Report for the
Department of Trade and Industry

Synthesis of Information on the Benthos of Area SEA 8

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Prepared by

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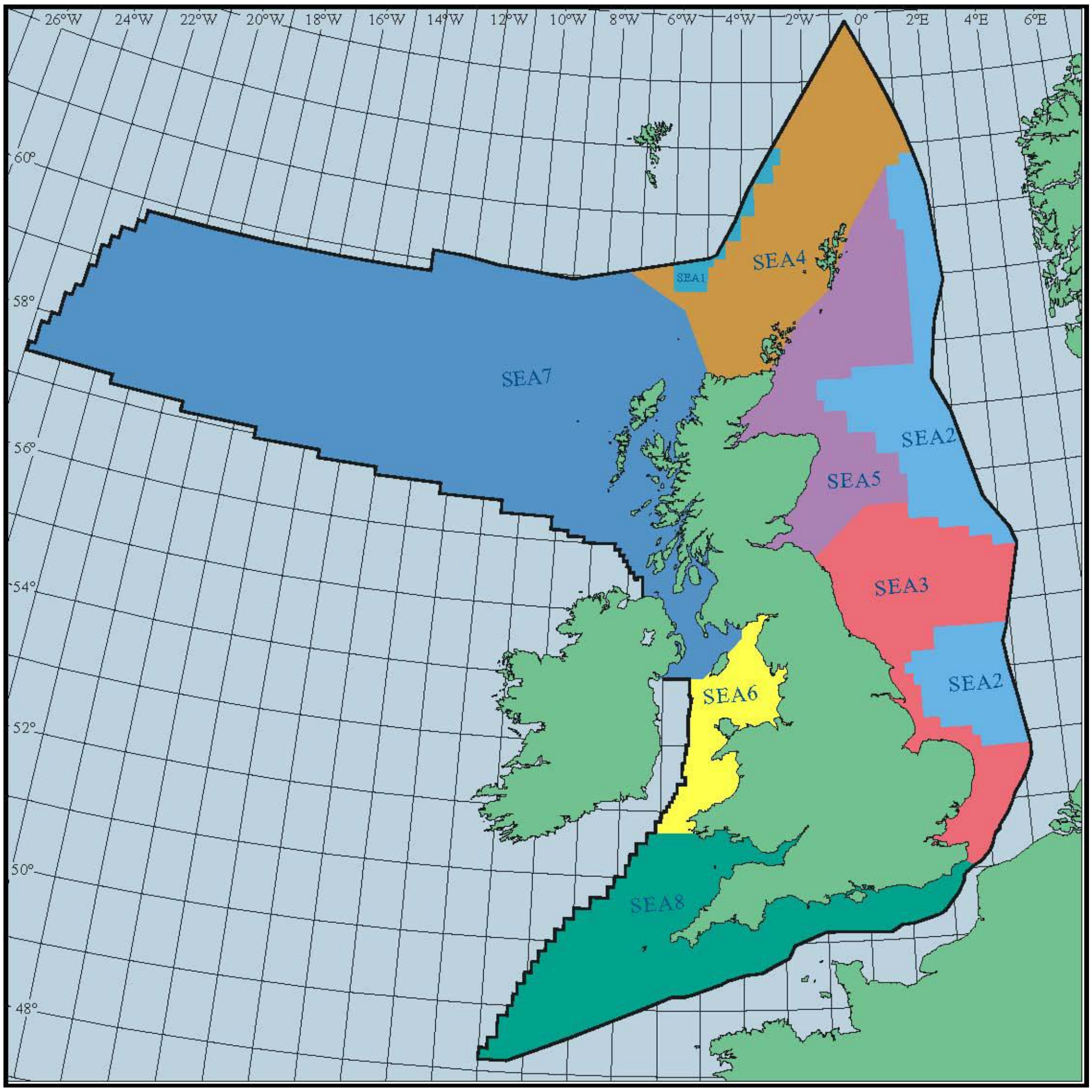
CONTENTS

1. INTRODUCTION

The DTI SEA 8 Area in the southwest of the UK Continental Shelf encompasses the Bristol Channel, NE Celtic Sea, SW Approaches and English Channel. It is bordered to the north by the Irish Sea (SEA 5) and the Pembroke Peninsula, to the west by the Irish shelf and to the south by the French shelf. It includes parts of the following Weather Areas: Lundy, Fastnet, Sole, Fitzroy, Plymouth, Portland, Wight and Dover. From a fishing perspective, SEA 8 covers parts of ICES Divisions VIId-j.

Figure 1. The Strategic Environmental Assessment areas



The study area for this review has been split into different geographical regions as follows:

- The Bristol Channel & Severn Estuary: reaching inland to the Severn Estuary and extending out to just south of Milford Haven, South Wales and Barnstaple Bay, Devon. Milford Haven was included in the SEA 6 report (Wilding et al., 2005). The Bristol Channel is subdivided into three sections; inner, central and outer.

- The North-East Celtic Sea: offshore areas from (51°40’N) to the Isles of Scilly and inshore from Barnstaple Bay to Land’s End, Cornwall.

- The Western Approaches & Shelf Edge: Offshore areas southwest of Land’s End and the Isles of Scilly to the shelf edge at 48°10’N, 10°W.

- The Western English Channel: east from Land’s End as far as Swanage.

- The Solent and the Isle of Wight: from Swanage and Poole Bay to Selsey Bill.

- The Eastern English Channel: from Selsey Bill to Folkestone at the edge of SEA8.

2. HISTORICAL OUTLINE

Naturalists have been visiting the South Coast since preVictorian times. John Ellis, interested in zoophytes, visited the Sussex coast in the mid-1700s and Thomas Pennant, in his British Zoology published in 1777, described many marine species from the region. The 1800s saw the development of marine biology, driven by interested amateurs and professional natural historians. Among the greatest and most influential of these was Philip Henry Gosse, who lived and worked in Dorset and, later, Devon. His Actinologica Britannica was, until recently, the standard work on British sea anemones and corals. He became a household name in Victorian Britain, and his works lead to an upsurge of interest in marine biology and aquarium keeping. The general wide interest in fisheries and marine biology, stimulated by the International Fisheries Exhibition held in London in 1883, led to the foundation of the Marine Biological Association of the United Kingdom (MBA) which, in 1888, built a laboratory in Plymouth which became the major centre for marine biological research in Europe for much of the twentieth century. The importance of the MBA may be guaged from the number of publications quoted in the reference list of this report which appeared in the association's Journal, particularly those by Norman Holme and Allan Southward. In the latter part of the twentieth century the MBA was joined in Plymouth by the Institute of Marine Research (now the Plymouth Marine Laboratory) which undertook major work in the Bristol Channel. Plymouth remains a centre of excellence for marine biology today, and the MBA library (now the National Marine Biological Library, see http://www.mba.ac.uk/nmbl/) houses one of the world's greatest collections of marine biological literature.

3. THE PHYSICAL ENVIRONMENT

The area under review is large and extremely heterogeneous, encompassing examples of nearly all of the marine and coastal habitats and features to be found in the United

Kingdom. The SEA8 area ranges from the edge of the continental shelf to shallow current-swept regions of the eastern English Channel and muddy estuarine waters of the Severn. Throughout the area there is a complex and important relationship between the fauna inhabiting the seabed, underlying geology and geological history, and hydrodynamics. Tides are very important, creating rapid streams in the Channel, and fierce currents in the Bristol Channel where the tidal range is one of the greatest in the world. Geologically conditions range from hard igneous outcrops in the west, such as Haig Fras, the Isles of Scilly, and Land's End, to the very old and unique serpentines of the Lizard, through examples from nearly the whole geological history of England as one travels from west to east. This includes the Devonian rocks of Devon, the Jurassic Coast, which stretches from the borders of Devon to the Isle of Wight, to later chalks and more recent deposits further east. Evidence of the effects of glaciation are to be found everywhere, and winnowed glacial deposits are an important component of seabeds and seashores. Offshore habitats range from deep, low energy muds and sands to extremely exposed reefs and current-swept gravels. Along the coast there are hard and soft cliffs and rocks, huge areas of intertidal sediments (especially in the Severn and the Solent), rias, bays, shingle bars and beaches, sandy beaches, sheltered estuaries, lagoons, and man-made structures. All of these provide substrata for marine benthos.

4. BIOGEOGRAPHY

Historical marine biogeographic works (Briggs, 1974; Ekman, 1953) recognized the southwestern region of the British Isles as one of faunal change and overlap. This was evident for both intertidal and sublittoral faunas (e.g., Lewis, 1964; Hartley, 1979). Certain species with known southern (Lusitanian) distributions could be found near their northernmost limits, while other northern (Boreal) species reached their southernmost ones. Hiscock (1991) consequently considered the western parts of the SEA 8 area a boreal-lusitanian province, bounded to the north and east respectively by the boreal Irish Sea and central/eastern English Channel). French waters off western Brittany had a similarly transitional fauna, but had a greater lusitanian species presence. The western Channel is therefore an important area for monitoring changes in the distribution of fauna and flora. In the UK, any alterations in the presence or abundance of species due to climate change are likely to be noticed in the SEA 8 area before extending to adjacent areas (Hawkins et al., 2003; Herbert et al., 2003; Southward et al., 1995). Hiscock et al. (2004) used life history information to provide hypotheses for species distribution change in relation to increases in water temperature.

5. BENTHIC COMMUNITIES, ASSEMBLAGES AND ASSOCIATIONS

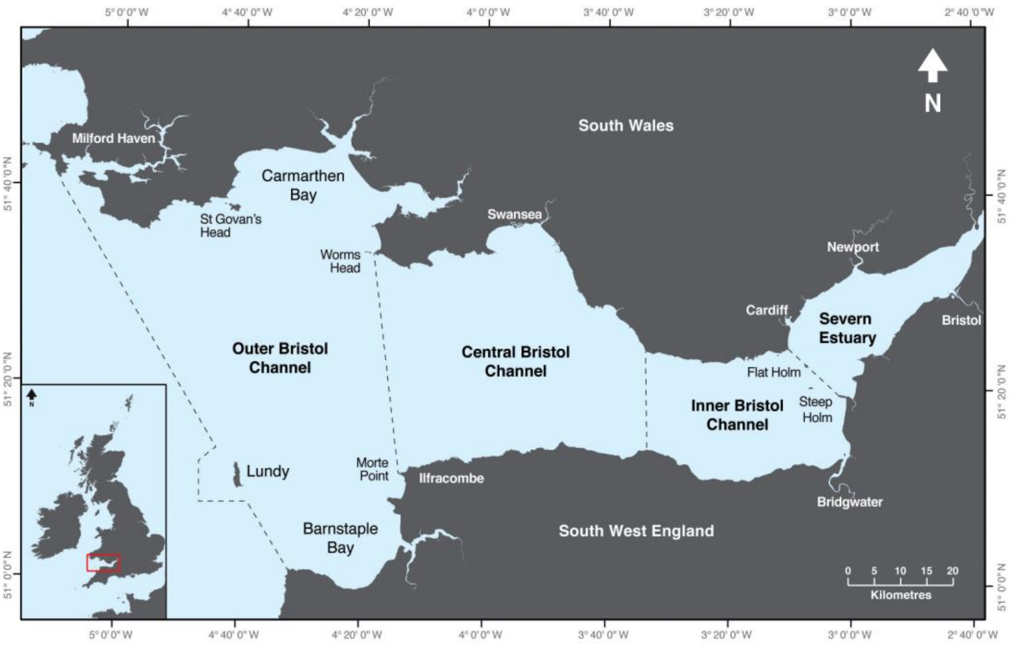
In the following sections, the fauna is considered relative to different geographical scales (regional to local) and marine zones (intertidal and sublittoral to the shelf edge).

5.1 The Bristol Channel & Severn Estuary

This area is characterised by strong tidal streams and low salinity in the Severn Estuary and the inner section of the Bristol Channel, with extensive mud and sand flats (Davies, 1998b). It is the second largest estuary in Britain, with an area of 557 km^2 including an intertidal area of 100 km^2 (Davidson, 1991). It has an extremely large tidal range of up to 14.5 m (Henderson et al., 1992). Southeast Wales and the Avon are industrialised areas with four large ports in the inner channel and Severn estuary. This has changed the conditions in the area with the building of docks at Avonmouth and Portbury and the Cardiff Bay Barrage on the Welsh shore completed in the 1990s (Cordrey, 1996). The outer channel in the west contrasts this with very exposed rocky shores, high cliffs and exposed sandy beaches. North Cornwall, north Devon and Wales are generally rural areas popular with tourists in the summer (Davies, 1998a).

The vertical distribution of common marine macroalgae and fauna on rocky shores along the estuary were described by (Mettam, 1994). Conditions changed along the channel, with greater shelter and an increased tidal range in an easterly direction, along a gradient of salinity and turbidity. West of Swansea was considered ‘marine’ and was termed the Bristol Channel. A transitional stage was recognised between Swansea and Cardiff, and the ‘estuarine’ area east of Cardiff regarded as the Severn Estuary (Mettam et al., 1994). However, for planning purposes relating to marine aggregates, the National Assembly for Wales use slightly different definitions (Figure 2)

Figure 2. Regions within the Bristol Channel and Severn Estuary (from Mackie et al., 2006)

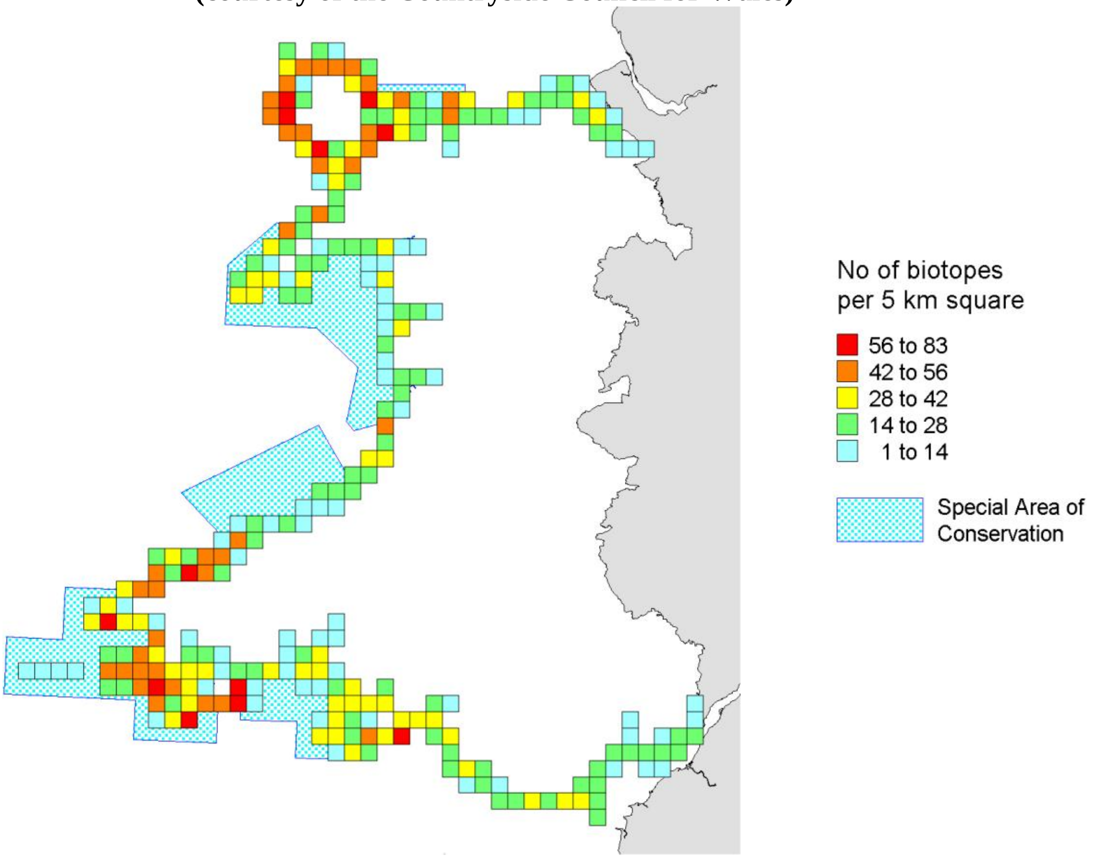


42a OBC location map in perspective with the wider British Isles

5.1.0.1 Intertidal fauna

The shores fauna of the Severn Estuary is well-known from a variety of detailed studies (Bassindale, 1941, 1942; Boyden et al., 1977; Boyden & Little, 1973; Haderlie & Clark, 1959; Purchon, 1948, 1957). Between 1996 and 2004, the Countryside Council for Wales (CCW) carried out extensive assessments on the intertidal biotopes on the Welsh side of the Bristol Channel and Severn Estuary (Wyn et al., 2006). The biotope maps produced were very detailed and can only be interpreted fully using the MapInfo GIS package. The numbers of biotopes present were higher on Gower and west of Carmarthen Bay (Figure 3). An example of the output maps for West Aberthaw (between Barry and Llantwit Major) is provided below. MapInfo shape files for specific sites can be provided by CCW on request.

Figure 3. Schematic distribution of biotope number around the Welsh coast (courtesy of the Countryside Council for Wales)



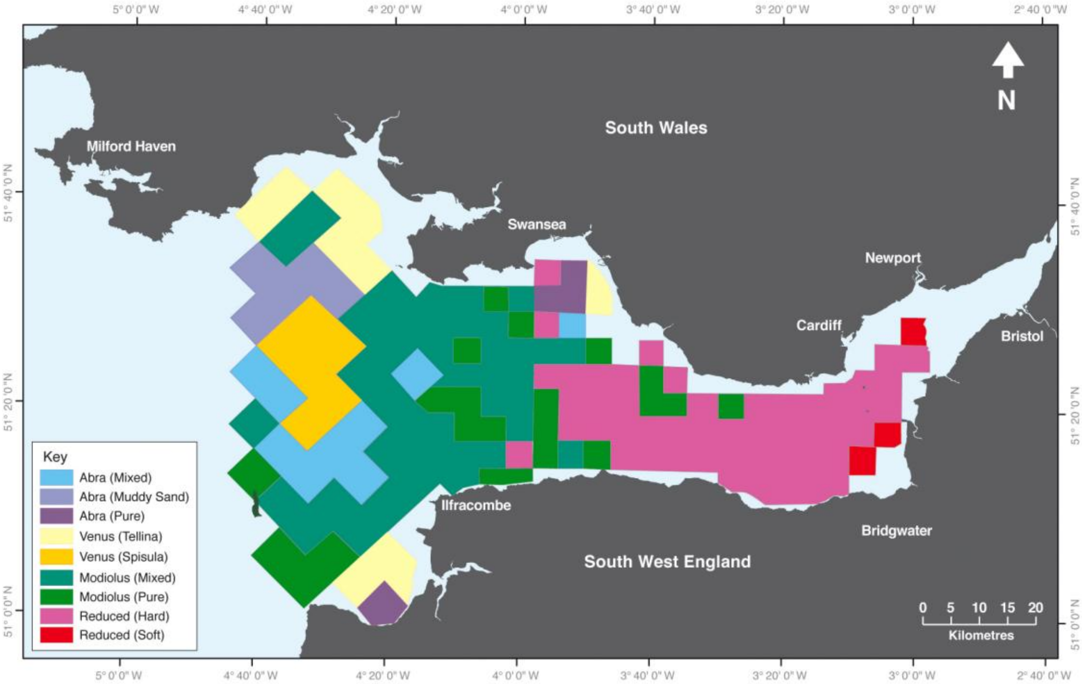
5.1.0.2 Sublittoral fauna

The most comprehensive study of the benthic fauna of the Bristol Channel and Severn Estuary was carried out under an integrated research programme by the Institute for Marine Environmental Research (IMER) (1975). Some 40 research cruises took place between 1971 and 1975, collecting data on water circulation, chemistry, plankton and benthos. The broad benthic survey took place in 1972-1973 and 155 stations were sampled using a 0.07 m^2 Day grab and 0.5 mm mesh sieve and a rectangular Naturalist's Dredge with a 1.3 cm mesh net (Warwick & Davies, 1977). Sediments were assessed visually.

The 294 species identified were analysed using a semi-quantitative abundance scale and five Petersen-type 'communities' recognised (Petersen, 1918, 1924; Thorson, 1957). The communities (Figure 4), primarily named after their prominent bivalve mollusc species, were:

Venus community
Abra community
Modiolus community
Reduced hard-bottom community
Reduced soft-bottom community

Figure 4. Distribution of benthic macrofaunal assemblages in the Bristol Channel (after Warwick & Uncles 1980; Warwick 1984).



The *Venus* community was described as having two sub-communities, *Tellina* and *Spisula*. Transitions between the communities were also noted.

I. *Venus* community

Occurring in shallow hard-packed sands, the *Tellina* sub-community, was characterised by the bivalve molluscs *Fabulina* (as *Tellina*) *fabula*, *Pharus legumen* and *Donax vittatus*, opisthobranch mollusc *Philine aperta*, amphipods *Bathyporeia guilliamsoniana* and *Pontocrates arenarius*, cumacean *Iphinoe trispinosa*, polychaete worms *Magelona mirabilis/Magelona johnstoni* (as *Magelona papillicornis*), *Lagis koreni*, and *Aphelochaeta marioni*, brittle-star *Ophiura ophiura*, and starfish *Astropecten irregularis* and *Asterias rubens*.

II. *Abra* community

This was found in silty or mixed sediments and was characterised by the bivalves *Abra alba* and *Nucula nitidosa*, polychaetes *Scalibregma inflatum*, *Lagis koreni* and *Nephtys hombergii*, and amphipod *Ampelisca spinipes.*

III. *Modiolus* community

The least well-defined community found, this occurred on a variety of hard bottoms (gravels to rock), particularly in the central channel between Gower and north Devon. The characterising species were the hermit crab *Pagurus bernhardus*, crabs *Pisidia longicornis* and *Ebalia tuberosa*, polychaetes *Lepidonotus squamatus* and *Syllis armillaris*, amphipod *Gammaropsis maculata*, chiton *Leptochiton asellus*, brittle-stars *Ophiothrix fragilis* and *Ophiura albida*, starfish *Asterias rubens*, sea urchin *Psammechinus miliaris.* The Horse Mussel *Modiolus modiolus* was relatively infrequent in the samples.

There was an indication of subdivision within the community. Stations with mixed sand, silt and gravel had many species also found in the *Venus* and *Abra* communities. Conversely, harder rockier substrata associated with the Morte and Lundy platforms supported more crevice dwelling or attaching species.

IV. Reduced Hard Bottom Community
Found on hard rocky bottoms subject to strong tidal scour in the Central and Inner Channel. Characteristic species were predominantly encrusting or crevice-dwelling: the polychaetes *Syllis armillaris, Eulalia tripunctata, Sabellaria alveolata* and *Sabellaria spinulosa*, bivalve *Sphenia binghami*, amphipods *Unciola crenatipalma*, *Gammarus zaddachi* and *Janira maculosa, starfish Henricia sanguinolenta,* and anemone *Sagartia troglodytes*.

V. Reduced Soft Bottom Community
A reduced soft bottom association was found in fluid mud in the Inner Channel and Severn Estuary. The fauna was sparse and characterised by the polychaetes *Aphelochaeta marioni* and *Nephtys hombergii,* and a small oligochaete, *Tubificoides* sp. (as *Peloscolex* sp.)

In a later analysis of the same data, (Warwick & Uncles, 1980) used all 9 communities, sub-communities or groups previously delineated and showed that the sediment and faunal distributions were directly related to tidal bed stress as derived from a hydrodymamic model. (Warwick, 1984) reviewed the benthos relative to the possible building of a Severn Barrage.

5.1.0.3 Epifauna

The epibenthic invertebrate and fish assemblages of the Outer and Central Bristol Channel were examined in more detail by (Ellis, 1999; Ellis & Rogers, 2000; Ellis et al., 2000). A 4 m beam trawl was used with a 40 mm mesh cod-end. In the third publication, five faunal assemblages were identified from these areas:

1. *Pleuronectes-Limanda* assemblage
Characterised by flatfish, including Plaice (*Pleuronectes platessa*) and Dab (*Limanda limanda*), and scavenging invertebrates such as crabs (*Liocarcinus* spp. *Pagarus bernhardus*), Common Whelk *Buccinum undatum* and Common Starfish *Asterias rubens*. This assemblage occurred on the sands of Carmarthen Bay and its approaches.

2. *Maja* assemblage
Characterised by the spider crab *Maja squinado*, flatfish (sole, *Solea solea*) and the small gadoid, Bib (*Trisopterus luscus*). The assemblage also had the large starfish *Marthasterias glacialis* and attached colonial epifauna such as hydroids and soft corals. Although the authors were cautious about this assemblage since *Maja* is known to migrate inshore in Spring and Summer, the other taxa seem indicative of the harder substrata found off south Gower, Swansea Bay, Barnstaple Bay and on the Morte Platform (north of Barnstaple Bay).

3. *Microchirus-Pagurus* assemblage
Characterised by Thickback Sole (*Microchirus variegatus*) and the hermit crab *Pagurus prideaux*, this too had an abundance of Common Starfish, sole and Common

Dragonet (*Callionymus lyra*). This assemblage occurs on the coarser mixed sediments found offshore.

4. Echinus-Crossaster assemblage
Characterised by large echinoderms, the Common Sea Urchin *Echinus esculentus* and Common Sunstar *Crossaster papposus*, with the Common Starfish again abundant too. This assemblage occurred widely throughout the offshore gravely sediments of the Irish Sea, but was only found once in the mid Central Bristol Channel. However, this lack of representation may simply be due to the low level of sampling carried out in this part of the Channel.

Ellis et al. (2000) considered this assemblage, plus the *Microchirus-Pagurus* assemblage, to equate to the *Adamsia carciniopados-Psammechinus miliaris* one described by (Rees, Pendle, Waldock, Limpenny & Boyd, 1999). The anemone *Adamsia* is a commensal on *Pagurus prideaux*.

5. *Alcyonium* assemblage
Characterised by the Dead-man's Fingers, the soft coral *Alcyonium digitatum*, this assemblage also included Dab, Plumose Anemone (*Metridium senile*), Velvet Swimming Crab (*Necora puber*) and the urchin *Psammechinus miliaris*.

The assemblage was infrequent in the study and, in the Bristol Channel, only occurred southeast of Caldey Island. This, and four Irish Sea localities that were mostly off headlands, was likely to have a stony substratum.

Ellis et al. (2000) carried out a species-environment analysis using the BIO-ENV routine in the PRIMER computer program (Clarke & Ainsworth, 1993). Depth, surface water temperature and weight of rocks collected were the variables best 'explaining' the faunal assemblages (ρ_w=0.46).

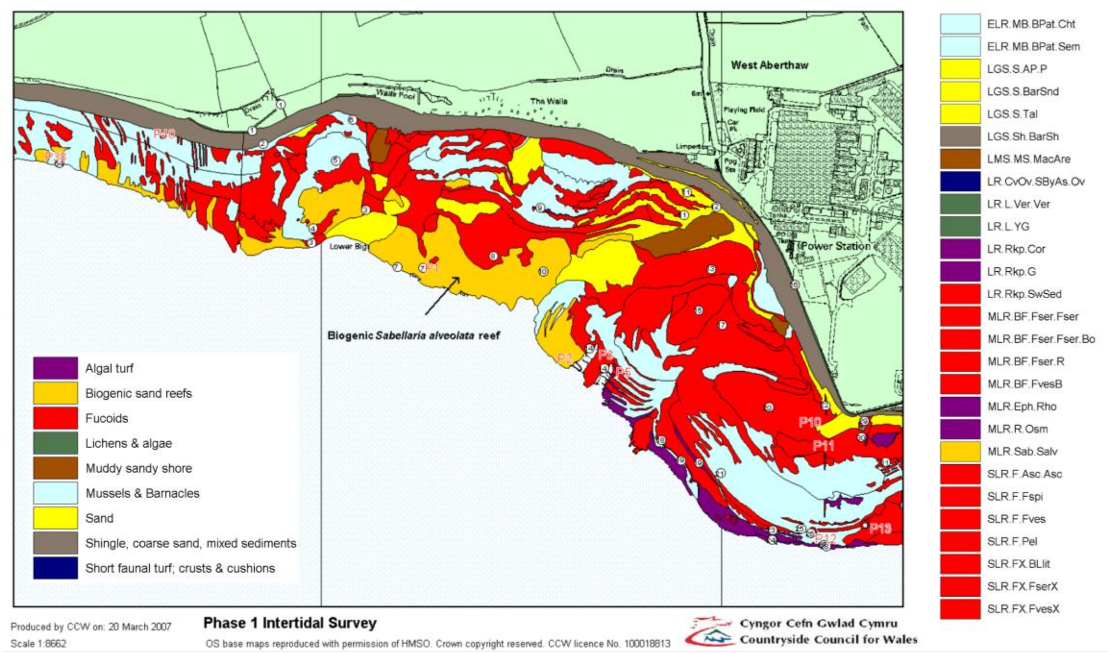
5.1.1 Severn Estuary & Inner Bristol Channel

5.1.1.1 Intertidal Fauna
Bassindale (1941, 1942) and Purchon (1948, 1957) published lists of intertidal species from a number of localities on the English and Welsh shores respectively. Haderlie & Clark (1959) gave a summary account of the sandy and muddy shores, and the main macrofaunal species encountered, on both sides of the Severn Estuary and Inner and Central Bristol Channel. Quantitative distributional data of the species inhabiting the English intertidal sediments from the upper Estuary (at Epney, south of Gloucester) to the Inner Channel (Minehead) were compared in Boyden & Little (1973). Later, Boyden et al. (1977) compiled a detailed species inventory from many studies of the Severn Estuary. Davies (1991) provided a useful map showing the locations of 19 intertidal and sublittoral investigations (1941-1988) through to Ilfracombe (north Devon) and Port Eynon Bay (Gower) in the Central Bristol Channel.

Warwick et al. (1991) compared the intertidal macrofauna and associated environmental variables of 6 estuaries from SW Britain. Nine sites in the Severn Estuary and one from the Inner Bristol Channel (Bridgwater Bay) were analysed alongside 28 sites from Poole Harbour, Southampton Water, and the Exe, Tamar and Plym estuaries. Two additional sites in the upper Severn Estuary were omitted since the unstable sands there contained few animals. The Severn intertidal fauna was found to be quite distinct from the five other estuaries, which had more similar animal assemblages. In the Severn, the molluscs *Hydrobia ulvae* and *Macoma balthica*, polychaete *Nephthys hombergii* and amphipod *Bathyporeia* sp. were more abundant. Tubificid oligochaetes, amphipods *Corophium volutator* and *Corophium arenarium*, cirratudid, capitellid, spionid and orbiniid polychaetes, and amphipod *Melita palmata* were less abundant. Suspension-feeding bivalves such as *Scrobicularia plana* and *Mya arenaria*, and the isopod *Cyathura carinata* were noticeably absent at the Severn Estuary sites. Turbidity and sediment instability associated with the dynamics of a large macrotidal estuary were considered the probable factors influencing the fauna.

The recent countrywide study of Welsh shores by the Countryside Council for Wales (Wyn et al. 2006) has yielded a wealth of information on the biotopes present. A MapInfo GIS output map for West Aberthaw (between Barry and Llantwit Major) is provided here as an example (Figure 5). The distributions of the biotopes can be displayed according to the MNCR classification of Connor et al., 2004). However, due to the large number of biotopes present, a simplified Lifeform (Bunker & Foster-Smith, 1996) version is easier to interpret as a printed map.

Figure 5. Biotope map of the West Aberthaw shore simplified to show the broader 'Lifeform' mapping units. The biotope key is provided on the right. Example courtesy of the Countryside Council for Wales



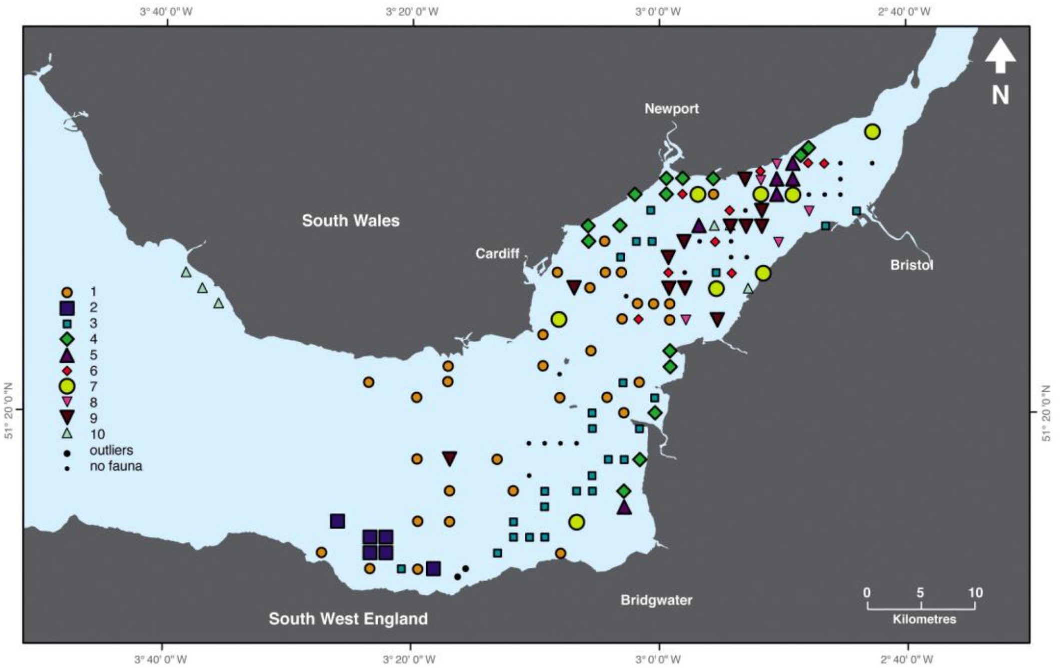
5.1.1.2 Sublittoral benthos

In a large-scale sublittoral survey (Warwick & Davies, 1977) 41 stations were located in the Severn Estuary (9) and Inner Bristol Channel (32) areas. The seabed here is predominantly hard with rock outcrops and areas of clean sand or mixed sand/gravel (Evans, 1982; Mettam et al., 1994; Tappin et al., 1994). Muddy sediments occur in the intertidal and shallow sublittoral between Cardiff and Newport, and extensively off Bridgwater Bay. Warwick & Davies (1977) reported an impoverished variant of their 'Reduced Hard Bottom community" in this area (Figure 4). The anemone *Sagartia troglodytes* and amphipod *Gammarus zaddachi* were noted as prominent.

The muddy sediments of Bridgwater Bay likewise hosted an impoverished variant of their ‘Reduced Soft Bottom community’. The cirratulid polychaete *Aphelochaeta marioni* and oligochaete *Tubificoides* sp. were abundant. In the west of the bay, where the mud met rock (stn 26), the muddy tubes of the ampharetid polychaete *Melinna elisabethae* (recorded as *M. cristata*; see Mackie & Pleijel, 1995) formed a dense ‘turf’ of 76,000 individuals/m^2. Coal fragments and polystyrene spherules constituted prominent constituents of these tubes.

In 1988 the benthic macrofaunal assemblages of the intertidal and sublittoral dediments were investigated by Mettam et al. (1994). Sampling involved 0.1 m^2 Day grab samples and a 0.5 mm mesh sieve. The hardness of much of the substrata made sampling difficult and the removal of up to 50% of the sample for sediment analysis reduced the quantitative value of the sampling. A total of 112 taxa were identified from the 136 samples containing fauna; 33 samples contained no animals. The data was analysed using cluster analysis and TWINSPAN (Hill, 1979). Ten faunal groups were identified using the former technique (Figure 6) and 9 using the latter. After considering both sets of results together, the authors recognised 8 faunal groups (here designated A-H) — each occupying different sediment types and depths.

Figure 6. Distribution of benthic faunal groups in the Inner Bristol Channel and Severn Estuary (after Mettam et al. 1994).



Group A (Figure 6: cluster 1) was found in sublittoral areas of exposed rock and hard gravelly sediments. The honeycomb worm *Sabellaria alveolata* was common, as were associated polychaetes *Eulalia tripunctata* and *Syllis armillaris,* and bivalve mollusc *Sphenia binghami*.

Group B (cluster 2) occurred in sublittoral gravelly patches. The small syllid polychaete *Exogone naidina* was a characteristic species.

Group C (cluster 3) was primarily localised in the soft sublittoral muds of Bridgwater

Bay and off Wentlooge Flats between Cardiff and Newport. These correspond to the 'Reduced Soft Bottom community' of Warwick & Davies (1977). The characterising species were the polychaete *Nephtys hombergii* and oligochaete *Tubificoides amplivasatus*.

Group D (cluster 4) was common in the intertidal muds on the Welsh side of the Severn Estuary. It occurred also on the English side, between Sand Point (north of Weston-Super-Mare) and Burnham-on-Sea (Bridgwater Bay). Characteristic species included the small bivalve *Macoma balthica*, gastropod *Hydrobia ulvae*, oligochaete *Tubificoides benedeni*, and polychaetes *Nephtys hombergii*, *Hediste diversicolor*, *Pygospio elegans* and *Streblospio shrubsolii*.

Group E (cluster 5) occurred on the offshore sand banks of the Welsh Grounds in the eastern Estuary and, on the English side, in the intertidal sandy sediments at Sand Point and Berrow Sands in Bridgwater Bay. Characteristic species included the amphipods *Bathyporeia pelagica*, *Bathyporeia pilosa* and *Haustorius arenarius*, cumacean *Cumopsis goodsiri*, and polychaete *Nephtys cirrosa*.

Group F (cluster 10) occurred in fine to medium sands subtidally inshore of Nash Sands (Central Bristol Channel) and sporadically in the Estuary; on the outer part of the Welsh Grounds, and at low water between Avonmouth and Portishead. *Nephtys cirrosa* was a characterising species.

Group G (cluster 9) was associated with the coarse sands of linear sand banks (Culver and Cardiff Grounds) and mid-Estuary sands containing little fauna. Some similar sands had no fauna. The isopod *Eurydice pulchra* was a characteristic species.

Group H (clusters 6-8) occupied a large area of intertidal and subtidal sand to the east of 3°10'W, but mainly in the Estuary. The fauna was very impoverished and some similar sands had no fauna. Characterising species included the opportunistic polychaete *Capitella capitata* and mobile crustaceans, the amphipod *Gammarus salinus* and mysid *Mesopodopsis slabberi*.

5.1.1.3 Eastern Rivers & Estuaries

Moore et al. (1998) compared the fauna of the estuaries that flow into the main Severn estuary. It was found that the fauna of the Rivers Avon, Usk and Wye was similar to that for the soft sediment in the Severn estuary. The polychaete *Nereis diversicolor*, the mud shrimp *Corophium volutator*, the Baltic tellin *Macoma balthica* and oligochaetes dominate the faunal assemblage. Maximum densities of tellin and amphipods were higher in than in the main estuary.

River Wye is a long narrow inlet with a high freshwater input, the banks are dominated by muds with the exception of a few rock outcrops. There are a number of weirs that maintain the water levels. The fauna is dominated by the gastropod *Hydrobia ulvae*. Further upstream there are high numbers of the oligochaete *Tubifex sp.* The major human influence of this inlet is the discharge of sewage into it from Chepstow (Moore et al., 1998).

River Usk flows down from the Brecon Beacons and meets the Bristol Channel near Newport. It is tidal for almost 30 km, and is dominated by mud with some areas of saltmarsh. The waters are of poor quality due to the high levels of effluent discharge from the populated areas along the river. Surveys were carried out on the benthic fauna to assess the impact of the Western Valley Trunk Sewer on behalf of the Welsh Water Authority. These showed that communities were impoverished and the sediments were fine and poorly sorted (Davies, 1998a). There was on average only four taxa per station. There is low salinity and high turbidity in this inlet. The mud at the mouth of the estuary is subject to higher salinity and thus has a greater diversity of infaunal species. The fauna there is characterised by the polychaete *Hediste diversicolor*, and the Baltic tellin *Macoma balthica*. The polychaete *Streblospio shrubsolii* and the isopod *Cyathura carinata* are also found; these species are known to tolerate a wide range in salinity. The human influences on this estuary include the discharge of effluent both from industry and domestic sewage, and also the presence of docks, bringing in shipping and dredging (Moore et al., 1998).

5.1.1.4 Cardiff Bay & South Glamorgan coast

Rees (1940) carried out a preliminary study of faunal zonation on the mudflats between Peterstone Wentlooge and the River Rumney, east of Cardiff. Ten stations were sampled from low to high water, 150 m from a sewage outfall. Quantitative analysis (0.2 mm sieve) of the fauna revealed a macrofauna dominated by *Hydrobia ulvae*, *Hediste diversicolor* and *Macoma balthica*. Nematodes were the most abundant meiofaunal group, reaching a maximum of 104,000 individuals per 100 cm^2. Rees drew attention to an apparent inverse relationship between the abundance of *Hediste diversicolor* and the numbers of meiofaunal copepods, nematodes, oligochaetes and ostracods. A simplified food web was presented. This area was re-sampled 40 years later (Mettam, 1983) to investigate the impacts of sewage outfalls that had been constructed in the interim period. It appeared that there was little change, although the polychaete *Streblospio shrubsolii* had spread along to Wentlooge flats. It was concluded that this might reflect the tidal movement of sewage in this area.

Purchon (1948) carried out surveys on and off the coast from Petersone Wentlooge, to Breaksea Point including Barry, Cardiff, Penarth, Flat Holm, Steep Holm and Sully Island. A brief description of the shores is given, along with a species list for each location. It was concluded that the sublittoral fauna was impoverished, contributed to by the low salinity and strong currents in the area. 184 species were identified 38 of which were new to British records at the time. Steep Holm had previously been studied by Yonge & Lloyd (1939) who found that the paucity of species was attributable to the low salinity and high turbidity. Some of the species found were usually associated with brackish areas. Molluscs dominated the community, however this may be a result of the fact that no sampling was undertaken of the muds around the low water mark. An area of mudflats near Rumney Great Wharf has been claimed by poldering. A study of this area was carried out by White & Mettam (1989). The results of this study were compared to those from Boyden et al. (1977) and Mettam (1983) and it was considered that the fauna was a transitional stage between sandflat and saltmarsh fauna.

5.1.1.5 River Parrett, Somerset

River Parrett is a bar-built estuary that flows into Bridgewater Bay embayment. The inlet is a meandering channel, bound by sea defences, and is increasingly canalised beyond Bridgewater to limit the penetration of seawater. Muds, influenced by strong tidal currents and low salinity, dominate this inlet. Steep sided channels are formed at low tide, and artificial structures such as wooden groynes are exposed. These hard substrates support fucoid algae, but the fauna is generally impoverished. The mud shrimp *Corophium volutator* is found on the sandy upper banks and is joined by the amphipod *Bathyporeia pilosa* on the lower shore where the mud content is higher. The mud flats, below the areas of saltmarsh, support *H. diversicolor* and *C. volutator*. The sublittoral zone consists of a small shallow channel of extremely mobile muds. These muds support the amphipod *Gammarus salinus*, the Baltic tellin *M. baltica* and polychaetes (Moore, 1989).

5.1.1.6 Bridgewater Bay & the Somerset Coast

The sublittoral zone consists of a small shallow channel of extremely mobile muds. These muds support *Gammarus salinus*, *Macoma baltica* and polychaetes (Moore, 1989). There are also areas sand waves and reefs formed by *Sabellaria*, a tube building polychaete (Glover, 1984). Bridgewater Bay has been subject to a number of investigations on its extensive area of littoral sandflats (Davies, 1998a). Henderson et al. (1992) carried out a 10-year study looking at the seasonal stability within the trophic structure and food webs of this area. This concentrated on the fish and crustaceans and found that the trophic structure followed a seasonal cycle as a result of the migration of principal organisms in the food web.

5.1.2 Central Bristol Channel

5.1.2.1 Intertidal Fauna

The sedimentary and rocky shores of the Welsh coast were investigated in a number of overlapping studies (Nelson-Smith, 1974; Shackley, 1981; Withers, 1977b). The intertidal biotopes of the area were recently examined by the Countryside Council for Wales as part of their Phase 1 study (Wyn et al. 2006). Holme & Nichols (1976) described the rocky shore fauna and flora on the northern shores of Devon and west Somerset.

5.1.2.2 Sublittoral Fauna

Warwick & Davies (1977) found the seabed fauna to vary from a 'Reduced Hard Bottom community' in the east to a '*Modiolus* community' in the west. Swansea Bay was heterogeneous with areas of both alongside a transitional *Tellina-Spisula* '*Venus* community' (Figure 4).

5.1.2.3 Swansea Bay

This area extends from Port Talbot to the Mumbles Peninsula. It is a shallow industrialized embayment, largely comprised of muddy sands (Davies, 1998a). The port used to be heavily used by shipping, but now the docklands area has been converted into a marina and accommodation. Queen's Dock used to be greatly affected by the heated effluent outflow from the nearby power station. This is discussed later in terms of anthropogenic impacts, and has been stopped since 1975, so the faunal community has returned to its normal state (Bullimore et al., 1978). The infauna of sandy shores was summarised by Shackley (1981). It was concluded that the exposure of the Bay to prevailing south-westerly winds, and the resulting wave action, reduces the species richness and biomass of the communities present. Harkantra (1982) examined the sublittoral benthic macrofauna and concluded that there was correlation among the benthic faunal element, their feeding habit, organic carbon and sediment texture. Rocky shore communities were examined by Nelson-Smith (1974) in order to collect base-line data for studies of the effects of pollution. He concluded that at the time the effects of pollution were minimal, and that visitors to the beach trampling on the biota were causing more damage.

In 1992 the construction of an amenity barrage was completed in Swansea at the mouth of the River Tawe. As a result of the construction of the barrage the hard shore invertebrates disappeared, due to the area being permanently submerged once the barrage was operational. There was also a degree of sedimentation upstream. The green alga *Enteromorpha intestinalis* did persist on the hard surfaces, but in lower quantities than pre-barrage. Pre-barrage the intertidal fauna was predominantly opportunistic annelid worms. When surveyed twenty-three species were identified, the assemblage was typical of a eutrophicated, polluted, muddy estuary. The usual estuarine species (*Macoma balthica, Corophium volutator, Hydrobia ulvae* and a selection of polychaetes) were present, but in low densities. Post-barrage surveys showed that the number of species had decreased from twenty-three to nineteen. However three species that were no longer found were amphipods, which were seen to be scarce before the barrage as well. *Nereis diversicolor* and *Macoma balthica* decreased in the now submerged areas, while *Nephtys hombergi* increased in numbers downstream from the barrage. The oligochaete *Tubifex costatus* increased too, this species is typical of organically enriched anaerobic mud (Dyrynda, 1994). Other effects were a disruption to the migration routes of fish, despite a fish pass being built, which along with the submergence of areas of mud flats reduced the food available for birds. Mullet disappeared from the area, but the numbers of juvenile flounder increased. Along with the mullet, shore crabs and brown shrimps disappeared after the barrage was built, despite being common before building. The overall effects of this barrage were not as dramatic as they may have been due to the estuary being in poor condition prior to the construction of the barrage.

Sublittoral communities were examined by Warwick & George (1980) who looked at the annual production in the *Abra* community in the Bay. It was classified as an *Abra* community but was in fact dominated, in terms of biomass, by *Spisula elliptica* and *Nucula nitidosa*. Other common species found were; brittlestars *Ophiura ophiura*, and polychaete worms *Nephtys hombergii* and *Ampharete acutifrons*. Pollutants from local industry, and sewage outfall have long influenced the fauna in Swansea Bay.

River Neath is a narrow inlet that has been greatly affected by man, not least by the construction of a retaining wall to secure the main channel. It leads in to Swansea Bay and at low tide is a narrow meandering channel with mud flats on either side. The mudflats are replaced by sandier substrate towards the mouth of the inlet. Full surveys of the marine fauna in this area have not been undertaken, but inferences have been made from the empty shells found in the area. It has been observed that there is a sparse covering of fucoid algae on the man-made structures in the inlet. The NCC (Nature Conservancy Council, 1977) suggests the presence of cockles *Cerastoderma edule,* Baltic tellin *Macoma balthica, Buccinum undatum, Polinices catens* and *Ensis ensis*. The influences of industry are strong in this area; there is landfill, oil spillage and heavy commercial use of the area. Subsequently this area is not used for recreation, except in the upper region (Moore et al., 1998).

The benthic ecology of the linear sandbanks off Swansea was examined by Tyler & Shackley (1980). They found that this was a high-energy environment dominated by tidal currents and wave action. The faunal diversity is greatly reduced, being dominated by crustaceans *Gastrosaccus spinifer* and *Pontocrates arenarius* and the polychaete worm *Nephthys cirrosa*. This suggests that these linear sand banks represent a reduced *Spisula* community. Smith & Shackley (2006) examined the benthos of the inner western part of the bay, before and immediately after the cessation of sewage discharge at Mumbles Head. It was clear that there was a significant improvement in the water quality, and changes in the composition of the benthic community in the area. There was an increase in the diversity of deposit feeders, especially amphipods, and a decrease in the diversity of filter feeders, especially polychaetes. This was attributed to the reduction of suspended particulate organic matter and sewage contaminants discharged into the Bay. Smith & Shackley (2004) also investigated the effects of the commercial mussel *Mytilus edulis* lay that was established in the Bay in 1998. It was seen that within a year the species composition of the benthic community had changed. Previous to the fishery the area supported a diverse inshore benthic community typical of the sand/mud substrate in the area. The mussels out competed the other filter feeding organisms, by preventing settlement, or simply smothering them, and the abundance of carnivores and deposit feeders increased.

5.1.2.4 The Gower Peninsula

Gower was the first area in Britain to be designated an Area of Outstanding Natural Beauty (AONB). It is also considered to have primary marine biological importance by the Intertidal Survey Unit (Powell et al., 1979). The north coast of Gower is part of the Burry Inlet, a sheltered sedimentary estuary (Davies, 1998a). The south west coast has rocky shores comprised of Carboniferous limestone and some Millstone Grit. These shores are all fairly well protected so are only moderately exposed rocky shores. They tend to be very irregular and pitted, smoothing as you move further up the shore. The level of exposure and the substrate type controls the faunal assemblages on Gower's beaches. The south coast has sheltered sandy shores, like Oxwich (Powell et al., 1979).

A literature review of the flora and fauna of Gower exists (Freytag, 1977). The rocky shores were dominated by barnacles and limpets in the mid-shores and had algal rich lower-shores. Most sites were also seen to have rich rockpool communities. In 1978 twenty-one sites from Worms Head to Mumbles were surveyed, examining the nearshore sublittoral habitats (Hiscock et al., 1980). This was part of a study by the Nature Conservancy Council looking at nearshore areas of South West Britain. The influences on the beaches surveyed were considered in terms of locality, exposure and the presence of industrialisation in the vicinity. To the east of the study area the coastal areas are heavily developed in terms of industry and urbanisation, a possible source of pollution to the area. Sewage is discharged at Mumbles, and may be carried along the coast causing stress to some of the more sensitive organisms. Sediment loading increases from west to east along the South Wales coast. High turbidity may benefit suspension-feeding organisms, offering a good food source as long as their feeding organs do not become clogged and they survive such conditions. It also means that light penetration is poor, reducing the abundance of algae that are able to grow. The stability of the substrate is also important; boulders are a more dynamic substrate and so tend to have fast growing species with high recruitment levels. Compared to similar coastal areas in southwest Britain, the algal-dominated infralittoral fringe is very compressed. This is a reflection of the high turbidity in the area. Sublittoral habitats were typically gently sloping bedrock, which supported extensive areas of mussels *Mytilus edulis*, and the tubeworm *Sabellaria spinulosa*. A number of boring species were found in the limestone, these included the sponge *Cliona* sp., the bivalve *Hiatella arctica* and the horseshoe worm *Phoronis hippocrepia*. The vertical and overhanging surfaces were found to be particularly rich in animal communities.

Withers (1977b) examined sixteen beaches between Milford Haven and Swansea Bay, identifying one hundred and sixteen sand–dwelling macrofaunal species. The species diversity was greatest on the sheltered and semi-exposed beaches, with clean sands. The beaches on the south coast of Gower were found to have a considerable number of species. However the more exposed beaches were not as rich as the equivalent beaches in Camarthen Bay. Oxwich Bay, a large moderately exposed sandy bay, is a National Nature Reserve (Davies, 1998a). The littoral zone has high densities of the heart urchin *Echinocardium cordatum* and the razor shells *Ensis siliqua* (Bishop & Holme, 1980).

Tyler (1977) described the sublittoral sediment community at Oxwich Bay. This sandy faunal community is dominated by *Spisula elliptica* with the occasional polychaete *Nephtys hombergii* or *Lanice conchilega*. The eastern part of the bay has an 'impoverished' *Venus* community. Within the tidal gyres formed by the shape of the bay, the population appeared to be a typical rich *Syndosmya (Abra)* community. The dominant species were polychaetes, gastropods and other molluscs. It was found that the currents transporting the larvae dictated the distribution of burrowing species in the sublittoral community. So it seems that the benthic community here results from the hydrodynamic regime and not the bottom sediment type. This is possible due to the winnowing out of organic material and the influence of currents on the settlement of meroplankton. Errant species however did not remain in the same area in which they first settled. The other sublittoral communities of Gower have been investigated (Hiscock, 1979; Hiscock et al., 1980). Sediment shores had a sparse epifaunal community including the burrowing anemone *Cereus pedunculatus*, sand mason worms *Lanice conchilega* and the mollusc *Hinia reticulata*. Shackley (1981) found only a single species, the isopod *Eurydice pulchra*, at Foil Bay near Worm's Head and none at all at Bracelet Bay, Mumbles Head.

5.1.2.5 North Devon Coast

Moore & Little (1994) examined the habitats and associated faunas of six estuaries in North Devon (and Carmarthen Bay in S. Wales). The study was commissioned by the Nature Conservancy Council, and undertaken by the Field Studies Council Research Centre. The incursion of sand in sandy estuaries in the Bristol Channel has formed dunes at the estuary mouths, and filled channels. This means that tidal currents are fast flowing and the bed of the estuary is scoured by this wave action. Areas with coarse mobile sediments have few species; 3 amphipod species, an isopod and sandeels *Ammodytes marinus*. Other species found in more mobile sediments are polychaete and bivalve species tolerant of reduced salinity. The sediments further up are more stable and have smaller grain size, so the fauna is characteristic of mud flat species.

Dramatic, rugged cliffs dominate the coast of north Devon. The broad sandy beaches at Bideford Bay interrupt these, it is this combination that attracts many visitors to the area (Davies, 1998a). Crothers (1985) described many of the beaches during an extensive study of the dog whelk *Nucella lapillus*. Powell et al. (1978) examined the different habitats and the pressures that they were exposed to. Rocky shores tended to support quite a poor community, and the sandy shores with richer communities were more easily accessible and so under greater pressure from human activities. The principle cause of pollution in this area tends to be sewage, which is a greater problem in the tourist season. Hiscock (1981b) surveyed the sublittoral habitats and communities from Morte Point to Lynmouth as part of the South-West Britain Sublittoral Survey summarised in a report to the NCC. Wilson (1977) monitored the growth of the *Sabellaria* colonies on a small sandy beach at Duckpool, on the north coast to the north of Bude.

5.1.2.6 Ilfracombe

While recuperating from ill-health at Ilfracombe, the naturalist Philip Henry Gosse (1810-1888) revelled in the richness of the intertidal marine life and subsequently published (Gosse, 1853) his inspirational *A Naturalist's Rambles on the Devonshire coast*. Gosse' discoveries and book encouraged many, for example the novelist George Elliot, to explore the shores at Ilfracombe (Bellanca, 1997) and other places.

Palmer (1946) published lists of the marine flora and fauna for the district of Ilfracombe. The areas that he mentioned have been revisited and are still seen to have a rich littoral fauna, especially in the overhangs and shaded areas (Davies, 1998a). The seabed a few kilometres off Ilfracombe was studied by George & Warwick (1985) and was found to be a hard bottom community dominated by *Sabellaria* reefs. Ninety-four species were recorded in this study, with the exclusion of some colonial organisms, which could not be enumerated. The biomass and productivity of the most abundant organisms was then assessed.

5.1.3 Outer Bristol Channel

5.1.3.1 Intertidal Fauna

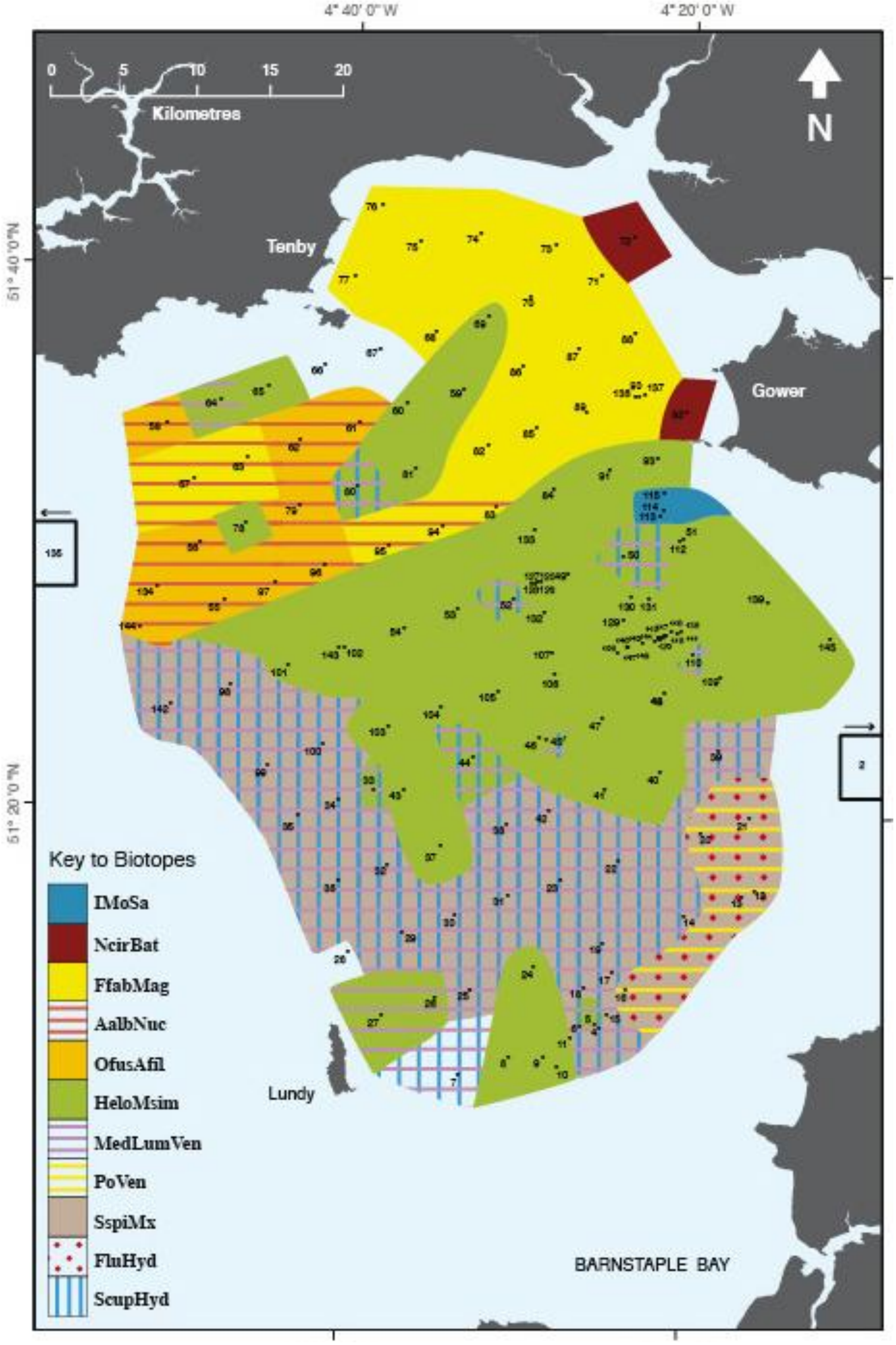
The intertidal soft sediment fauna was described by Withers (1977b).

5.1.3.2 Sublittoral Fauna

Warwick & Davies (1977) described the sublittoral fauna Outer Bristol Channel as belonging the '*Abra*', '*Venus*' and '*Modiolus*' communities (Figure 4). Mackie et al. (2006) carried out a more intensive survey of the area, including Carmarthen Bay.

The multivariate patterns in the macro-infauna and epifauna were investigated using quantitative and semi-quantitative cluster analyses. The resulting clusters and their subgroups were drawn on the sampling station map with reference also to features on the seabed character and bedforms map, to produce assemblage maps. The macrofaunal assemblages and their subgroups were examined in detail relative to their species compositions, dominant species and characterising species. These assessments plus details of the physical environmental characters were then used to manually determine the biotopes present (Connor et al., 2004); using the EUNIS classification eunis.eea.eu.int/habitats.jsp). A biotope map was then drawn as a modification of the macrofaunal assemblage maps (Figure 7). Although the community names used by Warwick & Davies (1977) differed, there was good agreement with the component species and the biotopes recognised by Mackie et al. 2006).

Figure 7. Benthic biotope map of the Outer Bristol Channel area (from Mackie et al. 2006)



A total of 8 infaunal and 3 epifaunal habitats (biotopes) were determined from the classifications of Connor et al. (2004). In certain areas (Figure 7; Table 1) a combination of up to 3 different habitats could co-occur, the epifaunal ones being present as overlays on the infaunal ones. The distributions of some habitats, particularly epifaunal such as SspiMx (*Sabellaria spinulosa*), were difficult to determine precisely at the scale of the study. Sediment characteristics (sand, mud carbonate in gravel, mean phi & Inman Sorting) and depth were found to be the variables 'best explaining' (ρ=0.62) the faunal distributions.

Table 1. EUNIS and MNCR habitat codes for the *Outer Bristol Channel Marine Habitat Study*

EUNIS	MNCR	Description
Infauna		
A5.231	SS.SSa.IFiSa.IMoSa	Infralittoral mobile clean sand with sparse fauna
A5.233	SS.SSa.IFiSa.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand
A5.242	SS.SSa.IMuSa.FfabMag	*Fabulina fabula* and Magelona mirabilis with venerid bivalves and amphipods in infralittoral compacted fine muddy sand
A5.261	SS.SSa.CMuSa.AalbNuc	*Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment
A5.272	SS.SSa.OSa.OfusAfil	*Owenia fusiformis* and *Amphiura filiformis* in offshore circalittoral sand or muddy sand
A5.124	SS.SCS.ICS.HeloMsim	*Hesionura elongata* and *Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand
A5.132	SS.SCS.CCS.MedLumVen	*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel
A5.451	SS.SMx.OMx.PoVen	Polychaete-rich deep *Venus* community in offshore mixed sediment
Epifauna		
A5.611	SS.SBR.PoR.SspiMx	*Sabellaria spinulosa* on stable circalittoral mixed sediment
A5.444	SS.SMx.CMx.FluHyd	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment
A5.232	SS.SSa.IfiSa.ScupHyd	*Sertularia cupressina* and *Hydrallmania falcata* on tide-swept sublittoral sand with cobbles or pebbles

5.1.3.3 Burry Inlet

At the mouth of the Loughor River, to the north of Gower, this is a small, shallow, sedimentary estuary with strong tidal flow and shifting sandbanks (Davies, 1998a). This area has been reviewed and described (Moore, 1989) as part of a report for the Nature Conservancy Council. The sandflats at the mouth of the estuary have rich infaunal communities, and support a cockle *Cerastoderma edule* fishery. The Inlet is an SSSI for its bird life, as Whiteford Sands on the western side, and attracts internationally important numbers of waders and wildfowl. They were also considered a site of primary marine biological interest due to the presence of a well-developed *Tellina* community (Bishop & Holme, 1980).

Littoral habitats are mainly sedimentary with limited hard substrata. Whiteford Scar is composed of cobbles and pebbles, and has a rich algal community dominated by mussels *Mytilus edulis*. The lower estuary has extensive areas of moderately stable fine sand, which is characterised by bivalve molluscs and polychaetes. The sublittoral areas are restricted to the centre of the main channel, and are sedimentary. The mobile medium-fine sands at the mouth of the estuary have an impoverished faunal assemblage. Further up the estuary there is an increase in diversity as the mud content increases. Burry Inlet was found to have a rarely recorded polychaete *Ophelia bicornis* (Moore, 1989).

5.1.3.4 Carmarthen Bay

Carmarthen Bay, is an extensive, shallow embayment with unusually well sorted sandy sediment, exposed to the south-westerly winds. It encompasses a wide range of rich and diverse coastal and marine habitats including broad sandy beaches, wide river estuaries and cliffs in the west (Davies, 1998a). Large sand dunes and salt marshes back this sandy shore (Smith et al., 1995). The estuaries of the Taf, Tywi and Gwendraeth, locally known as the 'Three Rivers', converge and enter the bay through a common mouth. All three rivers are subject to substantial infilling by marine sediments from the bay. This movement of sediments has led to the Gwendraeth being a bar-built estuary (Moore et al., 1998). A survey of these three estuaries was carried out (Mercer, 1989). Mussels *Mytilus edulis* and cockles *Cerastoderma edule* are harvested commercially on a small scale. It was considered whether the shellfisheries could be extended, with the introduction of other native species. The industry in this area was considered to be under threat from bait digging, the effects of which were considered by Cadman (1989).

Hard substratum within the estuary is limited and where it does exist it is sand scoured and supports a very impoverished community. Sediment dominates the system and ranges from moderately mobile fine sediments to stable sand flats. Fine mobile sediments at the river mouths have communities with low diversity characterised by the Baltic tellin *Macoma balthica*, thin tellin *Angulus tenuis* and polychaetes *Nephtys* spp. The species richness increases as the influence of the tidal stream and fluctuating salinity decline. In the lower estuary and upper middle shores are stable sand flats. Theses support typical bivalve/polychaete and amphipod assemblages. Moderately stable sandflats are found on the upper and mid-shore of all three rivers. Here the community includes sand gaper *Mya arenaria*, mud snail *Hydrobia ulvae*, mud shrimp *Corophium arenarium*, peppery furrow shell *Scobicularia plana*, and polychaete *Pygospio elegans* (Moore et al., 1998). Further up the estuary where there are soft sediments, often-waterlogged mud, the faunal community changes again, excluding organisms that cannot cope with the fine sediment.

Withers (1977b) studied six beaches in Carmarthen Bay: Tenby, Pendine Sands, Whitford, Llangennith and Rhossili. Callaway (2006) investigated the effects of the dense lawns of the tube-dwelling polychaete *Lanice conchilega* at Rhossili Bay, west Gower. They increase the complexity of the environment; providing surfaces for attachment, refuge from predators, changing the sediment characteristic and in some cases the hydrodynamic regime. The species seen to benefit from the presence of *Lanice conchilega* were the scaleworm *Harmothoe* spp., the polychaete *Eumida sanguinea* and the amphipod *Urothoe posidonis*.

The western half of the bay was heavily oiled in February 1996 as a result of the *Sea Empress* oil spill. Prior to the oil spill, information on the macrofaunal community in Camarthen Bay came from Institute for Marine Environmental Research (IMER) Bristol Channel sublittoral survey (Warwick & Davies, 1977) and the survey of the soft intertidal sediments by Withers (1977b). Warwick et al. (1978) examined a station representative of the *Venus* community in the bay at regular intervals from 1974 – 1975 and estimated the annual secondary production. After the spill and clean up there was a monitoring programme for the Environment Agency by OPRU.

An extensive survey of the sublittoral macrofauna (Woolmer, 2003) revealed that Carmarthen Bay was dominated by the *Tellina* sub-group of Petersen's *Venus* community characterized by the polychaetes *Spiophanes bombyx, Magelona* spp. and *Spio* spp., the amphipods *Perioculodes longimanus, Pontocrates arenarius* and *Bathyporeia* spp., and the bivalves *Fabulina fabula, Mysella bidentata* and *Chamelea gallina.* It was concluded that the spatial patterns of species richness and abundance are strongly influenced by the hydrodynamic and sedimentary gradients in the region. Mackie *et al.* (2006) resampled Carmarthen Bay, including a number of Warwick/Davies and Woolmer sites. The bay fauna was predominantly composed of a *Fabulina-Magelona* biotope (SS.Ssa.ImuSa.FfabMag) with a *Nephtys cirrosa-Bathyporeia* biotope (SS.Ssa.IfiSa.NcirBat) in the shallower waters to the east. A tongue of a *Hesionura-Microphthalmus* biotope (SS.SCS.ICS.HeloMsim) indicative of less stable sand was present in the mid-outer Bay (Figure 7).

5.1.3.5 Tenby

Tenby is located to the west of Camarthen Bay, and attracted great naturalists in Victorian times, including T. H. Huxley and S. Wilberforce (Chatfield, 1979). There is also a famous book, *Tenby: A sea-side Holiday,* by Gosse (1856) that describes the flora and fauna found on the shores. Withers (1977b) considered the beach at Tenby to have sediment characteristics between those at Milford Haven/Angle Peninsula and Carmarthen Bay, but the presence of *Donax vittatus* and other bivalves allied the fauna more with Carmarthen Bay. The majority of recent work on this area relates to the effects of the *Sea Empress* oil spill and the recovery of affected beaches and so is not discussed in this section.

5.1.3.6 Lundy

Lundy is a small island 1.25km by 5km, located 18km off the north coast of Devon. The marine biology of the its rocky shores and sublittoral areas has been extensively studied and was reviewed by Hiscock (1997). The island became the first voluntary marine nature reserve in Britain in 1973 and then the first of Britain's statutory Marine Nature Reserves in 1986. Lundy is formed of granite, with softer slate in the southeast, off the south coast and offshore to the north. The fauna of the two shore types was examined (Harvey 1950, 1951) and lists of the fauna occur in reports to the Lundy Field Society. The shores of the island are strongly influenced by the rock type, most of them are granite cliffs with inaccessible beaches with well weathered granite boulders (Davies, 1998a). The exposure levels and the geology of the shores determine the species diversity that they are able to support. The rocky shores (Hiscock, 1981a; Hiscock & Hiscock, 1979) and the sediment macrofauna (Hoare & Wilson, 1976; Wilson, 1979) were examined. Studies for the monitoring of the long-term community change have been carried out, summarised by Fowler & Pilley (1991).

The sublittoral communities have high species richness and include some rare and uncommon species. These include two species of nudibranch *Caloria elegans* (Picton, 1979) and *Tritonia manecata* (Brown, 1978), both of which have distributions limited to the south coast of the UK and the Mediterranean. Hiscock (2003) reported on the decline in corals at Lundy between 1969 and 1981. The species identified include some not found elsewhere in the UK, and others that are only found in the south of the UK. *Leptopsammia pruvoti* the Sunset Cup Coral is one of the species identified as being in decline (Hiscock, 2003; Irving, 2004). Other species include the sea fan *Eunicella verrucosa*, the Carpet Coral *Parerythropodium hibernicum* and the cluster anemones *Parazoanthus axinellae* and *Parazoanthus anguicomas*. It is suggested that the decline in species may be attributable to long-term cycles in the faunal assemblage (Hiscock, 2003). They are being monitored, but there is little that may be done to halt the decline.

These communities were much studied and sublittoral habitats mapped in the 1970s, with surveys commissioned by the NCC and reports by the Lundy Field Society (1974). Community studies are numerous (Field Studies Council OPRU, 1978; George, 1974; Hiscock, 1970; Hiscock, 1974; Mendelssohn, 1973; Nash & Hiscock, 1978; Rodhouse & Tyler, 1978), and Nash & Hiscock (1979) mapped habitats.

5.1.3.7 Taw-Torridge Estuary

The Taw and Torridge Rivers converge to flow out into the same estuary opening out into Bideford Bay, the estuary is surrounded by low-lying flood plain (Davies, 1998a). The area has been influenced by agriculture over the last 200 years and with the building of marinas and flood defences in the 1980s and 1990s (Cordrey, 1996). The estuary consists mostly of sediment, with limited areas of hard substrate. Large areas of saltmarsh exist at Yelland and Penhill, large areas of sand dunes flank both sides of the estuaries mouth at Braunton Burrows and Northam Burrows (Moore et al., 1998).

Little (1989) surveyed the marine communities and habitats on behalf of the Field Studies Council. The lower estuary was considered to display good examples of moderately exposed broken rocky shores. These were colonised by a wide variety of flora and fauna, with higher densities and variety in the rock pools. Sediment shores were described as having low diversity. The subtidal part of the estuary is subjected to strong tidal currents and consists of bedrock overlain by sediments. The community is species poor and consists predominately of hydroids *Obelia longissima*, breadcrumb sponges *Halichondra panicea*, and barnacles *Balanus crenatus*; also present are shore crabs and mussels (Moore et al., 1998).

5.1.3.8 Barnstaple/Bideford Bay

Warwick & Davies (1977) described the sublittoral fauna as a transitional *Tellina-Spisula* '*Venus* community'. A 'Modiolus community' was found in the south of the Bay. Little (1989) surveyed the marine communities and habitats on behalf of FSC. The lower estuary was considered to display good examples of moderately exposed broken rocky shores. These were colonised by a wide variety of flora and fauna, with higher densities and variety in the rock pools. Sediment shores were described as having low diversity. The subtidal part of the estuary is subjected to strong tidal currents and consists of bedrock overlain by sediments. The community is species poor and consists predominantly of hydroids *Obelia longissima*, breadcrumb sponges *Halichondra panicea*, and barnacles *Balanus cretanus*; also present are shore crabs and mussels (Moore et al., 1998).

5.2 Northeast Celtic Sea

The Celtic Deep Trough southwest of Pembrokshire is flanked on the east by the Lundy Platform, the west by the Nymphe Bank Platform and the south by the Haig Fras Platform (Tappin et al. 1994). The muddy sediments of the Celtic Deep range from mud through to muddy sand and are surrounded by sand or gravelly sand. Further south sand and gravelly sand predominate, interspersed by large areas of muddy sand. Stonier ground is present in the vicinity of the Isles of Scilly. There are important fisheries in the Celtic Sea, including the Norway Lobster *Nephrops norvegicus*. The *Nephrops* stocks in Sea Area VIIgh are mainly exploited by Irish and French ships and some 4932t were landed in 2005 (ICES 2006; Marine Institute 2006).

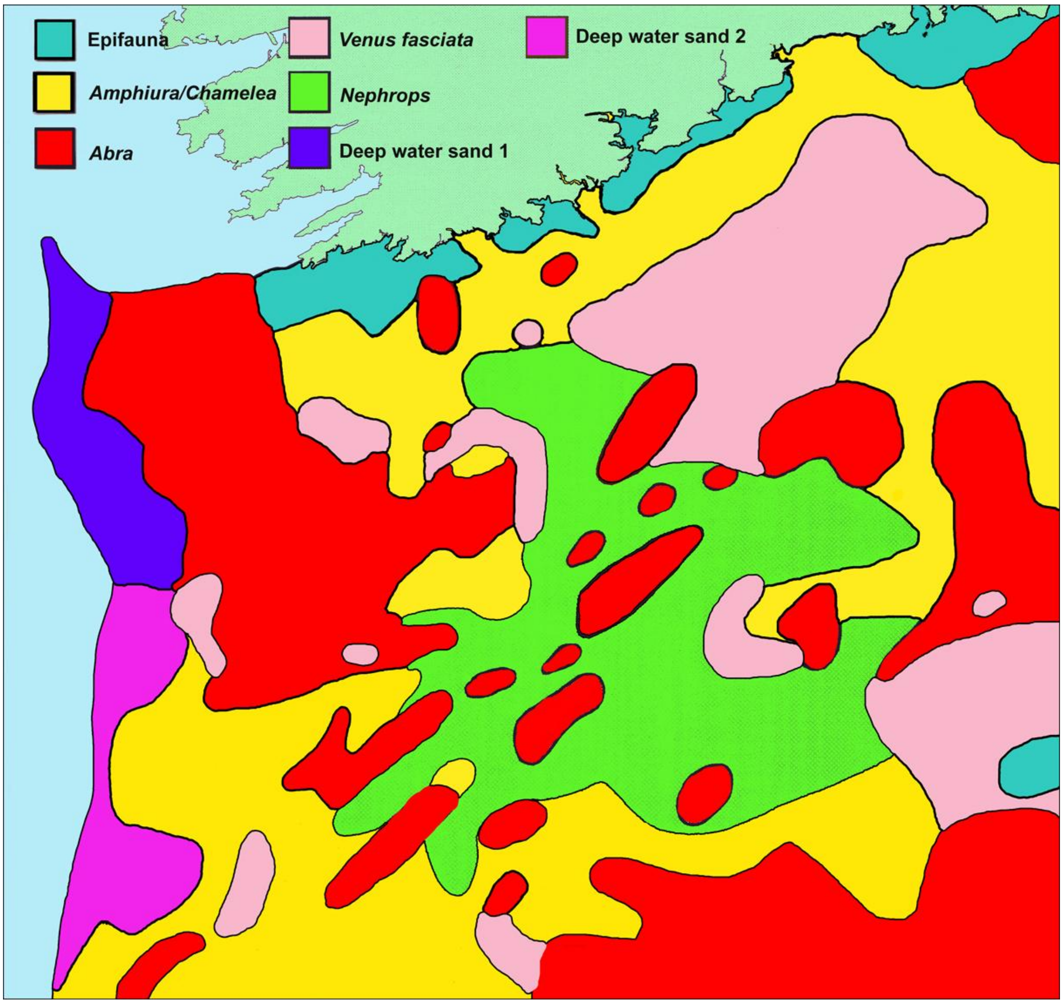
Surprisingly, relatively little published information is available for the benthic fauna of the northeast Celtic Sea. In the 1970s two major surveys were carried out over the whole area, spanning both Irish and UK waters: Hartley & Dicks (1977) and Cabioch et al. (in prep). The first sampled 86 stations between 50°25'N and 52°16'N using a variety of grabs, dredges and trawls. It yielded a 16-page report and a large appendix listing almost 600 taxa and the stations at which they occurred, plus distribution maps for 63 species. The most detailed outcome was an account of the 143 molluscan species collected (Hartley 1979), a number of which were interpreted as being at the southernmost limit of their distribution. Ellis et al. (2002) similarly provided lists of epifaunal species at their southern or northern limits. The French-Irish study was carried out a little later, between 1977 and 1983, but is as yet unpublished. However, a preliminary summary account recently appeared in print (Cabioch et al. in prep.).

5.2.1 Sublittoral Fauna

The study of Hartley & Dicks (1977) provided much basic information of the benthic macrofauna of the NE Celtic Sea and southern St George's Channel, though no analysis was attempted and the report was not widely circulated.

Rees et al. (1999) carried out an analysis of infaunal (Day Grab: 1 mm mesh) and epifaunal (2 m Beam Trawl: 3 mm mesh cod-end) samples from 25 and 69 locations respectively, including UK National Marine Monitoring Programme (NMMP) stations. One NMMP quantitative station was located in the Celtic Deep (stn W50), while three epifaunal stations were in the Celtic Deep, in the approaches to the Outer Bristol Channel, and west of Newquay, north Cornwall. The analyses were rather coarse, reflecting the low number of widely separated stations. The Celtic Deep infauna had the closest affinity with a muddy station off Northumberland (see below) and two stations southwest of Plymouth in the western English Channel. In the epifaunal analysis, the Celtic Deep station was again similar to the Northumberland one, however the other two Celtic Sea stations grouped within an 8-station Irish Sea to western English Channel *Adamsia carciniopados* - *Psammechinus miliaris* assemblage on gravelly sediments.

Figure 8. Schematic representation of the major macrofaunal benthic assemblages in the Celtic Sea (after Cabioch *et al*. in prep.)



Cabioch et al. (in prep.) provided a schematic representation of the benthic macrofaunal assemblages in the Celtic Sea from the Irish south coast (approx. 6°-11°W) to south of the Isles of Scilly at about 49°15'N. Five of the 7 identified assemblages occurred in the SEA 8 area (Figure 8):

1. The epifaunal assemblage was found on rocky substrates to the west of the Scillies. Characteristic species were the brittle-star *Ophiothrix fragilis* and Green Urchin *Psammechinus miliaris*.

2. The *Amphiura/Chamelea* assemblage occurred on muddy/fine sand and was viewed as representing a continuum between the *Amphiura* and *Chamelea* communities described by Thorson (1957). There were areas where the communities were separate and others where they overlapped. Apart from the key species, the brittle-star *Amphiura filiformis* and bivalve *Chamelea gallina*, other characteristic species included the bivalves *Cultellus pellucidus* and *Nucula nitidosa*, gastropod *Turritella communis*, starfish *Astropecten irregularis* and serpulid polychaete *Ditrupa arietina*.

3. The *Clausinella fasciata* assemblage in coarse sands and gravels was primarily located to the north and west of the Isles of Scilly. The characteristic species included the bivalves *Clausinella (*as *Venus) fasciata*, *Chamelea casina* and *Astarte* spp., Purple Urchin *Spatangus purpureus* and cephalochordate *Branchiostoma* (as *Amphioxus*) *lanceolatum.*

4. The *Nephrops* community occupied several thousand hectares of sandy mud in the central part of the Celtic Sea. Typical species were the Norway Lobster *Nephrops norvegicus*, burrowing crab *Gonoplax rhomboides*, brittle-star *Amphiura chiajei* and capitellid polychaete *Notomastus latericeus*.

5. The *Abra prismatica* community found in large patches throughout the area.

The most comprehensive study of the epifauna of the Celtic Sea was carried out in March 2000 (Ellis et al. 2002). A 2 m Beam Trawl with a chain mat and 4 mm knotless mesh liner was deployed at 61 stations throughout the Celtic Sea and nearby areas, from the Celtic Deep and off southwest Ireland in the north to the shelf edge west of Brittany in the south.

Over 340 species of fish and invertebrate were recorded and analysed. Cluster analysis produced two broad epifaunal assemblages, one dominated by the anemone *Actinauge richardi*, the other by the hermit crab *Pagurus prideaux* and its commensal anemone *Adamsia carciniopados*. The second assemblage exhibited more variation and three sub-assemblages were determined:

1. The *Actinauge richardi* assemblage was prevalent at 25 stations along the shelf edge (132-350 m depth), from off southwest Ireland to the southernmost extent of the Sea 8 area. Other dominant species were the Devonshire Cup Coral *Caryophyllia smithii*, hermit crab *Pagurus variabilis*, swimming crab *Macropipus tuberculatus* and brittle-star *Ophiothrix lutkeni*.

2. The *Pagurus prideaux* assemblage occupied the remaining 36 stations in the Celtic Sea, Southwest Approaches and the most western part of the English Channel. The other dominant species were the shrimp *Crangon allmanni*, swimming crab *Liocarcinus depurator*, brittle-star *Ophiura ophiura* and hydroids including *Nemertesia antennina* and *Lytocarpia myriophyllum*.

A. The *Pagurus prideaux - Crangon allmanni* sub-assemblage was largest, occurring widely at 20 stations over the Celtic Sea and one station southwest of Plymouth in the western English Channel. The dominant species were the shrimp *Crangon allmanni*, and the swimming crabs *Liocarcinus holsatus* and *Liocarcinus depurator.*

B. The *Pagurus prideaux - Psammechinus miliaris* sub-assemblage was restricted to 5 stations (82-108 m), 2 in the Celtic Sea off Padstow, Cornwall and three in the far western English Channel. Inshore species such as the urchin *Psammechinus miliaris*, Common Starfish *Asterias rubens* and spider crab *Inachus dorsettensis* were dominant.

C. The *Pagurus prideaux - Porania pulvillus* sub-assemblage occurred at 8 stations along the shelf edge (150-232 m), primarily at 7 stations in the south between the southernmost extent of the Sea 8 area and an area southwest of Brest, Brittany. Large echinoderms were characteristic, with Red Cushion Star *Porania pulvillus*, Goose Foot Starfish *Anseropoda placenta* and Rosy Starfish *Stichastrella rosea* the dominant species. This sub-assemblage had the most diverse molluscan and echinoderm fauna of all assemblages or sub-assemblages.

Two stations were intermediate between the *Pagurus prideaux - Crangon allmanni* sub-assemblage and the other two in the cluster analysis. One was located south of Milford Haven, the other southwest of Concarneau.

A BIO-ENV analysis found depth, catches of rock and shell, and bottom water temperature to be the most important environmental variables correlating with the faunal distributions. With the inclusion of latitude, the five variables combined produced the highest correlation (ρ_w=0.47)

5.2.2 Celtic Deep

The Celtic Deep area has been subject to repeated grab sampling by the National Museum Wales and partners (Mackie *et al.* 1995; Wilson *et al.* 2001; Mackie *et al.* 2002; HabMap, in prep. www.habmap.org) and as part of the UK National Marine Monitoring Programme (Rees et al. 1999; Schratzberger et al. 2004). In addition, the NMMP station (muddy sand, 95 m), near station 60 of Mackie *et al.* (1995), has been sampled for meiofauna (Schratzberger *et al.* 2000, 2004).

Schratzberger *et al.* (2000) reported on the meiofauna at a number of inshore and offshore UK NMMP stations, including the station on the edge of the Celtic Deep. Nematodes dominated at all stations (>80% of abundance), however the diversity of harpactacoid copepods was generally higher in the Celtic Deep muddy sand. In common with all offshore stations, the Celtic Deep nematode fauna was dominated by *Sabatieria breviseta*, albeit at a lower abundance (Schratzberger *et al.* 2004*).* The other top-ranked nematodes were *Aponema torosa*, *Paramonohystera* sp. and *Pomponema multipapillatum.* The most abundant harpactacoid copepods were *Cletodes longicaudatus*, *Bradya* sp., *Laophonte longicaudata*, *Haloschizopera pygmaea* and *Proameira signata.*

The macrobenthic infauna was shown to grade from a species rich assemblage in the gravelly sediments west of Pembrokeshire to a low diversity assemblage in the muddy Celtic Deep (around ~51°22'N, 6°12'W). The infauna also graded from the Celtic Deep toward the Outer Bristol Channel as the depth decreased from about 100-130 m to 80-90 m and the sediments became sandier. The assemblages and sub-assemblage groups (Mackie *et al.* 1995) were:

Group A1 in the muddier and deeper (~110-130 m) parts of the Celtic Deep was characterised by the Norway Lobster *Nephrops norvegicus*, polychaete *Nephtys hystricis* and bivalve *Saxicavella jeffreysii*. The burrowing urchin *Brissopsis lyrifera* was present sporadically. In the MNCR biotope classification (Connor *et al.* 2004) this was described as *Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud (SS.SMU.CfiMu.BlyrAchi). The current EUNIS classification is A5.363 (www.jncc.gov.uk/page-3249). In the trawl surveys of Rees et al. (1999) this assemblage was referred to as "Group 2: Muddy".

Group A2 occurred in fine sand/muddy sand (~95-110 m) bordering the Group A1 stations to the north and west. The NMMP station sampled regularly by Cefas (Rees *et al.* 1999; Schratzberger *et al.* 2004) is located within this area. Characteristic species included the gastropod *Vitreolina philippi*, bivalve *Myrtea spinifera* and isopod *Cirolana borealis*. Mackie *et al.* (1995) found similarities between this group and the muddy sand fauna west of the Isle of Man, the *Astrorhiza* variation of the *Amphiura filiformis* subcommunity off northeast England, and foraminiferid-*Amphiura* assemblages in the northern North Sea. The group does not fit any currently recognised biotope (but see Connor *et al.* 2004: 121).

Group B2 comprised two sandy stations (~89-90 m) on the Lundy Platform southwest of Milford Haven, between the Celtic Deep and the Outer Bristol Channel. The group was difficult to define and was regarded as transitional, having a species complement that reflected several other assemblage groups. For example, among other species, the polychaetes *Magelona filiformis* and *Magelona johnstoni* were indicative of a *Fabulina* assemblage – but the bivalve *Fabulina fabula* was infrequent. Alternatively, large numbers of the brittle-star *Amphiura filiformis* and small urchin *Echinocyamus pusillus* were perhaps more suggestive of assemblages from sediments with higher silt or gravel contents respectively. Mackie et al. (2006) interpreted the fauna at these two stations as close to an intermediate *Abra* - *Nucula* (SS.SSa.CMuSa.AalbNuc; A5.261) / *Owenia fusiformis* - *Amphiura filiformis* (SS.SSa.OSa.OfusAfil; A5.272) biotope.

Group C1 was present in the more gravelly sediments to the northeast of the Celtic Deep (~105-115 m), and into the St George's Channel and the southern Irish Sea. Characteristic species included the Dog Cockle *Glycymeris glycymeris*, Tiger Scallop *Palliolum tigerinum* and serpulid polychaete *Protula tubularia*. The numerically dominant species were the Horse Mussel *Modiolus modiolus*, Baked Bean Sea-squirt *Dendrodoa grossularia* and small poychaetes *Mediomastus fragilis* and *Aonides paucibranchiata*. The fauna was regarded as equivalent to the 'Offshore gravel community' found off the Isle of Man. There were also strong similarities with the Warwick & Davies (1977) '*Modiolus* community' in the Bristol Channel, though *Glycymeris* was not recorded. However, in a more recent survey the Outer Bristol Channel benthos, Mackie et al. (2006) found *Glycymeris* to be sporadically present. Group C1 has affinities with two biotopes:

• *Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel (SS.SCS.CCS.MedLumVen; A5.132)

• Polychaete-rich deep *Venus* community in offshore mixed sediments (SS.SMX.OMx.PoVen; A5.451)

Two stations on the edge of the Celtic Deep (~100 m) were sampled in the trawl survey of Ellis et al. (2002). The fauna was part of the *Pagurus prideaux - Crangon allmanni* sub-assemblage that occurred over most of the Celtic Sea between the Irish south coast and 49°N.

5.2.3 Lundy Platform

The seabed between the Celtic Deep and Lundy/Outer Bristol Channel has been studied little. Group B2 (see above) of Mackie et al. (1995) was considered to be a transitional fauna. This was also the case for another location further east, south of Linney Head, Pembroke Peninsula (Mackie et al. 2006; stn 135).

A Beam Trawl from a nearby location south of the entrance to Milford Haven (Ellis et al. 2002; stn 30) caught an epifauna intermediate between three sub-assemblages of a widespread *Pagurus prideaux* assemblage (see above). However, the epifauna from a Beam Trawl northwest of Lundy (Rees et al. 1999; stn W51) was representative of an *Adamsia carciniopados - Psammechinus miliaris* assemblage on gravelly sediments. The most frequently occurring species included the spider crab *Hyas coarctatus*, brittle-stars *Ophiura* spp. and serpulid polychaetes.

5.2.4 Haig Fras

The following text is provided by Ivor Rees (School of Ocean Sciences, University of Wales Bangor) who carried out underwater imaging of the seamount in 2000.

Haig Fras is an isolated seamount in the Celtic Sea located about 95 km northwest of the Scilly Isles (~50°15'N, 7°40'W). Geologically it is the submerged remnant of a granite boss similar to other tors on the Cornubian Peninsula and also the Scilly Isles. It measures approximately 45 km by 15 km, with a peak of less than 1 km across. Admiralty charts show that it rises abruptly to within 36 m of the sea surface from a surrounding seabed at around 140 m. Surrounding the actual peak the wider area at near the surrounding depths is shown on sidescan as blocky exposure of the bedrock with sediment filled channels between.

Information on the fauna present on the reef is sparse, being based mainly on drop-down camera deployments and camera sled tows in the surrounding area during a limited sidescan survey of the locality in May 2000 by RV *Prince Madog* (University of Wales Bangor). The photographs showed that the uppermost parts of the reef, where there is likely to be enough water movement to keep the rock surface clear of silt, were largely covered by small sea anemones. These appeared most likely to be *Corynactis viridis*, a species with different coloured clones. All on Haig Fras seemed to be the same colour clone. In some of the crevices on the upper rock there were a few *Echinus esculenta*, but apart from some small patches of encrusting yellow sponge little else was visible. It was not possible to specify the depths at which the bottom-triggered photographs were taken because sonic depths were changing so rapidly during the drift deployments, but the shallowest photographs were from about 45-50m. Deeper, on the sides of the reef where there was more of a coating of silt, the dominant organisms visible were large numbers of cup corals, probably *Cariophyllia smithii*. At the foot of the peak, on silt coated talus boulders as well as bedrock, the visible fauna was more diverse with a range of erect sponges, including branching forms and axinellid cup sponges. Bryozoans such as *Pentapora foliacea* and feather stars were also seen. The sediment in the surrounding area and in the channels appeared on the photographs to be heterogeneous deposits of muddy sand with much shell, including numerous *Glycymeris glycymeris* shells. A few grab samples taken to collect sediment confirmed this and picked up live *Glycymeris* and other gravelly sand living bivalves.

Haig Fras is one of several locations being considered as an offshore Special Area of Conservation (SAC).

5.2.5 North Cornwall

5.2.5.1 Camel Estuary

The Camel estuary is the largest inlet on the north coast of Cornwall. It has been influenced by human activity when the flood defences were built (Cordrey, 1996). Locally it is of considerable nature conservation importance; it has been designated an AONB and has 5 SSSIs with regards to birds within the estuary (Davies, 1998a). Camel estuary is shallow and consists mostly of sediment, deepening at the mouth where it flows into Padstow Bay. Large areas of intertidal sands and mudflats are exposed at low water; the sediments become finer and more stable towards the inner reaches. Saltmarsh has developed in some of the small bays and inlets, and hard substrata may be found towards the mouth of the inlet. There is a low input of freshwater into the system (Moore et al., 1998).

5.2.5.2 The Gannel

The Gannel is a narrow inlet that widens considerably as it flows into the eastern end of Crantock Bay. The mouth of the inlet has clean sands, which extend towards the head of the estuary where the substrate changes to sandy mud fringed by saltmarsh. The fauna in this area changes in relation to the substrate. The sands support the amphipods *Bathyporeia elegans*, *B. pelagica* and the isopod *Eurydice pulchra*. These continue to be found further up the inlet, where they are then accompanied by polychaete species such as *Pygospio elegans*, *Streblospio shrubsolii* and capitellids. There is a distinct change in fauna where the sediment becomes sandy mud, the amphipods and isopod are replaced by the mud shrimp *Corophium volutator*. Polychaetes are also found in the muddy parts of the inlet, the most abundant of these being *Hediste diversicolor*, the Ragworm. The area is influenced by human activities; there have been modifications to the area in the form of sea defences and a causeway. The inlet receives some effluent from industry and urban areas, and sedimentary lead levels are elevated due to leaching from a disused mine site. Despite this the area is still popular with tourists and so is used by small boats and anglers in the tourist season (Moore et al., 1998).

5.2.5.3 St Ives Bay

River Hayle opens out into St Ives Bay and has been influenced post 1945 by infilling of Copperhouse (Cordrey, 1996). Historically the estuary was polluted with heavy metals from mining activities. Land-claim south of the causeway has altered the inner part of the estuary, with the formation of reservoirs. The rest of the estuary is comprised of intertidal mudflats and some saltmarshes. The estuary mouth has long sandy beaches along each side, backed by sand dunes. However the water is now considered to be of high quality. The outer estuary is impoverished with a community dominated by the polychaete *Pygospio elegans* and isopod *Eurydice pulchra* (Moore et al., 1998).

5.2.6 Isles of Scilly

The Isles of Scilly are an island archipelago situated 45 km west of Land's End. There are over a thousand islands and islets, but only five are inhabited. The location of the islands means that they are generally frost-free and the average surface sea temperature is 12.4^{o}C (Barneet al., 1996c). The largest quantities of shingle in the southwest occur on the Isles of Scilly in the form of a series of bars, raised beaches and shingle spreads. The shingle in this region is mostly in very high-energy environments and suffers considerable storm movement. Currents are predominantly west-to-east, and there is no freshwater run-off from the islands; so the salinity and turbidity of the waters is fairly constant (Barne et al., 1996c; English Nature, 1994). These warmer and more constant conditions have enabled the presence of a strongly southern influenced biota on the islands. Many of the marine species recorded on the islands have not been seen on the mainland, for example the bryozoan *Turbicellpora magnicostata*. There are also some species considered common on the mainland that are rare on the islands, for example the barnacle *Semibalanus balanoides*, and the common periwinkle *Littorina littorea* (Davies, 1998b). Despite the fact that there are some differences between the communities on the mainland and those on the Isles of Scilly a study of biogeography (Kendall et al., 1996) did not reveal any differences in diversity between the two areas.

The area was declared a Marine Park in 1988 by the Isles of Scilly Council and has been a Voluntary Marine Nature Reserve (VMNR) since 1989 (Barne et al., 1996c). Since then the islands have been designated as a Special Area of Conservation (SAC) for their sublittoral sandbanks and the intertidal sand flats. There are also many areas that have been nominated as SSSIs for the birds and seals and the fact that they are some of the most exposed shores in Britain.

There has been considerable study of the marine biology of the islands, a review of the early work was compiled by Harvey (1969) in the *Journal of Natural History*. There then followed a series of papers describing the distribution and abundance of the main marine groups on the islands (see e.g. Faubel & Warwick 2005).

5.2.6.1 Intertidal Fauna

Intertidal areas are comprised of both sediment shores composed of coarse-grain granite and rocky shores varying from bed rock to sediment covered boulders (Davies, 1998b). Warwick et al (2006) undertook sampling to assess the integral structure of the benthic infaunal assemblage and examine the mechanisms that may influence biodiversity. They found 464 species in a small area of St Martin's flats. 207 species were nematodes and 75 were harpacticoid copepods. Macrofauna were very much less diverse than meiofauna. Another study of nematodes on the flats (Somerfield et al. 2007) found 152 species, of which 59 could not be ascribed to species known to occur in the UK. This illustrates our poor knowledge of meiofauna, even in apparently well-worked areas. The sediment shore macrofauna is characterised by polychaetes, with the lower shores also having bivalves and burrowing heart urchins *Echinocarduim cordatum* and *Echinocardium pennatifidium* (Nicholls, 1982). There are also areas of eelgrass *Zostera marina* beds, which provide a home for many other species. The associated community includes; anemones, lucernarians (stalked jellyfish), polychaetes, molluscs and echinoderms. *Anthopleura ballii* is a rare sea anemone that has been recorded in these eelgrass beds, and is found in few other locations in Great Britain. The burrowing heart urchin *Spatangus purpureus* has also been recorded at extreme low water on sediment shores. St Martin's Flats is a large continuous area of sand, and as a result has varying degrees of sediment-sorting. This has lead to the infaunal community here being different up the shore. The sand mason worm *Lanice conchilega* was found in large populations extending from mid to low tide level. Rich infaunal communities were characterised by heart urchins and bivalve molluscs including *Lutraria lutraria* (Nicholls, 1982).

The rocky shores vary in the levels of exposure as well as the substrate type. Some shores are exposed to extreme wave action, the outer shores of the western islands, and others are sheltered, the shores in the channels between islands (Hiscock, 1984). A total of 237 animal species were identified on those rocky shores surveyed by Hiscock. The extremely exposed shores were characterised by red algae with occasional kelp *Alaria esculenta* plants and the coralline alga *Corallina officinalis*. The mid shore had barnacles *Chthamalus* sp. and the limpet *Patella vulgata*. Lichens dominated the splash zone at the top of the shore. At the other end of the scale are the rich under boulder communities on the sheltered shores. The shore communities on these sheltered shores were characterised by fucoid algae.

5.2.6.1 Sublittoral Fauna

Subtidal habitats in the Isles of Scilly were surveyed by the Underwater Conservation Society (Dipper, 1981). Sublittoral rock habitats vary from very sheltered to extremely exposed habitats. Clear waters allow the growth of algae to lower limits and result in kelp forests. Sponges, anemones, soft corals and sea squirts dominated the rock surfaces below the kelp. Deeper than the algal belt, on the sheltered coast of St Mary's, several southwestern species were found. These south-western species included the zoanthid anemone *Parazoanthus axinellae*, the rare hard corals *Leptopsammia pruvoti* and *Hoplangia durotrix* and the sea fan *Eunicella verrucosa*. Hiscock (1984) described twenty-four sublittoral habitats, eighteen of which had a rocky substrate. There were also 'restricted' habitats such as caves, overhangs, crevices and underboulders. These restricted areas tended to have richer faunal communities.

There has been monitoring work carried out in the Marine Park during the eighties that has revealed marked changes in the populations of the Devonshire cup coral *Caryophyllia smithii* (Fowler & Pilley, 1991). The slime mould *Labyrinthula* that causes the 'wasting disease' in eelgrass *Zostera* made a re-appearance in 1991, which decimated the eelgrass beds in the 1930s and 1940s (Raines et al., 1993).

5.3 The Western Approaches & Shelf Edge

Benthic faunal data for the area south and southwest of the Isles of Scilly are sparse compared to that available from the northeast Celtic Sea and the western English Channel. Therefore, for convenience, we have considered this as the Western Approaches (and shelf edge), although English Nature defined the northern limit of the Western Approaches to be the 100 m isobath.

The seabed of the Western Approaches is dominated by a series of long northeast-trending sand banks, including Jones Bank (south of Haig Fras), Haddock Bank and Melville Knoll. Little Sole Bank and Parson's Bank are located near the shelf edge. Sediments are predominantly sand or gravelly sand. Whiting, hake, anglerfish and sole are among the commercial fish caught in the area. The Fan Shell *Atrina fragilis* is a UK Biodiversity Action Plan (BAP) species that was recorded the Western Approaches. In a 1991 MAFF survey of scallops, 14 specimens were collected from 14 different trawls in the Melville Knoll and Haddock Bank areas (Solandt 2003).

Rees et al. (1999) reported on grab and trawl sampling at a NMMP location (S48) near the shelf edge. In the grab sampling, the fauna was most similar to that found at two coarse sand stations in the English Channel. The dominant species in this cluster were the polychaetes *Typosyllis* spp., *Sphaerosyllis hystrix*, *Polycirrus medusa* and *Glycera lapidum*, and the small urchin *Echinocyamus pusillus*. In the epifaunal trawl survey the station grouped with 7 other coarse ground locations (mainly in the Irish Sea & English Channel), forming a 'stony' *Abietinaria abietinal – Alcyonidium mytili* assemblage. The hydroids *Sertularia cupressina* and *Hydrallmania falcata*, bryozoan *Flustra foliacea* and serpulid polychaetes were the species most frequently recorded.

In the Celtic Sea epifaunal survey of Ellis et al. (2002), most of seabed of the Western Approaches supported the widespread *Pagurus prideaux - Crangon allmanni* sub-assemblage. However, near the shelf edge the fauna differed to the east and west of ~9° west. To the east, the *Pagurus prideaux - Porania pulvillus* sub-assemblage occurred; to the west, the *Actinauge richardi* assemblage.

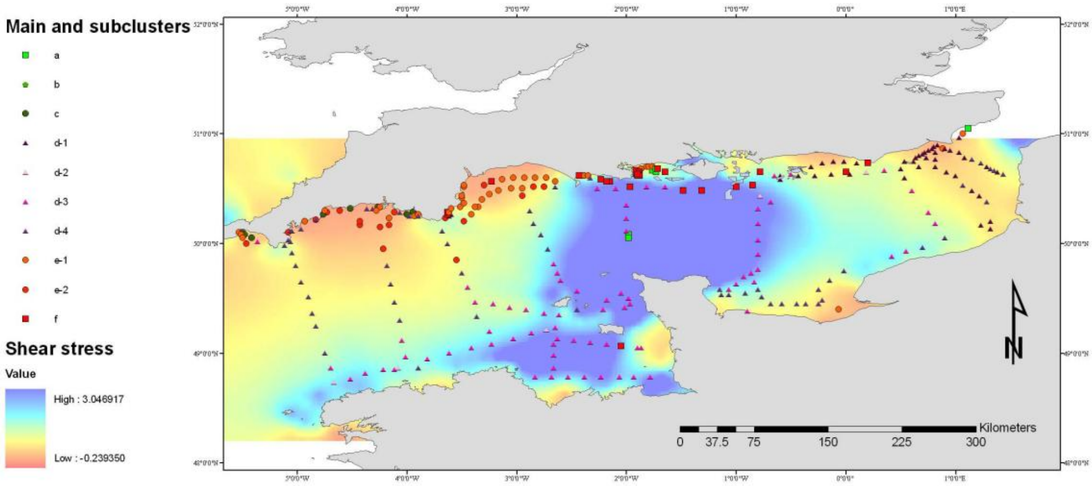
In 1973, the French research vessel *Thalassa* carried collected about 13000 polychaetes from 63 stations (350-1800 m) at the shelf edge and south of the SEA 8 area. A total of 248 species were recorded, including 6 new to science (Amoureux 1977, 1982a, 1982b).

The EU Ocean Margin EXchange (OMEX I) programme carried out a series of studies on the physical, chemical and biological processes on a 200 km long shelf edge and slope transect in the Goban Spur area of the Celtic Sea. Samples were taken from the shelf down to the Porcupine Abyssal Plain at water depths ranging from 208 m (~49°30'N, 11°W) to 4460 m (49°N, 14°'W), Hence the shallowest station was just to the west of the southerly extent of the SEA8 area. Various benthic macrofaunal and meiofaunal studies have been published, and macrofaunal diversity and evenness was lowest at the shallowest station (Flach & de Bruin 1999). Only 101 species and 1516 individuals in 2061 cm^2 were recorded. Polychaetes (~75%), mainly spionids and paranoids, were dominant. Echinoderms were the next most abundant group. Flach *et al*. (2002) detailed the faunal community structure of the Goban Spur area relative to the Iberian Margin. Nematodes dominated the meiofauna at all stations. On the Goban Spur transect, the shallow shelf station had marginally the lowest nematode contribution (93%) and the lowest meiofauna:macrofauna ratio (~110).

5.4 The English Channel

There are marked biogeographic changes that occur between the western and eastern English Channel. Influences on the distribution of the intertidal organisms along the channel may be explained by the substrate type, the difference in water temperature and the aspect of the shoreline, which influences the level of wave action and the effect of water movement on the dispersal of larvae (Crisp & Southward, 1958). This work was then followed up, some 20 years later, by the MBA/SMBA survey of the littoral zone (Powell et al., 1978). The Solent and the Isle of Wight mark the boundary between the eastern and western channel. This marks the eastern limit of many littoral and sublittoral species with a southern distribution. A number of investigations were carried out on estuaries along the English Channel on behalf of the EA and English Nature to characterise some candidate Special Areas of Conservation (cSAC, see Joint Nature Conservation Committee, 2005). The benthic fauna and environmental conditions in the channel have been examined (Holme 1961, 1966; Cabioch et al. 1977; Holme and Wilson 1985; Southward et al. 1995) It was found that in the western channel there was a seasonal thermocline in the summer months and that the bottom temperatures were lower than those of the eastern channel (Holme, 1966). Distributions of faunal assemblages in the Channel are strongly related to hydrodynamics (Fig. 9).

Fig. 9. Holme macrofauna re-analysed by Hilmar Hinz & Stuart Jenkins, Marine Biological Association of the United Kingdom. Each cluster denotes a faunal assemblage. Note how assemblages vary with tidal shear stress.



5.4.1 Western English Channel

5.4.1.1 Cornish Coast

The exposed rocky shores and the sheltered sandy coves of the Cornish coast have long attracted the interest of both amateur and professional marine biologists (Davies, 1998b). The Cornish Biological Records Unit (CBRU) in Redruth has a large amount of information on the area, both published and unpublished. Some of the major taxanomic groups were detailed for this area in the eighteenth century. These studies include those on the marine mollusca (Tregellis, 1896), and the sea anemones and corals (Tregelles, 1891). The conchology of the area was reviewed by (Turk, 1983), with descriptions of the Cornish shores. An offshore area, 16 miles from Plymouth, has been sampled (Holme, 1953), and the faunal assemblages associated with the fine sands and mud described. They were dominated by polychaetes, but also present were sea cucumbers *Leptosynapta inhaerens* and the burrowing prawn *Callianassa subterranea*. The sediments further west are muddier and characterised by an '*Echinocardium cordatum – Amphiura filiformis*' community described by Holme (1966).

5.4.1.2 Helford Estuary

Helford estuary is a narrow inlet, leading inland to a series of wooded creeks. It is shallow and sedimentary, with rocky shores at the mouth. The tidal stream is moderate in the lower estuary. (Powell et al., 1978) and Bishop & Holme (1980) described the estuary as a site of national marine biological importance. In 1987 the area was already an SSSI, and was then designated a Voluntary Marine Conservation Area (VMCA), it is now also a Special Area of Conservation (SAC). The area has a rich marine fauna that has attracted the attention of numerous naturalists; their results and findings were reviewed by Holme & Turk (1986). Spooner & Holme (1986) surveyed the area in 1949 and recorded the fauna, concentrating on the species associated with the extensive eelgrass *Zostera marina* beds. Covey & Hocking (1987) and Tompsett (1991, 1994) found a dramatic decline in the species richness of this area, along with a reduction in the area that the eelgrass covered. It is suggested that this is as a result of increased boating activity in the area, which has caused physical disturbance and hence affected the fauna present (Davies, 1998b). A report of a subtidal survey was produced for the Nature Conservancy Committee (Rostron, 1987). It was reported that large areas of the eelgrass beds had indeed been destroyed. It was also suggested that some species had been severely impacted by bait digging and winkle picking. These species included the clam *Chlamys varia*, razor shell *Solen marginatus* and the polychaete *Sabella pavonina*.

The rocky shores at Menaver, the mouth of the estuary, are interspersed with coarse sediments. They are dominated by limpets, barnacles and well developed rockpool communities (Davies, 1998b). In the Monitoring Report by the Helford Voluntary Marine Conservation Area Group (VMCA) (Tompsett, 1994) it is noted that the population of the Australian barnacle *Eliminius modestus* has increased. It is suggested that this may be due to the TBT ban, but there is no data to support this (Langston et al., 2003e). The lower shores were described (Powell et al., 1978) as having rich faunal communities. These communities included abundant crustaceans, molluscs, sponges and sea squirts. A full list of the invertebrates and the fish species found at Helford was compiled by Turk & Tompsett (1993).

The VMCA group has carried out work based on four monitoring stations in the area, and reported the changes. They have also investigated some of the activities that take place in the area, which involve a population study of the cockles *Cerastoderma edule* (Jones, 1993) and a survey of the native oyster *Ostrea edulis* (Protz, 1995). Non-native gastropods were found in association with the oysters in some locations, namely the American slipper limpet *Crepidula fornicata* and the 'Chinese hat' *Calyptraea chinensis*.

5.4.1.3 Fal Estuary & Falmouth Harbour

The maze of creeks and tidal rivers that starts at Falmouth extends inland for 17 km. The littoral zone in this area ranges from moderately exposed rocks to extremely sheltered sediments. The tidal patterns within the estuary mean that there are few rocky sublittoral sites (Davies, 1998b). Some sites within the estuary have been studied by PML since 1955. These include Place Cove and Carricknath Point. The amount of work that has been carried out in this region is largely due to the presence of institutions of higher education and other facilities such as PML. Much of the data is unpublished, but may be found at the Cornish Biological Records Unit. The area was reviewed, and both published and unpublished literature considered, by the Environment Agency and English Nature (Langston et al., 2003e). Parts of the upper estuary were subject to eutrophication. Problems associated with nutrient levels and chronic contamination events have resulted in toxic algal blooms and mortality of invertebrates in some cases. It was found that Carrick Roads continue to be impacted by past mining activities, discharge from mine drainage and the remobilisation of sediment. The whole system in the Falmouth area was affected by organotin contamination. Falmouth Dockyard was the primary source of this; sediments now contribute to the overall burden. The crustacean species *Corophium volutator* and *Cyathura carinata* are absent from the Fal estuary, while small opportunistic annelid species are abundant (Warwick, 2001). Extensive mining in the catchment area due to the heavy metal pollution in the estuary causes this; the intertidal sediments have the highest metal concentrations in Britain. These metals include copper, zinc, arsenic, cadmium and iron (Bryan & Gibbs, 1983). The differences in the community composition cannot be attributed to organic enrichment (shown by the absence of capitellid polychaetes, which are regarded as indicators of organic enrichment (Warwick, 2001)). Meiofaunal communities (nematodes and copepods) are closely correlated with metal levels in the sediment (Somerfield et al. 1994a)

The rocky shores were first surveyed by Clark (1907), and considered to have a rich biota. These were also examined by Powell et al. (1978) during the intertidal survey, which considered other locations in the vicinity to be of greater importance. Place Cove was one of these; it is a sheltered sediment shore with a rich infaunal community. Polychaete worms and bivalves dominate the infaunal community. The community present was considered to be similar to those at Salcombe Harbour and Kingsbridge estuary. The sheltered rocky shores from Amsterdam Point to Carricknath Point were seen to have well developed zonation. Bishop & Holme (1980) considered the whole of the St. Mawes inlet to be of importance and classified the communities found on the sheltered sediment shores as '*Echinocardium-siliqua*', '*Pullastra*' and '*Lanice*' communities.

Falmouth Harbour has three species of red algae which are the main producers of maerl; *Phymatolithon calcareum, Lithothamnium corallioides,* and *L. glaciale* (Willing, 1998). Falmouth Harbour has large quantities of living maerl beds, mainly *P. calcareum* on St. Mawes Bank, observed at depths 6-10m. Living maerl supports epiphytes, especially flocculent ephemeral algae, such as *Antithamnion spirographidis* (Blunden et al., 1981). These beds may be harvested and sold for use primarily on acid soils to increase the pH. These may be important habitats as they could support life that does not occur anywhere else. *Soloeria chordalis* was found in Falmouth Bay for the first time (Blunden et al., 1981). It has been suggested that this was introduced from France, possibly on a ships hull, or on ballast stones (Farnham & Jephson, 1977). The beds have also been found to support around a hundred species, some of which are specifically dependent on the maerl (Willing, 1998).

5.4.1.4 Mevagissey Bay

The effects of local pollution have also been investigated in this area with regards to the pollutants caused by local industry. In Victorian times there was a large mining industry extracting copper, tin and china clay. Some studies have concentrated on the influence of metals (Bryan et al., 1987; Grant et al., 1989; Schratzberger et al., 2004) and numerous others besides. There are others looking at the affects of the china clay waste washing into the rivers and subsequently the sea (Howell & Shelton, 1970; Knight, 1988; Probert, 1973, 1975, 1981). These are centred on Mevagissey and St. Austell. The main river entering the bay at Mevagissey was called the White River due to the colour of its waters, caused by the waste products from the china clay industry (Davies, 1998b). China clay waste is composed of fine mica and quartz rich silt. In Mevagissey Bay it was found that the shell-gravel substrate had been buried by the waste deposits; in some places 2 m deep. The faunal community in this area was therefore determined by the extent to which the original substrate had been buried. Studies made in 1968 at the peak of the discharge were compared with later studies after the discharge ceased. These showed that there was an increase in diversity after the discharge was stopped, suggesting that things were returning to how they should be (Knight, 1988).

5.4.1.5 St Austell

The bay at St. Austell was impacted by the china clay discharge in a similar way to Mevagissey. An investigation was carried out here (Forster, 1979) to investigate the substantial mortalities of benthic fauna and fish that occurred in 1978. It was concluded from the observations made by diving and analysing water samples that the cause was linked with unusually calm sea conditions and algal blooms, in particular *Gyrodinium aureolum*. More recent studies in this area include a broad scale study (Barnay et al., 2003) to determine whether the English Channel is a closed system. This was achieved by looking at the larval supply of the polycahete *Owenia fusiformis* in various locations along the south coast.

5.4.1.6 Fowey estuary

Fowey estuary is a sheltered natural harbour that has been used in recent times for the shipping of locally mined china clay (Davies, 1998b). The estuary is included in the JNCCs review (Moore et al., 1999). There is also literature from the 1970s kept by the local natural history society, including a description of the marine life on the foreshore (Turk, 1971). There were new records of the mollusc species *Paludinella littorina* found at Fowey on the upper shore interstitial pebbles and gravels in an estuarine environment, as well as at Poldhu Cove, Cornwall in an upper shore cave (Light, 1999). More recent work in this area has looked at the benthic communities in the heavily fished scallop grounds off Fowey and at Eddystone (Kaiser et al.,, 1998). It was established that there were three faunal assemblages present; the substrate type determined these, with the most diverse being associated with sandy sediments.

5.4.1.7 Plymouth Sound

Plymouth Sound estuary is a large estuary that straddles the Cornwall/Devon border, and is an example of an extensive ria system. There is an enclosed bay into which two major rivers, the Plym and the Tamar, flow (Barne et al., 1996b). In addition to the input of the Plym and Tamar, the rivers Lynher and Tavy flow into the River Tamar adding to the volume of freshwater entering the system. The breakwater in the Sound was completed in 1841 and greatly increases the level of shelter. There are extensive areas of saltmarsh in the Tamar and Lyner estuaries (Davies, 1998b). The Plym estuary experienced a decline in habitat as a result of reclamation in 1800s and 1970s (Cordrey, 1996). The Tavy and the Tamar are affected by mine drainage discharge, run-off from spoil heaps and the remobilisation of metals from sediments as a result of past mining activity in the area. The upper estuaries are also subject to nutrient enrichment, although most inputs are diffuse agricultural run-off. Sewage discharges add to the nutrient loading causing chronic contamination of affected areas. The conditions associated with this contamination (low oxygen levels) may be responsible for salmonid mortalities. Some pesticides and PAHs (Polycyclic Aromatic Hydrocarbons) have also been reported to be relatively high in parts of the system.

The source of these is urban run-off, combustion and dockyard activities and levels are thought to occasionally exceed probable effect levels (Langston et al., 2003c). Studies have been carried out on the sediment metals and their effects on the benthic organisms (Langston et al., 1994).

The *Journal of the Marine Biological Association of the United Kingdom* (JMBA) is based in Plymouth and was first published in 1887. Since then it has published many papers discussing the marine biology of the Plymouth region. Heape (1888) was one of the first such papers, comprising a preliminary report on the fauna and flora of Plymouth Sound. Allen (1904) produced the first review of the marine invertebrate fauna in Plymouth, complied from records from the Marine Biological Association laboratory. Numerous papers exist detailing the different taxa and groups that may be seen in the area. Some of the broader papers, looking at whole communities, have been used here to describe the sediments and fauna of the area.

Sediment shores have particularly rich infaunal communities in Jennycliff Bay and Mountbatten Bay. The rare sea slug *Calliopaea bellula* was found there (Davies, 1998b). Rocky shore colonisation was documented (Moore, 1939; Moore & Sproston, 1940) for the area below the MBA laboratory. The outer part of the Sound from Penlee Point to Renny Rocks was considered of high scientific interest (Hiscock & Moore, 1986). The littoral habitats in this area are very diverse and their associated communities representative of sheltered open coast areas. The limestone below the Hoe was of particular interest as it is formed into a series of caves, gullies and overhangs. The red sea squirt *Dendrodoa grossularia* and the purse sponge *Granita compressa* dominated the rock surfaces, below which was the boring bivalve *Hiatella arctica*. The area was studied further as part of the ‘Surveys of harbours, rias and estuaries in southern Britain’ (Hiscock & Moore, 1986).

Bedrock and boulders in the main channels are subject to strong tidal streams. The substrate supports a community with high species richness. The rocks are limestone and thus allow several rock-boring species to occur; they create holes in the rock that provide shelter for other species. The rare anemone *Aiptasia mutabilis* and the polychaete worm *Myxicola aesthetica* were recorded in these channels. The rocks swept clear of sediment by the tidal currents supported suspension feeders such as sponges, hydroids, feather stars and ascidians (Hiscock & Moore, 1986).

Sublittoral sediments were sampled and classified according to Petersen’s system (Ford, 1923). A ‘*Spatangus purpureus – Venus*’ community characterised the coarser sediments to the west of the system. The muddier sediments inside the breakwater were characterised by an ‘*Echinocardium cordatum – Venus*’ community. This second community was then split into two groups based on the percentage of sand in the sediment. The sediment and distribution of polychaetes was studied (Gibbs, 1969). Samples were taken in the Sound, from Jennycliff Bay and Cawsand Bay during 1995 (Kendall & Widdicombe, 1999). They examined the small scale patterns in the structure of macrofaunal assemblages of shallow soft sediments and found that the sediment at Jennycliff Bay is heavily bioturbated by burrowing shrimps *Upogebia deltura* and *Callianassa*. Large specimens of *Mya truncata* were observed; the surface layer was dominated by polychaetes *Chaetozone gibber* and *Mellina elizabethae*, slightly deeper were *Euclymene oerstedi* and *Praxilella affinis*. This was different from the infauna found at Cawsand, which was numerically dominated by the polychaete *Magelona filiformis*. Other polychaetes represented were *Scoloplos armiger, Chaetozone gibber* and *Mellina elizabethae*. Also more common in the muddier areas were the echinoderms *Amphiura brachiata* and *Amphiura filiformis* and the lophophores of *Phoronis mulleri*. Similar studies were then carried out in 2000 using an ROV in Jennycliff Bay, finding there was no uniformity to the distribution or temporal stability of the megafauna (Parry et al., 2003). There have been recordings of the sabellarian polychaete *Lygdamis muratus* at various locations off Plymouth; these are restricted to a few grounds of limited area. Some of these restricted locations include shell gravel off Stoke Point, 'Bridge Ground' thought to be the shallow region between Drake's Island and Mount Edgecumbe and 23.3 miles SSW of the Eddystone (Wilson, 1977).

Three sublittoral sites were surveyed outside the mouth of the inlet, beyond the area of kelp, at Stoke Point Rocks (Forster, 1954; Forster, 1955). These were some of the first to be carried out using scuba in Britain and enabled the scientists to look under the rocks and overhangs for the first time. The deeper communities were dominated by sea fans *Eunicella verrucosa*, soft corals *Alcyonium glomeratum*, and anemones *Corynactis viridis, Epizoanthus couchii* and *Actinothoe sphyrodeta*. These sites have recently been resurveyed by Hiscock (pers comm..) and appear to be essentially similar.

The south Devon coast from Plymouth east to Lyme Regis is composed of shingle and sand beaches backed by high cliffs. There are small villages where a break in the cliffs occurs, as most of the coastline is inaccessible. The cliffs from Lyme Regis to Beer are chalk cliffs, and those from Beer to Exmouth are sandstone (Davies, 1998b). There is little information about the littoral zone in this area, possibly due to the inaccessibility of the coastline. There are reports by the Devon Wildlife Trust on the marine wildlife of Plymouth Sound and the adjacent coastline (Devon Wildlife Trust, 1993b).

5.4.1.6 Tamar Estuary

Tamar Estuary has been extensively studied since the early 1920s. Hartley & Spooner (1938) provided an introduction to a series on the ecology of the Tamar published by the JMBA. This series provided information on the following: dimensions, geology, intertidal sediments, physiography, saltmarshes, bathymetry, tidal streams and fisheries, and included reviews of previous work. Since then the macrofaunal and meiofaunal communities and production levels of estuarine mudflats have been investigated (Warwick & Price, 1975, 1979). The changes in meiobenthos related to salinity were also examined (Warwick & Gee, 1984). Davey (1993) studied the effects of bioturbation along an estuarine gradient. Six sites along the central axis of the river were sampled. The macro and mesofaunal characteristics of each station were discussed, and the importance of the polychaetes *Hediste diversicolor* and *Nephtys hombergii* as agents of bioturbation was noted.

The area between Calstock bend and Weir Quay was considered of national biological importance (Hiscock & Moore, 1986). The estuary has a well-developed salinity gradient, and hard substrata in both the littoral and sublittoral zones. The rare hydroid *Cordylophora caspia* was recorded in high densities, and the polyhaline hydroid *Hartlaubella gelatinosa* on shells and hard substrate, where the estuary opens out at Weir Quay.

5.4.1.7 River Yealm

River Yealm enters the sea at Wembury, and is a narrow estuary with mud flats in the upper reaches, moving through to sand flats and then a predominantly rocky shore. There is a sand bar at the entrance making the area fairly sheltered from the prevailing south-westerly winds. The Yealm is of conservation interest due to the wide range of biotopes present; the entrance to the inlet has both rocky and sediment shores. At the entrance to the inlet is Cellar beach, which has a range of substrates from sediments to rocks. The rocks have a variety of algae growing on them, the species depending on the level on the shore, exposure and the orientation of the rock. The protruding rocks in the area are dominated by barnacles *Balanus balanoides* and limpets *Patella* sp. (Moore et al., 1999). The distribution of the barnacles on this shore was investigated (Moore, 1936). Evans (1947) describes the distribution of the differing barnacle species on various shores in the vicinity, commenting on how the species and their position on the shore can be used to indicate the level of exposure in each area. The overhangs on this shore have a rich fauna with several species not generally found on open shores. These species included the anemones *Metridium senile* and *Sagartiogeton undatus*, ascidians *Morchellium argus* and *Sidnyum turbinatum*. The *Fucus serratus* was densely colonised by hydroids, spirorbid tube-worms and byozoans; the top shell *Osilinus lineatus* was also occasionally found. The rocks on the lower mid shore were found to have the sponges *Halichindria panicea* and *Hymeniacidon perleve* attached. There are also wide areas of sand and gravel, which support a community dominated by the sand mason worm *Lanice conchilega.* The polychaetes *Pygospio elegans* and *Spio martinensis*, and the amphipod *Corophium crassicorne* are also found in these areas in large numbers; also occurring in the sediments were the lugworm *Arenicola marina* and the razor shell *Ensis ensis* (Moore et al., 1999).

Warren Point is slightly further up the inlet on the opposite shore to Cellar beach. The substrate is predominantly shingle and muddy sand, with areas covered by fucoids. These fucoid patches have high densities of the edible winkle *Littorina littorea* and the rough periwinkle *Littorina rudis* is found on boulders and gravel (Evans, 1947); (Moore et al., 1999). On the lower shore attachment sites have been colonised by the American slipper limpet *Crepidula fornicata*, the Chinaman's hat *Calyptraea chinensis*, the painted top shell *Calliostoma* and the rare sea hare *Aplysia punctata*.

The upper reaches of the inlet are predominantly mud and muddy sand flats. These areas are colonised by a variety of polychaetes; in high abundances are *Ampharete acutifrons*, cirratulids, spionids and tubificids. Also present are ragworms *Nereis diversicolor*, *Lanice conchilega* and the cockle *Cerastoderma edule*, the Baltic tellin *Macoma balthica* and the peppery furrow shell *Scrobicularia plana* (Moore et al., 1999). These areas were compared with the areas of eelgrass *Zostera* adjacent to the mudflats. The areas of eelgrass were seen to have higher numbers of individuals as well as greater species richness. The species seen in high numbers in the eelgrass beds were the polychaetes *Spio filicornis, Exogone hebes, Nereis pelagica* and the tanaidacean *Apseudes talpa* (Turner & Kendall, 1999). Some of the rarer species increasing the species richness of the area were the anemone *Anemonia viridis* and the greater pipefish *Syngnathus acus* (Moore et al., 1999). The effects of shoot density on the infaunal macro-invertebrate community of the sea grass beds at Cellars Cove was investigated (Webster et al., 1998). The shoot density at this site was found to be lower than others studied, which may explain a relatively lower abundance of infauna. However, even at this site variations in the shoot density and related infaunal community were seen.

5.4.1.8 River Erme and River Avon

River Erme flows through a narrow wooded valley with some areas of salt marsh and enters the sea at Bigbury Bay. It is similar to the other inlets in the area with steep sides and has been extensively in-filled, so the channel is very shallow and broad at low tide. The input of fresh water is low and the water quality is high, so Atlantic Salmon *Salmo salar* and Sea Trout *Salmo trutta* migrate up the river to spawn. The substrate is mostly sediment, with an extensive beach at Wonwell comprised of clean, mobile, rippled and waved sand. There is an impoverished infauna with a few lugworms *Arenicola marina* and patches of the polychaete worm *Scolelepis squamata*. Where the sediments are particularly mobile this is reflected in the community present; the amphipod *Bathyporeia* and the isopod *Eurydice pulchra* are found in these areas (Barne et al., 1996b).

The River Avon flows through a narrow steep sided valley and also enters the sea at Bigbury Bay. It is dominated by sediments, and almost dries out at low tide; there is some hard substrate near the entrance and also on the upper shore of the upper reaches. The area has not been extensively studied, but is known to be an important nursery area for bass *Dicentrarchus labrax*. Atlantic Salmon *Salmo salar* and Sea Trout *Salmo trutta* are also known to migrate up the river to spawn. Seine netting for salmon takes place, as does bait digging and some cultivation of the mussel *Mytilus edulis* and the Pacific oyster *Crassostrea gigas* (Barne et al., 1996b).

In the upper estuary the polychaete *Nereis diversicolor* and the peppery furrow shell *Scrobicularia plana*, as well as the amphipod *Corophium volutator,* dominate the infaunal community. This is also true for the mud flats in the middle reaches, although there are small areas of gravel and shale. The steep mid-shore areas of rock and boulders in this area are influenced by freshwater runoff, and are covered by filamentous green algae. On the north shore at Mount Folly in the lower estuary there is a small area of sheltered bedrock, subject to sand scour. It has a community typical of sheltered shores, with barnacles dominating the open rock surfaces. The exposed, clean sandy beach between Burgh Island and the mouth of the Avon contains sand eels *Ammodytes* sp. a typical community of polychaetes, including *Scolelepis tridentate, Nephtys* sp., and *Magelona mirabilis* (Moore et al., 1999).

5.4.1.9 Salcombe Estuary

Salcombe Estuary has rich and diverse intertidal and subtidal benthic communities, with sheltered rocky shores inside the estuary mouth (Barne et al., 1996b). The area may be considered in three sections; Kingsbridge estuary – from Kingsbridge to Snape's Point, Salcombe Harbour – from Snape's Point to Sandhill Point, and the outside harbour from Sandhill to the estuary bar (Allen et al., 1900). The outer area is fully exposed to the south, but only covered with a few feet of water at low tide. The entrance to the harbour is a little narrower and then opens out to the sheltered harbour with two shallow creeks and the entrance to Kingsbridge estuary at the northern end. Kingsbridge estuary has exposed mud flats with a winding channel at low tide. There are eelgrass *Zostera* beds at the upper end of the estuary. This whole area was extensively studied (Allen et al., 1900), and the communities in each of the areas and habitats have been described.

5.4.1.10 Dart Estuary

Dart Estuary is a sheltered estuary with considerable freshwater input from several tributaries. This causes a marked salinity gradient within the estuary, which opens out to the sea at Start Bay. The upper regions have steep sided channels with narrow sediment flats flanking them at low tide. Hard substrate is more common in the lower part of the estuary, consisting of bedrock and artificial walls around Dartmouth and Kingswear (Davies, 1998b). The area is not heavily industrialised, but is affected by the presence of the Britannia Royal Navy College. The area is also very popular with tourists and has large marinas with moorings for around 2,000 leisure craft (Moore et al., 1999). This had a serious effect on the water quality in the area; concentrations of the antifoulant tributylin (TBT) were very high (Bryan et al., 1986), until its use on small craft was banned in 1987 (Matthiessen et al., 1995). Studies have been undertaken in the area to monitor the recovery of dog-whelks in the TBT affected communities (Birchenough et al., 2002; Bryan et al., 1993; Gibbs et al., 1988).

The habitats within the Dart estuary can be split into five different biotopes (Moore, 1988). The entrance to the Bay is known as the Range, the water is fully saline and the area is exposed to strong wave action and weak tidal action. The communities on the open shore are typical of the conditions and have clearly visible zonation. The upper shore, with a splash zone extending some 15 m above chart datum, has lichens; the middle shore has barnacles and limpets, and the lower shore algae. This is made more complex by the presence of rock overhangs, which have rich communities associated with them. The lower shore also has under-boulder communities, but these are not considered particularly rich. Sublittoral areas are comprised of muddy sand and support a fairly rich community of bivalves, polychaetes, echinoderms and other infauna. The infralittoral rocks are dominated by kelp *Laminaria hyperborea*, foliose red algae and bryazoan turf. Some areas are sediment scoured and so have a reduced diversity of flora and fauna. Mill Bay Cove has some shallow caves and these, along with the other vertical surfaces, are colonised by encrusting species typical of surge gullies.

The entrance to the inlet itself is the short transitional stage between fully marine conditions and sheltered areas with reduced salinity. The tidal streams are fairly strong as the entrance is comparatively narrow, causing the channel to be scoured very deep. The open shore communities are similar to those described above, at the Range. There is, however, some reduction in diversity and fewer algal species may be found on the lower shore. The sublittoral area is quite different due to the sharp change in conditions. Most of the species found at the Range are absent here; instead the fauna in the sediment and on the cobbles and pebbles is very rich. Dredge sampling showed that the community on the hard substrate was composed of sponges, hydroids, and anemones. The areas of muddy sediments contained large numbers of polychaetes including *Ampharete grubei*, *Melinna palmata* and *Tharyx* sp.

5.4.1.11 Teign Estuary

Teign Estuary is a small sheltered region with predominantly soft sediments. Strong tidal streams are caused in the lower part of the estuary by the narrow entrance at Babbcombe. Seaward from Babbcombe the habitats are comprised of bedrock and boulders. There are extensive anthropogenic influences in the estuary; power boating and jet skiing are permitted, unlike in most estuaries in the southwest. The area also provides a location for the cultivation of oyster *Ostrea edulis* and mussels *Mytilus edulis*. Salmon *Salmo salar*, trout *Salmo trutta* and bass *Dicentrachrarchus labrax* are netted, and tiles are in place to collect recently moulted crabs *Carcinus maenas* for angling bait (Davies, 1998b). A survey carried out (Frid, 1989) on behalf of the FSC, showed that the communities and the habitats were typical of a small estuary. The intertidal flats near the mouth of the estuary were composed of coarse mobile sand and had crustacean-polychaete communities with low species richness and abundance. The mudflats in the mid and upper estuary had polychaete-bivalve communities. Hard substrata, including man-made structures, were colonised by the estuarine species of alga *Fucus ceranoides*. The associated communities changed considerably as the salinity levels changed along with the strength of wave action in different parts of the estuary.

5.4.1.12 Exe Estuary

Exe Estuary is substantially sediment-filled due to the double spit across the mouth of the estuary. Areas of marsh and the sand dunes at Dawlish Warren back the estuary. Dawlish Warren is considered of ornithological importance and maritime botanical interest, and is an SSSI in recognition of this. The area lost areas of intertidal mud and salt marsh and grazing marsh due to construction of the railway in the mid 19th Century (Cordrey, 1996). The input of freshwater is high causing a salinity gradient from north to south. The river has a large catchment area, resulting in high sediment loading, and the deposition of this leaves large areas of sediment flats (Davies, 1998b). The estuary opens into the western side of Lyme Bay and the tidal basin it occupies is approximately 15km long and 1-2km wide (Langston et al., 2003b). At low tide a channel is exposed fringed by both mud and sand flats. There is little hard substratum; there are some stones and small boulders near the high water mark, and sections of the stone-faced railway embankment. The sediment is finest at the head of the estuary, where there are muds, and becomes coarser towards the mouth of the estuary, where there is some gravel and stones. Nematode community structure varies accordingly along the estuary (Clarke & Warwick, 1994).

Surveys were carried out in the estuary as early as the beginning of the 20th Century (Allen & Todd, 1902). They produced a detailed description of the marine fauna and natural history of the estuary. This work was followed up by Holme (1949) who examined the fauna of sand and mud banks near the mouth of the estuary, concentrating the influence of sediment type on the macroinvertebrate community structure. The Field Studies Council surveyed the area as part of the 'Surveys of harbours, rias and estuaries in southern Britain'. They compared their results to those of Allen & Todd in 1902 and suggested that there was no significant change (Dixon, 1986). Harris (1980) described five areas near Bull Hill Bank off Exmouth, each of which had distinctive substrata. These five substrata and their associated communities are as follows: Muddy shore – *Spartina/Scrobicularia* - Cordgrass and Peppery Furrow shell; Sandy shore – *Arenicola/Cerastoderma* – Lugworm and Cockles; Well drained Sand – *Ophelia* – Polychaete; Heavily scoured – *Ophelia* – Polychaete; *Mytilus* community – Mussel beds. As well as these communities there have been recordings of nationally important species; these include the tentacled lagoon worm *Alkmaria romijni* and the polychaete worm *Ophelia bicornis*. *O. bicornis* was first recorded there in 1902 (Allen & Todd, 1902) and has been recorded at various locations in the estuary since (Harris, 1991). The pink sea fan *Eunicella verrucosa* has been found on near-shore reefs off Exmouth (Langston et al., 2003b).

5.4.1.13 Lyme Bay

Lyme Bay is the region that extends from Exmouth to Portland Bill. The Isle of Portland, a limestone outcrop, protrudes from the Dorset coast and greatly affects the hydrodynamics in the English Channel. This generates strong tidal streams off Portland Bill, which cause marked changes in the phytoplankton community (Davies, 1998b). Several studies have been conducted across the bay (Rostron & Little, 1995; Smith, 1995a, 1995b), recording the intertidal benthic fauna. The studies carried at this time were extensive and also included subtidal studies (Cleator, 1995; Dyrynda & Cleator, 1995; Grist & Smith, 1995), and an assessment of the environmental quality (Smith, 1995c).

The coast from Chesil to Lyme Regis has shingle beaches, backed by cliffs. Armitage (1970) surveyed the littoral marine fauna of the Axmouth-Lyme Regis nature reserve, including notes on the effect of freshwater run-off. The properties of the rock on these beaches allow the presence of boring molluscs. The populations include *Pholadidea loscombiana*, few other colonies of which are known in the UK (Davies, 1998b). The distribution of *Littorina saxatilis* and *Littorina arcane* in Lyme Bay were examined by Mill & Grahame (1990). They noted that *L. arcana* does not occur in the English Channel to the east of Lyme Regis. The Dorset Underwater Survey (Dixon et al., 1979; Roberts et al., 1986) describes six nearshore sublittoral associations, four of which had been identified on the Purbeck coast. The two that had not been seen at Purbeck were a crustacean association of *Pagurus bernhardus-Maja squinado* and a hydroid-ascidian-sponge association. The latter were found in areas with broken bedrock and boulders. Eagle & Hardiman (1977) sampled 14 stations within the bay and found that an *Echinocardium cordatum/Amphiura filiformis* community occupied 13 stations. The fauna was dominated numerically by the polychaetes *Chaetozone setosa* and *Magelona filiformis*. Other polychaetes, bivalves and crustaceans were also abundant.

The subtidal nematode and macrofaunal assemblages in Lyme Bay were examined (Schratzberger et al., 2004) along with samples from 4 other locations around Britain for use as baseline data for investigations into the effects of pollution. The effects of scallop dredging in the bay were investigated by the (Devon Wildlife Trust, 1992). This involved spot dives on ‘dredged’ and ‘un-dredged’ sites and although there was a difference in the communities at the different locations this may have been as a result of the ‘un-dredged’ site being close to a wreck. It was concluded from the report that the area was subject to ‘severe environmental damage’. The following year a report on the effects of mobile fishing gear on the inshore reefs was produced (Devon Wildlife Trust, 1993a). Eight reef areas were studied and a diverse epibenthic community was described. A more comprehensive study was then carried out (Cleator, 1995; Dyrynda & Cleator, 1995) which described communities similar to those seen in the Wildlife Trust studies. In addition to these a population of sunset coral *Leptopsammia pruvoti* was identified. This has been seen at Lundy, but few other locations in the Britain. There were also extensive populations of the sea fan *Eunicella verrucosa*. Again this is seen at Lundy, but has been seen no further east than Lyme Bay.

5.4.1.14 Chesil Bank and Fleet

Chesil Bank forms the western end of Lyme Bay. This is a shingle structure up to 13m in height in places and 28km in length. It stretches from Abbotsbury to Weymouth and encloses the Fleet Lagoon; a large, shallow, tidal lagoon (Barne et al., 1996a). The pebbles from which it is comprised range in size from pea gravel to cobbles and are graded reducing in size in a westerly direction (Ladle, 1981; Langston, 2003). In the Fleet Lagoon the water is brackish as there is freshwater run-off from the land and saltwater intrusions from the sea through the shingle bank. There is poor mixing in the lagoon due to it being so shallow. This also causes extreme temperatures, with large areas freezing in the winter and becoming very warm in the summer. The lagoon can be divided into two zones; the 'lagoonal basin' and the 'inlet channel'(Langston et al., 2003f).

The 'lagoonal basin' is very sheltered from wave action and has a minimal tidal range, weak currents and very poor flushing. The substrate is mostly soft organic mud with salinity being low and variable. There are extensive areas of seagrass and algae during the summer. Extensive areas of eelgrass *Zostera* sp. and wigeongrass *Ruppia* sp. cover much of the intertidal (Holmes, 1986). The 'inlet channel' is located at the south-east of the lagoon and occupies about a quarter of the area. This area has a pronounced tidal rise and fall, strong currents and better flushing than the rest of the lagoon. The bottom has been subject to scour in this area revealing a range of substrates including limestone, bedrock, hard clay, sand, coarse sediment, and shingle (Dyrynda & Farnham, 1985). This area supports a curious and diverse assemblage of algae and invertebrates. Rare or scarce species include the sponge *Suberites massa*, the burrowing anemone *Scolanthus callimorphus* and the southern Black faced Blenny *Tripterygion delaisi* (Downie, 1996). Also found on the sediment flats is the lagoonal specialist polychaete *Armandia cirrhosa*. The non-native ascidian *Perophora japonica* has also been identified in the Fleet (Baldock & Bishop, 2001). Little et al. (1989) recorded the distribution of the intertidal molluscs in the lagoon.

There are two communities within the lagoon; one typical of the upper shore, above the height at which water emerges as springs, and the other restricted to the lower shore in spring areas. The populations in the upper shore were seen to be very patchy; this is thought to be a result of the shingle in which they live being mobile and susceptible to wave action. Species found at these patchy sites included *Truncatella subcylindrica, Ovatella myosotis, Leucophytia bidenata, Cingula cingillus, Littorina saxatilis*, and small numbers of *Lasea rubra, Crepidula fornicata*, and *Mytilus edulis*. *Cingula cingillus, Littorina saxatilis*, and *Lasea rubra* were all found on the lower shore spring areas, the latter in quite high densities. Also found in these areas were the normally sublittoral species *Emarginula conica* and *Leptochiton asellus*, and in very low densities *Bittium reticulatum* and *Calyptraea chinensis*. The following were also found alive in the springs; the prosobranchs *Skenea serpuloides, Cingula semistriata, Caecum armoricum*, the pyramidellids *Brachystomia eulimoides, Turbonilla lactea* and the bivalves *Kellia suborbicularis* and *Mysella bidentata*. *Caecum armoricum* has only been found in this location and has not been recorded anywhere else in Britain (Seaward, 1987). It is found as part of the interstitial community occupying the areas of the shingle bank where seepage occurs. Other species that were identified as new records in this area were the tiny gastropod *Ammonicera rota* and *Cingulopsis fulgida*, although the latter was not found alive (Palmer, 1987).

5.4.1.16 Weymouth Bay

Portland Harbour at the western edge of Weymouth Bay is a large water mass sheltered by man-made breakwaters installed in the latter half of the 19th century. Water temperatures in the harbour are slightly elevated due to the restricted water exchange with the open ocean (Davies, 1998b). The elevated temperatures allow the presence of Mediterranean species and other species that have a limited distribution around Britain. Many of these have been investigated in attempts to map their distribution. Williams (1996) examined the taxonomy and distribution of the octocoral *Cervera atlantica*. Southward et al. (2004) looked at the habitat and distribution of the barnacle *Solidobalanus fallax* and Townsend et al. (2006) discusses the occurrence of the nationally rare, Mediterranean polychaete *Sternaspis scutata* in the English Channel.

Weymouth Bay is a sheltered sandy bay; the inshore sands give way to mud and gravel further offshore. Spooner & Holme (1961) analysed a series of dredge samples from this stretch of coast. They found a high diversity of bivalves including *Abra alba* and *Spisula subtruncata*. Also present were the American slipper limpet *Crepidula fornicata* and the brittlestar *Amphiura filiformis*. Holme reviewed the fauna in Weymouth Bay and Poole Bay in 1967 to assess the changes in the community as a result of the cold winter of 1962-3 (Holme, 1967). There have also been dredges carried out by the Conchological Society since 1973, the results of these have been published in the society's newsletter (Light, 1984; Palmer, 1990). There are also records of some unusual specimens of the chiton *Acanthochitona* being found at Weymouth (Baxter & Light, 1990). There are extensive eelgrass *Zostera marina* beds that extend into Weymouth Bay, with associated fauna including the small gastropod *Rissoa membranacea* (Davies, 1998b).

Weymouth Harbour is at the mouth of the River Wey and is very small and narrow. It has a sandy and muddy bottom and no intertidal areas, other than the walls of the breakwater and the pier pilings. These vertical walls are built from limestone blocks, which are dominated by kelp *Laminaria digitata* and *Laminaria saccharina*. The fauna associated with the kelp include sponges, hydroids and ascidians. The piles of the pier are wood and concrete, and support a moderately rich algal community. The upper 50cm has large kelp plants and some eelgrass, below that are tufts of red and brown algae; up to 27 species were recorded in this habitat. In contrast few faunal species were recorded, the ones that were included the hydroid *Obelia plicata* and several ascidians including *Morchellium argus* and *Diplosoma listerianum*. At the base of the pier is a layer of diatom rich mud, which covers the underlying stiff clay. The fauna associated with this area includes lugworms *Arenicola marina*, the burrowing anemone *Cerianthus lloydii*. There are also patchy distributions of nematodes, shore crabs *Carcinus maenas* and the hermit crab *Pagurus bernhardus* (Howard, Howson & Moore, 1988a; Moore et al., 1999).

Kimmeridge is a Voluntary Marine Nature Reserve which is annually monitored (Collins & Mallinson, 1990). The Bay is composed of Blackstone, which is Kimmeridge oil shale. Nearshore sublittoral communities were studied by Dixon et al. (1978) and summarised at a later date (Roberts et al., 1986). Dorset Heritage Coast commissioned underwater surveys, which were carried out in this area and also westwards to Lyme Regis for 3 years in the late 1970s (Brachi et al., 1977; Dixon et al., 1978; Dixon et al., 1979). These surveys give detailed reports of the marine flora and fauna that can be found in the different habitat types in this area as well as photographs of some of the more unusual organisms. These habitats include limestone, chalks, boulders, shale, shell gravel, maerl beds and sands (Brachi et al., 1977).

Purbeck Voluntary Marine Wildlife Reserve was established in 1978 and is now part of the Dorset and East Devon World Heritage Site created in 2001 (Pinn & Rodgers, 2005). The Marine Reserve was created to protect the area and raise public awareness of the marine environment; this in turn increased the numbers of visitors to the area. Pinn & Rodgers (2005) compared two sites within the reserve, one that had high visitor numbers and the other that was reasonably inaccessible and so had low numbers of visitors. It was found that the area with high numbers of visitors, and hence high levels of trampling, had mostly ephemeral and crustose species notably *Enteromorpha linza* and *Verrucaria* spp. Larger branching species *Fucus serratus* and *Cladophora rupestris* were found were visitor numbers were lower. Barnacles and limpets were also more abundant on these shores.

5.4.2 The Solent and the Isle of Wight

Southampton Water and The Solent extends from Sesley Bill and includes Southampton and Portsmouth; it is enclosed from the rest of the English Channel by the Isle of Wight. The area includes the natural harbours of Portsmouth, Langstone, and Chichester. These harbours all have similar benthic habitats; mud and muddy-sand dominate, with cobbles, pebbles and shells found in the drainage channels. The area and its biology have attracted considerable interest from higher education institutions, research centres and corporate industry. A summary of the marine survey work undertaken in the Solent and adjoining waters was compiled by Southern Science (1991) for the Southern Water Services Ltd. A previous review of the work in the area was provided by the NCC in the form of the harbours, rias, and estuaries survey (Dixon & Moore, 1986). They identified four littoral and nine sublittoral habitat types with poor epifaunal community diversity. Christchurch Ledge, off Hengistbury Head is a wider area than just the Harbour and takes in Poole Bay too. Sublittoral surveys have been carried out in this area with scuba using photography and diver observations. Collins & Mallinson (1986) recorded the flora and fauna in the various habitat types in this area. These habitats included sand, gravel, and boulders at various depths.

5.4.2.1 Poole Harbour

Poole Harbour is a naturally saline lagoon, which extends around 10km from Wareham to Bournemouth. The area is unusual as the harbour is a bar-built estuary with a double high water and micro tidal regime. The north and the middle shipping channels are regularly dredged. The sheltered nature of the estuary, along with the reduced currents in the upper bay encourages siltation (Langston et al., , 2003a). An area of the mudflats in Holes Bay, Poole Harbour was studied to determine the impact of a macroalgal mat on the benthic biodiversity. Macroalgal blooms may be attributable to localised organic-enrichment and consist of the opportunistic alga *Ulva* and *Enteromorpha*. The algal mats caused stress to the organisms in the underlying benthos, impacting the species richness, abundance, and biomass of the macrofauna. However there was an overall increase in the abundance and diversity of the invertebrate assemblage, caused by the development of a faunal community within the mat of previously unobserved species. The effect was seasonal as the mats dispersed in the winter.

The Harbour has been quite extensively studied, by Dyrynda (1984, 1987) who examined the subtidal areas. In conjunction with this the ecological analysis of the shore line at Poole by Gray (1985) provides a fairly good overview of the system. The area was surveyed in 1986 and a total of 115 taxa were identified, showing a species poor environment (Covey, 1998). Dyrynda & Lewis (1994) found that some species inhabited areas of the shore above the normal upper boundary of their littoral distribution. This is likely to be a characteristic of the double high tide that is experienced in this system. The literature concerning this system was reviewed and summarised by Howard & Moore (1988) and again by Covey (1998). The Harbour was characterised by Langston et al. (2003a) as part of the process of making the area a SPA, which has now been completed.

The Harbour has extensive intertidal mudflats, and to the southwest there are also areas of saltmarsh and reedbed. There are two major types of habitat in the harbour; fine sediments and clay, usually in the sheltered creeks and embayments, and coarser sediments, usually in areas exposed to greater wave action and tidal currents. There is very little hard substrate, the only patches being outcrops from the islands, or the mainland. Species diversity is limited, and the community is dominated by polychaetes; also found were the bivalaves *Abra alba* and the mud shrimp *Corophium volutator* (Langston et al., 2003a). Nationally important species in the Harbour include the peacock worm *Sabella pavonina* and rare species, the sponge *Suberites massa*, the two bryozoans *Anguinella palmate* and *Farella repens*, and the nudibranch *Aeolidiella sanguinea* (Howard & Moore, 1988; Langston et al., 2003a).

5.4.2.2 Poole Bay

Poole Bay is separated from the Harbour by the Studland Dunes that form a natural barrier between the two. The sublittoral sediment communities of Poole Bay have been the subject of sampling during larger scale investigations. The bottom fauna of the English Channel was examined by Holme (1961, 1966) who looked at the species present and their abundance at different stations. Spooner & Holme (1961) looked at the community types found along the Dorset coast and following on from that the changes in the fauna at Poole Bay and Weymouth following the severe winter of 1962-3 (Holme, 1967). Poole Bay was found to be the only location on the English Channel to have all five associations; mud, muddy sand, sand, muddy gravel, gravel (Holme, 1966). Jensen (1990) described the main infaunal and epifaunal communities found at 35 stations. Of the ninety macro-infaunal taxa identified the most abundant group were the polychaetes. The polychaete *Nephtys hombergii* was the most abundant and widespread. The results from this study were analysed using cluster analysis and eight different assemblages were identified (Covey, 1998).

The infauna has been examined at various locations, with differing substrate; Rowe et al. (1990) looked at the area off Handfast Point, Collins & Mallinson (2004) focused on maerl, but in a wider area. An overview of the epifauna in the Bay was produced (Jensen, 1990) and the mollusca in the area were mapped (Light, 1994).

Recent studies in the area have been looking at the colonisation of the artificial reef in Poole Bay (Baldock et al. 2001; Hatcher, 1994, 1997, 1998). Blocks were constructed from pulverised power station fuel ash and gypsum, and wastewater sludge. The initial colonisation was rapid, and eighty species were identified in the first two months.

5.4.2.3 Christchurch Harbour

Christchurch Harbour exhibits several lagoonal characteristics, it is shallow and has limited flushing of brackish water. This is due to it being almost completely cut off from the sea by a sand/shingle spit (Barne et al., 1996a). As a result of this a restricted range of brackish water communities inhabits this area (Dixon, 1988). A report for the NCC was complied by Dixon (1988) as part of the survey of harbours, rias and estuaries in Southern Britain.

5.4.2.4 Southampton Water and The Solent

The Solent is a high-energy system, which gives it high turbidity, and there is a limited amount of hard substratum. The lack of suitable substrate and clear water reduces algal abundance in the enclosed areas of the Solent (Barne et al., 1996a). The subtidal habitats range from sheltered silty mud to tide swept coarse sand, pebbles and cobbles. The coarser sediments tend to occur in the west arm of the Solent where the tidal currents are stronger. There are mounds of gravel and flint stones, with the occasional exposures of clay (Barne et al., 1996a). The finer sediments are found in Southampton water and the east arm (Thorp, 1980). The small areas of silty pebbles and shells around the moorings at the entrance to the Emsworth Channel have rich faunal communities. These include sponges, hydroids and sea squirts, possibly as a result of these areas not being dredged in the winter months (Barne et al., 1996a). The area from Selsey Bill to the east Solent was surveyed by Collins & Mallinson (1983). They list the conspicuous fauna of the various substrate types, and note that infaunal communities were dominated by polychaetes and were of low density and species diversity. The diversity and abundance of species does however increase as the grain size and stability of the substrate increases. Substrates from gravel upwards were covered in ascidians, hydroids and bryozoans. The ascidian *Dendrodoa grossularia*, the hydroids *Nemertesia antennina* and *Tubularia indivisa*, the foliose bryozoan *Alcyonidium diaphanum* were visually dominant. The American slipper limpet *Crepidula fornicata* occurs throughout Southampton Water, its empty shells providing a substrate for encrusting and sessile organisms (Covey, 1998). The Solent has been colonised by a large number of non-native species that constitute a large part of the communities in some areas (Covey, 1998). These include the Pacific sea squirt *Styela clava* and the Japanese seaweed *Sargassum muticum*. The American hard-shelled clam *Mercenaria mercenaria* was numerous, but only small numbers now remain in Stanswood Bay. Numerous studies have been carried out on the effects of harvesting this non-native species (Ansell, 1963; Coughlan, 1981; Sheader, 1986).

The shores of the Solent and Southampton water are predominantly sedimentary, however a study of seven rocky littoral sites in the Solent was carried out by Crisp & Southward (1958). The sedimentary shores have been studied (Holme & Bishop, 1980); around thirty sites were visited, and as a result the faunal assemblages found were split into five main community types; Crustacean-polychaete; *Lanice conchilega* (sandmason worm); *Arenicola marina* (Lugworm); *Venerupis pullastra* (Carpet shell); and *Scrobicularia plana* (Furrow shell). Stanswood Bay, a sandy beach considered to be typical of those in the Solent was studied (Bamber, 1993). This was a four-year study looking at the sandy infaunal community, which in this case was a crustacean-polychaete assemblage. This study shows the seasonal changes of infauna and examines other possible reasons for the community changes observed. Eelgrass *Zostera* beds occur in some of the estuaries on the western side of the Solent, also with extensive areas of green algae *Enteromorpha* sp. These areas have a high biomass of invertebrates and so provide food for large numbers of wildfowl and waders over the winter months (Barne et al., 1996a).

Fawley is the site of an Esso Refinery and as a result has been the subject of considerable study. The site is also surrounded by salt marshes that have been the subject of studies carried out in the 1970s (Baker, 1976a, 1976b; Baker & Petpiroon, 1976, 1979; Baker et al., 1978; Dicks, 1981b, 1982; Dicks et al., 1979; Dicks, Hartley & Petpiroon, 1979; Petpiroon et al., 1978; Petpiroon & Griffiths, 1977). Benthic (Dicks, 1972, 1980, 1981a, 1981b, 1881c; Dicks et al., 1980, 1981; Levell, 1980; Levell et al., 1980, 1981) and littoral (Bamber & Stockwell, 1988) studies were conducted. The outfall was the subject of further studies (Coughlan & Holmes, 1971; Dicks, 1972; Dicks et al., 1980, 1981), and many of the investigations were completed by the FSC.

5.4.2.5 Portsmouth Harbour

During the 1980s studies were carried out in the area of Portsmouth harbour on behalf of the NCC to assess the effects of the proposed barrage across the entrance. The effect of sewage effluent on the growth of macroalgal mats on the mudflats was investigated on behalf of the Southern Water Authority (SWA). Soulsby et al. (1978, 1982) found that, similar to the situation in Langstone Harbour, a reduction in the effluent would be likely to reduce algal growth and improve the quantity of infauna. Tubbs (1975b) produced an ecological appraisal for the site, highlighting the national importance of the harbour for wading birds.

5.4.2.6 Langstone Harbour

Langstone Harbour has been studied to assess the effects of sewage effluent in the area. Portsmouth Polytechnic (1976) produced a report on the effect of sewage effluent on the ecology and amenities of the harbour. The mudflats in the area were supporting considerable growths of the green algae *Enteromorpha*, and this report suggested that a reduction in the effluent might help control algal growth. This would then improve the quality of the infauna, making it a better food source for the wading birds. These findings were echoed in further studies (Montgomery & Soulsby, 1980; Soulsby et al., 1978, 1982). The macrobenthos inhabiting the sandbanks in the harbour was described by Withers & Thorp (1978) who identified forty-nine taxa, dominant were the polychaete *Scolopsis armiger* and amphipods *Bathyporeia sarsi* and *Urothoe brevicornis*.

5.4.2.7 The Isle of Wight

The Isle of Wight is located to the south of Southampton, in the Solent, and has a major influence on the water movement in the central English Channel. The chalk communities of the island have been included in the survey of chalk shore carried out on behalf of the British Natural History Museum (Tittley et al., 1986). Sites in the Isle of Wight were included in the NCC survey of the littoral zone of the British coast (Holme & Bishop, 1980). The marine sites on and around the island were summarised in the review of benthic marine ecosystems in Britain (Covey, 1998). The lagoons on the island were surveyed (Sheader & Sheader, 1987) in a report to the NCC. The Yar, Wootton Creek, Newtown and Bembridge Harbours were all included in the survey of harbours, rias and estuaries in southern Britain (Howard et al., 1988b; Johnston, 1989). The marine biology of the island continues to be studied with the Medina Valley Centre's maintenance of marine records and field courses. Reports have been produced for a number of years, beginning in the early 1990s (Herbert, 1991, 1994, 1997, 1998). There have also been exercises to map the benthic biotopes in the area (Brown et al., 2002, 2004; Sotheran & Foster-Smith, 1995) and Newtown harbour has a management plan (Tubbs & White, 1977).

The Medina estuary flows into the Solent on the Northern shore of the Isle of Wight. Withers (1976, 1979) reported on the macrofauna and flora of the estuary, and the infaunal communities. An ecological appraisal for the area was produced for the Isle of Wight County Council in 1975 (Tubbs, 1975a). The Yar estuary was described (Johnston, 1989); it was noted as having habitats typical of south coast inlets. It differed in that the there were rich communities in the upper reaches to the north of King's Manor. There are current swept cobbles colonised by sponges, anemones and ascidians, including the scarcely recorded sponge *Suberites massa*. The Yar Estuary was assessed for conservation management (Waters & Tubbs, 1977).

Newton Harbour was described by Howard et al. (1988b) and a conservation management assessment was completed (Tubbs & White, 1977). The harbour includes extensive fringing mudflats and sublittoral channels. Epifauna is sparse as the flats are almost entirely sediment, although the winkle *Littorina littorea* and the slipper limpet *Crepidula fornicata* were found in significant numbers. The sediment itself was found to contain an abundance of polychaetes and oligochaetes, with a few crustaceans and molluscs. The shores were split into three types, showing that the sediment type and level of exposure determined the community found. The subtidal channels were mostly composed of tide swept cobbles and pebbles colonised by red foliose algae and brown seaweed. Typically estuarine fauna dominated some areas of hard substrata, these included the fan worm *Sabella pavonina*, the bryozoan *Amathia pruvoti*, the sea squirt *Dendrodoa grossularia*; the oyster *Ostrea edulis* was also present. Sheader & Sheader (1987) reported the presence of the nationally important species of amphipod *Gammarus insensibilis* at the old saltings, at the edge of the salt marsh around the harbour.

Bembridge has been studied both on shore and off, many studies have been carried out over a number of years due to the rich algal flora on Bembridge Ledges (Covey, 1998). Bembridge Ledges and St Helen's Ledges have been designated as part of an SSSI partially due to the rich algal communities in the pools. Dixon & Moore (1986) noted the brown seaweed *Sargassum muticum* and the fleshy green alga *Codium fragile* dominated the pools. Other studies looking at the flora and fauna of the area are by Collins et al. (1991) who studied Bembridge and St Helens, and Gray (1978) who investigated the fauna related to the *Sargassum muticum*. Harbour Farm Lagoon, behind the sea wall in brackish marshland, was included in the study by Sheader & Sheader (1987) who recorded two species of national importance at the site: the stonewort *Lamprothamnion papulosum* and the sea anemone *Nematostella vectensis* (which has been found at other locations around the island).

Other areas of specific interest were identified in a number of the surveys carried out. The shore at Ryde Sands was identified by Bishop & Holme (1980) as being of marine biological interest, mainly for the presence of the uncommon bivalve *Loripes lucinalis*. The sediments at Ryde Sands were investigated (Withers, 1977a); the lugworm *Arenicola marina* was dominant overall and the mud snail *Hydrobia ulvae* was also locally abundant. The fauna associated with the eelgrass *Zostera* sp. beds to the west of Ryde pier was considered more abundant and diverse, with fifty-seven species being recorded. Lakeside old mill pond at the tidal limit of Wootton Creek was considered moderately diverse, and noted for the presence of the rare anemone *Nematostella vectensis* (Sheader & Sheader, 1987).

Sublittoral areas off the north coast of the island are considered as part of the Solent, but for the areas elsewhere information is limited. Collins & Mallinson (1988, 1989) surveyed the nearshore areas (between Horestone Point and Culver Cliff), and reviewed the existing knowledge of the flora and fauna in the area. This area off Bembridge was a proposed SSSI at the time. The area was considered of interest due to the wide range of habitat types. They described the communities associated with a range of substrates including limestone, clay and sedimentary substrate. The more unusual of these habitats is the area of chalk bedrock and boulders, found to be home to sponges *Dysidea fragilis*, *Halichondria panicea* and *Amphilectus fucorum*. The other prominent group was anemones; *Anemonia viridis*, *Urticina felina* and *Cereus pedunculatus*. This was similar to the community found on the limestone boulders, though they were also noted as having bryozoans, ascidians, hydroids and worms growing in association with them. The most abundant mollusc in the area was the slipper limpet *Crepidula fornicata*, an alien species that was introduced into the Solent in the last century. The area was considered particularly rich, and surveys were extended to include communities further offshore that were faunal-dominated (Collins & Mallinson, 1989). Areas deeper than 10m below chart datum were found to have a gravel substrate with rock outcrops. The rock surfaces were dominated by the foliose bryozoan *Flustra foliacea* and hydroids, mainly *Nemetesia antennina* as well as sponges and ascisdians. A mud patch off St Helen's Roads was found to have a population of the echiuriod worm *Maxmuelleria lankasteri*. Areas to the southwest and southeast of the island were surveyed as part of the investigation into the effects of sludge dumping on benthic communities (Jenkinson, 1972). The bottom sediments were poorly sorted, with gravel and stones. The samples consisted mostly of epifauna and were similar to those found by Lees et al. (1990). This work was undertaken during investigations of gravel dredging grounds carried out by MAFF; these areas were subject to the effects of both gravel dredging and the dumping of dredged material. The investigations, anchor dredging at twenty-two stations, revealed communities dominated by sessile epifaunal species. The epifauna was mainly sponges, hydroids, bryozoans, ascidians, and the bivalve *Nucula*. Previous to these studies Jenkinson (1972) looked the effects of sewage sludge dumping on the benthic communities at sites around the Isle of Wight. The locations of these sites included off the Needles, Christchurch Bay, Atharfield Point and south of Nab Tower. Details of the fauna found at these sites are given in the paper; both diving observations of larger organisms and the more common species found in the grab and dredge samples.

5.4.2.8 Chichester Harbour

Chichester Harbour is a large sheltered estuary; the harbour is predominantly saline with a small inflow of fresh water, and is largely infilled reducing the tidal effects. At the narrow entrance to the Harbour is a 20 m-deep trench with steep sides where the sediment is bound together by tubes of the polychaete worm *Sabellaria spinulosa*

(English Nature, 1994). There are areas of mud and salt flats with eelgrass *Zostera* spp. beds and saltmarsh. There are also a number of lagoonal areas near the mouth of the harbour. The mudflats have large mats of green algae suggesting that there is eutrophicaiton in the harbour. The other major anthropogenic impact is from the moorings for leisure craft, of which there are around 4,000. The area is designated a Special Protection Area (SPA) because it has been recognised as being internationally important for migrating and wintering waterfowl populations of Dark-bellied Brent geese *Branta bernicla* amongst others. Thirteen waterfowl species are of national importance, six of these are also internationally important (Barne et al., 1998a). It is the only estuary in the area that is a major nursery for sea bass *Dicentrarchus labrax*.

Stubbings & Houghton (1964) carried out an ecological survey of Chichester Harbour, paying special attention to some fouling species, hydroids, barnacles and tunicates. Since then there has been work carried out on behalf of the NCC to catalogue the literature relevant to Chichester Harbour (Thomas et al., 1978). There was also a preliminary survey of the invertebrate fauna for the NCC to accompany the literature review (Withers et al., 1978). The mudflats of Chichester Harbour and Langstone were investigated using both remote sensing and field sampling (Coulson et al., 1980). This was followed up by the ecological mapping of the main habitats in the intertidal zone of Chichester Harbour (Budd & Coulson, 1981). The mudflats were dominated by oligochaetes *Tubificoides benedeni*, the polychaetes *Manayunkia aestuarina* and *Scoloplos armiger,* the bivalve *Abra tenuis* and the mud snail *Hydrobia ulvae*. The areas of coarse muddy gravel had a different associated community, dominated by the polychaetes *Amphitrite johnstoni, Arenicola marina, Capitella capitata* and the cockle *Cerastoderma edule* (Covey, 1998).

5.4.3 Eastern English Channel

The area of coastline in the Eastern Channel is predominantly comprised of rock or shingle. However there are extensive chalk platforms in the intertidal region to the east (Covey, 1998). The main body of water that flows up the English Channel from the southwest is the predominant influence on this area; although there is some influence from the water coming from the North Sea (Crisp & Southward, 1958). The substrate along the coast in both East and West Sussex is mostly mobile shingle, formed from flint pebbles, with occasional patches of muddy sand, particularly on the lower parts of the shore. The estuaries and marinas in the area tend to have muddy sediments. There are a number of saline lagoons and ponds along this stretch of coast (Covey, 1998). Areas of the shingle systems and saline lagoons have been designated Sites of Special Scientific Interest (SSSIs). These areas are important for nationally rare invertebrates and specialist lagoonal fauna (Barne et al., 1998b). Rising sea levels and the fact that the surrounding land is low-lying means that most estuarine shoreline is now defended by a sea wall. There are few remaining areas with natural shoreline, however most of the estuaries remain in rural areas. The sublittoral sediments in near shore areas are mixed sediments and sand. However there are also sandstone and limestone reefs of bedrock and boulders, and chalk and clay exposures (Barne et al., 1998b). Sussex is also the only place in the British Isles to have chalk as off shore cliffs and reefs, which can be several hundred meters long. Tittley et al. (1986) described the communities of the chalk and greensand shores in south-eastern England, and then later the macrobenthos of non-chalk rocky shores in the same area (Tittley et al., 1989).

Offshore there are extensive areas of gravels which are the target of major exploitation activities over coming decades. Although several baseline reports on the area, including a large habitat mapping project (Defra ALSF-MEPF 04/01), are in the process of being completed they are not covered here.

5.4.3.1 Pagham Estuary

Pagham Estuary along with Chichester Harbour is recognised as having some of the highest densities of breeding waders, especially those associated with wet grassland and saltmarsh (Covey, 1998). Partially for this reason, the area is a local nature reserve and an SSSI. The natural history of the area was reviewed by Rayner (1975) who looked at the plants and animals other than the birds and mammals. The harbour consists mainly of mud flats and the afore mentioned saltmarsh (Covey, 1998).

5.4.3.2 River Arun

River Arun estuary is now embanked for much of its tidal length, which is considerable, as it cuts through the Southern Downs. The estuary discharges into the sea at LittleHampton; the mouth of it is surrounded by small areas of saltmarsh and tidal mudflats. To the west of the estuary mouth is Widewater Lagoon, a shallow saline lagoon that is separated from the sea by a shingle ridge (Barne et al., 1998b).

5.4.3.3 Hastings

Tittley et al. (1989) reported to the NCC on the macrobenthos of the non-chalky shores in southeastern England, including Hastings. The subtidal communities in the area and off shore areas were surveyed as part of a study comparing gravel assemblages off the east and south English coast (Kenny et al., 1991). This was part of a larger study looking at the effects of aggregate dredging. Gravel deposits off Hastings and the Isle of Wight were similar in some ways, both having the following species; the bryozoan *Flustra foliacea* and *Alcyonium* sp., the American slipper limpet *Crepidula fornicata* and the ascidian *Dendrodoa grossularia*. Brown et al. (2004) mapped the habitats at Hastings Shingle Bank using a combination of sidescan sonar, Hamon grab samples, a video camera and a beam trawl. Four biotopes were identified: shallow water, polychaete dominated fine sand; coarse gravel with attached epifauna; deeper water, coarse sand with *Ophiura ophiura*; and disturbed (dredged) sandy gravel. The shallow fine sands were characterised by polychaetes such as *Spiophanes bombyx*, *Magelona johnstoni*, *Nephtys cirrosa* and *Aphrodita aculeate*a; also present were the burrowing amphipod *Bathyporeia* and the sand goby *Pomatoschistus*. The coarser areas with epifauna were characterised by the dead man's finger *Alcyonium digitatum*, the bryozoan *Flustra foliacea*, the sea urchin *Psammechinus miliaris*, the sea anemone *Metridium senile*, the hydroid *Sertularia* sp., the polychaete *Pomatoceros triqueter* and the encrusting bryozoan *Schizomavella* sp. The deeper habitats had fewer polychaetes than the shallower ones, although *Nephtys cirrosa* and *Spiophanes bombyx* were present. The characterising species in this area were *Ophiura albida* and *Ophiura ophiura*. The areas that had been dredged had fewer large epifauna and were characterised by the whelk genus *Hinia*.

The shores between Folkestone and Dungeness are a mix of shingle and sand. There has been little work published on the marine biology of this area, even though the largest area of shingle in Britain is found at Dungeness. There is a report to the NCC (Morris & Parsons, 1991) comparing the invertebrate infauna of the shingle beaches at Dungeness and Rye Harbour. The sediments are mobile and therefore relatively inhospitable, reducing the richness of the fauna present (Barne et al., 1998b). The Rother River flows past the town of Rye and out into Rye Bay. Shingle has moved eastwards and infilled much of the former estuary, so it is now a narrow river channel with fringing saltmarsh. To the west of the estuary are two lagoonal areas, which support specialist lagoonal species (Barne et al., 1998b). Newell et al. (2001) sampled 44 stations off the coast at Folkestone. The sediments at these stations were dominated by medium and coarse sands, with finer sand at the sites closer to the shore. Cnidarians, polychaetes, crustaceans, molluscs and bryozoans dominated the macrofauna. 343 taxa were recorded, demonstrating a relatively high species variety. A new species of cirratulid polychaete was described from this area along with the re-description of *Caulleriella zetlandica* (McIntosh) (Woodham & Chambers, 1994). Prior to the building of the Channel Tunnel, a number of surveys were carried out in the area (Fincham & George, 1986; Tittley et al., 1986; Wood, 1989).

6. RARE AND ALIEN SPECIES

Phylum	Class	Species
Cnidaria	Hydrozoa	*Gonionemus vertens* A. Agassiz 1862
		Clavopsella navis (Millard 1959)
	Anthozoa	*Haliplanella lineata* (Verrill 1869)
Nematoda	Dracunculoidea	*Anguillicola crassus* Kuwahara, Niimi & Itagaki 1974
Annelida	Polychaeta	*Goniadella gracilis* (Verrill 1873)
		Marenzelleria viridis (Verrill 1873)
		Clymenella torquata (Leidy 1855)
		Hydroides dianthus (Verrill 1873)
		Hydroides ezoensis Okuda, 1934
		Ficopomatus enigmaticus (Fauvel 1923)
		Janua brasiliensis (Grube 1872)
		Pileolaria berkeleyana (Rioja 1942)
Chelicerata	Pycnogonida	*Ammothea hilgendorfi* (Böhm 1879)
Crustacea	Maxillopoda	*Elminius modestus* Darwin 1854
		Balanus amphitrite Darwin 1854
		Acartia tonsa Dana 1848
	Ostracoda	*Eusarsiella zostericola* Cushman 1906
	Eumalacostraca	*Corophium sextonae* Crawford 1937
		Eriocheir sinensis H. Milne Edwards 1854
		Rhithropanopeus harrisii (Gould 1841)
Mollusca	Gastropoda	*Crepidula fornicata* (Linnaeus 1758)
		Urosalpinx cinerea Say 1822
		Potamopyrgus antipodarum (J.E. Gray 1843)
	Pelecypoda	*Crassostrea gigas* (Thunberg 1793)
		Tiostrea lutaria Hutton
		Ensis americanus (Gould in Binney 1870)
		Mercenaria mercenaria (Linnaeus 1758)
		Petricola pholadiformis Lamarck 1818
		Mya arenaria (Linnaeus 1758)
Tunicata	Ascidiacea	*Styela clava* Herdman 1882

Non-native marine invertebrates in British waters, taken from Eno et al. (1997).

Phylum	Species	Common name	Comment
Annelida	*Hydroides elegans*	-	Died out.
	Pilumnoides inglei	-	Not recorded since 1913.
Crustacea	*Brachynotus sexdentatus*	Mediterranean crab	No longer present (formerly in Queen's Dock, Swansea).
	Neopanope sayi	Caribbean mud crab, Mud crab	No longer present (formerly in Queen's Dock, Swansea).
	Penaeus japonicus	-	Only three records in Britain to date (not established).
	Callinectes sapidus	Blue crab	Only two records in Britain to date (not established).
	Homarus americanus	American lobster	Only three records in Britain to date (not established).
	Crassostrea virginica	Amercian oyster	Introduced to Britain for relaying 1870s - 1939 and briefly in 1984; never became established.
	Tapes philippinarum	Manila clam	Held for aquaculture purposes only, not established in wild.
Mollusca	*Choromytilus chilensis*	Chilean mussel	Not established in the wild.
	Crassostrea brasiliensis	Mangrove oyster	Not established in the wild.
	Rapana venosa	Japanese whelk	Single live catch from Silver Pits, south of Dogger Bank in the North Sea in 1991 (Anon 1992).
	Aulacomya ater	Magellan mussel	Recovered from deep water in the Moray Firth in 1994, believed to have fallen off a barge (McKay 1994).
Bryozoa	*Bugula neritina*	-	No longer established in wild.
Vertebrata	*Oncorhynchus gorbuscha*	Pink or humpback salmon	Some escapes to the wild but not self-sustaining.
	Oncorhynchus kisutch	Coho salmon	Rare escapes to the wild.
	Oncorhynchus keta	Chum salmon	Once recorded from the wild.
	Oncorhynchus mykiss	Rainbow trout	Primarily freshwater species but migratory (steelhead) crosses, not self-sustaining.

Some non-established introductions (aliens) which have been recorded in British waters. Taken from Eno et al. (1997).

6.1.1 Not quite Aliens

There are a number of criteria that determine whether a species may be considered an alien or not. The exceptions are explained here to describe why they are different. Non-established introductions are species that have been brought into British waters, but are not able to maintain populations. They may rely on changed conditions, like those in the outflow at a power station, or continual renewal of individuals from outside the system. So a population may be present for a while, but if the environmental conditions return to normal or the input of new individuals is stopped, the population will die out. Cryptogenic species have been defined as those that cannot be determined to be native or introduced. This term is not widely used, but its use would eliminate errors such as introduced species being described as new species, for example the leathery sea squirt *Styela clava*. Vagrant species are not the same as non-natives, they may be considered as 'visitors' that have strayed from their usual migratory routes, or home range. These are often lone individuals and are not able to form a self-maintaining population, even if the individual remains in the new region. The other exceptions are 'recent colonists'; these are species that have naturally extended the range of their distribution. This is normally due to a change in environmental conditions, for example climate change. An example of this in British waters is the extension of the alga *Laminaria ochroleuca,* which is thought to have crossed the English Channel during the warm period prior to 1940 (Eno et al., 1997)

6.1.2 Alien species

These are non-native species that have established self-maintaining populations in UK waters. Such species are of most concern when they are invasive, that is they form large populations which outcompete or otherwise negatively influence native species. There are a number of ways in which they may have been introduced in the first instance. This may have been accidental, e.g in ship's ballast water, or stuck to the hull, or some species may have been deliberately introduced. The latter are species that are brought to British waters for aquaculture, some of which become established, and also may have associated species that are transported along with them (Eno et al., 1997). There is currently concern about these species A report was prepared for JNCC by Just Ecology to look at the action that needs to be taken and the further research that needs to be carried out (Callaghan, 2003). Thus, attempts are being made to monitor and potentially control the spread of some of species.

The following websites offer some information on the marine aliens that are being monitored:
www.marlin.ac.uk/marine_aliens/species
www.solaster-mb.org/mb
www.swan.ac.uk/biodiv/poole
www.swan.ac.uk/biodiv/fleet
www.nonnativespecies.org

Probably the best-known alien species on British shores at the moment is the American slipper limpet *Crepidula fornicata*. It is one of a number of slipper limpet species native to the east coast of North America. The first occurrence in Europe was at Liverpool Bay in 1872; those specimens were introduced with the American oyster *Mercenaria mercenaria* (McMillan, 1838). Since then the species has been accidentally introduced in other locations, by the same method. MarLIN are now monitoring the increase in the range of distribution of this species. The distribution of this species has been studied for the most part of the nineteenth century (Belcher, 1922; Blanchard, 1997; Burton, 1930; Minchin et al., 1995; Orton, 1950). Investigations have also been carried out on oyster beds to study the slipper limpets (Cole, 1952).

In September 2004 a rapid assessment survey of the marinas on the south coast of England was carried out to record the alien species present. Surveys were conducted at twelve sites, focusing on the algal communities and invertebrates colonizing floating pontoons in these marinas (Arenas et al., 2006). There were a number of species identified in British waters for the first time during these surveys. For example, the southern hemisphere solitary ascidian *Corella eumyota* was was recorded at three sites and the colonial ascidian *Botrylloides violaceus* was also recorded as new to the UK. This was more widespread, suggesting it has probably been present for a number of years but misidentified as the native congener *B. leachi*, which was infrequent. The survey demonstrated that diverse assemblages of algae and invertebrates, including a substantial number of non-native species, are found on floating pontoons in docks and marinas. This suggests that ports should be monitored periodically for the presence of non-native species (Arenas et al., 2006).

A small selection of other alien species currently found in UK waters is detailed briefly below.

6.2.1 Cnidaria

Clavopsella navis a brackish water cnidarian, was first noted in 1973 in Widewater Lagoon, Shoreham, West Sussex. It is thought to be an introduced species transported on ships' hulls (Eno et al., 1997).

6.2.2 Annelida

Hydroides ezoensis is a non-native annelid species that is found in Southampton Water fouling structures in the harbour, ships' hulls and buoys. It is provides food for predatory fish and can provide shelter for smaller species due to the massive encrustations it forms (Eno et al., 1997). The other non-native polychaete species that are mentioned in the report as being in the British Isles are *Hydroides dianthus* and *Ficopomatus engmaticus*. It is thought that these species were introduced either in ballast water or attached to ships' hulls.

6.2.3 Crustacea

Chinese mitten crab *Eriocheir sinensis* is a freshwater species that moves to marine waters to breed. Information about the distribution of this species has been collected by governmental agencies, the Natural History Museum (London) and the general public and collated by Herbourg et al. (2005). It has been expanding its range since the species' arrival in 1973, and it has been suggested that is has the potential to establish itself in all major estuaries in the UK (Herbourg et al., 2005). Another crustacean from Asia is a large caprellid amphipod, the Japanese skeleton shrimp *Caprella mutica* indigenous to northeast Asia, which has been discovered in Oban, Scotland. The population has become established since 2000, and was found all year round in high abundances on the man made structures at a salmon farm (Willis et al., 2004). The probable accidental methods of introduction were with Japanese oysters or in ballast waters.

A warm-water barnacle *Solidobalanus fallax* was recorded on oyster shells off Plymouth in 1994 and with one exception was not recorded in Europe before 1980 (Southward, 1995). Incidences of this species within SEA area 8 include at Chesil beach and Lundy Island on sea fans and on lobster pots in Portland Harbour. It has also been found at various locations on the Gower peninsula. It does not settle on rocks, but instead is found on biological substrates, or plastic. It is thought that the increase in temperatures and the increase in the abundance of plastic in the seas have lead to this species becoming more prevalent (Southward et al., 1994, 1995). Other warm water species of barnacle that have become established in British waters are *Eliminius modestus* (Crisp, 1958) and the Japanese barnacle *Balanus improvisus* (Furman & Yule, 1991).

6.2.4 Mollusca

Some widespread molluscs in UK waters are actually introductions. *Mya arenaria*, a native of North America, is a good example.

The fresh water Zebra mussel *Mytilopsis leucophaete* has been found in a brackish dock in South Wales in association with other alien taxa. *Mytilopsis* species are thought to be primarily Caribbean and tropical west African in origin, although they have spread to other parts of the world, including western Europe. It is thought that the species was brought into the area on a ship from either Europe or directly from North America. The rare American non-native crab *Rhithropanopeus* is also found in the basin at Roath, suggesting that the mussels were in fact introduced directly from America. The species appears to require quite specific environmental conditions, perhaps limiting its range and ability to colonise new areas (Oliver et al., 1998).

The Manila clam *Tapes philippinarum* was introduced deliberately to Poole Harbour, and now there is a naturalized population. It was originally thought that this wouldn’t happen in UK waters, and indeed did not happen in the Exe estuary where they were also introduced. It is thought that the favourable conditions in Poole Harbour have allowed this population to become established. In this case, it is a positive non-native species as the population supports a local fishery, and allows fishing when other areas may be closed due to bad weather (Jensen et al., 2004).

6.2.5 Tunicata

The ascidian or leathery sea squirt, *Styela clava*, is native to the Northwest Pacific, and was first recorded in British waters in 1954. However, it was originally thought to be a new species and not recognised as an alien (Arenas et al., 2006). Since its discovery this species has spread along the west coast of Europe. It is not clear how this has happened and four possible mechanisms gave been put forward. Natural dispersion; the drifting of larvae and adults; man-aided dispersion involving the transport of individuals attached to oyster shells or the hull of ships (Davis & Davis, 2004). Other proposed theories were that eggs and larvae could be carried in ballast water tanks, or sea chests. The colonial sea squirt *Perophora japinca* has been found on the south coast too; it was first identified in Plymouth Sound marina in 1999 and was still present in spring 2000 (Nishikawa et al., 2000) and later in 2004 (Arenas et al., 2006). They were then found in a second location on the south coast, the Fleet, 130km from the original population in Plymouth where it is thought to have spread from (Baldock & Bishop, 2001).

6.2.6 Algae

Sargassum muticum is a brown alga native to Japan, where it grows to a relatively small size. First recorded in the UK from the south coast in 1973, this species is now common on shores throughout the SEA 8 area, where on sheltered parts of shores (including amongst *Zostera* on the Isles of Scilly) it forms clumps up to 1 m high which overgrow and shade native species.

Undaria pinnatifida was first recorded in the UK in 1994 and is spreading throughout the SEA 8 area. A large brown kelp of commercial interest (wakame) in its native Japan, it was probably introduced to Europe along with spat of *Crassostrea gigas*, although commercial introductions to France also occurred. It is a large species, with stipes up to 3 m in length, which is important as a fouler among pontoons where boats are moored. It is spreading on the hulls of pleasure craft.

Asparagopsis armata, introduced from New Zealand in the 1970s, is widespread. Warwick (1976) found a diverse nematofauna amongst fronds in the Isles of Scilly, very comparable with assemblages living amongst native species of algae.

7. ANTHROPOGENIC ACTIVITIES AND IMPACTS

In recent years it has been recognized that habitat mapping is a useful tool in the management of marine resources in relation to spatial planning. In order to carry out sound environmental management and planning it is necessary to know the nature of the habitat and associated community of an area, as well as the human influences. Human/anthropogenic influences may include aggregate dredging, petrochemical extraction, fisheries, coastal development, and dredge disposal. Mapping European Seabed Habitats (MESH) is a project that started in 2004 involving a number of different partners. The aim is to use available geographical, physical and hydrographical data in combination with, where possible, ecological data to produce simple broadscale and ecologically relevant maps of the dominant seabed and water column features. The full details of this project and the subsequent maps may be seen on the MESH website: www.searchMESH.net.webGIS.

7.1 Tourism

Tourism can have a number of impacts on the marine environment; these include an increased input of sewage and litter, the cleaning of sandy beaches to make them aesthetically pleasing and the trampling of flora and fauna on rocky shores. It has been suggested that encouraging visitors to marine parks may be damaging to the marine fauna that is supposedly protected. This was investigated at Purbeck Marine Wildlife Reserve (Pinn & Rodgers, 2005) and it was decided that although there was damage due to trampling and investigation it was at an acceptable level. There was seen to be a reduction in the cover of branching algae and the limpet population. The collection of souvenirs by some divers may be very damaging to populations of some species. Divers have been known to take the sea urchin *Echinus esculentus,* which sometimes carries the rare external parasitic mollusc *Pelseneeria stylifera*, or the sea fan *Eunicella verrucosa,* which grows very slowly and may be host to the southern prosobranch *Simnea patula* (Turk, 1983).

7.1 Bait collection

Bait-digging usually occurs on soft sediment shores and estuaries, with the most commonly collected species being lugworms *Arenicola marina* and ragworms *Nereis diversicolor*. This may be an individual turning over the sediment with a fork, or in some cases, commercial digging using highly damaging machinery (Sewell & Hiscock, 2005). The areas where this occurs are often the feeding grounds of wading birds and bait digging can destroy suitable habitat and disturb these birds (Huggett, 1995). Another activity that may impact these areas is tractor harvesting for cockles. The degree of disturbance depends partially on the sediment type in the area (Sewell & Hiscock, 2005). Crab-tiling for bait is widespread in estuaries. This is the placement of artificial shelters on sediments to attract moulting crabs, which are a popular angling bait. This may impact the benthos directly, through the presence of the tiles, or indirectly through activities associated with collecting the crabs (Johnson et al., 2007).

7.3 Beam-trawling

Beam-trawling is known to have an immediate impact on the megafaunal component of the benthic community (Jennings & Kaiser, 1998). Trawling is one of the most disruptive and widespread human-induced physical disturbances to seabed communities and is therefore of environmental concern (Engel & Kviterk, 1998). Dredges are used to collect scallops, oysters, clams and mussels; this method may also be very destructive, depending on the type of dredge used, and can greatly disturb the benthos (Sewell & Hiscock, 2005; Kaiser et al. 2006). Benthic studies have provided evidence that high levels of trawling can decrease bottom habitat complexity and enhance the abundance of opportunistic species (Engel & Kviterk, 1998). The direct effects are the removal of the target species, mortality of non-target species in the form of by-catch, and the physical impact of towing the fishing gear over the seabed. These direct effects have further consequences; a reduction in the density of the target species impacts on the predator/prey relationships and competition levels. Some seafloor environments are more sensitive to damage than others, in particular Sabellid reefs, maerl beds and seagrass beds (Sewell & Hiscock, 2005).

7.4 Crustacean traps

Crustacean traps are used to catch crabs *Cancer pagurus* and lobsters *Homarus gammarus* in UK waters. The effects of these traps on the benthic fauna in Lyme Bay was examined by Eno et al. (2001). The effects on rocky substrates were limited to the detachment of some sponges and ascidians and damage to some individuals of the ross coral *Pentapora foliacea*. Tennants Reef was part of the study area, where there are pink sea fans *Eunicella verrucosa*. These were seen to bend under the pots and spring back once they had passed. The short-term affects on the benthic fauna, other than the ross coral, was not seen to be detrimental. Lost or discarded gear can continue to catch fish (so-called ghost-fishing) and attract scavenging benthos for years.

7.5 Aquaculture

Aquaculture can take a couple of forms depending on the species involved; finfish farmed include Atlantic Salmon *Salmo salar,* halibut *Hippoglossus hippoglossus* and turbot *Scophthalmus* and shellfish include mussels *Mytilus edulis,* Manila clams *Tapes philippinarum,* and in a few cases abalone *Haliotus tuberculata*. The effect of these fisheries is dependant on the surrounding benthos and the methods of farming being employed. The main impact from finfish farming is organic enrichment, as a result of faeces and uneaten food falling from the cages. Communities typical of organic enrichment follow the Pearson and Rosenberg model and are dominated by *Capitella capitata* and nematodes in extreme cases (Eleftheriou et al., 2004). The other obvious impact that may result from aquaculture is the use of medicines that inevitably filter through to the marine environment. At present, however, there is little finsfish aquaculture within the SEA8 area.

Molluscs are cultured in SW England. Nugues et al. (1996) carried out a study of the environmental impacts of the cultivation of Pacific oysters *Crassostrea gigas* using trestles, in the River Exe, Devon. Small, but significant changes in the macrofaunal community were detected. These changes were associated with an increase in the organic matter and sediment to the system. These were considered to be minor compared to the effects of finfish farms, and the suspended culture of bivalves. Smith & Shackley (2004) examined the effects of a commercial mussel *Mytilus edulis* lay on a sublittoral, soft sediment benthic community in the western inner Swansea Bay. It was found that the presence of the mussel lay decreased the diversity and number of individuals of benthic deposit feeding species as they were out competed by the mussels. There was an increase in the abundance of carnivorous and deposit feeding benthic species. The area had previously been an important nursery ground for juvenile flatfish, which were dependent on the benthos as a source of food. A change in the benthic community as a result of the mussel lay could affect the growth patterns and recruitment of these fish species.

7.6 Dredging

Dredging may be carried out for a number of different reasons, to obtain aggregate, maerl, or oysters or to keep shipping channels open. Aggregates are used in the construction industry and for beach renourishment, and as the primary source in South Wales, the marine environment may be under pressure as demand increases (Wilson et al., 2001). In UK waters sand and gravel are removed from the seabed by the marine aggregate industry. A license for this is issued by The Crown Estate and revenue paid to it depending on the tonnage of aggregate removed. The only dredging sites for aggregates in the SEA8 areas inshore waters are in the central English Channel, around the Isle of Wight and the inner and central Bristol Channel (Gubbay, 2005). It is necessary to monitor these areas to ensure that the marine community has not been impacted too greatly. The impacts of dredging on the benthos may include disturbance, loss or change in habitat, burial, and redistribution of pollutants. The effects at a particular site will depend on various factors, including the extraction method, sediment type and mobility and the bottom current strength (de Groot, 1996). Newell et al. (2004) looked at the impacts of marine aggregate dredging on benthic macrofauna at a dredge site off the south coast of England. Where anchor dredging was used the effects were limited to the dredged area; they included the suppression of species variety, population density and biomass. It also altered the species composition compared to the surrounding substrate. The biomass of the community was not restored as quickly as the species diversity or population density. The initial colonization of commercially exploited sites is by fast-growing, opportunistic species. These are slowly replaced by a wider species diversity of slow-growing species until the equilibrium community is reached, providing there is no further disturbance.

Trailer dredging was found to have little or no impact on the community composition within the dredged site. It was found that around the dredge site there was an increase in species diversity, population density, biomass and mean body size. This may be due to the organic enrichment that dredging causes within the local area. The sediment plumes from dredging can be detected for a few kilometres in some cases.

These may be caused by the trailer dredge itself, or the process of screening when large quantities of sediment may be dumped if they are of the wrong grain size for the customer.

Currently studies are being carried out by a number of governmental and non-governmental organisations into the effects of aggregate dredging, several of which are funded through the Marine Environment Protection Fund within the Aggregate levy Sustainability Fund. The final reports of several studies are due as this review is being prepared.

7.7 Dumping

Dumping may be referring to a number of different substances being dumped on the seabed or near shore. These substances include coal wastes, fly ash, china clay wastes, sewage, mineral wastes, and dredged material (Shelton, 1973). The effect of dumping sewage sludge in the central English Channel was investigated (Jenkinson, 1972). Neither the presence nor absence of any species in the dumping grounds could be attributed to the dumping of sludge, so it was acknowledged that further work was required. The disposal of sewage sludge at sea has been discontinued. Dredged material being dumped may be as a result of it being the wrong grain size for the aggregate industry or as a result of dredging shipping channels or a harbour (Wilson et al., 2001). Changes in benthic assemblages resulting from dredgings disposal tend to be within the bounds of natural site to site variation (Somerfield et al. 2006).

7.8 China clay

China clay is mined at a few locations on the south coast, in open cast pits using high pressure jets of water to wash the clay out (Probert, 1981). Powell et al. (1978) state that 'Large quantities of chemically inert fine solid wastes from the china clay industry were formerly discharged into certain streams and rivers in Devon and Cornwall, Those principally effected were the Tory Brook (a tributary of the River Plym), the Luxulyan River and the St Austell 'white river' discharging into St Austell Bay, and the River Fal.' Due to policy changes in the 1970s these waste products are now deposited on land and not discharged into the rivers. Howell & Shelton (1970) looked at the effect of china clay deposits on the bottom fauna at St Austell and Mevagissey Bays. It was seen that only where deposition rates were particularly high was the fauna smothered. However even though there was a rich community of deposit feeders, suspension feeders were largely absent (Probert, 1981). There was a further pollution event in the River Fal in 2000 when part of a tailings dam collapsed. The sludge released by this visibly impacted a 10-mile stretch of the river and threatened the biota in the area. The two main threats were smothering effects on the gills of fish and filter-feeding organisms, and the reduction of light impacting the levels of photosynthesis possible (Langston et al., 2003e).

7.9 Oilfields

Wytch Farm is an oil field in the South-east of Dorset; it extends from the Purbeck district to Poole Bay and is the largest onshore oil field in Europe. British Petroleum (BP) began producing oil from this site in 1979, and oil is piped from Wytch Farm to Hamble on Southampton Water, about 40 miles away. The majority of the oil field lies in areas protected by various conservation laws, both terrestrial and marine, so great care was required to protect the environment when developing this site. The conservation laws include the Jurassic Coast world heritage site, Purbeck Heritage

Coast and a number of SSSIs and AONB including Studland and Brownsea Island. It stretches underneath the Eolian clays and sands of Poole Harbour, Pool and Bournmouth, and under the Cretaceous chalk hills and Jurassic limestone shale of the Isle of Purbeck (Windram, 2003).

7.10 Oil spills and marine accidents

The major oil spills and marine accidents that have had a direct effect on the beaches in this area are listed below in chronological order:

Vessel	Date	Reason	Area	Amount of spill
Napoli	Jan 2007	Storm	Off Lyme Bay	Cargo
Gudermes	April 2001	Collision	Off Dover	110 tons fuel
Cita	March 1997	Struck rocks	Scillies	Cargo
Sea Empress	Feb 1996	Struck rocks	Off S. W Wales	72,000 tons
Rose Bay	May 1990	Collision	Off Devon	1,073 tons
Torrey Canyon	March 1967	Struck rocks	Off Cornish coast	100,000 tons

Oil is very damaging to the marine environment, but is not always the only problem after a spill. In some cases the dispersants used to 'clean up' after the spill cause as many problems. Long-term records have been used to try and determine the changes caused by the Torrey Canyon spill and the clean up afterwards (Hawkins et al., 2002; Hawkins & Southward, 1992; Southward et al., 2005; Southward & Southward, 1978).

The effects of the 'Sea Empress' oil spill were monitored by a number of government agencies and non-government environmental groups, forming the Sea Empress Environmental Evaluation Committee (SEEEC). The initial report was published in 1996. The area surveyed was from west Wales to Pendine to the west of Carmarthen Bay (SEEEC, 1996). Another report was produced by (Dyrynda, 1996); the fifteen monitoring sites in this case were from Langland to Westdale Bay. It is noted that the amenity shores were cleaned first, and that even on these shores there were impacts. Algal-blacks were seen, and mass mortalities of the invertebrates and shore fish on rocky shores. On sediment beaches there were mortalities of the burrowing shellfish and heart urchins. The shores were seen to recover fairly quickly as they were colonised by pioneer species, but this was a false positive, as things had not by any means returned to how they were before the incident (Dyrynda, 1996). A compilations of reports relating to the spill is to be found in Edwards & Sime (1998). In general the effects of the spill were not long-lasting, and in many cases were less than initially appeared.

7.11 Radionuclides

Radionuclides are not generally a concern in the SEA 8 area, however there are some areas of concern in the estuaries notably the Severn estuary and Plymouth Sound. Disposal of organic tritium at Cardiff in the past has resulted in high concentrations of tritium in the sediment and benthic biota such as flounder and mussels, although it is not considered a threat to humans. There have also been discharges of tritium from Devonport Dockyard affecting the Tamar estuary and consequently the Plymouth Sound. Relatively little is known of the bioavailability, assimilation pathways and effects of organically bound tritium on marine life, so further research is needed in this area (Langston et al., 2003d). Discharges were known to be entering Swansea

Bay via the sewage system after people had received certain treatments in the local hospital. Iodine-131 and Technetium-99 radioiodine were detected in the seaweeds at Mumbles, at the western edge of Swansea Bay (Birks, 1980).

7.12 Metal pollution

Metal pollution may be assessed by looking at biological indicators, due to metals being absorbed from different sources like the sediment or the water and varying habitats there is no universal indicator species. Also, different metals affect organisms in different ways and to varying degrees, so some species are better indicators of specific metals than others. Examples of biological indicators are the ragworm *Nereis diversicolor* for copper, and the winkle *Littorina littoralis* for cadmium. Investigations have been carried out of certain species to show how they respond to contamination by specific metals; for example Hateley et al. (1989) looked at the heavy metal tolerance of *Nereis diversicolor*. The population used to represent the highly polluted condition was taken from Restronguet Creek that flows into the Fal estuary. A good investigation should involve a range of species including a seaweed, different trophic levels in the benthic food chain and contamination from different sources, both dissolved and particulate (Bryan et al., 1985). Tin mining was long established in the area around the Fal estuary, the last mine being closed in 1991. In 1992 a dam collapsed causing a massive discharge of acidic metalliferous water into the Carnon River. It then flowed into Restronguet Creek and the Carrick Roads. The meio and macrobenthic communities were only seen to experience small changes in the period after this. Those changes could be attributable to natural fluctuations in populations over time. So it would seem that this event had little damaging effect, as sediment metal concentrations were not seen to alter significantly either (Somerfield et al., 1994b).

A review of the dissolved mercury in the Bristol Channel and Severn Estuary was carried out by Gardner & Riley (1973), who found that the higher concentrations were in the estuary up stream from Cardiff. Morris & Bale (1975) carried out sampling on eight cruises, taking samples at thirty-two stations in the Bristol Channel, and measured the levels of Cadmium, Copper, Manganese and Zinc as dissolved metals and in the brown algae *Fucus vesiculosus*. The results showed where there were increased levels of metals, relating in most cases related to known sites of input, at Mumbles, Barry, Newport and Cardiff. The heavy metal distribution in the bottom sediments in the Bristol Channel is discussed by Barrie (1980). The distribution of metals in the sediment is not seen to reflect the level of input in the local vicinity. The levels of sediment metals are influenced by the sediment granulometry, bathymetry and tidal influences of a specific location.

7.13 Eutrophication

Eutrophication can be caused by untreated domestic discharges, industrial effluent, the waste from aquaculture and/or sewage effluent (Eleftheriou et al., 2004). Eutrophic conditions have developed in Langston Harbour as a results of sewage effluent, both biologically treated and raw, being discharged into the area (Montgomery & Soulsby, 1980). In this case it has caused an overgrowth of the alga *Enteromorpha* spp. on the mud flats. However in other cases where the conditions are different it can cause algal blooms, which are in some cases harmful and can lead to the closure of aquaculture sites.

7.14 Tributyltin (TBT)

Tributyltin (TBT) was used in antifouling paints on the hulls of ships and pleasure craft; this was banned in 1987 on boats less than 25m in length. It causes problems in the marine and estuarine environment as it leaches into the water and has a detrimental effect on some marine molluscs. It can cause imposex, the formation of a penis and vas deferens in the female suppressing oogenesis, leading to the extinction of local populations of the susceptible species (Gibbs et al., 1988). This problem has been extensively studied for the dog whelk *Nucella lapillus*. Crothers (2003) observed the recolonization of a rocky shore near Ilfracombe by *N. lapillus*. The area was recolonized from the open coast, and it took around 13 years to recolonize a distance of 30m. The instance of TBT causing imposex is not however exclusive to *Nucella* sp., *Nassarius (Hinia) reticulatus* has also been recorded as being affected. They were not as sensitive as *Nucella lapillus* and were only affected at higher concentrations (Bryan et al., 1993). The levels of TBT and its effects appear to have been reduced since the ban in 1987. However there are still accumulations of TBT in the sediments, which have slowed the recovery of affected populations. There is concern that remobilisation caused by dredging could further slow the recovery of areas where dredging is necessary (Langston et al., 2003d). It is still used on large ships, although it is to be banned on all ships in EU ports from January 1st 2008. Its use and presence on large ships and structures (e.g. oil platforms) means that it remains a problem in port areas, particularly Carrick Roads, the Tamar, Southampton Water and Portsmouth.

7.15 Barrages

A barrage across the river Severn was first proposed as an alternative energy source in the 1970s (Department of Energy, 1977). It was the prospect of this barrage that underpinned IMER's comprehensive studies of the Bristol Channel in the late 1970s and early 1980s. Since then the construction and effects of such a barrage have been discussed periodically. The Department of Energy, Central Electricity Generating Board and the Severn Tidal Power Group have produced reports on these discussions. In these reports the environmental effects of the proposed barrage have not been fully considered; further survey work is likely to be required. These results are at odds with the large body of work considering the environmental effects of a barrage conducted by IMER (see, e.g., Warwick, 1984). In one report it is suggested that although tidal ranges in the estuary would be altered, it would not cause a huge effect to the fauna in the area (Severn Tidal Power Group, 1989a, 1989b). It is suggested that primary productivity may be increased due to reduced turbidity, and that water quality should not be significantly altered. It is not thought that the wildfowl, which feed in the estuary, would be detrimentally affected. The effects on the fish and shrimp in the area however are unclear. Fish passes would be required as well as deterrent devices to stop fish being damaged by the turbines; the response of the local populations to these is unclear.

The effects of the smaller Swansea Bay barrage have been discussed in the section referring to Swansea; in that case the affects were minimal due to the poor health of the estuary prior to construction of the barrage (Dyrynda, 1994).

7.16 Power Stations and thermal pollution

Power Stations often use water to cool certain elements of the system; this may be fresh water or saline and in some cases is discharged into the sea or a river without first entering cooling pools. Markowski (1959) carried out a survey of the fauna in power station cooling water at twelve locations in Britain, six of which are in the SEA8 area. These six were the power stations using seawater were at East Yelland, Plymouth, Poole, Portsmouth and Brighton. The organisms in the cooling water are subjected to increased temperature, pressure, turbulence and chlorine levels. The main focus of the survey was freshwater and planktonic fauna. However 62 species of marine organism were identified, including some benthic species. No detrimental effect was observed on the organisms examined in this survey. Some decapods *Palaemonetes varians* were found to be more abundant in warm outfall waters than elsewhere.

The heated effluent from the power station near Queen's Dock, Swansea, created unnaturally high water temperatures in the dock. The water was elevated by 7-10 degrees above the sea temperature outside. Naylor (1959) surveyed the faunal community within the area, and found it was altered as a result of the increased temperatures. Alien species introduced by shipping were able to establish small populations, and in some cases displaced the native fauna. The seasonal cycles of the species within the dock area were examined in 1965 (Naylor, 1965); it was found that these had been altered by the elevated temperatures too. Bullimore et al. (1978) resurveyed the benthic fauna of Queens Dock, Swansea, and the faunal composition was compared to observations made between 1957 and 1967. It was seen to be significantly different. When the first observations were made the dock temperature was raised considerably by the power station's outflow. This was gradually reduced from 1960, and was finally terminated in January 1975. So the temperature now follows that of the sea outside. Some of the alien species are still found, like the barnacle *Balanus amphitrite* var. *denticulata* and the crab *Neopanope texana sayi*, whilst others are now absent. Local species have also been recorded at higher levels, which is attributable to the temperatures returning to normal.

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