shore at Ryde Sands was identified by Bishop & Holme (1980) as of marine biological interest mainly because of the presence of the uncommon bivalve *Loripes lucinalis*. Withers' (1979a) studies of intertidal sediments at Ryde found the lugworm *Arenicola marina* to be dominant overall with the mud snail *Hydrobia ulvae* and amphipods locally abundant and common respectively. A more diverse and abundant fauna occurred in association with a bed of *Zostera* sp. to the west of Ryde Pier with 57 species being recorded. Wootton Creek was mentioned by Holme & Bishop (1980) as having a typical estuarine fauna and a description of the communities present was given by Johnston (1989). The description by Johnston (1989) emphasises epibiota attached to stones and shells which included fucoid algae, filamentous red and green algae and animals typically found in estuaries such as *Carcinus maenas*, the mud snail *Hydrobia ulvae* and the bryozoan *Bowerbankia imbricata*. The marine fauna of Lakeside old mill pond at the tidal limit of Wootton Creek was studied by Sheader & Sheader (1988) who considered the fauna moderately diverse and noted the presence of the rare sea anemone *Nematostella vectensis*. The mill pond as also surveyed by Johnston (1989) and by Thomas & Herbert (1990), who recorded 17 species, predominantly crustaceans, distributed according to a salinity gradient up the pond, from the saline incursion to the freshwater input. The mill pond was further described by Thorp (1992).

The shores and coastal marine habitats around Bembridge have been surveyed and sampled for many years especially because of the rich algal flora present on Bembridge Ledges. Harbour Farm Lagoon, which lies behind the sea wall in brackish marshland, was surveyed by Sheader & Sheader (1988) who considered the species diversity relatively high and recorded two species of national importance: the stonewort *Lamprothamnion papulosum*, and the sea anemone *Nematostella vectensis* (for which this is the type locality). *Nematostella vectensis* was also found in a further lagoon adjacent to Bembridge Harbour. Bembridge Ledges and St Helen's Ledges have particularly rich algal communities in the pools there and part of the area is designated as SSSI because of interest of the algae. Dixon & Moore (1987) noted that the pools were dominated by *Sargassum muticum* and by the fleshy green alga *Codium fragile*.

The subtidal regions off the north coast of the island are considered above in the Solent studies. Elsewhere around the island information on the sublittoral zone is limited. Collins & Mallinson (1988) surveyed the nearshore areas off Bembridge, describing a range of communities on limestone, clay and sedimentary bottoms between Horestone Point and Culver Cliff within the boundaries of a proposed voluntary marine reserve. The area was considered particularly rich and their work continued in 1988 to include faunal-dominated communities farther offshore (Collins & Mallinson 1989). Here, the seabed deeper than 10 m below chart datum was essentially of gravel with outcropping rock. The rock surfaces were dominated by hydroids (especially *Nemertesia antennina*) and the foliose

bryozoan *Flustra foliacea* together with sponges and ascidians. A population of the echiuroid worm *Maxmuelleria lankesteri* was found in mud off St Helen's Roads. Jenkinson's (1972) assessment of spoil-dumping grounds included sampling the bottom fauna at locations off Christchurch Bay and south-west and south-east of the Isle of Wight. The bottom was predominantly of poorly sorted sediment with gravel and stones and the most frequently sampled species were of epifauna and similar to those described later by Lees *et al.* (1990). To the south-east of the Isle of Wight, investigations of gravel dredging grounds by MAFF (Lees *et al.* 1990) revealed associations dominated by sessile epifaunal species, principally sponges, hydroids, bryozoans and ascidians with locally abundant slipper limpets *Crepidula fornicata* and the bivalve *Nucula* sp. The assemblages were similar to the B1 and B2 assemblages described by Holme & Wilson (1985) (see Chapter 1). The sublittoral chalk communities at Culver Cliff in the south-east, and between Freshwater Bay and the Needles in the south-west have also been examined (Wood 1992), and complement other work on this limited habitat in both littoral and sublittoral zones.

The marine biology of the Isle of Wight continues to be studied with the Medina Valley Centre's maintenance of marine records (Herbert, Marston & Surujballi 1987; Medina Valley Centre 1987; Herbert 1988, 1991a, 1991b), and ongoing surveys of Mollusca (Killeen & Light 1990) and algae (W.F. Farnham pers. comm.). The *Proceedings of the Isle of Wight Natural History and Archaeological Society* act as a vehicle for publishing papers and reports of local natural history interest.

7.5 Hurst Point to Durlston Head

To the west of the Solent from Hurst Point to Durlston Head, intertidal areas of the open coast have been relatively poorly researched, with Holme & Bishop (1980) commenting that a consequence of the impoverished nature of the open coast was the lack of marine biological literature. Melvill (1928) noted some algae collected at Milford-on-Sea, and the algae (Cotton 1914) and fauna (Waddington 1914) between Lymington and Swanage were included in a natural history of Bournemouth (Morris 1914). The sublittoral zone between Hengistbury Head and Christchurch Ledges was surveyed by Collins & Mallinson (1986). The area includes communities on sand, gravel, clay and boulder, with those on boulders being the richest. They also commented on the devastation since 1978 of the formerly extensive mussel *Mytilus edulis* beds in the area by the starfish *Asterias rubens*.

Littoral studies in Poole Bay have been limited. Crisp & Southward (1958) investigated at Studland and Sandbanks as part of a study into the distribution of certain littoral species in the Channel. Holme & Bishop (1980) looked at Hengistbury Head, Southbourne, Shell Bay, and three sites in Studland Bay. Their conclusions were that most shores were moderately exposed (except north-east facing Studland Bay, which was sheltered). Much of the coast was urban with a sea wall or promenade protecting the base of the cliffs, with groynes traversing the rather narrow sediment beaches. The chalk outcrops and cliffs between Studland Bay and Old Harry Rocks were the subject of a detailed study of algae by Tittley (1988) whilst George, Tittley & Price (1989) carried out a littoral survey of macrobenthos in the same area. Studland Bay was also surveyed as part of a littoral and sublittoral study of the Dorset coast by Roberts *et al.* (1986). Dorset Naturalists' Trust (1974) highlighted the shores at Seacombe and Dancing Ledge, Peveril Point and at Studland Bay in their conservation assessment of the county's coast.

The enclosed waters between the Solent and Durlston Head include the large natural harbour at Poole, the smaller harbour at Christchurch, and a number of coastal lagoons and ponds. NCC commissioned research in all these areas, with the Field Studies Council surveying Christchurch Harbour as part of the Harbours, Rias and Estuaries programme (Dixon 1988), and Sheader & Sheader (1985) reporting on the saline lagoons. Christchurch Harbour has been surveyed for its benthic foramaniferan (Murray 1968 and Howarth & Murray 1969) and ostracod (Whittaker 1981) assemblages. Twenty-three intertidal and eight subtidal sites were surveyed in the Harbours, Rias and Estuaries surveys (Dixon 1988) from which analysis of quantitative macrofaunal data from intertidal sediments suggested four zones in Christchurch Harbour:

- **Open coast lower shore sediments of clean sand** characterised by the amphipods *Bathyporeia sarsi* and *Bathyporeia pelagica* together with Paraonidae indet. and the lugworm *Arenicola marina*.
- **Sheltered estuarine mixed sediments** in the gravelly sediments and the entrance to the harbour and sandbanks just within the harbour numerically dominated by polychaetes such as *Hediste diversicolor*, *Pygospio elegans* and *Streblospio shrubsolii* together with an unidentified oligochaete.
- **Sheltered fine sediments under brackish-water influence** occurring in the major part of Christchurch Harbour and characterised most abundantly by the amphipod *Corophium volutator*, the spionid polychaete *Streblospio shrubsolii* and unidentified oligochaetes. Other characteristic species were the ampharetid *Alkmeria romijni*, the small sabellid *Manayunkia aestuarina*, the isopod *Cyathura carinata* and the bivalve *Scrobicularia plana*.
- **Current-swept mixed sediments under fresh or brackish water influence** occurred at the mouth of the River Avon and were numerically dominated by oligochaetes with insect larvae, a cladoceran, ostracods, at least two species of gammarid

amphipod, the freshwater isopod *Asellus aquaticus*, a single specimen of the estuarine tanaid *Heterotanais oerstedi* and eels *Anguilla anguilla*.

Subtidal habitats and communities sampled by diving and dredging were separated into six types:

- **Offshore infralittoral ironstone bedrock or stable boulders** dominated by foliose algae and erect hydrozoans and bryozoans with rock surfaces encrusted by the barnacle *Balanus crenatus*.
- **Offshore infralittoral cobbles and pebbles** dominated by *Balanus crenatus* and by algae, especially ones characteristic of sandy habitats (mainly *Polysiphonia nigrescens*, unidentified foliose Chlorophycota, *Polyides rotundus* and *Gracilaria verrucosa*.
- **Offshore clean sandy sediments** (probably the major offshore habitat along this stretch of shallow coastline) characterised on the surface by hermit crabs *Pagurus bernhardus*, by the snail *Hinia reticulata* and the goby *Pomataschistus pictus*. The infauna was rich and dominated by polychaetes especially the sandmason worm *Lanice conchilega*.
- **Estuarine current-swept vertical concrete or metal surfaces and small boulders** occurred in the entrance channel and the outer harbour and had a low diversity community dominated by filamentous algae.
- **Estuarine current-swept cobbles and pebbles on sandy sediments** occurred near to the entrance within the harbour and were mainly bare but with occasional hydroids *Obelia ?dichotoma* and frequent shore crabs *Carcinus maenas*.
- **Brackish estuarine muddy sands** were very similar to those recorded from intertidal sediments.

Two coastal pond lagoons were surveyed by Sheader & Sheader (1985) in Christchurch Harbour. Grimbury Pond near the head of the inlet had a salinity of only 3‰ and the fauna was characterised by oligochaetes, a variety of Crustacea, mainly *Gammarus* spp. and insects. The old man-made harbour system just within the entrance at Hengistbury Head had salinities varying between 6 to 31‰ with the infauna of the main lagoon, channel and side creeks mainly comprised of the worm *Streblospio shrubsolii*, the mud-snail *Hydrobia ulvae*, the amphipod *Corophium volutator* and a few worms *Hediste diversicolor*. The amphipod *Gammarus insensibilis* which is restricted to shallow brackish habitats was also present.

Poole Harbour has been particularly thoroughly surveyed. Sublittoral surveys by Dyrynda (1983, 1984, 1987) and an assessment of the intertidal habitats by Gray (1985) complemented an overall appraisal of the harbour by Doody & Dennis (1984). The intertidal sediments of Poole Harbour were sampled by the Institute of Offshore Engineering (1986) at high, mid and low tide levels at 15 transects. A total of 115 taxa were recorded representing a species-poor environment. A more recent survey of the northern sediment shores of Poole Harbour (Dyrynda & Lewis 1994) found that some species exhibited elevated upshore zonations, a consequence of the double high tidal cycle experienced in the inlet. Jensen *et al.* (1992) surveyed areas near to the entrance of the harbour for British Petroleum. Howard & Moore (1988) provide a review of the literature available for Poole Harbour and present the data of several other researchers in similar format to other reports in the NCC's Harbours, Rias and Estuaries series. The following descriptions, predominantly of epibiota, are summarised from that report.

- **Intertidal hard substrata** occupy only a small proportion of intertidal habitats and occur mainly near to high water mark. They are characterised by widespread rocky shore species including fucoid algae, the green algae *Ulva* and *Enteromorpha*, limpets, barnacles, prosobranchs and mussels. Epifaunal species on gravelly substrata include the slipper limpet *Crepidula fornicata*, mussels *Mytilus edulis* and the tubeworm *Pomatoceros triqueter*. Mixtures of shingle and mud were colonised by the worms *Hediste diversicolor, Nephtys hombergii, Nephtys cirrosa* and *Lanice conchilega* with bivalves *Mya arenaria, Cerastoderma edule, Venerupis decussata* and *Venerupis pullastra*.
- **Intertidal sedimentary shores** were described in four broad categories:
  1. Very sheltered embayments to the west of Poole Harbour where the predominant species include the amphipod *Corophium volutator*, the worms *Streblospio dekhuyzeni, Manayunkia aestuarina, Polydora ciliata* and *Hediste diversicolor* and the bivalve *Abra alba*.
  2. Sheltered embayments lying closer to main seawater channels along the south shores of the harbour where oligochaetes and capitellids predominate but retaining some species from 1. Additional common species include the worms *Capitella capitata, Pygospio elegans* and *Exogene naidina*.
  3. Moderately exposed sediment flats located on the north-east of the harbour and on the south at Brownsea Island. Oligochaetes and cirratulids predominate and there is a much reduced mollusc component compared with other locations.
  4. Areas exposed to tidal currents predominantly around Furzey Island and adjoining the South Deep where oligochaetes and cirratulids are numerically dominant but the polychaetes *Scoloplos armiger, Polydora ciliata* and nereids are also important.
- **Subtidal current-swept natural bedrock and boulders** were only found at one location east of Brownsea Island at a depth of 9 m. The site was species rich and dominated by the foliose bryozoan *Flustra foliacea* and the massive sponge *Suberites domuncula*. The most current scoured boulders supported only the estuarine barnacle *Balanus improvisus* and the tubeworm *Pomatoceros lamarcki*. Boulder interstices supported mobile species including the crustaceans *Carcinus maenas, Galathea strigosa* and *Liocarcinus puber*, the native oyster *Ostrea*

edulis and the slipper limpet *Crepidula fornicata*. Algae present included *Sargassum muticum, Laminaria saccharina* and *Ulva lactuca*.

- **Subtidal sheltered boulders** were located at Green Island (adjacent to Furzey Island) where a causeway had been constructed. The boulders supported a high cover of sponges and ascidians with common species being typical of sheltered rock exposed to variable salinity including the sponges *Suberites massa, Halichondria bowerbanki, Haliclona oculata* and *Hymeniacidon perleve*, the ascidians *Ascidiella aspersa, Styela clava* and *Diplosoma listerianum*.
- **Subtidal clays, peat and lignite** were present in areas of tidal scour but supported only the burrowing bivalve *Petricola pholadiformis* and a small variety of mobile or drift species.
- **Subtidal cobbles, stones and gravel** were present in various channels subject to strong current scour. They were colonised by the algae *Laminaria saccharina, Ulva lactuca* and *Sargassum muticum*, by the molluscs *Crepidula fornicata* and *Ostrea edulis*, and by crustacea similar to those in tide-swept boulders. The polychaetes *Cirriformia tentaculata* and *Amphitrite johnstoni* were abundant at the entrance to Holes Bay.
- **Subtidal coarse sand** occurred on the flanks of channels and was usually devoid of conspicuous benthos and supported the most species-poor communities in Poole Harbour. Sand eels *Ammodytes tobianus* were the only common species although stones and shells provided a point of attachment for the alga *Gracilaria verrucoa*, the hydroid *Hydrallmania falcata* and the bryozoan *Walkeria uva*. Where the sand was slightly less coarse, beds of the sand mason worm *Lanice conchilega* occurred together with the peacock worm *Sabella pavonina* and the anemones *Cereus pedunculatus* and *Sagartia troglodytes*. Stacks of the slipper limpet *Crepidula fornicata* and individual oysters *Ostrea edulis* provided a substratum for the sponge *Suberites domuncula*, the bryozoans *Walkeria uva* and *Alcyonidium diaphanum* and the ascidians *Ascidiella aspersa* and *Styela clava*. Mobile species were hermit crabs, the swimming crab *Liocarcinus depurator* and the spider crab *Maia* (now *Maja*) *squinado*.
- **Subtidal medium sands** occurred in most tidal channels and were colonised by beds of the sandmason worm *Lanice conchilega* with localised beds of *Sabella pavonina, Crepidula fornicata* and *Sargassum muticum*. A limited variety of epibiota occurred on stones and shells.
- **Subtidal fine sands** supported species-rich communities and extended in a broad band running from north to south across the harbour. *Sabella pavonina* was particularly abundant. In moderately current exposed areas, the most characteristic coloniser was the sponge *Halichondria bowerbanki* which encrusted the tubes together with the sponge *Amphilectus fucorm*, the ascidians *Ascidiella aspersa* and *Diplosoma listerianum* and the algae *Polysiphonia elongata* and *Gracilaria verrucosa*. Many mobile species were asociated with beds of *Sabella* and included the spider crabs *Inachus phalangium, Macropodia rostrata* and *Maia squinado*, and the fishes *Gobius niger, Pomatoschistus minutus, Gobiusculus flavescens* and *Syngnathus acus*. Elsewhere, species assemblages similar to those for coarse sands, gravel and pebbles were present.
- **Subtidal mud** was present in very deep areas and was characterised on the surface by various massive sponges including *Cliona celata, Haliclona oculata, Hymeniacidon perleve, Haliclona cinerea* and *Suberites massa*. Other colonisers on stones included the sea anemone *Metridium senile*, mussels *Mytilus edulis*, the bryozoan *Anguinella palmata* and the barnacles *Balanus improvisus* and *Elminius modestus*. A bed of the brittlestar *Ophiothrix fragilis* was present in one location. Extensive tracts of anoxic mud with little infauna also occur and the firm areas support the horseshoe worm *Phoronis psammophilia* and burrows of the eel *Anguilla anguilla* with the worms *Nephtys hombergi* and *Melinna palmata* and the amphipod *Corophium volutator*.
- **Subtidal artificial substrata** were particularly colonised by sponges or hydroids and bryozoans.

Howard & Moore (1988) reached the conclusion that the littoral and sublittoral habitat diversity was low; however, the high productivity of intertidal mudflats makes the area important for waders and wildfowl. They also reported that at least four marine invertebrate species which are thought to be rare in Britain occur in the Harbour; these being the sponge *Suberites massa*, the bryozoans *Anguinella palmata* and *Farella repens* and the nudibranch *Aeolidiella sanguinea*.

The sublittoral sediment communities of Poole Bay were the subject of sampling by Spooner & Holme (1961) and Holme (1961, 1966, 1967). Much of this work related to the results of anchor-dredging, describing the species present and their abundance at each station (Spooner & Holme 1961) and identifying community types (Holme 1961, 1966). Holme (1966) stated that Poole Bay was probably the only site in the English Channel containing all five English Channel associations: mud, muddy sand, sand, muddy gravel, and gravel. Particularly high numbers of bivalve molluscs were also noted. Such large populations of bivalves were only exceeded on the English side of the Channel in Falmouth and Rye Bays. Holme (1967) referred to the effect of the severe winter of 1962–63 on the benthic infauna at sites previously dredged and described in earlier reports. More recent interest in the bay for the extraction of oil prompted benthic surveys for British Petroleum, carried out by Southampton University's Department of Oceanography (Jensen *et al.* 1989). This reported the results of sediment analysis, and described the main infaunal and epifaunal communities found at 35 stations. Ninety macro-infaunal taxa, mostly polychaetes, were identified from core samples. The polychaete *Nephtys hombergii* was most widespread and abundant. Eight different assemblages of infaunal species were identified by cluster analysis. Two different analyses produced similar results and the

characterising species identified for one of the analyses are noted below.

- No single species identified as dominant or common to all stations in the group.
- *Nephtys hombergii* occurred at all stations. Other species occurring at the majority of stations were *Tharyx marioni*, *Scoloplos armiger* and *Capitomastus minimus*.
- Dominated by *Tubificoides* sp. with *Capitomastus minimus* and *Nephtys hombergii*.
- Dominated by *Scoloplos armiger* with *Nephtys hombergii* and *Tharyx marioni* occurring in two of the three sites.
- Dominated by *Scoloplos armiger*.
- *Nephtys hombergii*, *Nucula nitidosa* and *Heteroclymene robusta* occur and this was the only cluster with significant numbers of the latter two.
- Dominated by *Lanice conchilega* with *Nephtys hombergii* as a secondary dominant.
- Dominated by *Spio* sp. with *Tharyx marioni* and *Scoloplos* armiger of secondary and tertiary importance.

Several widely dispersed sediment epifauna species were described by diver surveys including the prosobranchs *Aporrhais pespelecani* (pelican's foot shell) and *Lunatia poliana* and the brittlestars *Ophiura ophiura* and *Ophiura albida*. The epifauna was diverse and locally abundant, especially at stations with hard substrata such as frequent slipper limpet *Crepidula fornicata* beds with their associated flora and fauna. Further studies were undertaken in 1990 sampling off Handfast Point and Swanage Bay, including a study of the infauna of the maerl (*Phymatolithon calcareum* and *Lithothamnium coralloides*) bed south of Handfast Point (Rowe, Sheader & Jensen 1990). The infauna of the maerl bed was dominated by polychaete worms (particularly *Spio armata* and *Caulleriella zetlandica*) with a variety of amphipods (largely dominated by *Urothoe elegans*). Adjacent areas were dominated by the bivalve *Nucula nucleus* and the amphipod *Leptocheirus hirsutimanus*, by amphipods *Bathyporeia guilliamsoniana* and by dead maerl with the amphipod *Ampelisca tenuicornis*. The distribution of sublittoral Mollusca in Poole Bay and off Purbeck was mapped following Conchological Society dredging trips in 1993 and 1994 (Light 1994). Several other studies of benthos have been commissioned by British Petroleum and undertaken by Southampton University in Poole Harbour and in Poole Bay (for instance, Jensen *et al.* 1990; Jensen *et al.* 1991; Jensen *et al.* 1992).

A recent experiment which is still ongoing in Poole Bay is the development of an artificial reef (Collins, Jensen & Lockwood 1991; Jensen *et al.* 1994). Blocks were constructed from pulverised power station fuel ash and gypsum, and waste water sludge. Blocks weighing 32 kg each were deposited, totalling 50 tonnes in 1989. Initial colonisation was rapid, with 80 species identified on the reef within two months.

The sublittoral fauna of Swanage Bay has been briefly described, with rich communities noted for the pier piles in Swanage Harbour (Robins & Thurston 1969).

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Chapter 8: Western Channel (Durlston Head to Cape Cornwall, including the Isles of Scilly) (MNCR Sector 8)*

Jon Davies

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Synopsis

The coastline from Durlston Head in Dorset to Cape Cornwall and the Isles of Scilly includes habitats which range from those in the extreme shelter of many inlets to the most severely exposed to wave action in south-west Britain. The Fleet, which lies behind Chesil Beach in Dorset, is the largest lagoon in England and Wales. Estuarine habitats are especially well developed in some of the marine inlets, especially the Tamar and Exe estuaries whilst those typical of wave-sheltered coasts but where full salinity prevails are found in the outer parts of flooded river valleys or ria inlets such as Salcombe Harbour, parts of Plymouth Sound, the Fal and Helford. The Fal is especially notable for the presence of a well developed and extensive bed of maerl, *Phymatolithon calcareum*. Most of the open coast is rocky but extensive sediment areas occur in the Isles of Scilly and support rich intertidal communities and extensive beds of seagrass *Zostera marina*. Rocky intertidal and subtidal communities include many southern species in a wide range of habitats.

8.1 Introduction and overall studies

Sector 8 (Figure 8.1) has a complex coastal geology, ranging from the soft Lias at Lyme Regis to the very hard granite of Cape Cornwall and the Isles of Scilly. Prevailing westerly winds combine with Atlantic swells to frequently subject the open coastline with large waves. These waves erode the different rock types at different rates, the eroded rock being ground down to shingle and sand which is deposited in more sheltered areas. Consequently the open coastline is one of startling contrasts with spectacular cliffs, natural arches, stacks, sea-caves, small secluded sandy coves, sandy beaches and extensive shingle banks.

Marine inlets punctuate the coastline, sheltered havens which have very different marine communities to those encountered on the open coast. These marine inlets are mainly drowned river valleys, or rias. Rias differ from estuaries in having a low freshwater input in proportion to their volume which results in near fully saline conditions even in the upper reaches. Also, they are often steep-sided with rocky shores and, in some locations, rocky subtidal habitats occurring in very sheltered conditions. Estuarine conditions are present in some inlets and may be extensive where a large river enters the system. The southern and westerly position of this region in Great Britain provides suitable climatic conditions for the growth and development of many species of animal and plant more commonly found in southern Europe and the Mediterranean. The composition of the south-west Britain biota therefore has a distinct southern character.

All the features described above combine to produce an area of considerable marine biological importance.

* 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.

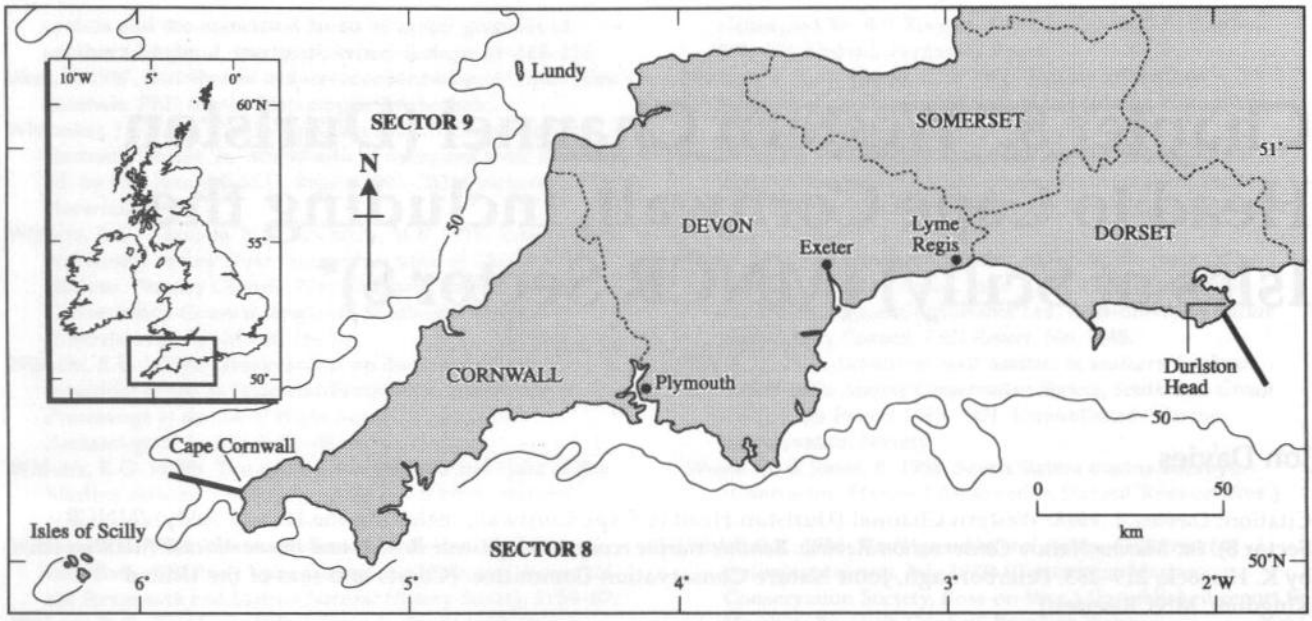

Figure 8.1. MNCR Sector 8.

Many early naturalists were attracted to the region and, reflecting this interest, the Marine Biological Association (MBA) laboratory was established at Plymouth in 1884. Pioneering studies on the structure and distribution of marine habitats and communities were undertaken in the vicinity of Plymouth and the results from many of these studies have been published in the *Journal of the Marine Biological Association of the United Kingdom*. In addition, the MBA published three editions of the *Plymouth Marine Fauna*, the latest edition in 1957, which describes the main collecting grounds and lists all species recorded from Plymouth and adjacent areas. In 1970, the Natural Environment Research Council (NERC) established the Institute for Marine Environmental Research (IMER) at Plymouth and, now as the Plymouth Marine Laboratory within the NERC Centre for Coastal and Marine Sciences (CCMS), occupies the IMER laboratory and the MBA laboratory.

Most descriptive studies of marine communities have concentrated on restricted areas, while only a few studies have investigated large areas in a comparative manner. One of the first studies to encompass many sites throughout the western Channel was a study of littoral communities by Crisp & Southward (1958). They described in detail east–west trends in physical environmental factors such as temperature and tidal oscillations, and related these factors to the distribution of littoral species. Species distributions on both the English and French coasts were summarised by diagrams; an example is presented in Figure 8.2. Crisp & Southward (1958) concluded that temperature was the main environmental factor which influenced the distribution of littoral species within the western and eastern Channel.

Sublittoral habitats and their associated communities within the English Channel were described by Holme (1961; 1966) and later by Cabioch *et al.* (1977). Holme (1966) reported the results of 311 anchor-dredge samples taken throughout the Channel. Seven faunistic associations (after Jones 1950) were described:

1. Boreal shallow sand association.
2. Boreal shallow mud association.
3. Boreal offshore sand association.
4. Boreal offshore muddy sand association.
5. Boreal offshore mud association.
6. Boreal offshore gravel association.
7. Boreal offshore muddy gravel association.

The distribution of these associations is shown in Part 1, Figure 22 of this volume.

The Nature Conservancy Council (NCC) commissioned two major marine biological studies which described many sites throughout the region. The Marine Biological Association/Scottish Marine Biological Association Intertidal Survey Unit surveyed and described marine communities present in the littoral zone (Powell *et al.* 1978; Bishop & Holme 1980). Subsequently, the Field Studies Council (FSC) Oil Pollution Research Unit undertook a project to survey and describe the Harbours, Rias and Estuaries of south-west Britain (Figure 8.3). The latter study considered the littoral and sublittoral environment and also included sites on the open coast adjacent to each marine inlet.

In recent years conservation of estuaries has assumed considerable importance and a number of review studies have been undertaken to collate data on the estuarine resource. Davidson *et al.* (1991) provided an overview of the British estuarine resource, their wildlife, present conservation status, and human activities. Buck (in

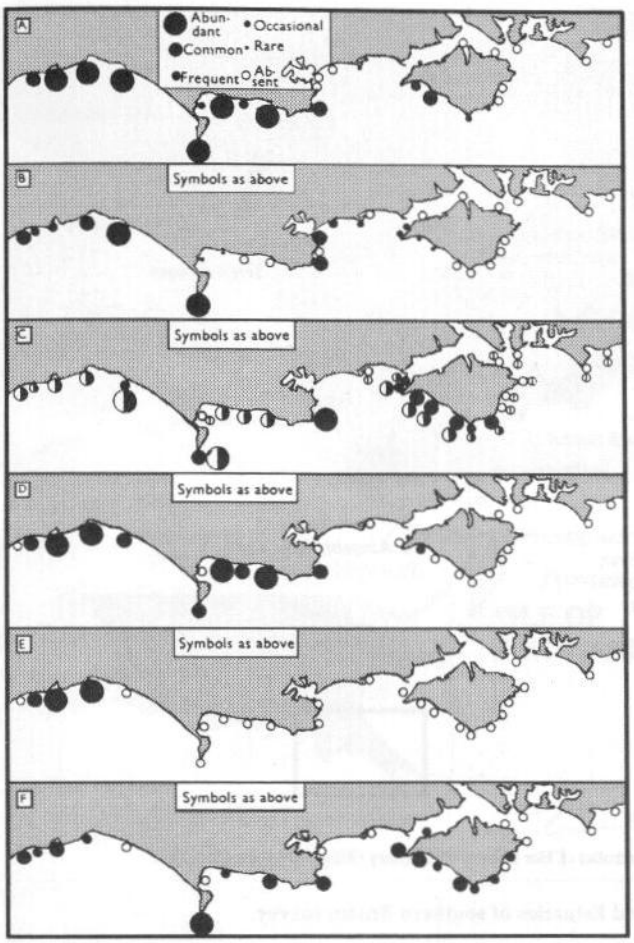

Figure 8.2. Distribution in the 1950s of some species with geographical limits of distribution in the Channel. A: *Chthamalus stellatus* (identification is prior to separation into two species); B: *Balanus perforatus*; C: *Patella aspera* (now *Patella ulyssiponensis*) (filled or open circles) and *Patella depressa* (half black or barred circles); D: *Gibbula umbilicalis*; E: *Monodonta lineata*; F: *Littorina* (now *Melarhaphe*) *neritoides*. (After Crisp & Southward 1958.)

prep.) provides summaries of the physical characteristics, the wildlife features, human use, and conservation status of 15 estuaries in Sector 8.

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 1993). This volume described the results of a literature review for 22 estuaries and coastal areas in England and Wales including the Exe, Salcombe and Kingsbridge, Plymouth Sound and the Tamar, and the Fal/Ruan and Helford estuaries in Sector 8. Data were presented on species richness and distribution. Potts & Swaby (1993) 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.

Estuarine habitats are extensively sampled by the Environment Agency (the National Rivers Authority up to 1996) and, although their data are available, the information has not been widely disseminated and is not described here.

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. Bamber *et al.* (1992) described the ecology of brackish-water lagoons in Britain including information on their physical characteristics, the flora and fauna; some of the sites considered were located in Sector 8. They also presented the results of detailed analyses which aimed to improve the understanding of the factors that define the lagoonal status and to classify the lagoons according to their biotic components. The same study highlighted areas that require further investigation and offered guidelines for the conservation management of these lagoons. To assess the extent of lagoons in England, 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 owing to different sampling regimes and inconsistent species identification. Data were summarised by geographical area, including south-west Britain.

8.2 Dorset (Durlston Head to Lyme Regis including Lyme Bay)

8.2.1 Durlston Head to Weymouth Bay

Durlston Head and Isle of Portland (Figure 8.4) are limestone outcrops which enclose a section of coast where the chalk downs of Dorset meet the sea. Chalk is a relatively soft rock which has been eroded to form some magnificent natural structures such as the great arch of Durdle Door and the oyster-shaped Lulworth Cove. Descriptions of the marine biology of the Dorset coast extend back to the middle of the 19th century when Gosse (1854) undertook a wide-ranging programme of observation and sampling describing collections made especially in relation to the development of domestic marine aquaria. That early work pointed to a diverse fauna in the area with several species present which were rarely encountered elsewhere in Britain. The coast from Durlston Head to

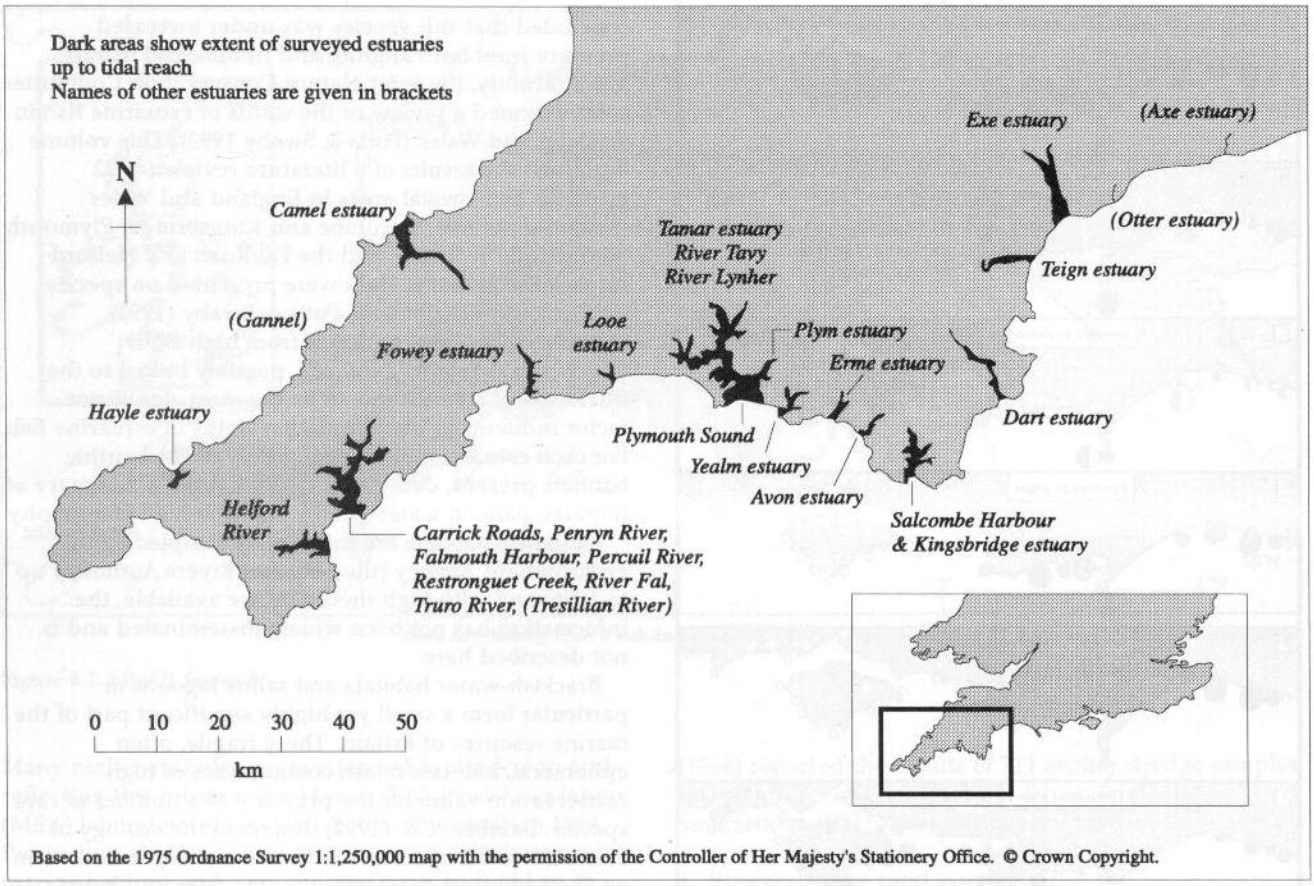

Figure 8.3. The marine inlets surveyed during the Harbours, Rias and Estuaries of southern Britain survey.

Weymouth Bay is notified as a Site of Special Scientific Interest (SSSI), and is part of the Dorset Heritage Coast which includes the Purbeck Voluntary Marine Wildlife Reserve. It is an area of significant marine biological interest; a number of southern species reach the eastern limit of their distribution in the English Channel.

Access to the shore is difficult and consequently the littoral zone has been poorly studied. However, the Kimmeridge area has long been recognised as a site of marine biological importance (for a review see Brachi *et al.* 1978). The Kimmeridge area is a Voluntary Marine Nature Reserve and an annual monitoring programme was established (Collins & Mallinson 1990). The reserve attracts many visitors and an underwater nature trail illustrates the main habitats and communities present (Collins & Mallinson 1989). Dorset County Council sponsored a study of the nearshore sublittoral communities of the Purbeck Coast from Studland Bay to Ringstead (Dixon *et al.* 1978a&b). The results of these surveys were summarised by Roberts *et al.* (1986) who describe ten associations, their composition largely determined by substratum and depth below chart datum. The seabed of the Purbeck coast is a mixture of horizontal ledges, vertical faces and boulder slopes. Tidal streams sweep the area clear of sediment. Horizontal ledges and the upper surfaces of shallow boulders were covered with dense kelp forests with a turf of red algae; vertical faces had abundant encrusting sponges, bryozoans, and solitary and colonial ascidians. In deeper water, boulder communities were dominated by erect species such as the sponge *Stelligera stuposa*, the bryozoan *Flustra foliacea* and dead-man's fingers *Alcyonium digitatum*. Mobile substrata such as sand and loose stones were dominated by gastropod molluscs and hermit crabs, with red algal crusts on the stones. Roberts *et al.* (1986) considered the three-hour stand of low water along this coast (part of the double low water which occurs between Durlston and Portland) as a possible factor responsible for the presence of seaweeds with a generally more southern distribution, for example, *Gigartina acicularis*, *Zanardinia prototypus*, *Padina pavonina* and species of *Cystoseira*. They also drew attention to the absence of the sea urchin *Echinus esculentus* which reduces grazing pressure. The ten habitats and associations identified are listed below.

1. Littoral/sublittoral rock fringe.
   Fucus serratus–Laminara digitata association.
2. Shallow limestone/chalk bedrock and boulders.
   Laminaria hyperborea association.
3. Shale bedrock and boulders.
   Halidrys siliquosa association.
4. Offshore bedrock and boulders.
   Phyllophora crispa association.
5. Deep offshore bedrock and boulders.
   Stelligera stuposa–Flustra foliacea association.

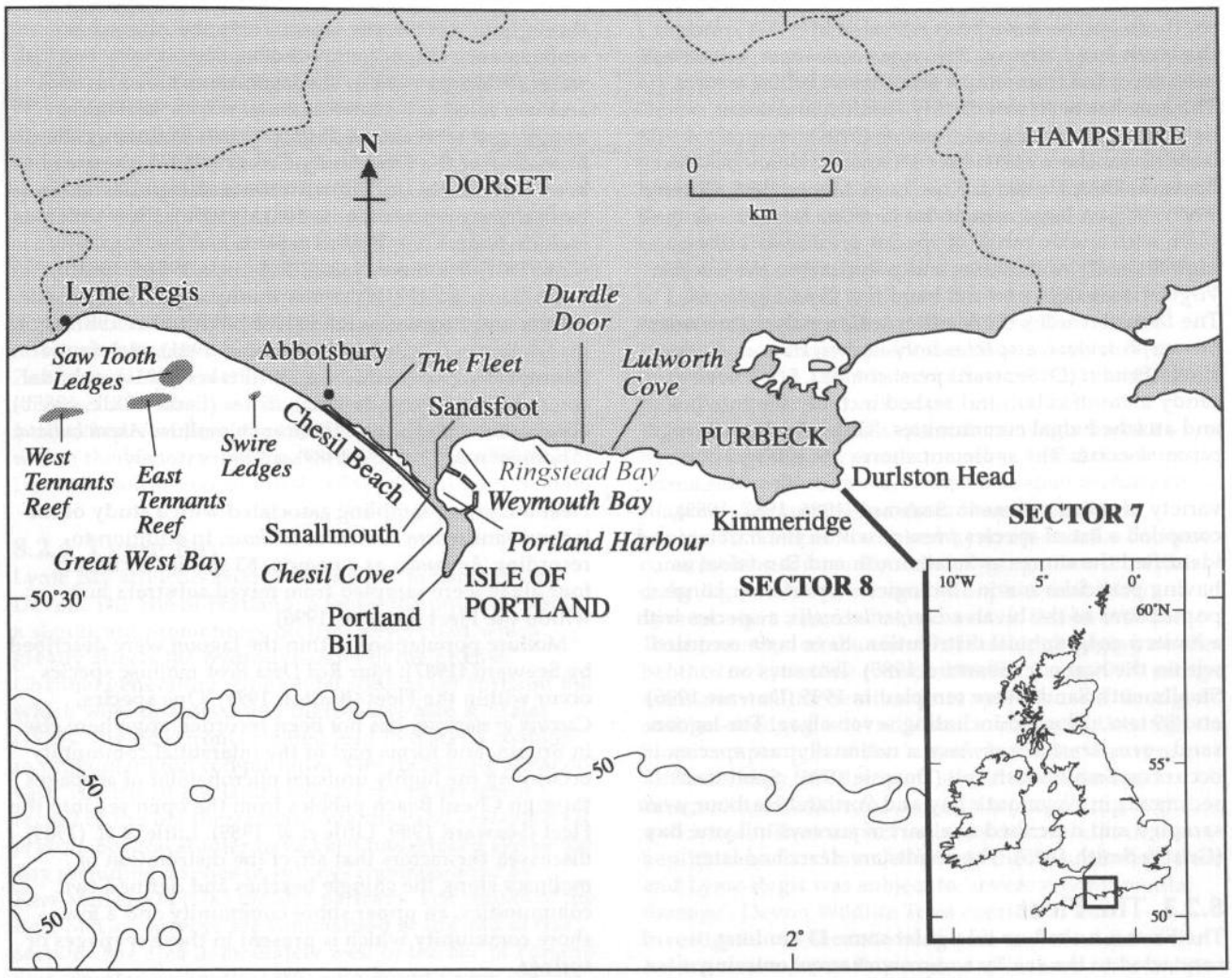

Figure 8.4. The coastline from Durlston Head to Lyme Regis showing the location of places mentioned in the text.

6. Shallow vertical rock faces.
   Meredithia microphylla–encrusting sponge association.
7. Deep vertical rock faces.
   Pachymatisma johnstonia–Alcyonium digitatum association.
8. Shell gravel/maerl.
   Gibbula magus–Phymatolithon calcareum association.
9. Sand.
   Eupagurus [now *Pagurus*] *bernhardus–Nassarius* [now *Hinia*] *reticulatus* association.
10. Loose stones and shells on sand.
    Loose-lying *Chorda filum–Laminaria saccharina–Saccorhiza polychides* association.

Weymouth Bay is a sheltered sandy bay where the sand inshore gives way to mud and gravel further offshore. A series of dredge samples revealed that the sediment had a high diversity of bivalves such as *Abra alba* and *Spisula subtruncata*, the American slipper-limpet *Crepidula fornicata* and the brittlestar *Amphiura filiformis* (Spooner & Holme 1961). During a survey of Lulworth Banks, Forster (1961) found the rock surface covered with small red algae and finely branched bryozoans; vertical surfaces were covered with encrusting sponges and bryozoans. Weymouth Bay and adjacent areas have been the subject of annual dredging trips by the Conchological Society since 1973 with the results published in the Society's newsletter (for example: Killeen 1991; Palmer 1990; Symonds 1988). There was an extensive seagrass *Zostera marina* bed extending from Ringstead Bay into Weymouth Bay, with associated fauna including the small gastropod *Rissoa membranacea* (D.R. Seaward pers. comm.).

8.2.2 Portland Harbour

Portland Harbour is a large sheltered water mass enclosed by man-made breakwaters constructed in the latter half of the 19th century. A restricted exchange of water with the open sea leads to slightly elevated water temperatures within the harbour. Consequently, many

southern species have been recorded here, for example the black-faced blenny, *Tripterygion atlanticus*, which has been recorded from only a few sites in British waters. The area has been extensively studied, and some habitats considered of national marine biological importance (for a review see Hiscock & Hannam 1986; Seaward 1987; Howard, Howson & Moore 1988; Downie 1995, 1996). A large area of the harbour forms a soft mud plain with a wide range of species present including a high diversity of molluscs and polychaetes, the sea pen *Virgularia mirabilis* and red band fish *Cepola rubescens*. The fauna includes the Mediterranean polychaete worm *Sternaspis scutata*, a species only known from one other site in Britain (D. Seaward pers. comm.). Shallower sandy areas of sublittoral seabed include rich infauna and attached algal communities. 'Groves' of *Sabella pavonina* occur. The sediment shores have seagrass *Zostera marina* beds and bivalve communities with a rich variety of species present. Seaward (1986, 1987, 1989) compiled a list of species present within the harbour and identified the shores at Smallmouth and Sandsfoot as having particular marine biological importance. Large populations of the bivalve *Loripes lucinalis*, a species with a limited geographical distribution, have been recorded within the harbour (Seaward 1986). Two sites on Smallmouth Sands were sampled in 1995 (Downie 1996) and 89 taxa recorded including seven algae. The lagoon sandworm *Armandia cirrhosa*, a nationally rare species, occurs on Smallmouth spit (Downie 1996). Sublittoral sediments in Weymouth Bay and Portland Harbour were sampled and described as a part of surveys in Lyme Bay (Grist & Smith 1995). The results are described later.

8.2.3 The Fleet

The Fleet is a shallow tidal inlet some 13 km long connected to the sea by a narrow channel entering Portland Harbour (Figure 8.5). Tidal streams up to 4 knots (2 m s^{-1}) have been recorded within the channel. Sea water percolates through Chesil Bank influencing salinity along the length of the Fleet. Low freshwater input results in fully saline or polyhaline conditions throughout most of the lagoon; only the Abbotsbury embayment at the western end has low-salinity brackish water (Whittaker 1980). The lagoon is notified an SSSI and was rated as a site of national marine biological importance by Holme & Bishop (1980). Following the formation of the Fleet Study Group in 1975, the area has been extensively studied with the results published in two seminar reports (Ladle 1981a, 1985a); these volumes include papers on physical aspects and hydrography (Carr 1981; Whittaker 1981a; Robinson 1981a, 1981b), algae (Burrows 1981), the distribution of the seagrasses *Zostera* and *Ruppia* (Holmes [1985]; Whittaker 1981b), invertebrates (Ladle 1981b; Seaward 1981), meiofauna (Humphrey 1985), ostracods (Whittaker 1981c), subtidal communities (Dyrynda 1985), fishes (Ladle 1981c, 1985b), observations on the opisthobranch mollusc *Akera bullata* (Thompson & Seaward 1989), and an extensive bibliography (Ladle 1985a). Work has continued in the Fleet including sampling associated with a study of the lagoon sandworm *Armandia cirrhosa*. In addition to recording *Armandia* as common, 83 species including four algae were sampled from mixed substrata just within the Fleet (Downie 1996).

Mollusc populations within the lagoon were described by Seaward (1987): four *Red Data Book* mollusc species occur within the Fleet (Bratton 1991). One species, *Caecum armoricum* has not been recorded anywhere else in Britain, and forms part of the interstitial community occupying the highly unusual microhabitat of seepages through Chesil Beach pebbles from the open sea into the Fleet (Seaward 1989; Little *et al.* 1989). Little *et al.* (1989) discussed the factors that affect the distribution of molluscs along the shingle beaches and defined two communities, an upper shore community and a low shore community which is present in these seepages or springs.

A wide range of habitats are present within the lagoon, ranging from tide-swept cobbles and bedrock in the narrows to soft mud in the western embayment. The narrows have a complex series of different habitats with a number of important species including the large

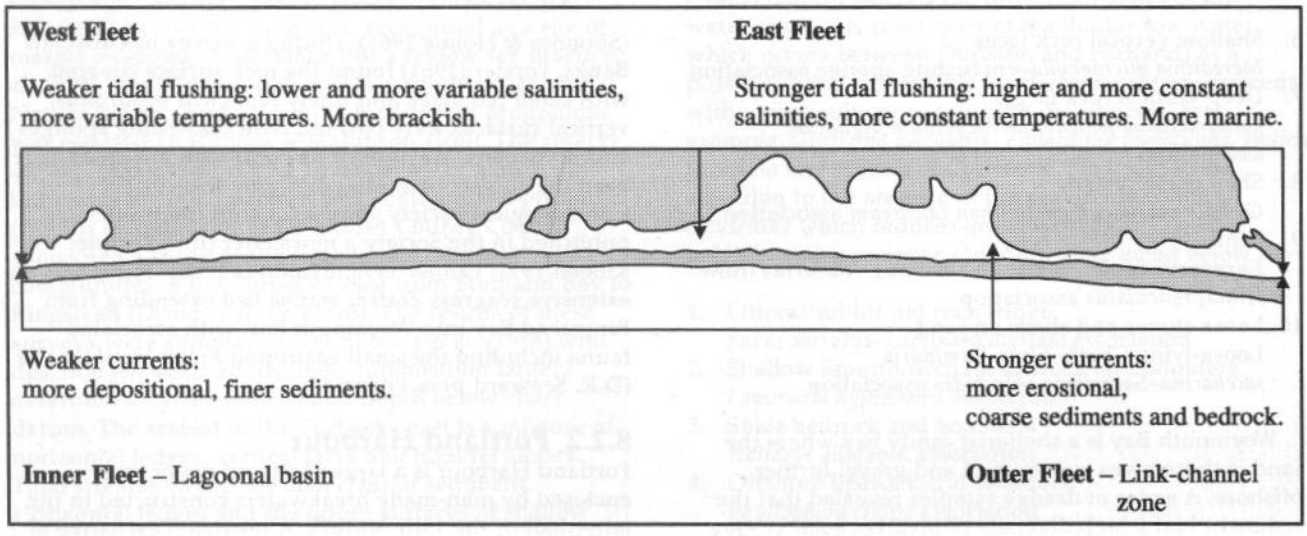

Figure 8.5. A diagrammatic map of the Fleet lagoon showing the major subdivisions in relation to environmental features (from Dyrynda 1984).

mound sponge *Suberites massa*, a species recorded from very few other localities in Britain. The burrowing anemone *Scolanthus callimorphus* had only been found in Weymouth Bay and western Ireland prior to its discovery in the Fleet. The mid-region of the lagoon has extensive narrow-leaved seagrass *Zostera angustifolia* and spiral tasselweed *Ruppia cirrhosa* meadows, which provide food for the Abbotsbury swans. Seagrass beds are restricted to small areas in Britain, and large beds are rarely recorded. Holmes (1983) mapped the distribution of the marine angiosperms within the Fleet and recorded populations of spiral tasselweed *Ruppia cirrhosa*, beaked tasselweed *Ruppia maritima*, narrow-leaved seagrass *Zostera angustifolia*, dwarf seagrass *Zostera noltii*, seagrass *Zostera marina*, and the scarce foxtail stonewort *Lamprothamnium papulosum*. Sublittoral communities within the lagoon were described by Dyrynda (1984) and Dyrynda & Farnham (1985).

8.2.4 Lyme Bay

Lyme Bay stretches from Portland Bill to Exmouth in Devon. The Isle of Portland, a limestone outcrop, forms a significant promontory on the Dorset coast which greatly affects the hydrodynamics of the English Channel generating strong tidal streams off Portland Bill which were described by Pingree, Bowman & Esaias (1978). The tidal fronts created lead to marked changes in phytoplankton communities with increasing distance east. The Isle of Portland provides the easternmost record of the Mediterranean–Atlantic coral *Leptopsammia pruvoti*. Several studies have been undertaken across the Bay including a series of surveys commissioned by Kerr-McGee Oil (UK) plc and partners. The results of the Kerr-McGee surveys are summarised at the end of this section. The area immediately west of the Isle of Portand was sampled by Smith (1985) who found a very diverse fauna with over 350 taxa in 18 samples.

At the eastern end of Lyme Bay, Chesil Bank is a 28 kilometre-long shingle structure – up to 13 m high in places – extending from the Isle of Portland to the west of Abbotsbury. The pebbles are graded from east to west, the size diminishing with increasing distance west. The geomorphology and biology of the shingle bank has been extensively described and is noted for the paucity of marine flora and fauna (Carr 1969). Carr & Seaward (1991) surveyed 11 sections across Chesil Bank and when they compared their results with earlier studies, they concluded that the crestline had receded landward along sections where there had been no sea defence works. Dixon *et al.* (1978a) reported that large boulders in nearshore sublittoral areas at Chesil Cove had a low algal diversity but supported a rich Hydrozoa–Ascidiacea–Porifera community.

The coast between Abbotsbury and the Dorset/Devon border at Lyme Regis is predominantly shingle beaches backed by cliffs. Armitage (1970) described a survey of the littoral fauna of the Axmouth to Lyme Regis nature reserve. At Lyme Regis, the littoral zone is largely composed of soft Lower Jurassic Lias reefs which have considerable geological importance. Apart from geological and physiographic studies there have been few investigations on this coast. The presence of boring molluscs in the rocks at Lyme Regis was noted by Cundall (1887). These mollusc populations include *Pholadidea loscombiana*, for which few other live colonies are known in the British Isles – in Dorset and south Devon and west Scotland (D.R. Seaward, pers. comm.). Mill & Grahame (1990) studied the distribution of the gastropods *Littorina saxatilis* and *Littorina arcana* within Lyme Bay, and noted that *L. arcana* does not occur in the English Channel to the east of Lyme Regis, but has been recorded in the North Sea.

Nearshore sublittoral communities from Chesil Bank to Lyme Regis were surveyed during the Dorset underwater survey (Dixon *et al.* 1978a; Roberts *et al.* 1986). Six associations were described of which four (numbers 1, 2, 3 and 9 listed in Section 8.2.1) had been recorded on the Purbeck coast and two had not: a *Pagurus bernhardus–Maja squinado* association and a hydroid–ascidia–Porifera association. Infralittoral communities were characterised by algae ('*Halidrys siliquosa*' community), while broken bedrock and boulders in deeper water had hydroid–ascidia–Porifera communities. Unusually dense aggregations of hermit crabs *Pagurus bernhardus* and the spider crab *Maja squinado* were recorded at some sites. Devon Wildlife Trust investigated the effects of scallop dredging on the benthos of Lyme Bay (Devon Wildlife Trust 1992) using a assessment of the benthos from spot dives on 'dredged' and 'un-dredged' sites adjacent to a wreck. Although the biotic composition of the 'un-dredged' site was very different from the 'dredged' site, the experimental design did not allow for any differences owing to the wreck itself. Their report includes descriptions of the benthic fauna and concludes that the area between Beer and Lyme Regis was subject to 'severe environmental damage'. Devon Wildlife Trust continued this investigation in the following year and considered the nature conservation importance of inshore reefs in Lyme Bay and the effects of mobile fishing gear (Devon Wildlife Trust 1993a). A highly diverse epibenthic community was described on these reefs which were estimated to account for 7% of the benthos of Lyme Bay; data were provided for eight reef areas. The communities described were similar to those included in a more intentive survey in 1994 (Cleator 1995) descibed later. A population of the sunset coral *Leptopsammia pruvoti* was recorded, one of only a few locations known for Britain. Extensive populations of the sea fan *Eunicella verrucosa* were present on East Tennants Reef off Lyme Regis, for which no similar population has been recorded to the east, and were considered equivalent to the population described by Hiscock & Moore (1986) for Plymouth Sound. Devon Wildlife Trust (1993a) discussed methods to conserve these reefs by controlling fishing effort, particularly scallop dredging, and implementing some form of site protection.

Sublittoral sediment communities in the centre of Lyme Bay were described by Eagle & Hardiman (1977). The community present was classified as an *Echinocardium cordatum/Amphiura filiformis* community (after Petersen 1918) although the samples were numerically dominated by the polychaetes *Chaetozone setosa* and *Magelona filiformis*. Eagle *et al.* (1978) surveyed the infaunal assemblages at the sewage sludge disposal sites within Lyme Bay and reported that the

macrofaunal community was a classic *Echinocardium cordatum/Amphiura filiformis* community. These species were not the most numerically dominant although they were, together with the gastropod *Turritella communis*, the most conspicuous organisms; a total of 116 species was recorded. Holme (1950) collected samples throughout Lyme Bay during a study of the wider area of Great West Bay.

The surveys of Lyme Bay undertaken for Kerr-McGee in 1994 describe the communities found on sand and mud shores (Smith 1995a), cobble and boulder shores (Smith 1995b), rocky shores (Rostron & Little 1995), in sublittoral sedments (Grist & Smith 1995) and on the surface of sublittoral soft and hard substrata (Cleator 1995). Eight sediment shores were sampled in inlets and West Bay and Lyme Regis harbours. The Fleet and the lower Exe estuary were considered to have a particularly high species richness. The five sites surveyed on cobble and boulder shores had impoverished examples of rocky shore communities. Eighteen rocky shore sites were surveyed, including steeply sloping shores exposed to strong wave action, bedrock and boulder shores and rock platforms: five different shore types were identified. Beer Head was especially mentioned for its chalk caves and algal communities, those in deep fissures not being seen elsewhere in Lyme Bay. It was noted that the algal communities were distinctly different on hard and soft rocks. Large pools with luxuriant algal communities were present on some moderately exposed shores. Crusts of the tube-building worm *Sabellaria alveolata* were present on rocks adjacent to sand.

Samples of sublittoral sediment infauna were taken from a grid of 44 stations. Seven groups of sites were identified; their distribution is illustrated in Figure 8.6 and the main features of infauna described below.

A. **Mixed sediment**. The dominant species were the amphipod *Ampelisca spinipes*, which appears to be typical of stable, muddy sand, the polychaete *Aricidea catherinae* and the amphipod *Urothoe elegans*. The high gravel content allows for some epifauna, while a modest silt content was suitable for deposit feeding bivalves such as *Abra alba* and *Corbula gibba*.

B **Offshore slightly muddy sand**. The typical species were those to be found in mud communities. The bivalve *Corbula gibba*, the amphipod *Bathyporeia tenuipes*, the polychaetes *Chaetozone setosa* and *Magelona filiformis* and the bivalve *Nucula nitidosa* were much more common in Group B than in other groups.

C **Offshore mixed sediment with stones**. These were tide-swept areas of coarse sediments with attached epifauna. There were large numbers of the worms *Lumbrinereis gracilis* and *Praxillella affinis* together with smaller numbers of the species noted above for Group A. Many of the dominant species were associated with the stones or epifauna including the brittlestar *Amphipholis squamata* and the syllid worms including *Sphaerosyllis taylori*.

D **Mud**. Only one site in Lyme Bay was characteristic of this cluster, which otherwise included sites in Portland Harbour and Weymouth Bay. All of the sites were colonised by the worms *Melinna palmata* and *Chaetozone* sp. (possibly an undescribed species), *Magelona minuta* and the bivalve *Abra alba*. This assemblage of species also occurs in Group B but in lower numbers and may thrive in the more anoxic conditions of muddy habitats. Two polychaetes, *Sternaspis scutata* and *Monticellina dorsobranchialis* were important in Portland Harbour but not other sites.

E **Inshore sandy gravel**. Sites in this group were pockets of sediment in rocky or gravelly areas. The community had high species diversity suggesting stable conditions and was considered a modification of the more typical Lyme Bay fauna represented in Group F and G. Dominant species of this grouping were the worm *Lumbrinereis gracilis* and bivalve *Corbula gibba* which were equally common in other areas, the worms *Mediomastus fragilis* (characteristic of muddy sediments) and *Pisione remota* (a gravel species). The tube-building amphipod *Photis longicaudata* was present in small numbers at some sites, possibly associated with hydroids.

F **Offshore sand**. Characteristic species were typical of clean (mobile) sand and sites were in or adjacent to bands of mega-rippled sand which arched across the bay. Species present included the amphipod *Bathyporeia elegans*, the polychaetes *Ophelia borealis* and *Nephthys cirrosa* and the sea urchin *Echinocyamus pusillus*.

G **Inshore sediment**. Sediment composition was variable although both sites in this group had a fairly high gravel content. Both sites had small numbers of each species present although the polychaete *Poecilochaetus serpens* was fairly common.

Grist & Smith (1995) note that the numerically dominant taxa in Group B are in close agreement with those recorded by Eagle & Hardiman (1977) and would be expected to merge with the *Echinocardium cordatum–Amphiura filiformis* community found in the western part of Lyme Bay. Hard substrata surveyed by diving and remotely operated vehicle (ROV) were dominated by red algae in shallow depths and by sponges and bryozoans in deeper water. A total of 253 taxa of algae and animals was recorded and separated into seven groups based on Bray-Curtis similarity index determined from dive survey results. Two of the groups were from sediments. The results of ROV surveys were matched to the diving results and the distribution of the seven communities is shown in Figure 8.6. The communities identified were:

1 ***Calliblepharis ciliata/Phyllophora crispa* on infralittoral bedrock reefs**. This community was typified by a luxuriant and diverse algal flora on horizontal surfaces with the trumpet anemone *Aiptasia mutabilis* and the sponge *Haliclona simulans*, large tubiferous polychaetes and the tompot blenny *Prablennius gattorugine* conspicuous on vertical surfaces.

2 **Mobile epifauna on unstable sand and gravel dominated areas**. This community was dominated by

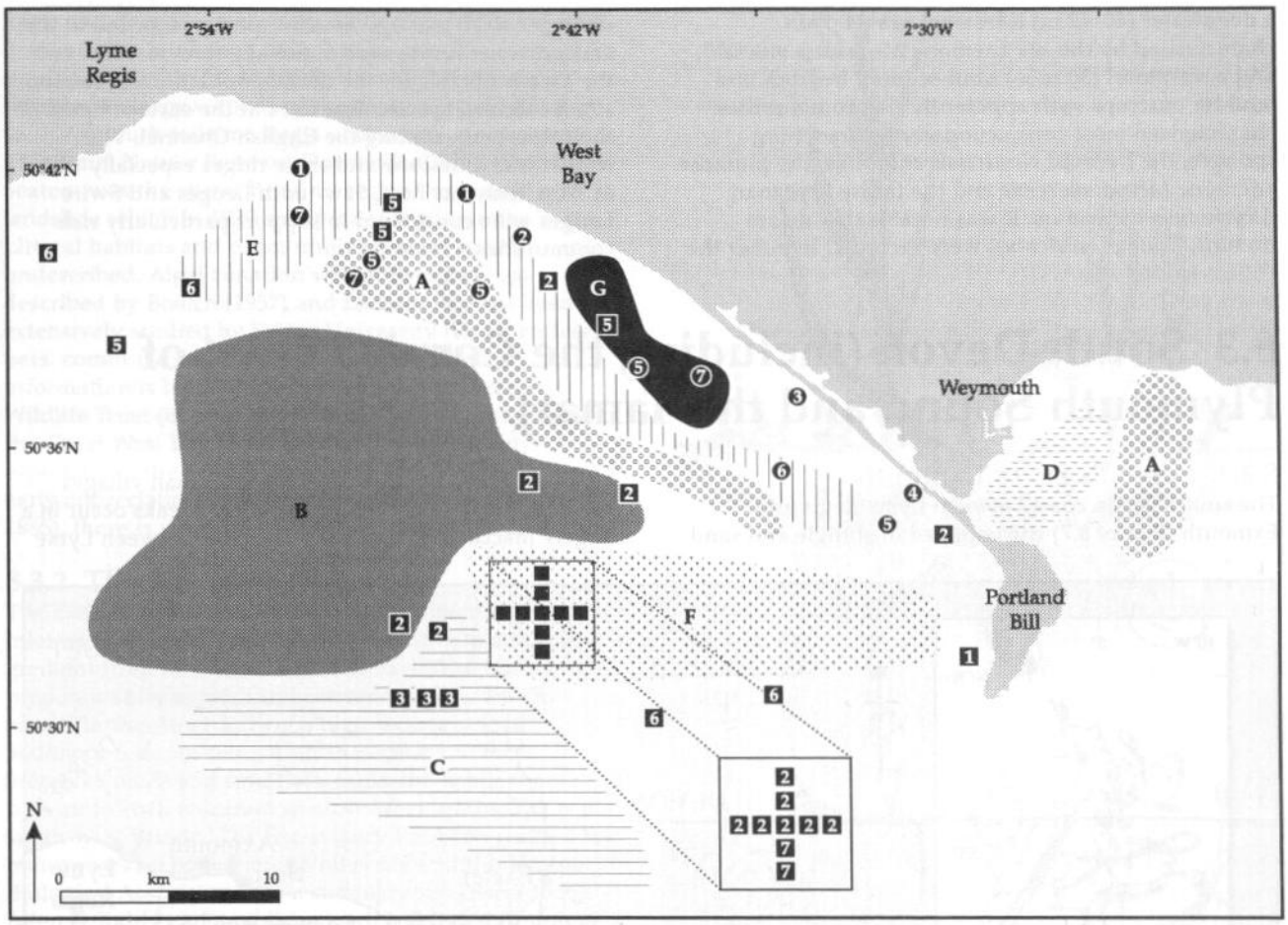

Figure 8.6. Distribution of infaunal communities in Lyme Bay and Weymouth Bay and Portland Harbour derived from cluster analysis and shown as likely extent. Location of hard substratum communities derived from cluster analysis and shown as spot locations. Groups are keyed and described in the text. (From Grist & Smith 1995 and Cleator 1995.)

infaunal burrowing species with mobile epifauna and fauna attached to cobbles and pebbles.

3 **Hydroids/*Pagurus* on stable shell gravel and pebbles**. A more diverse fauna than community 2 including infaunal burrowers and epifauna on the larger sediment particles.

4 **Ephemeral and mobile epifauna/epiflora on inshore mobile cobbles**. The community had low species richness and was dominated by mobile decapods, solitary tunicates (*Ascidiella scabra*), the barnacle *Balanus crenatus* and ephemeral, filamentous brown and red algae. The holothurian *Thyone* sp. was recorded in the sediment.

5 ***Pentapora/Eunicella*/Porifera on offshore bedrock and boulders**. This community occurred predominantly on bedrock in depths of 19 to 25 m. The communities were diverse with high abundances and visually dominated by species such as the ross *Pentapora foliacea*, the sponges *Iophon ingalli* and *Axinella dissimilis* and the sea fan *Eunicella verrucosa*. The vertical edges of rock terraces supported large colonies of the sponge *Pachymatisma johnstonia* and the jewel anemone *Corynactis viridis*.

6 **Hydroid bryozoan turf/occasional *Pentapora* on mixed boulders, cobbles, pebbles and muddy gravel**. Although similar, the community was less diverse than community 5 with fewer large erect species. A hydroid turf was generally well developed, with the encrusting tubeworm *Pomatoceros triqueter*, encrusting bryozoans and mobile species such as the starfish *Asterias rubens* and the whelk *Buccinum undatum* particularly conspicuous.

7 **Porifera/tunicate/hydroids on flat bedrock with occasional boulders and gravel**. The characterising species were similar to those of community 5 but with more mobile epifauna and, at some sites, solitary tunicates including the rarely recorded *Phallusia mammilata*. Sessile species tolerant of sand cover were notable and included the sponges *Ciocalypta penicillus* and *Adreus fascicularis*. The sponge *Dysidea pallescens* was also recorded from this community and for the first time in Great Britain.

The report of the ROV survey emphasised large conspicuous species in its account of sites and separated descriptions into 11 main habitats. In addition to the habitats surveyed by diving, the ROV survey identified

a deepwater (40–42 m) tideswept gravel plain characterised by the sea anemone *Mesacmaea mitchelli*, and circalittoral (30 m +) sand-scoured bedrock and boulder outcrops with apparently rich communities characterised most conspicuously by branching sponges, the hydroid *Nemertesia antennina*, the plumose anemone *Metridium senile* and the fleshy bryozoan *Alcyonidium diaphanum*. It was notable that no sea urchins, *Echinus esculentus*, were recorded in either the diving or ROV surveys. Several species recorded in this and previous surveys are nationally rare or scarce and the area is notable for the dense populations of several south-western species near to or at the eastern limits of their distribution along the English Channel. The circalittoral limestone and shale ridges especially those at West Tennants Reef, Saw-tooth Ledges and Swire Ledges were considered to support particularly rich communities.

8.3 South Devon (including the Cornish coast of Plymouth Sound and the Tamar)

8.3.1 Lyme Regis to Exmouth

The south Devon coast between Lyme Regis and Exmouth (Figure 8.7) is comprised of shingle and sand beaches backed by high cliffs. Several small villages nestle at the base of these cliffs where breaks occur in a largely inaccessible coastline. The cliffs between Lyme

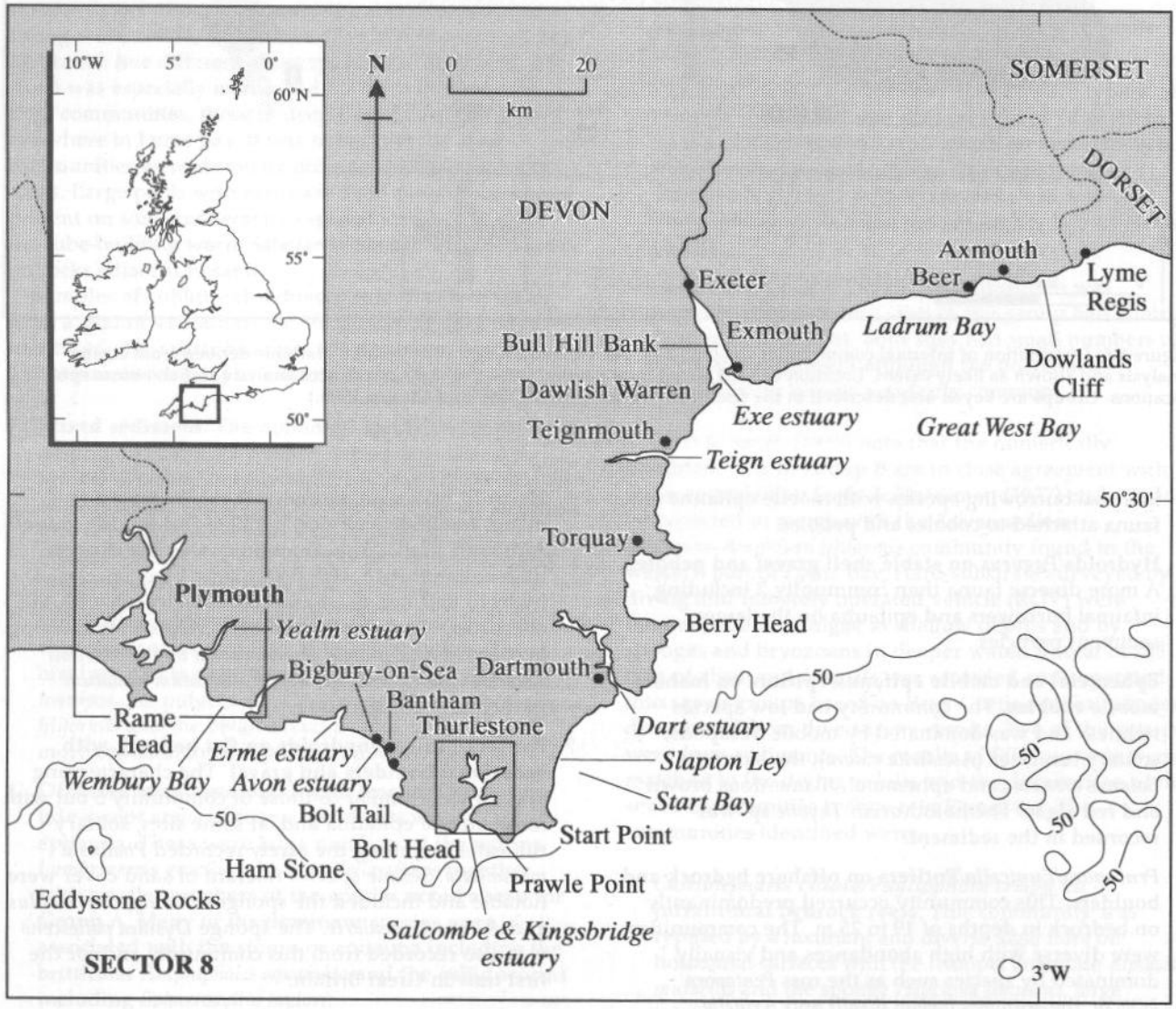

Figure 8.7. The central part of Sector 8, showing the location of places mentioned in the text. Salcombe Harbour and the Kingsbridge estuary and Plymouth Sound and estuaries are enlarged in Figures 8.10 and 8.11.

Regis and Beer are chalk cliffs while those from Beer to Exmouth are sandstone cliffs. These cliffs have significant geological and palaeontological interest, resulting in large sections of the coast being notified an SSSI; Axmouth to Lyme Regis undercliffs are designated a National Nature Reserve. Dowlands Cliff, to the east of Seaton, was the site of Britain's biggest recorded landslide which in 1839 sent 8 ha of land into the sea. Littoral habitats and communities remain largely undescribed. Algal zonation within Beer Bay was described by Boalch (1957) and Ladram Bay has been extensively studied by Exeter University (Dr D. Laffoley, pers. comm.); a large amount of unpublished information is held by the University. The Devon Wildlife Trust (in prep.) have undertaken survey work in the Great West Bay (from Portland to Start Point) especially in the area of Torbay for which, despite the early appreciation of its variety of marine life (Gosse 1865), there is very little published information.

8.3.2 The Exe estuary

The Exe estuary is a predominantly sedimentary marine inlet with a high freshwater input leading to a salinity gradient from north to south. The River Exe has a large, predominantly agricultural catchment area, which results in the water having a high sediment load. Sediment is deposited within the estuary to form extensive mud- and sandflats, estuarine habitats not present to such an extent in most other marine inlets in south-west Britain. The Exe estuary has been studied for many years by both Exeter University and the Marine Biological Association (for a summary see Dixon 1986). Allen & Todd (1902) published a detailed description of the marine natural history of the Exe estuary. Their account has become a valuable reference text against which more recent habitat changes may be evaluated. Holme (1949) completed a detailed investigation of the effects of sediment type on macroinvertebrate community structure in which sediment type and silt content were closely correlated with species distribution. Harris (1980) described five areas on and adjacent to Bull Hill Bank off Exmouth, each with distinctive substrata. Diagrams of the communities present at three of these sites are presented in Figure 8.8. Each area supports a clearly distinguishable faunistic association:

- a muddy shore *Spartina/Scrobicularia* community;
- a sandy shore *Arenicola/Cerastoderma* community;
- a well drained sandy *Ophelia* community;
- a heavily scoured *Ophelia* community;
- a *Mytilus* community.

The estuary was surveyed by the FSC as part of the survey of marine inlets in southern Britain (Dixon 1986). A comparison of the results of Allen & Todd (1902) with those of Dixon (1986) did not suggest any significant changes. Dixon (1986) concluded that the sedimentary communities of the Exe estuary are representative of their type [for a large estuary with significant freshwater flow] in south-west Britain.

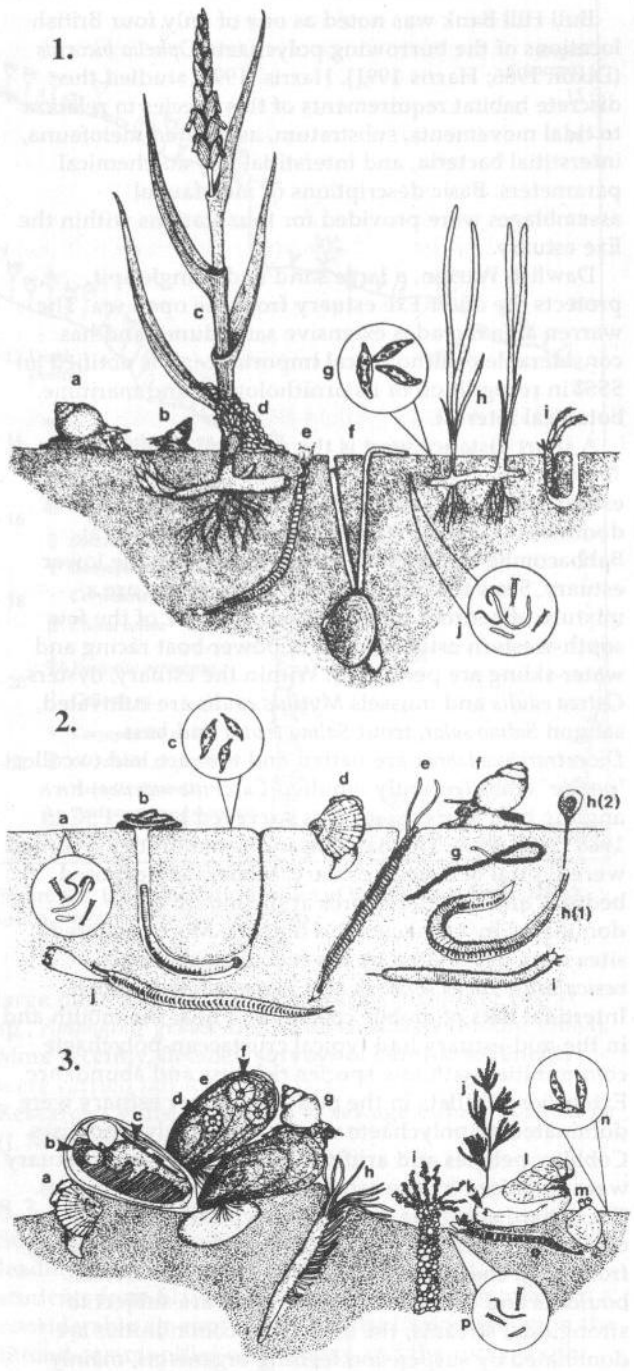

Figure 8.8. Three of the sediment communities identified in the Exe estuary (from Harris 1980).

1. Mud-shore community. a. *Littorina* sp. b. *Hydrobia ulvae*, c. *Spartina anglica*, d. *Vaucheria* sp., e. *Neanthes* (now *Hediste*) *diversicolor*, f. *Scrobicularia plana*, g. surface diatoms, h. *Zostera hornemanniana* (now *Zostera angustifolia*), i. *Corophium volutator*, j. meiofauna.

2. Sandy-shore community. a. meiofauna, b. *Arenicola marina*, c. Surface diatoms, d. *Cerastoderma edule*, e. *Nerine cirratulus*, f. *Littorina littorea*, g. *Cephalothrix rufifrons*, h. (1) *Scoloplos armiger*, h. (2). the egg-mass of *Scoloplos*, i. *Nephtys cirrosa*, j. *Glycera alba*.

3. *Mytilus* community. a. *Cerastoderma edule*, b. *Pinnotheres pisum*, c. *Mytilicola intestinalis*, d. *Elminius modestus*, e. *Mytilus edulis*, f. *Semibalanus balanoides*, g. *Littorina littorea*, h. *Cirriformia tentaculata*, i. *Lanice conchilega*, j. *Dynamena* (now *Sertularia*) *argentea*, k. *Pomatoceros triqueter*, l. *Crepidula fornicata*, m. *Spisula solida*, n. surface diatoms, o. *Eunereis* (now *Nereis*) *longissima*, p. meiofauna.

Bull Hill Bank was noted as one of only four British locations of the burrowing polychaete *Ophelia bicornis* (Dixon 1986; Harris 1991). Harris (1991) studied the discrete habitat requirements of this species in relation to tidal movements, substratum, associated meiofauna, interstitial bacteria, and interstitial physio-chemical parameters. Basic descriptions of meiofaunal assemblages were provided for four stations within the Exe estuary.

Dawlish Warren, a large sand and shingle spit, protects the outer Exe estuary from the open sea. The warren area includes extensive sand dunes and has considerable ornithological importance; it is notified an SSSI in recognition of its ornithological and maritime botanical interest.

A short distance west is the port and holiday resort of Teignmouth. The Teign estuary is a small sheltered estuary with soft sedimentary substrata being the dominant estuarine habitat. A narrow entrance at Babbacombe creates strong tidal streams in the lower estuary. Seaward of the narrows, the shores are a mixture of bedrock and boulders. It is one of the few south-western estuaries where power-boat racing and water-skiing are permitted. Within the estuary, oysters *Ostrea edulis* and mussels *Mytilus edulis* are cultivated, salmon *Salmo salar*, trout *Salmo trutta* and bass *Dicentrarchus labrax* are netted and tiles are laid to collect 'peeler' crabs (recently moulted *Carcinus maenas*) for angling bait. The estuary was surveyed by the FSC in 1988 (Frid 1989). The habitats and communities recorded were typical of a small estuary. Moderately exposed bedrock and boulder shores at the mouth were dominated by barnacles and limpets. More sheltered sites were dominated by the fucoid algae, *Fucus vesiculosus*, *Fucus serratus* and *Ascophyllum nodosum*. Intertidal flats of mobile coarse sand near the mouth and in the mid-estuary had typical crustacean-polychaete communities with low species richness and abundance. Extensive mudflats in the mid- and upper estuary were dominated by polychaete worms and bivalve molluscs. Cobbles, pebbles and artificial walls in the upper estuary were colonised by the estuarine algae *Fucus ceranoides*. These hard substrata exhibited a typical change in community composition with increasing distance away from open coast fully saline conditions. Sublittoral boulders and cobbles near the mouth are subject to strong tidal streams; the associated communities are dominated by suspension feeding organisms, mainly sponges, hydroids and ascidians.

Immediately offshore of the Teign estuary, a survey of the shallow sublittoral sediments (Smith 1990) in an area about 6 km × 3 km revealed five main communities. Most sites belonged to a "shallow/intermediate depth mud community" with the bivalve *Abra alba*, the turret shell *Turritella communis*, the worms *Magelona filiformis* and *Melinna palmata* and the burrowing sea urchin *Echinocardium cordatum*.

8.3.3 Dawlish to Start Point

The long sweeping coastline from Dawlish to Start Point forms the western boundary of Great West Bay. It is composed of a multiplicity of geological forms brought about through a complex succession of rock types varying between limestone, shales, grits and igneous dolerite, for example the large natural arches of London Bridge and Daddyhole, a great cleft in the cliff. Sheltered from the prevailing westerly winds, it has many sandy bays. These beaches attract a large number of visitors, where Torquay and the other local seaside towns depend upon the tourist industry for a large proportion of their income. The Devon Wildlife Trust (in prep.) describe Torbay as "the jewel in south Devon's crown" for marine wildlife. They point to the profusion of animal species in damp shaded locations on the shore, citing particularly the limestone wall of Princess Pier in Torbay and noting that Torre Abbey Sands is the only littoral site in the Bay for seagrass *Zostera marina*. Underboulder communities were characterised by a particularly high diversity of sponges and decapod crustacea. The wide range of fish species recorded included the nationally scarce Connemara clingfish *Lepadogaster candollei*. The honeycomb worm *Sabellaria alveolata* was noted as frequently consolidating boulder areas on shores. These reefs were considered exceptionally well developed at Ladram Bay. Rock platforms had rich in algal communities, including some rare species such as the peacock's tail *Padina pavonina* and the red alga *Gigartina teedii*.

Inshore areas of Torbay are predominantly soft muddy sands with communities characterised by the heart urchin *Echinocardium cordatum* and brittlestars *Amphiura* spp. and *Ophiura* spp., whereas cleaner sands close inshore held dense populations of razor shells *Ensis* spp., heart urchins *Echinocardium cordatum* and seagrass *Zostera marina* (Devon Wildlife Trust in prep.). Communities of polychaete worms within Torbay were described by Elwes (1908). Piddocks *Pholas dactylus* occurred in rock, submerged peat and clay substrata in Torbay. Sublittoral limestone rock pinnacles were considered especially rich with sea squirts, sea anemones and sponges common. Where the seabed becomes muddy, burrowing species including the angular crab *Goneplax rhomboides* and the red band fish *Cepola rubescens* were reported (Devon Wildlife Trust in prep.). The offshore seabed fauna of Great West Bay was extensively studied by Holme (1966). The substratum was relatively uniform, the community present was characterised as a 'Boreal offshore muddy-sand association'; a community which corresponds to Petersen's (1918) '*Echinocardium–filiformis*' community. These communities were dominated by bivalve molluscs, holothurians (sea cucumbers) and other echinoderms.

Berry Head is a Middle Devonian limestone outcrop and, though much changed by the quarrying of limestone, the area has considerable nature conservation importance for nesting seabirds and its cliff vegetation; it is designated a Local Nature Reserve. The limestone has been eroded leading to the formation of caves, an uncommon marine habitat. Marine communities within the caves were described by Proctor (1985). Littoral caves pepper the headlands and islets of Torbay, and at Berry Head many extend into the sublittoral or are entirely sublittoral. The communities were described as "a colourful patchwork of tubeworms, barnacles, sponges, anemones, hydroids and sea squirts with fish and crustaceans common" by Devon Wildlife Trust (in prep.).

However, the marine biology of the caves remains incompletely described. Littoral habitats and communities of Berry Head were described by McCarter & Thomas (1980) in a study of south Devon. Algae were sparse; the communities were characterised by limpets, mussels *Mytilus edulis* and barnacles. Well developed lichen communities were recorded from the splash zones. Warner (1971) studied dense beds of the brittlestar *Ophiothrix fragilis*, and Hughes (1977) studied the ecology of hydroids off Berry Head.

8.3.4 The Dart estuary

The Dart estuary is very sheltered and an important pleasure boating area. A considerable freshwater input leads to a marked salinity gradient along the inlet. Dartmouth has a long seafaring history and is the site of the Britannia Royal Navy College. The town is a very popular tourist centre and has a large marina. These developments have had a marked effect on the water quality within the system; concentrations of the antifoulant tributyltin (TBT) were very high in the Dart (Bryan *et al.* 1986), until its use was banned for small boats.

Littoral and sublittoral habitats in the middle and upper estuary are predominantly mud with occasional rock outcrops. In the lower estuary, muddy shores and adjacent sublittoral areas incorporate shingle with bedrock and other hard substrata. The mouth of the estuary has steep Dartmouth slate bedrock extending into the sublittoral. An early sublittoral survey at three sites at and near the mouth of the Dart was described by Forster (1954, 1955). Turbid conditions limits algal growth to shallow water; the communities in deeper water were dominated by sea fans, *Eunicella verrucosa*, the soft coral *Alcyonium glomeratum* and the anemones *Corynactis viridis*, *Epizoanthus wrightii* (now *Epizoanthus couchii*) and *Actinothoë sphyrodeta*. Forster (1954) drew diagrammatic profiles of sublittoral habitats at Stoke Point at the mouth of the Dart estuary (Figure 8.9). The Dart was surveyed by the FSC (Moore 1988a). Exposed rocky shores at the mouth had extensive splash zones (extending 15 m above chart datum) with well developed lichen communities. Mid-shore habitats were dominated by barnacles and limpets. With increasing shelter, mid-shore habitats became characterised by algae. Rocky habitats within the lower and middle estuary had typical fucoid-dominated communities. There appeared to be a gradual change in community structure with decreasing salinity rather than an abrupt change. Moore (1988a) considered the community recorded on steep upper and mid-shore bedrock in the upper reaches of the estuary to be of regional or possibly national marine biological importance. This community was dominated by the brackish-water alga *Fucus ceranoides* and the estuarine barnacle, *Balanus improvisus*. Mudflats within the estuary were considered to have a low species richness but high biomass. Ragworm *Hediste diversicolor* was abundant throughout the estuary; all the infaunal communities were dominated by polychaete worms. Sublittoral habitats were predominantly composed of muddy pebbles and cobbles, with sponges, hydroids and anemones characterising the communities recorded. Dredge samples of muddy sediments revealed

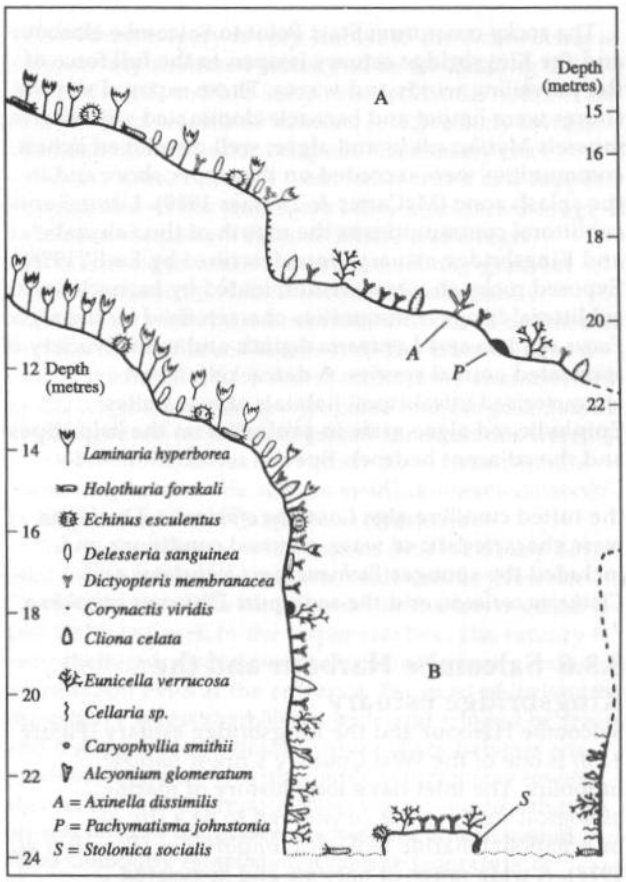

Figure 8.9. Diagrammatic profiles of the rocks at Stoke Point, south Devon (from Forster 1954).

large numbers of polychaete worms including *Tharyx* sp., *Ampharete grubei* and *Melinna palmata* (Moore 1988a). More recently, detailed surveys of benthic sediments were carried out for South West Water by the FSC Research Centre in relation to sewage effluent discharge (J. Moore pers. comm.).

8.3.5 Start Bay

Start Bay has a series of shingle banks and sandy coves leading to the rocky headland of Start Point. Staff and students from Slapton Ley Field Centre have collected a considerable amount of unpublished information on the littoral communities of Start Bay and the rocky shores between Start Point and Prawle Point. McCarter & Thomas (1980) described littoral communities around Start Point. Steep littoral zones were predominantly limpet and barnacle-dominated, while increasing shelter to the east of the point results in greater algal biomass.

Start Bay was surveyed by Holme (1966) during a wide-ranging study of the English Channel. Faunal associations within the bay were identified as 'Boreal offshore muddy-sand' and 'Boreal offshore mud' associations. 'Boreal offshore muddy-sand' was characterised by bivalve and gastropod molluscs, burrowing crustaceans (e.g. *Callianassa subterranea*), brittlestars, heart urchins *Echinocardium cordatum*, and sea cucumbers. 'Boreal offshore mud' was characterised by the burrowing echiuran *Maxmuelleria lankesteri*.

The rocky coast from Start Point to Salcombe Harbour and the Kingsbridge estuary is open to the full force of the prevailing winds and waves. These exposed sloping shores were limpet and barnacle-dominated with sparse mussels *Mytilus edulis* and algae; well developed lichen communities were recorded on the upper shore and in the splash zone (McCarter & Thomas 1980). Littoral and sublittoral communities at the mouth of the Salcombe and Kingsbridge estuary were described by Earll (1978). Exposed rocky shores were dominated by barnacles with sublittoral fringe communities characterised by the algae *Fucus serratus* and *Laminaria digitata* and with a variety of associated animal species. A dense kelp forest characterised infralittoral habitats at many sites. Epiphytic red algae grew in profusion on the kelp stipes and the adjacent bedrock. Species recorded include *Delesseria sanguinea, Dilsea carnosa, Plumaria elegans* and the tufted coralline alga *Corallina officinalis*. The fauna were characteristic of wave-exposed conditions and included the sponges *Pachymatisma johnstonia* and *Clathrina coriacea*, and the sea squirt *Distomus variolosus*.

8.3.6 Salcombe Harbour and the Kingsbridge estuary

Salcombe Harbour and the Kingsbridge estuary (Figure 8.10) is one of the West Country's finest natural harbours. The inlet has a long history of marine biological study and is considered to be a site of international marine biological importance (Powell *et al.* 1978). A wide range of habitats and associated communities have been described. In the early 19th century, George Montagu collected type specimens of a number of new species from the area (Marine Biological Association 1957). The first detailed survey was reported by Allen & Todd (1900) and the estuary was surveyed again by the FSC in 1985 (Hiscock 1986). The records in the *Plymouth Marine Fauna* from Salcombe Harbour reflect the extensive use of the area for sampling and teaching. The estuary is notified an SSSI for its marine biological and ornithological interest. Its particularly notable features are the extensive seagrass (*Zostera marina)* beds and rich infaunal communities. Fort Charles and Black Stone have a series of overhangs, gullies and crevices on the low shore and shallow sublittoral which have a high species richness.

The areas of shore below the Marine Hotel at at Mill Bay were considered of international marine biological importance for their commensal species (Powell *et al.* 1978), a group with a long history of study at these sites (Marine Biological Association 1957). Throughout Salcombe Harbour and the Kingsbridge estuary, but at Mill Bay in particular, tide-swept mixed coarse substrata dominate sublittoral habitats. Hard substrata within the estuary had rich and diverse communities of red algae including the rare species *Gracilaria foliifera*. Steeply sloping littoral bedrock at Snapes Point and Scoble Point extends into the sublittoral zone, forming a habitat not usually encountered within ria systems. The fan-worm *Sabella flabellata* and the bivalve *Pinna* (now *Atrina*) *fragilis* were recorded from these areas. These sites were subsequently degraded by the dumping of dredge-spoil (Little 1987).

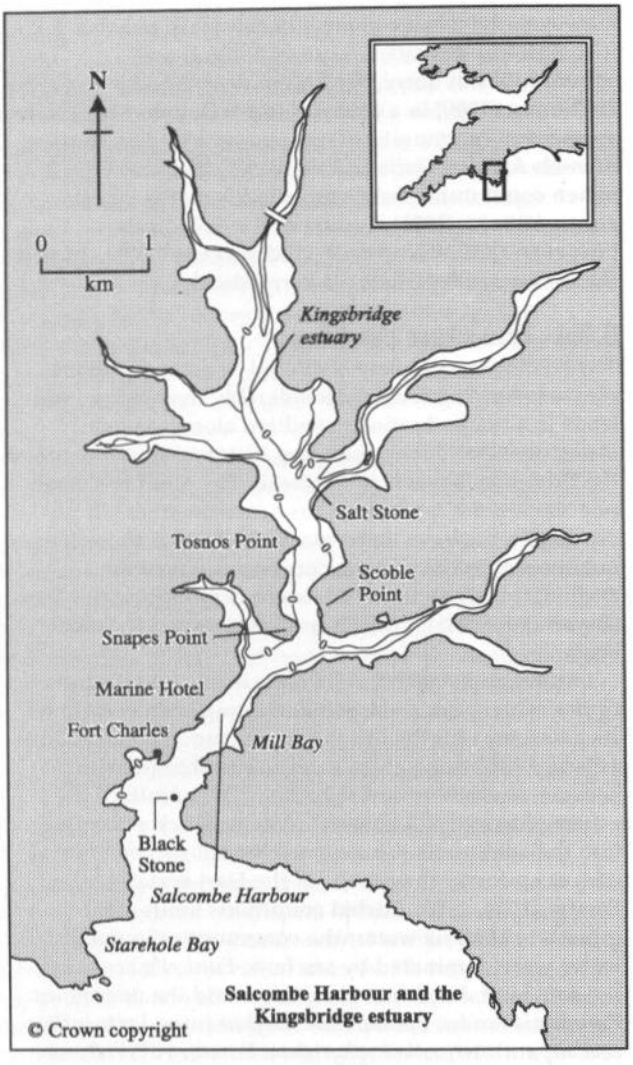

Figure 8.10. Salcombe Harbour and the Kingsbridge estuary showing the location of places mentioned in the text.

Sheltered sediment communities at Tosnos Point were considered of national or possibly international marine biological importance (Hiscock 1986). Salt Stone in the upper part of the Salcombe and Kingsbridge estuary has a long history of marine biological investigation and is renowned as a good site for specimen collection (Marine Biological Association 1957). Powell *et al.* (1978) identified a rich fauna of composed of tube-dwelling and burrowing polychaetes and a rich sponge and ascidian surface-dwelling community at the Salt Stone. Adjacent channels have well developed populations of the fan-worm *Sabella pavonina* (Hiscock 1986). In recent years, the estuary has suffered an invasion by the non-native brown alga *Sargassum muticum*. Rapid growth of this species smothers shores and clogs navigation channels. In addition, the marine communities throughout the ria are threatened by dredge spoil-dumping, bait-digging, an increase in water sports activity and over-collecting for scientific educational purposes. The whole system has been designated a Local Nature Reserve in an effort to control these activities

and protect an estuary of significant marine biological importance.

Starehole Bay, a small sandy bay to the west of the entrance to Salcombe Harbour, was investigated by Hiscock (1986) and was the site of a synecological study of community structure by Rubin (1980). The bay itself is predominantly sandy with occasional rock outcrops; a much-broken wreck lies within the bay. Large populations of the burrowing hearturchin *Echinocardium cordatum* were present within the sand. Infaunal samples revealed high numbers of polychaete worms including *Magelona mirabilis*. Rock outcrops had abundant red algae including *Gracilaria foliifera*. In his study, Rubin (1980) considered a rock-face at the southern end of the bay where an exposure gradient along the face leads to a corresponding change in the biotic assemblage from one end to the other. Sheltered surfaces were dominated by arborescent bryozoans such as *Crisia denticulata* and *Cellaria fistulosa*, encrusting bryozoans, and the erect organ-pipe hydroid *Tubularia indivisa*. These species attracted many nudibranch predators such as *Polycera quadrilineata*, which preys on the encrusting bryozoan *Electra pilosa*. Overhanging surfaces were covered with the jewel anemone *Corynactis viridis*. Exposed rock surfaces were dominated by tubeworms *Pomatoceros triqueter*. In addition, the white anemone *Actinothoë sphyrodeta* was recorded in large numbers.

8.3.7 Bolt Head to Wembury, including the Avon, Erme and Yealm estuaries

The exposed coast between Bolt Head and Bolt Tail, where the cliffs rise over 100 m out of the sea, has important geological formations and is notified an SSSI. From Bolt Tail to the mouth of the Avon estuary, there is a mixture of sandy coves and exposed rocky shores. McCarter & Thomas (1980) surveyed the rocky shores at Thurlestone and at Bantham. These rather broad, flat rocky shores had characteristic zonation patterns. The zones present from upper to lower shore were characterised by lichens, *Pelvetia canaliculata*, *Fucus spiralis*, limpets/barnacles, *Ascophyllum nodosum*, *Fucus vesiculosus*, *Fucus serratus* and *Laminaria* spp.

The Avon estuary, a narrow sheltered inlet, extends for 7 km from the sands at Bigbury-on-Sea and Bantham at the mouth to Aveton Gifford. Bantham was established as a port where small coasters unloaded their cargoes of fish, lime and coal; cargoes which were then ferried up the river to Aveton Gifford. The estuary has since been infilled by an accumulation of sediment and, at low water, the channels are narrow and shallow. The estuary was surveyed by Moore (1988b), who reported that a restricted range of habitats was present. The mouth of the estuary had semi-exposed rock platforms with rockpool, underboulder and overhang communities on the low shore. The sediment shores at the mouth had characteristic exposed shore crustacean-polychaete communities (Bishop & Holme 1980) with *Nephtys* sp. and *Magelona mirabilis*. Sediment communities within the estuary were typical of variable salinity conditions, the communities present were numerically dominated by ragworm *Hediste diversicolor* and the bivalve *Scrobicularia plana*.

The Erme estuary is very similar to the Avon, being a narrow, very sheltered estuary some 6.5 km long. It is very secluded, and has steep wooded banks notified an SSSI for their woodland interest. It is privately owned and has remained undeveloped. The estuary is a spawning ground for sea trout *Salmo trutta* and supports a population of the otter *Lutra lutra*. A restricted range of habitats were present (Moore 1988b) and a high freshwater input leads to a marked salinity gradient within the estuary. Habitats were predominantly sedimentary with some broken sand-scoured bedrock at the mouth. Mobile sediments near the channel have a typical crustacean–polychaete community characterised by the amphipods *Bathyporeia pilosa* and *Eurydice pulchra*; more sheltered sediment infaunal communities were characterised by ragworm *Hediste diversicolor*. Shingle and cobble habitats on the lower shore were colonised by the brackish-water alga *Fucus ceranoides*.

The Yealm estuary, which opens into Wembury Bay, is tidal for 6.5 km inland with two side creeks: Newton Creek adjacent to Newton Ferrers in the lower estuary, and Cofflete Creek in the upper reaches. The estuary is very sheltered; a sand-bar at the mouth greatly reduces wave action even at the entrance. For most of its length, the estuary is less than 300 m wide and fringed by steep and mainly wooded slopes. Upper shore habitats are predominantly rocky with mainly sedimentary lower shores. Sand at the mouth gives way to muddy shingle on soft mud in the upper reaches. The International Paint Company established a marine laboratory at Newton Ferrers in 1926 to study the effectiveness of antifouling paints. Rafts were set up within the estuary to study the settlement of marine organisms onto panels. In addition, records of seawater temperature, surface salinity and rainfall have been maintained in conjunction with the settlement studies.

Habitats and their associated communities within the Yealm were studied by staff at the Marine Biological Association Laboratory, Plymouth earlier this century. Their work was summarised in the *Plymouth Marine Fauna* (Marine Biological Association 1957). The Yealm estuary was surveyed by the Intertidal Survey Unit who considered it to have primary marine biological importance (Powell *et al.* 1978). Three areas were highlighted for their marine biological interest: the south shore between Newton Creek and Misery Point; Cellars Beach and the rocks to the west; and, at the entrance to the Yealm, the Yealm Sand Bank. Littoral zones between Newton Creek and Misery Point were sheltered with a narrow band of rocks on the upper shore with muddy gravel in mid- and low shore zones. Low shore habitats had infaunal communities characterised by polychaetes, sipunculids and bivalve molluscs. At Cellars Beach, sandy shores had a seagrass *Zostera marina* bed on the low shore and in the shallow sublittoral zone. Dense populations of the razor shell *Ensis arcuatus* were recorded in the clean sand of the Yealm Sand Bank.

Littoral habitats and their associated communities in the Yealm were surveyed by Cunningham & Hawkins (1985), who recorded a total of 82 taxa from six sites. Hiscock & Moore (1986) described seven littoral and six sublittoral habitats and communities within the estuary.

Within the channel, the substrata were mainly cobbles and pebbles subject to tidal streams, and the associated communities had a high species richness, which was considered of national importance (Hiscock & Moore 1986). Dense populations of the scarce red alga *Gracilaria foliifera* were present within the Yealm estuary. A small seagrass *Zostera marina* bed was present at Misery Point. Within the *Zostera*, pipe-fish, wrasse and other small fish were formerly common, although these fish species are now rarely encountered within the *Zostera* bed (Marine Biological Association 1957; Hiscock & Moore 1986). Southwood (1991) described the results from a transect surveyed across Cellars Beach from 1951 onwards, mainly to investigate populations of four species of barnacle: *Chthamalus montagui, Chthamalus stellatus, Semibalanus balanoides* and *Elminius modestus*. Fluctuations in barnacle populations were linked to sea temperature and the solar cycle, changing weather patterns and shifts in climate, although no one factor could conclusively account for the full extent of fluctuations in barnacle numbers.

Wembury Bay, to the west of the Yealm estuary, has long been recognised as an area of outstanding marine biological importance. Wembury was considered a site of primary marine biological importance (Powell *et al.* 1978); it is an SSSI and has been declared a Voluntary Marine Nature Reserve. Wembury Bay was described in the *Plymouth Marine Fauna* (Marine Biological Association 1957) as "... one of the best collecting grounds on the open coast in south-west England". Wembury is the type locality for a number of marine species (Marine Biological Association 1957). In particular, the two reefs known as Church Reef and West Reef merit special attention. These reefs, broken into an uneven series of ridges parallel to coast, afford some protection from prevailing wave action and facilitate the development of gully and crevice communities. The crevice communities at Wembury were described by Morton (1954) and include an unusual mixture of marine and terrestrial species. Some of the earliest systematic studies of zonation patterns on the shore were undertaken by Colman (1933) and re-surveyed by Boalch *et al.* (1974) at Wembury. Two freshwater streams flow over the littoral zone providing a suitable habitat for the archiannelid worm *Protodrilus flavocapitatus*, a species restricted to this type of habitat. One of the earliest sublittoral diving surveys studied a gully to the east of Wembury Bay (Kitching, Macan & Gilson 1934). Three associations were described: a *Laminaria* forest association, a *Distomus–Halichondria* association and 'undergrowth layers'.

8.3.8 The Eddystone

Lying some 20 km south of Plymouth Sound are the Eddystone Rocks, the site of one of the first lighthouses to be built in Britain in 1698. Sublittoral communities off the Plymouth coast and around Eddystone Rock were first described by Allen (1899), and later by Holme (1953) following an extensive dredging programme. The bottom deposits ranged from coarse muddy sand to fine gravel; areas subject to tidal scour were composed of patches of shell gravel. South and east of the Eddystone, the substratum was mostly uniform, clean fine sand supporting an '*Echinocardium–Venus*' community (Ford 1923). Coarser sediments were characterised by a '*Spatangus–Venus*' community and there are large numbers of amphioxus *Branchiostoma lanceolatum* present in the shell gravel.

8.3.9 Plymouth Sound and estuaries

Plymouth Sound is an enclosed bay into which two major rivers discharge (Figure 8.11). To the west, the River Tamar enters via the Hamoaze; to the east the River Plym via the Cattewater. In addition, the Rivers Lynher and Tavy flow into the Tamar. A breakwater completed in 1841 greatly increases the degree of shelter within Plymouth Sound. Plymouth has long been a major naval port and large areas of waterfront adjacent to the town have been developed as port facilities.

The Plymouth area provides a great range of habitats of interest to the marine biologist. In the late 19th century, the increasing interest in marine biology and the need for fisheries information led to the establishment of the Marine Biological Association of the United Kingdom (MBA) in 1884 and the opening of the Citadel Hill Laboratory at Plymouth in 1888. The *Journal of the Marine Biological Association of the United Kingdom* (JMBA) was first published in 1887 and has since included many papers discussing the marine biology of the Plymouth region. In 1904, the MBA published the first edition of the *Plymouth Marine Fauna*, with the latest (third) edition in 1957. This volume provides detailed descriptions of the main collecting grounds used by the MBA in the Plymouth region and lists all the species recorded with additional notes on location and abundance. It remains a valuable source of information for the Plymouth region. Southward & Roberts (1984) described the establishment and the first one hundred years of the MBA. Their fascinating paper summarises the types of research and the staff involved during this period and includes a detailed bibliography.

Some of the earliest marine biological studies undertaken at Plymouth were those of Boswarva (1862), who published *A catalogue of the marine algae of Plymouth*. Early volumes of the JMBA included reviews of studies in the Plymouth region; for example, Heape (1888) compiled records of fauna and flora from published sources and local knowledge. Allen published a series of notes on the fauna of the Plymouth area (e.g. Allen 1895). During the 1920s and 1930s, a series of detailed studies described the Plymouth region. Ford (1923) sampled sublittoral sediments, classifying the communities present following the system established by Petersen (1918). A '*Spatangus purpureus–Venus* [now *Clausinella*] *fasciata*' community characterised coarser grounds at the western entrance, on Queen's Ground and a reduced form of this community was recorded off Bovisand Pier. An '*Echinocardium cordatum–Venus* [now *Chamelea*] *gallina*' community characterised the muddier grounds inside the breakwater. The latter community was subdivided into two sub-communities based on the percentage of sand in the sediment. Gibbs (1969) sampled sediment communities off Cawsand Bay, north of Drakes Island and in Stonehouse Pool east of Millbay Docks to describe the polychaete populations. In comparison with studies of sedimentary habitats, rocky

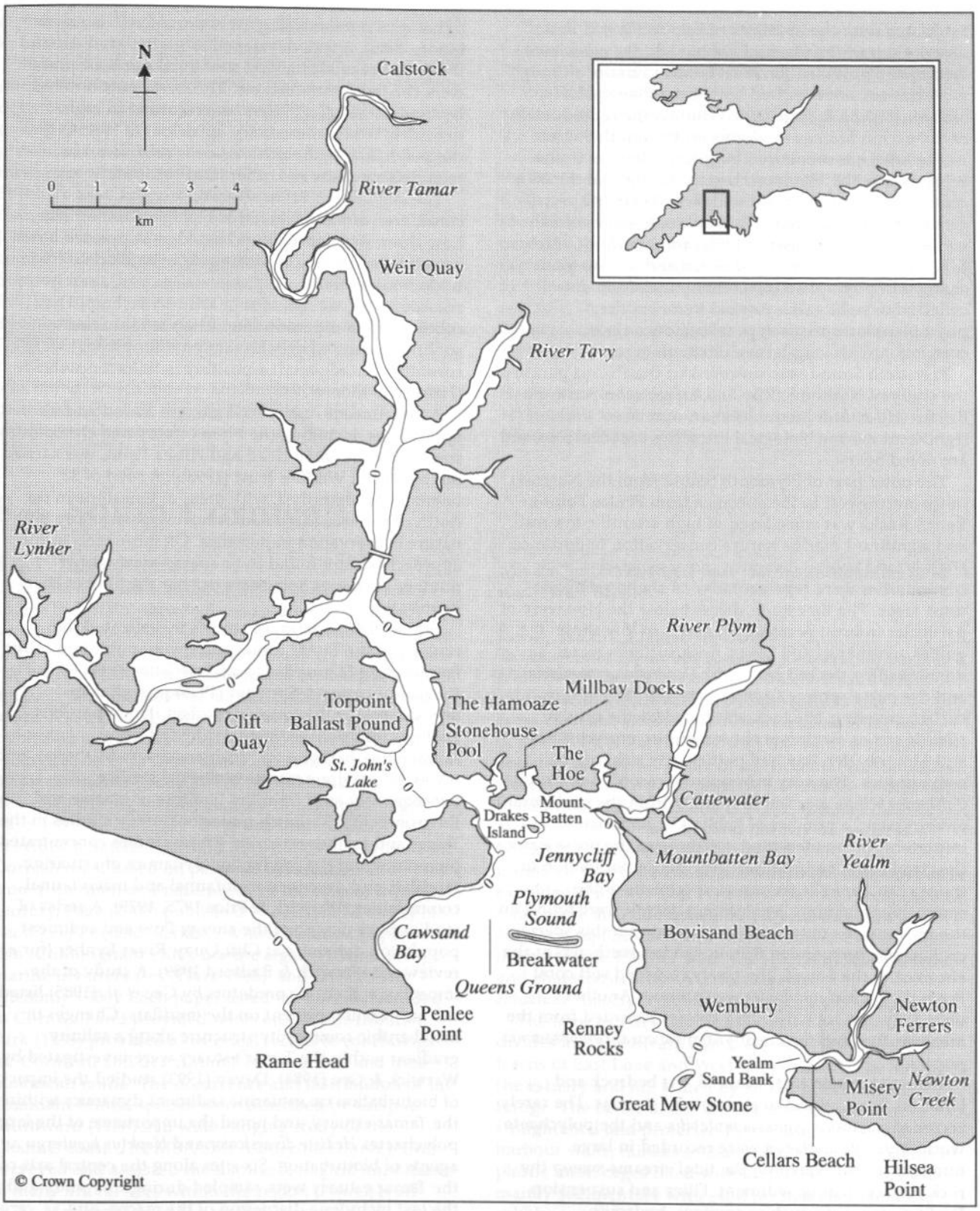

Figure 8.11. Plymouth Sound and estuaries showing the location of places mentioned in the text.

shore ecology has received less attention. Many unpublished records are held by the staff at the Plymouth Marine Laboratory. Moore (1939) and Moore & Sproston (1940) documented the colonisation of a rocky shore below the Marine Laboratory. Weiser (1952) investigated the microfauna inhabiting algae in the sublittoral fringe also on the rocky shore below the Marine Laboratory. Scarratt (1961) surveyed the fauna

associated with the holdfasts of kelp *Laminaria*. Basic descriptions of the physical habitat and the associated fauna were provided for 18 stations in Britain, although most stations were located within the Plymouth area. Nichols, Bishop & Sime (1985) studied the reproduction of the urchin *Echinus esculentus* off Plymouth Sound.

The MBA has monitored long-term changes in the ecosystem in the Plymouth region throughout the 20th century by studying the abundance of certain species groups. Long-term trends in planktonic stages of fish were described by Russell (1973), and Maddock, Harbour & Boalch (1989) described seasonal and year-to-year changes in phytoplankton communities from data collected over 24 years. Annual trends in the phytoplankton species appear to show a close correlation with long-term climatic changes.

Plymouth Sound was surveyed by the FSC as part of the study of Harbours, Rias and Estuaries in Southern Britain (Hiscock & Moore 1986). A number of areas of significant marine biological interest were identified and are noted below.

The outer part of Plymouth Sound from the Narrows in the north-west to the entrance from Penlee Point to Renny Rocks was considered of high scientific interest and significant marine nature conservation importance. High littoral habitat diversity and associated communities were representative of sheltered open coast areas. The limestone shores below the Hoe were of particular interest because of a series of low shore gullies, overhangs and caves. Rock surfaces were dominated by the red sea squirt *Dendrodoa grossularia* and the purse sponge *Grantia compressa*. Below this surface covering, the rock was bored by the bivalve *Hiatella arctica*. Sediment shores within Jennycliff Bay and Mountbatten Bay had particularly rich infaunal communities. The very infrequently recorded sea-slug *Calliopaea bellula* was found there. Within the sublittoral environment, a number of habitats of national importance were identified. Offshore of the breakwater, the circalittoral bedrock had very dense population of the sea fan *Eunicella verrucosa*. Specimens of the commensal anemone *Amphianthus dohrnii* were found on the sea fans, the only recorded location for this species on *Eunicella verrucosa* in Britain. Under overhangs at the entrance to the Sound, the rarely recorded soft coral *Parerythropodium coralloides* was present. Another nationally rare rock-dwelling species recorded from the area was the Mediterranean–Atlantic coral *Leptopsammia pruvoti*.

Within the main tidal channel, the bedrock and boulders were subject to strong tidal streams. The rarely recorded anemone *Aiptasia mutabilis* and the polychaete worm *Myxicola aesthetica* were recorded in large numbers. In the Narrows, the tidal streams sweep the rock surface clear of sediment. Filter and suspension feeding organisms such as sponges, hydroids, featherstars and sea squirts dominated the communities. High species richness within these communities is facilitated by the limestone rock allowing several rock-boring species to occur; other species shelter in these holes, further increasing species richness.

Within the Tamar and Lynher estuaries, the area between Calstock Bend and Weir Quay was considered of national marine biological importance (Hiscock & Moore 1986). A well developed estuarine gradient and the presence of littoral and sublittoral hard substrata were the important features. The rarely encountered hydroid *Cordylophora caspia* was recorded in high densities. Where the estuary opens out at Weir Quay, the polyhaline hydroid *Hartlaubella gelatinosa* was recorded on shells and other hard substrata.

The area off the Ballast Pound, Torpoint, was considered of national marine biological importance. Low shore shale cobbles and boulders supported a rich assemblage of finely branching algae and a rich underboulder fauna. *Griffithsia devoniensis*, a rarely recorded alga, was present in abundance here. The cobbles and boulders on mud extended into the sublittoral zone where the communities present were considered of regional or possibly national importance (Hiscock & Moore 1986).

A more recent survey of Plymouth Sound and its approaches, including the Plym estuary and the open coast between Rame Head and Hilsea Point, was carried out by Devon Wildlife Trust (1993b). A total of 22 habitats was described, with areas of limestone in the north of the area identified as having particularly high nature conservation importance. Offshore reefs in the approaches were found to be species rich, with a number of species being rare or near the limit of their distribution.

In the 1930s, a series of studies investigated the ecology of the Tamar estuary and were published in the *Journal of the Marine Biological Association of the United Kingdom*. Hartley & Spooner (1938) provided an introduction to the series, described the dimensions, geology, intertidal sediments, physiography, saltmarshes, bathymetry, tidal streams and fisheries, and reviewed previous marine biological studies. Subsequently, staff from the Institute of Marine and Environmental Research undertook many studies in the Tamar and Lynher estuaries. These studies concentrated on quantifying the production dynamics of estuarine mudflats and described meiofaunal and macrofaunal communities (Warwick & Price 1975, 1979). A series of studies have described the energy flow and sediment population dynamics at Clift Quay, River Lynher (for a review see Warwick & Radford 1989). A study of the impact of epibenthic predators by Gee *et al.* (1985) listed the macrofauna present on the mudflats. Changes in meiobenthic community structure along a salinity gradient within the Tamar estuary were investigated by Warwick & Gee (1984). Davey (1993) studied the impact of bioturbation on estuarine sediment dynamics within the Tamar estuary, and noted the importance of the large polychaetes *Hediste diversicolor* and *Nephtys hombergii* as agents of bioturbation. Six sites along the central axis of the Tamar estuary were sampled during this study and the text includes a discussion of the macro- and meso-faunal characteristics at each station. Pelagic populations of the mysid shrimp *Mesopodopsis slabberi* were studied by Moffat & Jones (1993), who determined a correlation between the position of the salinity gradient and the distribution of this species of mysid. The authors suggested that mysids form an important link between pelagic and benthic systems and could be used to help

explain some benthic population dynamics, particularly in relation to salinity gradients within estuaries.

St John's Lake, a large area of intertidal mudflats and saltings on the west bank of the Hamoaze, was described by Spooner & Moore (1940). Quantitative descriptions of the infaunal communities were also presented for three areas of St John's Lake and a further three sites within the Tamar. The intertidal mudflats in St John's Lake support a more species-rich community than other similar sediments in the Plymouth area. St John's Lake was re-surveyed in 1988 during a comparative estuarine study for the Energy Technology Support Unit (ETSU) (Warwick *et al.* 1989; Warwick *et al.* 1991). A comparison of the species abundance recorded by Spooner & Moore (1940) with those of Warwick *et al.* (1989) revealed a marked reduction in biomass. In particular, a marked reduction in the mollusc biomass was noted, which may be attributable to an increase in disturbance by bait-digging and/or the levels of toxic antifoulant chemicals.

Turk & Turk (1960) surveyed the flora and fauna of Cawsand Bay which is located near the entrance to Plymouth Sound on the western side. Basic descriptions of the biology were presented for the major intertidal habitats, plus notes on how the shore could be used for the teaching of natural history.

The intensity of marine biological investigation within the area has led to many species new to Britain being first recorded from the Plymouth area. For example the southern kelp species *Laminaria ochroleuca* was first recorded in Britain from Plymouth in 1948 (Parke 1948). Populations of other species having a southern distribution have been identified in the area. For example, three species of cup-coral *Hoplangia durotrix*, *Balanophyllia regia* and *Leptopsammia pruvoti*, the anemone *Parazoanthus axinellae* and the small polychaete worm *Myxicola aesthetica*. Populations of two species of rarely recorded red algae *Schmitzia hiscockiana* and *Schmitzia neapolitana* were found in Plymouth Sound (Hiscock & Moore 1986).

8.4 South Cornwall

8.4.1 Introduction

Dramatic high cliffs, some of the most exposed rocky shores in Britain, sheltered sandy coves and sheltered, sinuous marine inlets form the south Cornwall coastline (Figure 8.12 and 8.16). The south-westerly position and the range of marine habitats present have attracted both amateur and professional marine biologists for many years. A substantial amount of information, both published and unpublished, is held at the Cornish Biological Records Unit (CBRU), Redruth. Some of the major taxonomic groups were comprehensively described during the last 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. At the turn of the 20th century, Page (1906) published *The Victoria history of the counties of England: Cornwall* which 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) provided a historical record of conchology for Cornwall and descriptions of the shores and their molluscan fauna. The occurrence and distribution of the dominant littoral species were described by Crisp & Southward (1958) in a wide-ranging study of the Channel coast. The MBA/SMBA Intertidal Survey Unit surveyed and assessed the marine biological importance of many littoral sites within the region (Powell *et al.* 1978). Marine inlets in the region were described by the FSC during the study of the Harbours, Rias and Estuaries in Southern Britain. Tregenza (1988) published the results of 50 years of cetacean sightings off the Cornish coast. In a similar vein, Penhallurick (1991) listed sightings of live turtles, and descriptions of the remains of dead specimens, off the coasts of Cornwall, Devon and the Isles of Scilly. The author noted that 1988 was an "unprecedented year" for turtle sightings in south-west Britain.

8.4.2 Rame Head to Looe

To the west of Plymouth Sound is Rame Head, beyond which is Whitsand Bay, a 6 km stretch of sand and shingle with gullies carved by strong tides and cross-currents. Offshore sediment communities were described by Holme (1953) from fine sand and mud at about 45 m depth – 'Rame mud'. Infaunal communities were numerically dominated by polychaete worms but, in addition, the sea cucumbers *Leptosynapta inhaerens* and *Trachythyone elongata*, and the burrowing prawn *Callianassa subterranea* were present. Mare (1942) estimated that the fresh tissue within the Rame deposits exceeded 100 g m^2. East Whitsand Bay was composed of clean sand, also dominated by polychaetes with *Magelona papillicornis* (now *Magelona mirabilis*) occurring in abundance. Farther west, the sediment was muddier and characterised by an '*Echinocardium cordatum–Amphiura filiformis*' community (Holme 1966).

The Looe estuary has a single narrow entrance but divides into the Rivers East Looe and West Looe. The towns of East Looe and West Looe straddle the mouth of the estuary and are joined by an old multi-arched bridge. The banks of the lower estuary have been straightened and protected by the construction of harbour walls, railway embankments and revetments of plastic mesh cages filled with boulders. The estuary is mainly sedimentary with sand on small boulders and cobbles in the lower reaches, sandbanks near the junction of the two rivers and muddier sediments in the upper reaches. Freshwater inflow is low although the dimensions of the estuary result in very brackish conditions within the channel at low water. The estuary was surveyed by the FSC (Little 1988). Sediment habitats and their associated communities were considered of local marine biological importance. These sediments

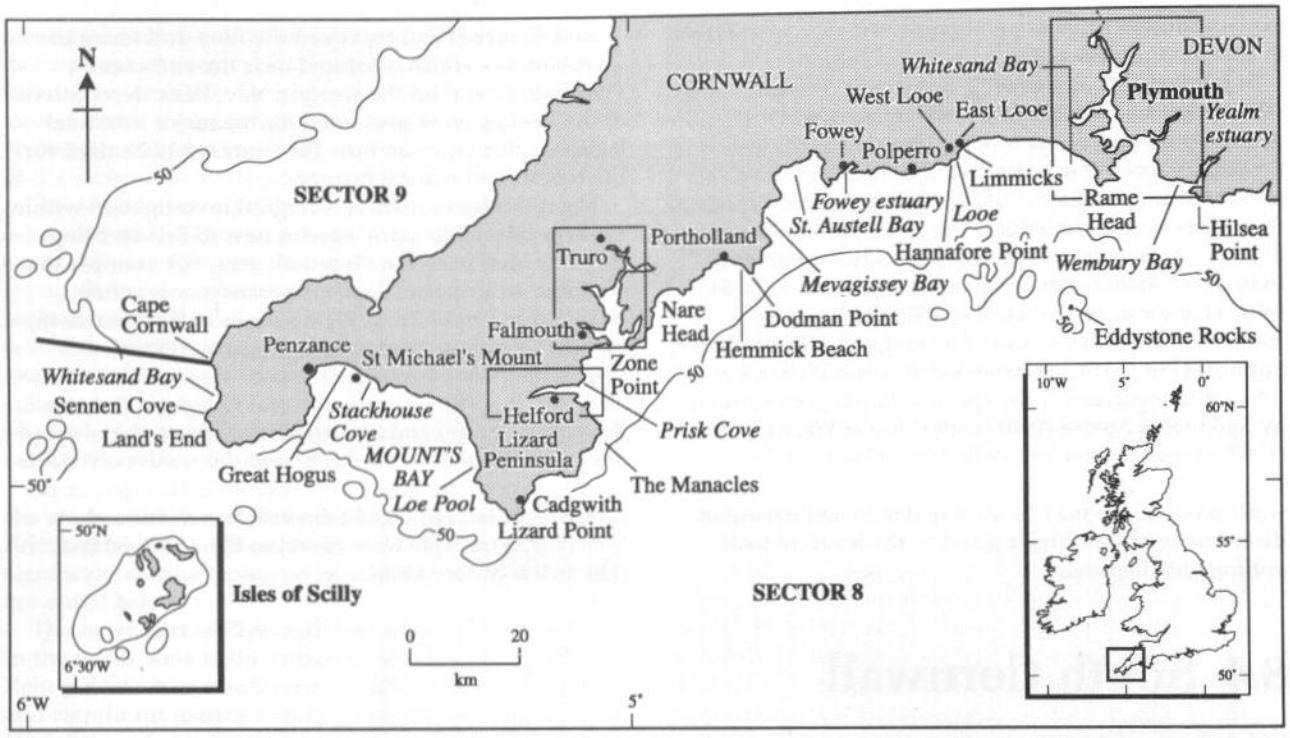

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Figure 8.12. The western part of Sector 8 showing the location of places mentioned in the text. The areas of the Fal and Helford are enlarged in Figures 8.14 and 8.15.

were characterised by a crustacean-polychaete community, the ragworm *Hediste diversicolor* and the amphipod crustacean *Corophium volutator* were the most abundant species. Where freshwater runoff occurred, the brackish-water algae *Fucus ceranoides* was common. Hard substrata near the mouth had a characteristic limpet and barnacle-dominated midshore and mussel-dominated low shore; the most abundant barnacle was *Chthamalus montagui*.

Powell *et al.* (1978) considered the broken rocky coast from Limmicks reef to Hore Stone headland (outside the Looe estuary) to be a site of primary marine biological importance. Hannafore Point was highlighted as an area of special interest for the range of habitats present. An extensive series of gullies, overhangs, reefs and rockpools were present on the low shore. Also, extensive partially sand-filled shallow lagoons supported a great variety of plants and animals including patches of seagrass *Zostera marina*. *Jania rubens*, a southern species of red coralline alga, was unusually abundant within these pools. A well developed crevice fauna including the tentacle worm *Terebella lapidaria* was also recorded.

8.4.3 Fowey estuary to the Fal

The Fowey estuary is a sheltered natural harbour which has been a busy port since the Middle Ages. In more recent times, the port has been important for the shipping of locally mined china clay. Ships of up to 15,000 tonnes often navigate up river to the china clay wharves. The estuary was visited by the MBA/SMBA Intertidal Survey Unit (Powell *et al.* 1978) and later surveyed by the FSC during the study of Harbours, Rias and Estuaries in Southern Britain; the results are included in Moore (in prep.).

The geological structure of Cornwall propagated a large mining industry in Victorian times; copper, tin and china clay were the main materials extracted. The effluent from this industry was discharged into the local rivers and ultimately into the sea. The main river entering Mevagissey Bay is White River, a name derived from the colour of the water due to china clay waste. The impact of china clay effluent on the benthic fauna of St Austell Bay and Mevagissey Bay has been well documented (Probert 1981; Knight 1988). China clay waste, a fine mica and quartz rich silt, has buried the shell-gravel substrata of Mevagissey Bay by up to 2 m (Knight 1988). Five different benthic communities have been identified within the Bay; their faunal composition and distribution determined by the quantity and nature of the china clay waste (Figure 8.13). Knight (1988) compared the present faunal composition of communities with the results of similar studies collected during the peak discharge (1968) and during the reduction of discharge (1970–73). In general, species diversity had increased following cessation of the discharge (Knight 1988).

The very exposed coastline between Dodman Point and Zone Point is predominantly high cliffs with occasional sandy bays. Powell *et al.* (1978) considered the shores at Hemmick Beach and Portholland a site of secondary marine biological importance. During the South Cornwall Sublittoral Survey (James 1983), three sites near Nare Head were described. Infralittoral broken, outcropping bedrock was characterised by a

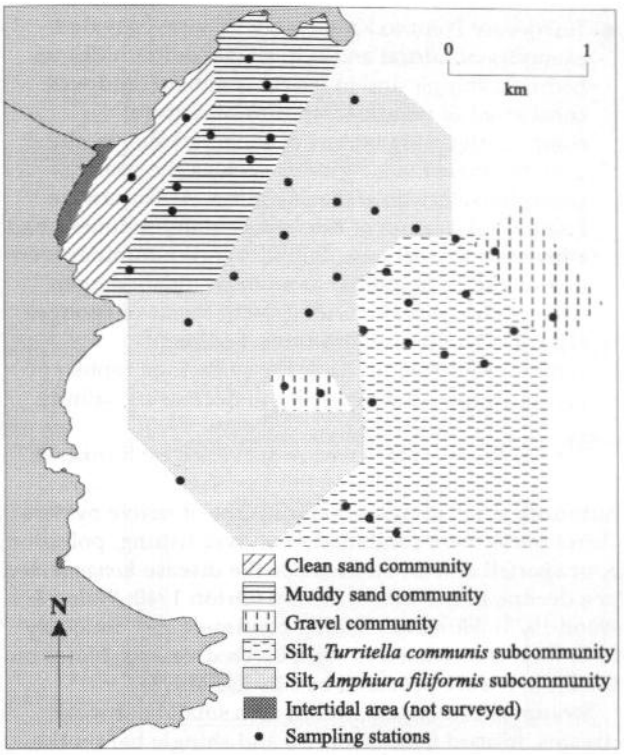

Figure 8.13. Distribution of the benthic communities inhabiting the china clay waste in Mevagissey Bay (re-drawn from Knight 1988).

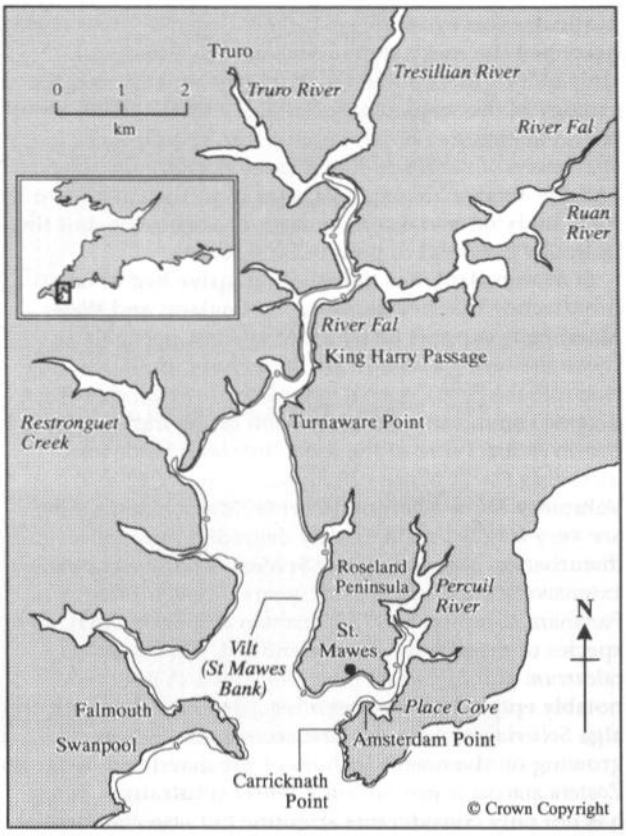

Figure 8.14. The Fal estuary complex showing the location of places mentioned in the text.

kelp forest. An algal turf was predominantly red algae; large numbers of the sea-urchin *Echinus esculentus* were also recorded. In deeper water, rock surfaces were animal-dominated, dead-man's fingers *Alcyonium digitatum* and the featherstar *Antedon bifida* were abundant. The sea cucumber *Holothuria forskali* and the large starfish *Marthasterias glacialis* were locally abundant. The remainder of the coast and the offshore regions remain largely undescribed.

8.4.4 The Fal estuary complex and Helford River

Falmouth is the gateway to a maze of creeks and tidal rivers extending some 17 km inland (Figure 8.14). A deep ria system allows large vessels to navigate as far as King Harry Ferry, and small coasters to the quays at Truro. However, slow tidal streams and a high rate of siltation results in a paucity of sublittoral rock habitats and the presence of extensive sediment banks.

The Fal and Ruan estuary complex has long been recognised as a site of major marine biological importance.Within the littoral environment, there is a wide range of habitats from moderately exposed rock to very sheltered sediment. Sites within the estuary, notably Place Cove and Carricknath Point, have been studied since 1955 by scientists from the Plymouth Marine Laboratory. Many of these records are unpublished; the Cornish Biological Records Unit retains a large amount of data for the area.

The earliest rocky shore surveys were described by Clark (1907) who considered the area to have a particularly rich biota. The MBA/SMBA Intertidal Survey Unit visited a number of shores within the system but considered Place Cove and the shore from Amsterdam Point to Carricknath Point to be a site of primary marine biological importance (Powell *et al.* 1978). Place Cove is a sheltered sediment cove with rich infaunal communities. The communities present were dominated by the polychaete worms *Myxicola infundibulum, Sabella penicillus* (now *Sabella pavonina*) and *Lanice conchilega*, the bivalves *Venus striatula* (now *Chamelea gallina*), *Tellina* (now *Angulus*) *tenuis* and razor-shells *Ensis arcuatus*. A number of commensal species were present; the communities were considered similar to those present in Salcombe Harbour and the Kingsbridge estuary. Sheltered rocky shores from Amsterdam Point to Carricknath Point were algal-dominated and displayed well developed zonation patterns. Bishop & Holme (1980) rated the whole of the St Mawes inlet of national marine biological importance for the sediment communities present. Sheltered flats composed of sand and muddy sand had a wide range of burrowing invertebrate species which were classified as '*Echinocardium–siliqua*', '*Pullastra*' and '*Lanice*' communities. Later field visits (Davies 1989) failed to record these communities despite sampling from the same locations as Bishop & Holme (1980) and the species richness was considered low.

Mining effluent is discharged into the many creeks of the Fal and Ruan system and the resultant impact on benthic communities has been well documented (Bryan & Gibbs 1983; Bryan *et al.* 1987). Restronguet Creek in

particular was extensively studied. Bryan & Gibbs (1983) described the rocky shore communities; Liverpool University's Environmental Advisory Unit studied the ecology of the whole creek (Holliday & Bell 1979). Bryan & Hummerstone (1973a, 1973b & 1973c) collected specimens of ragworm *Nereis* (now *Hediste*) *diversicolor* and the bivalve *Scrobicularia plana* from the Fal system for a study on metal contamination, adaptation and the indicator potential to polluted conditions.

St Mawes Bank has the most extensive bed of maerl (unattached calcified seaweed) in England and Wales. Maerl beds support many other species, particularly those sheltering amongst the branching interstices, for example the rare Couch's goby *Gobius couchi*, creating a diverse community. In recognition of the high conservation value of the area, Roseland Peninsula including the St Mawes Bank has been declared a Voluntary Marine Nature Reserve. Maerl communities are very fragile and are easily degraded by siltation and disturbance. Maerl from the St Mawes Bank has been extensively studied for many years (Howell 1969; Farnham & Jephson 1977; Farnham & Bishop 1985). Two species of maerl have been identified, *Phymatolithon calcareum* and *Lithothamnium corallioides*. A number of notable epiphytes have been recorded from the area; the alga *Solieria chordalis* was first recorded in Britain growing on the maerl. Inshore of the maerl bed, seagrass *Zostera marina* is present on a sandy substratum. Maerl has not only considerable scientific but also commercial importance; dead maerl from Falmouth Harbour is extracted commercially by suction dredge and marketed as an organic fertiliser. Extraction is strictly controlled to protect the maerl but proposals in 1989 to construct a container terminal at Falmouth threatened the existence of both the seagrass *Zostera marina* and maerl beds. Deeble & Stone (1985) considered that a large development at the entrance of the Fal would alter the hydrodynamic regime throughout the whole estuary complex.

Rostron (1985) reported the results of a wide ranging survey of the Fal ria system as part of the Harbours, Rias and Estuaries in Southern Britain study. A number of habitats and communities were noted for their marine biological and conservation importance.

- St Mawes Bank was considered of national importance for the maerl bed and its associated species. The nationally important alga *Halymenia* sp. and the rarely recorded Couch's goby *Gobius couchi* were present on the maerl. A diverse community associated with seagrass *Zostera marina* was present closer inshore. The shores were dominated by fucoid algae with a rich variety of species under the canopy and within rockpools.
- The Percuil River, inland of Carricknath Point/St Mawes Harbour, had rich littoral and sublittoral communities. Sublittoral sediment communities were considered of national importance. Patches of sublittoral rock, an uncommon habitat within the ria system, provide a suitable substrata for a rich sponge and ascidian community. The rarely encountered anemone *Aiptasia mutabilis* was recorded here.
- Turnaware Point to King Harry Passage provided examples of littoral and sublittoral communities on bedrock, shingle and in coarse sediment, and was considered of regional importance. Littoral communities were typical of sheltered shores, the growth form of some groups such as the sponges were characteristic of marine inlets. At Turnaware Point, a substratum of tide-swept stony sediment had a high species richness. Sublittoral communities were considered to be similar to an impoverished open coast community but with growth forms of sponges typical of sheltered conditions. Sediment communities beyond King Harry Passage rapidly become impoverished owing to decreasing salinity.

The Fal-Ruan estuary was re-surveyed by Bunker & Perrins (1993) under contract to the National Rivers Authority. The Fal was a major source of native oysters *Ostrea edulis* but a combination of over-fishing, pollution, poor spatfall and an outbreak of the disease *Bonamia*, led to a decline in the oyster fishery (Orton 1940; Walne & Wood 1973). However, fishing continues and, uniquely in Britain, is restricted to sail-powered vessels. Notes on the fishery were provided by Masters (1994).

Swanpool is a lagoon, fed by two small freshwater streams, formed behind a sand and shingle bar on the open coast to the south of Falmouth. It was probably formed at the end of the last ice age and first recorded as early as 1540. For much of its existence it was probably a freshwater pool, but in 1826 an outlet culvert to the sea was constructed. Seawater can now enter the pool at high water of spring tides. Swanpool is about 400 m by 100 m in surface area with a maximum depth of 3.1 m at the seaward end. From 1968 to 1982 a series of investigations studied the hydrography and ecology of the pool (Barnes, Dorey & Little 1971; Dorey, Little & Barnes 1973; Little 1985, 1986). A well defined halocline persists throughout the year. In summer, the upper saline layers are fully oxygenated with a pH of 7 while the lower hyperlimnon becomes anoxic, the pH increasing to 9 (Dorey, Little & Barnes 1973). In 1983 the outlet culvert was replaced and at the same time freshwater inflow increased. These changes have resulted in more erratic salinity changes and a loss of two lagoonal species *Plumatella repens* and *Procerodes littoralis*. Swanpool has the only known natural population in Britain of a species of bryozoan, the trembling sea mat *Victorella pavida* (Whitten 1990).

The Helford River (Figure 8.15) is a narrow estuary with a series of wooded creeks at the landward end. It is shallow and predominantly sedimentary with rocky shores at the mouth. There are moderate tidal streams in the lower reaches, leading to the development of interesting marine communities. Powell *et al.* (1978) and Bishop & Holme (1980) described the estuary as a site of national marine biological importance. Already notified an SSSI, the Helford River was declared a Voluntary Marine Conservation Area (VMCA) in 1987. An increase in pleasure-boat activities along with the ever-increasing search for sheltered moorings has generated considerable concern over the increasing damage to marine communities. It appears that species richness has

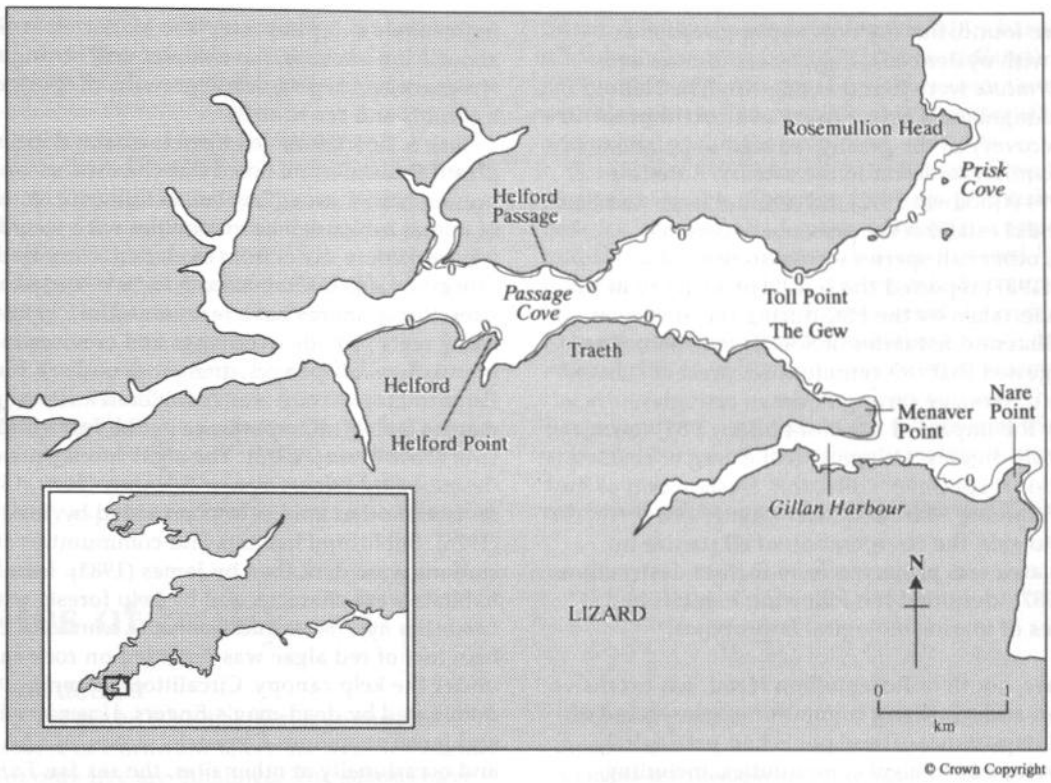

Figure 8.15. The Helford River showing the location of places mentioned in the text.

declined in recent years, possibly as a result of this increased physical disturbance (see below).

The varied and rich marine communities within the Helford River have attracted many naturalists (see Holme & Turk (1986) for review). Spooner & Holme (1986) surveyed the area in 1949 and recorded especially the fauna associated with extensive seagrass *Zostera marina* beds. They compare the Helford River with Salcombe Harbour and elsewhere in the Plymouth area noting features of the Helford area scarce or absent there. These include the presence of attached variegated scallop *Chlamys varia*, the burrowing bivalve *Venerupis aurea* (now *Tapes aureus*) and the abundance of certain polychaetes especially the tubeworms *Myxicola infundibulum* and *Sabella penicillus* (now *Sabella pavonina*) and the burrowing species *Amphitrite edwardsi* and *Neoamphitrite figulus*. Notes on the *Zostera marina* beds were first published by Gardiner (1927) but more recent surveys revealed a dramatic decline in species richness and a marked reduction in the area covered by seagrasses *Zostera* (Covey & Hocking 1987; Tompsett 1991, 1994b). An experimental attempt in 1992 to reintroduce seagrass *Zostera marina* to a site where it had died out was not successful (Tompsett 1994a). Powell *et al.* (1978) noted the presence of rich infaunal communities, especially in the adjacent Gillan Harbour, which had a rich *Echinocardium–siliqua* community (Bishop & Holme 1980). Helford Point is the type locality for the nationally rare Couch's goby *Gobius couchi*. Menaver Beach, near the mouth of the River, was highlighted as a site of primary marine biological importance (Powell *et al.* 1978). At Menaver, rocky ridges, interspersed with coarse sand, have representative limpet and barnacle-dominated shores with well developed rockpool communities; the pools had abundant algae with a distinct southern distribution, for example *Cystoseira tamariscifolia*. Low shore pools were described as having rich faunal communities with abundant crustaceans, molluscs, sponges and sea squirts. Price, Hepton & Honey (1979, 1980) published a comprehensive review of the distribution of algae along the southern shore and sublittoral of the Helford River. Distributional information was collated from published and unpublished records and a species list compiled for the area. A full species list of fish and invertebrates recorded from the Helford River was further provided by Turk & Tompsett (1993).

Under the auspices of the Helford VMCA Working Group, four monitoring surveys were carried out at nine transects in the estuary between 1986 and 1993. Tompsett (1994b) gave an overview of these surveys, noting the disappearance of intertidal *Zostera marina*. The Helford VMCA Working Group has instigated a number of other studies, including, in 1992, a population study of cockle *Cerastoderma edule* beds at Helford Passage (Jones 1993). There is a tradition of hand-collecting ('trigging') the cockles; Turk & Tompsett (1994) provided a history of this fishery. The estuary also supports an oyster fishery, described by Masters (1994). Protz (1995) investigated the distribution of native oysters *Ostrea edulis* in the estuary, and found a strong bias towards individuals under 18 months old. This was attributed to historical factors such as TBT pollution, parasitism, and illegal collection. No introduced oyster

species were found, but the non-native gastropods associated with oyster beds, *Calyptraea chinensis* and *Crepidula fornicata* were found at one site. The Helford River was designated a bass nursery in an attempt to allow the recovery of the greatly reduced populations of sea bass *Dicentrarchus labrax* in the estuary. A netting study in 1994 (Goodwin 1995) did not find large numbers of bass, but did establish the presence of juvenile age-classes; other fish species were also recorded.

Rostron (1987) reported the results of a survey of the Helford undertaken by the FSC during the Survey of Harbours, Rias and Estuaries in Southern Britain. The results suggested that the communities present showed many signs of damage through human activities, particularly the impact of the anti-foulant TBT, sewage pollution, bait-digging, 'trigging' (collecting of cockles) and educational specimen collection. Designation of the river as a Voluntary Marine Conservation Area attempted to gain the co-operation of all parties to ensure this area was protected from further destruction. Rostron (1987) identified the following habitats and communities of marine biological importance:

- Prisk Cove, south of Rosemullion Head, has extensive rockpools and overhang communities considered of national importance. These pools had particularly well developed red algal communities, including some rarely recorded species. The seagrass *Zostera marina* and some 55 species of algae were recorded, including live maerl *Phymatolithon calcareum*. The algal communities had a distinct southern character, for example *Cystoseira tamariscifolia* and *Cystoseira foeniculaceus* were found in abundance. This area is notified a Site of Special Scientific Interest for its marine and geological nature conservation interest.
- Treath slipway to the Gew and offshore to mid-channel was considered of regional or possibly national importance. Small stones, shell-gravel and empty shells are subject to moderate tidal streams and have well developed red algal communities. A narrow band of seagrass *Zostera marina* was recorded in shallow water with a maerl bed in deeper water. The latter is important as it is the most south-westerly location of maerl in Britain. Associated with the maerl were two nationally important species of red algae, *Gracilaria multipartita* and *Gymnogongrus devoniensis*.
- Passage Cove was considered of regional importance for the burrowing infauna within the sediment. Dense populations of the tubicolous polychaete worms *Myxicola infundibulum* and *Branchiomma bombyx* were recorded.

8.4.5 The Lizard Penisula

The Lizard Peninsula, a National Nature Reserve, is the most southerly part of mainland Britain. Western shores are 'very exposed' to wave action and are often cited as classic examples of this shore type. The east coast is more sheltered and has a number of small protected harbours and interesting geological features. South of the village of Cadgwith, the roof of a former cave collapsed in 1868 to form a spectacular blow-hole called the Devil's Frying Pan. Most of the coastline is inaccessible except by foot. The Manacles, rocks lying about 2 km offshore, have moderately strong tidal streams encouraging dense growths of sponges, hydroids and sea squirts.

Turk & Turk (1976) described the natural history of the Lizard Peninsula and noted that the marine communities present have a strong Lusitanian influence. A wide variety of littoral habitats and communities were recorded; the wave exposure varies from moderate to exposed. A very rare green alga *Codium adhaerens* was recorded at several sites. Rocky shores have representative communities and rocky reefs provide overhangs and crevices for diverse populations of sponges, anemones and sea squirts. Nare Point to Lizard Point was considered a site of primary marine biological importance by the Intertidal Survey Unit (Powell *et al.* 1978). The algal species present were described by Price, Hepton & Honey (1979, 1980); a review of other studies was provided by Turk & Turk (1976). Sublittoral habitats and communities at 16 stations were described by James (1983). Infralittoral habitats were characterised by kelp forests with *Laminaria hyperborea* and *Laminaria ochroleuca* common; a lush turf of red algae was recorded on rock surfaces under the kelp canopy. Circalittoral communities were dominated by dead-man's fingers *Alcyonium digitatum* and jewel anemones *Corynactis viridis*. At The Manacles and occasionally at other sites, the sea fan *Eunicella verrucosa* and Ross coral *Pentapora foliacea* were present. A littoral and sublittoral survey of the Lizard peninsula was carried out by the MNCR in 1994. During this survey, the most dense beds of the sea fan *Eunicella verrucosa* known from Britain were recorded.

The west coast of the Lizard has an unusual shingle bar enclosing a saline lagoon, Loe Pool. It is notified an SSSI for its botanical, entomological and ornithological features. The marine communities present were described by Murphy (1986).

8.4.6 Mounts Bay to Cape Cornwall

Mount's Bay includes a variety of intertidal habitats from extensive sandy shores to rocky reefs. The area was considered a site of primary marine biological importance (Powell *et al.* 1978). Particular mention was made of St Michael's Mount, a tidal island separated from the mainland by a paved causeway. Boulder shores on the north-west corner were described as having exceptionally rich communities with a very high biomass. Large specimens of the red algae *Palmaria palmata* were found here. A small seagrass *Zostera marina* bed was recorded to the east of the causeway. Tavis Vor Reefs were noted for the presence of the non-native red alga *Asparagopsis armata* and the first record of the Mediterranean hermit crab *Clibanarius erythropus* in Britain in 1960 (Carlisle & Tregenza 1961). Great Hogus reef, located to the west of St Michael's Mount, is an isolated rock outcrop set within a long sandy coast. The reef was an especially important reference area following the *Torrey Canyon* oil spill in 1967 as detergents were not used on the reef despite oiling and, in contrast to nearby areas where detergents were used, no adverse effects on shore fauna were recorded (Smith 1968).

Sublittoral habitats and communities in the western part of Mount's Bay were described by James (1983).

Infralittoral habitats were characterised by dense kelp forests; circalittoral bedrock was characterised by sea anemones, especially the jewel anemone *Corynactis viridis*.

Penzance is the centre of a sea-urchin *Echinus esculentus* fishery and data from 1981 revealed about half a million animals were collected each year. Nichols (1981) investigated the impact of this fishery on local populations and concluded that there was no biological evidence to suggest that, at the level of fishing effort in 1981, the fishery was having a serious effect on the total population size.

Land's End, the south-westerly tip of mainland Britain, is a granite headland exposed to the full force of the Atlantic breakers. Land's End was considered to be a site of primary marine biological importance (Powell *et al.* 1978) and was considered to have some of the finest examples of very exposed rocky shore communities in Britain. Upper shores were dominated by barnacles (*Chthamalus montagui* and *Chthamalus stellatus*), limpets and winkles *Littorina* spp. Low shores were carpeted with the pink tufted coralline alga *Corallina officinalis* and overlain with the kelp *Alaria esculenta*.

Powell *et al.* (1978) highlighted Sennen Cove as a site of particular interest. Composed of large granite boulders on bedrock, the shore had sparse biota on the upper and mid-shore but a dense growth of thong weed *Himanthalia elongata* on the low shore. Among this dense covering, a luxuriant growth of red algae covered the rock surface. Kelp species dominated the sublittoral fringe. Boulders in more sheltered places had a very well developed bed of the unusual green alga *Codium tomentosum*. Whitesand Bay, a sandy bay exposed to the full force of the waves appeared barren of life with only meiofaunal species, small enough to live between sand grains, surviving the extreme conditions present there (Harris 1972).

8.5 Isles of Scilly

8.5.1 Introduction

The Isles of Scilly are an island archipelago situated some 45 km west of Cornwall. There are over 100 islands and islets but only five are inhabited. The islands have long been recognised as having international nature conservation importance. Many areas are notified SSSIs, and the islands are a major breeding area for seabirds and seals with some of the most exposed areas of coastline in Britain. The archipelago was classified as a site of international marine biological importance (Powell *et al.* 1978); the islands are a proposed Marine Nature Reserve in recognition of the considerable marine biological interest. In 1988, the islands were declared a Marine Park by the Isles of Scilly Council.

The geographical position provides a mild frost-free climate where the mean annual air temperature is 11.4 °C, mean annual rainfall is 831 mm and mean surface sea temperature is 12.4 °C. Predominantly west-to-east ocean currents and an almost total lack of freshwater runoff results in uniform salinity and low turbidity; the alga *Laminaria ochroleuca*, which occurs in dense stands, has been recorded at depths of up to 30 m (Powell *et al.* 1978). Pingree & Mardell (1986) studied tidal streams around the islands and noted the presence of strong tidal jets which propagate in a clockwise direction; a peak current flow of 175 cm s^{-1} was recorded.

The islands have a long history of marine biological investigations and early studies are summarised in Harvey (1969). Studies of the marine flora of the Isles of Scilly were reviewed and described by Russell (1968) following a meeting of the British Phycological Society held on the islands. In the 1960s, major collecting exercises were initiated, with assistance from the London University Sub Aqua Club, to describe the marine fauna of the Isles of Scilly. These and other collections ultimately produced a series of papers in the *Journal of Natural History* describing the distribution and abundance of marine fauna in the Isles of Scilly. The groups included are:

Taxonomic group(s)	Reference(s)
Foraminifera	Atkinson 1970
Cnidaria and Ctenophora	Robins 1969
Gastrotricha	Hummon and Warwick 1990
Free-living Nematoda	Warwick and Coles 1977
Polychaeta	Harris 1972
Pycnogonida	King 1972
Copepoda: Harpacticoida	Wells 1970
Ostracoda	Neale 1970
Mysidacea	Makings 1987
Eucarida	Thurston 1969
Mollusca	Turk & Seaward 1997
Bryozoa I and Entoprocta	Hayward 1971
Bryozoa II	Hayward 1976
Echinodermata	Rowe 1971
Enteropneusta, Ascidiacea, Thalacea, Larvacea and Cephalochorda	Rowe 1972
Tardigrada	King *et al.* 1981
Digenea from invertebrates	Newell 1986

Pugh (1988) studied the shore-dwelling mites (Acari) and recorded 75 species from littoral and supralittoral zones. In recognition of the international marine biological importance of the islands, NCC commissioned a series of surveys to describe the marine habitats and communities as a precursor to designating the islands a Marine Nature Reserve. Rocky shores were described by Hiscock (1984a), sediment shores were described by Nichols & Harris (1982) and Holme (1983); sublittoral rocky habitats were described by Hiscock (1984b), and sublittoral sediment communities by Rostron (1983; 1989). Foster-Smith (1991) completed a boulder survey of 11 sites to describe the communities of the under-surfaces of boulders.

8.5.2 Rocky shores

Nine different rocky shore types were identified, ranging from those exposed to very severe wave action

on the outer shores of the western islands, to very sheltered rocky shores in the channels between the islands (Hiscock 1984a) (Figure 8.16). Rock habitats range from bedrock to sand-covered boulders. A total of 128 algal, 13 lichen and 237 animal species were identified from these rocky shores; communities were distinctly southern in character. Rocky shore habitats identified by Hiscock (1984a) were:

1a *West-facing, steeply sloping bedrock shores exposed to the full force of the prevailing wind-driven waves and swell.* Communities present were characterised by a small range of species in distinct belts. Low shore communities were characterised by red algae with scattered plants of kelp *Alaria esculenta*. The tufted coralline alga *Corallina officinalis* dominated the lower shore. A lichen-dominated splash zone extended up to 11 m above chart datum at some sites.

1b *West and north-facing, steeply sloping bedrock shores exposed to very strong wave action.* Communities present were similar to those described above except the abundance of species was higher.

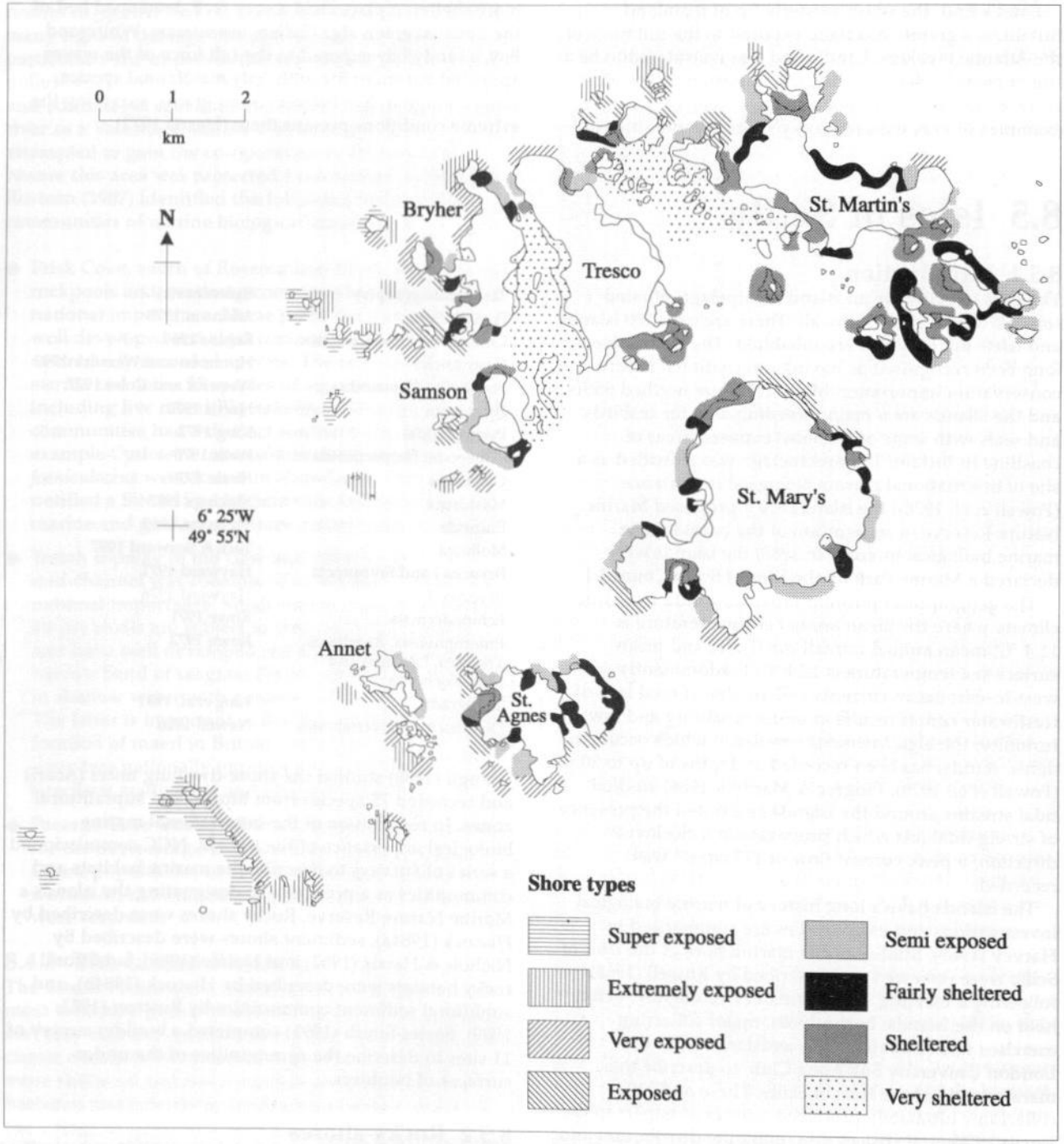

Figure 8.16. Wave exposure of rocky shore types in the Isles of Scilly (unshaded areas are predominantly sandy). Larger areas than the scattered intertidal areas are shaded. (From Hiscock 1984a.)

Midshore zones were characterised by a broad belt of the barnacles *Chthamalus* sp. and the limpet *Patella vulgata*.

2 *Rock slopes on wave-exposed coasts.*
These shores are protected from the full force of the prevailing wave action by offshore rocks or adjacent shallow inshore water. Low shore zones were characterised by *Corallina officinalis*, the thong weed *Himanthalia elongata* with scattered kelp plants *Alaria esculenta*, *Laminaria digitata* and *Saccorhiza polyschides*; red algal species richness was high. Mid-shore zones were characterised by barnacles and limpets while upper shore habitats were characterised by fucoid algae.

3 *Rock slopes on the seaward-facing shores of the outer islands but sheltered by aspect or offshore rocks.*
These shores were dominated by limpets and barnacles; the barnacle *Chthamalus stellatus* was present on lower to mid-shore while *Chthamalus montagui* was present on the upper shore.

4 *Rock slopes on east-facing or locally sheltered shores of the outer islands.*
Shores were characterised by fucoid algae with a rather bare limpet/barnacle-dominated mid- to upper shore.

5a *Bedrock and large boulder slopes near the open coast but within bays.*
Shores within this category had rich algal communities on the low and upper shore; mid-shore zones were dominated by barnacles and limpets. Underboulder habitats with high species richness were identified.

5b *Bedrock and boulder shores near the open coast but within bays and extending to sand or sand-covered rock on the lower shore.*
Communities are very similar to those of 5a except that the red alga *Audouinella* sp. colonised sand-covered rock.

6 *Bedrock and boulder shores extending to sand and sheltered from strong wave action.*
Lower shore algal communities were characterised by encrusting calcareous algae occasionally overgrown by foliose algae. *Laminaria* spp. were present where boulders extend to the lowest shore. Low-shore animal communities including underboulder communities had a high species richness with many rarely encountered species recorded. Gastropod molluscs characterised mid- and upper-shore habitats.

7 *Bedrock and boulder shores on enclosed coasts where fetch does not exceed a few hundred metres except within a narrow angle.*
Bedrock in the upper shore usually gives way to boulders and to boulders and sand on the low shore. Where boulders are not embedded in sediment, rich underboulder communities were recorded. Shore communities were characterised by fucoid algae.

Hiscock (1984a) listed a series of features that distinguish the rocky shores of the Isles of Scilly from those of mainland Britain. The islands are the only recorded British location for the bryozoan *Turbicellepora magnicostata*. Another notable record was the alga *Pikea californica*, the first north-east Atlantic record of this Pacific species (Maggs & Guiry 1987). Rather surprisingly, some species regarded as abundant on the mainland are rare or absent within the islands: for example the barnacle *Semibalanus balanoides* and the common periwinkle *Littorina littorea* are rare in the Isles of Scilly. These distributions may be the result of the predominantly west-to-east ocean currents reducing larval transfer from the mainland (Southward 1976).

8.5.3 Littoral sediments

Littoral sediments were studied by Nichols & Harris (1982), and are composed of coarse-grained granite sand. Five principal areas of extensive sedimentary flats occur within the islands: east of Samson; between Bryher and Tresco; adjacent to Old Grimsby; Tresco and south of St Martin's. Nichols & Harris (1982) described these five areas and put forward suggestions concerning their conservation. Samson Flats composed of clean, well sorted sand at the northern end with the gravel and mud content increasing towards the southern end. Species richness within upper shore areas was considered low and communities were characterised by lugworm *Arenicola marina*. In contrast, low shore zones had a high species richness with communities characterised by polychaetes, bivalve molluscs, and the burrowing hearturchins *Echinocardium cordatum* and *Echinocardium pennatifidum*. Tresco Flats are subject to a strong tidal surge through the Tresco-Bryher Channel, which results in highly mobile sediment on the flats. Areas sheltered from this surge have pools of standing water with dense populations of the anemone *Cereus pedunculatus*. A small seagrass *Zostera marina* bed is present, which provides shelter for many other species. Anemones and lucernarians (stalked jellyfish) were present on the fronds; polychaetes, molluscs and echinoderms were associated with the roots. *Anthopleura ballii*, a rarely recorded sea anemone, is often present in large numbers within the *Zostera* beds, and the Isles of Scilly are one of the few locations in Great Britain where this species has been recorded. At extreme low water, dense beds of burrowing hearturchins including *Spatangus purpureus* were recorded. An area of particular interest was Old Grimsby Harbour for an extensive meadow of *Zostera marina*. Attached to the leaves and bases were algae, in particular the southern species *Asparagopsis armata*. Rich animal populations were recorded in association with the *Zostera* beds, and dense populations of the burrowing anemone *Cereus pedunculatus* and hearturchins were noted, with hearturchins attaining densities of 25 m^{-2}.

St Martin's Flats is the largest continuous area of sand in the Isles of Scilly. Tidal streams vary over the area, resulting in differing degrees of sediment-sorting, which in turn leads to different infaunal communities. Small populations of amphioxus *Branchiostoma lanceolatum* were occasionally present. Large populations of the sand-mason worm *Lanice conchilega* extend from mid- to low tide level. Rich infaunal communities were characterised by hearturchins and bivalve molluscs including *Lutraria lutraria*. Nichols & Harris (1982)

recommended that these sediment shores be considered for statutory protection in view of their high habitat diversity and associated species richness. They were designated as SSSI in 1996.

8.5.4 Sublittoral habitats

The Underwater Conservation Society completed a series of broadscale surveys of sublittoral habitats in the Isles of Scilly (Dipper 1981). These studies recognised a number of features of conservation importance, for example, the very high habitat diversity occurring over a short distance in which very exposed to very sheltered habitats can occur within a few hundred metres.

Sublittoral rock habitats range from extremely exposed to very sheltered. Clear water results in extensive kelp forests and kelp parks. In addition, many species of algae have been recorded including *Pikea californica*, *Cruoria cruoriaeformis* and *Desmarestia dresnayi*, which are not found or rarely found elsewhere in Britain. Below the kelp, the rock surface was dominated by sponges, anemones, soft corals and sea squirts. Hiscock (1984b) described 18 sublittoral rock habitats and six sublittoral sedimentary habitats. In addition, information was presented for restricted areas such as caves, overhangs, crevices and underboulder habitats. Most communities identified had a strong southern element. Species such as the kelp *Laminaria ochroleuca*, the alga *Asparagopsis armata* and red sea fingers *Alcyonium glomeratum* were present in higher abundance than previously recorded on the mainland. In addition, these southern species were recorded from more wave-exposed conditions than other areas surveyed.

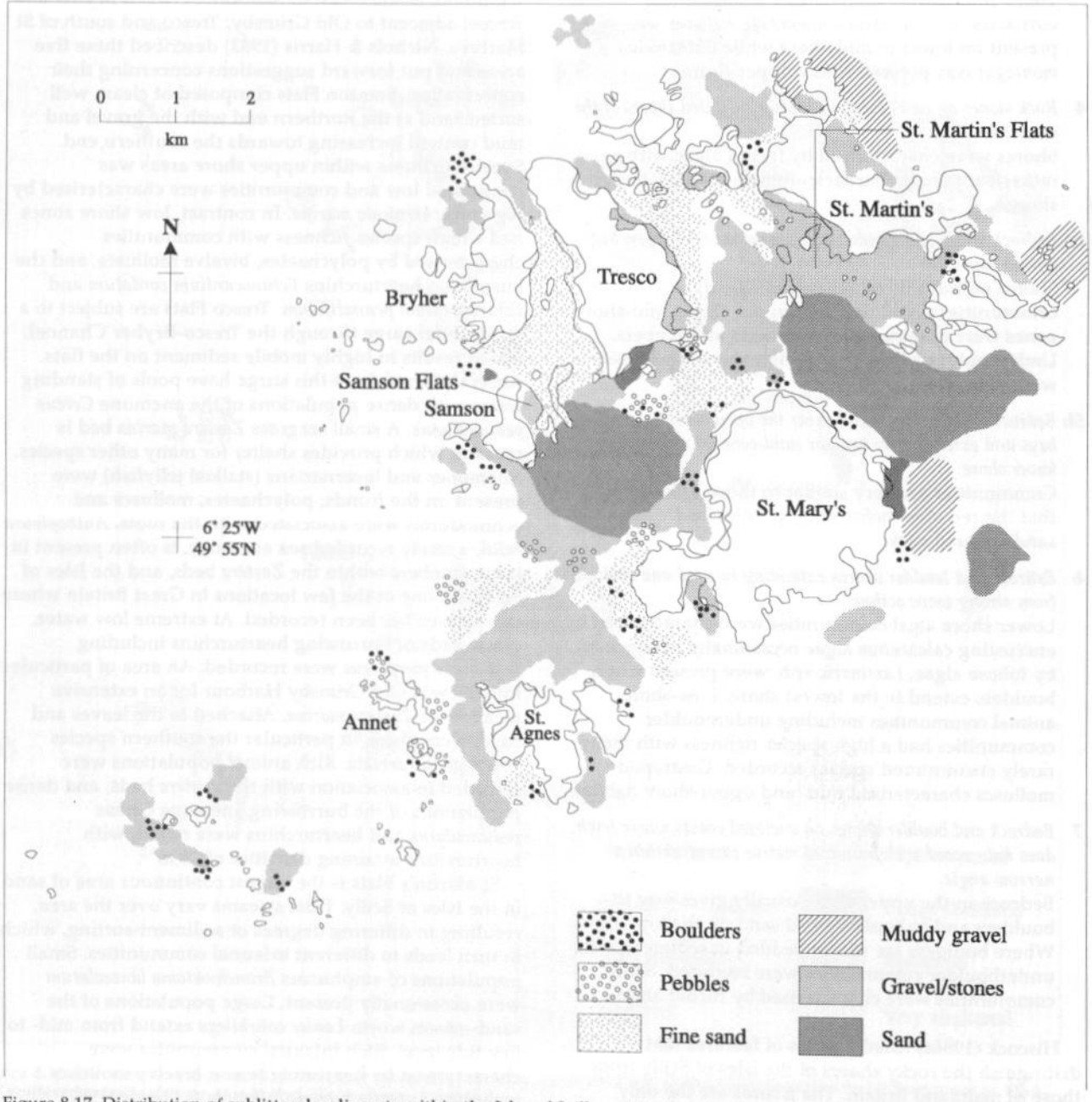

Figure 8.17. Distribution of sublittoral sediments within the Isles of Scilly archipelago (re-drawn from Rostron 1989).

Tide-swept infralittoral cobble habitats had rich algal communities and were considered to be of national importance (Hiscock 1984b).

The descriptive surveys were followed by the establishment of sites to monitor communities of high nature conservation interest. These included the animal communities of sponges and anthozoans on circalittoral rock on the east-facing coast of St Marys, examples of seagrass *Zostera marina* beds and underboulder communities on the shore. During these studies, further sites have been described, emphasising the richness of circalittoral sponge assemblages on east-facing coasts (Hiscock 1984b). Irving (1987) presented the results of the monitoring projects in 1985 and 1987 and noted changes in the populations of Mediterranean–Atlantic species of conservation interest. Fowler (1990, 1991) described the monitoring projects in 1988, 1989 and 1991 (only the subtidal sites were monitored). Fowler & Pilley (1992) analysed the results of the Isles of Scilly monitoring projects from 1988 to 1991. There were large changes in the populations of the cup-coral *Caryophyllia smithii*, storm damage to the seagrass *Zostera marina* beds, and colonisation by the non-native alga *Sargassum muticum* (Japweed). In contrast, the populations of south-western species remained constant except for a possible small recruitment to the population of sunset coral *Leptopsammia pruvoti*.

Sublittoral sediment communities range from coarse sand and gravel to fine sand to muddy gravel; distribution of the sediment types within the archipelago are shown in Figure 8.17. Seven sediment types and associated communities were identified by Rostron (1989). Of particular interest were the *Zostera marina* beds and their associated fauna and flora. A number of rare species have been collected within the sediments; the polychaetes *Spio mecznikowianus* and *Ehlersia garciai* were previously unrecorded in Britain.

Species richness of the Isles of Scilly was not as high as other similar offshore islands such as Lundy; nevertheless a number of southern species recorded within the Isles of Scilly have not been recorded on the mainland, for example the crustacean *Melita* (now *Abludomelita*) *gladiosa* (Rostron 1983). Habitat diversity within the archipelago is high, and many sites have a complex array of habitat types in a small area. Wave exposure varies from extremely exposed to very sheltered, often within a short distance. It is this complex array of habitat types, wave exposure and the associated communities which is of significant marine biological importance.

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