Britain's estuarine wildlife resource

Introduction

As already outlined in Chapter 7, estuaries support a wide range of wildlife that has evolved the capacity to cope with the fluctuating physical and chemical conditions of estuaries. Some plants and animals, for example many intertidal invertebrates, depend entirely on estuarine conditions for their survival throughout their lives. Others, particularly the more mobile organisms such as birds and fish, depend on estuaries for a part of their lifecycles. Nonetheless estuaries are important for their survival through critical periods.

This chapter describes the range and variety of wildlife on estuaries that together make estuarine wildlife such an important component of Britain's remaining conservation resource. Wildlife importance in Britain is currently assessed on the presence of both wildlife habitats and taxonomic groups. Hence the wildlife importance of an estuarine ecosystem is assessed on the importance of its various key component elements rather than on its importance as a whole ecosystem. This chapter follows current conservation practice in describing the estuarine wildlife resource according to these categories, and is divided as follows:

8.1 Estuarine habitats
8.2 Terrestrial and non-marine invertebrates
8.3 Aquatic estuarine communities
8.4 Fish
8.5 Amphibians and reptiles
8.6 Birds
8.7 Mammals

This approach does mean, however, that some facets of estuarine ecosystems are not afforded detailed separate coverage in this report. For example, intertidal macrobenthos is covered as a component of aquatic estuarine communities (Chapter 8.3) rather than in a separate section. This treatment is used because tidal flats and their macrobenthos have so far been included in estuarine conservation sites largely because of their significant role as feeding grounds for the large and important migrant and wintering bird populations (Chapter 8.6) which feed on the macrobenthos, rather than for the macrobenthos or other tidal flat features themselves.

Nationally important wildlife sites in Britain were identified by Ratcliffe (1977). Ratcliffe listed these as Nature Conservation Review (NCR) sites, further described in Chapter 9. Many of the NCR sites on coasts and estuaries are included by virtue of a range of different habitats: as described in Chapter 8.1, an estuary typically comprises typically a mosaic of several important wildlife habitats. Nevertheless the selection of sites worthy of conservation for their habitat features is made by habitat (e.g. saltmarsh or sand-dunes), so that many coastal and estuarine NCR sites include several different features of wildlife interest.

For each feature of wildlife interest the text follows a broadly similar pattern. A general description of the ecological and behavioural characteristics of the wildlife that are relevant to their conservation is followed by an analysis of the extent and distribution of the wildlife feature around the 155 Estuaries Review sites. As far as possible this estuarine resource is then set in its wider context both in terms of the British resource and its European and international significance. This resource description is followed by a description of the current approach to conserving the particular wildlife feature and an identification of the major pressures and threats as they affect that part of the wildlife resource. These two sections complement the overall analyses of conservation status in Chapter 9 and human activities in Chapter 10 by focusing on the particular needs and issues of each different component of the wildlife resource.

Inevitably some parts of this chapter are able to go into considerably more detail and to describe more of the key ecological needs of the wildlife than others. For example, there is less comprehensive information available on the distribution of aquatic estuarine communities, and much less is known of the ecological requirements of many individual terrestrial invertebrate species than is known of the distribution and requirements of estuarine bird populations. This is in part a reflection of the historical balance of effort directed at the conservation of the various features of estuarine ecosystems.

The Estuaries Review is restricted to looking at the wildlife of the 155 sites identified as estuarine in nature. It is important, however, to recognise that estuaries are not isolated from other coastal and wetland ecosystems. Although many estuaries form discrete areas separated from the next by very different landforms such as exposed rocky shores and cliffs, and although many plants and animals are concentrated on estuaries, estuaries form just part of the coastal zone. There are thus many links between the wildlife of estuaries and coastal systems outside them. Similarly, estuaries can be regarded as being towards one end of a spectrum of types of wetland ranging from the truly marine through inland freshwater bodies, rivers and fens to peatlands. Many of these wetlands face similar pressures and conservation problems to those described for estuaries. Overall analysis of
all such wetland systems is, however, outside the scope of this report. Other current studies are directed towards broader coastal zone conservation, notably the Directory of the North Sea Coastal Margin (Doody et al. in prep.) and the report of the Irish Sea Study Group (Irish Sea Study Group 1990).

We have treated each section of this chapter as self-contained for bibliographic purposes: a reference list appears at the end of the section to which it refers rather than there being one very long reference list at the end of the chapter. We have also included a brief summary at the start of each of the longer sections.

A review of the diverse wildlife interest of estuaries has needed the help and knowledge of many habitat and taxonomic group specialists within the Nature Conservancy Council. Hence this chapter has been written by a number of specialists, with contributions and information from many more. Authors and contributors for each section are identified and acknowledged in Chapter 2.

References


Estuarine habitats

Contents

Summary
8.1.1 Introduction
8.1.2 Subtidal habitats
8.1.3 Rocky shores
8.1.4 Tidal flats
  - British distribution of estuarine tidal flats
  - Conservation of tidal flats
  - Pressures on tidal flats
8.1.5 Saltmarshes
  - Saltmarsh development
  - Saltmarshes and estuaries
  - Plant communities of saltmarshes
  - The Spartina story
  - The importance of grazing management for saltmarshes
  - Conservation importance and protected status of saltmarshes
  - Site protection
8.1.6 Sand-dunes
  - Introduction
  - Sand-dunes and estuaries
  - Sand-dune stability
  - Sand-dunes and rabbits
  - Conservation importance and protected status of sand-dunes
  - Threats to sand-dunes
8.1.7 Shingle
  - Introduction
  - Shingle structures and estuaries
    - Chesil Beach
    - Orfordness
    - Culbin Shingle Bar
  - Conservation and protected shingle sites
8.1.8 Sea cliffs
  - Introduction
  - Vegetation on cliffs
  - Coast protection
8.1.9 Strandlines
8.1.10 Marine/maritime islands
8.1.11 Saline lagoons

Introduction
- Types of saline lagoon
- Distribution
- Lagoonal species
- Conservation of British saline lagoons

8.1.12 Coastal grazing marshes
- Introduction
- Grazing marsh grasslands
- Washlands
- The ditch systems
- Conservation importance and protected status

8.1.13 Rare and scarce vascular plants
- Introduction
- Rare and scarce estuarine plants
- Coastal species as part of the British flora
- Endemic species
- Wider distribution and status
- Conservation of rare and scarce plants

8.1.14 References

Summary

Even small estuaries are typically composed of a mosaic of between four and nine major habitat types of wildlife interest (subtidal, intertidal mudflats, intertidal sandflats, saltmarshes, shingles, rocky shores, lagoons, sand-dunes and grazing marshes/coastal grassland). Tidal flats occur on all, and subtidal areas and saltmarshes on almost all, estuaries.

Tidal flats are a major part of estuarine ecosystems. They vary from soft muds in the sheltered inner parts of estuaries to firm sandflats in outer parts. Mudflats especially support large numbers and biomass of characteristic estuarine invertebrate animals, notably crustaceans, molluscs and worms on which fish and many of the nationally and internationally important waterfowl feed. There are over 265,000 ha of tidal flats – over 83% of the intertidal area of estuaries.

Major British tidal flat areas are in Morecambe Bay, The Wash, the Dee Estuary and North Wirral, the Humber Estuary, around the Thames Estuary, and in north-east Scotland.

Tidal flats are vulnerable to progressive land-claim,
bait and shellfish collecting, and the impacts of waste discharge and pollution. Maintaining healthy tidal flats is crucial to estuarine conservation since this habitat is the source of much of the richness of the estuarine ecosystem.

Saltmarsh vegetation develops in a series of characteristic zones on fine sediments on the upper shore in sheltered parts of estuaries. Saltmarshes are a major source of nutrients to an estuary.

Extensive saltmarshes with full zonation occur mostly only where there is ample sediment, but land-claim has now removed much of the upper zone vegetation from many saltmarshes.

Saltmarshes larger than 0.5 ha are found on 135 estuaries. They total over 42,250 ha – over 95% of the British saltmarsh resource and almost 14% of the total intertidal area on estuaries. Largest saltmarsh areas are in the Greater Thames estuaries of Essex and Kent, and in Liverpool Bay. Individual estuaries with the largest areas (more than 3,000 ha each) are The Wash, Morecambe Bay and the Solway Firth.

Saltmarsh plant communities are particularly diverse in southern and eastern Britain, where they include plants such as sea-purslane in low-mid marsh, and sea-lavender and shrubby sea-blite in mid-upper marsh.

Cord-grass swaths now occur on 82 estuaries and dominate the lowest zones of saltmarsh especially in southern and western England. Overall cord-grass forms over 18% of the British saltmarsh area. It first appeared in Southampton Water in the late 19th century and has spread both naturally and by widespread planting to aid sea defence and land-claim. Cord-grass now appears to be dying back naturally in southern England, but elsewhere its spread is still causing loss of tidal flat feeding grounds for waterfowl.

Saltmarshes are grazed extensively by livestock. Crazed and ungrazed marshes each have conservation value for different types of estuarine wildlife. 39 estuaries have nationally important saltmarshes and 101 estuaries have saltmarshes within Sites of Special Scientific Interest.

Sand-dunes, an important and widespread coastal feature, are associated with 55 estuaries. They develop in more exposed parts of estuaries than saltmarshes.

Many form spits across estuary mouths and in some places have been a major force in shaping the estuary. Sand-dunes on barrier islands shelter the shore from waves, permitting estuarine intertidal habitats to develop in their lee.

Many sand-dunes are naturally mobile, particularly on their outer edges. On their landward side dune vegetation, especially marram grass, gradually binds the sand together, resulting in grassy swaths, wetter slacks and sometimes heath, scrub and woodland. Major areas of once-mobile dunes have been afforested, greatly reducing their wildlife value, which is most often enhanced by grazing and sand mobility. Housing, recreation (including caravan parks), roads, golf courses and intensive agriculture also affect the wildlife interest of estuarine sand-dunes.

There are seven nationally important shingle structures in Britain, five of them associated with estuaries. The protection afforded by these shingles, on the Moray Firth, Spey Estuary, North Norfolk Coast, Ore/Alder/Butley Estuary and The Fleet, has been a major influence in the development of these estuaries.

Shingle is an important estuarine feature for its geomorphology, characteristic vegetation and invertebrate animals.

About 83% of the area of British saline lagoons is associated with only 37 estuaries in England and Wales.

About half are natural lagoons behind shore barriers, often shingle. They support a highly specialised flora and fauna, often very local distribution. Natural saline lagoons are very vulnerable to damage from sea defence and other construction work, and from changes in hydrology and water quality.

There are few sea cliffs on estuaries, but soft cliffs including those outside estuaries are often important sediment sources for estuaries such as the Humber Estuary and The Wash. They have an important but neglected invertebrate fauna.

Coastal grazing marshes (many of them originally saltmarsh) and other lowland wet grasslands are associated with at least 53 estuaries, especially in southern England where they are fast vanishing. Coastal grazing marshes have a wide range of salt-tolerant which encourages the growth of a large variety of often rare or scarce plants, especially in the ditches.

Some lowland wet grasslands (especially around The Wash and Severn Estuary) are washlands created to prevent more widespread winter flooding. These are important waterfowl breeding and wintering areas.

Almost all the nationally rare vascular plant species of tidal flats, saltmarshes, shingle, sandy shores and sand-dunes are associated with estuaries. One or more rare plant species is found on 38 estuaries, mostly in southern and western England and Wales.

Ten nationally rare plants in Britain are entirely dependent on estuarine habitats. Estuaries and the maritime habitats surrounding them also support populations of four rare or scarce endemic plants.
8.1.1 Introduction

A vital consideration for the wildlife importance of estuaries is that estuaries consist of a complex mixture of many distinctive habitat types that are, to a varying extent, affected by proximity to the coast. (Habitat is used here in its broad sense of a land feature occupied by a characteristic group of organisms.) These habitats within the matrix that comprises each estuary do not exist in isolation. Rather, there are physical, chemical and biological links between them, for example in their hydrology, in sediment transport, in the transfer of nutrients and in the way mobile animals move between them both seasonally and during single tidal cycles. This means that many organisms depend on more than one estuarine habitat during their lifetime, and many (notably fish, mammals and migratory birds) depend also on habitats far removed from estuaries.

Some of these habitats, notably tidal flats and saltmarshes, are characteristic of estuaries and, as described below, almost all the British resource of these features occurs within review sites. Others such as shingle and sand-dunes are more widespread coastal features but with many important examples on estuaries. Some habitats such as rocky shores and sea-cliffs by definition occur mostly on open coasts outside estuaries. Nevertheless some rock features do occur within estuaries, usually as small patches of shore or in the outer parts of review sites.

As Ratcliffe (1977) pointed out, the landward limits of coastal habitats are difficult to define since such a division has to be based chiefly on the strength of the effects of the sea rather than on distance. This applies equally to the subset of estuarine habitats described here. We focus chiefly on maritime and sublittoral terrestrial habitats (see Ratcliffe 1977) as well as those falling below high water mark. We also give attention to coastal grazing marshes and other coastal wet grasslands since these are particularly associated with estuaries. Many are still strongly influenced by the sea, since they were originally saltmarsh claimed by man for more intensive agriculture. Others, particularly those adjacent to the upper, tidal but freshwater, parts of estuaries are under little direct influence of the saline conditions of the coast. In addition to all these habitats, a few other habitats of wildlife interest occur fringing a few British estuaries. These include lowland heath in places such as Poole Harbour and woodlands on the Stour Estuary in Essex and along some of the steep-sided rias of south-west England.

Most British estuaries consist of a mosaic of several habitats: at least 144 review sites (93% of the total) are composed of three or more of the nine major habitat types. Estuaries with many habitats are widely distributed around the British coastline (Figure 8.1.1). It is also important to recognise that it is not only physically large estuaries that are made up of such mosaics: even small estuaries generally have several estuarine habitats present.

![Habitat diversity](image)

**Figure 8.1.1** Estuaries are typically composed of a mosaic of habitats, as shown by the minimum number of main habitat types present on each review site. Nine habitat types are included: subtidal, intertidal mudflat, intertidal sandflat, shingle, rock, saltmarsh, lagoon, sand-dune and grazing marsh/coastal grassland. A few estuaries are also fringed by other habitats such as fen, woodland and heathland.

![Histogram](image)

**Figure 8.1.2** The average number of characteristic estuaries habitats (see Figure 8.1.1) on British estuaries of different sizes shows that both small and large estuaries consist of habitat mosaics, but that the number of habitats increases as estuaries become larger. The vertical bars show one standard deviation above the average value for each size category of estuary.
(Figure 8.1.2). Figure 8.1.2 does show, however, that there is a progressive increase in the diversity of habitats present on review sites as the size of the estuary increases. Even so, some very small estuaries are extremely diverse, with six or seven (of a possible nine) habitat types on and around several estuaries of less than 500 ha of intertidal and subtidal area.

The sections below describe the characteristics, distribution and conservation of the various habitats of British estuaries. The treatment of information is consistent with the current approach to wildlife conservation and is not intended as a detailed review of current knowledge of estuarine ecology. In addition to descriptions of each habitat, we have included here information on rare and scarce vascular plants since their distribution is defined in terms of estuarine and coastal habitats.

8.1.2 Subtidal habitats

Many of the characteristic habitats of estuaries occur both in zones exposed by the tide and subtidally, below low water mark. Subtidal areas are widespread, occurring within the defined boundaries of 146 review sites (94% of review sites) shown in Figure 8.1.3. Subtidal areas are effectively absent from only 10 review sites, chiefly the embayments and open coast sites such as Dengie Flats where there is little or no freshwater outflow and no major subtidal channels draining the intertidal flats. In practice most of even these sites are likely to retain small areas that are permanently inundated, in tidal channels and depressions in tidal flats. The characteristic plant and animal communities associated with these varied subtidal habitats, that include muddy and sandy bottoms, gravel and rocky shores subject to a variety of degrees of wave exposure and salinity, and their conservation, are described in detail in Chapter 8.3 (Aquatic estuarine communities). The distribution and significance of the key intertidal habitats of estuaries, mudflats and sandflats, are described in more detail below.

8.1.3 Rocky shores

Estuaries are characterised by their predominately soft sediments and shores. Since rocky coastlines have been explicitly excluded from this review, rocky shores (i.e. intertidal areas of rocks) would not be expected to be a widespread feature of review sites. Nevertheless rocky shores are present within at least 52 (34%) of the estuaries covered by this review. Most of these rocky shores are on estuaries in the north and west of Britain; few are on the predominantly soft shores of eastern England. (Figure 8.1.4). In most estuaries rocky shores form only a minor component of the habitat mosaic and appear mostly as small areas of outcrop on the shore or as rocky promontories sheltering bays of soft sediments. On a very few, such as at Blue Anchor Bay, areas of flat rocky shore form a major feature of the site. In places such as here and the Severn Estuary, the rocky exposures on the shore are of considerable geological and geomorphological interest (see Chapter 9). Elsewhere rocks feature in estuaries chiefly on the outer fringes of the review sites and on rocky islands in the mouths of estuaries such as the Firth of Forth.

These intertidal rocky areas, as well as subtidal rocks and boulder shores, support a considerable variety of aquatic tidal communities, many of which are also characteristic of rocky shores outside estuaries (see Chapter 8.3), and contribute much to the overall diversity of aquatic estuarine communities within estuaries, although forming only small areas in comparison with soft substrates.

8.1.4 Tidal flats

Intertidal mudflats and sandflats form a major and vital part of the British estuarine resource. The varying tidal and river currents and often large volumes of sediment carried in suspension in the water column during periods of high tide result in river estuaries and other shallow shores usually being places of active change and key zones for
the formation of geomorphological features.

Estuaries are therefore important in the accretion of sedimentary deposits that ultimately form much of the sedimentary rock of which the land is built.

The precise nature of the substrate in an estuary, its form and particle size, depends on a complex interaction between these physical factors in an ever-changing environment. In general the finest suspended sediments are deposited in the most sheltered places, so mudbanks generally form in the inner parts of estuaries. Closer to the mouth, in main river outflow channels and on more exposed shores, higher wave energy and/or faster tidal currents usually keep fine sediments in suspension. In these areas only the coarsest sediments are deposited, resulting in sandflats. Such features can form substantial parts of high-energy estuaries such as the Severn Estuary. There most of the intertidal flats in the main part of the estuary are highly mobile sandbanks. Movement of windborne sand on estuaries where there are extensive intertidal sandflats often leads to the development of sand-dune systems above the high water mark. These sand-dune habitats are described below in Section 8.1.6. Smaller estuaries are, however, generally more sheltered and so a greater proportion of their intertidal flats are mudflats.

Although many mudflats appear relatively stable in location and form, their continued presence intertidally depends on the maintenance of a dynamic equilibrium between the rate of deposition of sediments from the water column and the rate of erosion by tidal currents and wave action. Where deposition exceeds erosion tidal flats accrete. Higher tidal level flats become suitable for colonisation by pioneer saltmarsh plants which in turn generally increase accretion by trapping sediment amongst their roots and stems. This development of saltmarsh plant communities is described further in Section 8.1.5 below.

Tidal flats provide a substrate within which lives a very large biomass of macrobenthos, notably polychaete worms and gastropods and bivalve molluscs. These animals often live in very high densities and provide abundant food for estuarine fish when the flats are covered by the tide. When the flats are exposed they provide feeding grounds for many species of migratory and wintering waterfowl for which British estuaries are nationally and internationally important (see Chapter 8.6).

The characteristic macrobenthic fauna varies on different substrate types. For example, soft mudflats typically support high densities of the small gastropod mollusc Hydrobia ulvae, bivalve molluscs such as the clam Mya arenaria, the polychaete ragworm Hediste (Nereis) diversicolor and the amphipod crustacean Corophium volutator. On sandier mudflats the macrobenthic fauna is often dominated by bivalve molluscs such as the cockle Cerastoderma edule and Baltic tellin Macoma baltica. The polychaete lugworm Arenicola marina is also characteristic of these stable muddy sandflats. Substantial beds of mussels Mytilus edulis develop where there is sand or gravel or sometimes on sheltered mudflats. Such places generally support the highest biomass of any part of the tidal flats which forms an important food source for waterfowl, notably oystercatchers Haematopus ostralegus and eiders Somateria mollissima. Sandflats, however, because of their greater instability, generally support smaller numbers and a lower biomass of macrobenthos. These flats have their own typical fauna, notably several species of isopod and amphipod crustaceans that are capable of swimming strongly and so maintaining their position in the estuary in the face of strong wave and tide action.

The characteristic plant and animal communities of these various types of tidal flat are described further in Chapter 8.3 Aquatic estuarine communities.

**British distribution of estuarine tidal flats**

By definition every review site includes tidal flats since the presence of tidal flats was used as a key...
selection criterion for the sites included in the Estuaries Review.

For the purposes of this report the area of tidal flats on each review site was estimated by subtracting the area of saltmarsh (see Section 8.1.5) from the total intertidal area (Appendix 2). This will give a slight overestimate of the area of tidal flats for some review sites since it includes intertidal shingle and rock features. Since, however, extensive rocky shores are explicitly excluded from the review the overall error is small. These figures show that there is a total of 265,568 ha of tidal flats on British estuaries. Tidal flats are a very major feature of British estuaries, forming 86.3% of the intertidal area of review sites. They form the most abundant estuarine habitat (in terms of their area) and are a substantial feature of the British coastline as a whole, forming almost 72% of the total intertidal area of the coast (cf. Table 5.2).

As would be expected from the overall size of the estuarine resource (Chapter 6), British tidal flats form a large part of the tidal flat resource of northwest Europe. Elsewhere, the international Wadden Sea has the single largest area of tidal flats, with an area of 489,000 ha (Wolff & Smit 1984). Only the Federal Republic of Germany, with 319,000 ha of tidal flats in the Wadden Sea, has a larger national area of tidal flats than Britain. Even including the 26,400 ha of tidal flats remaining in the Dutch Delta area (Methe et al. 1989), The Netherlands with 156,400 ha has less than two-thirds the total area of tidal flats on British estuaries.

As with total estuary areas, most of the tidal flat area in Britain is concentrated in just a few large estuaries and embayments. The largest single expanse of intertidal flats, 30,500 ha (11.5% of the estuarine total), is in the embayment of Morecambe Bay. Elsewhere The Wash (25,540 ha) and the Solway Firth (24,630 ha) have very large areas of tidal flats. Only three other estuaries, the Severn Estuary, the Humber Estuary and the Dee Estuary and North Wirral, have in excess of 10,000 ha of tidal flats. Together these six estuaries contain 119,600 ha of tidal flats, almost half (45.8%) of the British estuarine resource.

Figure 8.1.5 shows that, in addition to these individual estuaries with very large tidal flat areas, several parts of the coastline have concentrations of estuaries with large tidal flats. These include southeast England, where the 10 constituent review sites of the 'Greater Thames estuary' (from the Colne Estuary to the Swale Estuary) have a total of 25,500 ha of tidal flats, making this one of the four largest continuous areas of tidal flats in Britain. Elsewhere the four large firths of north-east Scotland (Loch Fleet to the Moray Firth) have almost 12,300 ha, the 11 review sites around the Solent on the south coast of England over 5,100 ha, and those of the south coast of Dumfries and Galloway have over 6,700 ha of tidal flats.

Most of the tidal flats are concentrated on these few areas, but the remainder are scattered around the whole coastline on smaller estuaries (Figure 8.1.5). Many British estuaries have only a small area of tidal flats: 86 review sites (58% of the total) have intertidal flats of less than 500 ha. Nevertheless these smaller areas together contribute over 13,000 ha of tidal flats (5% of the total area of flats). Hence they form an important component of the resource since they are often largely mudflats of high productivity which support high densities of wintering waterfowl (see Section 8.6.2).

As well as the local conditions within different parts of an estuary that lead to the formation of intertidal flats from a variety of types sediment, there are also some broader-scale patterns. In general, coarse-grained sandflats tend to be prevalent in the north and west of Britain and fine-grained mud is in the south and east (Ratcliffe 1977). The distribution of major sandflats and mudflats around review sites (Figures 8.1.6 and 8.1.7) reflects this trend. It should be noted that these figures show only the presence of the relevant habitat. Figures 8.1.6 and 8.1.7 thus show wider distributions than those for the aquatic estuarine communities that occur within these habitats (Chapter 8.3), since a location for a community is shown only where there is
documented evidence of the presence of the constituent plant and animal species. The large sandflats in places such as the Moray Firth and in the Outer Hebrides are often also of importance as a source of sand for the extensive sand-dune and machair systems that have developed on their landward edge. There are of course major exceptions to this general pattern of mudflat and sandflat distribution, for example the extensive mudflats of major north-western estuaries such as the Solway Firth and Morecambe Bay.

The abundant supplies of fine sediments and the sheltered conditions in the southern North Sea and south coast of Britain lead to the intertidal sediment on these estuaries being predominantly muddy and sometimes supporting extensive beds of eel-grass Zostera spp. and green algae Enteromorpha spp., the latter especially in nutrient-rich areas. Although most estuaries have small areas of different substrate types associated with a preponderance of either mudflats or sandflats, there are rather few British estuaries in which there is a wide range of intertidal sediments well represented: Ratcliffe (1977) notes particularly the Exe Estuary and the Dyfi Estuary.

**Conservation of tidal flats**

On the basis of their plant communities Ratcliffe (1977) divided coasts into six physiographic categories. Of these, tidal flats are distinctive in supporting very little vegetation. Consequently within the Nature Conservation Review tidal flats were identified as of national importance chiefly in terms of the abundance of their macrobenthic fauna and the consequent ability of an area of tidal flats to support large populations of migrant and wintering waterfowl. In these terms areas of tidal flats attain particular importance if they are extensive, exposed at a variety of tidal heights and muddy and so support large waterfowl populations. All 50 coasts sites with a major element of tidal flats that were identified by Ratcliffe (1977) as being of national importance are within estuaries. Their distribution between only 48 review sites (Figure 8.1.8) reflects closely the distribution of large estuaries (cf. Figure 8.1.5) and especially those with fine sediments in south-east and southern England.

Since Ratcliffe (1977) was published, the increasingly comprehensive understanding of the numbers and distribution of migrant and wintering bird populations (see Chapter 8.6, e.g., Figures...
for mudflat and sandflat communities most, except for Zostera and Ruppia beds, have so far been assessed as of only local or regional, rather than national or international, significance. This contrasts with the overall national and international importance of many of the estuaries concerned, and of the overall British resource. Comprehensive marine community assessments, including those of tidal flats, are currently being made for Britain through the NCC’s Marine Nature Conservation Review (MNCR). A review is also underway of the extent to which features of marine conservation significance are present within existing coastal and estuarine SSSIs.

Ratcliffe (1977) notes that coastlands are of great physiographic importance and that the series of nationally important coastal sites for the Nature Conservation Review was chosen in part for the range of features illustrating the dynamic processes involved in their formation and continuing development. Some NCR sites were at that time chosen to illustrate the relationships between the different physiographic features and habitats on an estuary. Nevertheless, earth science conservation currently treats the different types of geomorphological feature separately on estuaries. Hence only major shingle, sand-dune and some saltmarsh features are included in the Geological Conservation Review (GCR) (see Chapter 9). Ironically, despite being the key feature identified in this review as characteristic of estuarine ecosystems, tidal flats themselves do not currently feature in the GCR coastal geomorphology series of SSSIs. The physiographic features surrounding estuaries often derive much of the sediment of which they are built from tidal flats. Although the surrounding saltmarshes, sand-dunes and shingle ridges are thus inextricably linked to tidal mudflats and sandflats through their sediment transport regimes, whole estuaries are not currently treated for conservation purposes as features based on their geomorphological type (see Chapter 5).

Pressures on tidal flats

Tidal flats as an estuarine habitat are vulnerable to many of the pressures affecting estuaries. Since they are a key wildlife habitat central to most estuaries their continued existence and health is pivotal to the maintenance of the British estuarine resource. Land-clamp that leads directly to loss of tidal flat habitat is therefore a key pressure on British estuaries. As is described further in Chapter 10, land-clamp generally occurs in a piecemeal way, although very large areas can be claimed at one time and for many different purposes.

In some British estuaries the overall impact of such piecemeal land-clamp has been to entirely or almost entirely eradicate the mud and sandflats of the estuary. Examples include the Tees Estuary, where over 80% of the intertidal flats have been claimed for agriculture, industry and ports since 1720, and the Tyne Estuary, where no broad intertidal flats remain. On the Taw in south Wales the whole river estuary has been claimed. There
are many other estuaries on which some land-claim has affected tidal flats, and such pressures continue (see Chapter 10).

The area of intertidal flats can be eroded in a number of ways. As well as by direct land-claim, tidal flats can be reduced by sediment extraction from intertidal areas and by widening and dredging tidal channels. Such dredging, especially where it involves deepening of tidal channels, can have indirect consequences for adjacent tidal flats by increasing erosion as sediment is drawn down into the channel (see also Chapter 10). In a similarly indirect fashion land-claim involving saltmarsh above the level of tidal flats can also result in a gradual further loss of the flats. In places such as The Wash new saltmarsh accretes outside the new sea-wall on what was formerly the upper tidal flats (Hill & Randerson 1987), leading to a reduced tidal flat area on a steeper shore profile.

A downdeshore spread of saltmarsh leading to overall loss of tidal flats has been accelerated on some estuaries (chiefly in south and west England and Wales) by the planting of cord-grass Spartina anglica, and also by its subsequent natural spread. On some estuaries Spartina is, however, now dying back to reveal bare mud again, albeit usually at an initially higher tidal level and without the abundant macrofauna of established mudflats. The impact of Spartina on British estuaries is further described in Section 8.1.8.

Areas of tidal flats can also be reduced by the manipulation of water levels in estuaries through the use of barriers and barrages. The impacts of barrages vary. The most immediately and comprehensively damaging to tidal flats are those 'leisure' barrages designed to provide for waterborne recreation, since these maintain constant high water conditions.

Barrages that lead to reductions in tidal amplitude, for example tidal power and storm surge barrages, also usually substantially alter the distribution and structure of tidal flats within an estuary. High tidal flats cease to be inundated and low tidal flats cease to be exposed. The immediate effect of barrage closure is thus a loss of tidal flat area within the estuary. In the longer term the area of tidal flats may become further reduced by the downdeshore development of saltmarsh below the new high water mark. Temporarily increased deposition in the less turbid waters, and a longer-term redistribution of sediment through changed erosion patterns and infilling of tidal creeks, may eventually lead to a stable new pattern of tidal flats. Behind barrages such flats are generally likely to become muddier at the expense of the extensive sandflats characteristic of high-energy coastal plain estuaries. Such changes are, however, proving difficult to predict and reestablishment may take many years (e.g. Hooghiemstra & Posthumus 1989).

In addition to such direct changes to tidal flat structure from barrages across estuary mouths, there is concern that barrages placed on tidal rivers upstream of tidal flats can alter the sediment budget by inhibiting sediment delivery into the estuary.

Overall loss of tidal flat area has serious implications for the organisms which depend on them. Since the number of birds using an estuary depends partly on its intertidal area (see Figure 8.6.31), reduction in the area of available feeding grounds is likely to lead to reduced bird populations. Indeed the reduction of intertidal flat areas through Spartina spread has been implicated in the decline in the British wintering population of dunlins (Goss-Custard & Moser 1988). Many land-claims disproportionately affect the upper tidal levels of estuarine flats, since land-claim episodes are generally excursions from the shore. Permeable barrages also affect these upper tidal levels as well as the low level flats, since they act to damp down the tidal range such that the former high tidal levels then remain permanently exposed and low tidal levels permanently submerged.

The presence of high tidal level flats (areas which are only covered by the tide for short periods) are very important for the many migrant and wintering wader species which feed on tidal flats since these birds at times need to feed for most or all of the tidal cycle to gain their energy requirements. Removal of upper tidal flats restricts this feeding period on heavily man-modified estuaries. This increases the risk of the birds dying of starvation, especially during periods of severe winter weather when energy demands are high (Davidson & Clark 1988). At times, however, this shortfall in feeding time has apparently been buffered, on extensively land-claimed estuaries such as the Tees, by the incidental development of peripheral wetlands, on which birds can continue to feed during high water (Davidson & Evans 1986). In addition to its effects on birds, loss of high level tidal flats may also interfere with the life-cycles of major components of the intertidal macrofauna since this is where most successful spatfall occurs in some species prior to their dispersion into the intertidal flats throughout the estuary.

In addition to land-claim, some human activities can damage the quality of intertidal flats. Notable amongst these are some forms of collection of intertidal macrofauna, for example suction dredging for cockles Cerastoderma edule and lugworms Arenicola marina (reviewed by Fowler 1989). The sediment disturbance and filtering techniques from even shallow dredging for cockles can kill large numbers of undersized cockles and other macrofauna such as Baltic tellins Macoma balatica as well as destroying eel-grass Zostera in the dredged areas. Some deeper dredging, such as for clams Mercenaria mercenaria and lugworms, may be even more damaging to both the physical integrity of the tidal flats and the macrobenthic populations living in them (van den Heijdenberg 1987). Although some mobile species can recover quickly by migrating into the dredged areas, others, particularly those with slow or variable recruitment of young into the population, can take much longer. Hence dredging can reduce biomass and alter species composition of tidal flats.

Hand-digging lugworms and ragworms for bait can
have similar consequences to dredging on intertidal flats. Carried out intensively it has at times resulted in the local eradication of the target species and heavy mortality of other macrobenthos in the dug areas (van den Heiligenberg 1987).

Physical disturbance to tidal flats from activities such as digging and hydraulic dredging is also of concern in polluted estuaries, since such disturbance can release pollutants such as heavy metals and other toxins from anoxic layers of sediment (Howell 1988). This highlights one impact of pollution, which is a major factor affecting the quality of tidal flats.

Pollution stress from organic discharges and inputs is known to change the structure of benthic communities, which become dominated by a low diversity of small animals (Cray 1972). At severe pollution levels anoxic conditions develop and macrobenthos mostly dies; such places can support few fish and bird predators. Such eutrophication also leads to the growth of dense algal mats, which both physically prevent predators feeding and induce anoxic conditions in the underlying mud, so reducing macrobenthic populations (e.g. Hull 1987). Conversely under some less extreme conditions of eutrophication there is evidence of increased benthic production (e.g. Beukema & Cadee 1986) which may lead to temporary increases in some bird populations (van Impe 1985), although for most estuaries there is no clear point known at which such nutrient enrichment ceases to increase production.

Such organic enrichment is seldom, however, the whole pollutant picture on estuaries since organic waste discharges are often accompanied by persistent pollutants, notably polychlorinated biphenyls (PCBs) and heavy metals. Some come directly from industrial sources in estuaries and some enter and accumulate in estuaries from their river catchments, probably in enhanced quantities as a consequence of human activities such as mining in metaliferous strata. Such persistent pollutants become bioaccumulated as they pass from the water column and from sediment up through food chains. Some heavy metal pollutants can have a drastic effect on some estuarine organisms, a notable example being the widespread disruption of the reproductive biology of the dogwhelk Nucella lapillus by leachates from tributyl tin (TBT)-based antifouling paints used on boats (Spence et al. 1990).

Only in exceptional circumstances, however, are pollutant levels known to cause mortality of top predators feeding on tidal flats, an exception being mortality of durnins and other waders in the Mersey Estuary in 1979 in which organic lead compounds were implicated (NERC 1983). Waders are, however, known to accumulate substantial heavy metal loads on polluted British estuaries such as the Tees (Evans & Moon 1981; Evans et al. 1987). Impacts on top predators are more likely to be chronic and may involve depression of lifetime breeding output, as recently found for tufted ducks fed on mussels from a polluted Dutch estuary (Scholten & Feokema 1988 in Meire et al. 1989).

Overall then effective estuarine conservation depends on safeguarding the continued existence, quality and variety of tidal flats, particularly through the enhancement of degraded systems. The efforts to reduce pollutant levels on beaches and in estuaries, directed through approaches such as Water Quality Standards (WQS) for estuarine waters, will help restore the natural state of many of the still extensive and internationally important tidal flats of British estuaries.

Tidal flats have suffered more than most habitats even on estuaries from the view that estuaries are wastelands suitable for cheap waste disposal and the claiming of building land. The widely misused word ‘reclamation’, generally used in such proposals, implies that estuarine land-clain is designed to take back what was previously dry land. In the current post-glacial period of rising sea-levels it would seem, however, to be the sea rather than man that is undertaking the reclamation.

Some tidal flat land-claim proposals go further than simply treating intertidal land as wasteland of no intrinsic value. It is regrettable that a primary objective of some schemes, notably leisure barrages and associated waterfront developments, appears to be that of covering up the tidal flats regardless of even their national and international importance to wildlife. Such tidal flats are apparently deemed an unsuitable setting for modern ideals of housing and leisure.

It is ironic that this ‘stinking mud’ attitude towards some of Britain’s most important natural resources is strongest where man’s activities themselves, by heavily polluting estuaries, have created the smelly anoxic conditions used to justify the destruction of the tidal flats.

8.1.5 Saltmarshes

Saltmarsh development

Saltmarshes develop wherever tidal waters are sufficiently quiescent to allow the deposition of fine sediments. Stabilisation of the sediment begins with the binding action of surface algae. Aeration of the ‘soil’ by the numerous mud-dwelling invertebrates and the interaction between these and plants such as Enteromorpha, which may become attached to loose invertebrate shells, encourages further sediment deposition. Above this zone, which usually exists at the lower levels of the shoreline, progressively more terrestrial types of vegetation occur, depending on the number of tidal inundations which cover the plants.

At the lowest levels, where immersion occurs on nearly every tide (i.e. approximately 700 times per year), higher plants, which are tolerant of high salinities and able to withstand physical movement by the incoming tide, become established. These
are represented by a very few species (eel-grass Zostera and tasselweed Ruppia) which are essentially aquatic in type and lie flat when the tide is out. Above this zone, at about the mean water level of the lower, neap tides, plants with a more terrestrial growth form predominate. Again these are dominated by a few salt-tolerant species such as the annuals glass-wort Salicornia spp. and seablite Suaeda maritima and the perennial cord-grass Spartina anglica (see below) whose seedlings require a number of days free from tidal movement to become rooted in the sediment. At this level the flats receive less than 600 tidal immersions per year. Chapman (1960) distinguishes between ‘lower marshes’ which have more than 360 submergences per year and ‘higher marshes’ with less than 360 submergences per year. In the former, the important point is that the maximum period of freedom from tidal inundation is nine days.

Once established, these plants help the deposition of sedimentation and, in the classic model (Chapman 1938, 1939) succession takes place. This results in the marsh level at any one point receiving progressively fewer tidal inundations as the process of sedimentation raises the marsh level. As this happens, the vegetation and its associated animals become more varied. This general picture is, however, very simplified, and true succession of this kind may only occur in estuaries where relatively rapid sedimentation takes place. Elsewhere in higher energy coastal environments, such as on more exposed high sandy beaches or in areas where sediment supply is restricted, such as Scottish sea-lochs, a spatial zonation of communities occurs, which changes only very slowly with time, if at all. Another important factor in the successional development is the nature of the anthropogenic management, which can extensively modify the community structure and wildlife value.

Given ideal conditions and with an ample supply of sediment, extensive saltmarshes can develop. These show, in the best examples, the full successional sequences from pioneer low-marsh through mid-marsh communities and transitions to other terrestrial vegetation such as grazing marsh, sand-dunes, fens and, in a very few cases, woodland. The extent of the transitional habitats, in particular, is dependent on the extent of enclosure for the development of agriculture, ports, houses, industry, roads and the like. Today very few of the larger marshes within estuaries show the complete sequence of vegetation as depicted in Figure 8.1.9.

### Saltmarshes and estuaries

Saltmarshes play a fundamental role in the life of an estuary. Not only do they help to bring stability to its margins but they also operate as a source of primary productivity. Estimates vary as to the contribution to the overall energy budget, but the rates of production may be very high. Carter (1989) quotes net values between 500 g and 1,500 g m$^{-2}$ yr$^{-1}$ carbon. Comparisons between the dry-weight production of plant material for a variety of saltmarshes was made by Hussey & Long (1989). These ranged from 153 to 2,722 g m$^{-2}$ for the mean live weight and 63 to 1,534 g m$^{-2}$ for mean dead weight. The lowest figures are for Puccinellia maritima marsh in the Netherlands, the highest for Spartina foliosa in California, USA (mean live weight), and Spartina cynosuroides in Georgia, USA.

The precise (relative) importance of this depends on other contributions, mainly from the algae of the tidal waters (the benthos) and the extent of detritus being brought in from the river or by the tides. The distribution of saltmarshes amongst Estuaries Review sites is shown in Figure 8.1.10. These data are derived from a national survey of the saltmarsh resource (Burd 1989) made between 1981 and
The largest concentrations of saltmarsh occur around the Greater Thames estuary in Essex and Kent – 8,526 ha (19%) – and Liverpool Bay – 8,862 ha (20%) – where shallow offshore waters are able to deliver vast quantities of fine sediment to the coast. Individually, two sites, The Wash and Morecambe Bay, each have a large proportion of the total resource, with 4,226 ha (9.5%) and 3,753 ha (7.3%) respectively. The Solway Firth has almost 3,000 ha, and the North Norfolk Coast, Loughor Estuary, Ribble Estuary and Dee Estuary and North Wirral each have in excess of 2,000 ha of saltmarsh. In order to give some indication of the significance of this to the functioning of the estuaries, the ratio of saltmarsh to total intertidal area is shown in Figure 8.1.10 and for major sites in Table 8.1.1.

### Table 8.1.1 The relative proportion of saltmarsh within the 10 review sites with the largest total intertidal areas

<table>
<thead>
<tr>
<th>Site</th>
<th>Intertidal area (ha)</th>
<th>Saltmarsh area (ha)</th>
<th>% saltmarsh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morecambe Bay</td>
<td>33,749</td>
<td>3,253</td>
<td>9.6</td>
</tr>
<tr>
<td>The Wash</td>
<td>29,769</td>
<td>4,226</td>
<td>14.2</td>
</tr>
<tr>
<td>Solway Firth</td>
<td>27,550</td>
<td>2,895</td>
<td>10.6</td>
</tr>
<tr>
<td>Severn Estuary</td>
<td>16,930</td>
<td>833</td>
<td>5.0</td>
</tr>
<tr>
<td>Humber Estuary</td>
<td>15,521</td>
<td>1,419</td>
<td>9.5</td>
</tr>
<tr>
<td>Dee Estuary and North Wirral</td>
<td>12,961</td>
<td>2,108</td>
<td>16.2</td>
</tr>
<tr>
<td>Maplin Sands/Chocolate-Roach Estuary</td>
<td>10,979</td>
<td>1,059</td>
<td>9.6</td>
</tr>
<tr>
<td>Ribble Estuary</td>
<td>10,674</td>
<td>2,184</td>
<td>20.5</td>
</tr>
<tr>
<td>Loughor Estuary</td>
<td>6,556</td>
<td>2,187</td>
<td>33.4</td>
</tr>
<tr>
<td>North Norfolk Coast</td>
<td>8,674</td>
<td>2,127</td>
<td>36.2</td>
</tr>
</tbody>
</table>

* Saltmarsh areas are derived from the Saltmarsh Survey of Great Britain (Burd 1991)
* The Saltmarsh Survey of Great Britain site boundaries overlap these two adjacent review sites

Review sites with the largest areas of saltmarsh are amongst those where there has been relatively little alteration of the estuary shape by man. On the North Norfolk Coast saltmarsh exists in close association with other coastal habitats, chiefly sand-dunes and shingle bars (see Figure 8.1.11). There has been relatively little enclosure and the plant communities span the full successional range from low-marsh to high-marsh and transitions into swamp vegetation and other habitats. The saltmarshes are old and structurally diverse with a rich flora and fauna. On the Loughor Estuary there has also been almost no land-claim. Here the landward boundary is natural sand-dune transition. In the Loughor Estuary the larger proportional area of saltmarsh is, however, partly related to the spread of Spartina anglica, which currently accounts for almost 20% of the saltmarsh area. Elsewhere, such as on the Dee Estuary, the saltmarshes are much younger, dating from about 1910 when the last major land-claims of the upper estuary took place. Some 25-30% of the estuary has been enclosed (Figure 8.1.12) and transitions to upper saltmarsh and other habitats, notably Phragmites swamp, are very restricted. Overall, although large, these saltmarshes are less

Saltmarshes have been recorded in 135 of the 155 Estuaries Review sites. Their areas range from 1 ha in the Wansbeck Estuary to 4,226 ha in The Wash. Saltmarsh almost certainly occurs in the remaining 20 estuaries, though only as small pockets at the very edge of the sites and of less than 0.5 ha, the usual lower limit for inclusion in the Saltmarsh survey of Great Britain (Burd 1989).

The total area of saltmarsh within the 135 estuaries is 42,251 ha and represents 95.2% of the total Great Britain resource of 44,370 ha. This very high proportion is not surprising since it is the fundamental nature of estuaries – soft, shallow, sheltered, tidal shores – that provides the most favourable conditions for saltmarsh growth. Elsewhere, limited sediment supply and/or exposure restrict their growth to very localised and small areas such as at the heads of otherwise hardshore sea-lochs.
Figure 8.1.11 The complex pattern of habitats on Scolt Head Island on the North Norfolk Coast

Figure 8.1.12 Land-claim and saltmarsh development on the Dee Estuary
<table>
<thead>
<tr>
<th>Saltmarsh Survey community</th>
<th>NVC communities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <em>Spartina</em></td>
<td>SM4 <em>Spartina maritima</em></td>
</tr>
<tr>
<td></td>
<td>SM5 <em>Spartina alternifolia</em></td>
</tr>
<tr>
<td></td>
<td>SM6 <em>Spartina anglica</em></td>
</tr>
<tr>
<td>2a. <em>Salicornia/Suaeda</em></td>
<td>SM7 <em>Arthrocnemum perenne</em></td>
</tr>
<tr>
<td></td>
<td>SM8 <em>Arctium Salicornia</em></td>
</tr>
<tr>
<td></td>
<td>SM9 <em>Suaeda maritima</em></td>
</tr>
<tr>
<td>3b. <em>Aster</em></td>
<td>SM11 <em>Aster tripolium var. discoideus</em></td>
</tr>
<tr>
<td></td>
<td>SM12 <em>Rayed Aster tripolium</em></td>
</tr>
<tr>
<td>3a. <em>Puccinellia</em></td>
<td>SM10 <em>Puccinellia maritima</em></td>
</tr>
<tr>
<td></td>
<td>SM13 <em>P. maritima sub-comm.</em></td>
</tr>
<tr>
<td>3b. <em>Halimione</em></td>
<td>SM14 <em>Halimione portulacoides</em></td>
</tr>
<tr>
<td></td>
<td><em>H. portulacoides sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Juncus maritimus sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>P. maritima sub-comm.</em></td>
</tr>
<tr>
<td>4a. <em>Limonium/Armeria</em></td>
<td>SM13 <em>Puccinellia maritima</em></td>
</tr>
<tr>
<td></td>
<td><em>Limonium/Armeria sub-comm.</em></td>
</tr>
<tr>
<td>4b. <em>Puccinellia/Festuca</em></td>
<td>SM13 <em>Puccinellia maritima</em></td>
</tr>
<tr>
<td></td>
<td><em>Glaux maritima sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Plantago/Armeria sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>turf facoid sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td>SM16 <em>Festuca rubra</em></td>
</tr>
<tr>
<td></td>
<td>*t. <em>P. rubra sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td>SM17 <em>Artemisia maritima</em></td>
</tr>
<tr>
<td>4c. <em>Juncus gerardii</em></td>
<td>SM16 <em>Festuca rubra</em></td>
</tr>
<tr>
<td></td>
<td><em>P. maritima sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>J. gerardii sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Festuca/Glaux sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Leontodon autumnalis sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Carex flaccasub-comm.</em></td>
</tr>
<tr>
<td>4d. <em>Juncus maritimus</em></td>
<td>SM15 <em>Juncus maritimus/Triglochin maritima</em></td>
</tr>
<tr>
<td></td>
<td>SM16 <em>Juncus maritimus</em></td>
</tr>
<tr>
<td></td>
<td><em>J. maritimus/C. lachenalii sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Festuca arundinacea sub-comm.</em></td>
</tr>
<tr>
<td>5a. <em>Agropyron (Elymus)</em></td>
<td>SM24 <em>Elymus pycnanthus</em></td>
</tr>
<tr>
<td></td>
<td>SM18 <em>Elymus repens</em></td>
</tr>
<tr>
<td>5b. <em>Suaeda fruticosa</em></td>
<td>SM25 <em>Suaeda vera drift line</em></td>
</tr>
<tr>
<td></td>
<td><em>E. pycnanthus sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>H. portulacoides sub-comm.</em></td>
</tr>
<tr>
<td>6. Upper marsh swamps</td>
<td>S4 <em>Phtagnies australis</em></td>
</tr>
<tr>
<td></td>
<td>S19 <em>Eleocharis palustris</em></td>
</tr>
<tr>
<td></td>
<td>S20 <em>Scirpus lacustris ssp. tabernaemontani</em></td>
</tr>
<tr>
<td></td>
<td>S21 <em>Scirpus maritimus</em></td>
</tr>
<tr>
<td>7i. Shingle/Dune transition</td>
<td>SM21 <em>Suaeda vera/Limonium binervosum</em></td>
</tr>
<tr>
<td></td>
<td><em>typical sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Frakenia laevis sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td>SM22 <em>H. portulacoides/F. laevis</em></td>
</tr>
<tr>
<td>7ii. Freshwater transition</td>
<td>MG11 <em>F. rubra/A. stolonifera/P. asperina</em></td>
</tr>
<tr>
<td></td>
<td><em>Lilium peregrine sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Artemisia hastata sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Hookera peploides sub-comm.</em></td>
</tr>
<tr>
<td>7iii. Grassland transition</td>
<td>MG12 <em>Coarse Festuca arundinacea</em></td>
</tr>
<tr>
<td></td>
<td><em>Lilium peregrine/Adonis annua sub-comm.</em></td>
</tr>
<tr>
<td></td>
<td><em>Oxalis aethiopica sub-comm.</em></td>
</tr>
</tbody>
</table>
biologically diverse than those of North Norfolk. They are younger, have resulted from a rapid expansion of Spartina anglica and are grazed — all factors which tend to reduce biological diversity.

The relatively smaller areas of saltmarsh on Maplin Sands, including the Crouch-Roach Estuary, and the Severn Estuary are probably the result of the exposed nature of much of the tidal flats. Elsewhere the saltmarsh area provides a significant proportion of the intertidal land. In terms of productivity, 1 ha of saltmarsh could provide 10,000 kg or 10 tonnes in one year (assuming a net dry weight production of approximately 1,000 g m^-² — a relatively conservative estimate of productivity) — making a significant contribution to the primary productivity of an estuary.

**Plant communities of saltmarshes**

The National Vegetation Classification (NVC) has identified communities, including transitions to other habitats, which are predominantly dependent on or associated with tidal regimes (Rodwell in press). A summary of these is given in Table 8.1.2 which also shows their relationship with the saltmarsh communities recorded in the Saltmarsh survey of Great Britain (Burd 1969).

The distribution of these community types nationally provides some indication of the factors which influence the type of marsh which develops. The following discussion highlights some of the more important features, namely climate and anthropogenic impacts. For a more complete description see Burd (1969), Adam (1976) and Rodwell (in press).

Climatic factors operate across Great Britain to produce communities with distinctive characteristics. South of a line running roughly from the Solway in the west to north-east Fife in the east, several species which do not occur further north are either characteristic or major components of a number of important saltmarsh communities. Sea-purslane Halimione portulacoides is one of the more significant and forms sometimes extensive communities in the low-mid marsh zone. A high proportion, 55%, of review sites in England and Wales have examples of those communities. They are well represented in the estuaries of the Humber, The Wash, the North Norfolk Coast, Essex and north Kent (Figure 8.1.13).

Other species have similar distributions to that of sea-purslane, for example common sea-lavender Limonium vulgare, sea-couch Elymus pycnanthus, sea wormwood Artemisia maritima and hard-grass Parapholis striata (Perring & Walters 1976). It is thought that the controlling factor may be temperature, although as described below anthropogenic factors also restrict their occurrence on individual sites.

Northern saltmarshes are characterised by the absence of the above species rather than their replacement by other plants with a northern distribution. An exception is saltmarsh flat-sedge Sporobolus rupestris which can be dominant in the upper saltmarsh, notably on rocky or gravelly shores.

In the north and west there are more frequent transitions to non-tidal vegetation, notably grassland. In these regions the salinity of the regime is diluted by the high levels of rainfall, allowing non-halophytic plants to form a more significant feature of the vegetation. This is most clearly exemplified by the distribution of transitional grassland (Figure 8.1.14). The absence of extensive transitional communities, in the south and east particularly, is also a function of the extent of land-claim (see below).

Sites with communities transitional to sand-dunes are amongst the more important botanical examples of saltmarsh. In particular, on sites in south-east England, notably North Norfolk, there are species with an essentially southern and Mediterranean distribution. These include rare and scarce species such as shrubby sea-lime Sarcococcus, matted sea-lavender Limonium bellidiforme and sea-heath Frankenia laevis, the last species
and the structure of the marsh is altered. At the
most intensive grazing levels, experienced in
north-west England (up to 8.5 sheep per ha year-
round) (Gray 1972), 'lawns' of lightly grazed,
species-poor, grass-dominated marsh are
prevalent.

The significance of this for nature conservation
interest is considerable, not only in relation to the
diversity of saltmarsh plants, but also for the
structure of the plant communities. In its turn this
has important consequences for the associated
animals, notably terrestrial invertebrates and birds.

Enclosure of saltmarsh by the erection of earth
banks or other sea-walls has been an established
practice for centuries at some sites, notably in The
Wash, where some 32,000 ha of agricultural land
have been created. Historically, as the sea
receded, during periods of sea-level fall or when
saltmarsh accretion rates exceeded rates of sea-
level rise, saltmarsh expanded onto exposed
mudflats. As the number of tidal inundations
became less frequent the marshes were used more
extensively for grazing. The erection of a summer
earth bank extended the grazing period and
stronger defences ultimately resulted in the
complete exclusion of the tide.

As enclosure techniques improved, the saltmarsh
was bunded at lower and lower levels and the
resulting land area 'won' from the sea became
extensive. In Essex and north Kent, as much as
4,040 ha of the current agricultural land was
obtained in this way (Boorman & Ranwell 1977).
This same pattern of historical land-claim has taken
place in some of our major estuaries. Today many
are much smaller versions of the originals;
examples include the Ribble Estuary (Figure
8.1.15) and the Dee Estuary and North Wirral
(Figure 8.1.12), which have been reduced in area
by at least one third (see also Chapter 10.5).

The consequence for saltmarshes of these
sometimes extensive incursions is to remove from the
tidal regime the transitional and upper
saltmarsh communities, which are usually
biologically the most diverse. The implications
for the remaining marshes are that they have
proportionally more low marsh and pioneer
communities in relation to the total marsh area.

Figure 8.1.16 shows the area of each of the
saltmarsh survey communities for the 10 sites with
the largest total saltmarsh area. This clearly shows
the impact on the community mosaic across the
marsh of the repeated reclamations in The Wash,
where 80% of the saltmarsh is pioneer marsh or
low-mid marsh. By comparison, in the Solway
Firth, 80% of the remaining marsh is upper marsh.
The overall implications of this for the balance of
the community types is shown in Figure 8.1.17
where the areas are shown for two contrasting
NCC regions. The shift in proportion of community
type to the lower, species-poor end of the
spectrum in areas where there has been extensive
enclosure of saltmarsh is clearly shown.

occurring also at Merthyr Mawr (Ogmore Estuary)
in south Wales.

Anthropogenic factors are also significant in
helping to determine the type of saltmarsh
vegetation that develops. Grazing and enclosure
are the two most important, though the appearance
of common cord-grass Spartina anglica, a plant
which has been intimately associated with man on
the south coast, has also played a major role.

Grazing by domestic stock has been a feature of
saltmarshes for many centuries. Relatively low
densities (2 sheep or 0.33 cattle per ha) and open
range grazing are thought to be best from a nature
conservation point of view (Beaflink 1977).

As grazing levels increase, however, common
saltmarsh-grass Puccinella maritima and red fescue
Festuca rubra, which are nationally important and
diagnostic species of a wide range of low-mid and
mid-upper marsh communities respectively, are
given a competitive advantage. At the same time,
sensitive species such as common sea-lavender
Limonium vulgare and sea-purslane Halimione
portulacoides tend to be eliminated from the sward
The **Spartina** story

The history of *Spartina* is important and interesting in the context of both the development of saltmarsh vegetation and the conservation of winter bird feeding areas within estuaries. Prior to 1870 there was only one known species of cord-grass *Spartina* in Great Britain, small cord-grass *S. maritima*. This species, though never common, formed a significant community of the low marsh around The Wash, the Thames Basin and the Solent.

The accidental introduction of smooth cord-grass *Spartina alterniflora*, a native of America, to Southampton Water prior to 1870, and its subsequent crossing with the native plant, resulted in the appearance of a fertile amphidiploid, common cord-grass *S. anglica*, which is now the most frequent species encountered (see Marchant 1967 for a review of the origin of the species).

Since its appearance, the ability of *Spartina* to colonise open mudflats at a faster rate, and further seaward, than its rivals has been recognised as of potential benefit to man. As a consequence it was extensively planted throughout Britain (Hubbard & Stebbings 1967), in Europe, and even as far as China, as an aid to stabilisation of coastlines and a stimulus to enclosure and land-clain.

The benefit to nature conservation within estuaries is not so readily apparent. The rapid colonisation of
Although succession to other communities does take place these are themselves usually restricted in their species composition, and the general principle of control or eradication is the recommended course of action on sites of high wildlife value (Doody 1990).

Figure 8.1.18 provides a summary of Spartina distribution in the mid-1990s, derived from the NCC's Saltmarsh survey of Great Britain (Burd 1989) and the area of Spartina on review sites. Spartina occurs on 82 (52.9%) review sites. Spartina-dominated communities have a southern and western distribution and occur in generally small areas on only seven Scottish estuaries. In total Spartina dominates 6,774 ha of saltmarsh, 15.3% of the total estuarine saltmarsh area in Britain. The largest areas of Spartina are on the estuaries of southern England, particularly Poole Harbour and around the Solent. On these estuaries Spartina covers a major part of the total saltmarsh area: over 80% of saltmarsh is Spartina in Poole Harbour, and

**Figure 8.1.17** The distribution of major saltmarsh communities in two NCC regions with different extents of coast protection: a) East Anglia, with c. 60% of coastline protected by sea-walls and embankments; and b) North West England, with c. 30% of coastline protected by sea-walls and embankments, from Burd (1989). Names of main community types are listed in Figure 8.1.16.

Spartina over the extensive flats in sites with large wading populations of waders and wildfowl which feed in the intertidal zone has been identified as a major concern (see Chapter 8.6). As a consequence, there have been several attempts to control the species by spraying with herbicide in sites of high wildlife interest, for example the Caen Estuary in north Wales and Llandinarhe NNR in north-east England. These have met with some success although the current status of the species, which is expanding rapidly in north-west England and Wales, still poses a significant problem. Doody (1984) and, more recently, Gray & Belham (1990) give general discussions of the issue.

The impact of *S. anglica* on the native flora is also of some concern. Firstly, it appears that it may have helped the demise of the native *S. maritima*, though no causal link has been established. The latter is now much less widely distributed than formerly. Prior to 1930 it was recorded from 48 10-km squares, according to the Atlas of the British Flora. According to records since the 1930s, it had disappeared from 20 of these by the mid-1970s (Perring & Walters 1978). In addition, by taking over the mantle of the native pioneer species, *S. anglica* has altered the course of succession. Because of its invasive qualities it usually produces a mono-culture which has much less intrinsic value to wildlife than the normally occurring marsh.

**Figure 8.1.18** The distribution of Spartina-dominated saltmarsh on review sites, derived from data collected by the NCC's Saltmarsh survey of Great Britain. For each review site the size of the symbol shows the area of Spartina marsh and the filled segment shows the proportion of the total saltmarsh area of that site formed by Spartina marsh.
six of the 16 estuaries where Spartina covers over half of the saltmarsh area are on the Poole Harbour to Chichester Harbour coastline. These large areas and proportions of Spartina are there despite the phenomenon of ‘die-back’ that is being experienced on the south coast. This appears to be a natural process, although its cause is not fully understood. ‘Die-back’ is itself causing concern to those responsible for sea defence, as the demise of the saltmarsh can expose the toe of the sea-wall to greater wave attack. This is discussed in more detail below.

Large areas of Spartina occur also on the Severn Estuary and in Wales and north-west England (Figure 8.6.18). The present vigour of the species in north-west England and north Wales is giving some cause for concern. There extensive colonisation is taking place, notably in Morecambe Bay, although here as elsewhere in north-west England Spartina as yet forms only a relatively small proportion of the large saltmarsh area. In the Dee Estuary, which is at a later stage of development, much of the present large saltmarsh area has developed since 1910 as a result of rapid Spartina expansion (see Figure 8.1.12).

The importance of grazing management for saltmarshes

Grazing management has important consequences for the type of saltmarsh vegetation which develops, as has been discussed above. In summary, with little or no grazing by domestic stock (and in the absence of land-claim), saltmarshes:

- a) are rich in a wide variety of saltmarsh plants, including species-rich communities transitional to other vegetation;
- b) have a good structural diversity which provides important food for terrestrial invertebrates and habitat for breeding birds; and
- c) provide winter feeding for small populations of grazing ducks and geese.

Figure 8.1.19a shows a saltmarsh in north Norfolk with high wildlife interest: species diversity, and hence structural diversity, result in high invertebrate interest and high breeding bird numbers.

As grazing pressure increases and species and structural diversity decrease, the saltmarsh becomes less important floristically and relatively more important for animals (mainly birds) grazing on the palatable grasses that are favoured. Thus at the higher grazing levels (Figure 8.1.19b) saltmarshes:

- a) tend to have lower plant diversity, although some transitional communities may retain their species richness;
- b) have little or no structural diversity, resulting in a much reduced variety of terrestrial invertebrates and much lower densities of breeding birds; and
- c) provide important winter feeding for large numbers of grazing ducks and geese.

For a more detailed discussion of the principles see Doody (1987).

The assessment of the conservation value of any particular saltmarsh has to take into account each of the above factors. In fact, 101 review sites (65.7% of the total) have saltmarshes within Sites of Special Scientific Interest. This is dealt with in more detail below.

Conservation importance and protected status of saltmarshes

Saltmarshes are important for a variety of nature conservation reasons. They are a rare and specialised habitat in their own right. Overall, there are only 44,370 ha of saltmarsh in Great Britain. This compares with approximately 1,300,000 ha of peatland and 350,000 ha of ancient
semi-natural woodland (Burd 1989) — themselves rare in national terms. Many of the plants which occur there survive nowhere else and are specifically adapted to the high and often changing salinities of the soil and to regular tidal immersion.

Saltmarshes are among the most natural ecosystems remaining in Britain, especially where enclosure has not taken place and where grazing by domestic stock is either absent or present at a very low level. They support important and, in some cases, specially-adapted invertebrates which include a number of rare species (see Chapter 8.2). They are also home for a wide variety of breeding birds, and even where the communities are highly modified by domestic grazing they are still important in providing winter feeding grounds for sometimes internationally important numbers of waterfowl (described further in Chapter 8.6).

In addition to this they form an important and integral part of the life of an estuary, not only in relation to the interests described above but also as part of the functioning whole. As we have seen above, they sometimes make up a significant proportion of the estuarine system. By virtue of their high productivity, they can supply an important contribution to the primary sources of material for the complex food chains within an estuary (see Chapter 7).

The selection of sites within the SSSI series depends on a combination of features of conservation significance. Individual saltmarshes are selected primarily on the basis of their representation of the main types of geographical variation in the vegetation referred to above. In addition, the extent of the development of the full successional sequence from pioneer saltmarsh through the mid-upper levels and transitions to other habitats is an important factor. The presence of individual species (plants, invertebrate animals and breeding birds), including rare species, is a further consideration.

However, it is because of their importance to the functioning of the major estuarine systems and the survival of the large populations of winter feeding birds (wildfowl and waders — see Chapter 8.6) that a very high proportion — 83% in GB as a whole (Burd 1989) — of this habitat is protected as SSSI. This is not to denigrate the other interests, but their significance for birds is a much more obvious manifestation of the conservation value of saltmarshes.

Internationally, the largest area of saltmarsh is in the Wadden Sea where there is estimated to be a total of 35,000 ha. However, the total area of saltmarsh in Great Britain is greater than this. In addition, the sites are widely distributed and support communities which span the northern and southern elements of the European range of variation (Dikema 1984).

Site protection

Given these interests and the concentration of saltmarshes on review sites, it is perhaps not surprising that a high proportion of the saltmarshes within review sites are protected by designation as Sites of Special Scientific Interest. There are 101 Estuaries Review sites which include saltmarsh within the designated area.

Figure 8.1.20 shows the proportion of saltmarsh protected by SSSI status in Great Britain from information assembled between 1981-1986 (from Burd 1989). Of the 101 review sites with known saltmarshes, 39 have national importance as examples of saltmarsh habitat, i.e. they support a full and representative sequence of plant communities covering the range of variation in Great Britain. These places are named on Figure 8.1.21.

**Figure 8.1.21** The presence of saltmarshes within SSSIs on review sites. Nationally important saltmarshes are named.

Saltmarsh threats include the continuation of those activities which have historically caused substantial losses. These include enclosure (mainly for agriculture) and other 'land-claim' development,
Figure 8.1.20 The proportion of saltmarsh that is protected as SSSI in Great Britain, arranged by NCC regions, from Burd (1989)
through tipping and the building of roads, marinas and housing. More recently, proposals for tidal barrages have given great cause for concern since, whilst a tidal regime will normally continue, the modifications of the high tide levels and duration would have substantial effects on the higher saltmarsh zones. Moderation of the tidal regime would almost certainly cause a reduction in tidal levels and the number of tides reaching the upper saltmarsh levels. Such a change in tidal regimes after barrage construction can have rapid, dramatic and long-term effects on saltmarsh vegetation, as found for post-barrage vegetation changes in the Delta region of the Netherlands (see e.g. Hooghart & Posthumus 1989).

The continuing expansion of Spartina in north-west England also poses a threat to some aspects of estuarine conservation. By contrast in south and south-east England decay of the marsh and erosion, brought about by Spartina die-back in the former and, it is thought, sea-level rise in the latter, are resulting in major losses in these areas. Conservation measures must take into account these factors.

Recreation, including wildfowling, does not have a direct adverse impact on the saltmarsh habitat. Other activities such as pollution through effluent discharge, fertilizer outwash and oil, often quite toxic, materials are not known to have a long-lasting adverse effect on the habitat. Even oil pollution is not damaging to saltmarsh vegetation in the long-term if left to degrade naturally.

8.1.6 Sand-dunes

Introduction

Although sand-dunes are not so often intimately related to estuaries as are saltmarshes, sand-dunes are often found associated with them. In a number of places the extent of the sand and mudflats and saltmarshes which develop within an individual estuarine complex may largely depend on the presence of sand-dunes which afford protection from the higher energy environment to seaward. The two usual sand-dune formations which provide this protection are spits (to form 'bar-built' estuaries) and barrier islands (to form 'barrier-beach' estuaries), although sometimes more substantial hindshore dunes may occur (see Figure 8.1.22).

Sand-dunes normally develop in a higher energy environment than saltmarsh, an environment where by definition the larger-sized grains are moved by both the tide and the wind. The former deposits them on a high beach plain which, when large enough and exposed for long enough to enable it to dry out, makes material available to be driven on-land by wind. In this way, sometimes massive accumulations can occur, particularly on the west coasts, notably in northern Scotland, where prevailing and dominant winds reinforce each other.

The development of vegetation in this highly mobile environment is dependent on the establishment of specialist plants. As dunes develop above the strandline (the highest limit of the tidal range), plants such as marram Ammophila arenaria and lime-grass Elymus arenarius, which can tolerate rapid sand accumulation, comprise the major dune-forming species.

Behind this zone, grassland or heathland may develop. The type of vegetation is dependent on the age of the dune surface and the original calcium carbonate content of the beach sand. Rich plant and animal communities can occur where calcium carbonate content is high and may include a number of species specifically associated with dunes such as sea-holly Eryngium maritimum. As sand deposition decreases and the dunes become more stable, species-rich calcareous grasslands more typical of inland habitat types sometimes develop, under the influence of grazing. These often include orchid populations of considerable variety and, in a few cases, rarity.

On dunes with silica sand which is low in calcium carbonate or where leaching has removed it from the surface soil, dune heath may develop. Whilst this may support such a wide range of species, it is a rare habitat in its own right with a characteristic plant and animal association.

Details of the plant and animal communities and their importance are not given here; the most up-to-date description of the plant communities can be found in Rodwell (in press). The physical system is here considered to be the most important factor in relation to the conservation of Estuaries Review sites, and this is reviewed below.

Sand-dunes and estuaries

There are 30 British estuaries where sand-dune systems form a major component of the physical environment, and at least a further 25 sites have substantial sand-dunes associated with them. Their distribution is shown in Figure 8.1.23. Like saltmarsh the total area of sand-dunes in Britain is relatively small (c. 56,000 ha – Doody 1989) and, since many dune systems are on open coasts, the area associated with estuaries will be much less than this total. There are for example major dune systems in many parts of the Inner and Outer Hebrides, on the south Wales coast and on the Northumberland coast that are on open coasts rather than estuaries (Doody 1989). The precise contribution of estuaries to the British sand-dune resource will become clearer once the NCC’s current Sand-dune survey of Great Britain is completed.

Sand-dunes are widespread along the coasts of western Europe (Olson & van der Maarel 1989), with major stretches of dunes along much of the coast of Denmark, the islands of the International Wadden Sea, the coasts of The Netherlands and Belgium, the Atlantic coast of France and also on parts of the Irish and Spanish coasts. Dune systems
Figure 8.1.22 Major types of dune systems in Great Britain, from Ranwell & Boar (1986). All examples in this figure, except Bay of Crudin, are on review sites.
which is found in close association with review sites is the ‘barrier island’. These help protect the shore from wave attack and are often found in close association with shingle deposits. Estuarine conditions develop in their lee. The best example is Scott Head Island on the North Norfolk Coast where complex interactions between sand-dunes, shingle and saltmarsh also occur (see Figure 8.1.11). The critical factor in each of these examples is that the enclosing sand-dune provides shelter for the otherwise exposed coast. Behind it, in the quiescent water, the deposition of sediment can take place and the typical mudflats and saltmarshes develop. It is difficult to be precise about the fundamental role of sand-dunes, as opposed to cliffs or other hard structures, whether natural or man-made, or, as we shall see below, shingle structures, in the development and survival of estuaries. However, the above examples show that, in many cases, there is an important geomorphological interrelationship.

**Sand-dune stability**

The ability of sand-dunes to retain sand in relatively stable formations depends on several factors. Most important is the way in which vegetation helps bind the sand grains to create vegetated dune and dune grassland. Where dunes form an important component of the protection afforded to an estuary, their stability may be considered to be of critical importance. In this context a brief review of the patterns of vegetation development is appropriate.

Marram and lyme-grass are the principle dune-forming species in Great Britain. Sand is blown landwards and collects around these plants and, in some cases, buries them. Dune plants are specially adapted to accommodate this and assemblages may include a range of specialist drought-tolerant species in these early stages. As the dunes grow, other species invade and a more or less closed sward develops. Inland, sand deposition diminishes and the soil structure becomes more complex and stable. Plants specifically associated with sand-dunes decline in frequency and importance, and under certain circumstances scrub or even woodland may develop. These processes are described in a number of publications (see particularly Ranwell 1972). A simplified diagram of the processes is given in Figure 8.1.25.

To those concerned with the conservation of an estuary where dunes form an important component, the current status and likely future position of the dunes will be all-important. Thus a system which is highly mobile (i.e. consists of a high proportion of bare sand) may be considered to be a problem. However, in very few cases is this conclusion likely to be reached, given a full understanding of the relationship between the dunes and the estuary. It is likely that even if there is a catastrophic breakdown of the dune formation, it will be many months or even years before the effects are felt within the body of the estuary. Of more significance, particularly to the engineer or

---

**Figure 8.1.23** The distribution of major sand-dunes on review sites. Nationally important dune systems are named.

are also extensive along the southern shore of the Baltic Sea.

In Britain sand-dunes are most frequently found on an estuary as a spit or spits enclosing the mouth of the estuary. For a few small estuaries, such as the Esk in Cumbria (see Figure 8.1.24) and Loch Fleet in the Highland Region, the dunes form a major component in the development of the estuary. At many more they serve to enhance the protection afforded by other structures such as cliffs or shingle. They can be quite substantial, such as the Studland Peninsula which restricts the entrance to Poole Harbour and encloses an arm of the former estuary (now known as 'Little Sea'), or small, such as Gibraltar Point which has only limited and local influence on the extensive embayment of The Wash (Figure 8.1.24).

More substantial hindshore dunes may also have had a major influence on the development of a few estuaries. At Braunton Burrows, for example, a substantial dune has effectively overwhelmed the tidal land of the Taw-Torridge Estuary. A narrow estuary now exists with a substantial area of grazing marsh behind. The third type of dune
Figure 8.1.24 Examples of the scale of dune systems in relation to estuaries in Great Britain.
local planning authority, is the threat from flooding if an enclosing or protecting sand spit is lost.

Until now, the almost universal but erroneous view, even amongst nature conservationists, has been that sand-dune mobility poses a threat to both the dunes and the land behind them. Sand stabilisation has, as a consequence, become a major preoccupation at many sites, not only in Great Britain but also throughout the world. This has involved large-scale afforestation with pines, as at Tentsmuir in Fife at the north of the Tay Estuary (see Figure 8.1.26), and the sites where techniques for slowing down sand movement and fixing dunes have been undertaken are legion. Of the 50 review sites with sand-dunes associated with them, no less than 31 have operational sand stabilisation activities. Sand fencing (11 sites), marriam planting (20 sites) and the introduction of sea buckthorn Hippophae rhamnoides are amongst the more favoured options (see Ranwell & Bear 1998 for a recent analysis). This preoccupation has resulted in other, perhaps more damaging, changes taking place without their nature conservation significance being appreciated. Of these the most widespread is overstabilisation resulting in a loss of rich plant and animal communities. Rabbits may have played a critical role in the current status of sand-dunes, and the issues raised are discussed briefly below.

Sand-dunes and rabbits

Rabbits have probably been important agents in the development of sand-dunes since Roman times. Prior to the advent of myxamoxosis in 1953 they kept the vegetation short and introduced a degree of mobility in the system. Since then the drop in rabbit numbers, reduction in grazing of dunes by

Figure 8.1.26 Dune afforestation at Tentsmuir (Tay Estuary and Eden Estuary), from Doody (1989)
domestic stock and the success of stabilisation programmes have all served to fix dune landscapes, particularly in England and Wales. Thus whilst erosion is seen as a continuing problem at a number of localities with high recreational pressure, many sites are becoming overgrown with coarse grasses and scrub, to the detriment of their species-rich dune grasslands and dune slacks. The reintroduction of grazing or other methods of control of the rank vegetation is essential if the dunes are to retain their often precious wildlife interest. It is ironic that this problem is prompting the reconsideration of closing dunes to sand movement. The issues are discussed in relation to Holland by Wandelers (1989) and Great Britain by Doody (In press).

At first sight this approach might seem to be in conflict with the requirements of sea defence and the maintenance of shelter within estuaries. However, dunes are naturally mobile, and their formation is dependent on species adapted to the stresses imposed by this mobility. Allowing these natural forces to operate may in the long term provide a more cost-effective solution to the maintenance of the protection afforded to an estuary by a sand-dune. Crucial to this will be an understanding not only of the processes involved, but also of the ways in which the individual dune systems operate. This will require an extensive programme involving investigation of the relationship between dune development and the survival of the estuarine systems. This should result in a more complete understanding of the geomorphological setting in which estuaries and their associated habitats operate.

Conservation importance and protected status of sand-dunes

Sand-dunes are a rare and specialised habitat. They cover only approximately 58,000 ha in Great Britain. These are scattered widely but with particular concentrations in north-west Scotland. The machairs of the Western Isles, which, for the most part, are not associated with estuaries, form a large proportion of the total resource.

As with saltmarshes, at least in their early stages of formation they are relatively natural habitats. Modification by man, notably by their use as grazing for domestic stock, has created dune grassland. This is often rich in species, including those of calcareous grassland in addition to the more typical dune plants and animals.

Some dunes provide important breeding sites for birds, notably eiders Somateria mollissima in north-east Scotland and shelducks Tadorna tadorna throughout Britain (see Section 8.6.4). The beaches and bare mobile dune ridges can also be important nesting areas for gulls and terns. The dry, warm, open, sandy habitats provide favoured sites for some of our rarest reptiles, such as the smooth snake and sand lizard, and almost all Britain's natterjack toad breed in dune slacks associated with estuaries (see Chapter 8.5).

The selection of sand-dune sites for statutory designation as SSIs is determined on the basis of the representation of the full sequence of vegetation types, from mobile foredunes, dune grassland (or heathland) and dune slacks and transitions to, for example, saltmarsh, shingle or, in a very few cases, scrub and native woodland. Size is an important consideration, as is freedom from massive human interference such as forestry. The presence of rare characteristic invertebrates, together with the rare amphibians and reptiles, also provides a justification for notification.

All of the national sites identified as forming an important component of the estuarine environment are designated in whole or in part as SSIs. The majority of the other sites shown in Figure 8.1.23 are also designated as SSIs.

Threats to sand-dunes

Historically the planting of forests of non-native pine has caused a major loss of natural sand-dune habitat, affecting some of the largest sites. Culbin Sands (Moray Firth), for example, was once the largest mobile dune system in Great Britain, but is now almost completely stabilised and covered in pine forest. Additional adverse impacts affecting important nature conservation sites in decreasing order of significance are:

1. housing and industrial development,
2. static caravans and other recreational building,
3. airfields and roads,
4. golf courses and general recreation,
5. Ministry of Defence use, and
6. intensive agriculture, including cultivation and grazing.

Paradoxically, whilst all of these have caused direct destruction of the sand-dunes upon which either buildings or other surface structures were placed, some may have helped to protect the body of the dune from more extensive damage. Principle amongst these is their use by the MoD for bombing practice which, because of the large safety zones involved, prevents other more damaging activities from taking place (see Boorman 1977 and Doody 1989). However, even here protection is not assured. The recent decision by Shell (UK) to let a contract to develop a pipe fabrication facility in one of the most ecologically sensitive parts of Morrice More (Dornoch Firth) – nearly three years after the Secretary of State for Scotland granted permission following a Public Inquiry where the NCC, amongst others, objected – is extremely regrettable.

Threats to sand-dunes today come in a variety of forms. They include a continuation and increase in the activities described above. In addition a continuation of the process of stabilisation is certain to reduce species diversity in the long term, unless
remedial action is taken to either re-expose the dunes to a degree of mobility and/or reintroduce grazing. Recreation, whose effects stabilisation is often intended to ameliorate, is usually a localised problem. The techniques for dealing with this through remedial action and people-management are available and widely understood.

In the longer term, effects of the dune fronting and increased wave attack at the base of the dune. When combined with extraction of offshore sediments, which may serve to exacerbate the dune fronting, serious wholesale erosion could take place.

Few dunes in Great Britain are today prograding (i.e. creating new dunes to seaward of existing ones). Most appear to be fossilised in their present location or retreating landwards. Under attack from the sea and with major development landward (forests, recreational facilities, housing etc.), the natural response will be to try to defend the dune in its present location. However, as has already been indicated, dunes are naturally unstable and, if left to their own devicess, exist in a dynamic equilibrium. The foreshore sand which builds up in the dunes forms a reservoir of material which can replenish the beach during storms and helps to buffer the coast from wave attack (see Carter & Stone 1989).

A much more informed and enlightened approach to sand-dune management is required if they are to continue to perform their sea defence, nature conservation and recreational roles. This must be based on a better understanding of the way they behave and in particular on the role they play as an integral part of an estuarine system. Given this better understanding, it may be recognised that mobility may be an important characteristic of dunes and that all ‘erosion’ is not necessarily ‘bad’.

This approach will also require local authorities, who see their responsibilities to the recreational visitor on beaches and dune systems as paramount, to recognise the implications of some of their activities. For example, ‘beach cleaning’, which involves the removal of the strandline material, is practised to provide clean beaches for visitors in some areas. The link between the erosion of the dunes behind and this activity seems not to have been generally recognised.

At other sites, subtidal dredging for sand has not been directly linked with beach and foredune erosion nearby. However, given the predictions for sea-level rise, it would be prudent to look at the sediment budget, both within and outside estuaries, and review the system for granting extraction licences.

8.1.7 Shingle

Introduction

Shingle structures develop in high energy environments where the sea can move and pile up larger sized pebbles on shore above the normal tides. These pebbles may range from 2 mm up to 200 mm, though the normally encountered range on mobile shingle is 2 mm – 60 mm. The structures so formed include narrow fringing shorelines, and where successive beaches are piled against each other large systems can sometimes form, with predominately terrestrial habitats. As far as estuaries are concerned, there are very few examples of a shingle structure being a significant determinant of the form and location of intertidal habitats. Individual examples (mostly shingle bars or spits) are discussed below. In some cases they are mixtures of shingle and sand-dune, the sand-dune normally forming over the shingle bar and obscuring it, making the relative importance of the two structures difficult to determine. However, the shingle structures identified in relation to Estuaries Review sites are those where exposed shingle forms a significant part of the site (Figure 8.1.27).

![Figure 8.1.27 The distribution of major exposed shingle systems associated with review sites. Nationally important shingle sites are shown with an asterisk.](image-url)
Shingle structures and estuaries

The relationship between shingle structures and estuaries is very important, where they coincide. The major coastal lagoon of The Fleet is wholly dependent for its existence on Chesil Beach. The long river estuary of the Ore/Ade/Butley has been progressively pushed southwards since the original opening was closed by the southern development in about 1500 AD of Orfordness shingle spit, now one of the most important shingle spits in Great Britain. The Blakeney Point spit provides conditions for sand-dune, mudflat and saltmarsh development, as does the Culbin Shingle Bar in north-east Scotland. Both protect the inner coastline from major wave attack and allow relatively sheltered conditions to exist in which important saltmarshes are a major factor in the survival of the associated estuarine habitat. There are seven shingle sites of national importance, five of which are associated with Estuaries Review sites – Orfordness (Ore/Ade/Butley Estuary), Culbin Shingle Bar (Moray Firth), Chesil Beach (The Fleet), the Kingston Shingle (Seyy Estuary), and Blakeney Point (North Norfolk Coast) (Figure 8.1.27).

Stable shingle structures develop a variety of vegetation types. These include species, such as sea-kale Crambe maritima, specially adapted to the unstable and exposed nature of the storm beach associated with most shingle. Behind this, in the spray zone, maritime plants may occur and, sometimes, extensive lichen-rich vegetation. Acid grassland, heath or scrub may be found on the larger sites. In the highest energy environments none of these has a particular influence on the stability of the shingle since the forces acting upon them are much greater than any binding action of the plants. However, Carey & Oliver (1918) discussed the way in which shrubby sea-bright Suaeda vera helped build up the shingle at Blakeney Point.

In order to consider the conservation of these important shingle areas in relation to the Estuaries Review, it is most useful to look at some individual sites.

Chesil Beach

Chesil Beach is a 29 km bank of shingle which, over most of its length, encloses the largest lagoon in Great Britain (The Fleet). This shingle structure ranks among the four most important shingle sites in Great Britain, the others being Dungeness, Orfordness and the Culbin Shingle Bar.

Over much of its length the wide bank is devoid of vegetation; however, at the western end extensive stands of the specialist shingle plants sea-kale and sea-pea Lathyrus japonicus occur. Additional small patches of closed maritime vegetation, with thrift Armeria maritima and sea plantain Plantago maritima, occur on the more stable sections of the beach.

The biggest threat to this site is the extraction of shingle. Recent unlawful removal showed that, despite statutory protection, damage can occur. More difficult to control is the legitimate artificial protection of the beach near Portland to prevent overtopping and flooding. There is little doubt, however, that too much interference would detract from the scientific value of the site as a unique shingle feature. The future of the site and The Fleet which it protects may lie in a more thorough knowledge of its origin and development. Several authors have considered this (see Steers 1946), although no firm conclusions have been reached about its origin.

Orfordness

In contrast to Chesil, this beach consists of a ness, with several beaches piled upon each other, which has slowly migrated southwards. In front of it a shingle spit (Orford Beach) has been extending rapidly along the coast since at least about 1530 AD, when the early maps showed the village of Orford as a thriving port (Anon 1966). Since then the river Ore’s exit to the sea has been pushed progressively further south-west, until today it is some 6 km from the village (Figure 8.1.28).

![Figure 8.1.28 The historical development of Orfordness (Ore/Ade/Butley Estuary), from Beadell et al. (1988)](image-url)

The area of the spit south of the land owned by the Ministry of Defence, designated as a National Nature Reserve, contains probably the finest undisturbed shingle vegetation in Great Britain. In addition to the specialist shingle plants, it has an acid shingle heath second only to Dungeness and a fine, extensive and probably unique example of maritime lichen-covered shingle.

Whilst the future of the National Nature Reserve seems assured, the area of the Ness to the north is not. Past use for a wide range of military activities, development of gravel extraction and public access have all taken their toll on the surface of the shingle and its vegetation. The management of the beach at Orfordness to raise the sea defences has also not been sympathetic to the origins and development of the site. Fuller & Randell (1988)
suggest that, far from helping, these latter activities "have greatly restricted the width of the beach, threatening to worsen the situation...".

Culbin Shingle Bar

Culbin Shingle Bar acts much like the sand/shingle barrier islands already described, notably those on the North Norfolk Coast. Behind the protection afforded by the bar the high beach plain is sheltered and flats and saltmarshes occur. The extensive Culbin sand-dunes lie inland of this, and the bar is thought to be the latest of the series of ridges upon which the dunes have developed.

In the seventeenth century, the bar extended as a spit right across the mouth of the River Findhorn. The present bar represents the westernmost 55 ha of this spit, which is eroding at its eastern end, moving westwards. It remains one of the least disturbed sites in Great Britain and shows important coastal processes in action. The vegetation patterns and sequence in relation to the ages of individual shingle ridges are also significant. A detailed description of the site is provided by Fuller (1975).

Most other shingle structures occurring in association with Estuaries Review sites are of less conservation importance in their own right. Walsey Island, however, is an important shingle bar with extensive dune cover, enclosing part of Morecambe Bay and the adjacent Duddon Estuary.

Conservation and protected shingle sites

The nature conservation importance of vegetated shingle structures lies in the development on them of plant communities unique to such structures. Notable amongst them are those maritime lichen-dominated communities and the mostly single-species stands of plants adapted to growing just above the most mobile parts of the shore. The larger sites are also of considerable geomorphological significance. All the sites shown on Figure 8.1.27 are designated as SSSIs. The biggest threat to these important sites is from disturbance of the surface shingle. The tracks from a single passage of a vehicle over long-established vegetated shingle will remain visible indefinitely. Extraction of material, whether for construction or sea defence, destroys the shingle surface and its vegetation. When coupled with unsympathetic sea-defence measures, these activities can affect the sites to a considerable degree. As with other sedimentary habitats, understanding of the origins and development of each site is essential if long-term damage is not to be caused, which might ultimately in its turn threaten the associated estuarine habitats.

The problem of the stability of Hurst Spit (Lymington Estuary) in Hampshire provides an important illustration of the problem. This narrow spit provides protection for a major part of the intertidal land of the Solent. Recent storms breached this and only rapid action by the sea-defence authority prevented a major rupture. However, the seeds of this problem may lie in the extraction of gravel taking place elsewhere in the system and preventing the natural replenishment of the spit.

8.1.8 Sea cliffs

Introduction

Sea cliffs are rarely intimately associated with estuaries. Their geographical location may, however, form an important element in the way in which estuaries develop, since they can provide shelter from wave action, as do shingle or sand bars. However, their importance more often lies in the way they provide material for deposition within the estuary through erosion. In this section, therefore, the general features of cliffs associated with estuaries are described.

Cliff formations in Great Britain represent a range of rock types, from the hard granites of north-east Scotland, through the limestones of south Wales and the chalk cliffs of the south coast to, perhaps most importantly, the boulder clay cliffs of Holderness and further south on the east coast. These last are particularly important since they often provide the source material for estuarine structures - the shingle bars and sand-dunes as well as fine sediments. The Holderness coast, for example, may be the main source of fine material for the Humber Estuary, Lincolnshire coast and The Wash (see below).

Vegetation on cliffs

Cliffs support a range of vegetation types which are important in their own right. Their value as seabird nesting areas is discussed in Section 8.6.4. Hard rock cliffs (including the harder limestones) often support important examples of species-rich calcareous grassland. The more acid rocks, notably in north Scotland, can have high quality heathland vegetation. The coastal nature of the communities is emphasised in many main ways, first by the direct effects of exposure to salt spray and secondly by the effects of exposure to high winds, notably in the north and west. In the south and east and along some parts of the sheltered west coast, by contrast, the warmth of the sea may soften the climate.

These factors combine to give a range of variation which provides for a zonation inland across the cliff which is related to the maritime influences. Superimposed on this is the influence of the underlying geology which in the more stable rock types allows heathland or calcareous grassland to develop. In the most exposed situations, where the cliffs are drenched in salt spray, there are communities very similar to those of upper saltmarshes. However, more usually a few coastal plants such as sea campion Silene maritima and thrift are present as a narrow zone seaward of
the more inland community types. The effects of exposure to the prevailing winds can be seen in the wind-pruned scrub and stunted woodland of parts of south-west England and south Wales, notably Pembrokeshire.

Geographically the ameliorating effects of the coastal situation on the vegetation can be seen in the south-east, where the chalk cliffs of Beachy Head support grasslands with a number of thermophilous plants. In the north and west, the warm, wet winds facilitate the development of lichen- and moss-rich communities in woodland, mostly associated with the sea-lochs in Scotland. Sea cliff communities are described in the NVC (Rodwell in press).

Vegetation of the softer, slumping cliffs in south, south-east and eastern England can be very different. By its very nature, it comprises more ephemeral communities. Maritime effects, notably of salt spray, are also reduced as the sites are mostly situated away from the prevailing westerly winds and absorb rather than reflect wave energy. In this way they make sediment available through erosion at the bottom of the cliff slope, helping to retain mobility of sediments on the cliff face. The rate at which this takes is removed helps to determine the degree of stability in the soils above, resulting in a range of community types from closed scrub and woodland to open skeletal communities with a few ephemeral species.

The vegetation of cliffs and cliff tops has been modified by the long history of management of accessible areas mainly for agriculture, especially grazing of domestic stock. Whilst this continues in Scotland (with sheep), in much of England and Wales, the move away from more pastoral agriculture to intensive arable farming has resulted in losses of important open cliff vegetation. This has occurred principally through the direct loss of cliff-top vegetation to ploughing and seeding or conversion to arable land. However, the growth of rank grassland and scrub at the expense of species-rich grassland and heath has also been a major problem. Resolution of these issues is the subject of an NCC contract with Lancaster University, due to report in 1990. Reintroduction of grazing appears to be a major requirement if the value of some of the more important of the cliff and cliff-top grasslands is to be retained.

**Coast protection**

Coast protection is the second major issue affecting the soft coastlines of Great Britain. From a biological point of view, the effects are important. The use of concrete sea-walls, groynes or other structures to protect the toe of the cliff from erosion has important consequences for the vegetation and its associated animals, notably invertebrates. The presence of the protection may have the desired effect of slowing down erosion. This may occur at such rate and to such an extent that cliff stability (the engineer's desired state) is reached. Given time, this stability will result in the development of scrub and eventually woodland at the expense of the more open and, from a nature conservation point of view, often more interesting plant and animal communities.

The number of cliff sites protected as Sites of Special Scientific Interest and directly associated with Estuaries Review sites is small (see also the section on Geological Conservation Review Sites in Chapter 9). The future of these sites may not be directly related to the development of policies concerned with the conservation of estuaries. However, it is important to recognise that they do form part of the coastline and may in some instances be critical to estuary survival. Examples include the Naze in Suffolk and Hengistbury Head in Sussex, both of which are rapidly eroding and would expose the estuaries of Hamford Water and Christchurch Harbour respectively to wave attack if they disintegrate entirely. It is debatable from a nature conservation point of view whether this would be acceptable. In general, however, there is much advantage in allowing some of these natural processes to take place and for the coastline as a whole to re-adjust.

Protection of eroding cliff lines can be successful, though it often requires a considerable input of funds. In the long term it seems possible that the compartmentalisation of a coastline, where some areas are protected and some not, could lead to a greater likelihood of the catastrophic collapse of protected cliffs. Again, a better understanding of the mechanisms of cliff retreat and the role of beaches in protecting them may be important. Insofar as estuaries are concerned, the contribution of sedimentary material from eroding cliffs to the sediment budget of an estuary also requires a better understanding, if estuary conservation is to be fully integrated with other coastal uses.

### 8.1.9 Strandlines

A strandline is the accumulation at different high water levels along the upper shore of organic and inorganic material. Because of their position, strandlines are mostly ephemeral, and where they persist on the sheltered shores of estuaries they tend to be composed mainly of litter and rotting organic matter. However on exposed shores strandlines can be extensive. Here they can act as precursors to sand-dunes. On the few shores where sand-dunes are accreting progressively seaward (progressing), the species of the strandline, such as sea sandwort *Honkenya peploides*, prickly saltwort *Salsola kali* and sea rocket *Cakile maritima* form an important first stage in the process of trapping sand. Without these species the development of foredunes may be inhibited. This could have significant consequences for dune stability, particularly in areas of high recreational pressure. The practice of 'beach-cleaning' mentioned above is an important consideration, and recent proposals to extend this activity in north Wales give considerable cause for concern.
Deposits of litter at the upper tidal range can occur within estuaries and result in strandline communities developing. These may include species such as orache *Atriplex* spp., including grass-leaved orache *A. littoralis*, which may themselves act as precursors for other vegetation. In a very few sites sea wormwood *Artemisia maritima* may occur in this upper shoreline, and, whilst normally associated with upper saltmarsh, it is an important food plant for a wide variety of invertebrates, notably the rare Essex emerald moth *Thecidia smaragdaria*. No strandline conservation sites of importance have been identified separately on review sites.

### 8.1.10 Marine/maritime islands

There is virtually no direct relationship between marine/maritime islands and estuaries, except as far as they may reinforce the general patterns of shelter afforded by other physical structures (cliffs, bare etc.). However, there are a few islands which exist within the body of some estuaries. It is important to recognise their existence, since policies relating to the conservation of an estuary as a whole may well influence what happens on these islands. Examples include Flat Holme and Stoep Holme in the Severn, Hilbre Island in the Dee and the several islands in the Firth of Forth.

The importance of most of these areas is as habitat for birds, notably for breeding seabirds. Some of these birds rely on the associated estuary for their food. Some islands also support rare plants. Construction development of these areas may be the most serious threat, since they can provide firm foundations for proposed river or estuary crossings or barrages.

### 8.1.11 Saline lagoons

**Introduction**

Until recently Britain’s saline lagoon resource was poorly understood. Between 1984 and 1989 the NCC commissioned surveys to document the distribution and abundance of saline lagoons in Britain. During this work 444 potential sites were examined of which 210 were investigated in detail. Barnes (1989a) and Sheader (1989), in their overview reports for the NCC, carried out a conservation appraisal of all the sites considered, and these reports form the basis of this section.

Coastal saline lagoons occur in Britain mainly on the east and south coasts. The exact number of saline lagoons in Britain is difficult to determine as definitions vary between workers. For this review, lagoons are defined as those sites which fit into the two categories defined below or which contain species of animals and plants specific to lagoonal or brackish habitats. Lagoons can have salinities varying from less than 1‰ to full-strength sea water or may even be hypersaline.

**Types of saline lagoon**

There are two main types of saline lagoons: natural saline lagoons, formed behind shingle or sand barriers, and artificially constructed coastal saline ponds.

Saline lagoons are natural physiographic features consisting of shallow open bodies of brackish or saline water, partially separated from an adjacent coastal sea by a barrier of sand or shingle. All or most of the water mass is retained in the lagoon at low tide. Sea water is exchanged directly by a natural or man-modified channel or via percolation through, or overtopping of, the sediment barrier (Barnes 1988a). Barnes (1989a) splits this category into eight types on the basis of lagoon location and physiornorphological characteristics.

Coastal saline ponds comprise of a variety of artificially or naturally formed brackish or saline water bodies, which do not fit into the ‘natural saline lagoon’ category defined by Barnes, but which nevertheless have physical characteristics and species composition similar to those of natural saline lagoons (Sheader 1989). Sheader (1989) further divides this major category into five types using similar principles to Barnes (1989a).

The numbers of each of the major types of British saline lagoons are shown in Figure 8.1.29. Most lagoons occur as silled ponds, where there is some degree of direct exchange of water with the sea and where water is retained a low tide by a sill at the mouth. Lagoons that are isolated from the sea in saltmarsh or grazing marsh and receive seawater input periodically or, to a lesser extent, by seepage, form the next commonest group. Percolation pools, where seawater exchange is through a shingle barrier separating the lagoon from the sea, are less common still, whilst sea inlet lagoons are the least common type, accounting for only a handful of sites.

![Figure 8.1.29 The numbers of British saline lagoons of different lagoon types. Shaded areas represent those on review sites.](image)
The proportions of artificial, natural and mixed origin lagoons and ponds are shown in Figure 8.1.30. High proportions of all lagoon and pond types occur on Estuaries Review sites. Lagoons with an artificial origin are more common than natural lagoons and are formed as a result of a wide range of man's activities including sea-wall construction, the digging of borrow pits and the construction of drainage systems in low-lying land bordering estuaries.

![Graph showing the numbers of British saline lagoons of different origins](image)

**Figure 8.1.30** The numbers of British saline lagoons of different origins. Shaded areas represent those on review sites.

The distinction between 'natural' and 'artificial' saline lagoons is not, however, entirely clear-cut. Some of the different categories describe the same physical situation, the only distinction being that of natural or man-made origin. Most, if not all, naturally formed lagoons are modified by man. For example, The Fleet in Dorset is a good example of a natural lagoon formed by the isolation of a marine bay by the longshore shingle barrier of Chesil Beach (see also Section 8.1.7). However, the entrance channel to The Fleet has recently been considerably modified by man in order to rebuild a bridge. In addition the overall hydrography of The Fleet may have been modified by the earlier construction of Portland Harbour at its mouth.

**Distribution**

Saline lagoons are present on 37 Estuaries Review sites (Figure 8.1.31), with major concentrations around the Humber, the Thames Estuary and the Solent system. Only a limited amount of survey work has been carried out in Scotland, so it is unclear if the scarcity of lagoons on review sites in Scotland is as marked as it appears from the available data. The bulk of saline lagoons in Britain are very small (Figure 8.1.32), the majority being less than 10 ha in area and most as small as 1 ha or less. Taken together the total saline lagoon resource for Britain currently stands at around 770 ha. This does not including large sites such as The Fleet, Poole Harbour and Christchurch Harbour. All these sites have been classified by some authorities as lagoon in character, but for the purposes of the Estuaries Review they have been included within the classification of bar-built estuaries (see Chapter 5). By area, about 83% of the British saline lagoon resource can be found bordering Estuaries Review sites. If the three large sites are included as lagoons then the British resource increases to about 3,900 ha.

![Map showing the distribution of review sites with saline lagoons](image)

**Figure 8.1.31** The distribution of review sites with saline lagoons.

Barnes (1989b) and Shearer (1989) carried out a conservation appraisal of important coastal saline lagoon sites for the NCC. Natural lagoons and saline ponds were considered separately, but each site was assessed on a scoring system using an adaptation of the 14 criteria used by the NCC for appraising the conservation potential of sites. These criteria are defined in Chapter 8.3 (Aquatic estuarine communities).

For natural coastal lagoons, the best representatives of their type are listed in Table 8.1.3. Over half occur on Estuaries Review sites or form complete review sites.
fresh water, estuarine brackish water or the sea. These species are listed in Table 8.1.5. Five of these species are protected under Schedule 5 of the Wildlife & Countryside Act 1981. Of these five species, Ivel’s sea anemone Edwardsia ivelli is only known from Widewater Lagoon, West Sussex, near the mouth of the Adur Estuary. This lagoon has degraded over recent years, probably owing to reduced water percolation through the coastal defence works and to reduced freshwater input resulting from isolation of this lagoon from the surrounding marshland. An extensive search of the lagoon in the summer of 1990 failed to find any specimens of this anemone and it is highly likely that this species is now extinct worldwide.

The starlet sea anemone Nemastoma vectensis is restricted to southern Britain with major populations on review sites around the Solent and the Isle of Wight. Another protected lagoon species is the lagoon sandworm Armadilla cariosa. This also has a southern distribution but is restricted in Britain to just one review site on the Solent. The lagoon sand shrimp Gammarus insensibilis has a wider but also southern distribution and has been recorded from review sites stretching from around the Solent to the Humber on the North Sea coast. The other scheduled lagoon species is the foxtail stonewort Lamprothamnion papulosum, an aquatic plant which is limited in distribution to just three review sites around the Solent and Isle of Wight.

**Conservation of British saline lagoons**

British saline lagoons occur on the coastal fringe, an area of land particularly susceptible to damage from the construction of coastal defences and other engineering works. New lagoon formation is now therefore very restricted owing to a lack of suitable sites. In the north Atlantic, coastal saline lagoons formed in macrotidal conditions are a relatively short-lived feature. The natural rate of formation of new lagoons will inevitably be insufficient to replace lagoons as they are lost through natural processes of succession to freshwater lakes, fen or carr, or are lost through man’s activities. Natural coastal lagoons as a physiographic feature are a rare and diminishing resource.

<table>
<thead>
<tr>
<th>Saline lagoon site</th>
<th>Estuaries Review site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Blakeney Spit Pools, Norfolk</td>
<td>North Norfolk Coast</td>
</tr>
<tr>
<td>2 Holkham Salts Hole, Norfolk</td>
<td>North Norfolk Coast</td>
</tr>
<tr>
<td>3 Broadwater, Norfolk</td>
<td>North Norfolk Coast</td>
</tr>
<tr>
<td>4 Beacre Broad, Suffolk*</td>
<td>–</td>
</tr>
<tr>
<td>5 Shingle Street/Bawdsey, Suffolk*</td>
<td>–</td>
</tr>
<tr>
<td>6 Widewater Lagoon, W. Sussex</td>
<td>Adur Estuary</td>
</tr>
<tr>
<td>7 Bebridge Lagoons, Isle of Wight*</td>
<td>Bebridge Harbour</td>
</tr>
<tr>
<td>8 Christchurch Harbour, Dorset</td>
<td>Christchurch Harbour</td>
</tr>
<tr>
<td>9 Poole Harbour, Dorset*</td>
<td>Poole Harbour</td>
</tr>
<tr>
<td>10 The Fleet, Dorset*</td>
<td>The Fleet &amp; Portland Harbour</td>
</tr>
<tr>
<td>11 Swanpool, Cornwall</td>
<td>–</td>
</tr>
</tbody>
</table>
### Table 8.1.4 Important coastal saline lagoon sites in Britain (Sheard 1989).

<table>
<thead>
<tr>
<th>Saline lagoon site</th>
<th>Status</th>
<th>Estuaries Review site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Easington Lagoons, N. Humberside</td>
<td>**</td>
<td>Humber Estuary</td>
</tr>
<tr>
<td>2 S. Killingholme Lagoons, S. Humberside</td>
<td>**</td>
<td>Humber Estuary</td>
</tr>
<tr>
<td>3 Humberston Fitties, Lincolnshire</td>
<td>***</td>
<td>Humber Estuary</td>
</tr>
<tr>
<td>4 Aldburgh, Suffolk</td>
<td>***</td>
<td>–</td>
</tr>
<tr>
<td>5 Cliffe Marshes Lagoons, Kent</td>
<td>***</td>
<td>South Thames Marshes</td>
</tr>
<tr>
<td>6 Pagham Lagoons, W. Sussex</td>
<td>***</td>
<td>Pagham Harbour</td>
</tr>
<tr>
<td>7 Widewater Lagoon, W. Sussex</td>
<td>*</td>
<td>Actur Estuary</td>
</tr>
<tr>
<td>8 Birdham Pool, W. Sussex</td>
<td>*</td>
<td>Chichester Harbour</td>
</tr>
<tr>
<td>9 Fort Cilficker Moor, Hampshire</td>
<td>***</td>
<td>Portsmouth Harbour</td>
</tr>
<tr>
<td>10 Little Anglesey, Hampshire</td>
<td>**</td>
<td>Langstone Harbour</td>
</tr>
<tr>
<td>11 Shut Lake, Hampshire</td>
<td>***</td>
<td>Lymington Estuary</td>
</tr>
<tr>
<td>12 Keyhaven – Lymington Lagoons, Hampshire</td>
<td>***</td>
<td>Bembridge Harbour</td>
</tr>
<tr>
<td>13 Brading Marshes system, Isle of Wight</td>
<td>***</td>
<td>Taw-Torridge Estuary</td>
</tr>
<tr>
<td>14 Horsey Island Pool, Devon</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

** Of considerable conservation value
** Strongly recommended for conservation
* Recommended for conservation

### Table 8.1.5 Specialist British lagoonal plant and animal species

<table>
<thead>
<tr>
<th>Plants</th>
<th>Mollusca (Molluscs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chara canescens</td>
<td>Hydrobia ventrosa</td>
</tr>
<tr>
<td>Chara baltica</td>
<td>Hydrobia neglecta</td>
</tr>
<tr>
<td>Chara conviva</td>
<td>Ophiura aculeus</td>
</tr>
<tr>
<td>Lamprothamnium papulosum</td>
<td>Littorina tenebrosa</td>
</tr>
<tr>
<td>Polyepina n. midica</td>
<td>Tenellia adspersa</td>
</tr>
<tr>
<td>Ruppia maritima</td>
<td>Cerastoderma glaucum</td>
</tr>
<tr>
<td>Chaetomorpha linum</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cnidaria (Anemones and hydrooids)</th>
<th>Bryozoa (Bryozoaes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lacmedia loveni</td>
<td>Conopeum seurati</td>
</tr>
<tr>
<td>Edwardsia trelly</td>
<td>Victorella pavida</td>
</tr>
<tr>
<td>Nematocesta vectensis</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polychaeta (Polychaete worms – Anellida)</th>
<th>Insects (Insects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armandia curiosa</td>
<td>Sigara selecta</td>
</tr>
<tr>
<td>Alkmna romjini</td>
<td>Sigara stagnalis</td>
</tr>
<tr>
<td></td>
<td>Sigara coccmna</td>
</tr>
<tr>
<td></td>
<td>Agabus conspersus</td>
</tr>
<tr>
<td></td>
<td>Berosus spinosus</td>
</tr>
<tr>
<td></td>
<td>Coelambus paralleliparamns</td>
</tr>
<tr>
<td></td>
<td>Dytiscus circumsidus</td>
</tr>
<tr>
<td></td>
<td>Enochus bicolor</td>
</tr>
<tr>
<td></td>
<td>Enochus melanocephalus</td>
</tr>
<tr>
<td></td>
<td>Enochus halpilatus</td>
</tr>
<tr>
<td></td>
<td>Halplus apicille</td>
</tr>
<tr>
<td></td>
<td>Ochthebius marinus</td>
</tr>
<tr>
<td></td>
<td>Ochthebius punctatus</td>
</tr>
<tr>
<td></td>
<td>Paracyzus aeneus</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coastal saline ponds, however, although vulnerable to destruction by man, can be more easily conserved and may be created as new habitats. They are also important refuges for lagoonal species and, if suitably managed, form a habitat indistinguishable from naturally formed lagoonal habitat.

Both naturally and artificially formed lagoons, being small and shallow, are fragile and vulnerable. They are very susceptible to minor changes to their retaining barriers and salinity regimes and are particularly vulnerable to pollution, having only a limited ability to buffer changes in water quality. Many are potentially relatively easily claimed to form land, isolated from the sea to form freshwater lakes, or dredged to form harbours and marinas. Rising sea levels over the coming decades will place further pressures on coastal lagoons, and construction, or reconstruction, of sea-walls to combat this threat may cause an increased rate of loss of this habitat, unless such developments are carefully managed.
8.1.12 Coastal grazing marshes

Introduction

Grazing marshes are areas of flat low-lying grassland drained by complex networks of freshwater or brackish drainage ditches. These ditches control water levels, and provide supplies of drinking water for cattle and sheep and act as ‘wet fences’ to keep stock within the fields. Some of the best known grazing marshes are not coastal, for example the bulk of the Somerset Moors and the Pevensey Levels in East Sussex, but others have a degree of brackish influence stemming from their coastal location and many of these are closely associated with review sites. Figure 8.1.33 shows that coastal grazing marshes and other lowland wet grasslands are associated with at least 59 review sites. Most are in England, particularly in southern and eastern England, and the most extensive grazing marshes have been associated with review sites in south-east England. The few sites in Scotland are chiefly areas of wet machair grassland adjacent to review sites. They form part of the very extensive machair systems in these regions, most of which are not directly associated with review sites (Fuller et al. 1986).

Coastal grazing marshes generally originated through land claim of estuarine saltmarsh by the construction of enclosing sea-walls, although sometimes they have developed to lagoonward of natural barriers such as sand-dunes or shingle storm-borders. Many grazing marshes have been in their present condition only since the introduction of pumped drainage, often post-war; previously they flooded regularly, either with fresh water or, occasionally, sea water. Most grazing marsh in its present state is probably less than 200 years old, yet this recently developed habitat contains many features of value for nature conservation.

Grazing marsh grasslands

The grasslands of coastal grazing marshes are typically dominated by the more common grasses of neutral soils, for example meadow fox-tail Alopecurus pratensis, crested dog’s-tail Cynocurus cristatus, rye-grass Lolium perenne and meadow barley Hordeum secalinum. They contain few species in comparison with inland unimproved pastures and hay-meadows, although herbs such as hairy buttercup Ranunculus sardous, strawberry clover Trifolium fragiferum and grass vetchling Lathyrus nissolia may be frequent on coastal grazing marsh in southern and eastern England, and help to give these grasslands a distinctive, if not particularly striking, appearance.

Grasslands subject to brackish influence can support a number of species with predominantly coastal distributions in Britain, for example saltmarsh rush Juncus gerardi, slender spike-rush Eleocharis uniglumis and hard-grass Parapholis strigosa. Indeed, in south-eastern England coastal grazing marsh can support extensive areas of upper saltmarsh communities that are now either rare or absent from the adjoining tidally-influenced saltmarsh.

Grazing marsh grasslands (including the enclosing earth banks) support a large number of nationally rare or scarce plants which in Britain are very largely restricted to such habitats (see also Section 8.1.12). Examples are divided sedge Carex dividua, slender hare’s-ear Bupleurum tenueum, sea clover Trifolium squamosum, sea barley Hordeum marinum and least leathce Lactuca saligna. Stalked sea-purslane Halimione pedunculata was recently rediscovered in Britain, after an absence of 50 years, on saline grazing marsh in Essex (Leach 1968). Most rare plants associated with grazing marsh grasslands are ‘continental’ species having a markedly south-eastern distribution in Britain, and not surprisingly it is the grazing marshes of north Kent and Essex that are of greatest importance in this respect. These marshes are all associated with review sites.

Figure 8.1.33 Review sites with associated coastal grazing marshes and other lowland wet grasslands
Washlands

There are a number of 'washland' areas, notably in and around The Wash and the Severn Estuary, where this semi-natural habitat provides an important reservoir for winter flooding. The Ouse Washes and Nene Washes in Cambridgeshire are perhaps the best examples, where winter flooding of the surrounding fenlands, themselves reclaimed from the extensive wetlands of the fenland basin, is prevented by pumping water into a large area between two main drainage channels. This periodic winter flooding provides not only a wintering ground for large numbers of ducks and geese, but also summer habitat for a variety of breeding birds (Section 8.6.4). The unimproved grasslands of the 'washlands' are also used for a variety of agricultural purposes. The way in which these areas operate as a flood control mechanism may point to other ways of viewing the coastal grazing marsh resource, in the context of the possible impacts of global warming (Chapter 11).

The ditch systems

The wildlife interest of coastal grazing marshes is often chiefly to be found in their networks of drainage ditches. While water salinity is of overriding importance in determining species composition, position in the hydrozoic and soil type are also significant. Ditches are prevented from reverting to dry land by the management efforts of water authorities, internal drainage boards and landowners. Their interventions create a spectrum of ditch sizes ranging from broad deep drains, in which the vegetation is removed usually annually and in which re-profiling is frequently undertaken, to small field ditches which are irregularly managed depending on the farmer's priorities. Ditch structure can also influence the plant communities and is probably even more important than size in helping to determine the composition of the invertebrate fauna (see Chapter 8.2).

Brackish ditches support quite different assemblages of plants from freshwater ditches further inland. In the most saline ditches the tasselweeds Ruppia maritima and R. spiralis can occur, and the fringing emergent vegetation resembles saltmarsh with plants such as sea-aster Aster tripolium, saltmarsh grass Puccinellia maritima and cord-grass Spartina anglica. Less saline ditches typically have sea club-rush Scirpus maritimus as the dominant emergent, along with a number of aquatic species, for example fennel pondweed Potamogeton pectinatus, spiked water-milfoil Myriophyllum spicatum, and two nationally scarce species, brackish water-crowfoot Ranunculus aquatilis and soft hornwort Ceratophyllum submersum. The transition to fresh water may be either sharp or gradual, and is often marked by the abundance of dominance of common reed Phragmites australis. Inland from this transition are ditches supporting a varied and often very diverse assemblage of plant species, characterised by those more typically associated with freshwater swamps and fens, for example greater pond-sedge Carex riparia, reed sweet-grass Glyceria maxima and branched bur-reed Sparganium erectum.

In south-eastern England, where natural transitions between saltmarsh and other habitats have invariably been lost (see Section 8.1.5.), the presence of relict grazing marsh ditch vegetation often provides the strongest evidence that such transitions ever existed in the past. For example, in Broadland there is a distributional sequence of aquatic and emergent plant communities that is very closely related to water salinity (Figure 8.1.34) (Doarks & Leach in prep.).

Conservation importance and protected status

Coastal grazing marshes are important for a variety of nature conservation reasons; in particular brackish marshes are valuable as representing a scarce resource in a national context and support plant and animal species (including many that are nationally rare or scarce) that in Britain show a distinct preference for this habitat type. Grazing marshes are also important for a wide variety of breeding birds, including several rare species afforded special protection under Schedule 1 of the Wildlife & Countryside Act, and provide winter feeding and roosting for sometimes internationally important numbers of waterfowl (see Chapter 8.6). Some extensive areas of grazing marsh lie within SSSIs and NNRs. So far many of these have been included primarily for their ornithological interest, and it is likely that further areas will need to be added to the SSSI series once botanical and entomological surveys have been completed.

In recent decades grazing marshes have come under increasing pressure from improved (deep) drainage and conversion to arable or intensive grassland management (see e.g. Williams & Hall 1987; Mountford & Sheal 1982, 1989), while some large areas have been lost to industrial and residential developments (Thornton & Kite 1990). This has given rise to a considerable reduction in the overall extent of grazing marsh in many parts of Britain, including an overall reduction of 60% on the Thames Estuary over the period 1935-1981 (see also Chapter 10).

Much of this habitat loss has affected the ditch systems as well as the grasslands; for example for one area in Broadland Driscoll (1983) found that 33.5% of drainage ditches had been lost due to infilling between 1973 and 1981, while many of those remaining had become floriographically impoverished. Recent surveys have highlighted a widespread deterioration in the aquatic flora of grazing marshes in Broadland, with eutrophication of water supplies being the most probable cause (Doarks 1990). It is likely that similar changes have occurred on sites elsewhere in Britain, and the protection of surviving areas of high quality coastal grazing marsh is thus an urgent priority.
Figure 8.1.34 The distribution of selected ditch types on grazing marshes (mostly associated with the Breydon Water review site) in the Norfolk Broads from Doak & Leach (In prep.). Ditch types depend on soil salinities and have varying degrees of proximity to the tidal rivers: a) freshwater ditches, characterised by the emergents Carex riparia and Phragmites australis, widespread in the upper tidal reaches; b) slightly saline ditches dominated by species-poor stands of Phragmites australis, widespread but mostly in marshes on the lower reaches; c) moderately saline ditches characterised by the emergent Scirpus maritimus, with a similar but less widespread distribution to b); d) highly saline ditches characterised by an emergent fringe of saltmarsh species such as Juncus gerardi and Puccinellia maritima, closely associated with the variable salinity lower parts of the estuary around Breydon Water.
### 8.1.13 Rare and scarce vascular plants

#### Introduction

In addition to their importance for their characteristic mosaic of habitats and their various plant communities, Britain’s estuaries are also of wildlife interest for a number of individual rare and scarce plant species. Nationally rare vascular plant species are those found in 15 or fewer 10 km squares in Great Britain, and nationally scarce those found in 15 to 100 10-km squares. Distributional data on nationally rare plants in relation to review sites have been extracted from records held on the NCC’s Rare Plants Databank, obtained from national assessments made in 1984. Where major changes in status are known, some more recent information has also been incorporated.

#### Rare and scarce estuarine plants

There are at least 48 nationally rare and 65 nationally scarce species and subspecies occurring in coastal habitats in Great Britain. These species are located in eight main habitat types, which occur either on the intertidal parts of estuaries or the adjacent coastal land areas. The habitats and the numbers of the rarer species associated with them are listed in Table 8.1.6. Further details on all these species, their English names and their distribution patterns are listed in Appendix 5.

Not all of these rare coastal species occur on or adjacent to estuaries. Of the 48 nationally rare coastal species, 28 (58%) occur on one or more estuary in Britain. Estuaries with one or more nationally rare species are shown in Figure 8.1.35. Almost all species of tidal flats, saltmarsh, shingle, wastes, open areas, sand-dunes and dune-slacks are associated with estuaries. In contrast, most species of sea cliffs and coastal grassland are on coasts outside estuaries (Table 8.1.6). Estuarine tidal flats and creeks and lower saltmarshes alone have seven nationally rare plants (14.6% of coastal nationally rare species), and 10 nationally scarce species (15%). Similarly mid and upper

#### Table 8.1.6 Numbers of nationally rare and nationally scarce vascular plant species of coastal habitats in Britain, and the percentages of rare species of each habitat found on estuaries

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Nationally rare</th>
<th>% on estuaries</th>
<th>Nationally scarce</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal flats, creeks and lower saltmarshes</td>
<td>7</td>
<td>86</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Mid and upper saltmarshes</td>
<td>3</td>
<td>100</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Shingle</td>
<td>3</td>
<td>67</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Waste places, open areas and sandy shores</td>
<td>3</td>
<td>100</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>Rocks</td>
<td>5</td>
<td>80</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Dunes and dune-slates</td>
<td>5</td>
<td>100</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Sea cliffs</td>
<td>9</td>
<td>33</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Coastal grassland</td>
<td>13</td>
<td>23</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>48</strong></td>
<td><strong>58</strong></td>
<td><strong>65</strong></td>
<td><strong>113</strong></td>
</tr>
</tbody>
</table>

#### Figure 8.1.35 Review sites supporting one or more nationally rare plant species. Each symbol shows the habitat type occupied by one species on one review site. * indicates the presence of a species listed on Schedule 8 of the Wildlife & Countryside Act 1981.

Saltmarshes on estuaries support three nationally rare and nine nationally scarce species. Since almost all tidal flats and saltmarshes in Britain are within estuaries (see Sections 8.1.4 and 8.1.5), these 29 species (25.7% of coastal rare and scarce

107
Table 8.1.7 British distribution of nationally rare and scarce vascular plant species of tidal flats and creeks and saltmarshes. Species names are listed in Appendix 5.

<table>
<thead>
<tr>
<th>British distribution</th>
<th>Nationally rare</th>
<th>Nationally scarce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>South-western</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Southern</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>South-eastern</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Eastern</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Scattered</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9</strong></td>
<td><strong>19</strong></td>
</tr>
</tbody>
</table>

Species in Britain are all substantially dependent on estuaries. These species are listed in Table 8.1.7; their national distributions are given in Perring & Walters (1982).

More than half of the localities for most tidal flat, saltmarsh, sand-dune, waste and open area species are also on review sites (Figure 8.1.35). In contrast, even for those species of rocky shore, cliff or coastal grassland that do occur on review sites, only a small proportion of localities are estuarine. Nevertheless all localities for one sea-cliff plant, sea stock Matthiola sinuata, and one coastal grassland plant, sand crocus Romulea columnae, are adjacent to review sites. In all, 10 nationally scarce species are, in Britain, found only associated with review sites. These estuarine species are round-headed club-rush Scirpus holoschoenus, smooth cord-grass Spartina alterniflora, stalked sea-purslane Halimione pedunculata, matted sea-lavender Limonium bellidiforme, striking goosefoot Chenopodium vulvaria, Welsh mudwort Limosella australis, chidling pink Petrohagia nanteuilii, Jersey cudweed Gnaphalium lutec-album, sea stock Matthiola sinuata and sand crocus Romulea columnae. They grow in six different types of habitat (Figure 8.1.36).

The majority of nationally rare coastal species are found in south-west, south and west Britain, whilst nationally scarce species have a predominantly southern, south-eastern or scattered distribution (Appendix 5). The estuarine element of the flora also reflects these distribution patterns (see Table 8.1.7 and Figure 8.1.35). Figure 8.1.35 shows that nationally rare plants occur on 38 review sites (23% of British estuaries). 29 of these sites are in southern and western England and Wales, between Pagham Harbour (Sussex) and the Duddon Estuary (Cumbria); many of Britain's rare coastal species reach the northern and western limits of their largely southern and western European ranges here. Some British estuaries support several nationally rare species in different habitats, notably the Severn Estuary with four species on tidal flats and creeks, saltmarshes, rocks and coastal grassland.

Coastal species as part of the British flora

In Britain there are about 1,423 native species of vascular plants, 317 of which are nationally rare (Perring & Farrell 1993) and 307 of which are nationally scarce (NCC 1989). The 113 species of coastal habitats in these two categories represent 7.9% of the native British flora and 17.9% of the nationally rare and nationally scarce elements. The 17 rarer estuarine species contribute only 1.2% to the total flora, and 2.6% to the rarer element. However, it must be remembered that all these 16 species are confined to the very narrow range of niches offered to plants by estuaries and that they are only occasionally found in other related habitats, whereas species of other coastal habitats can often adapt to the more extensive inland conditions.

Endemic species

There are thought to be about 40 truly endemic species in Great Britain. These include several closely related species in the genera Euphrasia (eyebright), Sorbus (whitebeam), Taraxacum (dandelions) and Limonium (sea-lavenders). Out of the 113 rare and scarce coastal species there are eight endemics, six of which occur at very few sites in Britain (Table 8.1.8). The sea-lavenders Limonium paradoxum and L. recurrens and Lundy cabbage Rhychosonapis wrightii are each recorded from just one 10-km square. These three species are plants of cliffs and rocky places, but none, however, grows adjacent to British estuaries. Indeed none of the eight species is truly estuarine, most being characteristic of rocky outcrops or sandy shores.

What is of particular note is that there are three members of the sea-lavender genus Limonium amongst these endemics. Limonium has eight generally recognised species represented in Britain (although a recent taxonomic study has now indicated that there are many more - see Ingrouille & Stace 1986). Similarly coastal habitats support two out of the three British species of the cabbage genus Rhychosonapis. The two subspecies of little robin Geranium purpureum are rare, but it is the
Table 8.1.8 Nationally rare and nationally scarce endemic species of coastal habitats in Britain

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of 10 km squares in GB</th>
<th>Review sites*</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Epipactis dunensis</em></td>
<td>9</td>
<td>25, 37, 39, 91</td>
</tr>
<tr>
<td><em>Geranium purpureum</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>as. fosteri</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Limonium paradoxa</em></td>
<td>2</td>
<td>129</td>
</tr>
<tr>
<td><em>Limonium recurvum</em></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><em>Limonium transsilvanum</em></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><em>Primula scotica</em></td>
<td>28</td>
<td>66, 67, 68</td>
</tr>
<tr>
<td><em>Rhynchosia cognata</em></td>
<td>18</td>
<td>37, 39, 40, 41, 47</td>
</tr>
<tr>
<td><em>Rhynchosia wrightii</em></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

* See Appendix 1 for names and locations of review sites

endemic subspecies *fosteri* that is restricted to a handful of sites in Hampshire, centred on Langstone and Chichester Harbours.

The dune helleborine *Epipactis dunensis* is, as its name suggests, a plant of sand-dunes. It has a scattered but northerly distribution, being found on both the west and east coasts of Britain on Anglesey, in Lancashire and Northumberland and also at inland sites in Lincolnshire. Scottish primrose *Primula scotica* has an even more northerly distribution and is scattered along the extreme north coast of Scotland, with outliers on the north-east tip of Caithness and good populations on several of the Orkney Islands. It is restricted to a narrow zone of essentially maritime grassland and is rarely found more than 300 m from the sea, where it grows associated with three review sites.

The distribution on estuaries of the four endemic species of estuarine habitats is shown in Figure 8.1.37. It is notable that, in contrast to most nationally rare estuarine species, these endemics are chiefly northern and western in their distribution.

**Figure 8.1.37** Distribution on review sites of endemic nationally rare estuarine vascular plant species

---

**Figure 8.1.38** The biogeographical origins of coastal and estuarine rare and scarce plant species in comparison with those of the British vascular flora as a whole. The floral elements are from Matthews (1965)
Wider distribution and status

Matthews (1985) has reviewed the origins and distribution of the British vascular flora and has divided it into 12 biogeographical floral elements. These elements can be attributed from Matthews’ lists for 82 of the rare and scarce coastal species. These species are associated with nine of the 12 elements: Mediterranean, Oceanic Southern, Oceanic West European and Continental Southern. Similarly, 83% of the rare estuarine plants belong to these four elements, compared to only 48% of the British flora overall (see also Figure 8.1.38).

The presence of these largely southern and western biogeographical floral elements in higher proportions on coasts and estuaries than in the whole British flora is also reflected in the southern and western distribution in Britain of many of these rare estuarine species (Figure 8.1.35). So southern and western British estuaries are of particular significance for rare and scarce vascular plants. The continued presence of the habitats in which these species occur is thus essential for the maintenance of the diversity of particularly the southern and western biogeographical elements of the British flora.

Although northern and arctic elements of the British flora are generally poorly represented on coastal and estuarine habitats, there are clear exceptions. Several species, notably estuarine sedge Carex recta and oysterplant Mertensia maritima, belong to the Arctic-subarctic floral element (Figure 8.1.38). These have a generally northern and north-western British distribution.

<table>
<thead>
<tr>
<th>Species</th>
<th>Distribution</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atriplex longipes</td>
<td>long-stalked orache</td>
<td>rare</td>
</tr>
<tr>
<td>Corrigiola litoralis*</td>
<td>strapwort</td>
<td>not threatened</td>
</tr>
<tr>
<td>Carex recta</td>
<td>estuarine sedge</td>
<td>rare in Europe</td>
</tr>
<tr>
<td>Eleocharis parvula</td>
<td>dwarf spike-rush</td>
<td>very local over</td>
</tr>
<tr>
<td></td>
<td></td>
<td>much of its range</td>
</tr>
<tr>
<td>Halimione pedunculata</td>
<td>stalked sea-purslane</td>
<td>rare</td>
</tr>
<tr>
<td>Limosella australis</td>
<td>Welsh mudwort</td>
<td>rare</td>
</tr>
<tr>
<td>Limonium belidifolium</td>
<td>matted sea-lavender</td>
<td>rare</td>
</tr>
<tr>
<td>Scirpus holoschoenus</td>
<td>round-headed club-rush</td>
<td>not threatened</td>
</tr>
<tr>
<td>Scirpus triquetrus</td>
<td>triangular club-rush</td>
<td>not threatened</td>
</tr>
<tr>
<td>Spartina alterniflora</td>
<td>smooth cord-grass</td>
<td>rare</td>
</tr>
</tbody>
</table>

* British site coastal, not estuarine
Table 8.1.10 Species of coastal habitats on Schedule 8 of The Wildlife and Countryside Act 1981

<table>
<thead>
<tr>
<th>Species</th>
<th>Occurrence on review site*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bupleurum baldense</td>
<td></td>
</tr>
<tr>
<td>Chenopodium vulvaria</td>
<td></td>
</tr>
<tr>
<td>Corrigiola litoralis</td>
<td></td>
</tr>
<tr>
<td>Gnaphalium heteo-album</td>
<td></td>
</tr>
<tr>
<td>Lactuca saligna</td>
<td></td>
</tr>
<tr>
<td>Limonium paradoxum</td>
<td></td>
</tr>
<tr>
<td>Limonium recurtum</td>
<td></td>
</tr>
<tr>
<td>Ononis reclinata</td>
<td></td>
</tr>
<tr>
<td>Orobanche caryophyllacea</td>
<td></td>
</tr>
<tr>
<td>Petrothalia nanteuilii</td>
<td></td>
</tr>
<tr>
<td>Rhynchosia s. wrightii</td>
<td></td>
</tr>
<tr>
<td>Ionulae columnae</td>
<td></td>
</tr>
<tr>
<td>Scirpus triquetus</td>
<td></td>
</tr>
</tbody>
</table>

* Each of these species occurs on a single review site.

Figure 8.1.38 shows that there are particularly large proportions of the small Mediterranean element of the British flora present on coasts and estuaries. 37% of the 36 species listed by Matthews (1955) in this element are rare or scarce coastal species. Half the rare estuarine species for which origins are listed are Mediterranean.

Smith (1988) provides information on European status and distribution for nationally rare plants. This information is summarised in Table 8.1.9 for the 10 rare estuarine species of saltmarshes, tidal flats and creeks. Many of these rare species are of particular interest in the wider context. Few are widespread in Britain. Estuarine sedge Carex recta occurs at only six localities in Inverness, Ross, Sutherland and Caithness and dwarf spike-rush Eleocharis palustris at about seven places in Hampshire and Merioneth. Smooth cord-grass Spartina alterniflora has its only site in Southampton Water where it originally appeared in Britain. The two club-rush Scirpus species are both widespread in Europe, but restricted in Britain. S. holoschoenus growing in two confined patches in Devon and Somerset and S. triquetus being confined to the River Tamar (Plymouth Sound) on the borders of Cornwall and Devon. The latter species appears to be in danger of hybridising out.

Long-stalked orache Atriplex longipes is a northern European species. It is an obligate halophyte, confined to tall saltmarsh vegetation bordering estuaries. There it grows on silty substrates in relatively undisturbed sites that are flooded by brackish water on high spring tides. It has so far been recorded from seven 10-km squares in Britain but as it is not readily distinguished from other oraches it may prove to be more widespread. Matted sea-lavender Limonium bellidifolium is confined in Britain to the North Norfolk Coast; outside Britain it is, however, more common throughout the Mediterranean. Stalked sea-purslane Halimione pedunculata and strapwort Corrigiola litoralis are confined to one native site each in Britain, although the site for strapwort—the muddy shingle margins of the coastal lagoons at Slapton Ley in Devon— is not estuarine.

Welsh mudwort Limosella australis is of particular note since it grows nowhere else in Europe. The plants growing on the two Welsh estuaries on which it occurs thus represent the entire European resource. Welsh mudwort has, however, a wider but disjunct world distribution, being known also from localities in Africa, Australia and America.

Conservation of rare and scarce plants

17 (14.3%) of the 113 vascular plant species that are nationally rare or nationally scarce occurring in coastal habitats in Britain are restricted to the saltmarshes, mudflats and creeks of estuaries. It follows that their continued presence as a significant part of the British flora depends on the continuing effective conservation of the estuaries on which they occur. The presence of eight coastal endemic species, four of which occur on a total of 12 review sites, is of particular importance in a European context (Waiters 1978).

Specific national conservation measures exist for many British rare plants. The Wildlife & Countryside Act 1981 makes it illegal for anyone to pick or destroy intentionally any of the 93 species listed on its Schedule 8. Thirteen of the nationally rare coastal species, eight of which occur on review sites, are on this Schedule (Table 8.1.10). The other five species are those of rocks and cliffs on open coasts. The presence of a viable population of any of these species is a sufficient criterion for designation of a site as an SSSI. All such sites on estuaries are within existing or proposed SSSIs.

Most of the 317 nationally rare plant species in the British Isles have at least one of their sites protected in an SSSI (Perring & Farrell 1983). All the species listed in the British Red Data Book 1: vascular plants (Perring & Farrell 1983) are candidate species for designating SSSIs, and the guidelines for the different categories of species are given in Nature Conservancy Council (1989).
The nationally scarce plants are often 'indicator' species and as such highlight the good examples of different habitats in Britain, for example old chalk grassland, ancient woodland and unpolluted estuaries. These species are also used in SSSI selection: if four or more of them occur together at a site, then this area should be considered for notification as an SSSI.

The presence of endemic species is also a guideline for notification, and it is recommended that the location of the largest population of an endemic in each Area of Search – usually a county (NCC 1989) – should be notified wherever practicable.

In addition to national measures, existing and proposed international conservation measures directly and indirectly provide safeguards for rare plants. A Council for the European Communities (CEC) Directive on the protection of natural and semi-natural habitats and of wild fauna and flora is currently in draft. Appendix 1 of this Directive covers endangered and vulnerable species, including three rare coastal and estuarine species: dune gentian Gentianella uliginosa, stalked sea-purslane Halimione pedunculata and shore dock Rumex rupestris. Dune gentian and shore dock depend in part on the habitats surrounding British estuaries; stalked sea-purslane occurs in Britain only adjacent to a review site. All three species are declining throughout much of their European range. The species are also under pressure in Britain: the populations of dune gentian at several of its eight known British localities are under threat; similarly populations of shore dock are under pressure, particularly from increasing recreational use of sandy beaches, since shore dock often grows at the top of the beach. The populations are also vulnerable to oil spills along Britain's south-western coast, the most recent having occurred in May 1990 after a mid-channel collision.

Stalked sea-purslane was until recently considered extinct in Britain since it had not been seen growing since 1935. A single new colony was discovered, however, in 1987, growing in a narrow band of estuarine upper saltmarsh in Essex. This remains its only known British location.

In addition to the proposed measures in the EC 'habitats' directive for the direct safeguard of these rare species, international measures exist, notably the 'Ramsar' Convention on the Conservation of Wetlands especially as Waterfowl Habitat and the EEC Directive on the conservation of wild birds. These measures afford safeguard for estuarine habitats used by internationally important migrant waterfowl populations on many British estuaries and so also for the habitats on which many of the estuarine rare and scarce plants depend. These measures are described further in Chapters 8.8 and 9.

Rare plant species may be very restricted in their occurrence, but they serve to indicate good examples of natural and semi-natural habitat and ecological conditions which are themselves limited, either naturally or by human influence. They are often the first species to reflect change because of their sensitivity to environmental factors, and so can be used to give an early warning of change. The particular changes threatening coastal habitats in which these rare and scarce species occur are highlighted in sections 5-12 of this Chapter.

8.1.14 References


DAVIDSON, N.C., & EVANS, P.R. 1986. The role and potential of man-made and man-modified wetlands in the enhancement of the survival of overwintering shorebirds. Colonial Waterbirds, 9, 176-188.


114
8.2 Terrestrial and non-marine invertebrates

Contents

8.2.1 Introduction  
General features of distribution  
Coping with the tide  
8.2.2 Bare substrate  
8.2.3 Vegetation substrate  
8.2.4 Sand-dunes  
8.2.5 Saltmarsh  
8.2.6 Reedsbed  
8.2.7 Snag  
8.2.8 Strandlines  
8.2.9 Estuarine cliffs  
8.2.10 Brackish and freshwater pools  
8.2.11 Grazing marshes  
Grazing marsh faunas  
Rare and scarce species  
Environmental features influencing ditch invertebrate faunas  
8.2.12 Conservation of terrestrial and non-marine invertebrates  
8.2.13 Threats to terrestrial and non-marine invertebrates  
8.2.14 References

8.2.1 Introduction

A number of estuarine habitats support distinctive assemblages of terrestrial, semi-terrestrial and brackish water air-breathing invertebrates, here grouped under the general term 'terrestrial and non-marine invertebrates'. The aquatic intertidal and subtidal invertebrate fauna is treated separately in Chapter 8.3 (Aquatic estuarine communities).

General features of distribution

Individual vegetation types and successional stages of sand-dunes, saltmarshes, lagoons, reedsbeds, vegetated shingle, grazing marshes and soft-rock cliffs all have characteristic faunas which also vary with the geographical position of the site. Usually there is a decline in species richness northwards, which is perhaps more pronounced on Britain's east coast than on the west. The number of species occurring in these habitats may total several thousand, many of which are non-foodstorus species ranging widely over many different habitat types. Here it is only possible to give very limited examples to illustrate the particular microhabitats most crucial to species most typical of these types of habitat. Remarkably few, even of the typical species, are restricted purely to estuarine situations, most also occurring on similar habitats on non-estuarine sections of coast, or in saline or brackish water, or mobile, sandy conditions inland. Many species which also occur inland in southern Britain become more restricted to estuarine and coastal sites in the north.

Several microhabitats are of particular value for terrestrial and brackish-water invertebrates in estuarine situations. Their presence can give an indication of the potential of a site to support a significant fauna where there is a dearth of survey data.

Knowledge of the non-marine invertebrate fauna of British estuarine habitats is, however, extremely patchy. While certain elements of the fauna of most sand-dune sites around our coasts have been investigated in some detail, this cannot be said for other habitat types. The saltmarsh faunas of, for example, the Humber, Thames, Blackwater and Medway Estuaries, The Wash, the Swale Estuary and Rye Harbour are relatively well studied, whereas those of the Severn, Dee, Mersey, Ribble and Solway Estuaries are very poorly known. Within the NCC, available information on terrestrial invertebrates is collated by the Invertebrate Site Register (ISR) (see Section 8.2.12). Much of the information described in this chapter comes from ISR records, supplemented from other published sources. Endangered, rare, vulnerable and scarce insect species in Britain have been recently listed by Sherr (1987). The Red Data Book (RDB) status of such species is identified (e.g. by RDB2) where appropriate in the following text, and these status definitions are listed in Table 8.2.1.

Coping with the tide

Air-breathing invertebrates have to be able to cope with the rigours of a dynamic system in which the problems of respiration, osmotic/physiological stresses, and of being washed away, are great. Coastal terrestrial invertebrates have developed both physiological and behavioural mechanisms to overcome these difficulties, so allowing them to exploit the highly productive estuarine marshes. A simple mechanism is tolerance. Most arthropods of the supralittoral can tolerate several hours of immersion, with some species of spider and
Table 8.2.1 Status categories for threatened invertebrates in Britain, for Red Data Book (RDB) and other species, from Ball (1985) and Shirt (1987)

<table>
<thead>
<tr>
<th>Status</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Red Data Book</strong></td>
<td></td>
</tr>
<tr>
<td>RDB1 Endangered</td>
<td>Species in danger of extinction and whose survival is unlikely if the causal factors continue operating</td>
</tr>
<tr>
<td>RDB2 Vulnerable</td>
<td>Species believed likely to move into the endangered category in the near future if the causal factors continue operating</td>
</tr>
<tr>
<td>RDB3 Rare</td>
<td>Species with small populations that are not at present endangered or vulnerable, but are at risk</td>
</tr>
<tr>
<td>RDB4 Out of danger</td>
<td>Species formerly RDB1, 2 or 3 but now considered relatively secure</td>
</tr>
<tr>
<td>RDB5 Endemic</td>
<td>Species naturally occurring only in Britain. Such species may be also in RDB1-4</td>
</tr>
<tr>
<td>RDBx</td>
<td>Status uncertain</td>
</tr>
<tr>
<td><strong>Nationally scarce</strong></td>
<td></td>
</tr>
<tr>
<td>Scarce A</td>
<td>Species known from 16-30 10-km squares</td>
</tr>
<tr>
<td>Scarce B</td>
<td>Species known from 31-100 10-km squares</td>
</tr>
</tbody>
</table>

**Note**: The distribution of some species appears to qualify them for inclusion in the RDB lists, but their status is as yet too poorly known. These are usually given an RDBx status. For other species apparent RDB status has emerged after the preparation of the Red Data Book for insects. Such species are currently afforded provisional RDB status: pRDB.

carabid beetle able to survive 1-3 months provided the temperature is low (Heydemann 1979). The wolf spider *Pardosa agarista* has a coastal form (originally described as a distinct species *P. purbeckensis*) which has long been known to cope with the rising tide by walking down a plant stem and clinging to its base until the tide retreats (Bristowe 1958). Similarly, the predatory bug *Haloselis lateralis*, when caught by the tide, clings to a nearby piece of vegetation and climbs down to its base to wait for the tide to recede. Although this species can tolerate submersion for 2-3 hours its true habitat is above the high water mark (Southwood & Leston 1959). The tiny money spider *Enigone arctica* seeks shelter beneath a stone as the tide advances (Bristowe 1958).

A more complex adaptation to submersion by the tide involves synchronised patterns of locomotor activity, i.e. some animals are active only when not submerged. The behavioural mechanisms employed by a number of saltmarsh species are now known. For example the saltmarsh carabid beetle *Dicheirorhynus gustavi* has a circadian activity pattern which is suppressed by tidal submersion: it usually hunts nocturnally but not when the tide is high (Treherne & Foster 1977). The day-active saltmarsh mite *Bdeella interrupta* has two peaks of locomotor activity on the marsh, their timing being governed by the tide. During periods of tidal submergence they have a periodicity of 12.5 hours, but this alters to 11.5 hours during periods of tidal emergence. This ensures that the mite is active only during daylight when the tide is out (Foster et al. 1979). The intertidal collembolan *Anurida martina* has evolved the elegant strategy of maintaining an endogenous 12.4-hour circatidal rhythm, together with an exogenous rhythm of locomotor suppression during darkness. This rhythm is maintained throughout periods of immersion, so avoiding the need for a predictive mechanism for the timing of the next daylight low tide (Foster & Morton 1981).

Although posing behavioural and physiological problems, the tide is used to advantage by some terrestrial invertebrates. For example the intertidal aphid *Pemphigus trehernei* uses the shallowly flooding tide to disperse around saltmarshes (Foster & Treherne 1975).

### 8.2.2 Bare substrate

Firm intertidal and supralittoral sandy mud and sand, with sparse or no vegetation, is of importance for a number of groups of stenotypic invertebrates, including rare species. Adults of a number of families of beetles, most notably those of the *Heteroceridae* and rove beetles of the genus *Bledius* (*Staphylinidae*), burrow into estuarine sandy or clay sediments, different species...
preferring different particle size distributions within their substrate. These species are algal or detrital grazers, while some burrowing ground beetles of the genus *Dyschirus* are specific predators on individual species of *Bledius*. Distribution maps of *Dyschirus* and *Bledius* species are under preparation in atlases being produced by the Biological Records Centre. The detritivorous larvae of a number of flies also burrow into similar sediments, extending much further into the intertidal than the beetles, and also occurring in much silier sediments of large mudflats. Particularly significant are flies of the families Dolichopodidae (marsh flies), whose adults are predatory, Ephyridae (shore flies) and a few species of Tabanidae (horse flies), with adults of some species feeding on the blood of estuarine birds. A number of species of isopod and amphipod crustaceans, largely from marine groups, also burrow in sandy or clay sediments.

Bare or sparsely vegetated dry sandy substrates in sand-dunes are burrowed into by a considerable diversity of solitary wasps and bees, with different species nesting in flat and vertical sand faces, as well as by the larvae of three species of tiger beetles *Cicindela* spp., two of which are nationally scarce and confined to large dune areas in southern and western Britain. It is important that the substrate is sufficiently firm to support the burrows of these species as they are easily eliminated by excessive trampling.

Adults of a number of species of visually-hunting predatory insects and spiders need expanses of bare substrate over which to hunt. Sand and mud in different estuarine habitats support different faunas of these predators. Damp substrates support ground beetles (Carabidae) and shore bugs (Salticidae), e.g. *Salduia setosa* (RDB2) – a species in Britain on the edge of its known range, known only from the sandy silt at the top of the littoral zone in Poole Harbour, where it is able to withstand submergence by high spring tides (Southwood & Leston 1959; Shire 1987). There are also flies of the Dolichopodidae and Empididae (dance flies), as well as wolf spiders (*Lycosidae*). In dry, sandy substrates in dunes, these families are represented largely by different species, with the addition of flies of the Asilidae (robinet flies) and Theridiidae (stiletto flies). The warm microclimate of patches of bare sandy ground is also needed by a number of thermophilic species in many orders of insect to maintain body temperature, this being the likely reason that a number of species become restricted to dune habitats in the northern part of their range in Britain.

Very small patches of bare substrate can be of great significance within otherwise vegetated habitat. Such microhabitats include the margins of salt pans and edges of creeks in saltmarsh, and the surface of lightly trampled paths, rabbit burrows, and small sand-blowers in dunes. Large expanses of sand-flat are needed specifically by relatively few species. The ground beetle *Bembidion pallicipenne* and the two maritime tiger beetles *Cicindela maritima* and *C. hybrida* range very widely over extensive intertidal sandflats backed by dunes.

### 8.2.3 Vegetation structure

The structure of estuarine vegetation is almost as important as its plant species composition for determining the invertebrate assemblages that it supports. The extent of grazing of the vegetation is also significant in different ways for the invertebrates of sand-dunes and saltmarsh. On sand-dunes there are characteristic communities comprising species from most classes of terrestrial invertebrates associated with each stage of the early succession. This short vegetation is usually maintained by grazing, most commonly by rabbits but sometimes by domestic livestock. In the absence of grazing, coarser grasses and scrub eventually become dominant and the typical dune fauna becomes replaced by more generalist species common to many types of rough grassland.

In contrast, grazing on saltmarsh, particularly by sheep, is highly deleterious to the invertebrate fauna, there being relatively few species able to cope with the very short, even sward that this produces. This may contrast with the value of a saltmarsh to its avifauna, since grazed marsh may be very valuable as roosting or feeding grounds for wader birds, although certainly tall marsh supports important breeding bird populations (see Chapter 8.5). The botanical species richness and structural diversity of an ungrazed saltmarsh produces a wider spectrum of terrestrial invertebrate niches, ranging from sites for web-spinning by spiders to habitat for specific phytophagous species on saltmarsh plants and in accumulations of plant litter at the rocs of plants. Natural interfaces between saltmarsh vegetation and other terrestrial habitats, especially freshwater marsh, support a number of highly adapted species, notably among the two-winged flies.

### 8.2.4 Sand-dunes

The invertebrate assemblages of sand-dunes can be grouped according to habitat type characterised on the basis of floristic and structural diversity (Duffy 1968; see also Section 8.2.3). On young (yellow) dunes, the very open structure of the vegetation, with much bare sand between individual plants, is critical for the characteristic invertebrates. Species range from phytophagous insects associated with pioneer plants, such as the flea beetle *Psyllodes macrues* associated with sea-kale *Crambe maritima* and larvae of the noctuid moth *Photinus pyralis* on lyne grass, to spacer-hunting (pompilid) wasps such as *Eusyron rufipes* searching among the marram, and scarabaeid beetles like *Aegila arenaria* feeding underground on dry plant litter. Older dunes, with a slightly more closed cover of short vegetation, are important for numerous phytophagous ground and plant bugs, including the spectacular red and black
Coriæus hyoxanthus and seed-eating ground beetles of the genera Amara and Harpalus, and the pseudoscorpion Dactylocheilus lairei; a predator found in amongst tussocks of marram grass and under driftwood on the south and east coasts of Britain (Legg & Jones 1988). The shore wainscot moth Mythimna littoralis has larvae which feed nocturnally on marram grass and hide in the sand by day (Heath & Emmet 1983). The numerous rosette plants, such as plantains and storks-bills, provide important cover for the ground-dwelling species.

Most species found commonly on sand-dunes are not restricted to this habitat. For example the wolf spider Arctosa perita is one of the most common and characteristic spiders of the yellow dune zone and yet it is found also inland in areas such as sand or shingle/coal dust with a structurally similar substrate. Such distributions are fairly common and probably reflect microhabitat requirements, including plant architecture and release from competition (Duffey 1968).

A similarly intriguing disjunct distribution pattern exists for the sandhill rustic Luperina nickertii, a noctuid moth with four phenotypically and ecologically distinct isolated populations (Figure 8.2.1), each a separate subspecies. One subspecies, L.n. knillii, is found only on crumbling cliffs on the Dingle Peninsula in Co. Kerry where its larvae probably feed on red fescue Festuca rubra. Two subspecies - L.n. guenael on Anglesey and the north Wales coast, and L.n. leechi (known only from the shingle bar closing one coastal lagoon in south Cornwall) - have larvae which feed first on the sheaths and then on the rhizomes of sand couch Elymus farctus. They then pupate several centimetres deep in the sand. Adults of these two subspecies are found on sheltered sandhills where there is extensive growth of sand couch that is inundated only by the highest tides (Heath & Emmet 1983). The subspecies most recently confirmed as resident is L.n. nickertii, found only on east coast saltmarshes from Kent to Suffolk (Emmet et al. 1985; unpublished information from B Skinner, D Agassiz and others). All known for the guenaeli and nickertii subspecies are on sand-dunes associated with three Welsh and eight eastern English review sites.

**8.2.5 Saltmarsh**

As with most estuarine habitats, the terrestrial invertebrates characteristic of saltmarsh are either phytophages of saltmarsh plants or rely upon the provision of suitable microhabitats within the system (see Section 8.2.3).

The scarce capsid bug Orthotylus rubidus feeds on saltwort Salicornia and is found in areas of saltmarsh and seepages subject to only occasional inundation, from Devon to Norfolk (Southwood & Lesko 1959). Sea wormwood Artemisia maritima is host to a picture-winged fly Paroxyyna absinthi, whose larvae feed on the flower heads (White 1988). It also hosts the larvae of the scarce pug moth Xyphemera extensa (RDB3), a rare species confined to review site saltmarshes in Norfolk, Lincolnshire, Humberside and one site in Essex (Shirt 1987). Sea-lavender Limonium spp. supports a root-feeding weevil Apion linumii (Nb); a micro-moth Goniodoma linomella, and the plume moth Aglistis bennettii. Sea aster Aster tripolium has a similarly characteristic suite of obligate herbivores including two aphids: the root-feeding Pemphigus trehernei (Toester & Treherne 1975) and the stem-feeding Macrosiphoniella asteris (Heydemann 1979), a gall-forming picture-winged fly Paroxyyna plantaginis (White 1988), and the noctuid moth Cucullia asteris which feeds on the flower heads. This moth is another example of a species occupying two distinct habitats: its other habitat is woodland, where the larvae feed on goldenrod Solidago virgaurea. There is evidence, however, of distinct behavioural differences between the two populations, with the saltmarsh populations tending to be more sluggish and to take longer to develop (Heath & Emmet 1983). The
saltmarsh grasses also nourish a variety of moth species including sandhill rustics. Matthew’s wainscot Mythimna fuscicolor, and the crescent striped Apamea oblonga, whose larvae feed at night on the roots and stem bases of Puccinellia and spend the day in small chambers among the roots or under stones (Heath & Emmet 1983).

A particular estuarine rarity – Fisher’s estuarine moth Gortyna borelli lunata (RDB2) – is found only on one review site on the north Essex coast in a colony of its host plant, hog’s fennel Peucedanum officinale. The larvae feed first on the leaf-axil and then descend and feed on the rootstock, making massive excavations and burrowing to a depth of 30 cm (Heath & Emmet 1983).

### 8.2.6 Reedbeds

The fauna of brackish-water reedbeds is distinct from that of freshwater reedbeds, and a discrete suite of species of noctuid moths, in particular species of wainscot moth Mythimna and others, have caterpillar feeding on and in the reed stems. These species are particularly common in some estuaries. Reeds in standing brackish water may prove more favourable for some phytophagous species, by isolating them from ground-dwelling predators which are more prevalent in tidal reedbeds or reedbeds over reed litter, each of which supports a distinctive fauna. The hoverfly Sphaerophoria bombylans, a predator on aphide on reeds, seems also to be more common on reeds in standing water. Certain rare species of invertebrate also occur in fenland reedbeds, for example the reed-climbing ground beetle Dromius longipes, which is largely restricted to coastal reedbeds and fens in East Anglia and the reedbeds of the upper Humber Estuary.

### 8.2.7 Shingle

Invertebrates associated with coastal and estuarine shingle tend either to be associated with the specialised flora of the shingle or to be dependent on the shelter provided by the shingle itself and the litter that accumulates on it.

Examples of species dependent on the specialist shingle flora include the darkling beetle Omophlus rutifolius, known only from thrift Armeria maritima growing on shingle at The Fleet in Dorset, and the micro-moth Aethes margaritana (RDB2), the larvae of which feed on the roots of sea-holly Eryngium maritimum, itself a scarce plant. This moth was once known from a number of estuaries in southern England, but has declined and is now known only from Thorpness, outside the review site network (Shirt 1987). Another rare moth, Pima boisi diva (RDB3), has larvae that live in and feed on the pod of sea pea Lathyrus japonicus (Shirt 1987). The rare jumping spider Euophrys brownii (pRDB3) lives amid litter in a few east coastal estuarine shingle systems, preferentially sheltering in cast-up whelk shells on the shingle.

It has the distinction also of being one of the few spiders endemic to Britain (Roberts 1985). The ground beetle Aepus robini lives amongst stable intertidal shingles in estuarine conditions.

### 8.2.3 Strandlines

Accumulations of various types of drift litter are home to various assemblages of terrestrial invertebrates, depending on the composition, humidity and state of decay of the drift material. The specialized woodlouse Armadillidium album lives beneath drift material in the upper drift lines of fore-dunes and saltmarshes (Harding & Sutton 1995). It can burrow up to 10 cm into the sand and seems to burrow when the drift material is washed away or buried (Duffey 1968). In Britain it is known only from 15 widely scattered review sites (Figure 8.2.2). Accumulations of seaweed at high-water mark support a wide diversity of specialist flies, with different species inhabiting fresh, rotting and dry weed. Several species of diking beetles (Tenebrionidae), which are most frequent on
strandlines of dunes, as well as a large number of species of rove beetle (Staphylinidae), also live in rotting seaweed which can also support enormous numbers of wrack flies Coelopa upon which specialist predators feed. Dried out wrack high above average tidal strandlines is inhabited by the fly Helcomyza ustulata. One scarce beetle, Aphodius plagiatus, in a genus composed otherwise only of dung beetles, is associated with rotting fungi and accumulations of plant litter in dunes and saltmarsh. Species such as surface predators and nectar feeders, found also elsewhere in estuarine habitats, often breed in strandline material or use it as shelter. Examples include the wolf spider Arcosa fulvocinerea (RDB3), which lives and hunts amongst detritus and stones at the top of saltmarshes in East Anglia and around the Solent (Shirt 1997), and the spiders Trichoncus hackmani and T. affinis found on the south and east coast of England on shingle and in tidal litter (Roberts 1987).

Other species are associated with driftwood, either boring into saltwater-soaked timber, as does the wharf borer beetle Nacerdes melanura, sometimes a pest in wooden groynes, and the wood boring weevil Pseuctus spadix, or deriving shelter under individual pieces of wood. Many predatory ground beetles (Carabidae) and rove beetles (Staphylinidae) are frequent under large pieces of wood, often also living under human jetties on the strandline, such as fish-boxes and bits of old plastic. Particularly spectacular are the large ground beetles Broscus cephalotes; which construct long burrows in damp sand with the entrance under a piece of driftwood, feeding on sandhoppers Talitrus and Orchesta, and the yellow and black Nebria complanata. This sometimes occurs in large aggregations under flat pieces of timber such as old packing cases and is a species of very restricted distribution in Britain, occurring only on the strandlines of dunes along the south Wales and north Devon and Somerset coasts, including at least seven review sites (Figure 8.2.3).

8.2.9 Estuarine cliffs

Soil-rock and boulder clay cliffs, both along the coast and within estuarine situations, are the habitat of a number of burrowing invertebrates, again, including rare species. Cliffs along the north bank of the Humber Estuary support a discrete colony of the rove beetle Biedus dissimilis, which is known otherwise only from similar cliffs on the Holderness coast and a single colony on an inland cliff in an old clay-pit. Solitary wasps and bees nest in estuarine cliffs, especially when they are warm and south-facing. In the south of England, such cliffs are particularly important in the conservation of some of the rarest of these species in the country. Cracks and fissures and accumulations of clay debris and drift material at the foot of actively slumping cliffs are home to a number of beetle, fly and spider species, including the large cream and chestnut brown ground beetle Nebria livida. This nocturnal species is now restricted to the boulder clay cliffs of the Yorkshire and Norfolk coasts and may have

8.2.10 Brackish and freshwater pools

Brackish still-water bodies associated with estuaries, such as saltmarsh pools and coastal lagoons, support highly characteristic groups of halochile species, notably among the water-beetles, e.g. Berosus spinosus (RDB3), and bugs (e.g. Sigara stagnalis and the scarce S. selecta (Southwood & Leston 1959), caddis, two-winged flies (e.g. larvae of the snail-killing fly Stratiomyus longicornis (RDB2) and the crane fly Limonia bezzii (RDB2) (Shirt 1987), molluscs and crustacea. These include a number of scarce and threatened species. Other invertebrates are associated with
the characteristic vegetation of such water bodies, either feeding upon the plants themselves, or being dependent on their structural heterogeneity or upon the litter that builds up beneath them. The reed beetle *Macrolepia mutica* is a species mainly of brackish water, feeding on the roots of *Potamogeton pectinatus*. This beetle is also reputed to feed on the roots of *Zostera*, although this has not been proved in this country. Others again live on wet mud and algal mats that occur at pool margins, while the dolichopodid flies *Dolichopus diadema* and *Machaerium maritimum* skim over the surface of saltmarsh pools.

The water-beetle *Ochthebus lenensis* (RDB2) is known only from brackish pools on the saltmarshes of the Dorset and Dorset Firths (Foster 1990). Other members of this genus show a similarly restricted distribution: *O. leptida* is found in saline pools on rocky shores and will not tolerate fresh water; *O. exarata* is a thermophilous species and is found only in the coastal grazing levels of the south-east (Foster 1990). Such brackish-water bodies include natural lagoons and pools in saltmarsh, but now most commonly take the form of man-made sites such as ditches, drains and borrow pits, often behind a boundary sea-wall, where the saline influence may be entirely from seepage, as well as the ditches on estuarine grazing levels (see Section 8.2.11).

The interface between freshwater and brackish wetland supports a particularly rich assemblage of aquatic and semi-terrestrial species of fly and water-beetle. Such interfaces occur in freshwater outflows and seepages across saltmarshes and among the mazes of ditches on grazing levels. Temporary freshwater pools in dune slacks also have a characteristic fauna, especially of water-beetles and micro-crustacea, the water-beetle *Dyraphe stratiata* being almost restricted to this habitat. The vegetation of dune-slab pools also supports a characteristic fauna of phytophagous species, including the spectacular chestnut and green leaf beetle *Chrysomela populi* feeding on *Salix herbacea* on which plant the parasitic wasp *Brachymyia minuta*, a parasite on fly larvae, is most often found.

Hyposaline pools, including saltmarsh salt pans, also have specialist faunas of terrestrially-derived as well as marine species. The water-beetle *Paracycnum aeneus* is restricted to a single hyposaline lagoon behind the sea-wall at Bembridge Harbour on the Isle of Wight. (For a further description of saline lagoons see Section 8.1.11.)

### 8.2.11 Grazing marshes

Grazing marshes are a habitat of considerable conservation significance, lying adjacent to estuaries, chiefly in the south and east of England. Their distribution and zoological interest are described in Section 8.1.12. Their invertebrate faunas, particularly those associated with ditches, are also of considerable conservation interest.

During the last decade the invertebrate fauna of many of the major grazing marsh areas have been surveyed, concentrating on the aquatic fauna although terrestrial invertebrates have also been examined on the Somerset Levels, the Gwent Levels, several marsh systems on the Thames Estuary, and on the North Kent Marshes (Stubbbs et al. 1962; Drake et al. 1964; Drake 1968; Plant 1987; Everard et al. 1989).

#### Grazing marsh faunas

Much of the focus of invertebrate interest lies in grazing marsh ditches and their banks. The unimproved grassland of the pasture itself sometimes also holds species of note, but none is exclusively associated with grasslands on coastal grazing marshes. These are essentially linear ponds which provide extensive margins and a variety of water depths. Their fauna is similar to that of natural ponds and fens. The dominant aquatic macroinvertebrates of such places are beetles (Coleoptera), bugs (Heteroptera), snails (Mollusca – Gastropoda) and fly (Diptera) larvae. The first three of these groups form a substantial portion of the British species on coastal grazing marshes, and a ditch system can be home to over 50 species of water-beetle (Table 8.2.3). Other groups such as crustaceans, leeches, flatworms, caddis and mayflies are generally represented by only a few, although often abundant, species and so make a smaller contribution to the species richness. There is as yet little information on other, taxonomically difficult, groups such as bees, worms and small crustaceans. Comparable data for dragonflies (Odonata) are not available for all the grazing marsh areas in Table 8.2.1. Grazing marshes are, however, undoubtedly very important places for dragonflies since at least 12 species (of a British total of 44 species) occur on the Gwent Levels (Sovern Estuary) and 14 species on the Essex grazing marshes.

The terrestrial fauna of grazing marshes appears dominated by two-winged flies, although this may reflect more the level of expertise of invertebrate surveyors than the true distribution of taxa. These dipteran faunas can be very diverse: for example 530 species of flies, including many whose larvae are aquatic or live in damp soil, were recorded in one survey on the Gwent Levels (Drake 1989). Some groups of flies were particularly well represented on the Gwent Levels: two surveys found about 40% of British species of snail-killing flies (SCionychidae (27 species) and grass flies (Chloropidae (56 species), about 25% of British shore-flies (Ephydridae (32 species), hoverflies (Syrphidae (59 species) and Dolichopodidae (67 species), and about 10% of the British non-biting midges (Chironomidae (58 species) and dance-flies (Empididae (46 species) (McLean 1982; Drake 1989).

Despite the large number of aquatic species recorded on grazing marshes, relatively few are ubiquitous even within one geographical area. For example, in more than 40% of samples in surveys of Essex and Suffolk grazing marshes only 18
Table 8.2.2 The numbers of taxa in the major aquatic invertebrate groups found on different areas of coastal grazing marshes compared with the total in Britain

<table>
<thead>
<tr>
<th></th>
<th>Gwent Levels</th>
<th>Somerset Levels</th>
<th>N Kent marshes</th>
<th>Essex marshes</th>
<th>Suffolk marshes</th>
<th>Britain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leeches</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Molluscs</td>
<td>25</td>
<td>19</td>
<td>12</td>
<td>24</td>
<td>26</td>
<td>71</td>
</tr>
<tr>
<td>Bugs</td>
<td>21</td>
<td>29</td>
<td>25</td>
<td>26</td>
<td>32</td>
<td>63</td>
</tr>
<tr>
<td>Beetles</td>
<td>99</td>
<td>64</td>
<td>53</td>
<td>88</td>
<td>80</td>
<td>254</td>
</tr>
<tr>
<td>Caddis</td>
<td>13</td>
<td>5</td>
<td>6</td>
<td>13</td>
<td>10</td>
<td>134</td>
</tr>
<tr>
<td>Larger</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>crustaceans</td>
<td>8</td>
<td>7</td>
<td>10</td>
<td>14</td>
<td>13</td>
<td>20</td>
</tr>
</tbody>
</table>

species were found. There are thus considerable differences in the aquatic invertebrate assemblages on different grazing marsh systems. Even the most common species on each of six grazing marsh areas are dissimilar. Table 8.2.3 shows that only nine species (the snail Lymnaea peregra, the boattrap Hesperocorixa lineola, and the beetles Anacarta limata, Halipillus ruficolis, Helophorus brevipalpis, Hydrobusfuscipes, Hydrocoropus palustris, Hygroicus maculosus and Notonurus clavicornis) were widespread, occurring on four or more of the marsh areas. These are all generally ubiquitous species, common in most lowland water bodies.

**Rare and scarce species**

Many nationally rare and scarce invertebrates live on grazing marshes. In several NCC surveys of aquatic and terrestrial invertebrates (Palmer 1980; Stubbs et al. 1982; Drake et al. 1984; Drake 1986, 1985a, 1985b), Red Data Book (RDB) species (see Table 8.2.1) accounted for between 0.5-4.9% of all identified species, and nationally scarce species comprised between 11.2-17.1% of the identified species (Table 8.2.4). In addition, other records of rare species held by the NCC's Invertebrate Site Register (ISR) emphasise the conservation significance of grazing marshes for rare invertebrates.

For some rare species grazing marshes appear to provide their national stronghold. The geographical distributions of the RDB species great silver water-beetle Hydrophilus piceus (RDB1), three scarce beetles Felodrytes caesius, Limnozexus niger and Berosus affinis, and the soldier fly Odontomyia emata (RDB2) closely follow that of the major

Table 8.2.4 Numbers and percentages of Red Data Book (RDB) and nationally scarce species (see Table 8.2.4) of invertebrates on grazing marshes, from various NCC surveys. Surveys of terrestrial species were not made on the Suffolk and Essex marshes. The total named species includes only groups covered by Ball (1986) and Shir (1987).

<table>
<thead>
<tr>
<th></th>
<th>Gwent Levels</th>
<th>Somerset Levels</th>
<th>N Kent marshes</th>
<th>Essex marshes</th>
<th>Suffolk marshes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aquatic species</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDB2 &amp; pRDB2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>RDB3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Scarce A</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Scarce B</td>
<td>28</td>
<td>18</td>
<td>14</td>
<td>31</td>
<td>24</td>
</tr>
<tr>
<td>Total named species</td>
<td>223</td>
<td>150</td>
<td>128</td>
<td>211</td>
<td>201</td>
</tr>
<tr>
<td>% RDB</td>
<td>1.8</td>
<td>2.0</td>
<td>1.6</td>
<td>4.3</td>
<td>4.0</td>
</tr>
<tr>
<td>% scarce</td>
<td>12.6</td>
<td>13.3</td>
<td>11.7</td>
<td>17.1</td>
<td>12.4</td>
</tr>
<tr>
<td><strong>Terrestrial species</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDB1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDB2</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDB3 &amp; RDBk</td>
<td>9</td>
<td>0</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scarce A</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scarce B</td>
<td>59</td>
<td>26</td>
<td>43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total named species</td>
<td>576</td>
<td>217</td>
<td>388</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% RDB</td>
<td>2.6</td>
<td>0.5</td>
<td>4.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% scarce</td>
<td>11.5</td>
<td>12.9</td>
<td>11.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Table 8.2.3 The commonest invertebrate species on six coastal grazing marshes, derived from Palmer (1980), Drake (1986, 1988a, 1988b) and Drake <em>et al</em> (1984). The numbers of species included for the different areas varies between 22–26, depending on the analyses for each survey.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>Triclads</strong></td>
<td><strong>Gwent Levels</strong></td>
<td><strong>Somerset Levels</strong></td>
<td><strong>North Kent marshes</strong></td>
<td><strong>Essex coast</strong></td>
<td><strong>Suffolk coast</strong></td>
</tr>
<tr>
<td>Polycehis spp.</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Molluscs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anisus vortex</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bithynia tentaculata</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymnaea palustris</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>L. peregra</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Pisidium spp.</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Planorbus planorbus</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Potamopyrgus jenkinsi</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Ephemeroptera</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloeon dipterum</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Odonata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coenagrion puella</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ischnura elegans</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td><strong>Hemiptera</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calliconixa praestans</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corixa affinis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. punctata</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gerris lacustris</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. odontogaster</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Hesperocorixa lineolata</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>H. zihbergi</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hydrometra stagnorum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Ilocoxus vicidens</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notonecta glauca</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N. viridis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plea minutissima</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Sigara dorsalis</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>S. striata</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. stagnalis</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Trichoptera</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limnephilus affinis</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diptera</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dixella autumnalis</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oplonothea vindula</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agabus bipustulatus</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. sturmii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anacara globulus</td>
<td>+</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>A. limbata</td>
<td></td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Beroecus affinis</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cymbiodonta marginella</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Dytiscus circumflexus</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Enochrus halophilus</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gyrinus pictus</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Gyrinus striatulus</td>
<td></td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Haliphus apicalis</td>
<td></td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>H. lineatocollis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>H. rufocollis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>H. wehnkei</td>
<td></td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Gwent Levels</td>
<td>Somerset Levels</td>
<td>North Kent marshes</td>
<td>Essex coast</td>
<td>Suffolk coast</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------</td>
<td>-----------------</td>
<td>--------------------</td>
<td>-------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Helophorus brevicolpis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>H. grandis</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. minutus</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. obscurus</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydreaa riparia</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrophilus fascipes</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropsopus angustatus</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropsorus palustris</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. planus</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. pubescens</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>H. tessellatus</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Hygrotus inaequalis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hyphophrys ovatus</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Laccobius bipunctatus</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laccodilus minimus</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Noterus clavicollis</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ochthebius minusculus</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Podonotus lineatus</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhantus frontalis</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Scirtes spp</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

**Crustacea**

- *Asellus aquaticus* +
- *A. meridianus* +
- *Crangonyx pseudogracilis* +
- *Gammarus duebeni* +
- *G. zaddachi* +
- *Palamonetes varians* +

Grazing marsh areas are associated with review sites as follows:

- Severn Estuary
- Bridgewater Bay
- South Thames Marshes, Medway Estuary, Swale Estuary
- Colne Estuary, Blackwater Estuary, Dengie Flat, Crouch-Roach Estuary
- Orwell Estuary, Deben Estuary, Ore-Alde-Butley Estuary, Lyth Estuary
- Morecambe Bay

grazing marshes. The scarce diving beetle *Hydaticus transversalis* is now virtually restricted to the Gwent and Somerset Levels and Moors. The emerald dragonfly *Lestes dryas* (RDB2) has its stronghold in the ditches of the Essex grazing marshes. It has, however, recently been found in a few inland freshwater sites since its rediscovery (in 1983) after being considered extinct in Britain during the 1970s.

A much larger group of national rarities are amongst the more common or characteristic species of the grazing marshes but are not restricted to such places. They include the scarce soldier fly *Odonotrya tigrina*, the nationally scarce hairy dragonfly *Brachytron pratense*, the scarce blue damselfly *Coeagron pulchellum*, the scarce diving beetle *Rhantus Grillon* on the Somerset and Gwent Levels, and the scarce soldier fly *Stratiomys singularis*, the meniscus midge *Dixella atica* (RDB3), and the three scarce diving beetles *Agabus conspersus*, *Dytiscus circumflexus* and *Rhantus frontalis* on the Essex and Kent grazing marshes.

**Environmental features influencing ditch invertebrate faunas**

In areas of permanent pasture three factors dominate the structure and species richness of the invertebrate communities. These are the position of the ditch in the hydroserie, the soil type and the salt concentration.

Ditches are highly artificial systems with a rapid hydroseral succession leading to drier conditions of much less conservation significance than their wet state. The intervention of man keeps ditches at various stages of development from open water to fully clogged with vegetation (see also Section 8.1.12). There is a general trend for the more frequently maintained ditches to support a richer aquatic fauna that also contains more uncommon
species than neglected ditches. This situation reflects the greater range of habitats available in a ditch with a mixed vegetation structure of emergent marginal plants as well as floating and submerged species. Emergent plants eventually dominate ditches that are not cleaned and may eradicate the open-water habitat and many of the invertebrate species associated with it. Associated with management intensity is water depth. In general, species richness and rarity decline rapidly in water shallower than 30 cm in freshwater ditches. Exceptions are, however, the brackish marshes of the Essex and Kent coasts where water may be only 15 cm deep yet still support an important fauna. This is largely because Essex and Kent grazing marshes have a large proportion of ephemeral, summer-dry ditches which support uncommon but mobile invertebrate species when they are flooded.

TWINSPLAN (Two-way Indicator Species Analysis – Hill 1979) classifications of aquatic samples from the Somerset Levels and Moors and the Gwent Levels showed broad similarities in the features that characterised the main invertebrate communities (Drake et al. 1984; Drake 1986). Most samples were classified into a few large groups that reflected the hydroseral stage so that communities in wide deep ditches, smaller typical ditches with a varied vegetational structure, and those dominated by emergent vegetation in shallower water were distinguished in both TWINSPLAN classifications. The coastal element of the fauna was, however, poorly represented in these western grazing marshes in comparison with the brackish Kent and East Anglian marshes where the coastal fauna is the dominant component.

Nearly all coastal grazing marshes where the invertebrates have been surveyed are on clay soils since these soils are largely derived from estuarine sediments. A few marshes on the Suffolk coast, however, notably around Stowwell (outside review sites) and on Morecambe Bay, are partly on peat. Inland, peat and alluvium occur more frequently and grazing marshes on these substrata support a range of species additional to those generally found on coastal levels.

Salinity has a pronounced effect on the aquatic invertebrate community structure. Not only do coastal specialists appear on marshes subject to brackish influence but there is also a marked decrease in species richness as a result of several major groups being poorly represented in such places. For example, on freshwater marshes there are typically more than 20 species of molluscs, over 10 species of dragonflies and up to nine species of leeches. In contrast in slightly brackish ditches leeches are usually absent, only two species of snail, Lymnaea peregra and Potamopyrgus jenkinsi are normally present, and the only frequently occurring dragonfly is the common damselfly Ischnura elegans, apart from the localised presence of the scarce emerald dragonfly on the East Anglian coast. Amongst other invertebrate groups several of the most abundant and widespread species of freshwater ditches appear intolerant of even mildly brackish (oligohaline) water. At least 14 such species (the hoglouse Asellus aquaticus, the amphipod Crangonyx pseudograpsus, the mayflies Cloeon dipterum and Caenis robusta, the pond-skater Gerris lacustris, the saucer bug Iliocoris cimicoides, the caddis Allocyprus albinus, Limnephilus lunata, L. flavicornis and L. marmoratus, the caddis moth Callibaetis lemnata, and the beetles Agabus sternus, Anacanthia globulus and Gyractis puncta) are, however, found in ditches carrying fresh water from the hinterland across otherwise brackish marshes.

Replacing these freshwater species in oligohaline ditches is a different, distinct, assemblage of coastal species, a large proportion of which is nationally scarce as a consequence of the scarcity of the habitat. Among the more frequently occurring species on the Kent, Essex and Suffolk grazing marshes are the amphipod Gammarus duebeni and G. zaddachi, the water-boatman Sigara stagnalis, the caddis Limnephilus affinis and the beetles Agabus conspersus, Enochus halophilus, Gyractis bilineatus, Halipus apicalis, Limnaxes tigris and Berosus affinis. Slightly brackish conditions may be essential to maintain healthy populations of some of these species found on the eastern grazing marshes, for example the water-boatmen Sigara stagnalis and S. selecta and the beetles Agabus conspersus, Ceratoblatta paralegogramma, Halipus apicalis, Enochus halophilus, E. bicolor, Ochthebius marinus, O. viridis and most colonies of Helophorus alternans.

Many species that are characteristic of oligohaline water are, however, also found in smaller numbers at inland sites. Hence their distribution can be described as predominantly coastal although the ecological basis for such distributions has yet to be established. This predominantly coastal distribution occurs in, for example, the water-boatmen Corixa affinis and Notonecta viridis, the scarce emerald dragonfly, and the water-beetles Gyractis bilineatus, Dytiscus circumfleus, Gyrinus calpion and Ochthebius punctatus.

An even more curious distribution occurs in the beetles Limnaxes tigris, Berosus signaticollis and Helophorus alternans. These species are locally frequent in brackish grazing marshes and saltmarshes but are also occasionally found inland at peaty sites.

In strongly brackish ditches, for example those immediately behind sea-walls where the ditches may contain more than 10% sea water, species richness is lower still. Large obligate halophile crustaceans, notably Gammarus spp. and the prawn Palamonetes varians, are frequently dominant. Other typically estuarine species such as Sphaeroma spp., Neomysis integer and the mud snail Hydrobia ulvae can also occur in such ditches. Insects are poorly represented and, except for some chironomid larvae, are rarely numerous.
8.2.12 Conservation of terrestrial invertebrates

Compared with many other facets of conservation science, there has been a historical neglect of terrestrial invertebrate conservation in Britain. The current work on invertebrate conservation is aimed chiefly at assembling information on rare species and important sites so as to integrate practical conservation measures for invertebrates more fully into general conservation practice. A particular problem for invertebrate conservation is that it must not only address the often complex and widely differing conservation needs of species but also seek to conserve a great many species. Compared with many other groups of organisms, there are a very large number of terrestrial invertebrate species in Britain, for example, about 22,500 species of insects and about 7,500 species in other macro-invertebrate groups such as spiders, molluscs, woodlice, millipedes, centipedes and crustaceans (NCC 1989). Many of these species have specialised requirements which are as yet poorly understood. Lack of information is even more of a difficulty in the case of micro-invertebrate groups such as mites, of which there are about 2,000 British species currently known, and nematodes (about 1,000 species). So even basic distributional information is still needed for many invertebrates. Detailed ecological knowledge is even more sparse. This is in marked contrast to some other groups such as birds and vascular plants.

Many invertebrates have annual life cycles and so cannot survive even relatively brief periods when environmental conditions become unsuitable. This makes them susceptible to local extinctions. Furthermore many species, especially insects, have complex life-cycles in which one or more early stages may have different needs from those of the more mobile adult animals. For example, the hornfly Stylurus littoralis (RDB3) has larvae that inhabit estuarine mud, adult females which require a blood meal and males which feed on nectar from plants such as sea-lavender Limonium spp. This means that the conservation of habitat mosaic, both in terms of vegetation structure and different adjacent habitats, is of particular importance for invertebrates, whose needs may not always be served by the selection of a single habitat series as the basis of site safeguard (NCC 1989). Since estuaries are composed of such habitat mosaics (see Section 8.1.1), the general approach needed for the effective conservation of estuarine ecosystems is thus also entirely appropriate for terrestrial invertebrates.

All this means that the task of assessing the conservation needs of invertebrate species and assemblages is very substantial. The development of invertebrate conservation is being furthered through the NCC’s Invertebrate Site Register (ISR), begun in 1980, which seeks to identify threatened species and sites with a significant terrestrial or semi-terrestrial invertebrate fauna. The ISR currently holds information on over 6,700 sites, and on about 15,000 species including 5,390 species of Red Data Book or nationally scarce status. Sites are graded as to their importance, proven or potential, for invertebrate conservation, based on the occurrence of characteristic faunas and the presence of scarce stenotypic species. Information from the ISR is documented in a series of reports, detailing sites of known or suspected value in each country of Britain. Reviews of the national distribution, status, ecology and conservation needs of scarce species have been prepared for most major taxonomic groups of invertebrates, enabling a more meaningful interpretation of information presented on individual sites. Reviews of the invertebrate faunas of individual habitat formations, including those associated with estuaries, are currently in preparation.

Several hundred ISR sites occur on review sites, with large estuaries frequently being divided into smaller habitat sub-units for analysis of their invertebrate fauna. Of these estuarine ISR sites, 52 sites have been graded "A" within the ISR (sites of national importance, equivalent to NCR on the basis of the invertebrate fauna), and a further 86 sites graded "B" (equivalent to SSSI). Analysis and grading are not yet complete for the whole of Britain, and for Scotland in particular need to be reassessed in the light of increasing knowledge of species’ distribution and status.

In addition to the ISR, invertebrate conservation is supported by more intensive surveys of some habitats and areas, targeted at providing clearer information on the occurrence of invertebrates of special interest and of the effects of management practices on faunal abundance and composition. Such surveys currently include a study of East Anglian fens, including parts of the Norfolk Broads adjacent to the tidal rivers of Breydon Water. Several more detailed faunistic studies into threatened species aim to both refine conservation management for these species and give insights into the fundamental principles of invertebrate conservation. The current study of the entomology of several rare moths includes the Essex emerald Thetidia smaragdaria which in 1987 had declined to a single known population of less than fifty caterpillars from one estuarine saltmarsh but for which there is now a captive breeding population (Waring 1980).

SSSIs may be selected purely for their invertebrate interest, particularly for the presence of threatened species and/or their diverse assemblages with strong habitat affiliation. In practice viable populations of most of the commoner or widespread invertebrate species are covered by sites selected for their habitat representation, so it is the rarer, more specialised species for which SSSIs are generally selected on invertebrate grounds (NCC 1989).

As well as its provisions for safeguarding wildlife through the SSSI series (see Chapter 9), the Wildlife & Countryside Act also provides special
protection for a small number of terrestrial invertebrates listed in Schedule 5 of the Act. These include the Essex emerald moth, which was only the second species of insect to be afforded special legislative protection, under the Conservation of Wild Creatures & Wild Plants Act 1975.

Although it is as yet difficult to set Britain's terrestrial invertebrate fauna in an international context, some species are covered by international conventions, notably the Bern Convention, which lists invertebrates in its appendices, and the Ramsar Convention (see Chapter 9), which includes invertebrates amongst the wildlife features of wetlands appropriate for designation as wetlands of international importance.

8.2.13 Threats to terrestrial and non-marine invertebrates

The terrestrial invertebrate fauna of estuarine habitats is vulnerable to a variety of human influences but is also threatened in some instances by the natural succession of vegetation change. Pollution, particularly by spilled oil, may also pose a threat to intertidal and supralittoral invertebrates, but examples of damage to this fauna in pollution incidents have yet to be demonstrated.

The most significant threats to the fauna of sand-dunes come from the effects of human disturbance, usually from leisure activities. The thousands of trampling feet of holidaymakers, sand-slogging children and beach buggies have caused severe erosion of many dune systems and loss of vegetation cover and diversity. Many dunes have been irreversibly damaged by the siting of caravan sites and golf courses, and simple activities such as beach bonfires and barbecues may destroy the habitat of species dependent on driftwood.

Perhaps this has been the fate of the staphalid beetle Catius cicatricosus (RDB1). This beetle was known from the strandline of several beaches on the British south coast, but it has not been found since 1968, at Southsea and Milton Creek (Hampshire) (Shirt 1987). In some heavily used areas, special beach-cleaning machines are now used and these effectively remove all strandline habitat important to the invertebrate species described above.

Afforestation has also caused major losses of dune invertebrate habitat. The majority of dune systems that still support very rich dune faunas are now sites under some form of conservation protection, mostly as National or County Trust Nature Reserves, or are protected from leisure activity by their use as military areas, such as at Tywyn Point in Carmarthen Bay.

Compounding the habitat destruction and degradation caused by human agency, natural vegetation succession towards course grassland and scrub through lack of grazing has also reduced the area of useful invertebrate habitat on a number of protected sites.

Many of Britain's estuarine saltmarshes are very heavily grazed by sheep, considerably reducing their potential for terrestrial invertebrates. The introduction of grazing on previously ungrazed saltmarsh can be very damaging to its invertebrates. Removal of grazing on heavily grazed saltmarsh tends to lead to a dominance by low-diversity rank grassland, without the saltmarsh herb species on which many of the invertebrates depend. The invasion of cord-grass Spartina anglica into estuarine systems also has considerable potential for damaging invertebrate faunas, ultimately reducing saltmarsh vegetation diversity and isolating established saltmarsh faunas from tidal influence. Particularly damaging on saltmarsh has been the truncation of the natural vegetation succession by the construction of seawalls at the landward end, with the loss of much of the most floriferous vegetation of the upper saltmarsh and any natural transition to other habitats. It is ironic that one of Britain's rarest moths, the Essex emerald Theodonta marangaria, should now survive in the wild on only a few individuals of its foodplant Artemisia maritima, growing on the very sea-walls that have in part led to the loss of its natural habitat.

In addition to the general threats to wildlife on grazing marshes, such as conversion to arable, silage production or intensive grazing, the heavy management of ditches, lowering of water tables, and eutrophication, there are some factors that particularly affect invertebrates. The most damaging operations are those that reduce the available range of sizes, water depths and vegetation structures of ditches, particularly in the botanically less interesting ditches towards the end of the hedges. These tend to receive less attention from conservationists, yet they support a range of invertebrates not found in more intensively managed ditches. This is especially true of oligochnine ditches, which are aesthetically and often botanically unappealing yet support large numbers of rarities such as the scarce emerald dragonfly.

As most terrestrial and freshwater invertebrates have annual life-cycles, they are vulnerable to even temporary loss of habitat. So, wide man-induced fluctuations in water level that lead temporarily to lethal conditions, such as freezing in winter or drying-out in summer, can locally damage populations. A large proportion of ditch species prefer the narrow zone at the margin of ditches so that re-profiling to produce steep smooth sides removes a valuable part of the habitat. Fencing both sides of ditches to exclude stock also prevents them from trampling down the profile of the margins, which would render them more favourable for aquatic invertebrates.
8.2.14 References


Aquatic estuarine communities

Summary

8.3.1 Introduction

8.3.2 Description of aquatic estuarine habitats and communities

- Background to marine classifications
- The Estuaries Review aquatic estuarine habitat and community classification

8.3.3 Aquatic estuarine communities and their distribution

- Communities on soft substrates
  - Gravel/shell gravel community
  - Beds of calcareous algal maeoral
  - Exposed sand community
  - Clean sand community
  - Common mussel Mytilus edulis beds
  - Horse mussel Modiolus modiolus beds
  - European oyster Ostrea edulis beds
  - Algal community on sediment surface
  - Current-swept sand community
  - Sand/muddy sand community
  - Muddy gravel community
  - Muddy 'offshore' sand community
  - Normal/variable salinity muddy sand community
  - Eelgrass Zostera spp. beds
  - Variable/reduced salinity mud community
  - Reduced salinity mud community

- Communities on hard substrates
  - Exposed rocky shore community
  - Moderately exposed rocky shore community
  - Sheltered rocky shore community
  - Variable salinity rocky shore community
  - Variable (mainly reduced) salinity rocky shore community
  - Reduced salinity rocky shore community

8.3.4 Tidal freshwater habitats and communities

8.3.5 The diversity of aquatic estuarine communities

8.3.6 Conservation of aquatic estuarine communities

- Pressures on aquatic estuarine communities
- Conservation designations covering aquatic estuarine systems

8.3.7 Conclusions

8.3.8 References

Summary

Britain's shallow seas support a rich and varied mosaic of plant and animal communities, the species composition being determined by factors such as substrate type, salinity and degree of wave and tidal exposure. In the intertidal and subtidal parts of estuaries, conditions range from exposed marine systems at the mouths of river estuaries and on open coast estuaries, to tidal and predominantly freshwater conditions in the upper reaches. A classification of aquatic estuarine communities, based on the NCC Marine Nature Conservation Review (MNCR) classification, has been developed for the Estuaries Review and has been used in the description of communities on 102 estuaries.

Seventeen hard shore communities and 16 soft shore communities occur in estuaries. Individual hard shore community types typically occur only intertidally or subtidally, but 63% of soft shore communities occur in both situations. Many hard shore communities are also those characteristic of non-estuarine marine areas. Most are restricted to the outer parts of only a few estuaries: only two hard shore communities occur on more than 20% of Estuaries Review sites.

One is a sheltered rocky shore community, typically with dense growth of knotted wrack, found mostly in the outer parts of rias, fjords and fjards in south-west England and northern Scotland.

Rocky shore communities are most diverse on estuaries in south-west England and south Wales,
and scattered sites in Scotland. They are largely absent from eastern England, where soft sediments predominate.

Soft shore community types are more widespread, with five communities being found on more than 20% of estuaries. These include an exposed sand community dominated by small crustaceans and polychaete worms in outer parts of estuaries; mussel beds, widespread around Britain in both intertidal and shallow subtidal parts of estuaries; and beds of marine grasses associated with the lower intertidal mud and muddy sand areas within estuaries.

The other two soft shore communities are particularly widespread, occurring on over 60% of assessed estuaries throughout Britain: a muddy sand community in areas of variable or normal salinity, and a mud community in more sheltered areas of variable or reduced salinity. Muddy sand is dominated by lugworms, although intertidally cockles, Baltic tellins and several polychaete worms are also abundant. Mud in intertidal and shallow subtidal parts of estuaries is dominated by clams and worms, typically ragworms. Small snails and crustaceans are also abundant.

Estuaries of major marine conservation interest are currently those with many different aquatic communities, but some individual scarce communities are also significant.

These include the maerl beds (maerl is a delicate coral-like alga) of the Firth Estuary, Helford Estuary and Milford Haven; a sand or muddy sand community dominated by razor shells on a few sites in south-west England and Wales and the Outer Hebrides, and the rich fauna of a muddy gravel community in outer estuaries and marine inlets of south and south-west Britain.

The aquatic estuarine communities of many intertidal parts of estuaries are covered by conservation designations such as Sites of Special Scientific Interest (SSSIs), but few subtidal areas are yet afforded such protection either statutorily through designation of Marine Nature Reserves, or non-statutorily, e.g. Marine Conservation Areas (MCAs).

8.3.1 Introduction

The seas around Great Britain support the highest diversity of marine habitats, communities and species of anywhere on the European Atlantic coast. The extensive soft sediment shores and near-shore subtidal areas included in the Estuaries Review form a significant part of the British marine resource (3% of the area within British Territorial Waters – see also Chapter 6). Many of the aquatic estuarine habitats, communities and species inhabiting these areas are of significant marine nature conservation importance.

This Chapter reviews the aquatic estuarine communities that have been recorded from Estuaries Review sites and discusses, as far as is currently possible, their individual distributions and conservation importance on a national and international basis. The description of these communities has, in itself, only been possible through the development for this review of a classification of British aquatic estuarine communities. The development of the classification has proved complex, since each estuary has a differing set of characteristics, based on geomorphology, bathymetry, freshwater input and substrata, that affect community structure. Furthermore there is an absence of sharp boundaries between many of the aquatic communities and there are gross variations in community structure over Great Britain as a whole. These gross variations result from changes in component species around the country, reflecting the presence of different marine biogeographic regions.

The resulting classification defines communities using physical and chemical characteristics and species of macroscopic non-mobile flora and fauna, i.e. predominantly the algae and invertebrates of the system. Where relevant there is also reference to other parts of these communities, notably fish and birds. In general, however, these organisms high in the food web are not covered in this section. The importance of British estuaries for fish and birds are described further in Chapter 8.4 and Chapter 8.6 respectively. For conservation purposes, those invertebrate groups that are largely terrestrial or freshwater in habit are assessed independently from marine systems. Such terrestrial and non-marine invertebrates on estuaries are described in Chapter 8.2.

The classification covers the range of aquatic estuarine communities which are typical of open coasts with negligible freshwater inflow, to those typical of river estuaries with marked gradients in salinity caused by the dilution of sea water by fresh water inflows. Estuaries contain aquatic communities in both their intertidal and subtidal zones which differ from those found on the open coast. At their mouths the communities can be exceptionally species-rich. However the fauna of estuaries with variable salinity is generally poor in numbers of species (Barnes 1974), although it is often rich in numbers and biomass of individuals (Chapter 4). This is partly due to the inability of many freshwater species to inhabit saline conditions and of many marine species to withstand anything but full salinity (Figure 8.3.1). Salinity, although important, is not the only feature which can affect the distribution of marine organisms. In certain situations the degree of shelter and water turbidity, and the uniformity of the substratum, can also be very important. Different community types are defined within the Estuaries Review classification using these different physical characteristics.
The species which can tolerate variable or lowered salinity estuarine conditions can be grouped into recognizable and characteristic species assemblages or communities. The term 'community', used above and throughout this part of the review, is not intended to imply any interdependence between the individual species, although spatial and resource competition can occur.

Although aquatic estuarine communities occur in all 185 review sites around Britain, detailed information for all of them was not available to us during the preparation of this chapter. The community distributions described below are based on marine biological information from 102 of the sites (Figure 8.3.2). Data for several additional sites has subsequently become available, but too late for incorporation. It should be recognized, therefore, that the distributions described below are likely in many cases to be minima and do not necessarily document the full distribution of each community around review sites. Nevertheless these analyses do serve our primary purpose of describing the broad patterns of distribution of aquatic estuarine communities around the British estuarine resource. In reading the descriptions that follow it should be noted that we have included the presence of a community on a review site only where surveys have documented the presence of the plant and animal species characteristic of that community, and not just from the known presence of a particular substrate. Hence the distributions of the broad types of estuarine habitat (subtidal, rocky intertidal shores and tidal flats) described in Chapter 8.1 are generally known to be more widespread than the known distribution of the communities described in this chapter. The current extensive survey work underway for the NCC's Marine Nature Conservation Review will extend this comparable information base for more review sites and communities.

Many communities, particularly those of soft substrata, occur both in the intertidal and subtidal whilst others occur exclusively in the subtidal. In all, Table 8.3.1 shows that 58% of soft substrata communities occur both above and below low water mark. This is in marked contrast to the communities of hard substrata such as rocky shores (Table 8.3.2). These communities almost all occur either exclusively in the intertidal or in the subtidal, with only 11% occurring in both parts of the estuary. In this chapter intertidal rock communities have been distinguished from subtidal rock communities by the use of the word "shore" in the community name, i.e. sheltered rocky shore community compared to (the subtidal) variable salinity rock community.
Aquatic estuarine community data

Figure 8.3.2 The 102 Estuaries Review sites for which aquatic estuarine communities could be assessed for this report. Note that the known presence of a broad habitat type alone was not adequate for the assessment of communities. Collection and collation of community information continues as part of the NCC's Marine Nature Conservation Review.

Details of how habitats and communities are classified are given in Appendix 8. The criteria which are applied to produce marine conservation assessments are outlined in Section 8.3.6 and considered in more detail in Appendix 8.

8.3.2 Description of aquatic estuarine habitats and communities

Background to marine classifications

A classification system is useful in helping to categorise the marine environment as a series of habitats and associated communities and in the preparation of inventories of the resource. The results can be used to assist in the development of an overall marine conservation strategy allowing conservation assessments to be made for, and between, different areas. A classification also aids the identification of rare or particularly threatened examples of marine communities and species and so enables attempts to be made to conserve these examples, whether by voluntary or legislative procedures.

Since the start of this century there have been several notable attempts to produce a classification system which could be used to describe marine communities in the north-east Atlantic using physical and biological features. Petersen (1913, 1915) made a start on the classification of sediments and his approach was followed and expanded by workers such as Ford (1923), Spark (1929), Thorson (1957) and Holmes (1966). Jones (1960) and Clermarc (1973) also classified sediment communities but on a different basis from the 'characteristic species' approach used by Petersen and his followers. Borgensen (1905) used a classic phyto-sociological approach to describe hard substratum algal communities and this is the approach followed by other botanists, such as Den Hartog (1959) and Titly et al. (1985). The rocky shore studies of Ballantine (1961) and Lewis (1964) did not attempt a comprehensive classification but their work, together with that of the phytosociology school and of Stephenson & Stephenson (1972), greatly helps us to separate different types of rocky shore communities. Hiscock & Mitchell (1980) and Erwin (1983) tackled subtidal habitats and associated communities, particularly those of rocky substrata, not closely following any previous workers. Augier (1952) has come closest, so far, to classifying marine habitats and communities on the basis of both environmental factors and the plants and animals present. Augier's work is, however, based on the Mediterranean, and although many of these studies are still considered classic pieces of research, no overall detailed classification system for Britain, covering the communities which occur on both hard and soft substrata, has yet emerged. The NCC is, however, undertaking research which will lead to the development of just such a classification system (see below).

In practice, the production of a classification system for marine habitats and communities is problematical, but the advantages to be obtained from developing such a system outweigh any potential disadvantages. The difficulty of gathering marine data on a standardised and therefore directly comparable basis is a major complication. For instance, whereas sediments can be sampled quantitatively and the organisms present in them are amenable to counting, those on rock live in a very heterogeneous habitat where quantification is difficult, and the particularly short time available during SCUBA dives forces the use of semi-quantitative techniques. Even more fundamental are the problems of placing into a clear framework the infinite variations displayed by community composition and habitat features, such as substrate composition, wave exposure and exposure to tidal currents. The marine classification system must also meet the requirements for which it was developed, which, for the NCC, are usually the
<table>
<thead>
<tr>
<th>Community name</th>
<th>Typical substratum and characteristic situation</th>
<th>Intertidal</th>
<th>Subtidal</th>
<th>Normal salinity</th>
<th>Variable salinity</th>
<th>Reduced salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLEAN SAND COMMUNITY</td>
<td>Coarse sand, moderately exposed to wave action. Primarily occurs on clean well-sorted sandy beaches.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAND/MUDY SAND COMMUNITY</td>
<td>Sand or muddy sand, sheltered from wave action and tidal currents. Occurs on the open coast and in estuaries.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAVEL/SHELL GRAVEL COMMUNITY</td>
<td>Gravel or shell gravel.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAERL COMMUNITY</td>
<td>Gravel or shell gravel in weak, to very strong, tidal currents.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEDS OF THE HORSE MUSSEL MODICUS MODICUS</td>
<td>Occurs in moderately strong tidal currents on a wide range of substrata, predominantly muddy gravel or mud.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALGAL COMMUNITY ON SEDIMENT SURFACE</td>
<td>Associated with a wide variety of sediments in a wide range of tidal currents from weak to moderately strong.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MUDY OFFSHORE SAND COMMUNITY</td>
<td>Muddy sand sheltered from wave action and tidal currents.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EUROPEAN OYSTER OYSTER EDULIS BEDS</td>
<td>Associated with a wide range of substrata.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXPOSED SAND COMMUNITY</td>
<td>Coarse and medium sand exposed to wave action.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMMON MUSSEL MYTUS EDULIS BEDS</td>
<td>Sand, gravel or pebbles, sheltered from wave action but exposed to tidal currents. An open coast and estuarine community.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CURRENT-SWEEP SAND COMMUNITY</td>
<td>Coarse sand or muddy gravel moderately exposed to tidal currents. It occurs on the open coast and estuaries, in areas subject to tidal scouring or turbulence.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MUDY GRAVEL COMMUNITY</td>
<td>Muddy gravel sheltered from wave action and tidal currents. It occurs in the outer parts of estuaries.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NORMAL/VARIABLE SALINITY MUDY SAND COMMUNITY</td>
<td>Muddy sand sheltered from wave action and tidal currents. An open coast and estuarine community.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EELGRASS ZOSTERA SPP. BEDS</td>
<td>Fine gravel, sand or mud sheltered from wave action and significant tidal currents. An open coast and estuarine community.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VARIABLE/REDUCED SALINITY MUD COMMUNITY</td>
<td>Mud, or occasionally muddy sand, sheltered, or extremely sheltered, from wave action with negligible tidal currents. Occurs in estuaries.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REDUCED SALINITY MUD COMMUNITY</td>
<td>Mud in extreme shelter at the top of estuaries, at the limit of marine influence. Species diversity extremely reduced.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 For information on other community names which have been used in the classification systems found in the literature see Appendix 7
2 Individual species of Zostera have different habitat and salinity preferences. Data presented are for the genus as a whole.
Table 8.3.2: Summary of the major marine communities which occur on hard substrata at Estuaries Review sites. Communities have been ranked by salinity tolerance(s) and by their occurrence in the intertidal and subtidal zones.

<table>
<thead>
<tr>
<th>Community name</th>
<th>Typical substratum and characteristic situation</th>
<th>Intertidal</th>
<th>Subtidal</th>
<th>Normal salinity</th>
<th>Variable salinity</th>
<th>Reduced salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXPOSED ROCKY SHORE COMMUNITY</td>
<td>Open coast rocky shore exposed to wave action.</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MODERATELY EXPOSED ROCKY SHORE COMMUNITY</td>
<td>Open coast rocky shore exposed to moderate wave action.</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHELTERED ROCKY SHORE COMMUNITY</td>
<td>Open coast rocky shore sheltered from wave action which can also occur at the mouth of estuaries.</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SABELIARIA REEF COMMUNITY</td>
<td>A predominantly open coast community which occurs on hard substrata in areas subject to wind, storm and moderately strong tidal currents</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXPOSED ROCK COMMUNITY</td>
<td>Rock exposed to wave action. An open coast community.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHELTERED ROCK COMMUNITY</td>
<td>Rock sheltered from wave action. An open coast community which can occur in estuaries but in areas of normal salinity.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HYDROZOAN/BRYozoAN TURF COMMUNITY</td>
<td>Boulders, cobbles and coarse sediment. An open coast community which occurs in areas subject to moderately strong tidal currents.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLIPPER LIMPET Crenidila Fornicata beds</td>
<td>Cobble, pebbles, coarse gravel and shelly areas swept by moderately strong, or strong, tidal currents. A south coast community which can occur on the open coast and in estuaries.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARTIFICIAL SUBSTRATA COMMUNITY</td>
<td>Artificial substrata in areas swept by moderately strong tidal currents.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CURRENT-EXPOSED SHELTERED ROCKY SHORE COMMUNITY</td>
<td>The lower parts of rocky shores subject to significant tidal currents.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VARIABLE SALINITY ROCKY SHORE COMMUNITY</td>
<td>Rocky shores sheltered to extremely sheltered, from wave action. An estuarine community. Species diversity reduced.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VARIABLE SALINITY CLAY COMMUNITY</td>
<td>Clay sheltered from wave action, usually in strong tidal currents.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VARIABLE SALINITY ROCK COMMUNITY</td>
<td>Rocky substrate which is sheltered, or very sheltered, from wave action. Tidal currents very variable, ranging from weak to very strong. An estuarine community. Species diversity reduced.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VARIABLE (MAINLY REDUCED) SALINITY ROCKY SHORE COMMUNITY</td>
<td>Rocky shore sheltered to extremely sheltered, from wave action. Occurs in estuaries, predominantly in the middle or upper reaches. Species diversity very reduced.</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VARIABLE (MAINLY REDUCED) SALINITY ROCK COMMUNITY</td>
<td>Rocky substrate sheltered, to extremely sheltered, from wave action in predominantly the mid tide or upper reaches of estuaries. Species diversity very reduced.</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

134
Table 8.3.2 (contd.)

<table>
<thead>
<tr>
<th>Community name</th>
<th>Typical substratum and characteristic situation</th>
<th>Intertidal</th>
<th>Subtidal</th>
<th>Normal salinity</th>
<th>Variable salinity</th>
<th>Reduced salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>REDUCED SALINITY ROCKY SHORE COMMUNITY</strong></td>
<td>Rocky shore extremely sheltered from wave action at the top of estuaries, at the limit of marine influence; Species diversity extremely reduced.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>REDUCED SALINITY ROCKY SHORE COMMUNITY</strong></td>
<td>Rocky substrates extremely sheltered from wave action at the top of estuaries, at the limit of marine influence; Species diversity extremely reduced.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 For information on other community names which have been used in the classification systems found in the literature see Appendix 7

description and conservation evaluation of nearshore marine and estuarine areas. Various, usually descriptive, methods have been used and a description of the strategy and methods used in marine work by the NCC can be found in Hiscock (in prep.).

The development of survey strategy and methods, and of a system for the classification of marine habitats and associated communities, has been undertaken as a part of the NCC's Marine Nature Conservation Review (MNCR). The classification will fulfill a similar role to that of the National Vegetation Classification (Rodwell in press) which is now of central importance in the selection of terrestrial sites of botanical nature conservation importance.

The MNCR was initiated in 1987 and was designed to extend knowledge of British marine ecosystems, identity sites of marine nature conservation importance by virtue of the importance of the habitats, communities and species present, and provide a broad base of information to support the more general measures required to combat the adverse effects of development and pollution. The MNCR has utilised information and ideas from some of the studies mentioned earlier, especially those of Borgen (1905), Petersen (1915), Jones (1960), Den Hartog (1950), Bishop & Holme (1980) and Augier (1982), and has used them to develop a hierarchical and robust classification system.

There have been earlier systems, such as the classification developed by the NCC and the Royal Society for Nature Conservation and the initial classification developed by Coordination of Information on the Environment (CORINE). These, however, enable marine descriptions to be made only for intertidal or very shallow submerged areas and have the additional drawback that they have been based on vegetation characteristics alone. These classification systems were clearly inadequate for use with the MNCR as they could not deal with the broad spectrum of habitats and communities known to occur in the marine environment. A new system was required.

The MNCR classification system is based on a catalogue of definitive terms for describing marine sites and habitats. A complementary scheme for the identification of the community types associated with major site and habitat groupings is now being developed, the definitions of community types being based predominantly on the macroalgal and macroalgal species present. Details of the MNCR marine ecosystem classification system are given in Appendix 6. This classification system is currently being developed and has been tested on work for the Irish Sea Study Group, a major study describing the ecology of the Irish Sea (O'Connor 1980). Additional studies, such as the Directory of the North Sea Coastal Margin, will help to develop and expand the range of habitats and communities covered.

The MNCR system has so far been developed only for fully marine situations and does not yet take account of occurrences of greatly lowered salinity, except where this is a localised effect of, for instance, a stream crossing a beach; a 'stand-alone' classification of habitats and communities associated with variable or reduced salinity has yet to be formulated. It has been necessary, however, to describe these communities specifically for the Estuaries Review for the reasons mentioned above. The community descriptions in this section are, therefore, of a preliminary nature and represent only the rudiments of an MNCR aquatic estuarine habitat and community classification system proper; the 'community' approach and salinity divisions used may change considerably as more research and survey work is carried out. Nevertheless it provides a functional system which makes it possible for the first time to discuss the distribution, abundance and conservation importance of aquatic estuarine habitats and communities on a Great Britain basis.

**The Estuaries Review aquatic estuarine habitat and community classification**

The aquatic estuarine habitat and community classification is structured according to the MNCR classification (Appendix 6) and thus, in effect, extends the MNCR system into estuarine or reduced salinity conditions. The classification
produced for the Estuaries Review covers the habitats and communities present in estuaries sensu stricto and also those present in the open coast (full salinity) sites.

The classification was developed using the information from a wide range of survey reports and papers held on a computer database and drew particularly upon data held by the NCC, in particular the MNCR, and, to a lesser extent, on data held by outside bodies. The database was used to produce listings of species and/or communities by carrying out searches for particular features such as salinity range, substratum type or species composition. The results of the searches were then combined with information obtained from the literature to produce a basic but satisfactory initial classification system.

In the short timescale of this phase of the Estuaries Review, it was usually possible to consult only one major report, paper or symposium volume for each review site. For some sites no sources of suitable material were obtained in time for inclusion in the review, while for others no suitable studies have yet been carried out (Figure 8.3.2). However, more than enough information was obtained to make the general statements required for the purposes of this project; the information covers 102 (66%) of the 155 review sites – most of the remainder are small sites. The community abundances and distribution maps in this chapter are therefore far from complete; a recorded absence from a particular site may reflect the restricted amount of literature consulted rather than the true distribution of the community concerned. Details of the database are given in Appendix 7.

One major problem encountered in the classification of estuaries is how to divide up the variable salinity regime which occurs in estuaries. Several systems were considered, including the Venice system (a classification based on salinity gradients and most applicable to large estuaries), and studies conducted by a number of workers, including Den Hartog (1859), Remane (1971) and Wilkinson (1980), were consulted. Wilkinson (1980) noted that the Venice system was not universally applicable, one major problem is that each estuary is hydrographically individual, and so precisely similar algal distributions in relation to hydrographically correlated factors would not be expected in every estuary. After consideration, the classifications based on precise salinity gradients were rejected in favour of a simpler system revolving around a much broader division into normal (less than 40% but greater than 30%), variable (less than 30% but greater than 18%) or reduced (less than 18%) salinity. This more basic approach is appropriate in view of the extreme variability of survey data and the fact that the bulk of marine ecological data on macrofauna and macroalgae are not easily incorporated into a more precise classification system; very few surveys have exact and repeatable salinity measurements attached to them. In addition, the majority of Britain's estuaries are comparatively small, containing well mixed or slightly stratified waters (Ganesh 1973). In those conditions, variations in freshwater inflow may have a profound, probably seasonal, influence on local salinity levels, and thus it will always be extremely difficult to formulate a British estuarine classification system based on a salinity gradient of measurable, discrete units. In fact, such a system would have little utility.

### 8.3.3 Aquatic estuarine communities and their distribution

Thirty-three different major aquatic estuarine communities are identified as occurring at Estuaries Review sites (Table 8.3.1, Table 8.3.2). 20 of these communities have been recorded from the intertidal areas of review sites and 26 communities from the subtidal regions. 13 of the communities occur in both the intertidal and subtidal zones. In the intertidal zone nine communities occur in more than one salinity division. In the subtidal zone the number increases to 11 communities. Such a separation into intertidal and subtidal communities is usual in marine research as it recognises the different environmental conditions experienced by intertidal species from those encountered by species permanently submerged in fully saline or brackish water, in the subtidal zone. The communities have not been separated on the basis of intertidal or subtidal zones within the text descriptions, for reasons of economy of space.

The communities, and their associated habitats, have been named for the purposes of the Estuaries Review using key environmental features, e.g. 'exposed sandy shore community' or 'reduced salinity rocky shore community'. This has been necessary as some of the communities have not been named before. It also avoids the problems encountered in the past, particularly with sediment communities, when researchers named communities after a characteristic species, e.g. **Macoma** community (Petersen 1913), or the **Arzaccola** community (Bishop & Holme 1980). The species involved may not in fact occur in every example of that community type but the use of the species name in the community title implies it. It also erroneously implies that the species may be the most important one in the community. In addition, species undergo taxonomic name changes which makes their use in community names undesirable, e.g. the **Tellina** community described by Bishop & Holme (1980) was named after a bivalve, **Tellina tenus**, which has since been renamed **Angulus tenus**. Details of the other community names which can be applied are given in Appendix 7 (Table AT.1).

In the following section the major estuarine communities are described in terms of salinity,
exposure to wave action and currents, substrata composition and characteristic species and/or taxa. Only major community types have been covered in this preliminary classification. Minor communities will be incorporated as the classification is developed.

The communities have been divided into those which occur on soft substrata followed by the less widespread communities found on hard substrata. Technical terms have been kept to the necessary minimum in the text; the variation in species composition within each community is described, using examples, but only a limited number of characteristic or important species have been mentioned in each community description; many more species will in reality be present. The distribution of the communities, whether fully or partially known, is described and provisional community conservation assessments are given, but only where these have been made in the original source material (see earlier). Differences between the provisional conservation assessments made for a given community, in different review sites, are explained within the appropriate community description sections. The basis on which these conservation assessments are made is described further in Section 8.3.6. It is important to remember throughout the following sections that a conservation status refers only to that particular marine community and may not therefore be a guide to the overall marine nature conservation importance of the estuary on which the community occurs.

Where feasible, maps are provided to illustrate the documented distribution of the communities. As more information is analysed, or becomes available from new marine surveys, the distribution of community types will change; however the maps do provide an overall, but provisional, indication of the distribution of each community. In a similar way care should be taken over the interpretation of tables showing the relative abundance of communities (Table 8.3.3, Table 8.3.4) and those showing the relative conservation importance of communities (Figure 8.3.37, Figure 8.3.38). Both assessments will be subject to change as more data become available.

**Communities on soft substrata**

Sediments are a major feature of British estuaries and, by area, dominate the range of habitats available for colonisation by aquatic estuarine organisms. Nationally the estuaries and open coast sites included in this review account for most of the Great Britain resource of intertidal soft substrata. The inclusion of sites with extensive areas of sediment was one of the guiding principles of the review and accounts for the site selection criteria which were employed; the selection criteria have already been described in Chapter 8.

Coastal plain and bar-built estuaries are predominantly infilled by post-glaciational sediment; hard substrata are rare, occurring mainly in the form of small boulders, cobbles or pebbles. In these systems sediments form an essential part of the dynamic estuarine system, e.g. sediment forms the bars of bar-built estuaries. In other types of inlets, such as rias, fjords and fjords, sediment areas are not so common and areas of rock are present.

The commonest types of estuarine soft substrata are sands and muds and this fact is reflected in the high abundance of the communities which colonise these habitats. Together, the normal/variable salinity muddy sand community, and the variable/reduced salinity mud community, account for the bulk of the estuarine soft substratum types, both in terms of area and frequency of occurrence. Such estuarine communities are physiologically ‘stressed’ by a lowered salinity regime and so the species which may occur are fairly predictable. In the more fully marine situations, where low salinity is not a ‘stress’ on the communities, species composition is much more varied and less easy to predict. Included here are the less common communities such as the sand/muddy sand community, the muddy gravel community and the muddy ‘offshore’ sand community.

The interest of soft substrata communities is not purely marine. The biomass of sediment communities, particularly estuarine ones, may be exceedingly high, providing an essential source of food for many species of migrant and wintering waders and wildfowl.

**Gravel/shell gravel community**

In lower shore fully marine gravel/shell gravel, a community can develop which includes burrowing echinoderms such as the heart urchins *Spatangus purpureus* and *Echinocardium flavescens* and a range of bivalve molluscs, including *Nucula hanleyi*, *Glycymeris glycymeris* and *Dosinia exoleta*. The community is predominantly an open coast one and has rarely been recorded from review sites (Figure 8.3.3). It has been described in the intertidal zone from the Yealm Estuary in Devon and a particularly rich example of the community has been recorded from around the jetty in Kenira Bay, on the west coast of Scotland. The Intertidal Survey Unit (Bishop & Holme 1980) noted that in northern Britain the community is found more frequently on the open coast, where it is often associated with maeri gravel. The community can also occur in the subtidal zone, predominantly in the shallow waters between the Isle of Skye and mainland Scotland. Although no provisional conservation assessments have been made for this community it should be noted that the Yealm Estuary site was provisionally graded by Powell et al. (1978) as of national marine biological importance.

A similar community, including the bivalve *Spsula solida*, occurs in current-exposed coarse sands and gravels and was described by Bishop and Holme (1980). This may be a poorly developed example of the gravel/shell gravel community and has been included here until more information becomes available.
Beds of the calcareous alga maerl *Phymatolithon calcareum* and *Lithothamnion corallioides*

Maerl beds occur subtidally on gravel/shell gravel in areas of normal salinity that are exposed to a reasonable degree of tidal current. The general distribution is one of open or enclosed coasts with an absence from inlets with lowered salinity. Maerl are calcium-depositing red algae, similar to the *Corallinaeae* which form pinkish-red growths over rock surfaces. As maerl grows, it can form unattached, delicate, pinkish purple twig-like structures which, grouped together, form ‘beds’ on the gravel surface, or it can smother small pebbles to produce a ‘hedgehog-like’ effect. The community associated with maerl is most similar to the muddy gravel community (see below) but additional species may frequently be found in association. These species include a number of fish, polychaetes and foliose and filamentous red algae, including ephemeral species such as *Scinaea turgida*.

Within Estuaries Review sites, maerl beds have been recorded only from some of the ria systems in

---

**Figure 8.3.3** Provisional assessment of the distribution of the gravel/shell gravel community on in the 102 review sites for which marine data were examined. (S denotes sites with the *Spisula* variant of this community.)

available. The *Spisula* community variant has been recorded from a number of estuaries in the west of Britain (Figure 8.3.3). In the intertidal zone it has been documented from the Exe Estuary and Plymouth Sound (Powell *et al.* 1978), and in the subtidal from the Solway Firth (Perkins 1973), the Severn Estuary (Warwick & Davies 1977) and the mouths of the Dornoch and Moray Firths (Hunter & Rendall 1986). The Solway example is poorly developed, while in the Severn Estuary the community dominates the large sand banks formed by the strong tidal streams resulting from the exceptionally large tidal range. No provisional community conservation assessments have been made although the Exe Estuary was considered by Bishop & Holme (1980) to be overall of national marine biological importance.

Overall, the gravel/shell gravel community is one of the rarer soft substrata communities to occur in estuaries. Records indicate that it occurs in only 8% of review sites for which marine data have been examined (Table 8.3.3).

---

**Figure 8.3.4** Provisional assessment of the distribution of the maerl community on in the 102 review sites for which marine data were examined.
Table 8.3.3 The documented abundance of some of the major aquatic estuarine communities on soft substrata in review sites, ranked in order of decreasing frequency of occurrence. Information is also provided for each community on the number of review sites for which provisional conservation assessments have been made. Care should be taken in interpretation of this table; the relative abundance of some communities will change as more data become available. Insufficient data are available on the reduced salinity mud community for its inclusion in the table. NA indicates that no conservation assessments have yet been made.

<table>
<thead>
<tr>
<th>Community name</th>
<th>Abundance of Community (%)</th>
<th>Abundance of review sites for which conservation assessments have been made (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable/reduced salinity mud community</td>
<td>84</td>
<td>20</td>
</tr>
<tr>
<td>Normal/variable salinity muddy sand community</td>
<td>79</td>
<td>18</td>
</tr>
<tr>
<td>Beds of Zostera spp.</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td>Common mussel Mytilus edulis beds</td>
<td>29</td>
<td>6</td>
</tr>
<tr>
<td>Exposed sand community</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>European oyster Ostrea edulis beds</td>
<td>18</td>
<td>NA</td>
</tr>
<tr>
<td>Clean sand community</td>
<td>16</td>
<td>NA</td>
</tr>
<tr>
<td>Algal community on sediment surface</td>
<td>12</td>
<td>NA</td>
</tr>
<tr>
<td>Current-swept sand community</td>
<td>12</td>
<td>NA</td>
</tr>
<tr>
<td>Sand/muddy sand community</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Muddy gravel community</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Gravel/shell gravel community</td>
<td>8</td>
<td>NA</td>
</tr>
<tr>
<td>Horse mussel Modiolus modiolus beds</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Maerl community</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Muddy ‘offshore’ sand community</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

1 Abundance expressed as a percentage of the total number of sites for which marine data have been examined, at which the community occurs.

south-west Britain (Figure 8.3.4). The community is rare, occurring in only 4% of the review sites. Maerl is present in the Fowey Estuary (Hiscock in prep.) but only develops into ‘beds’ in the Helford Estuary (Rostron 1987), on St Mawes Bank in the Fal Estuary (Rostron 1985) and near Stack Rock in Milford Haven (Little & Hiscock, 1987). Maerl is delicate and the community is therefore very susceptible to damage resulting from man’s activities, particularly those which would either crush the maerl or alter the hydrodynamic regime of the inlet, causing the dispersal or sitting-up of the beds. The most extensive and best developed maerl bed is found in the Fal Estuary, covering some 150 ha of seabed, and possessing two species of maerl, compared with just one in Milford Haven. The northern species of maerl, Lithothamnion glaciale, has not been recorded from review sites.

Maerl is regarded as of high conservation interest, owing to its limited distribution, fragility and the species-rich communities which it supports; this is reflected in the provisional community conservation ratings which have been applied (see Figure 8.3.37). The Fal Estuary maerl bed has been designated as a Voluntary Marine Nature Reserve (formerly the Roseland Marine Conservation Area), a designation which was also applied, in 1988, to the Helford Estuary. Furthermore, Bishop & Holme (1980) concluded that, overall, the Helford Estuary could be considered of international marine biological importance for its sediment communities, while the Fal Estuary is of national marine biological importance.

Exposed sand community

The community occurs predominantly on normal salinity shores, generally consisting of coarse or medium sands that are exposed to wave action on the open coast or to tidal currents. The latter situation can occur inside estuaries along the sides of sand banks beside low-water channels; the steep slope of the sand allows it to dry out and, together with sediment mobility, precludes the development of any other community type. Such a situation may be exposed to lowered salinity levels. Conditions of wave or tidal exposure result in very mobile sediments which can be inhabited by only a limited number of very mobile species of invertebrates. The community is dominated by crustaceans, mainly small amphipod species such as Haustorius arenanus and Pontocrates norvegicus, and polychaete worm species such as Nephys cirrosa.
Malacoceros fuliginosus and Paroenis biligens. No species of bivalve molluscs are present as the wave exposure is too great. Under exposed conditions few species are present in the sand, but where the exposure is slightly less the number of species increases, although the dominance by Crustacea and Polychaetes is maintained.

The subtidal community is very similar to that in the intertidal zone. Additional species include sandeel's Ammodytes spp. in the sediment and hermit crabs Pagurus bernhardus on the surface of the sediment.

Under certain circumstances a variant of this community occurs where the polychaete Ophelia bicornis is characteristically present. Ophelia occurs in Britain only in the Exe Estuary in Devon (Dixon 1986), the Loughor Estuary in south Wales (Moore 1989) and in Langstone Harbour (Dixon & Moore 1987). The highly restricted distribution of this community variant is reflected in the comparatively higher community assessment ratings which have been made for these examples (Figure 8.3.37).

Clean sand community

The clean sand community occurs on normal salinity beaches, consisting of clean sand under moderate exposure to wave action, but where there is sufficient protection to allow colonisation by some species of bivalve molluscs. The community also occurs in the subtidal zone. The bivalve mollusc Angulus tenus and a slightly

Figure 8.3.5 Provisional assessment of the distribution of the exposed sand community on the 102 review sites for which marine data were examined

The community has been documented as present at 22% of Estuaries Review sites distributed throughout Britain (Figure 8.3.5). The communities so far assessed have been of mainly low marine biological conservation interest (Figure 8.3.37). Of note, however, is the community present in West Angle Bay in Milford Haven. The Intertidal Survey Unit concluded that this was the best example of this community in south-west Wales (Bishop & Holme 1980). They also noted that the example of

Figure 8.3.6 Provisional assessment of the distribution of the clean sand community on the 102 review sites for which marine data were examined
larger species of bivalve, *Donax vitattus*, may occur, depending on the fluctuating success of spatfall, along with other species typically found on wave exposed shores and belonging to the exposed sandy shore community described above. The clean sand community is best developed at mid- to low-tide levels on clean sandy beaches in land-locked bays, and the species are mostly tolerant of slightly brackish conditions, although the community as a whole does not penetrate far into estuaries owing to its dependence on sand with a low silt and clay fraction.

The community is one of the commonest sediment communities to occur on Estuaries Review sites (Figure 8.3.6); information from the literature documents the presence of the community in 16% of review sites (Table 8.3.3). The community occurs throughout Britain on moderately exposed beaches in, for example, the Outer Hebrides (Powell et al. 1979a), and inside inlets at the edges of, or on, sand banks, such as in Loch Fleet (Wells & Boyle 1978) and the Solway Firth (Perkins 1973). A well developed example of this community occurs in the Loughor Estuary (Powell et al. 1979b), while a variant of the typical community is present on Pendine Sands in south Wales (Bishop & Holme 1980). In the smaller, well drained inlets in west Wales the community occupies the low, beach-like area in the middle of the estuary, penetration further up the estuary being restricted by lowered salinity (Cook & Rees 1978). Too few assessments have been made of the conservation importance of this community to enable an overall appraisal to be given here.

**Common mussel *Mytilus edulis* beds**

In some areas the surface of sediments, consisting primarily of sand, gravel or pebbles, may become dominated by partial, or complete, cover of the bivalve *Mytilus edulis*, the common mussel. Mussel beds occur in both the intertidal and subtidal zones, in normal or variable salinity, in areas exposed to wave currents. Species which commonly occur on mussel beds include barnacles, the periwinkles *Littorina saxatilis* and *Littorina littorea* and the brown fucoid algae, *Fucus vesiculosus* and *Fucus serratus*. Subtidally the mussels may provide anchorage points for a number of species of small hydroids and Bryozoa, the variety of which will be greater in more fully marine situations. Rich interstitial communities can develop between the individual mussels, while large populations of the starfish *Asterias rubens*, which feed on the mussels, may also be present.

Mussel beds are recorded at a large number of review sites (25%) distributed throughout Great Britain (Figure 8.3.7). The examples which have been assessed so far are regarded as predominantly of low marine conservation importance. There are exceptions, however, such as the mussel bed communities present in the Loughor Estuary. Moore (1989) considered the rich and diverse mussel community at Whiteford

**Figure 8.3.7 Provisional assessment of the distribution of common mussel *Mytilus edulis* beds on the 102 review sites for which marine data were examined.**

Point, especially on the lower shore, to be of high marine biological importance. It should also be noted that in certain situations mussel beds contribute to the value of estuarine systems which have been given high provisional marine conservation ratings, such as the Exe Estuary (Bishop & Holme 1980).

**Horse mussel *Modiolus modiolus* beds**

On muddy gravels with shells, or on mud with shells, in subtidal areas exposed to strong water currents, horse mussel communities can occur. These are dominated by the horse mussel *Modiolus modiolus* accompanied by a characteristic assemblage of species including hydroids, sponges and bivalves, notably the queen scallop *Aequipecten opercularis*.

Horse mussel beds have been recorded from a limited number (5%) of review sites distributed throughout Britain (Table 8.3.3). The distribution is illustrated in Figure 8.3.8. In some locations, notably the Firth of Forth, the populations are just outside the seaward review site boundaries but
Oyster beds are distributed predominantly in the southern waters of Britain (Figure 8.3.9), especially in sheltered south east and south coast inlets, and have been recorded from 18% of review sites.

There is little information on the marine nature conservation importance of oyster populations.

Figure 8.3.9 Provisional assessment of the distribution of European oyster Ostrea edulis beds on the 102 review sites for which marine data were examined

Populations have, however, been reduced steadily this century by introduced pests, diseases, overfishing and declining water quality.

Algal community on sediment surface

A distinctive algal community may develop on the surface of sediments in the shallow subtidal zone in areas which are usually exposed to water currents. The community consists primarily of the kelp Laminaria saccharina and the bootlace-like alga, Chorda filum. In southern regions of Great Britain, the alien invasive alga, Sargassum muticum or 'topwood', may be especially common. A wide variety of other smaller algae frequently occur. The community often exists in association with a variety of other sediment surface or infaunal communities.
The community has been documented as present on 12% of review sites. This is certainly an underestimate of the distribution of the community, as detailed in Figure 8.3.10, and probably results from the community not being recognised as distinct by past workers. The marine biological importance of the community is very much dependent on whether or not it occurs in association with other communities. The basic community of Laminaria saccharina and Chorda filum is of comparatively low (local) interest. In some situations, however, it can be of national importance, such as in the mouth of the Helford Estuary, where it occurs in association with a rich variety of algae on pebbles, gravel and shells (Rostron 1987). Under other conditions the community may develop on sediments which have a rich infaunal community, such as in Salcombe and Kingsbridge Estuary (Hiscock 1986). This may raise the conservation importance of the community complex of which it forms a part to the level of regional marine biological importance.

Current-swept sand community

Current-swept sands can be colonised by high densities of the tube-dwelling polychaete worm, Lanice conchilega. The community mainly occurs on the lower shore of sandy beaches or subtidally in areas which are subject to tidal scouring or turbulence. This community, termed the Lanice community by Bishop & Holme (1980), is only considered a distinct community where Lanice conchilega occurs at high densities. In lower densities Lanice occurs as a component of other communities, notably the clean sand community, the common mussel community, the sand/muddy sand community or the normal/variable salinity muddy sand community. The Lanice community is not mentioned in other literature, but has been included here to maintain compatibility with the MNCR classification system.

The community has been recorded from 12% of the review sites examined (Table 8.3.3). This is almost certainly an under-representation of the distribution, resulting from the fact that, previously, few workers have recognised this as a community in its own right. It probably occurs throughout Britain, where conditions are suitable, and not predominantly in the south, as indicated in Figure 8.3.11. It has been recorded in the intertidal zone, from the fard systems in the Outer Hebrides to ria systems in south-west Britain. Very extensive intertidal beds are present in The Wash (R Mitchell pers. comm.). A rich population is present on Felsey Sand in Chichester Harbour (Bishop & Holme 1980). Subtidally it has been recorded from inlets such as The Wash (Fowler 1987). It is inappropriate, in view of the under-recording of this community, to talk in detail about provisional marine biological importance. However, it should be noted that the community does occur in inlets which, as a whole, have been given high provisional conservation ratings, such as the Fal and Exe Estuaries (Bishop & Holme 1980).

Sand/muddy sand community

The community is found in normal salinity clean or slightly muddy sand. Slight variations in substratum composition will have a profound influence on species composition and abundance. Such sensitivity to substratum composition results in extremely diverse combinations of species which, for simplicity, have been grouped within the broad heading of 'sand/muddy sand community'. Well developed examples of the community can occur under relatively sheltered conditions where they may be associated with beds of eelgrass Zostera marina. The community occurs from the lower shore down to depths of 65 to 70 m. The razor shell Ensis silicula is the predominant bivalve in the intertidal zone and may co-dominate this community, under moderately exposed conditions, with the burrowing echinoderm, Echinocardium cordatum. Under more sheltered conditions a wider range of species may be present, including polychaete worm species such as Chaetopterus.

Figure 8.3.10 Provisional assessment of the distribution of the algal (Laminaria saccharina/Chorda filum) community on the 102 review sites for which marine data were examined.
Variopedatus, Magelona papillicornis, and Notomastus latericeus; bivalve mollusc species such as Cerastoderma edule, Gari fervensis, Lutrina lutrina and Angulus squiatus; and a small assortment of brittlestar starfish, burrowing anemones and burrowing holothurian 'sea cucumbers'. In the subtidal zone the community can be very similar except that the razor shell Ensis siliqua is replaced by the bivalve mollusc species Chamelea gallina.

The community has been recorded from 11% of sites investigated (Table 8.3.3), and occurs throughout Britain, predominantly in the west. The distribution stretches from the Outer Hebrides (Powell et al. 1975a) southwards as far as the ria systems of south-west Britain (Figure 8.3.12). Rich examples are recorded from Bagh Nam Faoilean in the Outer Hebrides (Powell et al. 1975a), from Mill Bay in the Salcombe and Kingsbridge Estuary (Powell et al. 1978), and from Treath on the Helford Estuary (Powell et al. 1978a). At Small Mouth on The Fleet an unusual variant of this community was described by Bishop & Holme (1980) in which the bivalves Pandora albida and Lopires lucinalis were recorded as present. Bishop & Holme (1980) comment that these two bivalves have not been recorded from any other examples of this community.

In terms of provisional marine biological importance the community is of comparatively high marine biological interest owing to its sparse distribution and the fact that it can develop rich infaunal communities. This is reflected in Figure 8.3.37 showing the provisional marine conservation assessments which have been made for the community. Examples of such communities of high conservation interest include those present in Plymouth Sound (Hiscock & Moore 1986), Milford Haven (Bishop & Holme 1980; Little & Hiscock 1987) and in the Salcombe and Kingsbridge Estuary (Bishop & Holme 1980; Hiscock 1986).

Muddy gravel community

This community occurs on muddy gravel, sometimes with sand, in the outer parts of estuaries and marine inlets on the lower shore and in the subtidal zone. Once again, like the sand/muddy...
sand community, considerable species variation may occur within this broad community type. The bivalve mollusc species *Venerupis senegalensis*, which is frequently, but not necessarily, present may sometimes occur in large numbers in muddy gravels with the bivalve *Mya truncata* and, in less muddy conditions, with the razor shell *Ensis arcatus*. Under more brackish conditions another bivalve species *Mya arenaria* may also be present. In not too stony conditions a number of sedentary polychaete worms may occur including *Amphitrite edwardsi*, *Neopteropodites fugitus*, *Megalomma vesiculosum*, *Myxicola infundibulum* and *Sabella paxoni*. Species of the Spionulan *Gollingia* may be present and the anemone *Cereus pedunculatus* may be common attached to stones below the surface of the sediment. In the subtidal zone the community is very similar except that, in Southampton Water and the northern shore of the East Solent, the bivalve mollusc *Venerupis senegalensis* may be partially replaced by the alien species of bivalve *Mercenaria mercenaria* (R Mitchell pers. comm.). Also the polychaete species *Sabella paxoni* may on occasion be highly abundant, forming the dominant element in the community.

The community has only been recorded from comparatively few survey sites (3%), all of which are located in south or south-west Britain (Figure 8.3.13). Examples include Middlesbrough, where the community is present in Angle Bay and around Lawrenny (Powell et al. 1979b), the Helford Estuary, around Passage and Treath (Powell et al. 1978), the Salcombe and Kingsbridge Estuary (Powell et al. 1978), the Fal Estuary (Powell et al. 1978) and in the East Solent where *Mercenaria mercenaria* replaces *Venerupis senegalensis* as described above (Holme & Bishop 1980).

Examples of where the polychaetes *Sabellapaxoni* dominates the community occur in a small number of survey sites, notably Poole Harbour (Dyrynda 1987; Howard & Moore 1989), The Fleet and Portland Harbour (Howard, Howson & Moore 1986) and The Wash (Fowler 1987). Sparingly developed examples of this community occur at Hurst Spit (lymington Estuary review site) and at North Haven Point in Poole Harbour (Holme & Bishop 1980). The community is of comparatively high marine biological importance owing to its restricted distribution and the rich infraunal communities which can develop. This is reflected in Figure 8.3.37 which illustrates diagrammatically that the community is primarily of regional interest.

Muddy 'offshore' sand community

This community typically occurs in subtidal (‘offshore’) muddy sand, although a modified version occurs in more sheltered conditions where deposits are rich in organic material (Jones 1980). Considerable species variation may occur within this broad community type, and, as this community has such a restricted distribution, each example could almost be considered as a distinct community type in its own right. They have, however, been grouped together under this broad heading for simplicity. Overall a range of species can occur including bivalve molluscs ranging from small species like *Arca alba* to large species like *Arctica islandica*, polychaetes such as *Nephtys incisa* and *Pectinariidae* spp., and the burrowing echinoderm species *Echinothrix occlusum*, *Leptosynapta inhaerens* and *Amphiura brachiata*. On the sediment surface the brittlestar *Ophiura ophiura*, the mollusc *Pholad aperta*, and the seepen *Virgularia mirabilis* may also be present. The latter may be co-dominant with the echinoderm *Amphiura brachiata*, mentioned above.

The community is one of the rarest sediment communities to occur on survey sites; information in the literature suggests that it is present on only 3% of the sites so far investigated (Figure 8.3.14). The *Virgularia mirabilis* co-dominating community variant has been recorded from a sheltered location in Portland Harbour and was provisionally graded by Howard, Howson and Moore (1988) as
of national marine nature conservation importance. Other locations shown in Figure 8.3.14 may be of poorly developed examples or variants of this community.

![Diagram of Muddy 'offshore' sand community](image)

**Figure 8.3.14** Provisional assessment of the distribution of the muddy 'offshore' sand community on the 102 review sites for which marine data were examined.

Normal/variable salinity muddy sand community

This community is typically dominated by lugworms Arenicola marina. Populations of Arenicola marina reach their optimum development in the intermediate conditions of muddy sand, but do occur elsewhere in a wide range of sediments from almost pure mud to clean sand. The community occurs in both the intertidal and subtidal zones and has been recorded in the Baltic down to depths of 35 m (Lukasenas 1969). Also present in the intertidal zone are a range of polychaetes and bivalve molluscs, species, including some of the species which occur in the clean sand community, although species such as the bivalve Anguilla tenus and some of the small crustaceans may be less common or absent. Typical species include the polychaetes Pygospio elegans, Nephtys bombyx, Scoloplos armiger, and Spiophanes bombyrx and the bivalves Cerastoderma edule and Macoma balthica. The small gastropod snail Hydrobia ulvae often occurs on the upper surface of the sediment and on the eelgrasses Zostera noltii and Zostera angustifolia, which may occur in this community in the upper parts of estuaries. The subtidal community is similar to that present on the shore except that certain species are not present. In particular the bivalve species Macoma balthica and Cerastoderma edule are generally accepted to be restricted to the intertidal zone (Tebble 1976). Under rare conditions the eelgrasses Zostera noltii and Zostera angustifolia may occur in the very shallow subtidal zone, but they too are considered as predominantly shore species (see below).

The community is the second commonest soft substrata community to be recorded from Estuaries Review sites. It is present in 79% of the sites investigated so far (Table 8.3.3). It is probably present in more sites than are indicated in Figure 8.3.15, and the community distribution will expand as more information is analysed. The community occurs throughout Britain, although it is absent from estuaries which do not have sediment shores around the mouth and from small estuaries with high freshwater flow. Either set of conditions will preclude the development of this community within the inlet. The community is particularly widespread on sediment flats in the south-east of England (Kay & Knight 1976) and it may occur in association with beds of Spartina anglica (Millard & Evans 1984). In conservation terms the community, although widespread, is not of merely local interest (Figure 8.3.37). In some situations it forms part of the review site systems which have been highly rated in marine biological terms, such as Bigh Nam Fuillean (Bishop & Holmes 1980).

**Eelgrass Zostera spp. beds**

Zostera beds can occur on the surface of sediment inhabited by the sand/muddy sand community, the normal/variable salinity muddy sand community or the variable/reduced salinity mud community. Twelve species of Zostera occur in the temperate seas of the world but only three species occur around the coast of Britain (Clapham, Tutin & Moore 1987). The largest of these three species is the eelgrass or grass-wrack, Zostera marina, a rhizomatous perennial grass with leaves of up to 1 m in length (Campbell 1976). It occurs on fine gravel, sand, or mud, from low-water spring tides down to 4 m, mainly in the sea and fully marine inlets and only rarely in lower salinity estuarine conditions. The other two species, which are commoner in review sites with lowered salinity levels, are the narrow-leaved eelgrass, Zostera angustifolia, and the dwarf eelgrass, Zostera noltii. Zostera angustifolia is smaller than Zostera marina and more tolerant of lowered salinity, occurring on mudflats in estuaries and in shallow water, from mid-tide mark down to low water or, rarely, down to 4 m. Zostera noltii is smaller still, with leaves only 15 cm long. It occurs in a similar habitat and under similar conditions to Zostera angustifolia (Clapham,
Tutin & Moore 1987). The general distribution of the genus Zostera, and for comparative purposes the genus Ruppia (a group of brackish water grasses), is given in Figure 8.3.16. But it should be noted that, given the different habitat preferences outlined above, this represents a vast oversimplification of the situation.

Zostera beds occur on 36% of review sites (Table 8.3.3), and good examples can be found in Langstone Harbour (Tubbs 1975a), Portsmouth Harbour (Tubbs 1975b), The Fleet (Holme 1983), the outer Thames Estuary (Wyer, Boorman & Waters 1977) and at Lindisfarne on the Northumberland coast (Connor 1989). The beds in Langstone Harbour are particularly extensive and consist predominantly of Zostera angustifolia with small amounts of Zostera noltii and, in the subtidal zone, Zostera marina (Tubbs 1975a). Beds of Ruppia spp. frequently occur in association with Zostera beds, and notable examples occur in the Fleet (Holme 1983) and in the Dornoch and Moray Firths (Fox, Yost & Gilbert 1986; Sphere Environmental Consultants Ltd. 1981) on the east coast of Scotland. Ruppia maritima is the most widespread species of this genus, while the rarer Ruppia cirrhosa is restricted to a few scattered sites such as the Fleet in southern England (Holme 1983).

Zostera beds are particularly important as an invertebrate habitat, nursery areas for species of fish and as an invaluable food source for winter migrant birds, such as Brent geese and wigeon. The conservation importance rating of Zostera beds takes this into account with most examples being of regional importance and some of national and international importance (Figure 8.3.37).

Variable/reduced salinity mud community

The community occurs in intertidal and shallow subtidal muds in harbours and estuaries, often in conditions of reduced salinity. The bivalve mollusc Scrobicularia plana is widespread in suitable intertidal habitats and, under similar conditions of
reduced salinity but on more gravely substrata, the bivalve *Mya arenaria* may occur, often in large numbers. Accompanying polychaete species include the ragworm *Hediste diversicolor*, and *Ampharetta grubei* and *Melinna palmata*, in addition to those of the normal variable salinity muddy sand community. Particularly dense populations of cockles *Cerastoderma edule* can occur under these conditions of lowered salinity. The eelgrass *Zostera marina* may be present where the substratum is not too soft, and the small *Hydrobia ulvae* is often common on the surface of the mud and the *Zostera*. Subtidally the community is very similar to that described from the shore except that certain species, notably *Scrobicularia plana*, are absent in the subtidal zone (Pebley 1978). In the intertidal and subtidal zones of Southampton Water the bivalve mollusc *Mya arenaria* may be replaced by the alien bivalve species *Mercenaria mercenaria* (Mitchell 1974).

This community is the most common soft substrata community to occur at review sites, being recorded from 84% of those investigated so far (Table 8.3.3). The community occurs throughout Britain (Figure 8.3.17) but is absent from locations where suitable fine sediment or freshwater influence are not present. Such sites include some of the fjord systems in the Outer Hebrides. The bivalve *Scrobicularia plana*, which is characteristic of this community in England and Wales, appears to be less common in Scotland where it approaches its northern limit. The community, although widespread, is not of merely low marine nature conservation interest, as communities of higher, regional, importance have been described from a wide number of review sites, including the Dart Estuary (Moore 1988b), the Exe Estuary (Dixon 1986) and Otter Mhor (Bishop & Holme 1980). Nationally important communities have been described from the Loughor Estuary (Moore 1989) in south Wales and from Newton Harbour on the Isle of Wight (Howard, Moore & Dixon 1993).

**Reduced salinity mud community**

In extremely sheltered conditions and at the top of estuaries, near the limit of marine influence, an extremely species-poor mud community can develop. The intertidal mud can be dominated by vast numbers of oligochaete or tubificid worms, and the surface of the mud usually has a green covering of blue-green algae and diatoms. The bivalve *Scrobicularia plana* may penetrate this far up the estuary as, occasionally, may other marine species including the ragworm *Hediste diversicolor*. Also present may be a species of isopod crustacean, *Cystura carinata*. In the subtidal zone a similar situation may occur where the mud is dominated by oligochaetes and tubificids. Eels *Anguilla anguilla* and flounders *Platichthys flesus* may also be present, as may salinity-tolerant species of freshwater invertebrates.

The community has been poorly documented but is thought to be widespread and present at the marine limit of many British estuaries. The

---

**Figure 8.3.17** Provisional assessment of the distribution of the variable/reduced salinity mud community on the 102 review sites for which marine data were examined.

Community has been described from the Clyde (Wilkinson, Fuller & Randall 1989) and from the Great Ouse and Nene Estuaries feeding The Wash (Dyer & Grist 1987) and was noted as present in Christchurch Harbour and in the Taw and Torridge Estuary in south-west Britain (D Laffoley in litt.).

No information is available concerning the provisional marine biological interest of this community. It is interesting to note, however, that Dyer & Grist (1987), in their study of the benthos of the Great Ouse and Nene Estuaries, recorded a species of oligochaete worm new to Britain in this community.

**Communities on hard substrata**

Hard substrata in the form of natural rocky shores are a comparatively uncommon feature of estuaries in Great Britain; expanses of rocky shore do not occur on all review sites. Where natural rock outcrops occur is very much dependent on the general geomorphological features of review sites (Chapter 5) and, in particular, on the location of post-glacial sedimentation.
Rias, fjords and fjardar are the most important types of inlet for rocky substrata; sediment deposition is generally restricted and rock is a common substratum in both the intertidal and subtidal zones. Coastal plain estuaries and bar-built estuaries have very little rocky substrata, and what is present is primarily in the form of boulders, cobbles or pebbles. In some locations, where there is a general lack of natural rocky substrata, marine organisms will settle on deposits of empty or live mollusc shells or on artificial hard substrata like piers, pilings and pipelines. This is the case at many review sites including the sheltered inlets of the large east coast firths such as the Dornoch, Cromarty and Beauty (Terry & Sell 1986). Subtidal rocky substrata are less common than intertidal rocky substrata at many review sites and are a major feature only of ria and fjord systems; they occur elsewhere mainly in the form of rock ridges or stills, or as part of the seabed where sediment deposition is at a minimum. The infrequent occurrence of subtidal rock on review sites is in part explained by the fact that a number of review sites drain almost completely during the tidal cycle.

The individual algal and animal species which occur on hard substrata have their own ecological requirements, and so typical vertical zonations occur both in the intertidal and subtidal zones. Such zonations are far less apparent in soft substrata communities, where the sediment slope is far less pronounced and where far fewer species of algae are present. The exact combination of algal and animal species which occur on hard substrata is dependent on a number of factors including exposure to wave action and tidal currents and, more importantly in Estuaries Review sites, the salinity of the water. As with soft substrata conditions, the species composition of ‘stressed’ salinity communities is easier to predict than that of communities in fully marine situations. Accordingly, the open-coast or fully marine community descriptions given below are a considerable oversimplification, and some, in particular the sheltered rock community, could justifiably be split further into a number of distinct community types.

Review sites contain examples of hard substrata from full salinity, wave-exposed conditions, to reduced salinity, extremely sheltered conditions. Many of the more exposed communities can be found elsewhere, outside review sites. These communities are best assessed in relation to the open coast, and not just in relation to Estuaries Review sites. The generally lower marine conservation interest of these exposed communities as found in Estuaries Review sites, should not, therefore, be taken as an expression of their overall conservation status in Britain. Well-developed, high conservation interest examples of these communities occur elsewhere on the open coast. For Estuaries Review sites the communities of higher marine conservation interest are those in sheltered conditions, which reflects the fact that review sites generally hold a large proportion of the British sheltered hard substrata resource.

Exposed rocky shore community

Included here are rocky shores which are exposed to wave action. This type of shore is wide, owing to the sweeping of waves over the rocks, with a broad splash zone at the top of the shore, below the limit of terrestrial vegetation. A characteristic species at the top of the shore is the gastropod mollusc Littorina neritoides, whose small size enables it to live in crevices and cracks and thus avoid the dislodging effect of the waves. Also in the top shore zone other species occur, such as lichens (especially Vernicia maura) and the alga Porphyra. The middle of the shore is dominated by a variable mixture of barnacles (predominantly Chthamalus stellatus and Chthamalus montagui), mussels Mytilus edulis, limpets Patella and red algae (Rhodophyta) and the lower shore by the kelp Alaria esculenta and, in areas of slightly less exposure to wave action, another species of kelp, Laminaria digitata. Algae belonging to the group of Corallinaeae may be particularly common on the lower shore. These algae, which deposit calcium during growth, form a distinctive thin, pink, crust-like cover on the rock surface. Some species, such as Alaria esculenta, are essentially limited in distribution to wave-exposed conditions; while other species, such as the gastropod mollusc Littorina neritoides mentioned above, although not restricted in distribution to this situation, do occur here in characteristic abundance and associations.

Lewis (1964), in his classic work on the ecology of rock shores, describes a number of patterns of zonation of the animals and algae which occur on exposed shores. Variations on the exposed rocky shore 'theme' include the presence of the brown bootlace alga Himanthalia elongata and Rhodophyta on the lower part of the shore, the addition of the marine lichen Lichen pygmaea on the upper shore and the invasion of the mid-shore by the mussel Mytilus edulis and Rhodophyta.

Exposed rocky shores are comparatively uncommon within review sites as they are primarily an open coast feature. They have been recorded from 13% of the sites investigated (Table 8.3.4), the bulk of sites occurring in the south-west of Britain (Figure 8.3.18). Exposed rocky shores have been described from headlands at mouths of ria systems in the south-west, headlands in the Outer Hebrides and outside the mouths of firths on the east coast of Scotland lying outside review sites and so not shown in Figure 8.3.18. The rocky shores present at these sites are described by the various authors as 'exposed' shores but in reality they are on the less-exposed side of this category.

The exposed rocky shores that have been described are generally of low 'local' marine nature conservation interest with a single example of a nationally important site recorded from the mouth of the Salcombe and Kingsbridge Estuary by Hiscock (1986). Powell et al. (1979a) stated that the exposed to moderately exposed rocky shores outside the Laxdale Estuary, in the Outer Hebrides,
Table 8.3.4 The documented abundance of some of the major aquatic estuarine communities on hard substrata on review sites, ranked in order of decreasing frequency of occurrence. Information is also provided for each community on the number of review sites for which provisional conservation assessments have been made. Care should be taken in interpretation of this table; the relative abundance of some communities will change as more data become available. Insufficient data are available on the reduced salinity rock community for its inclusion in the table. NA indicates that no conservation assessments have yet been made.

<table>
<thead>
<tr>
<th>Community name</th>
<th>Abundance of community (%)</th>
<th>Abundance of review sites for which conservation assessments have been made (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable (mainly reduced) salinity rocky shore community</td>
<td>36</td>
<td>11</td>
</tr>
<tr>
<td>Sheltered rocky shore community</td>
<td>31</td>
<td>13</td>
</tr>
<tr>
<td>Moderately exposed rocky shore community</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Exposed rocky shore community</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Variable salinity rocky shore community</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Variable salinity rock community</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Hydrozoan/bryozoan turf community</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Artificial substrata community</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Variable salinity clay community</td>
<td>10</td>
<td>NA</td>
</tr>
<tr>
<td>Exposed rock community</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Sheltered rock community</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td><em>Sabellaria</em> spp. reef community</td>
<td>6</td>
<td>NA</td>
</tr>
<tr>
<td>Slipper limpet <em>Crepidula fornicata</em> beds</td>
<td>6</td>
<td>NA</td>
</tr>
<tr>
<td>Reduced salinity rocky shore community</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Variable (mainly reduced) salinity rock community</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Current-exposed sheltered rocky shore community</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

1 Abundance expressed as a percentage of the total number of sites for which marine data have been examined, at which the community occurs.

2 Abundance of community has been calculated on the distribution of extensive beds of *Crepidula fornicata*.

were of a type not seen elsewhere in the islands. Powell et al. (1979a) considered these shores, together with other features within Broad Bay, to be of national marine nature conservation importance.

The overall low conservation ratings applied to this community arise because much better examples of open coast communities are present elsewhere, on stretches of rocky coast not included in this review.

**Moderately exposed rocky shore community**

This community occurs on rocky shores that are only moderately exposed to wave action, and differs from the communities of exposed rocky shores by the general absence of species such as kelp *Alaria esculenta*, and by the addition of species such as the brown algae *Fucus vesiculosus* in the mid-shore and *Fucus serratus* on the lower shore. As a result of lessened wave activity, the shore may be vertically less extensive than exposed shores, with a comparatively reduced splash zone. On the upper shore the gastropod *Littorina neritoides* is present along with the related gastropod species *Littorina saxatilis*, two brown algae species, invariably *Pelvetia canaliculata* and sometimes *Fucus spiralis*, are also significant additions in this zone. *Littorina saxatilis* is larger than *Littorina neritoides* and, as a more ‘open surface’ species, is generally limited to shores that are not too wave-exposed. The mid-shore is dominated by a mixture of limpets *Patella* spp., barnacles (predominantly *Semibalanus balanoides*) and/or brown algae, the composition of which depends upon the extent to which the brown algae have replaced the mussel *Mytilus edulis* and barnacle communities typical in this zone on exposed rocky shores. Under conditions where there is a poorly developed barnacle zone and a poorly developed fucoid algal zone on the mid-shore, the mid-shore may be colonised by a variety of gastropod species, including limpets and topshells, and by *Fucus spiralis*. A number of moderately exposed rocky shore community variations have been recognised by Lewis (1984).
Moderately exposed rocky shores have been recorded from 19% of the sites investigated, with just over half the sites described from the southwest of Britain (Table 8.3.4, Figure 8.3.19). Like exposed rocky shores, moderately exposed examples have been described from the mouths of rias in southern Britain, and from the mouths of fjords and fjords in northern areas. Most of the examples are of local marine conservation interest but examples do occur of regional or even national importance (Figure 8.3.18). Regional examples have been described from Lindisfarne and Budle Bay (Connor 1989), Falmouth (Rostro 1985), the Avon Estuary (Moore 1988a), Milford Haven (Liddle & Hiscock 1987) and Plymouth Sound (Hiscock & Moore 1988), while nationally important examples have been described from Lindisfarne and Budle Bay (Connor 1989), and the Salcombe and Kingsbridge Estuary (Hiscock 1988). Powell et al. (1979a) considered the moderately exposed rocky shores present outside the Lizard Estuary and in Bagh Naam Facilean, both in the Outer Hebrides, to be parts of nationally important sites.

Sheltered rocky shore community

Under wave-sheltered conditions the width of the black band of Verrucaria lichen, at the top of the shore, is markedly reduced, bringing the familiar yellow and orange terrestrial-fringe lichens into almost direct contact with the upper shore algal species Pelvetia canaliculata. Typical sheltered shore species, such as the alga Ascorphyllum nodosum, occur on the mid-shore and the kelp, Laminaria saccharina, is present on the lower shore. In extreme shelter Fucus spiralis, which is usually present, may be absent, leaving an isolated band of the alga Pelvetia canaliculata at the top of the shore. Further information, including representations of some of the patterns of zonation, is given in Lewis (1984).

In general, variations within this community arise from incompleteness of the algal cover on the shore, or differing proportions of the shore being occupied by the various species of fucoid algae. Thus in a situation where there is some wave action, or where stones and shingle are present, the
brown fucoid algae *Fucus vesiculosus* and *Fucus serratus* predominate. Under more sheltered conditions and on a firmer substratum, however, it is *Ascophyllum nodosum* which dominates along with the characteristic red filamentous epiphytic alga *Polysiphonia lanosa*.

Sheltered rocky shores are the second commonest type of hard substratum community, being recorded from 31% of the sites investigated (Table 8.3.4). They are mostly restricted to ria, fjord and fjord systems and accordingly have a predominantly south-westerly or northerly distribution (Figure 8.3.20). Examples occur along the south coast in a small number of coastal plain sites; communities develop in these sites on artificial substrata or boulders and pebbles, rather than on natural bedrock shores.

**Figure 8.3.20** Provisional assessment of the distribution of the sheltered rocky shore community on the 102 review sites for which marine data were examined.

Sheltered rocky shores are predominantly of local or regional marine conservation interest (Figure 8.3.39), although a few examples of national importance occur, including Bagh Narn Faolean in the Outer Hebrides (Powell et al. 1979a). Shores in Milford Haven (Little & Hiscock 1987), Otter Mhor (Pewell et al. 1979a), Plymouth Sound (Hiscock & Moore 1986), Salcombe and Kingsbridge Estuary (Hiscock 1996) and in the Yealm Estuary (Hiscock & Moore 1996) were all considered to be of regional marine conservation importance. The site in the Outer Hebrides, Otter Mhor, is of note due to the fact that here, under very sheltered conditions, a free-living form of the brown alga *Ascophyllum nodosum* develops. This is the only review site at which the *mackaii* variant of *Ascophyllum* occurs, although *mackaii* itself is widespread in Scotland with extensive beds known elsewhere.

**Variable salinity rocky shore community**

This community occurs in situations where there is measurable and variable dilution of sea water. The community is similar to the sheltered rocky shore community of full salinity situations, except that the overall species diversity is reduced and some full salinity species, such as the lower shore kelp species, *Laminaria digitata* and *Laminaria saccharina*, are absent. The place of the kelp species is taken by brown algae, such as the sheltered shore species *Ascophyllum nodosum*, and by the fucoid alga *Fucus serratus*. These algal species are also found on the mid-shore. In both mid- and lower-shore situations the algae may be associated with barnacles (in particular *Semibalanus balanoides* and *Elminius modestus*) or limpets *Patella* spp.

Additional species which, although not purely estuarine in distribution, may occur in particular abundance include the small red algae *Catenella caspitsosa* and *Bostrychia scorioides*, the hydrozoans *Laomedia flexusa* and *Clavia mutica*, the bryozoan *Bowerbankia inbricata*, and estuarine amphipod crustaceans such as *Echinogammarus marinus*. The individual abundance of these and the dominant algal species may vary from estuary to estuary owing to factors such as variability of river flow rates and differences in water turbidity.

The community occurs at review sites only where there is intertidal rock exposed to variable salinities. The community therefore has a restricted distribution and has only been recorded from 11% of the review sites investigated (Table 8.3.4, Figure 8.3.21). Most of the sites are rias in south-west Britain and the community is surprisingly absent from fjord and fjord systems, although this is probably a reflection of lack of records rather than the true distribution. The community is mainly of low conservation interest (Figure 8.3.38) although there are examples displaying regional marine conservation interest, such as at Falmouth (Rosstron 1985), or national marine conservation interest, such as the rocky shores present in the Salcombe and Kingsbridge Estuary (Hiscock 1986). In the Cawsand Estuary (Gill & Mercer 1989) a variant of this community occurs where the rock is covered by growths of green algae *Enteromorpha* spp.. This may be partly related to the fact that under certain conditions sediment loading in the water column
Variable salinity rocky shore community

but this is dependent on a number of factors including the degree of freshwater down-flow into the estuary. The black lichen Verrucaria maura is still present on the upper and mid-shore, and lower shore levels may be dominated by two species of brown fucoid algae, either Fucus ceranoides (in areas where fresh water flows over the shore) or Fucus vesiculosus (in areas of more generally reduced salinity). The upper shore fucoid algae species, such as Pelvetia canaliculata, are replaced by algal species which are more tolerant of variable salinity, such as Bafina and Rhizoclonium. Such a modified shore zonation reflects the vertical salinity gradient which may be present at high tide this far up the estuary; sea water is denser than fresh water; hence at high tide the lower shore area is exposed to higher salinity levels than the upper shore (Wilkinson 1980).

Additional characteristic species which may occur include the estuarine barnacle Balanus improvisus, the estuarine isopod crustacean Sphaeroma rugicorda and occasionally the hydroid Cordylophora caspia. Considerable variation in exact species composition may occur because of local conditions such as river flow rate and water turbidity.

This community is the commonest hard substrata community, being recorded from 38% of the review sites investigated (Table 8.3.4, Figure 8.3.22). The community has been considered to be of local marine conservation interest (Figure 8.3.39), although on occasion, such as in the Dart (Moore 1986b), assessments have been made which suggest that the community warrants designation as of national importance.

Reduced salinity rocky shore community

In very reduced salinity in estuaries, at or close to the limit of tidal influence, an extremely impoverished rocky shore community develops. Most marine species are unable to tolerate such lowered salinity levels and rock surfaces are mostly colonised by blue-green algae and diatoms; filamentous green algae may be present.

The community has been recorded from very few review sites (Figure 8.3.23, Table 8.3.4), which suggests either a lack of hard intertidal substrata near tidal limits or under-recording. Examples are known from the tidal limits of rivers feeding the Firth of Forth (Wilkinson, Scanlan & Titly 1987) and from the upper reaches of ria systems, notably the Taw and Torridge Estuary (D Laffoley in litt.), and the Tamar (Plymouth Sound), in south-west Britain (Hiscock & Moore 1986). No assessments have been made of the marine nature conservation significance of this community.

Sabellaria reef community

On bedrock and boulders a distinctive community can occur consisting of aggregates of tubes belonging to the polychaete worms Sabellaria

Figure 8.3.21 Provisional assessment of the distribution of the variable salinity rocky shore community on the 102 review sites for which marine data were examined.

prevents the normal community from establishing: when turbidity decreases, opportunistic species, such as the one above, can colonise these areas. It may arise also partly because in estuaries which are completely flushed by fresh water at low tide, fucoids may be replaced below the low water mark by Enteromorpha spp. (Wilkinson 1980). Enteromorpha spp. is also known to be linked to nitrification; vast growths of these algae periodically occur in south coast inlets, indicating elevated nitrogen levels in the water.

Variable (mainly reduced) salinity rocky shore community

In conditions exposed to salinity levels which vary but which are predominantly low, a very species-poor rocky shore community occurs. Such a community is characterised as much by the large number of species which are absent as by the very few species which are present. The exact location of this community in estuaries depends very much on the topography of individual inlets; it predominantly occurs towards the upper reaches
alveolata or Sabellaria spinulosa. These aggregates vary from a thin patchy cover on the rocks to more substantial reef-like structures and can occur in areas subject to tidal scour with a high level of suspended material in the water. Both species can occur in the intertidal and subtidal zones; Sabellaria spinulosa has been reported to occur chiefly on the North Sea coast (Gubbay 1988).

Sabellaria reefs usually occur on the open coast and have only been recorded from 8% of the review sites investigated (Table 8.3.4, Figure 8.3.24). Sabellaria spinulosa has been recorded from Lindisfarne and Budle Bay (Connor 1989) but develops into larger aggregates only in the subtidal zone of The Wash (Fowler 1987). This species has undergone a dramatic decline over the years and is now either absent, or present only in very reduced numbers, in the Dee Estuary (Wallace 1962; McMillan 1982), the Humber Estuary, Morecambe Bay and the Thames Estuary (Rees et al. 1988). This decline has been attributed by some researchers to the destruction of the reefs by trawling for brown shrimps Crangon crangon and pink shrimps Pandalus montagui. Sabellaria is a prime source of food for shrimps, and declines in shrimp fisheries in the Humber and Morecambe Bay, and elsewhere, followed the eventual destruction of the reefs (Rees et al. 1988). No marine nature conservation assessment has been made of well-developed reefs formed by this species; the community in The Wash is now the only extensive example of Sabellaria spinulosa reef known from the literature examined for this section of the review.

Sabellaria alveolata reefs have been recorded from the intertidal of two review sites, the Exe Estuary (Dixon 1988) and the Taw and Torridge Estuary (Little 1990). Good examples of intertidal reefs have mainly been recorded outside review sites, such as at Duckpool, on the north coast of Devon, and on the shores of Cumbria (Covey & Davies 1989), and less well developed examples from the northern shore of the Outer Solway (Covey 1990). In the subtidal zone it is known from the Solway Firth (Perkins 1973) but forms extensive reefs only on one site in Britain, the subtidal zone of the Severn Estuary (University College Cardiff Consultants Ltd 1989), where it occurs along with
which is rich in species of sponges. It usually occurs on the lower part of the shore and may include rare and unusual species.

The community is rare and has only been recorded from two review sites (Table 8.3.4, Figure 8.3.25). The community is of high marine conservation interest. Covey & Davies (1989) describe a low shore community in Morecambe Bay which was dominated by the sponges Halichondria panicea and Hymeniacidon perleve, the latter species being present in well developed ‘pipe forms’. They considered the community to be of regional importance. A richer community which was densely colonised by a variety of sponges, ascidians and anemones was described from the Yar Estuary on the Isle of Wight by Johnston (1989). She considered the community to be of national marine conservation interest owing to, amongst other things, the presence of a sponge Suberites massa which has been recorded from only three other sites in Britain, namely the rock walls at Southampton and Poole and the narrows at the entrance to The Fleet.

**Current-exposed sheltered rocky shore community**

Under conditions of normal or variable salinity, in areas swept by tidal currents but sheltered from wave action, a fragile community can develop
Exposed rock community

The community occurs in full salinity on subtidal rocky substrata exposed to wave action. The algal or infralittoral zone is colonised by a kelp forest consisting predominantly of the species *Laminaria hyperborea*, along with a variety of smaller foliose red algae. Below depths which can support algae is the animal-dominated or circalittoral zone. In wave-exposed conditions this is colonised by a variety of erect sponges, hydroids, erect bryozoans, anemones and cup corals. The exact species composition may be very variable depending on local conditions and a range of minor habitats may be present ranging from subtidal cliffs and caves to fissured rock.

The exposed rock community has been recorded from only 9% of review sites investigated (Table 8.3.4), reflecting the infrequent occurrence of subtidal rock throughout review sites in general. The exposed rock community has been recorded from the mouths of a number of ria systems in south-west Britain (Figure 8.3.26), such as the Carmel Estuary (Gill & Mercer 1989), Milford Haven (Little & Hiscock 1987), Falmouth (Rostron 1985) and Plymouth Sound (Hiscock & Moore 1986).

Figure 8.3.26 Provisional assessment of the distribution of the exposed rock community on the 102 review sites for which marine data were examined.

Hiscock (pers. comm.) considers the infralittoral and especially the circalittoral community at the entrance to Plymouth Sound to be of high conservation importance. The community, which is uncommon on review sites, is best assessed in relation to open coast sites. The comparatively low marine conservation importance indicated in Figure 8.3.38 should not be taken as a reflection of this community's true conservation status; the community is essentially an open coast one, and well developed, high conservation interest sites occur in the rocky subtidal zone outside the areas considered for this review.

Sheltered rock community

The sheltered rock community develops in full salinity areas where there is subtidal rocky substrata which is sheltered from wave activity. The infralittoral (algal) zone may be dominated by the kelp species *Laminaria saccharina* and by a variety of foliose, or filamentous, red or brown algae. Particular smaller species of algae may form brown crusts on the rock surfaces. The circalittoral, animal-dominated, zone may have dense growths of encrusting sponges and bryozoans, with large solitary sea squirts which can often be abundant. Considerable variation in species composition may occur, depending on local conditions.

The sheltered rock community has been recorded from only 6% of review sites (Table 8.3.4), being almost completely restricted to ria systems in south-west Britain, although it is likely that the distribution is wider than that depicted in Figure 8.3.27. The community is of comparatively high marine conservation interest (Figure 8.3.38), being mainly of regional interest but with examples of both national and local interest. Nationally important examples have been recorded from Milford Haven (Little & Hiscock 1987) and from Plymouth Sound (Hiscock & Moore 1986), whilst regionally important examples include the sheltered rock communities present in The Fleet and Portland Harbour (Howard, Howson & Moore 1988), Falmouth (Rostron 1985), and the Yealm Estuary (Hiscock & Moore 1986).

Hydrozoan/bryozoan turf community

In subtidal conditions of moderately strong tidal currents a community may develop which is termed a 'hydrozoan/bryozoan turf'. The community is dominated by species of hydroids or bryozoans (hence the community name) and often develops on the upper surfaces of deposits of cobbles, pebbles and shells and on larger objects such as boulders. The community may develop in association with a number of other species or may have been recorded previously as part of subtidal community complexes. Species present range from foliose forms, such as the bryozoan *Flustra foliacea* and *Securiflustra secundum*, to the more 'bushy' species, such as the hydroid *Abietinaria abietina* and the bryozoan *Eucidrake loricata*.

The community has been recorded from 10% of the review sites investigated (Table 8.3.4), although
this figure is probably an underestimate; on occasion it has been difficult to decide from previous studies if a species-poor example of this community is present in some of the marine situations. The community has been recorded from enclosed coast sites throughout Great Britain (Figure 8.3.28). There does not appear to be any factor linking it to a particular classification of estuary, the only common theme is that it occurs in current-swept locations. Examples have been recorded from the Wash (Fowler 1987), Portland Harbour (Howard, Howson & Moore 1988) and from the current-swept middle reaches of the Dornoch and Moray Firths (Hunter & Rendall 1986). The community is of mainly local marine conservation importance (Figure 8.3.38), although examples of regional importance do occur, for example in the Dart Estuary (Moore 1988b).

**Slipper limpet Crepidula fornicata beds**

The slipper limpet Crepidula fornicata is an alien species of mollusc which was accidentally introduced into Britain with oysters imported from America. The species has spread around the south coast of Britain and under certain conditions forms extensive beds in the sublittoral zone. These beds support a variety of species of hydroids, bryozoans, tunicates and sponges. The Crepidula beds may in turn provide a settlement point for the European oyster Ostrea edulis or vice versa, and thus co-dominated Crepidula/Ostrea beds may develop. Crepidula is, however, normally regarded as a pest of oyster beds as it smothers the available hard substrata leaving less opportunity for oyster settlement.

Crepidula fornicata, as a species, has been recorded from 19% of review sites investigated (Figure 8.3.29, Table 8.3.4). It forms ‘beds’ in only 6% of review sites, but elsewhere well-developed beds dominate, for example, the central part of the west Solent (Dixon & Moore 1987). The distribution of the community is of interest as it shows the species to be limited to southern regions of Britain, the most northerly review site locations on the west and east coasts being Milford Haven and the Blackwater Estuary respectively. Very few marine nature conservation assessments have been made of Crepidula beds within review sites, although a
distribution essentially restricted to ria systems in south-west Britain (Figure 8.3.30); it is likely that this distribution will be expanded as further survey work is carried out. The presence of artificial substrata in a review site was taken as insufficient evidence to prove the presence of community at that site. Figure 8.3.30 therefore reflects the distribution of the community and not the distribution of artificial substrata within review sites. The community is predominantly of local or regional marine conservation interest (Figure 8.3.38). Examples assessed as of regional importance have been described from Milford Haven (Little & Hiscock 1987) and from The Fleet and Portland Harbour (Howard, Howson & Moore 1988).

**Artificial substrata community**

Under conditions of full or variable salinity, and in conditions of moderately strong tidal currents, a subtidal community can develop on artificial substrata. In estuaries the artificial substrata are most often jetty piles, piers, large mooring buoys or pipelines. The community is quite often very different from that of nearby natural substrates and is dominated by species of sponges and ascidians. Sponge species include Halichondria spp., Haliclonia oculata and Hymeniacidon perleve, and ascidian species Ascidia aspera, Ascidia mentula and Ciona intestinalis. The anemone Metridium senile, the feather star Antedon bifida, the introduced sea squirt Styela clava and a variety of bryozoans and hydroids may also be present.

The community has been recorded from 10% of the review sites investigated (Table 8.3.4) and has a

**Variable salinity rock community**

The variable salinity rock community occurs in the subtidal zone in areas which are sheltered or very sheltered from wave action. Lowered salinity is physiologically stressful to many marine organisms and thus reduces the species diversity of the community. The community is, however, still very
variable. Algae present include the kelp species *Laminaria saccharina* and a variety of predominantly green and red algal species. Sponges, such as *Halichondria panacea*, may dominate the community under some conditions, whilst in other circumstances the rock surface may be covered by high densities of the sea squirt *Dendrodoa grossularia*. Under certain conditions the sponge *Dysidea fragilis* may occur, growing in a massive form contrasting with the encrusting open coast form, and the branching sponge *Halichondra oculata* may also be present. A variety of other species may occur including hydrooids, bryozoans, anemones such as *Actinothoe sphyrroidea*, *Urticina felina* and *Metridium senile*, and common mussels *Mytilus edulis*. The barnacle *Balanus crenatus* can often dominate rock surfaces, and species which are normally considered to occur in the intertidal zone, such as the gastropod *Littorina littorea*, the brown alga *Fucus serratus* and the barnacle *Elminius modestus*, can extend into the subtidal zone.

The variable salinity rock community has a predominantly south-west distribution (Figure 8.3.31) and has been recorded from 11% of review sites investigated (Table 8.3.4). The community is usually of regional importance and very occasionally of national importance (Figure 8.3.38). Regionally important examples of this community have been recorded from, for example, the Camel Estuary (Cill & Mercer 1989), the Yealm Estuary (Hiscock & Moore 1986), the Tamar Estuary (Frid 1989) and the Dart Estuary (Moore 1986), whilst nationally important examples are known from Plymouth Sound (Hiscock & Moore 1986) and Milford Haven (Little & Hiscock 1987).

### Variable salinity clay community

In most, predominantly in areas of variable salinity, subtidal clay exposures can occur which may be colonised by a species-poor community. The impoverishment of the community is due largely to the unsuitability of clay for attachment or burrowing. The exposures frequently occur in areas subject to strong tidal currents; the currents account for the lack of sediment cover and the formation of the exposures in the first place. The community also occurs in the intertidal zone and is often associated with peat deposits and fossil forests, as at Brancaster on the North Norfolk Coast and in Southampton Water (R Mitchell pers. comm.). The community is characterised by the frequent presence of two species of burrowing bivalve, *Pholas dactylus* and the introduced species *Petricola pholadiformis*.

Exposures of clay occur in a number of review sites, mainly located on the central southern coast of Britain (Figure 8.3.32), although examples do occur in The Wash (R Covey pers. comm.), on the North Norfolk Coast (R Mitchell pers. comm.) and in the Blyth Estuary (Suffolk) (C Beardall pers. comm.). The majority of outcrops are in the Solent system, as at the mouth of Chichester Harbour (Holme & Bishop 1980), around the mouth of Newton Harbour (Dixon & Moore 1987) and in Southampton Water (R Mitchell pers. comm.). The community has been recorded from 10% of review sites (Table 8.3.4). No assessments have been made of the marine nature conservation importance of the clay community. Clay is, however, an unusual habitat and is restricted to only a few sites, suggesting that the impoverished community it supports is of some conservation interest.

### Variable (mainly reduced) salinity rock community

The community occurs in enclosed coast sites, mainly in the middle to upper reaches of estuaries, where there is a subtidal rock which is sheltered or very sheltered from wave action. The variations in salinity result in low species diversity within the community, with only a limited number of species able to tolerate the physiologically stressful environmental conditions. The water is usually, but not necessarily, turbid. The community which develops is either a species-poor hydrozoan/bryozoan turf or consists of single-species stands. Characteristic species include the
hydroids *Cordyiophora caspia*, *Hartlaubella gelatinosa* and *Coryne mucoides*, the erect bryozoan *Bowerbankia putulosa* and the encrusting bryozoan *Electra cristulata*. Barnacles are also present, such as *Elminius modestus*, *Balanus improvisus* and *Balanus crenatus*.

The community is very uncommon; it has been documented as present in only 3% of review sites (Figure 8.3.33, Table 8.3.4). Data on this community are limited and few assessments have been made of its marine conservation interest. An example which was assessed as of national importance was found in the Tamar (Plymouth Sound review site) by Hiscock & Moore (1986), whilst another possible example, present in the upper reaches of Christchurch Harbour, was assessed by Dixon (1988) as of local interest.

**Reduced salinity rock community**

The reduced salinity rock community occurs in the subtidal, on rocky substrates at the head of estuaries, at or near the limit of marine influence. The reduced salinity conditions mean that species diversity is highly reduced. Data are sparse but green algae, such as species of *Vaucheria*, *Blidingia* and *Cladophora*, are important in this situation (Wilkinson 1989). Blue-green algae, predominantly species of *Rivulana* and *Nostoc*, may be in evidence covering rock surfaces.

Information on the occurrence of this community is very limited and is insufficient to enable any comment to be made on its distribution or conservation interest.

### 8.3.4 Tidal freshwater habitats and communities

In the upper reaches of river discharge estuaries there is usually a tidal freshwater zone. The communities of these areas appear less well known than either the marine-influenced parts of estuaries or the non-tidal freshwater parts of rivers.

The extent of tidal freshwater conditions on an
individual site depends on a combination of the amount of inflowing water, the rate of delivery of fresh water and the nature of the tidal regime. Some of these alter on a weekly or seasonal cycle and result in great variability in the position and extent of freshwater tidal conditions at an individual site (Chapter 4.5). Seawater incursions may occasionally occur far upstream on spring tides and strong currents may develop in larger water courses at low water. Only a few species are able to tolerate these conditions, just as only a few can tolerate the conditions found in aquatic estuarine communities in reduced salinity at the tops of estuaries. Fringing vegetation of these tidally influenced river channels is similar to those of the adjacent freshwater grazing marsh ditches (see Section 8.1.12).

The actual transition to fresh water is often marked by an abundance of common reed *Phragmites australis*, which can also tolerate brackish conditions, for example in the extensive reed beds on the Firth of Forth. Inland from this transition banks and ditches support an often very diverse assemblage of plant species, characterised by those more typically associated with freshwater rivers, swamps and fens.

More work is required on the interface between full freshwater conditions and reduced salinity (estuarine) conditions in order to establish the true identity of the communities present and to discover more about their nature conservation significance and distributions on a local and national scale.

### 8.3.5 The diversity of aquatic estuarine communities

Estuaries usually contain a wide range of aquatic estuarine communities as a result of, for example, their salinity variations and habitat heterogeneity. The previous sections have described each community separately and have provided information, when known, on their nature conservation importance of each one. The overall nature conservation importance of the aquatic communities on a given estuary site does not, however, depend as much on these individual assessments as on the diversity and quality of communities within an estuarine ecosystem as a whole.

Provisional maps indicating the diversity of communities on soft and hard substrata are given in Figures 8.3.34 and 8.3.35. A reasonable range of communities on soft substrata are present on most review sites. With the highest diversity being in south-west England (Figure 8.3.34). Comparatively lower diversity occurs on the central, south-east and east coasts of England. A similar pattern of community diversity occurs with those communities described for hard substrata (Figure 8.3.35). The highest diversity of communities on hard substrata occurs in south Wales and south-west England, reaching peak values amongst the sites so far assessed in the larger sites such as Milford Haven and Plymouth Sound. South-east and east coast sites are predominantly of a sedimentary nature and accordingly have a very low diversity of communities on hard substrata.

The overall pattern of aquatic community diversity on Estuaries Review sites is given in Figure 8.3.36. This reinforces the individual patterns described for soft and hard substrata, revealing a marked trend of decreasing diversity from the ria systems of south-west England and south Wales to the coastal plain estuaries of east and south-east England.

![Number of aquatic communities on soft substrates](image)

**Figure 8.3.34** Provisional assessment of the diversity of aquatic estuarine communities on soft substrata on the 102 review sites for which marine data were examined.

### 8.3.6 Conservation of aquatic estuarine communities

As an initial step towards identifying a series of key sites showing all the representative and important features within the range of estuarine ecosystems in Britain, the aquatic estuarine habitats and communities of review sites have been defined and assessed individually, as described above. This process, and the community descriptions, follow that of the NCC’s Marine Nature Conservation...
Review which is undertaking key site assessment of the whole British marine nature conservation resource. Formerly the key site selection process was based on a consensus of expert opinion. Site evaluation criteria were subsequently introduced to provide a structured framework, allowing better integration and appraisal of the information available (NCC/NERC 1979; Mitchell 1987). The marine site evaluation criteria are similar in concept to those used as guidelines in the selection of terrestrial biological SSSIs and described in NCC (1989).

In Britain a number of criteria have become accepted by which the nature conservation value of terrestrial sites can be judged (Ratcliffe 1977). Ray (1976) cited the use of the Ratcliffe criteria in his International Union for Conservation of Nature and Natural Resources (IUCN) report on critical marine habitats and, at the same time, the NCC adapted the terrestrial comparative site evaluation criteria for selecting key marine sites around Britain (Mitchell 1977, 1979, NCC/NERC 1979). It is intended that the criteria-based approach will lead to the selection of a 'representative' range of marine Sites of Special Scientific Interest, reducing the bias towards high diversity, 'high interest', sites by ensuring the inclusion of an adequate number of areas of typically low diversity, including those which are naturally degraded (Mitchell 1987). Originally only 10 comparative marine site assessment criteria were put forward (NCC/NERC 1979) but these were expanded to the 14 criteria cited in Mitchell (1987). These recommended criteria fall into two main types, 'ecological/scientific' criteria, and 'practical/pragmatic' criteria, although there is inevitably some blurring of this distinction. The 14 marine criteria are listed below and brief definitions, together with notes on particular applications, are given in Appendix 8.

<table>
<thead>
<tr>
<th>Ecological/scientific</th>
<th>Practical/pragmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Naturalness</td>
<td>7 Situation</td>
</tr>
<tr>
<td>2 Representativeness</td>
<td>8 Recorded history</td>
</tr>
<tr>
<td>3 Rarity</td>
<td>9 Research and</td>
</tr>
<tr>
<td>4 Diversity</td>
<td>education potential</td>
</tr>
<tr>
<td>5 Fragility</td>
<td>10 Restoration</td>
</tr>
<tr>
<td>6 Size</td>
<td>potential</td>
</tr>
<tr>
<td>11 Intrinsic appeal</td>
<td></td>
</tr>
<tr>
<td>12 Vulnerability</td>
<td></td>
</tr>
<tr>
<td>13 Urgency</td>
<td></td>
</tr>
<tr>
<td>14 Feasibility</td>
<td></td>
</tr>
</tbody>
</table>
In using the criteria to evaluate sites and communities the ‘ecological/scientific’ criteria are applied first, to produce a short-list from which the potential conservation areas are selected on “practical/pragmatic” considerations (Mitchell 1987). The ordering of the criteria within these categories is considered to be an appropriate sequence for their application.

In order to provide a structured means of assessing the ‘international’, ‘national’, ‘regional’ and ‘local’ importance of the habitats and communities present at a particular location, a series of definitions have been developed which express the marine conservation importance in relation to north-east Atlantic marine ecosystems. These definitions of ‘international’, ‘national’, ‘regional’ and ‘local’ conservation importance are outlined in Hiscock & Mitchell (1989) and brief definitions are given in Appendix 8. The definitions are used to qualify the first six scientific site selection criteria, especially ‘representativeness’ and ‘rarity’.

The criteria-based approach has been successfully applied in the provisional assessment of the scientific interest and nature conservation importance of marine areas as a whole. They have also been applied to produce provisional conservation importance ratings for specific habitats, communities and species. The information to support a more thorough assessment of these will not be available until completion of relevant parts of the MNCR. Between 1973 and 1987 the criteria and definitions given above were developed and used on over 160 research projects commissioned, supported or undertaken by the NCC. These projects ranged from surveys of large areas of coastline (e.g. the partially completed Inter-tidal Survey of Great Britain: 1976 to 1981; the South-west Britain Sublittoral Survey: 1977 to 1981, and the Survey of Harbours, Rias and Estuaries in Southern Britain: 1985 to 1989) to much smaller studies of particular sites such as islands, lochs or marine sites. They are currently used by the MNCR, together with other sources of information, to evaluate the results of marine surveys carried out throughout Great Britain.

The provisional conservation assessments of the various aquatic communities described in Section 8.3.3 originate from over one-third of the NCC-commissioned reports resulting from the research projects discussed above. Whilst the Estuaries Review community classification was produced from the results of a wide range of studies conducted both by the NCC and by external organisations and individuals, conservation assessments have been provided primarily from the NCC-commissioned research. It was not possible within the Estuaries Review timescale to evaluate other ‘non-NCC’ data sources for review sites and produce additional comparative evaluations of the conservation importance of their communities.

Provisional conservation status ratings are summarised for selected individual soft substrata communities in Figure 8.3.37 and for individual hard substrata communities in Figure 8.3.38. It is noticeable that, especially for communities on hard substrata, most have been afforded local or regional conservation importance, with relatively few examples of communities of national or international significance. In the case of hard substrata communities this, as mentioned above, arises in part because the best known examples are outside estuaries. This cannot be so for soft substrata since most of the extensive soft shores in Britain are within review sites (Chapter 6). This apparent paradox between the overall very great conservation significance of British estuarine wildlife and these aquatic community ratings arises largely because the ratings have been applied to

<table>
<thead>
<tr>
<th>Community name</th>
<th>Provisional community conservation assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>International</td>
</tr>
<tr>
<td>Variable/reduced salinity mud community</td>
<td>●</td>
</tr>
<tr>
<td>Normal/Variable salinity muddy sand community</td>
<td>●</td>
</tr>
<tr>
<td>Beds of Zostera spp.</td>
<td>●</td>
</tr>
<tr>
<td>Beds of the common mussel Mytilus edulis</td>
<td>●</td>
</tr>
<tr>
<td>Exposed sand community</td>
<td>●</td>
</tr>
<tr>
<td>Sand/muddy sand community</td>
<td>●</td>
</tr>
<tr>
<td>Muddy gravel community</td>
<td>●</td>
</tr>
<tr>
<td>Mael community</td>
<td>●</td>
</tr>
<tr>
<td>Muddy ‘offshore’ sand community</td>
<td>●</td>
</tr>
</tbody>
</table>

Figure 8.3.37 Diagrammatic representation of the provisional conservation importance of selected soft substrata communities on review sites, ranked in order of abundance (see Table 8.3.3). The symbol size shows the percentage of sites of each community which have been assessed as of international, national, regional or local interest (see Appendix 8). The figure can be taken only as a guide to the conservation importance of the communities that have been assessed so far and the overall conservation importance of individual communities may change as more examples are assessed. In addition, the conservation importance of individual communities shown in the figure cannot be extrapolated to similar ‘un-assessed’ communities in the field: each new example has to be assessed on its individual merits using the 14 criteria listed in Appendix 8.
identification of key estuaries and other parts of the coast that are of major marine conservation importance, is in progress as part of the work of the MNCR. However, even at this early stage of their work, it is becoming clear that a number of review sites are of national or international importance for the aquatic estuarine habitats, communities and species that they support. Such sites are indicated where appropriate in Section 8.3.3 and include both larger, more diverse estuarine ecosystems, smaller sites containing classic examples of particular communities, and sites possessing an example of a community that is of great importance on a national or international basis.

Pressures on aquatic estuarine communities

The aquatic estuarine habitats, communities and species present on Estuaries Review sites can be damaged or destroyed as a result of a wide range of human activities. These activities are considered in brief below and also in Chapter 10.

Many human activities have only a low-level or temporary effect on the aquatic estuarine communities. Some, such as bait digging, only become of concern for these communities when carried out continually or at high intensity. Others cause substantial damage to the nature conservation interest of a site and so are of considerable concern, wherever and whenever they occur. One of the most significant activities in this respect is the loss of estuarine area through land-claim. Land-claim primarily affects the intertidal communities causing a loss of area for colonisation, which in turn can affect the abundances of bird populations dependent on these communities for food. Large land-claim schemes may, in addition, alter the hydrodynamic regime of an individual inlet causing the diversion of tidal currents and (potentially) increased scour of previously current-sheltered areas.

Another activity which results in increased scour and lowered marine community diversity is the canalisation of the upper reaches of estuaries with substantial flood banks. Such activity results in a decrease in the width of the estuary and (potentially) loss of meanders, together with markedly increased rate of water flow. This results in the community structure being dominated by a few communities that prefer higher flow rates. The erection of cost protection barriers in the lower reaches of the estuary also causes a loss of estuarine habitats, predominantly the upper parts of the intertidal zone.

Barrages and barriers constructed for a variety of purposes will, at the very least, restrict tidal amplitude, effectively raising the low water mark. In extreme cases, such as with leisure barrages, the tidal influence is entirely removed so that low water is effectively raised to equal high water. Barrages can accordingly have a profound effect on the aquatic estuarine communities, resulting, in extreme cases, in the loss of all intertidal
communities and the loss or redistribution of subtidal communities which are favoured by higher rates of water flow.

Spoil dumping and dredging for aggregates are other potentially damaging operations but these mostly occur outside review sites. There are notable exceptions such as the dredging for maerl that occurs in the Fai Estuary and the dumping of spoil from dredging activities which has, in the past, occurred inside the Salcombe and Kingsbridge Estuaries. Such operations result in the complete removal of areas of benthic community or the smothering of areas of the seabed. The communities affected may then take many years to re-establish. Dumping and dredging also release fine suspended material into the water which can affect organisms over a wider area by clogging the gills of fish and the water-filtering apparatus of filter-feeding organisms (Mitchell 1990).

Water quality may also affect marine communities. Extensive growths of green algae caused by eutrophication can smother intertidal sediment communities and, at the worst, kill or displace many species of algae and fauna. The effects are particularly evident in inlets with low water exchange rates with the open sea, e.g. Portsmouth and Langstone Harbours. The eutrophication of estuarine waters is currently a matter of some discussion and, following the announcement of new water quality criteria to be introduced in 1992, the NCC is carrying out work to establish criteria that will meet nature conservation objectives in estuaries.

Conservation designations covering aquatic estuarine systems

Conservation of marine wildlife on review sites is complex, whether it aims to protect individual communities or the estuarine system as a whole. Many intertidal areas, notably tidal flats on British estuaries, are identified as of national importance and are incorporated within SSSIs that generally cover a mosaic of estuarine habitats (see Chapter 8.1). These areas are usually selected for the habitat and macrobenthic food they provide for wintering and breeding birds, especially waterfowl, rather than for the aquatic estuarine communities themselves.

However, there are many marine areas of nature conservation importance which are outside the scope of SSSI notification. There are currently two main ways in which the marine interest of these subtidal areas may be afforded protection. One involves the statutory designation of a Marine Nature Reserve. The other is through the non-statutory, but nevertheless still formal, designation of a Marine Consultation Area. Both are considered below and, in relation to other forms of statutory and non-statutory protection, in Sections 9.3.7 and 9.3.8.

The Wildlife & Countryside Act 1981 makes provision for the designation of Marine Nature Reserves (MNRs) in order to conserve marine flora, fauna, geological or physiographical features of interest or to provide opportunities for the study of, or research into, these features. A Marine Nature Reserve can be designated out to the three mile limit and, by an Order in Council, out to the twelve mile limit. In practice, however, only nearshore and comparatively small sites have been put forward for designation or have been designated. The designation of an area as an MNR by the appropriate Secretary of State can only occur after all objections concerning the site have been resolved by consultation with interested parties. The argument for this process is that MNRs are difficult to police and therefore without the consent and co-operation of all interested parties the protection would be ineffective. The implementation of the MNR designation has accordingly proved to be both very complex and lengthy. Only two MNRs have been designated to date, Lundy in the Bristol Channel and Skomer off west Wales. Neither is close to a review site but amongst proposed sites is the Menai Strait in North Wales, which covers part or all of five Estuaries Review sites (see Section 9.3.7).

Marine Consultation areas (MCAs) are a form of non-statutory but formal protection for the marine environment. MCAs are areas identified by the NCC as "deserving of special distinction in respect to quality and sensitivity of their marine environment, and where the scientific information available fully substantiates their nature conservation importance". Twenty-nine MCAs have been identified so far and all are in rocky shore sea-lands in north-west Scotland. Only one, Loch Indaal, is on a review site. The white paper on the environment, This common inheritance (HMSO 1990), states that the Government are considering whether the MCA scheme in Scotland should be extended to England and Wales. If this does occur then it is highly likely that a number of estuaries and inlets in England and Wales would be afforded a degree of increased protection under this designation.

8.3.7 Conclusions

Britain’s shallow seas support a wide variety of marine life in a mosaic of plant and animal communities, the species composition being determined by factors such as substratum type, salinity and degree of wave and tidal exposure. In the intertidal and subtidal parts of review sites this ranges from exposed marine areas at the mouths of estuaries and open coast review sites to tidal, predominantly freshwater, conditions in the upper reaches.

Many of the communities described in this chapter generally only occur on British estuaries. A number of these communities are of interest at a regional level and some are of marine nature conservation importance on a national or international level. Accordingly the diversity and
quality of these communities at a given site contributes to our understanding of Britain's estuaries as a resource of national and international value.

In recent years, an increasing frequency of damage to the aquatic habitats, communities and species on review sites has been evident. This has ranged from a significant loss of estuarine area from activities involving land-claim and other coastal developments, to damage or destruction of subtidal communities from activities such as spoil dumping, water quality problems or dredging activities. In addition, there are ever-increasing pressures on the coastal fringe for recreation and associated developments, all of which have some degree of impact on the aquatic estuarine communities. Rising sea level over future decades will impose additional problems, squeezing the intertidal communities into an ever-decreasing area between immovable landward barriers and the sea itself (see Chapter 11).

It is important that planners and developers take account of the national and international value of these communities and that research is continued to identify further areas of marine nature conservation importance. Consideration should be given to increase the statutory protection of intertidal and subtidal estuarine aquatic communities as a whole.

8.3.8 References


PETERSEN, C.G.J. 1913. Valuation of the sea. II: The animal communities of the sea bottom and their importance for marine zoogeography. Danish Biological Station. Report, 81, 3-43.


