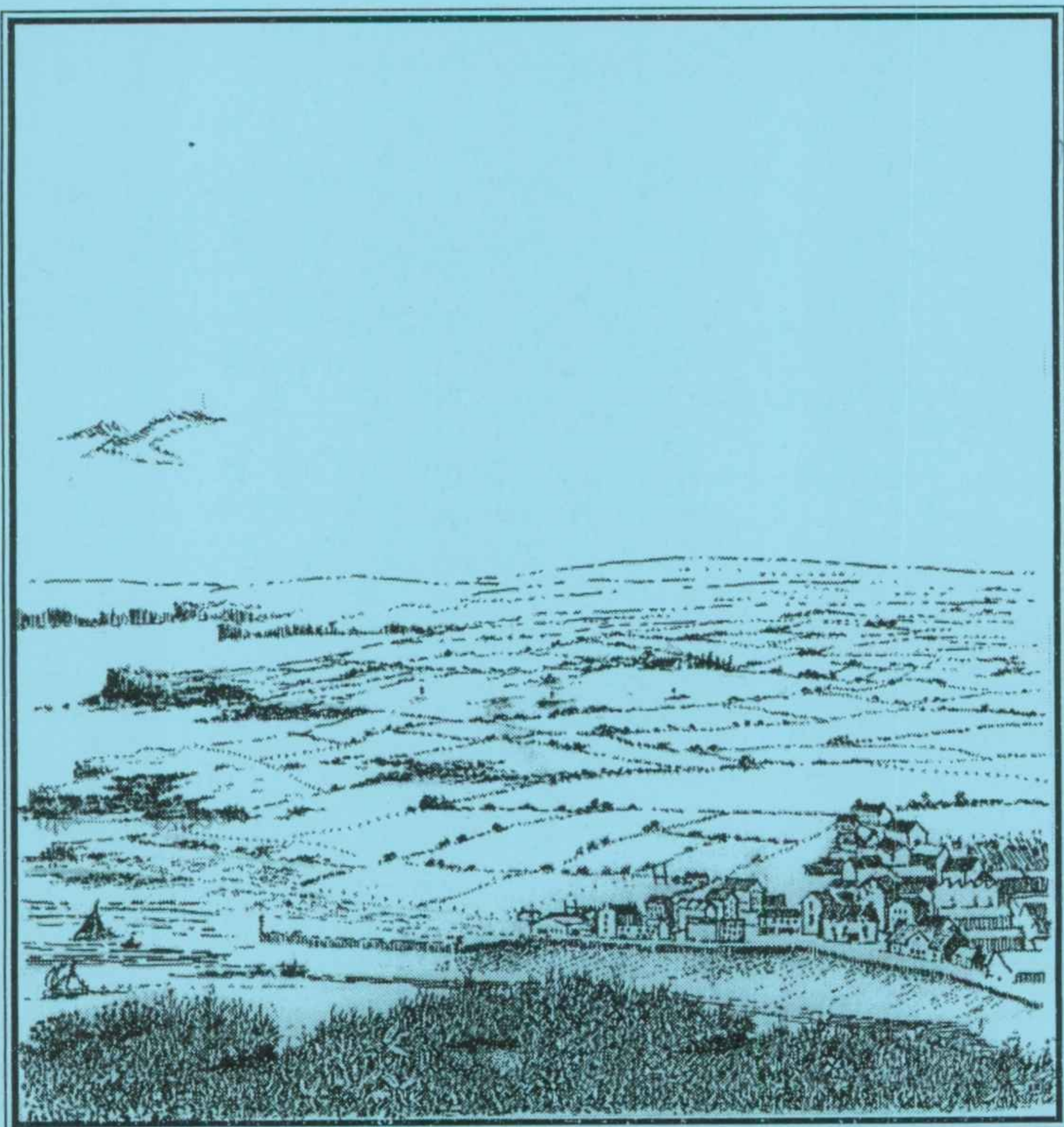
Department of the Environment



Current status and prospects for threatened habitats in England

Part 4

Coastal landscapes

ITE/ERM/UCPE contract report
to the
Department of the Environment

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Part 4

Coastal landscapes

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This Report is one of a series describing work on threatened habitats commissioned by the Department of the Environment. Views expressed in it do not necessarily concide with those of the Department.

CONTRACT

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CONTENTS

EXECUTIVE SUMMARY

Survey

1. In 1992, the DOE commissioned a research project to investigate the threatened habitats occurring within the landscape types included in the original Countryside Stewardship Scheme, of which coasts was one. The general aim of the project was to build on the work of the Countryside Survey 1990, and examine in more detail the distribution and quality of these habitats within the landscape types in England. This examination forms a basis against which future ecological changes, resulting from changing policies or specific initiatives, may be compared and measured.

2. The first step was to define the current geographical extent, and potential future extent, of the coastal landscape type. The broad geographical extent of the existing coastal landscape was determined by including all 1 km squares in England which contained land within 500 m of the high water mark, plus all contiguous areas of saltmarsh, dunes and coastal bare land. The 500 m zone within these squares comprised the 'coastal mask'.

3. The next step was to characterise the coastal mask in terms of ecology, landscape features and archaeology. The 1 km squares were stratified according to coast type (estuarine, soft geology and hard geology coasts) and designation status (designated or non-designated). Squares in these six strata were then randomly sampled, and land cover, vegetation in quadrats, landscape features and historical features were recorded. Historic features were also collected from existing archaeological datasets and archives.

Current status

4. The coastal mask comprised a range of land cover types from built and recreational land, through agricultural crops and improved grassland, to 'core' maritime vegetation types such as saltmarsh. Only 8% of the mask was covered by core coastal vegetation types and 64% of the coastal mask contained one or more designation type. Most of the core vegetation types were in the designated strata, with a higher proportion in estuarine and soft coastal types.

5. In addition to the core maritime vegetation, other semi-natural vegetation, such as unmanaged grassland, waterside vegetation and marsh, was recorded.

	Area (ha)
Core maritime vegetation types	29 500
Other semi-natural vegetation types	15 000
Coastal mask	734 100

6. Objective measures of vegetation (recorded in quadrats) have been related to quality criteria, to provide an empirical evaluation of the quality of coastal vegetation in different parts of the coastal landscape. Using at least two separate measures of each of the quality criteria, the four survey strata were ranked. The designated soft coast stratum ranked highest for most measures (10 out of 15) and the hard coast strata ranked lowest (having little maritime vegetation).

7. From examination of historic records, the coastal mask was shown to contain features from most periods of history. There appeared to be no correlation between density of features and designation status.

8. It was recognised that, without time-series data, it was difficult to assess the effect of designation. It was not known, for example, whether correlations between 'good' areas of coastal habitat and some form of designation were because the designation had been effective, or whether the designation was made because of the quality of the coastal vegetation. However, this study provides for the first time an essential baseline, necessary to conduct future monitoring of the effectiveness of designations.

Threats

9. The major factor determining the quantity and extent of coastal habitats is the process of ongoing erosion of sinking coasts and the advance of rising coasts. Other major threats are associated with agricultural land use, urban development and recreational

facilities. Industrial infrastructure, particularly polluting or risky installations, has also been located on the coast, and often in isolated areas of previously near-natural vegetation.

10. In the future *climate change* is expected to be a major factor, leading to sea level rise, temperature rise and seasonal variations in rainfall.

11. Airborne pollution is not considered to have a wide impact on coastal habitats overall, but sensitive habitats such as saltmarshes are vulnerable to coastal pollution and particularly oil spills from coastal shipping and offshore oil.

Prospects

12. To consider what vegetation changes may take place under different scenarios of perceived threats, the study has made use of the 'Competitors: Stress-tolerators: Ruderals' (C-S-R) classification of functional types, and the TRISTAR2 model which predicts vegetation change in response to environmental and/or management change scenarios.

13. Most of the core coastal vegetation was composed of competitor, ruderal and competitor/ruderal species. The remaining vegetation plot types were representative of all other combinations of functional types.

14. The TRISTAR2 model calculated the predicted change in abundance of the functional types, under each of six specimen change scenarios, and an index of vulnerability was produced. The coastal mask includes a heterogeneous grouping of saltmarshes, maritime, grassland and scrub types of habitat. The differences between habitat groupings are marked, with woody classes among the most vulnerable, saltmarsh and other maritime types being the least vulnerable, and grassland types occupying an intermediate position. Vulnerability of different habitat types differs only slightly according to scenario.

15. The coasts comprise a valuable landscape from a number of perspectives: ecological, recreational, scenic and historic. The survey results indicate that, of the core vegetation within the coastal landscape, about 29 490 ha (55%) is saltmarsh and other maritime vegetation. Most of the rest is unmanaged grassland.

16. Working from the MAFF strategy and English Nature and Countryside Commission initiatives for coastal areas as a starting point, it would appear feasible to establish the following objectives:
    - to enable natural physical processes to continue along the whole length of the coast through managed retreat (or advance) of the coastal belt;
    - to protect and enhance existing systems of near-natural habitats, particularly sand dune and saltmarsh systems;
    - to restore some near-natural habitats such as sand dunes which have been damaged by recreational or development pressures, and re-create habitats such as saltmarshes where opportunities arise.

17. Nature conservation designation and a number of well-established schemes now cover large proportions of the eligible land area. However, if further work indicates that the above objectives are justifiable, then opportunities do exist for re-creating grazing meadows and saltmarshes on arable and pastoral land as part of the managed retreat process. For hard coasts there have been fewer initiatives to re-create habitats, but in some areas cliffs are being left to retreat naturally in the hope that valued under-cliff habitats will re-establish themselves.

18. To ensure that the benefits of these measures are retained in the long term, and transferred to other areas, it is also essential that effective management approaches continue to be identified and publicised.

Chapter 1 INTRODUCTION: PURPOSE AND CONTEXT OF THE REPORT

1.1 Policy background

1.1.1 Despite much concern over the loss of semi-natural habitats in recent decades, there are inadequate levels of information as to the location and status of some rare and important habitats on a national scale. This information is becoming available through thematic and local surveys and is essential if assessments are to be made of the likely impacts of changing policies (eg Common Agricultural Policy, Habitats Directive, Biodiversity Action Plan) or of current incentive schemes (eg Countryside Stewardship) on the distribution and quality of these habitats.

1.1.2 To add to knowledge and understanding in these areas, the Department of Environment (DOE) commissioned a research project to investigate the threatened habitats occurring within the landscape types included in the original Countryside Stewardship Scheme. These are:

- i. lowland heath landscapes
- ii. chalk and limestone grasslands landscapes
- iii. upland landscapes
- iv. coastal landscapes
- v. river valleys and waterside landscapes

1.1.3 These landscape types, together with their constituent habitats (see Box 1), are seen as areas which have suffered serious losses and degradation of habitats in the past and appear to be still under threat. They are perceived as having great value for wildlife, landscape, history and amenity/public enjoyment.

1.1.4 The general aim of the project was to build on the work of the Countryside Survey 1990 and examine in more detail the distribution and quality of threatened habitats within the landscape types in England. This examination forms a basis against which future scenarios of change, resulting from changing policies or specific initiatives, may be measured and compared. The project has also attempted to develop a methodology for measuring change at the national level; it reviews current policy instruments affecting threatened habitats and considers prospects for the future.

1.2 Research context

1.2.1 Countryside Survey 1990 (CS1990), a project carried out by ITE, jointly funded by NERC, DOE and the former Nature Conservancy Council, was developed from earlier surveys of GB and included field surveys of land cover, landscape features and vegetation quadrats. It also included soil surveys of all sample squares and was linked to a project mapping the land cover of GB using satellite imagery (Barr *et al.* 1993).

1.2.2 For the Countryside Survey 1990 fieldwork, a standard sample unit of 1 km x 1 km square has been used. Squares visited in the earlier surveys (1978 and 1984) were surveyed in 1990 and an additional 124 squares were added to the sample, giving a total of 508 squares.

1.2.3 Although the 1978, 1984 and 1990 Countryside Surveys provide comparatively

> *Box 1.1*
>
> In the context of this project, the coastal **landscape type** is a conceptual term for geographical area(s) adjoining open sea or estuaries, and includes other land cover types (eg farmland) which abut and form mosaics with coastal habitats. The **mask** is a cartographic term which, in this project, is a map of that area of land extending 500 m inland from the high water mark plus contiguous areas of saltmarsh, dunes and coastal bare land. Individual **habitats**, such as dunes, woodland or saltmarshes, occur within the landscape type.

up-to-date information on general changes in the British countryside, the sample-based system was not designed to yield data on rarer, or localised, habitats. Thus, there was a need for information about these habitats which are perceived to be under threat, or which represent areas of concern to the Department. This Report describes work undertaken on the coastal landscape type.

1.3 Objectives

1.3.1 The objectives for each landscape type were to:

i. determine the distribution of the landscape type in England;
ii. survey the habitats (including major land cover types and ecological features such as hedgerows) and historic features within each landscape type;
iii determine, on a regional basis and in relation to current designations, the composition of each landscape type in terms of the quantity and quality of the surveyed features;
iv. develop models to predict the effect of environmental and management changes on the distribution and quality of the landscape types and their constituent habitats;
v. in the light of the above, make recommendations on ways in which policy instruments may be refined to further protect, enhance or re-establish the habitats which characterise each landscape type; and
vi. establish a baseline and develop a methodology for measuring change in these habitats which is sufficiently robust and precise to assess the effectiveness of policies, at a national (England) scale.

1.4 General approach

1.4.1 To meet the objectives of this project, a consortium was assembled which brought together the ecological and modelling knowledge and skills ITE and the NERC Unit of Comparative Plant Ecology (UCPE) with the policy-related expertise of Environmental Resources Management (ERM). Giving additional support, in relation to historical aspects, was the Archaeological Unit of the University of Lancaster.

1.4.2 The general approach used by the research team can be summarised in Figure 1.1.

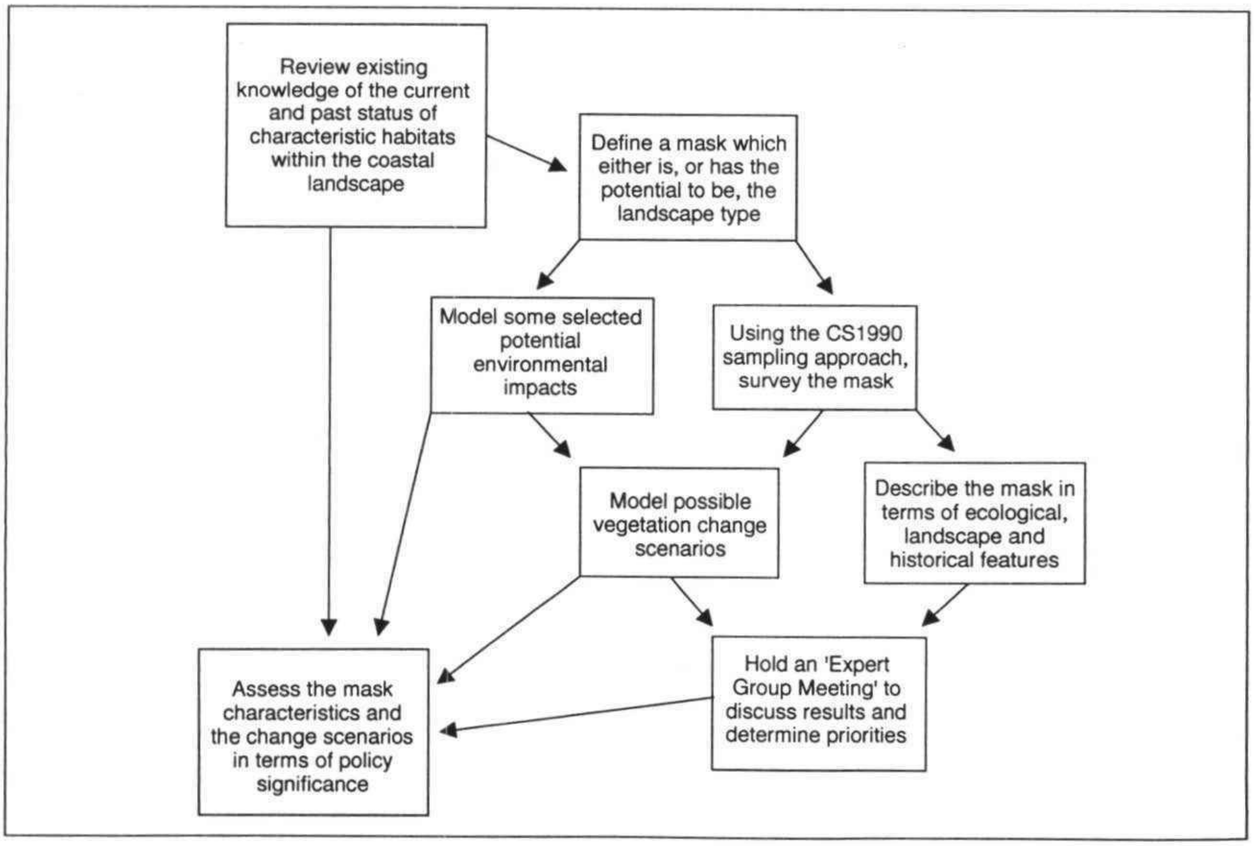

Figure 1.1 General approach used by the research team

1.4.3 Although this approach was used successfully in most aspects, it was decided, on the basis of expert opinion, that modelling the impact of acidification and enhanced nitrogen deposition was inappropriate for the coastal landscape, as the characteristic coastal vegetation types (eg saltmarsh) were considered to be relatively insensitive to these threats. The impacts of atmospheric pollution are not, therefore, considered for coastal landscapes.

1.5 Structure of the Report

1.5.1 The task of compiling this Report was undertaken jointly by members of the research team. The structure of the Report reflects the overall approach, as shown in Figure 1.1, with steps in the research being reported as separate Chapters. The final Chapter brings together the main conclusions from each phase of the work and gives a summary of the project, in relation to the objectives.

Chapter 2 BACKGROUND: THE IMPORTANCE OF THE COASTAL LANDSCAPE

2.1 Introduction

2.1.1 This Chapter is based on a review of existing literature and gives a general definition of the coastal landscapes and their distribution within England. It describes the distinctive ecological, scenic, recreational and historical characteristics, and explains why coastal habitats are important in a national and international context. The evolution of coastal habitats, and the factors important to their maintenance are discussed. Trends for change and threats to the coastal habitat resource are briefly reviewed and the need for conservation and enhancement is highlighted.

2.2 The coastal landscape – a general definition

2.2.1 Coastal landscapes are extensive and very varied in nature and there is no agreed definition of the coastal zone.

2.2.2 The Department of the Environment's *Planning policy guidance* note no. 20 on coastal planning (DOE/Welsh Office 1992) explains that 'the coastal zone extends seaward and landward of the coastline. Its limits are determined by the geographical extent of coastal natural processes and human activities related to the coast'. For planning purposes, the limit of the coastal zone in the seaward direction is the mean low water mark and the inland limit is variable and depends on the extent of direct maritime influences and coast-related activities.

2.2.3 Under the Countryside Stewardship Scheme for the coast, the term 'coastal land' is applied to the coastal fringe, coastal paths and cliff-top edges. It usually extends inland to at least a field's width, but in some areas of scenic or ecological importance can extend more widely.

2.2.4 The term 'coastal zone' will be used to refer generally to the area occupied by habitats associated with the coast. The coastal landscape of England therefore comprises the shore of coasts and estuaries, including the zone exposed by the tide and the belt of land immediately behind the shoreland. This belt of land is subject to strong winds and a mild oceanic climate. It contains a wide range of distinctively coastal habitats, including intertidal habitats (eg mudflats, saltmarshes) and terrestrial habitats (eg shingle structures, sand dunes and cliffs).

2.2.5 There is a great diversity of scenery within the coastal landscape, ranging from high cliffs accompanied by a narrow coastal zone to low-lying land accompanied by a broad coastal zone. The coastal landscape contains extensive wildlife habitats, some of international importance, with large and continuous areas of both natural and semi-natural vegetation. The scenic value of the coastal landscape is illustrated by the high proportion of the landscape which is designated (mainly Heritage Coast and Areas of Outstanding Natural Beauty

(AONB)). The coast is very popular with visitors, who come to use the beaches, to engage in water activities, or to walk the coastal paths. The historic importance of the coastal landscape is based on the specialised types of site represented and the diversity of remains preserved.

2.2.6 Coasts may be subject to rapid (often dramatic) changes caused by natural erosion and deposition processes, which may be intensified locally by sea level change. In general, the south-eastern coast is sinking and the north-west is rising. Decisions about how to manage the landscape often revolve around how to manage coastline change, and sea defence works (including coastal engineering) are a major influence in the coastal landscape. Much of the coastal landscape is inhabited, worked in, or used for recreation.

2.2.7 'Soft' coasts in England are backed by recent geological deposits (mostly gravels, sands and clays of the Tertiary era, and also rather older soft limestones and soft sandstones). They occur in the south-east, and around major estuaries and bays elsewhere, and typically feature earth cliffs, saltmarshes and reclaimed land, or sand dunes. Hard coasts are backed by older and harder sedimentary or metamorphic rocks. They occur in the north and west, and typically feature rocky shores and sea cliffs.

2.3 Coasts as an ecological resource

2.3.1 The nature conservation importance of coastal habitats relates mainly to the following.

- The English coastal zone supports internationally important numbers of wintering and breeding birds. The soft coast tends to be important for wintering birds which feed on the invertebrates in mudflats or on the vegetation of coastal fields, and for breeding waders, terns and gulls. Hard coasts are important for colonies of cliff-nesting birds, eg gulls, fulmars (*Fulmarus glacialis*) and guillemots (*Uria aalge*).

- Many distinctive coastal habitats and their associated plant community types are of restricted occurrence. Being confined to the coastal belt, they only form a very small proportion of British vegetation, by area, and within major vegetation types, eg sand dunes, the rarer subtypes may be very scarce indeed. For example, sand dunes of all kinds occupy no more than 12 000 ha in England, and the 11 rarest National Vegetation Classification types occupy less than 10 ha each (several being confined to a handful of sites). Among major habitat and vegetation classes, saltmarshes and shingle habitats have similar rarity characteristics; in addition, at least some reclaimed land habitats (eg grazed sea walls, brackish dykes) and cliff habitats (eg hard limestone headlands) are scarce. Among the very scarcest habitats are the various kinds of dune slacks, dune heaths, and vegetated shingle structures. Rare plants are sometimes uniquely associated with these scarce habitats (see para 2.3.8).

- Some coastal habitats are among the few examples of relatively natural habitats in England, developing and persisting without substantial human intervention or management (eg saltmarshes).

- Many coastal habitats are extensive and unfragmented, eg major saltmarsh and sand dune systems.

- Many coastal ecosystems demonstrate successional and other ecological processes unusually clearly. The idea of vegetation succession was first described in connection with sand dunes (in the late 19th century), and saltmarshes also provide good examples of successional plant communities. They are therefore important for scientific research. A great many coastal sites have been studied extensively over a long period of time, making them among the best-documented sites in Britain from an ecological point of view.

2.3.2 Within the coastal belt some habitats are tidally inundated, and have *inter alia* high levels of soil salinity that can only be tolerated by certain specialised plants; others are distinctively coastal by association, with uniquely coastal habitats, and may have low levels of soil salinity due to salt spray carried by wind; others are simply examples of inland habitats. Many habitats peculiar to the coast have highly specific vegetation types, especially saltmarshes, sand dunes, shingle beaches, cliffs, coastal heaths, and grazing marshes.

Table 2.1 Coastal communities in the National Vegetation Classification

Aquatic	A6	*Ceratophyllum submersum* community	SE coasts England
	A21	*Ranunculus baudotii* community	Coasts England
Swamp	S20	*Scirpus lacustris* spp. *tabernaemontani* swamp	Coasts England
	S21	*Scirpus maritimus* swamp	Coasts England
Saltmarsh		[28 communities and 24 subcommunities*]	
Sand dunes		[18 communities and 50 subcommunities*]	
Maritime cliffs		[12 communities and 29 subcommunities*]	
Grassland	MG11	*Festuca rubra–Agrostis stolonifera–Potentilla anserina* subcommunity	
	MG11b	*Atriplex prostrata*	W Coast England
	MG12	*Potentillo–Festucetum arudinaceae*	S & W Coasts England
	CG1	*Festuca ovina–Calluna vulgaris*	S & W Coasts England
Mire	M21	*Narthecium ossifragum–Sphagnum papillosum* subcommunity a *Rhynchospora alba–Sphagnum auriculatum*	S Coast Devon to Surrey
Heath	H7	*Calluna vulgaris–Scilla verna*	Coasts England
	H8	*Calluna vulgaris–Ulex galli* subcommunity (a) species-poor; subcommunity (c) *Sanguisorba minor*; subcommunity (d) *Scilla verna*	Coasts England
	H11	*Calluna vulgaris–Carex arenaria*	W Coasts England

* Source: J Rodwell, pers. comm.

2.3.3 Saltmarshes develop in levels on muddy shores between mid-neap tide and high water spring tides. A very limited range of higher plant species grow in places flooded by seawater (about 30 to 40 in the British Flora), and saltmarsh vegetation is relatively species-poor (never more than about 25 species in a site, and often far fewer). It is very distinctive as very few saltmarsh plants are capable of competing with terrestrial species on non-saline soils. The National Vegetation Classification recognises 28 different saltmarsh communities (Table 2.1).

2.3.4 Sand dune systems may develop in places where drying-out intertidal backshores provide a supply of wind-blown sand that can accumulate locally (beginning around obstructions to air flow, such as beach debris or vegetation). They normally comprise:

- fore dune zones where sand accretion commences,
- 'yellow dune' zones where high ridges of sand build up under marram grass but the sand surface remains unconsolidated, and
- 'grey dune' zones where the sand surface becomes consolidated by low-growing plants, eg mosses and lichens.

The yellow dunes support relatively few species, but of these several are confined to this habitat. The grey dunes support a much wider range of species. The most species-rich habitats in dune systems are dune heath and dune grassland habitats towards the landward edge, and dune slacks where fresh (or slightly brackish) water reaches the surface in depressions behind the dune ridges. These often support large numbers of rare plant species.

2.3.5 On low-lying soft coasts, land has historically been 'reclaimed' by 'inning' of saltmarshes behind earth sea walls. On such reclaimed land a large group of uncommon plants are associated with sea walls poached by cattle, and with rutted trackway behind the sea wall. These species require warm conditions, occasional disturbance (they are outcompeted in long-established grassy swards), and (in some cases) slightly saline soils. The dykes, fleets and drainage ditches of grassy grazing marshes on reclaimed land support a wide range of uncommon plants tolerating slightly brackish conditions. These dykes are also of great importance for rare invertebrates.

2.3.6 Cliff faces and rocky foreshore support vegetation which is possibly the most natural vegetation in England, in that it is undisturbed by the actions of man. Such vegetation receives very limited grazing –

generally only from rabbits (*Oryctolagus cuniculus*) or other small mammals. The vegetation is subject to severe winds, saline spray and very limited nutrients. Cliff surfaces tend to be fairly unstable through erosion, so early successional species can often be found. All these factors have produced a vegetation which is fairly unique in England.

2.3.7 Shingle beaches support a small number of highly specialised plants which are confined to the habitat. Old shingle structures may support lichen-heath communities which are exceptionally vulnerable to physical damage.

2.3.8 The coastal zone contains many rare plant species. Stewart, Pearman and Preston (1994) estimate that, of all the 'Nationally scarce' plants in Britain, at least 20% are coastal, making this the largest single habitat grouping for scarce plants. All scarce coastal habitat types have their own distinctive and usually substantial complement of 'Nationally scarce' plants and many also support *Red Data Book* plants.

2.3.9 A wide range of rare invertebrates are associated with the special plants of the coastal zone.

2.4 Coasts as a scenic resource

2.4.1 The coastline of England has great variety and beauty, encompassing cliffs and rocks, shores, sand and shingle bays, dune systems, estuarine saltmarshes and mudflats. This diversity – coupled with the interactions of land, sea and sky – provides a rich scenic resource. There is great variety in coastal landscapes but all share the common feature of wide views.

2.4.2 Coastal erosion is fundamental in creating the geomorphology and landscape patterns of the coast. It is these continuous forces which mould the shape and interest of the coast.

2.4.3 As well as natural features, some of the traditional built development in the coastal landscape can add attractive features such as ports and fishing villages. Typical coastal villages are built from local stone and are colour- or white-washed. They tend to be scattered around the slopes of harbours and seashores in a way which adds to the interest of the landscape. In addition to housing, the coastal landscape is also home to fishing boats and shipping which reflect the long-standing importance of these landscapes in the economy of the country.

2.5 Coasts as a recreational resource

2.5.1 The coasts of England are popular places with visitors, whether on day trips or longer holidays. They have long been the site of the traditional English summer holiday, and visitor numbers are large close to resort towns. In addition to bathing, simply sitting or playing, coastal areas are popular for walking. Many of the long-distance footpaths in England and Wales follow the coast and there are special routes with low-cost accommodation providing for walking holidays.

2.5.2 Coastal recreation has traditionally included fishing, boating and yachting, and these activities are increasingly popular. There is an increasing demand for marinas, and a growing interest in other water sports, such as jet-skiing, windsurfing and quad-biking (mostly on sand dunes).

2.5.3 Some sand dunes have been developed for golf courses. This has caused habitat destruction and fragmentation; however, it can provide protection for some plant and animal species in the margins and roughs.

2.6 Coasts as an historical resource

2.6.1 The coastal landscape has special interest as a site for archaeological remains because of the historical importance of the coast for an island people. The historical value of the coastal landscape lies in the specialised types and diversity of remains found.

2.6.2 The types of remains that characterise coastal areas include ports, forts, defence works, ship wrecks, salterns and fishing traps. In addition, organic remains such as wood are often well preserved in coastal sites, and the changing geomorphology can provide good places for the preservation of environmental indicators, such as pollen in waterlogged areas and plant macro-fossils in other areas.

2.6.3 Coastal erosion allows new discoveries to emerge but it can also lead to the loss of sites on coastal edges. Cliff faces and their erosion are of interest to earth scientists as they provide information about the historical formation of the land.

2.7 Coasts as a socio-economic resource

2.7.1 Tourism is a very significant industry in coastal areas and the issue of coastal change is of great importance, as development and increased activity, on the one hand, and natural and anthropomorphic processes, on the other, erode its resource base. Many resort towns depend upon tourism as a seasonal source of income, and problems such as pollution and poor weather can dramatically affect this income.

2.7.2 Coasts are also important for the fishing industry. They provide harbours and ports for docking ships and many fish processing plants are in the coastal landscape. Many industrial plants are positioned in the coastal landscape, especially those which require access to water or discharge outlets, such as power stations and chemical plants.

2.8 Dynamics of the coastal landscape

2.8.1 Some coasts are retreating and others are advancing. Whether coasts sink or rise depends on the balance between sea level change and the geological rise or fall of the land. Retreat and advance are also secondarily and locally determined by processes of erosion and accretion. These processes may cause dramatic geomorphological changes in some places over much shorter timescales than sea level changes *per se* (though sea level changes affect and may drive erosion and accretion processes), and their ecological importance is correspondingly great.

2.8.2 All coasts act as buffers to waves and stable coastal structures must be capable of dissipating wave energy; otherwise erosion will lead to coastal instability. The length of time this process takes will be different on hard and soft coasts.

2.8.3 Sediment supply is also critical to geomorphological processes in the intertidal zone. Sediments may arise either from coastal erosion, or they may be transported from inland sources by rivers.

2.8.4 Sediments form the raw material of many geomorphological structures on soft coasts, estuarine coasts and bays on hard coasts. They also act to dissipate wave and tidal energy (especially on soft and estuarine coasts). Geomorphological structures composed of sediments, eg shingle or sand beaches, mudflats, sand dunes and saltmarshes, will form where there is insufficient energy (water movement) in the intertidal zone to maintain sediments in aqueous suspension. Such low-energy coasts are especially common in bays and estuary mouths where waves cannot build up.

2.8.5 Sediments having different particle size distributions form different types of geomorphological structures. In particular, fine, cohesive sediments lead to mudflats and saltmarshes, while coarser, non-cohesive sediments lead to beaches, sand dunes and shingle structures.

2.8.6 For terrestrial coastal habitats the uppermost boundary of the shore, where vegetated structures such as saltmarshes and sand dunes may form, is ecologically significant. Mudflats, for instance, may be stabilised by marine algae and, when they reach a sufficient height to be exposed for most of the tidal cycle, they may then be colonised by certain highly specialised higher plants. The presence of vegetation substantially dissipates the energy of water flows over the mud, and sediment deposition accelerates greatly, leading to further accretion of the mud. This in turn leads to further invasion by a wider range of higher plants, and binding of the sediments by their roots. This process of saltmarsh formation has profound consequences for sediment patterns across the whole shore profile. Quantities of sediment are deposited on the upper shore, the shore profile steepens, and the saltmarsh forms a repository of sediment which under normal circumstances can only be released by the most severe storms. From a geomorphological point of view, the marsh therefore gives long-term temporal stability to the dynamic structure of the shore, allowing the whole complex of mudflats, channels and marsh to survive and develop.

2.8.7 On low-lying soft coasts, land reclamation by enclosing saltmarshes behind earth sea walls has been carried on since Early Medieval times (Darby 1983). Reclaimed land can be very productive, and close to markets it was historically used for crops as well as grazing. However, the uncropped grazing marsh habitat with sea walls, ditches and neutral grassland is especially characteristic of reclaimed land.

2.8.8 Land reclamation halts further deposition of intertidal sediments behind the sea wall but these can continue to accrete outside the sea wall depending on whether the coast is eroding or accreting. Over the centuries the level of the reclaimed land therefore falls relative to sea level and the saltmarshes outside the sea wall. Some old enclosures may therefore be as much as 2 m below present-day saltmarsh levels. This makes the reclaimed land vulnerable to marine flooding, especially during storm surges. Where a coast has been progressively reclaimed, these older enclosures are inland of the newer enclosures which accordingly rise towards the sea, creating problems in freshwater drainage. Most extensive areas of reclaimed land require some form of pumping.

2.8.9 Saltmarsh reclamation for agriculture has not been without environmental cost, even though it has been carried out over hundreds of years. It has had the long-term effect of removing sediment from the shore in many places, more rapidly than it could be replaced from natural sources, and shores have accordingly been narrowed and steepened (due to reclamation reducing the amount of saltmarsh available to absorb wave energy and thus concentrating that energy at the sea wall). The remaining saltmarshes and mudflats are therefore at increased risk of erosion. In addition, there are nature conservation disbenefits to narrowing of the shore, such as reduction in feeding areas for waders. For these reasons, nature conservation organisations have recently begun to oppose saltmarsh reclamation for agriculture, even in places where it has been practised on a progressive basis for generations (Doody 1992).

2.9 Loss of semi-natural habitat

2.9.1 Percentage losses of semi-natural coastal habitats during the post-war period have in general been lower than those of other semi-natural lowland habitat types, probably because much coastal land is unsuitable for intensive agriculture. This favourable picture must, however, be balanced by the consideration that specialised coastal habitats were always restricted in extent; and, because they are of high nature conservation importance, any loss is potentially serious.

2.9.2 Coastal habitats that are suitable for agriculture have suffered marked depletion just like other lowland semi-natural habitat types. This applies especially to grazing marsh. Doody (1992) states that 70% of grazing marshes in the Thames Estuary have been lost since 1945. Williams and Hall (1987) estimated that 82% of certain Essex grazing marshes were lost in the same period, mostly as a result of conversion to arable land. Landtake for port facilities and industries in estuarine areas may also have caused large losses in some areas, while marina developments have taken a small but locally significant toll of grazing marshes.

2.9.3 Another reason for the loss of coastal habitat is coastal erosion, especially in south-eastern England where sea level rise is rapid, and saltmarshes and earth cliffs are especially affected. The rates of land loss that might naturally occur are affected by structural defences which protect a large proportion of the south-eastern coast, eg 55% in Kent, Sussex and Hampshire (Bayliss-Smith 1990), and by coastal management policies. In Holderness, 61 km of unprotected earth cliff are eroding at the rate of 1.3 m yr^{-1} (Bayliss-Smith 1990).

2.10 Causes of loss

Sea level rise

2.10.1 There are several natural processes which lead to relative changes in sea level. The melting of ice sheets after the last ice age (eustatic change), mountain rise (tectonic change) and the delayed recovery of land masses following ice-loading during the last ice age (isostatic). Only the last of these is still thought to be causing major sea level change in the UK, with parts of Scotland still rising (up to 0.5 mm yr^{-1}), and southern England sinking at an average maximum rate of around 2 mm yr^{-1} in the Thames Estuary (averaged over the last 100 years). Some authorities consider the present rate of fall to be greater than this (perhaps as much as 5 mm yr^{-1}).

2.10.2 In addition, since about 1850, there has been a renewed eustatic rise (ie rise in sea level *per se*) which is generally attributed to global warming. Over the last 100 years this is thought to have averaged between 1 and 1.5 mm yr^{-1}, and may be due to thermal expansion of the seas and glacier ice melt.

2.10.3 Sea level rise is a key issue in relation to current and predicted ecological changes in the coastal zone, for the following reasons.

- There is concern that eustatic rise could become more severe because of global warming.
- Sea level rise poses a direct threat of flooding to coastal zone habitats at or below sea level, especially reclaimed land and the hinterlands of some sand dune systems.
- Sea level rise could exacerbate erosion processes in the coastal zone, leading to the total loss of saltmarshes in many areas, and threats to other intertidal habitats of nature conservation importance, especially those which support birds.
- Saltmarsh loss may itself render sea defences more vulnerable to wave action, especially earth sea walls, leading to increased threats of flooding.

The usual response to sea level rise problems has been to construct coastal defences of some kind. While these may protect resources (eg agricultural land) landward of the boundary, the landscape and nature conservation interest tends to be eroded away up to the boundary and the problem simply moves along the coast. If the coast is left to erode and land is abandoned, then coastal habitats together with their nature conservation interest move inland by natural processes.

Coastal engineering

2.10.4 Coastal engineering works which affect tidal flows or sediment supply may alter patterns of erosion and accretion, with subsequent effects on flora and fauna. These effects may be exacerbated by sea level rise. Offshore dredging of channels and mining of sediments (by dredging) may alter sediment budgets and have profound consequences for coastlines. Similarly, coastal works designed to prevent loss of sediments in one locality may cut off the supply to another.

2.10.5 Estuary barrages could cause some of these effects in areas seaward of barriers, though they could equally lead to local accretion of sediments on their landward side. Estuary barrages may also reduce tidal range and therefore the extent of intertidal feeding habitat for birds. These are among the main concerns in environmental assessments of estuary barrage proposals.

2.10.6 Coastal engineering works also tend to reduce the scenic and recreational qualities of the coastal landscape and may affect the accessibility of historic remains.

Pollution

2.10.7 Seaborne pollution may affect intertidal communities. Of greatest concern is oil fouling of saltmarsh vegetation (intensively researched during the 1970s). While short-term damage to saltmarsh vegetation may be severe, long-term recovery is usually good, provided that the marsh is not stressed in other ways.

2.10.8 Pollution and marine rubbish (from ships) may also reduce the scenic and recreational appeal of coastal areas, especially beaches where rubbish is not only unsightly but also a hazard.

2.10.9 Certain types of pollution which increase the nutrients in an area (eutrophication) – such as sewage or nitrogen runoff from agriculture – can cause algal blooms, reducing the scenic and recreational qualities of an area, and rendering some of the sea and shell fish inedible. Sewage pollution can also offend beach visitors who are worried about high levels of bacteria and viruses in the sea. Flag systems have been developed in the European Community to give an indication of the water quality on beaches.

Alien plants

2.10.10 Alien plants tend to be scarce in strictly coastal habitats, though they may be abundant and diverse in ruderal sites on estuarine coasts, especially where there are ports. However, on muddy shores the grass *Spartina anglica* is important; it colonises the lower mudflats ahead of other higher plants to form dense monospecific swards which may replace more species-diverse saltmarsh vegetation in some places. It may affect the usefulness of the habitat to birds.

Development

2.10.11 Development is a major issue in some coastal areas. As much of the open coast is designated in some way, estuarine coasts are the most at risk, even though their mudflats may be designated as Special Protection Areas (SPA). Moreover, industrial development is more likely to take place around ports, and these are mostly located on estuarine coasts. Development for housing tends to be rather closely controlled in the coastal zone, and infrastructure development predominates. Common types include power stations (including nuclear power stations which are often located in areas of high nature conservation importance, as at Sizewell and Dungeness, in order to reduce human risk), port facilities, waste disposal, sewage treatment plants and petrochemical plants.

2.10.12 A large number of estuarine barrages have been proposed for British estuaries, mainly for the purpose of tidal power generation. Many ecological issues are raised by these proposals, though most relate to intertidal and aquatic habitats beyond the scope of this study. Effects on sediment erosion and accretion outside of barriers could have consequences for vegetated habitats on upper shores, while inland of barriers there could be a loss of saltmarsh vegetation and brackish aquatic habitats. However, habitats of considerable ecological value might also be created. The issues are complex (British Ecological Society 1992).

Recreation

2.10.13 Recreation is a major issue in the coastal zone. Many different types are involved. Their effects may be summarised as follows.

- Water sports (yachting, sail-boarding, motor-boating, jet-skiing) mainly affect habitats in the coastal belt through landtake for marinas and related facilities. Reclaimed land in estuarine areas is especially at risk, as it can easily be bounded and flooded (to create marinas), and because these sports are most intensively carried out in the sheltered waters of estuaries. Other effects include erosion of saltmarsh edges by motor-boat washes, and landing on sensitive habitats, eg shingle structures. The major issue of concern, however, is the disturbance to nesting and wintering birds.

- Golf is the commonest use for dune grasslands. The prevalence of golf courses means that few unfragmented dune grassland systems exist, but the dune grassland plant communities do survive in a fragmented state (in the roughs). Rare dune grassland plants, birds and insects may therefore be very effectively protected (Nature Conservancy Council 1989).

- Scramble biking, 4x4 vehicle driving, and to a lesser extent mountain biking and horse-riding, are popular in dune systems where they may cause serious erosion damage. Especially at risk are dune heath communities in nutrient-stressed areas behind active dunes; these communities of stress-tolerators cannot survive major disturbance, and de-vegetation may result.

- The sheer weight of public access has profound effects in many coastal areas. These effects range from trampling of botanically important cliff-top vegetation to destabilisation of vegetation in early successional plant communities (especially sand dunes where trampling may cause major blow-outs).

- Wildfowling generally protects sites, especially if agreed sanctuary zones can be established, as wildfowl organisations require sites capable of supporting birds. Many nature conservation organisations let shooting rights because wildfowlers control poachers.

Agriculture

2.10.14 Agriculture is the main land use in the coastal zone, and intensification has led to post-1945 habitat loss as in other landscape types. Some special problems arise from coastal agriculture, including the following.

- Drainage and ploughing of fields behind cliffs may cause cliff-top erosion.

- The investment associated with intensive agriculture creates increased demand for sea defences, which may impair the conservation value of habitats both to seaward and to landward.

- Nitrogen runoff from coastal fields may increase eutrophication in coastal lagoons and estuaries.

- Cereal cultivation on coastal fields may attract large flocks of feeding geese (in winter), especially where more natural intertidal feeding grounds have been reduced in extent. Potential for conflict arises over control of protected species.

- Semi-natural grasslands are important wildlife habitats in coastal areas and fertilizer use causes loss of plant species diversity in such grasslands.

2.11 Conservation in the coastal landscape

2.11.1 Many scenic and nature conservation issues in the coastal landscape relate to the management of coastal erosion. In Britain most of the soft coasts which are susceptible to rapid erosion are in the south-east where they are sinking because of isostatic fall, while most of the hard coasts are in the north and west where they are rising. The effects of isostatic fall are thus maximised.

2.11.2 Coastal erosion in the hard coast creates the landforms typical of scenic coastlines. However, coastal erosion here may conflict with other priorities such as recreation, housing and transport. It may also force development inland, resulting in reduced areas of conservation interest. There is very little that can be done to prevent hard coast areas from eroding, other than encouraging land managers to put a field's width of land under pasture on the edge to reduce problems associated with unstable soil. This is indeed one of the targets of the Heritage Coast Scheme.

2.11.3 On low-lying soft coasts coastal erosion tends to be more dramatic. If coastal defence works are erected, then mudflats, saltmarshes or sand dunes to seaward erode more rapidly, and habitats that are important for birds may in the long term be reduced in extent because of the steepening of the shore.

2.11.4 For these reasons, most of the conservation bodies involved with coastal management favour a policy of managed retreat. This may involve allowing the sea to flood reclaimed land so that coastal habitats can redevelop inland of their former position in places where erosion pressures are smaller.

2.11.5 Research is being undertaken into coastal defences which may be more sensitive to ecological and landscape resources than concrete walls. These include designing 'beaches' from sand, shingle or concrete, and attempts to stabilise sediments. It seems unlikely that all such developments would favour the invertebrate populations upon which the ornithological interest of similar natural structures depends.

2.11.6 Given the wide range of interests involved in the coastal landscape, it may appear that agreement on policies will be difficult to reach. Indeed, separate interest groups often draw up parallel plans that may conflict with each other. However, one approach is that of amalgamating all interests into a coastal zone management plan. This has been undertaken in a few places (including the Isle of Wight) and appears to be a successful approach in that it encourages the consideration of wider issues and the development of compromise solutions.

2.11.7 Traditional methods of agricultural management can be important for some coastal vegetation types. Grazing is important in preventing scrub encroachment in a wide range of coastal and cliff grasslands (including dune grasslands). It even maintains breeding habitat for waders on some (but not all) types of saltmarsh.

2.11.8 Grazing has traditionally been carried out on reclaimed lands. Grazing marshes are generally high in nutrients and high stocking rates are therefore normal. Grazing is important in maintaining high species diversity by suppressing competitive species. Grazing of reclaimed lands is still economically viable, and failure to graze is seldom a problem where land remains in agricultural ownership (though it occurs rather extensively where land passes into the ownership of prospective developers). In the absence of grazing, coarse grasses dominate the sward and, in extreme cases, hawthorn (*Crataegus monogyna*) scrub may develop.

2.11.9 Saltmarshes are also traditionally grazed in some parts of Britain, especially the west.

Saltmarsh responses to grazing are very complex indeed. Different levels of the marsh respond in different ways to different levels of stocking, though it is generally true that fine-leaved grasses become dominant, and that the most species-poor saltmarsh communities become more diverse while the more species-rich communities become less diverse. Whether grazing benefits the nature conservation interest, therefore, depends heavily on local conditions.

2.11.10 Most sand dune hinterlands have also been grazed in the past, though the effects tend to be diverse (some dunes were used for rabbit warrening). On many dunes rabbits are the only grazing animal left and are therefore essential to the nature conservation interest.

2.12 Restoration

2.12.1 Because many coastal communities are early successional communities, they are relatively easy to restore. This is because the plants involved are colonising species which naturally establish themselves in suitable disturbed habitats, so that it is relatively easy to encourage their establishment by modifying the physical environment and planting.

2.12.2 Methods for dune restoration are especially well developed. The basic methods involve erecting openwork fences to trap sand, using brushwood or mulches to protect sand surfaces, and planting marram and other plants. In the 20th century these methods have been refined to deal with the widespread erosion pressures in dunes caused by intensive recreational use. They have also been used for restoring gas and oil pipeline breaches in sand dunes (Ranwell & Boar 1986).

2.12.3 Analogous methods for encouraging saltmarsh formation are successful in some situations (Holder & Burd 1990), but have not as yet been conspicuously successful in retrieving the situation where saltmarshes are eroding.

2.13 Summary

2.13.1 The coasts of England are a national and international resource for their nature conservation value, as well as their scenic, recreational and historic value. Coasts are also a valuable socio-economic resource, supporting tourism, fishing and industry. They support a diversity of interests and any attempts to conserve or protect them must necessarily balance often competing concerns. The realisation of this requirement in recent years has led to the increasing popularity of coastal zone management as a tool for bringing together disparate interests in planning, development and environmental protection.

Chapter 3 DEFINING THE COASTAL MASK

3.1 Introduction

3.1.1 The coastal landscape may be defined and described in a variety of ways (Section 2.2) but, at the outset of this project, there was no obvious existing classification which met the needs of the project.

3.2 Defining the coastal mask

3.2.1 The coastal mask was defined as that area of land extending 500 m inland from the high water mark (HWM) plus all contiguous areas of saltmarsh, dunes and coastal bare land.

3.2.2 The HWM data from Ordnance Survey were not available for use in this project so alternative means of defining the HWM were investigated. The ITE Land Cover Map gave the most accurate location of the HWM and this was chosen for use.

3.2.3 The coastline definition used in the production of the ITE Land Cover Map was a semi-automated procedure (Barr *et al.* 1993). Combined winter and summer Landsat satellite images were used to define land cover in every 25 m x 25 m area of Great Britain. From an initial classification, maritime land cover classes (sea, coastal bare and saltmarsh) were extracted and this area was smoothed using a combination of interactive editing and automatic filters to remove holes in the mask and erroneous 'inland maritime areas'. The inland edge of the mask was used to identify a smooth coastline which was then used to constrain land cover by imposing the rule that terrestrial habitats are found inland of the line and coastal habitats to the seaward. In many parts of the country, particularly in hard coast areas, there was close agreement (±50 m) between the coastline defined in

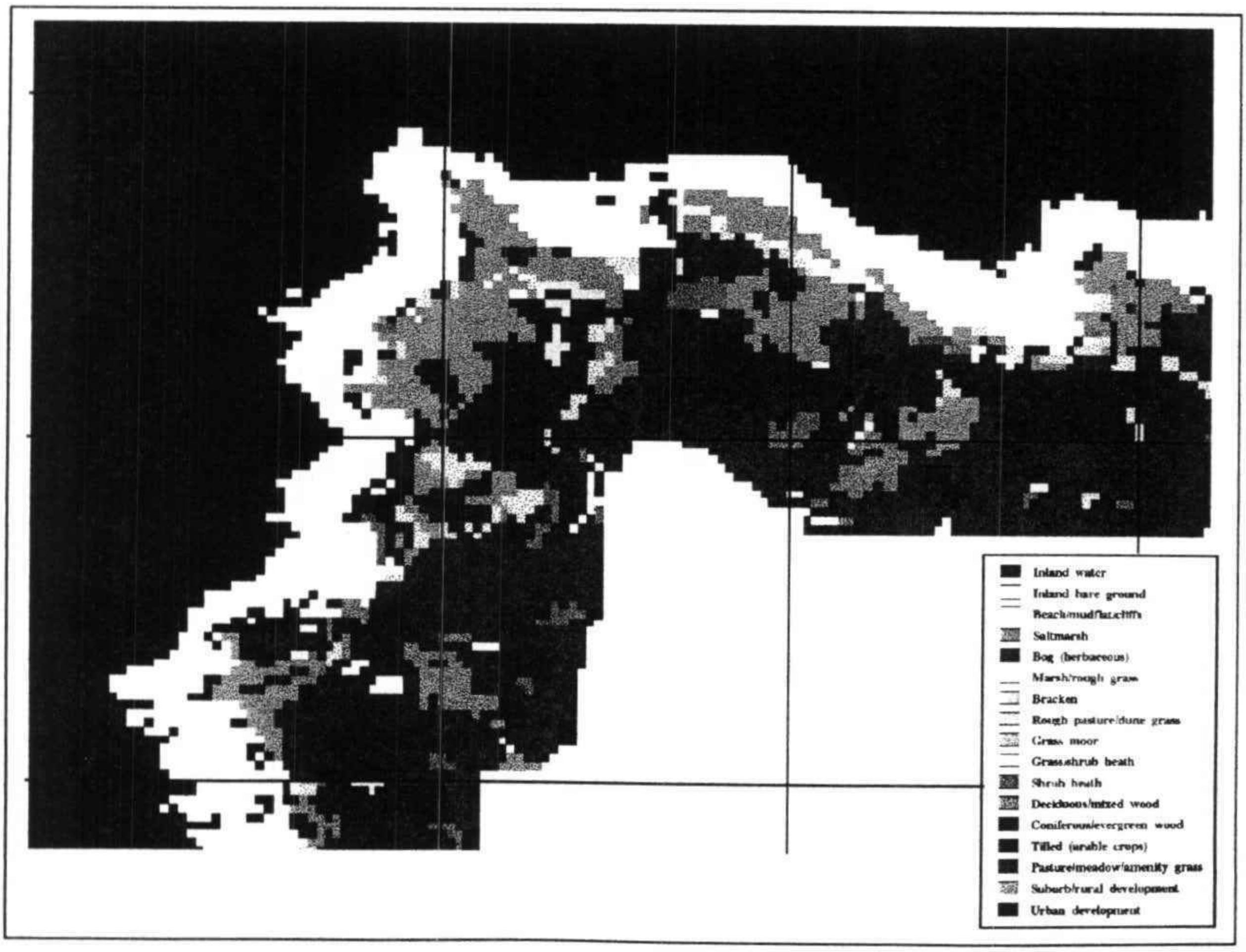

Figure 3.1. Example of the coastal landscape area at Hartland Point in Devon, showing land cover from the ITE Land Cover Map

this way and the HWM shown on 1:10 000 OS maps. In other areas, particularly on soft and estuarine coasts, the agreement was less close.

3.2.4 The coastline defined from the 25 m resolution ITE Land Cover Map was used to define the coastline within the coastal landscape, and a 500 m buffer zone extending inland of this defined the inland limit of this zone. This inland coastal buffer was created by expanding the coastline inland by 20 Land Cover Map grid cells (25 m x 25 m pixels), using an Arc/Info geographical information system. The coastal buffer was defined as that set of contiguous 1 km grid cells in England where coastal attributes (ie coastal buffer, saltmarsh or coastal bare) were present. The buffer lying inland or offshore of this area was discarded, apart from Lundy, as this represented isolated misclassified pixels from the Land Cover Map. The borders between England, Scotland and Wales were defined using Bartholomew's 1:250 000 map.

3.2.5 For each 1 km square, the total area of coastal buffer was calculated and then broken down into 14 main land cover types. The area of sea, saltmarsh and coastal bare within the square was also calculated.

3.2.6 The final 1 km square database contained 8870 km squares which were covered in some part by the coastal zone.

3.3 The coastal mask – outputs

3.3.1 The coastal mask (an example area is shown in Figure 3.1) occurs within 8870 km squares in England. Of these, 787 urban squares (>75% built-up) and 742 squares which were predominantly sea and which were not included in the ITE Land Classification were excluded, leaving a total of 7341. The locational data for these squares are available as a dataset for use in the DOE's Countryside Information System.

Chapter 4 ECOLOGICAL CHARACTERISTICS OF THE UPLAND MASK

4.1 Introduction

4.1.1 The methods used to define the coastal mask are described in Chapter 3. This Chapter goes on to describe the field survey which was completed in order to characterise the mask in terms of ecological components such as land cover, landscape features and vegetation.

4.2 Sampling strategy

4.2.1 The coastal mask was stratified to ensure that the sample of surveyed squares was representative, and to allow comparison between different types of coastal landscapes, and between coastal types in designated and non-designated areas. The six strata are:

i. estuarine coast – designated
ii. estuarine coast – non-designated
iii. hard coast – designated
iv. hard coast – non-designated
v. soft coast – designated
vi. soft coast – non-designated

4.2.2 The coast was classified into hard, soft and estuarine using information from an Ordnance Survey database (giving presence of coastal attributes), and from maps (NCC 1991; 1:50 000 OS maps). Thus, the predominance of cartographic symbols for features such as cliff and rock classified a square as 'hard' coast, while features such as sand and mud defined the square as 'soft'. Estuarine coast was defined as occurring from the river mouth to the upper limit of tidal rise along the river. Where more than one type of coast occurred in a 1 km square, the square was allocated to the most prevalent type.

4.2.3 'Designated' refers to the presence in all or part of a 1 km square of one of the following designations, according to databases assembled by ITE in 1988:

- Site of Special Scientific Interest (SSSI),
- National Nature Reserve (NNR),
- National Park (NP),
- Area of Outstanding National Beauty (AONB),
- Heritage Coast (HC),
- Green Belt (G Belt),
- Environmentally Sensitive Area (ESA).

These designations have varied objectives and were defined on the basis of different criteria, ranging from the conservation of rare species to landscape value. Some cover small homogeneous areas such as NNRs, whilst others are large and varied, like National Parks. They are administered by a range of bodies including English Nature (EN), the Countryside Commission, the Ministry of Agriculture, Fisheries and Food (MAFF), wildlife conservation trusts and local authorities.

4.2.4 The inclusion of a 1 km square in the designated strata indicates that at least some part of the square has at least one designation – in interpreting the following results it should be remembered that not all of the square is necessarily designated, so the area of the designated strata and areas of land cover types within it may be over-estimates. This point is mainly relevant to designations which affect small areas, eg SSSIs. Further the designation may not be related to the coastal nature of the vegetation.

4.2.5 The sampling unit, as for Countryside Survey 1990, is a 1 km square. Within each stratum, 1 km squares were chosen at random for field survey. In 1993, 49 squares were surveyed and, in addition, 23 squares which were surveyed in Countryside Survey 1990 fell within the coastal landscape; data from these squares have been extracted and added to the database. Within each sample square, a coastal zone was defined, reaching inland 500 m from the mean high water mark; land more than 500 m inland was not included in the field survey.

4.2.6 The results from the sample squares have been used to calculate estimates for the coastal landscape as a whole. The full dataset comprises the 500 m zone in 8870 km squares, but, of these, 742 squares were rejected because they included no land above high water mark (HWM). A further 787 km squares were rejected because they had more than 75% urban land (leaving a total of 7341 squares in the mask). The area of land in the coastal zone has been estimated by relating the area of land above the mean HWM in the survey squares to the information for coastal squares from the ITE Land Cover Map. The relationship between the survey squares and the size of each stratum is shown in Table 4.1.

4.3 Field survey

4.3.1 Land cover was recorded at 16 points on a grid within each field survey square, rather than mapping the whole square as in Countryside Survey 1990 (Barr *et al.* 1993). Only points within the coastal mask were recorded (ie up to 500 m from the mean HWM). Each grid point was accurately located on the ground and the land cover of the parcel of land (ie area of relatively homogeneous land cover) in which each point fell was recorded (code numbers were described in a field handbook). The nearest field boundary (within 100 m of each grid point) was also recorded.

4.3.2 For the 23 squares which had already been recorded as part of the CS1990 survey, the same approach was used, ie a grid of 16 points was placed over a map of each square and relevant data were extracted from associated databases.

4.3.3 Quadrats were recorded to provide quantitative botanical information about vegetation in the coastal zone. In each quadrat, all species were recorded and cover was estimated to the nearest 5%. All quadrats were permanently marked to allow future monitoring. Two different types of quadrats were recorded.

Main plots

At up to five randomly chosen grid points 200 m² nested quadrats were recorded to provide a representative sample of semi-natural vegetation. If the vegetation at these points was intensively managed (arable or intensive grassland which had been re-seeded or heavily fertilized), then no quadrat was recorded.

Habitat plots

Five 4 m² quadrats were also recorded in each survey square, in the less common habitats which were not represented by the

Table 4.1 The number of squares in the coastal mask and the number in the field survey sample

Stratum designation	Stratum size km²	Stratum size %	Number of sample 1 km squares 1990	1993	Total	%
Designated estuarine	946	36	7	9	16	22
Non-designated estuarine	464	18	2	8	11	15
Designated soft	371	14	1	5	6	8
Non-designated soft	208	8	3	8	11	15
Designated hard	496	19	7	11	18	25
Non-designated hard	119	5	2	8	10	14
Total	*2604*	*100*	*23*	*49*	*7*	*1002*

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main plots. The use of these targeted plots ensured that, if any maritime vegetation occurred in the survey square, then it was recorded with a quadrat.

4.3.4 Information from main plots and habitat plots from Countryside Survey 1990, where they occurred in the coastal zone, has been extracted to add to the 1993 data.

4.3.4 Considerable care was given to maintaining quality in field recording and to minimising variation between surveyors. Quality measures included the use of a field handbook, a training course for surveyors, and constant supervision. During the field survey, independent ecological consultants revisited a sample of the survey squares, and repeated quadrats and land cover descriptions. Information from these repeat visits was given to surveyors so that consistency of recording was maintained.

4.3.5 A pilot study was carried out to assess this survey approach, which showed that the grid system was reasonably accurate at estimating the most extensive, or widely distributed, land cover types, but was poor for those with limited geographical extent.

4.4 Field survey results: land cover

4.4.1 The land cover recorded at the 25 grid points in each 1 km sample square has been used to estimate the area of each land cover type in the four strata (Figure 4.1). Full details of the land cover estimates for each stratum, and for combined strata, are given in Appendix 1.

4.4.2 The hard coast, which is mostly composed of steep cliffs and rocky shores, had the smallest proportion of specifically maritime vegetation, but the most calcareous grassland and scrub. The vegetation at the top of cliffs is often not specifically maritime, frequently being ploughed close to the edge, but is affected by the maritime influence. The soft and estuarine coasts have shallower edges, occupying a greater area, with more specifically maritime vegetation. They showed major differences between designated and non-designated areas, particularly in the proportion of crops, which was much higher in non-designated areas. This evidence suggests that the major areas of coastal vegetation have been designated.

Table 4.2 Abundance of boundaries in the coastal landscape

Strata	% of points Without boundaries	With boundaries
Designated estuarine	62	38
Non-designated estuarine	55	45
Designated soft	72	28
Non-designated soft	63	37
Designated hard	51	49
Non-designated hard	49	51
Total	*55*	*45*

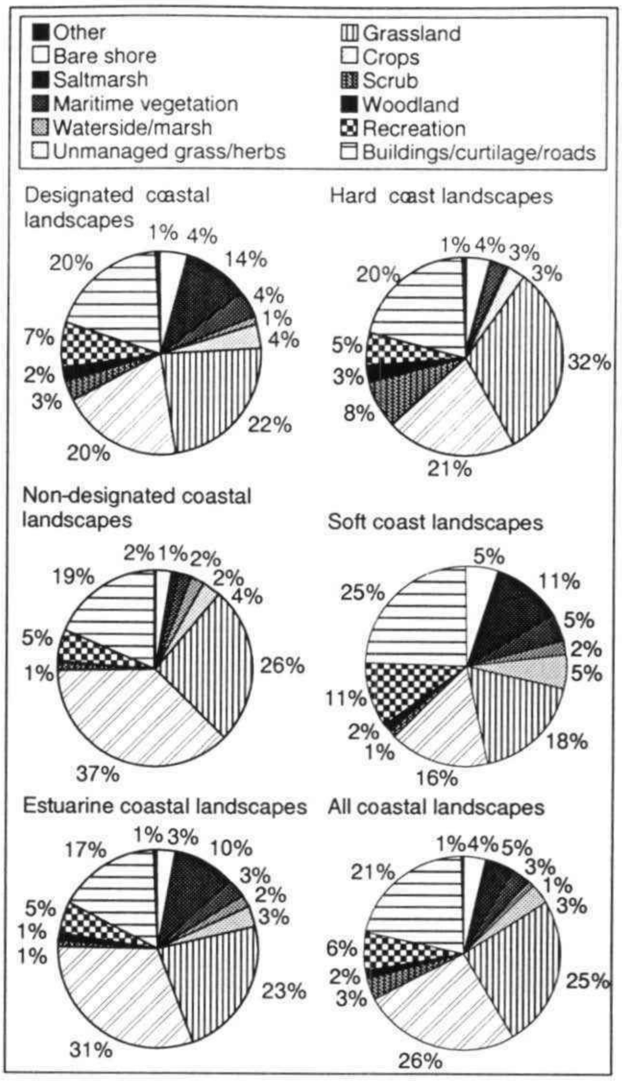

Figure 4.1 Estimates of the percentage area of each land cover type in the coastal mask

4.4.3 Of the 'core' coastal land cover types, saltmarsh was plentiful in the estuarine and soft coast strata, the majority of it falling in designated areas. Other maritime vegetation types (cliffs, dunes and foreshore) were much less common, but were also recorded more frequently in designated areas.

4.4.4 The dominant land uses in all strata were managed grassland (23% overall) and

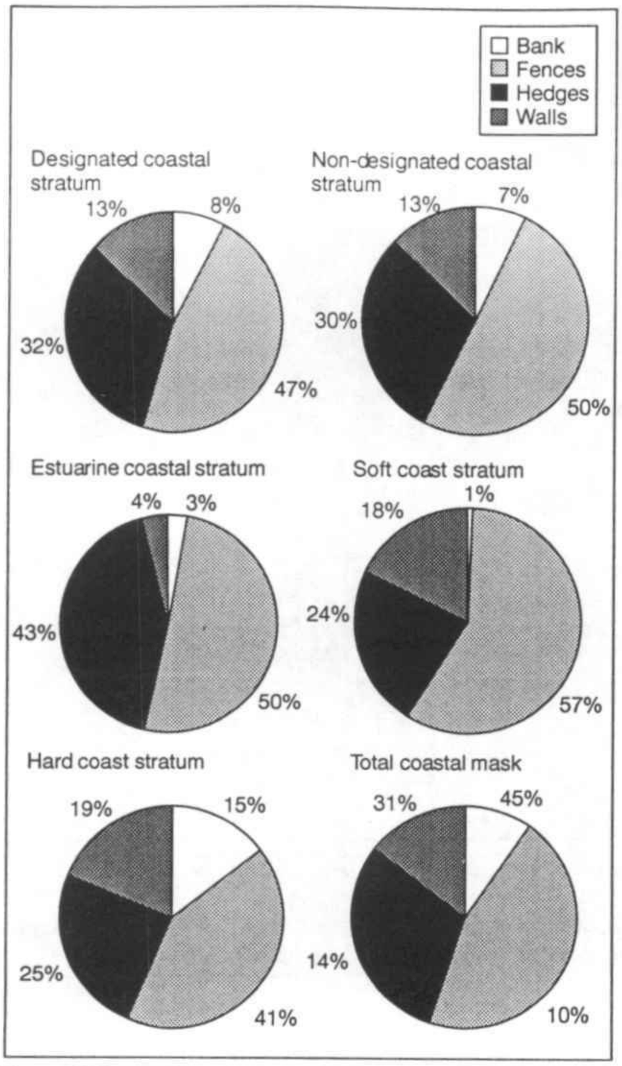

Figure 4.2 Proportion of boundary types in the coastal mask

crops (26%). Buildings/curtilages and roads (21%) also made up a significant element, and recreational use (6%, eg golf courses and caravan sites) was prevalent. Despite the removal of squares with more than 75% built land, many survey squares occurred on the urban fringe where the coastal vegetation was subject to considerable human disturbance.

4.5 Field survey results: boundaries

4.5.1 Overall, less than half (45%) of all grid points had a boundary within 100 m (Table 4.2). There was a clear difference between strata in the number of boundaries. The squares in designated strata had a lower proportion of field boundaries, which shows the greater areas of unenclosed land in these designated areas. The soft coast strata had fewer boundaries than the other coastal types, hard coasts having most boundaries. Overall, fences were the most common type of boundary, especially in the soft coast strata, with hedges and walls occurring significantly (Figure 4.2). The estuarine strata was were dominated by fences and hedges only, but walls were significant in soft coasts and banks were frequent in the hard coast strata. There was no appreciable difference between designated and non-designated strata. Further details are given in Appendix 1.

4.6 Summary of land cover and boundary results

4.6.1 The coastal landscape is dominated by managed grasslands and crops, which together make up over 50% of the coastal zone. Buildings, curtilages and roads contribute another 20%. The amount of core coastal vegetation varies considerable between coastal types, being least common

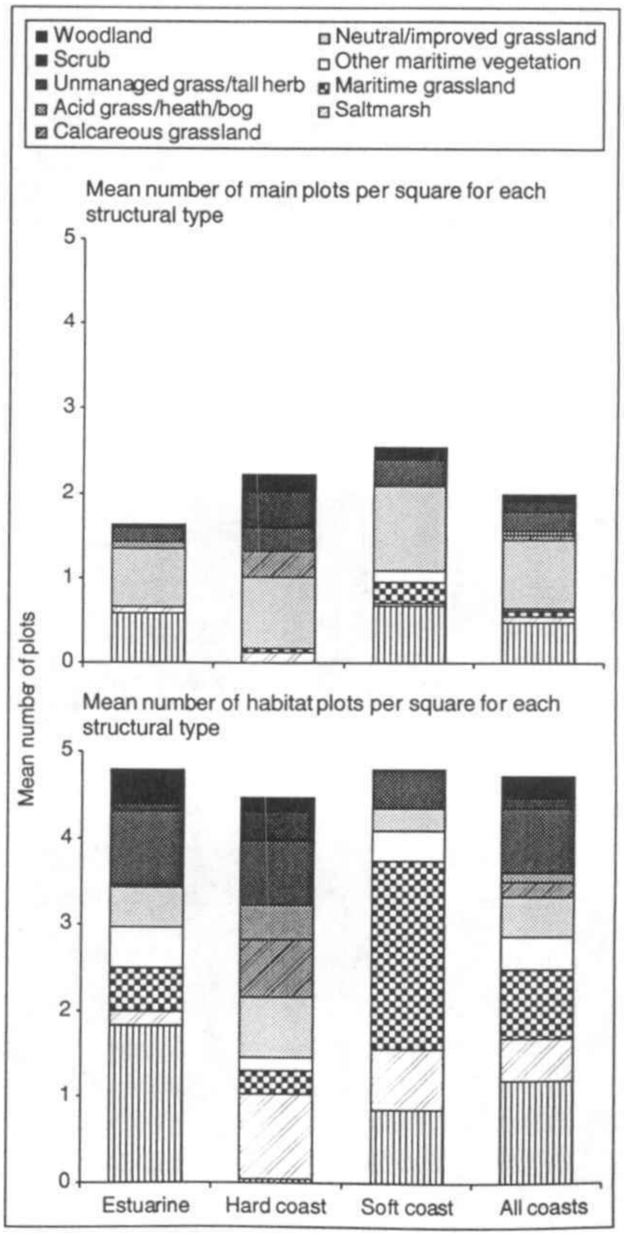

Figure 4.3 Abundance of structural types in the coastal mask

on the hard coasts (3%), and more common in estuarine (13%) and soft coasts (16%). Designated coasts have a higher proportion of the core vegetation (18%) than non-designated coasts (3%).

4.7 Vegetation sampling and analysis

4.7.1 The land cover data (as described in Section 4.3) represent the major vegetation categories and provide a baseline against which quantitative estimates of change can be made. To examine the more subtle changes that may take place as a result of new management or changing environmental conditions, the balance of vegetation species within the major land cover types needs to be recorded. To do this, species were recorded within quadrats. Two broad types of analysis have been carried out: first, quadrats have been analysed according to the species they contain, and, second, the species have been analysed according to their frequency of occurrence in quadrats.

Analysis of quadrats: 'structural types' and plot classes'

4.7.2 Two types of analysis have been carried out using the quadrat data: allocating the quadrats to structural vegetation types and classifying quadrats into plot classes.

4.7.3 The quadrats have been aggregated according to vegetation type, based on quadrat descriptions, into broad groups called '**structural types**':

Saltmarsh
Maritime grassland
Other maritime vegetation (including cliffs, dunes and foreshore)
Calcareous grassland
Neutral/improved grassland
Unmanaged grassland/tall herb
Acid grass/heath/bog

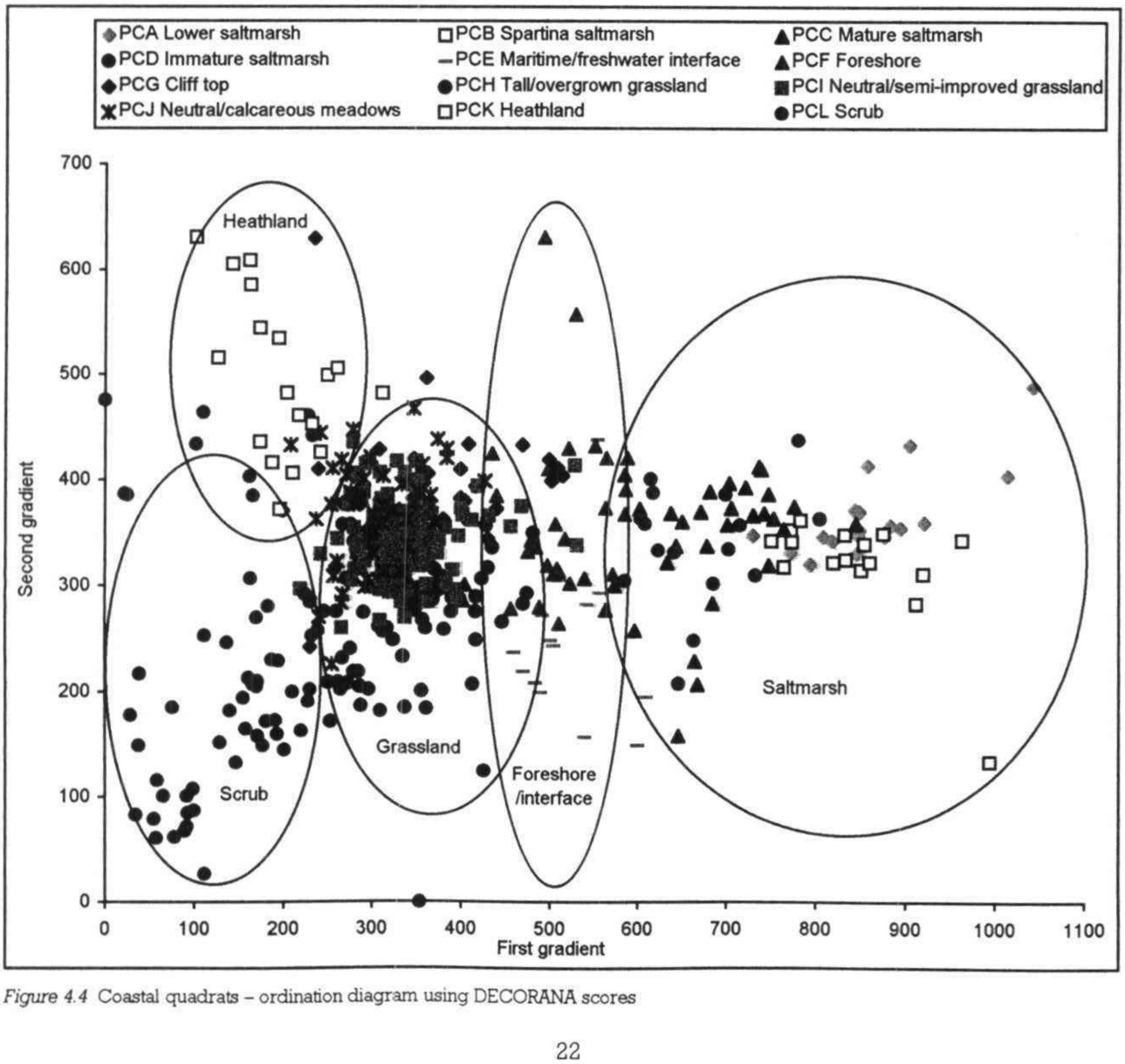

Figure 4.4 Coastal quadrats – ordination diagram using DECORANA scores

Marsh/aquatic macrophytes
Scrub
Woodland
(There were insufficient quadrats recorded on dunes for these to be treated as a separate category)

4.7.4 The quadrats were classified statistically into '**plot classes**' based on species composition (using a multivariate statistical classification, TWINSPAN – see hierarchy diagram Appendix 1). These plot classes have been given short descriptive names to aid interpretation (Table 4.3), and are ordered according to the principal gradient score (derived from the DECORANA analysis – see Figure 4.4). Further details of the plot classes are given in Appendix 1.

4.7.5 Plot classes A–F might be considered as the true, specialist maritime classes (core vegetation). The other classes are more generalist and may be found in non-coastal situations.

Analysis of species: 'habitat indicator groups' and 'species groups'

4.7.6 The species recorded have been allocated to '**habitat indicator groups**', based on expert knowledge, to identify the extent to which the species are associated with coastal vegetation (Box 4.1).

4.7.7 A multivariate statistical classification into 'species groups' has been produced which groups species with similar distributions across the quadrat dataset, using DECORANA and Ward's Minimum Clustering. The rare species (frequency <2%) have been excluded from this classification. These groups are shown in Table 4.4, ordered on the principal gradient.

4.7.8 Maritime species have been identified as being sensitive to particular threats (based on expert knowledge of species ecology), ie species which quickly disappear in the presence of:

Box 4.1

Maritime species,
eg *Elymus pycanthus, Aster tripolium*
Aquatic species,
eg *Phragmites australis, Apium nodiflorum*
Calcareous grassland species,
eg *Lotus corniculatus, Daucus carota*
Neutral grassland species,
eg *Festuca rubra, Achillea millefolium*
Damp grass/tall herb species,
eg *Pulicaria dysenterica, Eupatorium cannabinum*
Acid grass/moorland species,
eg *Agrostis capillaris, Pteridium aquilinum*
Woodland species.
eg *Hedera helix, Acer pseudoplatanus*
Woodland edge/scrub species,
eg *Rubus fruticosus, Crataegus monogyna*
Weeds and aliens,
eg *Cirsium arvense, Taraxacum* agg.

Table 4.3 Coastal 'plot classes'. A classification derived from multivariate analysis of quadrat data (using TWINSPAN)

Plot class	Name
PCA	Lower saltmarsh
PCB	*Spartina* saltmarsh
PCC	Mature saltmarsh
PCD	Immature saltmarsh
PCE	Maritime/freshwater interface
PCF	Foreshore
PCG	Cliff-top
PCH	Tall/overgrown grassland
PCI	Neutral/semi-improved grassland
PCJ	Neutral/calcareous meadows
PCK	Heathland
PCL	Scrub

Shaded plot classes (A–G) are those considered to be typical of the coastal landscape = 'core' coastal vegetation; non-shaded plot classes (H–L) are other vegetation types found within the mask = 'non-core' coastal vegetation classes

Table 4.4 Coastal landscapes: species groups. A classification derived from multivariate analysis of quadrat data (using DECORANA) for species in more than 2% of quadrats

Species groups		Typical species
SG1	Low/mid-saltmarsh	*Aster tripolium, Plantago maritima*
SG2	Foreshore/strand	*Elymus pycanthus, Halimione portulacoides*
SG3	Grassland/maritime interface	*Agrostis stolonifera, Cirsium arvense*
SG4	Maritime grassland/ low herb	*Festuca rubra, Hypochaeris radicata*
SG6	Weedy, short-term grassland	*Lolium perenne, Trifolium repens*
SG5	Semi-improved grassland	*Holcus lanatus, Plantago lanceolata*
SG8	Calcareous grassland	*Galium verum, Thymus praecox*
SG9	Woodland/scrub	*Rubus fruticosus, Poa trivialis*
SG7	Acid grassland/heath	*Agrostis capillaris, Teucrium scorodonia*

Shaded species groups (1–4) are those which are characteristic of the coastal landscape= 'coastal' species groups; unshaded species groups (5–9) are also found in the coastal mask = 'non-coastal' species groups

i. succession, ie colonisation by tree species resulting in scrub or woodland;
ii. reclamation, of marshes, eg by drainage;
iii. grazing, leading to dominance of graminaceous species – affecting marshes.

The presence of species from these 'sensitivity indicator groups' implies that the vegetation in which they occur has not been subject to these pressures.

Assessment of vegetation quality

4.7.9 These classifications of quadrats and species will be used to describe the types of vegetation in the four strata, and to compare them in terms of selected quality criteria.

4.7.10 The use of quality criteria to provide a comparative assessment of sites by other studies is discussed in Appendix 1 (Box A1.1). In this project, objective measures of vegetation have been related to quality criteria, to provide an empirical evaluation of the quality of coastal vegetation in different parts of the coastal landscape. Each criterion emphasises a particular aspect of quality, but they do inter-relate, and should not be considered as mutually exclusive. The following discussion of vegetation in terms of quality criteria is based on species information from quadrats, and makes use of the classifications described above (Section 4.4). The following quality criteria are considered in turn: size, diversity, naturalness, representativeness, rarity, fragility, potential value.

4.8 Vegetation quality: size/ abundance

4.8.1 Large size is usually considered a benefit, for a number of reasons. Each species has a minimum area (or resource) which is necessary to maintain a viable population. There is a relationship between area and species diversity affected by population size, extinction and immigration rates. Large sites provide a buffered 'edge' between the central core of the site and adjacent land, which helps to protect the core from disturbance, runoff, spray drift, etc. Larger sites usually (but not always) contain a greater range of local environments, reflected in a greater diversity of species. In the coastal regions of England, where semi-natural habitats tend to be highly fragmented, size is likely to be an important criterion.

Table 4.5 The mean number of main plots per square, by strata (indicating the relative amounts of semi-natural vegetation)

Strata	No. of squares	No. of plots	Mean no. of plots
Designated estuarine	16	30	1.88
Non-designated estuarine	11	13	1.18
Designated soft	6	19	3.17
Non-designated soft	11	16	1.45
Designated hard	18	41	2.28
Non-designated hard	10	20	2.00
Combined designated	40	90	2.25
Combined non-designated	32	49	1.38
Combined estuarine	27	43	1.65
Combined soft coast	17	35	2.55
Combined hard coast	28	61	2.22
Total	*72*	*139*	*1.98*

These figures represent the mean number of quadrats per square, including those squares where no quadrats were recorded. Figures for combined strata are weighted by strata size

Average area of semi-natural vegetation per 1 km square

4.8.2 More main plots were recorded in designated strata (Table 4.5), indicating that there was more non-intensively managed land in the designated areas compared to the non-designated ones.

Relative abundance of structural types

4.8.3 In terms of structural types, saltmarsh was the most common type of maritime vegetation recorded (Table 4.6). It was present in estuarine and soft coast areas, where it was more prevalent in the designated squares, particularly on the soft coasts. Maritime grassland was most frequent on hard coasts, but occurred in all coastal types, and more commonly in non-designated squares. Other maritime vegetation (dunes, foreshore) was recorded mainly on designated soft coasts. Squares on soft coasts had slightly more main plots in these three maritime types than the estuarine squares, and a lot more than the squares on hard coast. They also had the greatest variety of maritime vegetation, the estuarine squares being dominated by saltmarsh.

4.8.4 A much higher proportion of the habitat plots were recorded in maritime types, indicating that maritime vegetation frequently occurred in squares in quantities which were too small and too fragmented to be always sampled by the random plots.

Table 4.6 Mean number of quadrats per square, for structural types, by strata

	Estuarine				Hard coast				Soft coast				Combined				Combined							
	Designated		Non-des		Designated		Non-des		Designated		Non-des		Designated		Non-des		Estuarine		Hard coast		Soft coast		Total	
Structural type	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Main plots (200 m^2)																								
Saltmarsh	0.75	*40*	0.27	*23*	0.00	*0*	0.00	*0*	1.00	*32*	0.09	*6*	0.60	*27*	0.18	*13*	0.59	*36*	0.00	*0*	0.67	*26*	0.47	*24*
Maritime grassland	0.06	*3*	0.09	*8*	0.11	*5*	0.20	*10*	0.00	*0*	0.09	*6*	0.06	*3*	0.11	*8*	0.07	*4*	0.13	*6*	0.03	*1*	0.08	*4*
Other maritime vegn	0.00	*0*	0.00	*0*	0.06	*3*	0.00	*0*	0.33	*10*	0.09	*6*	0.08	*4*	0.02	*1*	0.00	*0*	0.04	*2*	0.25	*10*	0.07	*4*
Marsh/aquatics	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.17	*5*	0.09	*6*	0.03	*1*	0.02	*1*	0.00	*0*	0.00	*0*	0.14	*5*	0.03	*2*
Neut/impr grassland	0.81	*43*	0.45	*38*	0.78	*34*	1.10	*55*	1.00	*32*	1.00	*69*	0.84	*37*	0.69	*50*	0.69	*42*	0.84	*38*	1.00	*39*	0.80	*40*
Calcareous grassland	0.00	*0*	0.00	*0*	0.39	*17*	0.00	*0*	0.00	*0*	0.00	*0*	0.11	*5*	0.00	*0*	0.00	*0*	0.31	*14*	0.00	*0*	0.07	*4*
Acid grass/heath/bog	0.13	*7*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.07	*3*	0.00	*0*	0.08	*5*	0.00	*0*	0.00	*0*	0.05	*3*
Unmged grass/tall herb	0.13	*7*	0.27	*23*	0.33	*14*	0.00	*0*	0.50	*16*	0.00	*0*	0.26	*12*	0.16	*12*	0.17	*10*	0.27	*12*	0.32	*13*	0.23	*12*
Scrub	0.00	*0*	0.09	*8*	0.39	*17*	0.60	*30*	0.00	*0*	0.09	*6*	0.11	*5*	0.17	*12*	0.03	*2*	0.43	*19*	0.03	*1*	0.12	*6*
Woodland	0.00	*0*	0.00	*0*	0.22	*10*	0.10	*5*	0.17	*5*	0.00	*0*	0.09	*4*	0.02	*1*	0.00	*0*	0.20	*9*	0.11	*4*	0.07	*4*
Total	*1.88*	*100*	*1.17*	*100*	*2.28*	*100*	*2.00*	*100*	*3.17*	*100*	*1.45*	*100*	*2.25*	*100*	*1.37*	*100*	*1.63*	*100*	*2.22*	*100*	*2.55*	*100*	*1.99*	*100*
Habitat plots (4 m^2)																								
Saltmarsh	2.06	*42*	1.36	*31*	0.06	*1*	0.00	*0*	1.33	*27*	0.00	*0*	1.36	*28*	0.80	*18*	1.83	*38*	0.04	*1*	0.85	*18*	1.19	*25*
Maritime grassland	0.25	*5*	0.00	*0*	1.06	*23*	0.70	*17*	0.33	*7*	1.36	*31*	0.49	*10*	0.46	*11*	0.17	*4*	0.99	*22*	0.70	*15*	0.48	*10*
Other maritime vegn	0.56	*11*	0.36	*8*	0.11	*2*	1.00	*24*	2.33	*47*	1.91	*43*	0.80	*17*	0.86	*20*	0.50	*10*	0.28	*6*	2.18	*46*	0.82	*17*
Marsh/aquatics	0.25	*5*	0.91	*20*	0.17	*4*	0.10	*2*	0.50	*10*	0.09	*2*	0.28	*6*	0.57	*13*	0.47	*10*	0.15	*3*	0.35	*7*	0.37	*8*
Neut/impr grassland	0.38	*8*	0.64	*14*	0.72	*16*	0.60	*15*	0.00	*0*	0.73	*16*	0.39	*8*	0.65	*15*	0.46	*10*	0.70	*16*	0.26	*5*	0.47	*10*
Calcareous grassland	0.00	*0*	0.00	*0*	0.83	*18*	0.00	*0*	0.00	*0*	0.00	*0*	0.23	*5*	0.00	*0*	0.00	*0*	0.67	*15*	0.00	*0*	0.16	*3*
Acid grass/heath/bog	0.00	*0*	0.09	*2*	0.50	*11*	0.00	*0*	0.00	*0*	0.00	*0*	0.14	*3*	0.05	*1*	0.03	*1*	0.40	*9*	0.00	*0*	0.11	*2*
Unmged grass/tall herb	0.88	*18*	0.82	*18*	0.67	*15*	1.10	*27*	0.50	*10*	0.36	*8*	0.74	*15*	0.74	*17*	0.86	*18*	0.75	*17*	0.45	*9*	0.74	*16*
Scrub	0.06	*1*	0.09	*2*	0.33	*7*	0.30	*7*	0.00	*0*	0.00	*0*	0.12	*2*	0.10	*2*	0.07	*1*	0.33	*7*	0.00	*0*	0.12	*3*
Woodland	0.50	*10*	0.18	*4*	0.11	*2*	0.30	*7*	0.00	*0*	0.00	*0*	0.29	*6*	0.15	*3*	0.40	*8*	0.15	*3*	0.00	*0*	0.25	*5*
Total	*4.94*	*100*	*4.45*	*100*	*4.56*	*100*	*4.10*	*100*	*4.99*	*100*	*4.45*	*100*	*4.84*	*100*	*4.38*	*100*	*4.79*	*100*	*4.46*	*100*	*4.79*	*100*	*4.71*	*100*

The means for the combined strata are weighted by stratum area

4.8.5 The neutral/improved grassland was the most common category in all strata. Unmanaged grass/tall herbs was also found throughout, in smaller though significant quantities. Calcareous grassland, scrub and woodland were most often found in the hard coast squares, often on steep or inaccessible cliffs, whilst marsh/aquatic species were most common in the designated soft coast stratum, though recorded elsewhere as habitat plots.

Summary of size/abundance as a quality criterion

4.8.6 Of the maritime vegetation types, saltmarsh occurred extensively in the designated estuarine and soft coast areas; other maritime vegetation types were uncommon, and present in smaller patches. Figure 4.3 shows the relative abundance of the structural types in the different coastal landscapes. The estuarine coasts were dominated by saltmarsh and grassland. The soft coasts had similar quantities of saltmarsh and a greater variety of other types of maritime vegetation; grassland was the most common vegetation type recorded. The hard coasts had less maritime vegetation than the other coast types, with very little saltmarsh, but more maritime grassland. Grassland (non-maritime) was again common, including calcareous grassland which was only recorded in these hard coastal squares. The hard coast also had more scrub and woodland.

4.9 Vegetation quality: diversity

4.9.1 Diversity can be expressed both as the variety of vegetation types and the range of plant species within a site, thus reflecting the range of variation in physical variables as well as the species richness associated with each vegetation type. The number of 'plot classes' present indicates the diversity of different vegetation types or habitats; the number of 'species groups' recorded is used to assess the species richness. However, the number of species recorded in quadrats is not reported as some maritime vegetation is inherently species-poor, and a high species number may indicate the presence of ruderal species.

Number of different plot classes

4.9.2 The classification of quadrats into 'plot classes' has been used to consider the average range of vegetation present in each square, ie the higher the mean number of classes present in squares in a stratum, the greater the diversity of vegetation (Table 4.7). Estuarine squares have the smallest range of plot classes in the main plots and the largest in the habitat plots, implying that squares in the estuarine strata are uniform in terms of the major habitats but include a variety of small patches of other vegetation types.

Table 4.7 Mean number of plot classes represented per square, by strata

Strata	Main plots All PCs	Main plots PCA–F	Habitat plots All PCs	Habitat plots PCA–F
Designated estuarine	1.2	0.3	3.4	1.4
Non-designated estuarine	0.7	0.3	3.0	1.9
Designated soft	2.2	0.5	3.2	0.8
Non-designated soft	0.9	0.0	2.6	0.8
Designated hard	1.3	0.1	2.7	0.0
Non-designated hard	1.3	0.1	2.5	0.4
Combined designated	1.4	0.3	3.1	0.9
Combined non-designated	0.9	0.2	2.8	1.4
Combined estuarine	1.0	0.3	3.3	1.5
Combined soft coast	1.7	0.3	3.0	0.8
Combined hard coast	1.3	0.1	2.6	0.1
Total	*1.3*	*0.3*	*3.1*	*1.0*

Plot classes (PC) A–F represent the maritime vegetation types

4.9.3 In terms of the core maritime plot classes (PCA–PCF), the estuarine coast appears most diverse, but this reflects the preponderance of saltmarsh in these squares, as four of the six maritime plot classes represent different types of saltmarsh vegetation. For main plots, there is a greater range of the core maritime plot classes in the designated than the non-designated strata. The reverse is shown by the habitat plots, suggesting that these classes were less extensive but still present in the non-designated squares. (See para 4.11.2 for discussion of differences in the composition of plot classes between strata).

Number of different species groups

4.9.4 Table 4.8 uses the classification of species into 'species groups' to consider the range of different types of species present in each square. In the main plots, the estuarine squares had the smallest range of species groups. Overall, the designated squares had a greater range of species groups present, and habitat plots represented a greater diversity than main plots. In terms of main plots, the squares on soft coasts were more diverse than those on hard and

Table 4.8 Mean number of species groups represented per square, by strata

Strata	Main plots All SGs	Main plots SG1–2	Habitat plots All SGs	Habitat plots SG1–2
Designated estuarine	4.2	0.6	6.5	1.7
Non-designated estuarine	3.2	0.3	6.0	1.2
Designated soft	5.8	1.3	6.8	1.5
Non-designated soft	4.5	0.6	7.2	1.5
Designated hard	4.9	0.4	7.1	0.7
Non-designated hard	5.4	0.5	6.0	1.0
Combined designated	4.7	0.7	6.7	1.4
Combined non-designated	3.9	0.4	6.3	1.2
Combined estuarine	3.9	0.5	6.3	1.5
Combined soft coast	5.3	1.1	7.0	1.5
Combined hard coast	5.0	0.4	6.9	0.7
Total	*4.5*	*0.6*	*6.6*	*1.3*

Species groups (SG) 1–2 represent the maritime specific species

estuarine coasts, but for habitat plots the differences are much less. (See para 4.11.6 for discussion of species group composition).

Summary of diversity as a quality criterion

4.9.5 The designated squares had a greater diversity of maritime plot classes than the non-designated squares, for all coastal types. On estuarine and soft coasts the designated squares also had a greater diversity of species groups. The soft coasts were the most diverse, both in terms of the range of vegetation types and in the range of species groups. The hard coasts were least diverse in terms of maritime species and vegetation types. In all coastal types, additional diversity was recorded by the habitat plots, indicating that some vegetation types and some species groups were present only in small patches.

4.10 Vegetation quality: naturalness

4.10.1 'Natural' is a term sometimes applied to vegetation which is considered to be unmodified by human influence – it cannot be strictly applied to any habitat in England, certainly not to a subclimax habitat such as heathland. However, in this context, naturalness is used as a measure of the extent of modification or disturbance away from the optimum required to maintain an area as heathland. Too little 'modification' will allow succession to scrub and woodland, too much will move the vegetation towards grassland or bare ground. Such modification or disturbance is indicated by the presence of species which are not normally associated with heathland, eg grassland species like rye-grass (*Lolium perenne*), which in a heathland context might indicate eutrophication and/or over-grazing, or a woodland species, eg silver birch (*Betula pendula*), which might indicate that lack of grazing is allowing scrub development. It is clearly not only the presence of such species, but their relative abundance or cover which provides useful measures of 'naturalness'.

Numbers of habitat indicator species

4.10.2 The classification of species into 'habitat indicator types' has been used to examine the extent to which vegetation recorded in quadrats is dominated by maritime species, as opposed to those mainly found in grasslands or woodlands (Table 4.9). Neutral grassland species were the predominant group in all strata. Maritime species were most common in the soft coast and estuarine strata, suggesting that this is where the most 'natural' coastal vegetation occurred, and much less frequent in the hard coast squares. Aquatic margin species, which were often present in brackish situations, showed a similar pattern, although they were much less common. The calcareous grassland species were mostly found in hard coast strata.

Summary of naturalness as a quality criterion

4.10.3 Exclusively maritime species are relatively sparse in the hard coast squares where most maritime vegetation receives salt spray rather than the tidal immersion of the saltmarshes in the estuarine and soft coast squares, where exclusively maritime species were more common. A higher proportion of such species was recorded in the targeted habitat plots.

4.11 Vegetation quality: representativeness

4.11.1 Representativeness involves using a classification of the range of vegetation being considered, to allow comparison of examples of the same type. It is used to ensure that examples of the full range of types present within a region are conserved as well as giving emphasis to those which are 'typical'. The range of vegetation present is described here using the classification of quadrats into 'plot classes', and of species into 'species groups'.

Relative abundance of plot classes

4.11.2 *Spartina* saltmarsh (PCB) was only recorded in squares in the estuarine strata, but the other saltmarsh types (PCA, PCC, PCD) also occurred in the designated soft coast stratum (Table 4.10). All the quadrats in maritime plot classes (PCA–PCF) recorded on the soft coast occurred in designated squares, whilst in the estuarine strata there was much less difference between the designated and non-designated squares. The cliff-top class (PCG) was only recorded in main plots in the hard coast strata, although it was sampled by the targeted habitat plots elsewhere. All strata were dominated by the neutral/semi-improved grasslands (PCI), which were more extensive in the non-designated strata.

4.11.3 The hard coast squares had very little core maritime vegetation (PCA–PCF); none was recorded by main plots. They did have cliff-top vegetation (PCG) which includes species characteristic of, but not restricted to, coastal habitats, eg wild carrot (*Daucus carota*). The cliff-top vegetation was more abundant in designated squares, although it also occurred elsewhere.

4.11.4 The effects of designation appeared greatest on the soft coast squares where 42% of main plots occurred in the core maritime plot classes (PCA–PCF) in the designated stratum, but no main plots and only 22% of habitat plots were recorded in these plot classes in the non-designated stratum.

4.11.5 In the estuarine strata, saltmarsh was recorded in a similar proportion of plots in the designated and non-designated strata, but was more extensive in the designated stratum. The other core maritime plot classes (PCE–PCF) were only recorded as habitat plots.

Relative abundance of species groups

4.11.6 The mean number of species per quadrat for each species group is shown in Table 4.11 – this indicates the relative abundance of different types of species in quadrats in each stratum. Saltmarsh species (SG1) were recorded in estuarine and soft coast squares; in the latter they were much more common in the designated stratum. The foreshore/strand species (SG2) were also recorded mostly in the estuarine and soft coast strata, and were more common in the designated strata. The grassland/maritime interface species (SG3) were most common in the soft and hard coast squares, though also present in the estuarine strata. The semi-improved grassland (SG6) and the woodland/scrub species (SG8) were the most prevalent species groups throughout, whilst the calcareous grassland species (SG7) were mostly recorded in the hard coast squares. Overall, the soft coast strata had the highest proportion of maritime species, and showed the greatest difference between designated and non-designated strata.

Summary of representativeness as a quality criterion

4.11.7 All the maritime plot classes recorded in each coastal type were represented in the designated strata. In the soft coast squares, quadrats in core maritime plots (PCA–PCF) were largely restricted to designated squares. However, in the estuarine strata, there were many of these plots in non-designated squares. A similar pattern is shown by the species groups; specifically maritime species were recorded in both designated and non-designated estuarine strata, but in the soft coast squares were more common in designated squares. The designated areas seem, therefore, to cover the full range of coastal vegetation, although most types still occur in non-designated areas.

4.12 Rarity

4.12.1 The survey strategy employed for this project is designed to record representative examples of coastal vegetation, not rare types or rare species; although they may occur within the sample, it is not possible to make any general statements about their abundance or distribution.

4.12.2 The vascular species recorded have been checked against the *Red Data Book* (RDB) list of species, and against the 'Nationally scarce' species list defined *in Guidelines for selection of biological SSSIs* (NCC 1989). The only RDB species were spike rush (*Eleocharis parvula*), gilliflower (*Mattholia incana*) and sea stock (*Mattholia sinuatus*).

Table 4.9 Mean number of species per plot in each habitat indicator groups

	Estuarine				Hard coast				Soft coast				Combined				Combined							
	Designated		Non-des		Designated		Non-des		Designated		Non-des		Designated		Non-des		Estuarine		Hard coast		Soft coast		Total	
Habitat indicator groups	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Main plots (200 m^2)																								
Maritime species	2.4	*14*	2.9	*10*	0.4	*1*	0.5	*2*	3.6	*16*	1.3	*5*	2.1	*10*	2.1	*8*	2.5	*12*	0.4	*1*	2.8	*12*	2.1	*9*
Aquatic margin species	0.3	*2*	0.2	*1*	0.1	*0*	0.1	*0*	0.2	*1*	0.1	*1*	0.2	*1*	0.1	*1*	0.2	*1*	0.1	*0*	0.2	*1*	0.2	*1*
Calcareous grassland species	0.5	*3*	0.9	*3*	3.7	*12*	1.1	*4*	1.0	*4*	1.1	*5*	1.5	*7*	1.0	*4*	0.6	*3*	3.2	*11*	1.0	*4*	1.3	*6*
Neutral grassland species	7.2	*42*	13.1	*48*	10.8	*36*	11.5	*43*	9.7	*43*	12.5	*50*	8.7	*40*	12.7	*48*	9.1	*45*	11.0	*38*	10.7	*46*	9.9	*43*
Damp grass/tall herb species	1.1	*6*	0.4	*1*	0.5	*2*	0.7	*3*	0.7	*3*	0.8	*3*	0.9	*4*	0.5	*2*	0.8	*4*	0.6	*2*	0.8	*3*	0.8	*3*
Acid grass/moorland species	2.3	*14*	0.9	*3*	3.0	*10*	2.1	*8*	0.8	*4*	3.0	*12*	2.2	*10*	1.6	*6*	1.9	*9*	2.8	*10*	1.6	*7*	2.0	*9*
Woodland species	0.6	*4*	2.3	*8*	2.3	*8*	3.2	*12*	1.5	*7*	0.7	*3*	1.3	*6*	2.0	*8*	1.2	*6*	2.5	*9*	1.2	*5*	1.5	*6*
Woodland edge/scrub species	0.5	*3*	1.9	*7*	2.5	*9*	2.4	*9*	1.7	*8*	0.7	*3*	1.3	*6*	1.7	*6*	1.0	*5*	2.5	*9*	1.4	*6*	1.4	*6*
Weeds/alien species	2.1	*13*	4.9	*18*	6.4	*22*	5.2	*20*	3.4	*15*	4.5	*18*	3.6	*17*	4.9	*18*	3.1	*15*	6.2	*21*	3.8	*16*	4.0	*17*
All	*16.9*	*100*	*27.4*	*100*	*29.7*	*100*	*26.6*	*100*	*22.7*	*100*	*24.8*	*100*	*21.6*	*100*	*26.6*	*100*	*20.4*	*100*	*29.1*	*100*	*23.4*	*100*	*23.1*	*100*
Habitat plots (2 m^2)																								
Maritime species	2.4	*21*	2.0	*18*	0.7	*4*	1.0	*6*	2.7	*27*	2.1	*15*	2.0	*15*	1.9	*15*	2.3	*20*	0.8	*4*	2.5	*22*	2.0	*15*
Aquatic margin species	0.2	*2*	0.8	*7*	0.3	*2*	0.3	*2*	0.8	*8*	0.0	*0*	0.4	*3*	0.5	*4*	0.4	*4*	0.3	*2*	0.5	*5*	0.4	*3*
Calcareous grassland species	0.5	*5*	0.4	*4*	3.6	*19*	1.3	*8*	0.6	*6*	1.1	*8*	1.4	*11*	0.7	*5*	0.5	*4*	3.1	*17*	0.8	*7*	1.2	*9*
Neutral grassland species	3.5	*30*	4.5	*40*	7.1	*37*	6.6	*39*	3.1	*31*	6.3	*45*	4.4	*33*	5.3	*41*	3.8	*34*	7.0	*38*	4.3	*37*	4.7	*35*
Damp grass/tall herb species	0.5	*4*	0.2	*2*	0.7	*4*	0.5	*3*	0.4	*4*	0.5	*3*	0.5	*4*	0.3	*3*	0.4	*4*	0.7	*4*	0.4	*4*	0.5	*4*
Acid grass/moorland species	0.7	*6*	0.4	*4*	2.2	*12*	1.5	*9*	0.3	*3*	1.3	*9*	1.1	*8*	0.8	*6*	0.6	*6*	2.1	*11*	0.7	*6*	1.0	*8*
Woodland species	0.8	*7*	0.4	*4*	0.8	*4*	1.5	*9*	0.1	*1*	0.2	*2*	0.7	*5*	0.5	*4*	0.7	*6*	0.9	*5*	0.1	*1*	0.6	*5*
Woodland edge/scrub species	0.7	*6*	0.7	*6*	1.0	*5*	1.1	*6*	0.1	*1*	0.2	*1*	0.6	*5*	0.6	*5*	0.7	*6*	1.0	*5*	0.2	*1*	0.6	*5*
Weeds/alien species	2.1	*18*	1.7	*15*	2.5	*13*	3.1	*19*	1.9	*19*	2.5	*17*	2.2	*16*	2.1	*16*	1.9	*17*	2.6	*14*	2.1	*18*	2.1	*16*
All	*11.4*	*100*	*11.1*	*100*	*19.0*	*100*	*16.8*	*100*	*10.1*	*100*	*14.2*	*100*	*13.2*	*100*	*12.8*	*100*	*11.3*	*100*	*18.5*	*100*	*11.6*	*100*	*13.1*	*100*

The figures for combined strata are weighted by stratum area

Table 4.10 Mean number of main and habitat quadrats per square, in each plot class, by strata

Plot	Estuarine				Hard coast				Soft coast				Combined				Combined						Total	
	Designated		Non-des		Designated		Non-des		Designated		Non-des		Designated		Non-des		Estuarine		Hard coast		Soft coast			
class	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Main plots (200 m²)																								
1 Lower saltmarsh	0.06	*3*	0.00	*0*	0.00	*0*	0.00	*0*	0.17	*5*	0.00	*0*	0.07	*4*	0.00	*0*	0.04	*3*	0.00	*0*	0.11	*4*	0.05	*3*
2 *Spartina* saltmarsh	0.31	*17*	0.18	*15*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.16	*8*	0.11	*8*	0.27	*23*	0.00	*0*	0.00	*0*	0.14	*8*
3 Mature saltmarsh	0.25	*14*	0.18	*15*	0.00	*0*	0.00	*0*	0.67	*21*	0.00	*0*	0.27	*14*	0.11	*8*	0.23	*19*	0.00	*0*	0.43	*17*	0.22	*13*
4 Immature saltmarsh	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.17	*5*	0.00	*0*	0.03	*2*	0.00	*0*	0.00	*0*	0.00	*0*	0.11	*4*	0.02	*1*
5 Maritime/freshwater interface	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.17	*5*	0.00	*0*	0.03	*2*	0.00	*0*	0.00	*0*	0.00	*0*	0.11	*4*	0.02	*1*
6 Foreshore	0.00	*0*	0.00	*0*	0.00	*0*	0.10	*5*	0.17	*5*	0.00	*0*	0.03	*2*	0.02	*1*	0.00	*0*	0.02	*1*	0.11	*4*	0.03	*2*
7 Cliff-top	0.00	*0*	0.00	*0*	0.17	*7*	0.10	*5*	0.00	*0*	0.00	*0*	0.05	*3*	0.02	*1*	0.00	*0*	0.16	*7*	0.00	*0*	0.04	*2*
8 Tall/overgrown grassland	0.19	*10*	0.00	*0*	0.17	*7*	0.20	*11*	0.17	*5*	0.09	*6*	0.18	*10*	0.05	*4*	0.13	*11*	0.18	*8*	0.14	*5*	0.14	*8*
9 grassland	0.81	*45*	0.73	*62*	1.11	*49*	1.00	*53*	1.33	*42*	1.09	*75*	0.67	*35*	0.87	*63*	0.36	*30*	1.09	*49*	1.24	*48*	0.73	*42*
10 Neutral/calcareous meadows	0.00	*0*	0.00	*0*	0.22	*10*	0.10	*5*	0.17	*5*	0.09	*6*	0.10	*5*	0.04	*3*	0.00	*0*	0.20	*9*	0.14	*5*	0.08	*5*
11 Heathland	0.13	*7*	0.00	*0*	0.11	*5*	0.00	*0*	0.00	*0*	0.09	*6*	0.10	*5*	0.02	*1*	0.09	*8*	0.09	*4*	0.03	*1*	0.08	*5*
12 Scrub	0.06	*3*	0.09	*8*	0.50	*22*	0.40	*21*	0.17	*5*	0.09	*6*	0.20	*11*	0.14	*10*	0.07	*6*	0.48	*22*	0.14	*5*	0.18	*10*
Plot classes A-F	0.62	*34*	0.36	*31*	0.00	*0*	0.10	*5*	1.35	*42*	0.00	*0*	0.59	*31*	0.24	*17*	0.54	*45*	0.02	*1*	0.87	*34*	0.48	*28*
Plot classes G-L	1.19	*66*	0.82	*69*	2.28	*100*	1.80	*95*	1.84	*58*	1.45	*100*	1.30	*69*	1.14	*83*	0.65	*55*	2.20	*99*	1.69	*66*	1.25	*72*
All	*1.81*	*100*	*1.18*	*100*	*2.28*	*100*	*1.90*	*100*	*3.19*	*100*	*1.45*	*100*	*1.89*	*100*	*1.38*	*100*	*1.19*	*100*	*2.22*	*100*	*2.56*	*100*	*1.73*	*100*
Habitat plots (4 m²)																								
1 Lower saltmarsh	0.56	*11*	0.36	*8*	0.00	*0*	0.00	*0*	0.67	*13*	0.00	*0*	0.43	*9*	0.21	*5*	0.49	*10*	0.00	*0*	0.43	*9*	0.36	*8*
2 *Spartina* saltmarsh	0.50	*10*	0.18	*4*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.26	*5*	0.11	*3*	0.39	*8*	0.00	*0*	0.00	*0*	0.21	*4*
3 Mature saltmarsh	0.38	*8*	0.91	*20*	0.00	*0*	0.00	*0*	0.83	*17*	0.00	*0*	0.37	*8*	0.53	*12*	0.55	*11*	0.00	*0*	0.53	*11*	0.42	*9*
4 Immature saltmarsh	0.56	*11*	0.00	*0*	0.06	*1*	0.00	*0*	0.67	*13*	0.09	*2*	0.45	*9*	0.02	*0*	0.38	*8*	0.05	*1*	0.46	*10*	0.32	*7*
5 Maritime/freshwater interface	0.25	*5*	0.45	*10*	0.06	*1*	0.00	*0*	0.50	*10*	0.09	*2*	0.25	*5*	0.29	*7*	0.32	*7*	0.05	*1*	0.35	*7*	0.26	*6*
6 Foreshore	0.13	*3*	0.09	*2*	0.06	*1*	0.90	*22*	0.67	*13*	0.82	*18*	0.22	*5*	0.40	*9*	0.12	*3*	0.22	*5*	0.72	*15*	0.28	*6*
7 Cliff-top	0.13	*3*	0.00	*0*	1.00	*22*	0.50	*12*	0.17	*3*	0.27	*6*	0.38	*8*	0.15	*3*	0.09	*2*	0.90	*20*	0.21	*4*	0.31	*7*
8 Tall/overgrown grassland	0.94	*19*	1.18	*27*	0.94	*21*	1.20	*29*	0.50	*10*	0.55	*12*	0.85	*17*	1.02	*23*	1.02	*21*	0.99	*22*	0.52	*11*	0.90	*19*
9 grassland	0.56	*11*	0.91	*20*	0.50	*11*	0.70	*17*	0.83	*17*	1.82	*41*	0.60	*12*	1.12	*25*	0.68	*14*	0.54	*12*	1.19	*25*	0.76	*16*
10 Neutral/calcareous meadows	0.25	*5*	0.00	*0*	1.11	*24*	0.30	*7*	0.17	*3*	0.64	*14*	0.47	*10*	0.21	*5*	0.17	*4*	0.95	*21*	0.34	*7*	0.39	*8*
11 Heathland	0.13	*3*	0.00	*0*	0.33	*7*	0.00	*0*	0.00	*0*	0.18	*4*	0.16	*3*	0.05	*1*	0.09	*2*	0.27	*6*	0.06	*1*	0.12	*3*
12 Scrub	0.56	*11*	0.36	*8*	0.50	*11*	0.50	*12*	0.00	*0*	0.00	*0*	0.43	*9*	0.29	*7*	0.49	*10*	0.50	*11*	0.00	*0*	0.39	*8*
Plot classes A-F	2.38	*48*	1.99	*45*	0.18	*4*	0.90	*22*	3.34	*67*	1.00	*22*	1.98	*41*	1.56	*35*	2.25	*47*	0.32	*7*	2.49	*52*	1.85	*39*
Plot classes G-L	2.57	*52*	2.45	*55*	4.38	*96*	3.20	*78*	1.67	*33*	3.46	*78*	2.89	*59*	2.84	*65*	2.54	*53*	4.15	*93*	2.32	*48*	2.87	*61*
All	*1.94*	*100*	*4.45*	*100*	*4.56*	*100*	*4.10*	*100*	*5.00*	*100*	*4.45*	*100*	*4.87*	*100*	*4.40*	*100*	*4.79*	*100*	*4.47*	*100*	*4.81*	*100*	*4.72*	*100*

Table 4.11 Mean number of species records per quadrat, for each species group, by strata

Species		Estuarine				Hard coast				Soft coast				Combined				Combined						Total	
		Designated		Non-des		Designated		Non-des		Designated		Non-des		Designated		Non-des		Estuarine		Hard coast		Soft coast			
group	Description	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Main plots (200 m^2)																									
1	Low/mid saltmarsh species	1.7	*12*	2.2	*9*	0.1	*0*	0.3	*1*	1.5	*8*	0.3	*1*	1.2	*7*	1.4	*6*	1.9	*11*	0.1	*1*	1.1	*5*	1.3	*7*
2	Foreshore/strand species	0.4	*3*	0.0	*0*	0.1	*0*	0.2	*1*	0.9	*5*	0.3	*1*	0.4	*2*	0.1	*0*	0.3	*2*	0.1	*1*	0.7	*3*	0.3	*2*
3	Grassland/maritime interface species	1.7	*13*	3.2	*13*	2.3	*10*	1.8	*8*	2.3	*12*	2.8	*12*	2.0	*11*	2.9	*12*	2.2	*13*	2.2	*9*	2.5	*12*	2.3	*12*
4	Maritime grassland/herbs species	0.7	*5*	1.2	*5*	1.7	*7*	1.8	*8*	1.7	*9*	2.4	*11*	1.2	*7*	1.6	*7*	0.9	*5*	1.7	*7*	2.0	*10*	1.3	*7*
5	Weedy, short-term grassland species	1.7	*12*	3.4	*14*	3.2	*14*	2.8	*12*	2.1	*11*	3.1	*14*	2.2	*13*	3.2	*14*	2.3	*13*	3.1	*13*	2.5	*12*	2.5	*13*
6	Semi-improved grassland species	3.2	*24*	6.2	*26*	6.3	*27*	6.1	*26*	4.5	*24*	7.4	*34*	4.3	*25*	6.5	*28*	4.2	*25*	6.3	*26*	5.5	*28*	5.0	*26*
7	Calcareous grassland species	0.1	*1*	0.1	*0*	1.6	*7*	0.1	*0*	0.3	*2*	0.6	*3*	0.6	*3*	0.2	*1*	0.1	*1*	1.3	*6*	0.4	*2*	0.5	*2*
8	Woodland/scrub species	3.0	*22*	6.5	*27*	6.5	*27*	8.2	*35*	5.1	*27*	3.4	*16*	4.4	*25*	5.9	*25*	4.2	*25*	6.8	*29*	4.5	*22*	4.9	*25*
9	Acid grassland/heath species	1.1	*8*	0.9	*4*	2.0	*8*	2.2	*9*	0.5	*3*	1.9	*8*	1.2	*7*	1.4	*6*	1.0	*6*	2.0	*9*	1.0	*5*	1.3	*7*
Maritime species groups (1–4)		4.5	*33*	6.6	*28*	4.2	*18*	4.0	*17*	6.4	*34*	5.7	*26*	4.8	*27*	6.0	*26*	5.2	*31*	4.2	*18*	6.2	*31*	5.2	*27*
Non-maritime species groups (5–9)		9.1	*67*	16.9	*72*	19.7	*82*	19.3	*83*	12.5	*66*	16.5	*74*	12.7	*72*	17.3	*74*	11.7	*69*	19.6	*83*	13.9	*69*	14.1	*73*
All		*13.5*	*100*	*23.5*	*100*	*23.9*	*100*	*23.3*	*100*	*18.9*	*100*	*22.1*	*100*	*17.5*	*100*	*23.3*	*100*	*16.9*	*100*	*23.7*	*100*	*20.1*	*100*	*19.2*	*100*
Habitat plots (4 m^2)																									
1	Low/mid saltmarsh species	1.0	*12*	1.4	*15*	0.2	*2*	0.2	*1*	0.8	*11*	0.3	*3*	0.7	*7*	0.9	*9*	1.1	*13*	0.2	*1*	0.6	*7*	0.8	*8*
2	Foreshore/strand species	0.8	*9*	0.2	*2*	0.1	*1*	0.5	*4*	1.1	*15*	0.6	*5*	0.7	*7*	0.4	*3*	0.6	*7*	0.2	*1*	0.9	*10*	0.6	*6*
3	Grassland/maritime interface species	1.4	*16*	2.4	*26*	1.6	*11*	1.6	*12*	1.4	*19*	1.7	*14*	1.5	*14*	2.1	*20*	1.7	*20*	1.6	*11*	1.5	*17*	1.7	*16*
4	Maritime grassland/herbs species	0.7	*8*	0.4	*4*	2.0	*13*	1.6	*11*	0.9	*12*	2.1	*18*	1.1	*11*	1.0	*10*	0.6	*7*	1.9	*13*	1.3	*15*	1.1	*10*
5	Weedy, short-term grassland species	0.9	*11*	0.8	*9*	1.2	*8*	1.6	*11*	0.9	*12*	1.5	*13*	1.0	*10*	1.1	*11*	0.9	*10*	1.3	*8*	1.1	*13*	1.0	*10*
6	Semi-improved grassland species	1.5	*18*	1.6	*18*	4.6	*30*	4.2	*30*	1.3	*18*	3.0	*26*	2.3	*23*	2.4	*23*	1.5	*17*	4.5	*30*	1.9	*21*	2.3	*23*
7	Calcareous grassland species	0.1	*1*	0.1	*1*	1.4	*9*	0.2	*1*	0.1	*1*	0.4	*4*	0.5	*4*	0.2	*2*	0.1	*1*	1.2	*8*	0.2	*2*	0.4	*4*
8	Woodland/scrub species	1.9	*21*	1.9	*22*	2.7	*17*	3.3	*23*	0.8	*10*	1.2	*10*	1.9	*18*	1.9	*19*	1.9	*22*	2.8	*19*	0.9	*11*	1.9	*18*
9	Acid grassland/heath species	0.4	*4*	0.2	*2*	1.5	*9*	0.9	*6*	0.1	*1*	0.7	*6*	0.6	*6*	0.4	*4*	0.3	*4*	1.4	*9*	0.3	*4*	0.6	*6*
Maritime species groups (1–4)		4.0	*45*	4.3	*48*	4.0	*26*	3.9	*28*	4.3	*57*	4.8	*41*	4.0	*39*	4.4	*42*	4.1	*46*	3.9	*26*	4.4	*49*	4.1	*40*
Non-maritime species groups (5–9)		4.8	*55*	4.6	*52*	11.3	*74*	10.2	*72*	3.2	*43*	6.8	*59*	6.3	*61*	6.0	*58*	4.7	*54*	11.2	*74*	4.5	*51*	6.2	*60*
All		*8.8*	*100*	*8.9*	*100*	*15.3*	*100*	*14.1*	*100*	*7.5*	*100*	*11.6*	*100*	*10.2*	*100*	*10.4*	*100*	*8.8*	*100*	*15.1*	*100*	*8.9*	*100*	*10.3*	*100*

Table 4.12 Mean number of species per plot for each fragility type

Strata	Drying out		Grazing		Succession	
	Main	Habitat	Main	Habitat	Main	Habitat
Designated estuarine	1.47	1.33	0.80	0.77	1.07	1.27
Non-designated estuarine	1.92	1.20	1.08	0.71	1.46	1.02
Designated soft	1.89	1.50	1.37	0.90	2.26	1.43
Non-designated soft	0.69	1.22	0.25	0.57	1.13	1.61
Designated hard	0.22	0.38	0.15	0.21	0.27	0.46
Non-designated hard	0.35	0.71	0.15	0.34	0.35	0.78
Combined designated	1.21	1.10	0.74	0.64	1.09	1.08
Combined non-designated	1.36	1.13	0.72	0.62	1.21	1.14
Combined estuarine	1.62	1.29	0.89	0.75	1.20	1.19
Combined soft coast	1.46	1.40	0.97	0.78	1.85	1.49
Combined hard coast	0.25	0.44	0.15	0.24	0.29	0.52
Total	*1.26*	*1.11*	*0.73*	*0.64*	*1.13*	*1.10*

Nationally scarce species included lanceolate spleenwort (*Asplenium billoti*), divided sedge (*Carex divisa*), seakale (*Crambe maritima*), sea stork's bill (*Erodium maritima*), pale St John's wort (*Hypericum montanum*), golden samphire (*Inula crithmoides*), lax-flowered sea lavender (*Limonium humile*), corky-fruited water dropwort (*Oenanthe pimpinelloides*), round prickly-headed poppy (*Papaver hybridum*), and rootless duckweed (*Wolffia arrhiza*).

4.13 Fragility

4.13.1 Fragility reflects the degree of sensitivity of vegetation types and species to environmental change. Three types of change have been considered which may adversely affect maritime vegetation:

- drying out;
- succession;
- grazing.

4.13.2 Maritime species which are sensitive to each of these three processes have been identified; their presence implies that an area remains unaffected, therefore the relative abundance of these species can be used as a measure of quality. Table 4.12 shows the mean number of sensitive species for each of these processes, in each stratum. Species sensitive to drying out were least common in the hard coast strata, reflecting the good drainage and exposed nature of many of these sites. Over-grazing and succession show the same pattern – sensitive species were least common in the hard coast strata, and most common in the designated soft coast squares. The soft coast squares showed the greatest differences between designated and non-designated areas.

4.14 Vegetation quality: potential value

4.14.1 The potential value of areas of coastal vegetation depends on the current vegetation type, and on the potential for enhancement and restoration, the latter being affected by all the criteria discussed above. Existing maritime vegetation can be enhanced by increasing the patch size, incorporating associated habitats, linking patches and providing buffer zones.

4.14.2 Non-maritime elements of the 'coastal landscape' can be divided into two types.

i. Land cover types which have received high management inputs and whose vegetation no longer contains any maritime species (eg arable fields, improved grassland); although maritime vegetation may once have existed in these locations, re-creation would be difficult, and the current species composition and seed bank would not influence the resulting vegetation. The areas of these land cover types available for such habitat creation schemes are shown in Table 1.1 in Appendix 1.

ii. Habitats which still include maritime species – if these have appropriate soils and hydrological conditions, then restoration may be feasible, and the process would incorporate any maritime species present both above-ground and in the seed bank. The effort required to achieve this will depend on the current vegetation, as well as on soil type, past management, and the length of time since maritime vegetation was dominant.

4.14.3 The relationships between the vegetation types recorded are shown in the ordination diagram in Figure 4.4, on which each quadrat is plotted according to its score on the first and second gradient. The first gradient separates the saltmarsh from the other vegetation types. The second gradient separates out the scrub and heathland. It is clear from this graph that the first gradient gives a good measure of the degree of maritime influence. The saltmarsh, scrub and heathland plot classes are all quite separate, whilst the cliff-top plot class (PCG) overlaps with the grassland and other types. The foreshore (PCF) and maritime/freshwater interface (PCE) occupy an interface between the saltmarsh and grasslands.

4.14.4 The potential for restoring maritime vegetation is related to proximity to the sea, and to the topography of the coast. Below HWM, natural maritime vegetation persists. Above HWM, many marsh areas have been modified through agricultural management, with the use of drainage and fertilizers, and many others are subjected to high levels of human recreational use and disturbance. On steep cliffs, areas of inaccessible and relatively natural, scrub, heath and grassland persist, but the cliff-tops are usually used intensively with only narrow strips of natural vegetation remaining. Where sea walls have been built, their removal would subject the land behind to the tides, allowing maritime vegetation to develop. The area of land with potential for restoration is thus mostly dependent on land use and topography, rather than the current vegetation.

4.15 Quality criteria – ranking of coastal landscape strata

4.15.1 The six strata have been ranked in terms of the quality measures discussed above. Compared to the other landscape types considered in this project, there is much more variation in the way the strata are ranked for different criteria (Table 4.13). This variation reflects the different types of maritime vegetation associated with the three types of coast.

4.15.2 Overall the designated soft coast stratum ranks highest because it includes both a relatively high proportion of maritime vegetation and a range of different types.

Table 4.13 Summary of coastal strata ranked by quality criteria

Quality measure	Estuarine Design'd	Estuarine Non-des	Soft coast Design'd	Soft coast Non-des	Hard coast Design'd	Hard coast Non-des
Size						
Estimated area of maritime vegetation	2	3	1	6	4	5
No. of maritime main plots per square	2	3	1	4	6	5
Diversity						
No. maritime plot classes per square – main plots	2	3	1	6	4	5
No. maritime plot classes per square – habitat plots	2	1	4	3	6	5
No. maritime species groups per square – main	2	6	1	3	5	4
No. maritime species groups per square – habitat	1	4	2	3	6	5
Naturalness						
No. of maritime indicator species – main plots	3	2	1	4	6	5
No. of maritime indicator species – habitat plots	2	4	1	3	6	5
Representativeness						
No. of main plots in maritime plot classes	2	3	1	5	5	4
No. of habitat plots in maritime plot classes	2	3	1	4	6	5
No. of species in maritime species groups – main	4	1	2	3	5	6
No. of species in maritime species groups – habitat	4	2	2	1	4	6
Fragility						
No. of species sensitive to drying out	3	1	2	4	6	5
No. of species sensitive to grazing	3	2	1	4	5	5
No. of species sensitive to succession	4	2	1	3	6	5
No. of criteria ranked first	1	3	10	1	0	0
No. of criteria ranked second	8	4	4	0	0	0
No. of criteria ranked third	3	5	0	6	0	0
No. of criteria ranked fourth	3	2	1	5	3	2
No. of criteria ranked fifth	0	0	0	1	4	11
No. of criteria ranked sixth	0	1	0	2	8	2

The soft coast squares showed the greatest difference between designated and non-designated areas, with the latter ranked fourth overall.

4.15.3 The estuarine strata are ranked second (designated stratum) and third (non-designated stratum), with the designated stratum having a higher rank for diversity criteria. They include large areas of maritime vegetation, but less variety of different types than in the soft coast strata. The hard coast strata are ranked lowest because they have relatively little maritime vegetation, with fewer different types. Interestingly, the designated hard coasts are ranked just below the non-designated hard coast, although the latter tends to be always on urban fringes. However, small sample sizes mean that there is unlikely to be a significant difference.

4.16 Designations

4.16.1 The above discussion has considered designations as a whole, but clearly different types of designation may have different effects. Within the coastal landscape, SSSIs are the most common designation, being particularly important on estuarine coasts. AONBs are also extensive, particularly on the hard and estuarine coasts, whilst Heritage Coasts are mostly associated with the hard coasts (Table 4.14).

4.16.2 Analysis of individual designations was not an objective of the project, and was not incorporated into the sampling strategy. The number of sample squares available for each designation is insufficient to allow comparison (Table 4.15).

4.16.3 The situation is further complicated by the overlap between designations, with 47% of the designated survey squares having more than one designation (Table 4.16).

4.17 Conclusions

4.17.1 The coastal landscape is dominated by crops and managed grasslands, as for much of lowland England, but it also has an above-average area of land occupied by buildings and curtilages. The core coastal vegetation (saltmarsh and 'other' maritime vegetation) made up 8% of the land on average, but there were considerable differences between the hard, soft and estuarine coasts, both in overall land cover composition and in the types and quantity of maritime vegetation present.

4.17.2 The hard coasts, with their steep cliffs and rocky shores, had the smallest proportion of core coastal vegetation (3%), but higher

Table 4.14 Number of squares with designations within coastal landscapes

	Estuarine		Soft coast		Hard coast		Total coastal squares	
Designation	No.	*% of stratum*	No.	*% of stratum*	No.	*% of stratum*	No.	*% of mask*
SSSI	1374	*47*	793	*27*	737	*25*	2904	40
NNR	150	*37*	211	*52*	44	*11*	405	6
ESA	137	*50*	60	*22*	79	*29*	276	4
NP	40	*17*	41	*17*	155	*66*	236	3
AONB	900	*37*	515	*21*	1022	*42*	2437	33
HC	213	*15*	258	*19*	911	*66*	1382	19
G Belt	333	*81*	60	*15*	20	*5*	413	6
Any design	2060	17	1055	6	1580	20	4695	64

Squares may contain more than one designation, so the last row is not the sum of the above

Table 4.15 Number of survey squares with designations within coastal landscapes

	Estuarine		Soft coast		Hard coast		Total coastal squares	
Designation	No.	*% of stratum*	No.	*% of stratum*	No.	*% of stratum*	No.	*% of mask*
SSSI	14	*39*	6	*17*	16	*44*	36	50
NNR	0	*0*	1	*100*	0	*0*	1	1
ESA	1	*33*	0	*0*	2	*67*	3	4
NP	2	*100*	0	*0*	0	*0*	2	3
AONB	3	*18*	3	*18*	11	*65*	17	24
HC	0	*0*	1	*13*	7	*88*	8	11
G Belt	0	*0*	0	*0*	0	*0*	0	0
Any design	16	100	6	100	18	100	40	56

Table 4.16 Overlap between designations for coastal survey squares

Designation						% of designated squares
SSSI	NNR	AONB			HC	3
SSSI			NP			5
SSSI		AONB				20
SSSI		AONB		ESA	HC	3
SSSI		AONB			HC	10
SSSI					HC	3
SSSI						48
		AONB		ESA	HC	3
		AONB				5
				ESA		3

proportions of scrub, woodland and calcareous grassland than the other coastal types. The maritime vegetation present was mostly grassland on the top of cliffs, strongly influenced by salt spray, including species such as buck's-horn plantain (*Plantago coronopus*) and wild carrot. The estuarine coasts had a much higher proportion of core coastal vegetation (13%), of which the majority was saltmarsh. The soft coasts had the highest proportion of core coastal vegetation (16%), which was dominated by saltmarsh, but also included other maritime vegetation types such as dunes; the soft coasts were therefore the most diverse coastal type in terms of maritime vegetation.

4.17.3 The designated coasts had a smaller proportion of arable land, and more scrub and woodland compared to non-designated coasts. The biggest difference is in the proportion of core maritime vegetation, which averages 18% in designated areas compared to 3% in non-designated areas. This suggests that most areas where maritime vegetation is extensive have been designated.

Chapter 5 HISTORICAL CHARACTERISTICS OF THE COASTAL MASK

5.1 Introduction

5.1.1 The archaeological study was designed to provide an 'evaluation of distribution of historic (archaeological) features in the coastal mask and of the effectiveness of the designations in protecting these features'. In conjunction with this, the study was intended to examine the task of developing 'recommendations for modification/enhancement of policies to improve protection of historic features'.

5.1.2 There were three specific aims of the archaeological study:

i. to examine the distribution of archaeological features in the coastal landscape;
ii. to assess the relationship between features and designations in the coastal landscape;
iii. to develop recommendations for modifying designations to improve the protection of features.

5.2 Methodology

5.2.1 Two distinct types of archaeological data gathering were carried out: information from archives and from new survey work. The 'extended national archaeological database' (see below) constitutes the recorded archaeological resource in England and extraction of data from it constituted the major part of the work. Survey work was designed to assess the viability of estimating the percentage of the archaeological resource examined in the sample squares. Within the current project, work was restricted to three sources:

- fieldwork by ITE staff (non-archaeologists);
- selective aerial photography (AP) analysis; and
- map interpretation of recent edition Ordnance Survey map extracts supplied by ITE, County Sites and Monuments Records (SMRs) and the National Monuments Record (NMR).

5.2.2 No national standard was known to exist for the recording of the condition of archaeological monuments. It was therefore anticipated that local information, if available, would be difficult to use. However, information was collated within this project and its value was assessed. A work

Table 5.1 Quantity of features in the coastal mask – RCHME* classes by period

	Prehistoric	Palaeo	Mesolithic	Neolithic	Bronze Age	Iron Age	Roman	Early Medieval	Medieval	Post Medieval	Modern	Unknown
Agriculture and subsistence	6								7	25		35
Domestic	14					10	3	4	10	25		3
Civil									2	14		25
Recreation							1			2	2	1
Garden and parks									1			2
Commemorative							1				2	
Religious, ritual and funerary	2			1	13	3	4	7	22	7		20
Commercial										2		3
Industrial	3		1						2	64		14
Transport							2			40		4
Water and drainage						1			3	4		14
Maritime							1		1	8	2	4
Defence						3			5	10	11	6
Object	22	4	5	5	10	9	21	3	8	10		9
Unassigned	3				2	1	3		2	16	1	12

* Royal Commission on the Historical Monuments of England

Table 5.2 Quality of features – form groups by period for the coastal landscape

Form group	Prehis-toric	Palaeo	Meso-lithic	Neo-lithic	Bronze Age	Iron Age	Roman	Early Med-ieval	Med-ieval	Post Med-ieval	Mod-ern	Un-known
A–Structure								1	9	61	9	1
B–Ruin									7	30	2	
C–Underground												
D–Feature						1	1		1	13		2
E–Earthwork	19		1		2	9	1		7	25		11
F–Crop/soil	1				2				1	1		8
G–AP												
H–Find	25	4	5	5	11	11	26		9	11		11
I–Doc/oral	3				9	3	6	2	25	88	6	116
J–Exc/rem	1			1	1	3	2	11	4			
Unspecified	1											3

programme is shown in Appendix 2, together with a description of the available archaeological data.

5.3 Analysis and results

The distribution of archaeological sites in the coastal mask

5.3.1 The quantity of archaeological monuments is presented in Table 5.1 (with further details in Appendix 2). These data suggest that the coastal mask is characterised as follows.

- Prehistoric periods are mainly represented by 'find' sites (ie where objects have been found), together with hut circles and Bronze Age barrows.
- The Roman period is also dominated by find sites, although with a scattering of other types, including settlements.
- Representation of the Early Medieval period is sparse, but includes some evidence of settlements.
- The Medieval period has some settlement sites together with farms and defensive sites.
- The Post Medieval period is represented by nearly all types of feature but especially settlements forming villages and small towns, and industrial and transport sites.

Many of the unspecified sites almost certainly belong to the Post Medieval period, and this group follows the same pattern as the Post Medieval distribution.

5.3.2 Although some reference to the current condition of monuments is present in some SMR/NMR entries, it is widely variable and the only option is to examine the recorded 'form' of monuments. However, this examination can only give an indication of the form which monuments currently take. Some monuments of a given form may be stable (eg henges as 'ruins', barrows as 'earthworks'); others of the same form may be rapidly deteriorating (eg many industrial structures as 'ruins').

5.3.3 The number of sites within form groups (aggregations of 20 'forms' into 11 groups – see Appendix 2, Table A2.3) for different archaeological periods (Table 5.2) shows a broad pattern, as might be expected. Structures and ruins are generally of recent date (the Prehistoric sites are standing stones). Earthworks form a significant group, with many undated. Crop/soil sites, AP sites and find sites are rare. Sites identified from documentary sources form the biggest group, although artificially boosted within this dataset by the procedure employed to identify new sites (fieldwork would enable reallocation by both form group and period of the bulk of these sites). The number of excavated/removed sites appears small, but the unrecorded removal of sites is unquantified.

Designations and archaeological features

5.3.4 Of 630 sites, 335 occur in 30 designated squares (11.2 km^{-2}), with 295 in 31 non-designated squares (9.5 km^{-2}) (see Tables 5.3 & 5.4). There appears to be no correlation between designation status and density of sites.

5.3.5 Only 12 sites are Scheduled Ancient Monuments (SAMs) , seven of which were in AONBs. The 12 sites represent 1.9% of the total number of sites in the coastal dataset.

5.3.6 Condition information was, as expected, severely limited. The location of this information within SMR structures is very variable and the information given is to no standard either within or between SMRs. Virtually no information was available on the changing condition of the monuments.

5.4 Discussion

5.4.1 The results of the archaeological study are limited by the inadequacies of the available data. There is clearly a need to review the way in which information about archaeological site condition is recorded, such that recording over future decades will allow such analyses to be undertaken. Indeed, English Heritage is currently funding the Monuments at Risk Survey (MARS) project to compile precisely this type of information for a 5% sample area of England, looking at current condition and attempting to gauge changes over the past 50 years (Darvill, Fulton & Bell 1993).

5.4.2 Factors behind the inadequacy of the compiled data include the following.

- The expected variability of SMR data has been confirmed. There is particular variation in the terms used for 'site type' and 'form'. Entries for these fields required standardisation (often difficult to achieve objectively) at the data entry stage. The range in number and types of site represented also varies widely according to the sources used in the creation and enhancement of each SMR.
- A further problem is the absence of any standards in recorded information about management history of archaeological sites, even though all SMRs have database fields for this information.
- The analysis of aerial photography and the fieldwork carried out as part of the current project were too limited to be of much use in estimating the percentage of the total archaeological resource that has been recorded.
- The lack of location data for designations is a problem – the only designations for which we have consistent specific locations are the SAMs.

5.4.3 It is suggested that any attempt at this stage at useful comment on the effects of designations on archaeological sites might be provided by a combination of case studies with a programme of more detailed site identification and subsequent site inspection by experienced archaeologists.

5.4.4 However, the current project has shown that the coastal mask contains features from most historic periods, although representation of the Early Medieval period was absent. It is not possible to say whether designation status has helped to preserve sites or whether, by contrast, designated sites have been subject to more intensive examination.

Table 5.3 Designations – number and mean number of sites per km square by data source and designation

Data source	Designation	Total no. of sites	Mean km^{-2}
SMR/NMR	Yes	267	8.9
	No	198	6.4
Field survey	Yes	68	2.3
	No	97	3.1
Combined	Yes	335	11.2
sources	No	295	9.5

Table 5.4 Number of sites per square for each designation for the coastal landscape

Designation	No. of sites	No. of squares	Sites km^{-2}
G Belt	0	0	-
AONB	253	13	19.5
SSSI	139	15	9.3
NP	3	1	3.0
HC	123	6	20.5
NNR	3	2	1.5
ESA	98	2	49.0

Chapter 6 PRESSURES FOR CHANGE: ATMOSPHERIC POLLUTION

6.1 Introduction

6.1.1 This Chapter describes the development and use of conceptual models to predict the effect of environmental changes, and changes in agricultural management, on the quality of coastal landscapes.

6.1.2 TRISTAR (TRIangular STrAtegic Rules for British herbaceous vegetation) is an expert-system model which deals with the fundamental environmental and management processes controlling the composition of British herbaceous vegetation (Hunt *et al.* 1991). The TRISTAR2 model, developed for this project, is a program which extends this approach specifically into the areas involving climate change scenarios.

6.1.3 TRISTAR2 takes a given specification of an initial steady-state vegetation, adopts some altered environmental and/or management scenario, and then predicts the composition of the new steady-state vegetation in terms of its component functional types.

6.1.4 Vegetational survey data collected during this study (see Chapter 4) were processed in three distinct phases by means of the TRISTAR2 model. After the final phase, the outputs of the modelling are examined and interpreted.

6.2 Phase I – allocation of functional types

Brief description of methods

6.2.1 The initial steady-state vegetation was specified as a list of abundance of species in each of the survey plots. Each vegetation record has been classified according to both of two sets of criteria:

- the designated status, if any, of the site from which the record was taken, and
- the plant community type into which the vegetation of the quadrat falls.

The basis for the second of these classifications is a TWINSPAN analysis which divides the plots into 12 plot classes, as described in Chapter 4 (Section 4.4).

6.2.2 For each plot, one of 19 functional types (see Appendix 3) is then allocated to each of the component species using information from the databases of the Unit of Comparative Plant Ecology (UCPE) at the University of Sheffield. Briefly, two external groups of factors, called 'stress' and 'disturbance', both of which are antagonistic to plant growth, are recognised.

6.2.3 When the four permutations of high and low stress against high and low disturbance are examined, a different primary strategy type emerges in association with each of the three viable contingencies: **competitors** (C) in the case of minimum stress and minimum disturbance, **stress-tolerators** (S) in the case of maximum stress and minimum disturbance, and **ruderals** (R) in the case of minimum stress and maximum disturbance (Appendix 3, Figure B). Intermediate types of C-S-R strategy can be identified, each exploiting a different combination of intensity of external stress and disturbance.

6.2.4 TRISTAR2 conflated the weighted abundance of up to a maximum of 19 individual functional types which may be present within each sample. This process created weighted abundance for each of seven broader groups of functional types. These seven groups represent the three extreme corners of the C-S-R triangle ordination (see Figure 6.1), its centre, and its principal intermediate positions. These seven groups were each converted into a two-part numerical code which provided a computational mechanism for representing both 'pure' and intermediate functional types.

6.2.5 Once converted, the classifications according to functional type provided the basis for all further work on the vegetation sample by TRISTAR2. Appendix 3 provides details of the TRISTAR model and how it has been used. The presentation for each scenario consists of a divided percentage bar diagram illustrating the functional composition of all the plot classes present in the initial vegetation, with an ecological interpretation.

Results

6.2.6 As stated in Chapter 2, the English coastal areas contain a wide range of distinctively coastal habitats, including intertidal habitats (eg mudflats, saltmarshes) and terrestrial habitats (eg shingle structures, sand dunes and cliffs), as well as a wide range of more general habitats. Each of these habitats contains a variety of vegetation types, making the coastal landscape particularly heterogeneous and complex.

6.2.7 Because the survey was of a broad coastal mask, it contains a variety of semi-natural habitat types. For the purposes of analysis of functional types, these have been divided into three groupings that relate to habitat type:

- **saltmarsh and other maritime habitats** (plot classes A–F);
- **grassland and heath habitats** (plot classes G–K);
- **scrub** (PCL).

For examination of vegetation change, saltmarsh (plot classes A–D) is separated from other maritime habitats (plot classes E–F), and grassland is further subdivided by functional type into base-rich (plot classes G–J, relatively productive) and acidic (PCK, unproductive heathland).

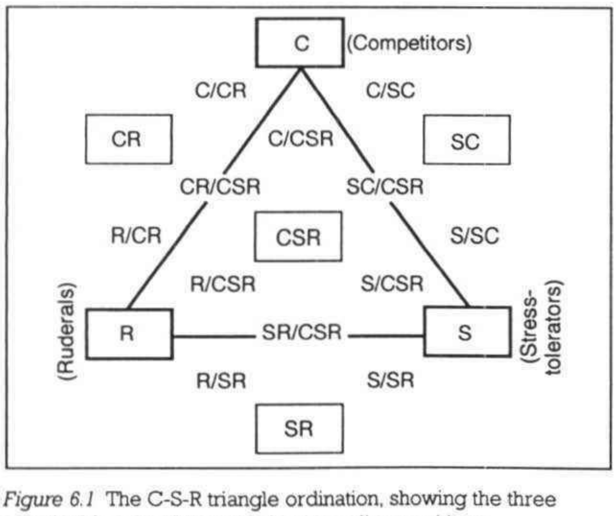

Figure 6.1 The C-S-R triangle ordination, showing the three principal functional types and intermediate positions

6.2.8 Of the saltmarsh and other maritime habitats, saltmarshes (plot classes A–D) appear eutrophic with a predominance of types ruderal and competitor/ruderal. This is particularly true for the lower marsh (plot classes A–B) which is more disturbed by tidal movements. These two classes also lack type competitor. Of the other maritime habitats, maritime with freshwater influence (PCE) is a productive somewhat disturbed habitat with a predominance of types competitor and competitor/ruderal. Foreshore (PCG) is even more disturbed, with more type ruderal and less type competitor.

6.2.9 In grassland habitats, the ecological theory is not yet available for TRISTAR to consider separately species from maritime habitats, and the base-rich elements of this grouping are rather heterogeneous. Tall/overgrown grassland and neutral/semi-improved grassland (PCH–PCI) are the more eutrophic habitats, and neutral/calcareous meadows and the semi-maritime habitat cliff-top (PCG and PCJ) the most unproductive, with type stress-tolerator well represented. An early stage in reclaiming the land for intensive agriculture would have been the application of lime. Thus, the acidic vegetation (PCK) is almost by definition 'unimproved'. It has most of type stress-tolerator and will be the least productive. Many species of type competitor, competitor/ruderal and stress-tolerator/competitor indicate low or no management inputs, ie dereliction. PCH (tall/overgrown grassland) is an example of abandoned grassland, with very high values of competitor, competitor/ruderal and stress-tolerator/competitor. The presence of ruderal types is difficult to interpret for grassland habitats.

6.2.10 Scrub habitats (PCL) are difficult to analyse because separate analyses have not been carried out on the shrub and herb layers. The two layers will not necessarily respond in the same way to the same change scenario.

6.2.11 In summary, the 'core' coastal (saltmarsh and other maritime habitats) vegetation was composed of competitor, ruderal and competitor/ruderal species. The remaining vegetation plot types were representative of all other combinations of functional types.

6.3 Phase II – effects of change scenarios on the abundance of functional types

Brief description of methods

6.3.1 The TRISTAR2 model was populated with six scenarios comprising selected combinations of two environmental factors – disturbance and eutrophication. Each scenario can have more than one possible management or climate change interpretation, and examples of the possible causes of each scenario are given in the results. The scenarios were:

i. decreased disturbance and no change in eutrophication;
ii. decreased disturbance and increased eutrophication;
iii. no change in disturbance and decreased eutrophication;
iv. no change in disturbance and increased eutrophication;
v. increased disturbance and decreased eutrophication;
vi. increased disturbance and increased eutrophication.

6.3.2 For each factor and functional type within the six specimen scenarios, TRISTAR2 applied an appropriate numerical multiplier according to our understanding of the effects of the factor. The essence of the approach is that seven functional types are each driven by this weighting in different directions and with different gradients, according to information from UCPE's extensive survey and screening databases.

Example results

6.3.3 Full outputs from the model are given in Appendix 3. Within this Chapter, summary results for only the saltmarsh and other maritime classes (plot classes A–F) are described.

Scenario 1. Decreased disturbance and no change in eutrophication

6.3.4 Possible causes of this scenario, as it affects the core coastal vegetation, include reduced effect of tidal activity either naturally following increased sedimentation or fewer storms, or as a consequence of human activity (normally these would also reduce nutrient inputs into the system), colonisation by a species tolerant of disturbance (cord-grass (*Spartina anglica*)), and less recreational pressure.

6.3.5 With respect to functional types, saltmarshes (plot classes A–D) are eutrophic and an increase in types competitor, competitor/stress-tolerator/ruderal and stress-tolerator/competitor might be predicted. However, for lower shore marshes (plot classes A–B), types competitor/ruderal and competitor/stress-tolerator/ruderal are predicted to expand at the expense of type ruderal, at least in the very short term. Some increase in type competitor might also have been expected, making the vegetation more similar to that in less disturbed habitats higher up the shore (plot classes C–D). In other maritime habitats (plot classes E–F), increases in types competitor, competitor/stress-tolerator/ruderal and stress-tolerator/competitor are predicted, primarily at the expense of types ruderal and competitor/ruderal.

Scenario 2. Decreased disturbance and increased eutrophication

6.3.6 Possible causes of this scenario, as it affects the core coastal vegetation, include reduced effect of tidal activity either naturally following increased sedimentation or fewer storms, or as a consequence of human activity (normally these would also reduce nutrient inputs into the system), colonisation by a species tolerant of disturbance (cord-grass (*Spartina anglica*)), and less recreational pressure, together with increased fertilizer runoff or atmospheric deposition.

6.3.7 Increased eutrophication in combination with decreased disturbance will have a greater and more rapid impact on the distribution of functional types than that exhibited in the previous scenario (disturbance decreased; eutrophication same). Taller, faster-growing vegetation should be produced and overall losses of types stress-tolerator, stress-tolerator/ruderal and ruderal and an increased representation by type competitor, competitor/stress-tolerator/ruderal and competitor/ruderal are predicted. Saltmarsh (plot classes A–D) is eutrophic and a similar but slightly greater change to that for productive grassland might have been predicted, namely an increase in types competitor and competitor/stress-tolerator/ruderal. However, for lower shore marshes (plot classes A–B), types competitor/ruderal and competitor/stress-tolerator/ruderal are predicted to expand at the expense of type ruderal, at least in the very short term. Some increase in type competitor might also have been expected, making the vegetation more similar to that in less disturbed habitats higher up the shore (plot classes C–D). Even if natural processes (erosion and sedimentation) restrict the impact of this type, sites should be more strongly vegetated. Eutrophication should encourage rapid recovery following disturbance. In other maritime habitats (plot classes E–F), the prediction of losses of types stress-tolerator and ruderals and an increased representation by types competitor and competitor/stress-tolerator/ruderal accords better with expectations.

Scenario 3. No change in disturbance and decreased eutrophication

6.3.8 Possible causes of this scenario, as it affects the core coastal vegetation, include decreased usage of or pollution from fertilizers and decreased inundation by nutrient-bearing waters (but this is normally associated with disturbance and the deposition of silt, sand or stones).

6.3.9 Generally, increases in types stress-tolerator, stress-tolerator/ruderal and stress-tolerator/competitor and decreasing competitor, competitor/ruderal and ruderal are predicted. In the more eutrophic saltmarsh and other maritime habitats (plot classes A–F), competitor/stress-tolerator/ruderal increases instead of the more extremely slow-growing functional types (eg stress-tolerator). However, type stress-tolerator, which grows very slowly, will take a considerable period to establish and results may be less marked than predicted. In practice, the decreased eutrophication scenario is likely to occur rather rarely in saltmarsh habitats.

Scenario 4. No change in disturbance and increased eutrophication

6.3.10 Possible causes of this scenario, as it affects the core coastal vegetation, include increased flooding (in the absence of appreciable disturbance) and increased fertilizer runoff or atmospheric deposition.

6.3.11 Increased eutrophication is one of the most important scenarios to consider with respect to changing land use. Saltmarsh and other maritime habitats (plot classes A–F) are eutrophic and some increase in types competitor might be expected.

Scenario 5. Increased disturbance and decreased eutrophication

6.3.12 Possible causes of this scenario, as it affects the core coastal vegetation, include the increased effect of tidal activity either naturally following increased sedimentation or more storms (normally these would also increase nutrient inputs into system), or as a consequence of human activity, more recreational pressure, decreased usage of or pollution from fertilizers, and decreased inundation by nutrient-bearing waters (but this is normally associated with disturbance and deposition of silt, sand or stones).

6.3.13 Increased disturbance coupled with decreased eutrophication will have a major impact on composition with respect to functional types. For saltmarsh and other maritime habitats (plot classes A–F), types competitor/stress-tolerator/ruderal, competitor and competitor/ruderal are expected to decline and annuals of type ruderal are predicted to increase.

Scenario 6. Increased disturbance and increased eutrophication

6.3.14 Possible causes of this scenario, as it affects the core coastal vegetation, include the increased effect of tidal activity either naturally following increased sedimentation or more storms (normally these would also increase nutrient inputs into system), or as a consequence of human activity, more recreational pressure, increased flooding (in the absence of appreciable disturbance), and increased fertilizer runoff or atmospheric deposition.

6.3.15 The combination of increased eutrophication and increased disturbance, which is a very common impact upon the British landscape, will have major impacts on composition with respect to functional types. Almost universally an increase in types ruderal and competitor/ruderal are predicted at the expense of all other types.

6.4 Phase III – computation of an 'index of vulnerability'

6.4.1 For each of six scenarios, predictions for each functional type in each semi-natural vegetation plot class present in the habitat (PCA, PCB, etc) are computed. An index of vulnerability is computed for each plot class. The index of vulnerability is displayed as a bar diagram for each plot class in Appendix 3 and is derived in three substages:

i. examine the original data to find the number of quadrats deviating appreciably from the typical;
ii. examine the TRISTAR2 predictions to find

Table 6.1 'Indices of vulnerability' for six change scenarios

Scenario	Characteristics	Mean index of vulnerability	Impact
1	Decrease disturbance; no change in eutrophication	0.16	Low
2	Decreased disturbance and increased eutrophication (eg decline in grazing pressure with an increase in fertilizer)	0.24	Medium
3	No change in disturbance and decreased eutrophication (eg no change in grazing pressure but a decrease in fertilizer)	0.22	Medium
4	No change in disturbance and increased eutrophication (eg no change in grazing pressure but an increase in fertilizer)	0.12	Low
5	Increased disturbance and decreased eutrophication (eg increase in grazing pressure with fewer fertilizers)	0.32	High
6	Increased disturbance and increased eutrophication (eg increase in grazing pressure and an increase in fertilizers)	0.33	High

the new number of quadrats deviating appreciably from the original composition;

iii. find the 'index of vulnerability' for each plot class.

Summary of results

6.4.2 Full outputs from the model are given in Appendix 3 and a summary is given in Table 6.1.

6.4.3 Scenarios 1–4 all have low/medium total indices of vulnerability, even where eutrophication increases. Within each scenario, some individual plot classes show moderate levels of vulnerability (Appendix 3) but, in all cases, the saltmarsh and other maritime classes are not vulnerable.

6.4.4 Similarly, although the overall index of vulnerability is high for scenarios 5 (increased disturbance and decreased eutrophication) and 6 (increased disturbance and increased eutrophication), the saltmarsh and other maritime classes remain at low risk. In these scenarios, all grassland and scrub types of vegetation are at high vulnerability but, as these are not the core coastal types, this may not prove to be a cause for concern.

6.5 Summary of modelling results

6.5.1 'Coastal habitats' form a heterogeneous grouping of saltmarsh and other maritime habitats, heath, grassland and scrub. Moreover, the individual classes differ in their representation of functional types. The plot classes with a predominance of ruderal types from eutrophic habitats (CR and R) are saltmarsh and other maritime habitats (plot classes A–F), although PCE also has the highest representation of type C. Grassland (plot classes G–K) predictably have most CSR; grazing is both a disturbance event (the removal of biomass) and induces stress (removal of nutrients). Furthermore, the least productive variants (plot classes G, J and K) have the highest proportion of types S and SR. Scrub, as befits a habitat dominated by woody species, has a high representation of type SC.

6.5.1 The coastal mask includes a heterogeneous grouping of saltmarshes, maritime, grassland and scrub types of habitat. However, the index of vulnerability differs between scenarios. The most extreme scenario appears to be 'increased disturbance and eutrophication', with the non-maritime plot classes showing high vulnerability.

6.5.2 The impact to the various scenarios can be ranked as follows.

Low/moderate impacts

- Disturbance same; eutrophication increased (lowest impact)
- Disturbance decreased; eutrophication same
- Disturbance same; eutrophication decreased
- Disturbance decreased; eutrophication increased

High impacts

- Disturbance increased; eutrophication decreased
- Disturbance increased; eutrophication increased (highest impact)

6.5.3 The differences between habitat groupings are marked, with woody classes (PCK – heathland, PCL – scrub) among the most vulnerable, and saltmarsh and other maritime types (plot classes A–F) the least vulnerable. Grassland types (plot classes G–J) occupy an intermediate position. Vulnerability of different habitat types differs only slightly according to scenario.

Chapter 7 SUMMARY OF THREATS AND POLICY RESPONSES

7.1 Introduction

7.1.1 This Chapter summarises what is known about the existing extent and quality of the coasts, reviews existing policy instruments, and assesses threats to this landscape type.

7.1.2 Coastal landscapes are rich in variety, reflecting geomorphological and climatic processes and phenomena. The coastal landscape, in this case defined as a 500 m belt inland from the high water mark, contains a diversity of different landscapes and habitat types, including cliffs, coastal grazing marshes, sand dunes, saltmarsh and coastal heath. This study does not include intertidal mudflats. Coastal landscapes are important at both national and international level for their birds, plants, landforms and fossils, and are rich in their archaeological and cultural heritage. Estuaries support more than one third of the north-west European wintering population of six species of wader and five of wildfowl; rocky cliffs and small islands support internationally important numbers of breeding seabirds; shingle bars and sand dunes support internationally important numbers of breeding terns. Coasts also provide diverse opportunities for formal and informal recreation.

7.1.3 The conservation and geological interest of coastal habitats derives from the dynamics of erosion and accretion processes, which lead to long- and short-term change along the shoreline and a succession of maritime plant communities from pioneer to mature habitats. Unspoilt coastline is particularly valued because, unlike other landscape types considered in this survey, extensive areas of near-natural habitats – cliff face, dune and saltmarsh systems – still exist. In addition to their nature conservation interest, coastal habitats serve important storm defence functions.

7.2 Key findings of the survey

Field survey

7.2.1 The results of the survey are shown in Table 7.1 which summarises the extent of the coastal belt, defined as a 500 m strip from the high tide mark along an estimated coastline of 10 700 km in England, excluding the developed coast (Coastwatch Database managed by the Joint Nature Conservation Committee (JNCC)). For the purposes of this study, the results are presented in three categories of coast, as follows.

- **Hard coasts** comprise mainly steep cliffs and rocky shores which are found mainly in the north and west of England. Semi-natural vegetation is predominantly calcareous grassland and shrub, with little specifically maritime vegetation; agricultural land use predominates with land ploughed or grazed close to cliff edges.

- **Soft coasts** fronted by sands, gravels and clays and dominated by mobile sediments are found mainly in the south and east of England. Soft coasts retain more specifically maritime vegetation (16% of the total), often in extensive dune and saltmarsh systems. Agricultural land uses (arable, grazing marshes and improved grassland) account for over a third of the total area, with buildings, roads and recreational uses such as golf courses accounting for most of the remainder. These are typically sinking or retreating coasts, but with shingle spits, mudflats, dunes and saltmarshes being created where natural processes are not impeded.

- **Estuaries**, defined as the area from the river mouth to the upper limit of tidal rise, have similar geophysical and vegetation cover to soft coasts, with extensive areas of saltmarsh. Crops and grassland cover more than half of the land area, with buildings and roads covering some 20%.

7.2.2 Within these coastal types, a range of distinct habitat types can be distinguished.

Saltmarshes

7.2.3 Saltmarshes are found along soft coasts or estuaries and represent a wide range of plant communities, progressing from saline pioneer species (often adjacent to algal-covered mudflats not covered in this survey) to seaward communities, through brackish communities found in ditches and channels, to grassland or freshwater marsh species. Many saltmarshes are bounded by artificial sea walls or embankments. The most extensive saltmarshes are found in the south-east (Essex, north Kent and Suffolk), north-west (Cumbria, Lancashire, Merseyside and Cheshire), east (Lincolnshire and Norfolk) and southern England (Hampshire, Dorset and west Sussex). The outer Thames Estuary contains almost 20% of all saltmarsh. The estimated loss of saltmarsh due to erosion and human activity has been extensive; Burd (1989) shows that between 1973 and 1988 some 20% of total marsh area was lost in Suffolk, Essex and north Kent.

Sand dunes

7.2.4 Sand dunes are found along soft coasts in north Norfolk, north Devon, Cornwall, Dorset, east Kent and north-west England. Unmodified systems comprise a succession of habitats, from embryo dunes through mobile and mature dunes, mire and swamp, to dune grassland or heath on the landward side. Unimpeded systems adjust naturally to coastal erosion by moving landwards. Extensive areas of sand dune still exist, with some 20 sites together accounting for 7500 ha (over 60% of the total estimated area). The estimated total net loss of dunes due to erosion over the last 20 years was only 1% (Pye & French 1993).

Cliffs

7.2.5 Cliffs may be either earth or softer hard rocks, such as the limestone found in the south coast; the latter may be relatively stable, with rare plant species found in the under-cliff. While the survey shows limited maritime vegetation, maritime influences on plant communities are important and cliffs are highly valued for geomorphic reasons and as breeding sites for seabirds.

Grazing marshes

7.2.6 Grazing marshes are mainly found in East Anglia behind saltmarshes, and are often protected by systems of dykes and ditches; grazing marshes have conservation interest for invertebrates and breeding birds and require ongoing traditional management in order to maintain their conservation interest.

7.2.7 The extent of all of these features in the landscape mask is summarised in Table 7.1. However, because of the linear nature of the survey, it has not been possible to compare the extent of key habitats with estimates from other sources which are made on the basis of the inventories of known sites, rather than on a strictly delineated coastal strip. In addition, it has not been possible to define features such as sand dunes separately, as they cover strips that may be no more than a few kilometres in length.

Threats

7.2.8 The major factor determining the quantity and extent of coastal habitats is the process

Table 7.1 Extent (ha) of the coastal mask by structural and habitat type (source: ITE)

Coastal landscape structure and habitats	Estuarine Designated	Estuarine Non-des'd	Hard coast Designated	Hard coast Non-des'd	Soft coast Designated	Soft coast Non-des'd	Total
Bare shore[1]	3405	835	2132	357	2337	70	9136
Saltmarsh	13244	1113	–	–	6566	–	20923
Maritime vegetation[2]	3405	1113	1488	273	1997	291	8567
Waterside/marsh[3]	1324	1345	–	–	927	291	3887
Unmanaged grass[3]	2175	2181	1736	1785	2819	416	11112
Total	*23553*	*6587*	*5356*	*2415*	*14650*	*1068*	*53629*

[1] including, shingle, sand and mud
[2] including dunes, cliff-tops, coastal heath with maritime species
[3] including some mature landward saltmarshes

of ongoing erosion of sinking coasts and the advance of rising coasts. The survey results show that in all the coastal types agricultural land use predominates, with up to 50% of total land area under either crops or improved grazing.

7.2.9 The other major land use reflects past infrastructural development of ports, roads and housing in the coastal zone; more recently, development has focused on recreation facilities such as marinas and golf courses. Industrial infrastructure, particularly polluting or risky installations, has also been located on the coast, and often in isolated areas of previously near-natural vegetation. While further developments of this type are limited in the coastal zone, all of these land uses have created an economic and social need to protect land, property and human life from erosion and flood, and have resulted in hard engineering approaches (such as the construction of physical barriers) to slow down natural geophysical processes. The results of these past efforts are now largely recognised to have had damaging effects on coastal habitats, either by speeding up erosion processes on other parts of the coast, or by fixing habitats at one stage of their development and preventing their tendency to move inland in response to erosion.

7.2.10 The key threats to coastal habitats were identified by a meeting of experts (convened as part of this project). In descending order of importance it was agreed that the key threats in the past have resulted from:

- **coastal protection and flood defences** using hard engineering solutions which have had major negative impacts on sediment deposition dynamics:
  - sea walls protecting land in retreating areas (the south and east) have led to the build up of sediment and land levels on the seaward side of defences and the relative lowering of levels on the landward side, so increasing vulnerability to overtopping, saline inundation, etc);
  - hard defences at the bottom of eroding cliffs have starved other areas of sediment and led to the erosion of beaches, loss of saltmarshes in estuaries, and consequent loss of their flood control functions.
- **expansion and intensification of agriculture** in the coastal zone which have had the following impacts:
  - reclamation of land behind sea defences for grazing, leading to the loss of saltmarshes;
  - drainage of marshes to allow intensive grazing or arable use, leading to loss of diversity and spring breeding sites for rare birds;
  - improvement of cliff-top grasslands, leading to increased runoff, reduced cliff stability, and accelerated rates of cliff erosion.

7.2.11 A number of other developments have had localised impacts on coastal habitats including:

- **dredging for aggregates** and channel clearing in estuaries.
- **recreational use of coasts** for water sports, cycling, vehicle use and golf courses, creating localised pressures in fragile habitats such as dune systems and saltmarshes.

7.2.12 In the future, climate change is expected to be a major factor, leading to sea level rise, temperature rise and seasonal variations in rainfall. Increases at spring tides and changes in monthly, seasonal and annual flood incidents will add dynamism to the system, but with unpredictable effects. The rate of loss of receding or sinking coasts is expected to accelerate as the impacts of sea level rise are felt over the next 50 years.

7.2.13 Airborne pollution is not considered to have a wide impact on coastal habitats overall, but sensitive habitats such as saltmarshes are vulnerable to coastal pollution, and particularly oil spills from coastal shipping and offshore oil.

7.2.14 A number of different farming scenarios have been modelled by UCPE (see Chapter 6 & Table 7.2). The implications are that the most beneficial agricultural management practices for coastal areas would differ considerably between habitat types, principally saltmarshes, cliff-tops and grazing marshes. Reducing stocking levels would reduce disturbance and eutrophication.

Conservation objectives

7.2.15 There has been a growing recognition of the importance of preserving the natural dynamics of coastal processes, and reversing the process of 'coastal squeeze'. This culminated in the publication of the MAFF/Welsh Office *Strategy for flood and coastal defence in England and Wales* (1993).

An expert group meeting within this study took as the starting point the MAFF strategy and the English Nature and Countryside Commission initiatives for coastal areas in agreeing the following broad hierarchy of objectives for the coastal landscape:

- to enable natural physical processes to continue along the whole length of the coast through managed retreat (or advance) of the coastal belt;
- to protect and enhance existing systems of near-natural habitats, particularly sand dune and saltmarsh systems;
- to restore some near-natural habitats such as sand dunes which have been damaged by recreational or development pressures and re-create habitats such as saltmarshes where opportunities arise.

7.2.16 In designing policies to meet these coastal habitat management objectives, a number of key issues need to be taken into account.

- As with other key habitats considered in this series, **land management approaches** are the key to meeting objectives.

- **Conflicts** exist **between different land uses** in coastal belts – eg transport and industrial infrastructure, urban development, high-value agricultural land, recreational areas and sites of nature conservation interest – and, together, these restrict the space in which natural processes of coastal dynamics can be allowed to proceed. In most situations, managed retreat will be the result of trade-offs between all these different interests and, in some cases, financial compensation may be required for the losers.

- **Ownership**. A significant proportion of the most valued habitats – dunes and saltmarshes – are now owned by conservation bodies. For instance, the Royal Society for the Protection of Birds (RSPB) and the National Trust together own some 28% of sand dunes and 45% of saltmarsh areas identified in English Nature inventories. English Nature and Local Wildlife Trusts also have substantial management interests. While these bodies are generally keen to undertake managed retreat, in some cases existing nature conservation sites have greater historic and scarcity value than those which could be created by re-instating more natural erosion processes.

7.3 The impact of current policies

7.3.1 Available policy instruments fall into a number of categories which may be summarised as follows:

- regulations to protect areas of high conservation value against deleterious activities and development planning proposals or to encourage sound coastal management practices;
- land use planning and management measures, such as coastal zone management plans;
- economic instruments such as the European Union's Common Agricultural Policy (CAP) and packages of grants and subsidies aimed specifically at coastal management;
- pilot and demonstration projects to determine the potential for managed retreat, advance and stabilisation.

Policies to protect coastal habitats

7.3.2 International and UK legislation provides a complex framework of designations for the protection of coastal habitats. A hierarchy of designations exists.

- NNR, SSSI and Scheduled Monument status are protective designations which also prevent deleterious actions.

- Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) are European designations under the Birds and Habitats Directives respectively, and are intended to strengthen national nature protection designations such as SSSI.

- National Park, AONB and Green Belt designations provide protection against planning permission for the change of use of the site; Heritage Coasts are not statutory designations but provide a framework for land use planning decisions.

- Other designations, such as Environmentally Sensitive Areas (ESA), delineate areas where incentives for positive management practices are available (see para 7.4.2).

7.3.3 Based on the field survey results, some 80% of the coastal landscape mask appears to have some form of designation (see Table 7.3).

Heritage Coasts

7.3.4 In addition to planning and nature conservation designations, Heritage Coasts were

Table 7.2 Summary of UCPE scenario findings

Potential threat	Possible causes	Interpretation of results
Scenarios which would threaten coastal habitat quality		
Decreased disturbance and no change in eutrophication	Reduced fire, reduced grazing or cutting in woodlands and grasslands, reduced tidal movement because of sedimentation, man-made barriers or colonisation by a species tolerant of disturbance on saltmarshes	Increases in competitive strategies (ie species of lower nature conservation interest such as gorse, bramble and coarse grasses) on base-rich grasslands; in saltmarshes the impacts will vary between shoreline habitats which would normally experience the greatest disturbance, and those with greater freshwater influence which are less dependent on constant disturbance
Decreased disturbance and increased eutrophication	Reduced burning, reduced grazing, less recreational pressure in all areas and barriers, colonisation or increased sedimentation on saltmarshes, increased fertilizer runoff and/or atmospheric deposition (nitrogen or sulphur)	As above, but eutrophication will lead to fast growth after disturbance – for grasslands, other maritime habitats and saltmarshes, competitor vegetation types will increase, mainly at the expense of types S and ruderals. Shoreline saltmarshes are likely to become more like less-disturbed habitats further from the shoreline. The slow-growing less productive (semi-maritime cliff-top) and dry heaths will be particularly sensitive initially to increases in bracken, followed by increases in tall competitive herbs and grasses
No change in disturbance and increased eutrophication	Increased fertilizer runoff or atmospheric deposition (nitrogen or sulphur) or, in the case of saltmarsh, increased flooding without appreciable disturbance	In base-rich grasslands, where many species are fast-growing, increased eutrophication will lead to a move from semi-natural species towards types dominated by tall competitive herbs and grasses. The most vulnerable appear to be acidic grasslands, whereas the impacts on saltmarshes and other maritime habitats in the short term may even increase their nature conservation interest
Increased disturbance and increased eutrophication	Increased use of burning, grazing, cutting with increased runoff and atmospheric deposition for grasslands and woodlands, more flooding, storms, sedimentation, runoff or atmospheric deposition for saltmarshes	This scenario has the greatest impact on vulnerable grassland and scrub habitats, with a likely increase in dominance of tall competitive herbs and grasses or bracken. Saltmarsh and other maritime habitats are less likely to be vulnerable
Scenarios which would improve coastal habitat quality		
No change in disturbance and decreased eutrophication	Decreased usage of/pollution from fertilizers on all habitat types, decreased inundation from nutrient-bearing water on saltmarshes	This will generally lead to a recovery of functional types at the expense of faster-growing competitors in the least productive grasslands (plot classes G-K), while in base-rich grasslands competitors may increase more than the very slow-growing functional types. In practice, saltmarshes are unlikely to experience both increased eutrophication and reduced disturbance
Increased disturbance and decreased eutrophication	Increased use of burning, cutting or grazing for grasslands and woodlands, less fertilizer runoff and atmospheric deposition, increased storms or flooding (but with no additional nutrients) for saltmarsh	This scenario would be positive for the least productive grassland types with growth of slow-growing S types; in other more productive grasslands, it will depend whether the disturbance is constant (from grazing) or sudden, which will determine whether damage to perennial species allows short-lived ruderals to thrive or not

introduced by the Countryside Commission with the objective of focusing management attention on the finest stretches of undeveloped coast in order to conserve and manage them comprehensively. Heritage Coasts have no statutory designation status, but now extend over 5500 ha along some 1000 km of coastline, covering all key maritime habitats, particularly saltmarsh and sand dunes.

7.3.5 Table 7.3 shows designations of different habitats based on inventories carried out on behalf of English Nature in 1993. This Table shows the very extensive network of SSSIs covering nearly 50 000 ha and accounting for some 80% of sand dunes and saline lagoons, and over 95% of shingle features and saltmarshes. Given the importance of coasts for breeding birds and waders, many of the identified sites are also designated as Ramsar sites (over 30 000 ha, mainly of saltmarsh) and are further strengthened by existing or proposed SPA status under the EC Birds Directive. SPA status is expected to strengthen national protected status against damaging development. SACs under the Habitats Directive have recently (June 1995) been proposed to the European Commission and

Table 7.3 Area (km²) of different coastal types by designation (source: Cambridge Environmental Resource Consultants Ltd, 1993)

	Sand dunes	Salt-marsh	Saline lagoons	Shingle	Total
SSSI	9530	32400	1020	4850	47800
Ramsar	4900	20910	920	4640	31390
SPA	5720	24840	900	4620	36080
Heritage Coasts	1030	2910	590	1100	5630
No designation	1190	45	100	50	1385
Total area	*11900*	*32470*	*1220*	*5030*	

are expected to offer a similar level of protection to that afforded by SPAs.

7.3.6 Although it has not been possible within the scope of this study to evaluate the impact of nature conservation designation on quality of habitat, designations do appear to have been successful in slowing down development in coastal belts which would result in either loss of threatened habitats or further pressures to maintain/develop hard sea defences in the future.

Land use and management planning approaches

7.3.7 Statutory land use planning for coastal zones is the responsibility of maritime district or borough councils who prepare land use plans in the context of DOE guidance contained in the *Policy planning and guidance note for coastlines* (PPG 20) and other forms of guidance shown in Table 7.4. PPG 20, the MAFF strategy on coastal defences, National Rivers authority flood defence strategy and English Nature's coastal objectives all call for tight restrictions on new development in areas at risk from flooding. A survey of how local authorities are reflecting PPG 20 in statutory planning terms is currently being undertaken by RSPB.

7.3.8 In addition to statutory plans, a wide range of other planning initiatives are being undertaken with a specific focus on coastal zones. These range from large area strategies to detailed local or shoreline plans. Each of the management plans sets out objectives, how these will be met, the organisations involved, resources required and a timetable for implementation. Plans fall into five main categories.

- National, regional and county strategies and plans. Strategies providing a broad contextual framework for coastal policies, strategic land use plans, agency programmes and local actions are usually drawn up by County Councils (Essex, Durham, Devon) or consortia of local authorities (eg SERPLAN) and interest groups (eg the North West Coastal Network).
- Shoreline management plans (SMPs) have been introduced since 1993 and are intended to provide a coherent, strategic approach to the management of coastal processes for coastal defence. SMPs should be completed according to MAFF guidelines which provide operating authorities with checklists for good practice. SMPs are based on an assessment of the environmental impacts of proposals, with a presumption in favour of soft engineering or 'do nothing' management approaches, wherever practical. SMPs can be regional such as the Standing Conference on Problems

Table 7.4 Guidance relating to developments affecting the coastal landscape

DOE/MAFF/WO	1991	Conservation guidelines for drainage authorities
DOE	1992	Circular: Development and flood risk areas
DOE	1992	Policy and planning guidance for coastal planning, no. 20
MAFF/WO	1993	Strategy for flood and coastal defence
MAFF	1993	Flood and coastal defence, project appraisal guidance notes
MAFF	1993	Coastal defence and the environment: a guide to good practice for the planning and maintenance of coastal defences
MAFF	1993	Coastal defence and the environment: a strategic guide for managers and decision-makers in the National Rivers Authority (NRA), local authorities and other bodies with coastal responsibilities
MAFF	1993	Interim guidelines for shoreline management plans, which provides an explanation and checklist of what is required for a good shoreline management plan

Associated with the Coast (SCOPAC) or local (eg Waveney District).

- Coastal management plans (CMPs) are integrated non-statutory plans for fairly local stretches of coast, usually involving both land and water resources in the coastal zone. The intention is that they should cover 'coastal cells' or areas of both eroding and advancing areas which can sensibly be managed as a unit. Issues are intended to be addressed in a comprehensive and interrelated manner.

- Estuary and harbour management plans are multi-lateral non-statutory management plans and studies for estuaries and harbours which may cover large (Humber and Severn) or small (eg Faversham Creek and Adur Valley) estuaries.

- Heritage Coasts and AONB coast management plans are CMPs focusing on defined or designated areas with a strong conservation focus, but also taking account of the needs of agriculture, forestry, fisheries and of small communities by promoting sustainable development to conserve and enhance natural beauty and heritage features through adoption in local authority and National Park land use plans. Many of the plans so far produced have been supported by the Countryside Commission and may be county-wide (eg North York Moors or Suffolk Coasts) or local (eg Seven Sisters Country Park, Isle of Wight AONB).

7.3.9 Finally, the National Trust scheme, Enterprise Neptune, is a targeted approach to the purchasing, often with grant aid from DOE or through the operation of the National Heritage Millennium Fund, of large tracts of coastline to ensure that they are managed according to conservation, recreation, landscape and heritage objectives. While this approach does not guarantee better management than private ownership, it does remove some commercial development pressures and guarantees public access to the shoreline.

7.3.10 A recent study by the National Coasts and Estuaries Advisory Group, based on a questionnaire in the April 1993 edition of *Coastline UK*, identified some 90 ongoing initiatives, which are summarised by King and Bridge (1994) in their users' guide on the state of action and current good practice. The guide illustrates the number of initiatives which are already underway, and the diversity of approaches reflecting the heterogeneity of coastal zones and the wide range of actors in this area – local authorities, NRA, countryside agencies, and voluntary conservation bodies.

Economic instruments

Agri-environment measures

7.3.11 The 1992 CAP reform contained options under the accompanying agri-environment regulation allowing for financial aid to farmers for the adoption of environmentally friendly practices, including long-term set-aside, reductions in pesticide and fertilizer use, and reductions in livestock grazing densities. The regulation has been applied in the UK through ESAs, Countryside Stewardship, Tir Cymen, the Habitat Scheme, the Moorland Scheme, Nitrate Sensitive Areas, Countryside Access Scheme, and the Organic Aid Scheme. The schemes with greatest direct relevance to coastal habitats are described below.

Environmentally Sensitive Areas

7.3.12 The most important of these schemes in terms of area is the MAFF Environmentally Sensitive Area scheme, which includes two coastal ESAs: the Essex Coast and North Kent Marshes. Both cover large areas not included in the study definition of the coastal landscape (ie the 500 m coastal belt), but have some overlap with the waterside landscape mask. Areas of coastal grazing marshes also fall within the Broads ESA, while other coastal habitats are covered by the Suffolk River Valleys, Exmoor Test Valley and West Penwith ESAs, for example. The Essex and Kent ESAs have tiers which provide for the maintenance of permanent grassland, for the raising of water levels, and for arable reversion.

7.3.13 Despite attracting the highest payment rates, arable reversion uptake has been very limited compared to extensification of grazing on existing pastoral areas. The reason is largely thought to be that payment rates are meant to offer an incentive but do not fully cover revenue foregone under the scheme.

7.3.14 The 22 ESAs within the scheme now cover an estimated 10% of the total farming area, with a total annual budget of £43.3M available in 1995; because coastal landscapes are not individually targeted, it is not possible to estimate the total spending on this landscape/habitat type. However, applications in 1996 for the second stage of the Essex Coast ESA indicate a growing number of farmers keen to enter the coastal fringes of their farms into the scheme.

Habitat Scheme

7.3.15 In order to take advantage of some of the opportunities for habitat creation identified by NRA and English Nature as a result of managed coastal retreat in south-east England, MAFF initiated a pilot scheme in 1994 which provides options for long-term set-aside (20 years) under the agri-environment programme. Part of the pilot project is targeted at farmers able to create intertidal, saltmarsh habitat by remediating coastal drainage and defences and allowing tidal inundation of improved grazing or arable land. Annual rates vary from £250 ha^{-1} for pastoral land to £525 ha^{-1} for arable reversion. A five-year pilot scheme aims to convert a maximum 150 ha of agricultural land to saltmarsh. By early 1996 four schemes had been agreed, covering 60 ha. No targets have been set for the total eligible land, because opportunities are expected to arise on a rolling basis as EN/NRA proposals for managed retreat are developed. MAFF recently increased payment rates for grassland. However, future uptake is likely to be constrained by a complex range of factors, not least the long-term loss in agricultural land value, which is more marked for coastal than other habitat types.

Countryside Stewardship Scheme (CSS)

7.3.16 The Countryside Stewardship Scheme provides incentives for the positive management of existing coastal areas and for the restoration of grazing meadows, with the overall objective of conserving and restoring areas of natural coastal vegetation, enhancing coastal landscapes, and improving public enjoyment through improved access. The scheme offers incentives for:

- beneficial management on existing areas of natural coastal vegetation by grazing or cutting for hay, and maintenance of high water levels where appropriate with grants of £70 ha^{-1} yr^{-1} for grass, £20 ha^{-1} yr^{-1} for conservation of saltmarsh, and £50 for the conservation of sand dunes;
- restoration of intensively farmed coastal areas by natural regeneration or by establishing a grass sward of native species with grants of £250 ha^{-1} yr^{-1};
- quiet informal recreation on a permissive basis on suitable land;
- the creation or restoration of coastal landscape features such as scrapes or reed beds.

7.3.17 A further first-year supplement of £40 ha^{-1} is payable for additional restoration or re-creation of coastal land.

7.3.18 Table 7.5 shows that a total of some 8000 ha has been entered into various management options of the scheme, equivalent to about 15% of the total semi-natural coastal landscape identified in this survey. Some 85% of the total area within the scheme involves management and improvement of existing habitats, including saltmarsh, cliff-tops, sand dunes and grazing marsh. Over 1000 ha of cultivated land has also been converted to maritime vegetation. The re-creation of very scarce features, such as reed beds, carrs and fens, has been limited to less than 30 ha. In some areas, such as the Durham limestone coast and Solway marshes, the scheme has been taken up on more than 50% of the eligible area. Initial estimates by the Countryside Commission of potential targets for the scheme after its transfer to MAFF in April 1996 suggest a total area of 160 000–170 000 ha of coastal landscape, of which some 5% is already covered by the existing scheme.

Information and demonstration projects

7.3.19 Coastal directories have been produced by the JNCC for the North Sea coast and are now in the process of production for 16 regions around the UK coast. The directories will provide baseline information on the resource and its features, wildlife, resource use and management for the whole maritime zone. Six regional reports will have been completed by mid-1995 and the remaining ten regional reports during 1996. Funding for the project is being provided by a consortium of UK Government departments, countryside agencies, local authorities, non-governmental organisations, and user groups such as petroleum, water and shipping companies and users of the coastal zone.

7.3.20 Techniques for the restoration of sand dunes are well established, saltmarshes less so, although work by English Nature, NRA and owners of coastal sites, such as the National

Table 7.5 Uptake of Countryside Stewardship Scheme for coastal areas, 1991–95

Type of agreement	Existing area covered (ha)
Management and improvement of	
• saltmarsh	3312
• cliff-tops, sand dunes and coastal grazing marsh	3593
Re-creation of coastal vegetation on cultivated land	988
Restoration/re-creation of reed beds, fens and carrs	18

Trust and RSPB, is providing a wealth of experience. This work includes:

- the first large-scale managed retreat project funded by MAFF in partnership with the NRA and EN at a 21 ha site in the Tollesbury Creek within the Blackwater Estuary, Essex;
- the English Nature Estuaries Initiative, which has generated information about opportunities for managed retreat within the context of an understanding of estuarine physical processes as a whole;
- a pilot project funded by DOE, MAFF, NRA, EN, the dredging industry, and the Crown Estate, researching the opportunities for using beach recharge as coastal defences between 1993–95.

7.4 Policy development

7.4.1 The coastal landscape covers an extensive and diverse resource, with close links between processes up and down the coastline, and changes in habitats from colonising and mobile communities on shorelines through stable, mature landward communities. Much of the wildlife and visual interest derives from unimpeded natural processes. The negative impacts of past approaches to coastal planning have now largely been recognised and the process of remediation has been started through a range of diverse and innovative initiatives.

7.4.2 Given the extent and diversity of the coastal landscape resource, it is necessary to prioritise action by the careful targeting of opportunities which provide the greatest benefits. The process of preparing inventories, identifying valuable features, and developing strategies for their conservation and enhancement within the context of other pressures on the coast – development, recreation, etc – is being tackled by consortia which represent a wide range of land use and management planning interests. An increasing body of experience on the costs, benefits and best practice for managed retreat has developed involving a number of different actors.

7.4.3 Nature conservation designation covers a large proportion of existing semi-natural habitats in the coastal landscape mask and is clearly offering some protection from damaging developments and consequent needs for hard engineering approaches to flood defence. A number of well-established schemes, such as Countryside Stewardship, now cover large proportions of the eligible land area. Following the review of Environment Land Management Schemes, it has been decided that the Countryside Stewardship Scheme should be the core scheme for conservation and enhancement of these habitats outside ESAs, and that merging of other schemes, such as the Habitat Scheme, with CSS should be considered in due course.

7.4.4 In the south-east of England, considerable opportunities exist for re-creating grazing meadows and saltmarshes on arable and pastoral land as part of the managed retreat process. However, it is not yet clear whether existing agri-environment schemes will provide sufficient long-term incentive to farmers to remove land from productive agriculture. In the case of hard coasts there have been fewer initiatives to re-create habitats, but in several National Trust areas cliffs are being left to retreat naturally in the hope that valued under-cliff habitats will re-establish themselves.

7.5 Increasing the body of knowledge and potential for further work

7.5.1 In the longer term there are no guarantees that resources will be available to cover ongoing management costs. Thus, it is imperative that new approaches for the economically viable long-term management of the coasts continue to be developed and publicised. More work is needed to:

- evaluate and extend existing experience;
- develop guidelines for landowners and managers on the most suitable and economically viable regime for their circumstances,
- assist in the establishment of arrangements/partnerships which will encourage managers to implement these practices.

Guidelines must reflect the type of coastal habitat, the level of invasive species, the climatic conditions, as well as size and location.

7.6 Conclusions

7.6.1 The coasts comprise a valuable landscape, dominated by vegetation which is determined partly by natural, physical processes and also by agricultural management practices. The survey results indicate that, of the core vegetation within the coastal landscape, about 29 490 ha (55%) is saltmarsh and other maritime vegetation. Most of the rest is unmanaged grassland.

7.6.2 An expert group meeting within this study took as the starting point the MAFF strategy and the English Nature and Countryside Commission initiatives for coastal areas in agreeing the following broad hierarchy of objectives for the coastal landscape:

- to enable natural physical processes to continue along the whole length of the coast through managed retreat (or advance) of the coastal belt;
- to protect and enhance existing systems of near-natural habitats, particularly sand dune and saltmarsh systems;
- to restore some near-natural habitats such as sand dunes which have been damaged by recreational or development pressures and re-create habitats such as saltmarshes where opportunities arise.

7.6.3 The present study has provided the first-ever coastal landscape survey. It has defined the coastal landscape in its broadest sense and has described its characteristics. It will be important to monitor the land cover changes and the quadrats which have already been recorded and to link these monitoring results with information on take-up from Countryside Stewardship Scheme monitoring. Links should be made explicitly with other environmental monitoring schemes, including any future Countryside Surveys and the Environmentally Sensitive Area monitoring. Only in this way can change be objectively determined and links with policy instruments properly understood

7.6.4 Nature conservation designation and a number of well-established schemes, such as Countryside Stewardship, now cover large proportions of the eligible land area. However, if further work indicates that the above objectives are justifiable, then opportunities do exist (eg in the south-east) for re-creating grazing meadows and saltmarshes on arable and pastoral land as part of the managed retreat process. In the case of hard coasts, there have been fewer initiatives to re-create habitats, but in some areas cliffs are being left to retreat naturally in the hope that valued under-cliff habitats will re-establish themselves.

7.6.5 The coastal habitats have been, and are being, subjected to a combination of pressures and threats, including urban and industrial development, landtake to agriculture and agricultural intensification, both marine and terrestrially derived pollution, and recreation. In the control of these combined pressures and optimisation of the benefits of the various schemes, such as Countryside Stewardship, it is essential that effective, integrated approaches to management of the coastal zone are identified, publicised and implemented.

Chapter 8 SUMMARY AND CONCLUSIONS

8.1 Introduction

8.1.1 This Chapter summarises the Report in terms of the original project objectives (as described in Chapter 1), briefly summarises the advantages and disadvantages of the approach, and discusses future research needs.

8.2 Summary in relation to the project objectives

Objective 1: To determine the distribution of the landscape type in England

8.2.1 The objective was to identify and map 1 km squares in England which support, or have some potential to support, coastal vegetation types. This objective was achieved by identifying 1 km squares which included land extending 500 m inland from the high water mark plus all contiguous areas of saltmarsh, dunes and coastal bare land. This cartographic mask was classified into hard, soft and estuarine coast using OS data (giving presence of coastal attributes: cliff, rock, sand, mud, shingle), and data from maps (NCC 1991; 1:50 000 OS maps).

8.2.2 Because of the use of a 1 km resolution, and the specific definition of a 500 m zone within each square, there is a mismatch between the number of 1 km squares involved (7341) and the mask available for sampling (2604 km^2). However, the mask does provide a good sampling framework for assessing the current status of the coastal resource.

Objective 2: To survey the habitats (including major land cover types and ecological features such as hedgerows) and historic features within each landscape type

8.2.3 For the field survey of habitats, the sampling unit was a 1 km square; 49 squares were surveyed in 1993, and data were added from 23 squares surveyed in Countryside Survey 1990, to give a total sample of 72. The results were extrapolated from the sample squares to the coastal landscape as a whole.

8.2.4 Land cover was recorded at points on a 16-position grid within each field survey square, and the nearest field boundary (within 100 m) was described. To provide 'quality' information, 200 m^2 nested quadrats were recorded at up to five randomly chosen grid points where the vegetation was indicative of coastal conditions, thus excluding most arable fields and fertilized, sown or neutral grasslands. In addition, five 4 m^2 'habitat plots' were recorded in each survey square, in the less common habitats not represented by the main plots.

8.2.5 For the mask area within each of the field sample 1 km squares, data on historic features collected in the field (by ITE surveyors) were supplemented by selective analysis of aerial photographs and map interpretation of recent edition OS map extracts, and examination of County Sites and Monuments Records (SMRs) and the National Monuments Record (NMR).

8.2.6 Archaeological data were compiled for 630 archaeological sites in 61 sample squares drawn from 18 counties. A breakdown by county shows considerable variation in the mean density of identified monuments.

Objective 3: To determine, on a regional basis and in relation to current designations, the composition of the landscape type in terms of the quantity and quality of the surveyed features

8.2.7 Quantitative estimates of land cover and boundaries have been made for the coastal mask and for strata within it. In relation to the 'core' maritime vegetation types, only 5% of the mask was composed of saltmarsh, most of which was in the designated strata, with a higher proportion in estuarine and soft coastal types. 'Other maritime vegetation', covering only 3% of the mask, was found in all coastal types but particularly in designated squares.

8.2.8 The mask was dominated by agricultural crops, improved grassland and buildings. They occurred in significant amounts in all strata but generally less so in designated strata. Recreational areas were found particularly in soft coast areas and were marginally more frequent in designated strata.

8.2.9 Objective measures of vegetation have been related to quality criteria, to provide an empirical evaluation of the quality of coastal vegetation in different parts of the coastal landscape: size, diversity, naturalness, representativeness, rarity, fragility, potential value.

8.2.10 Using at least two separate measures of each of the quality criteria, the six strata were ranked. Based on quadrat information, the designated soft coast ranked highest for most measures (10 out of 15) and the hard coast strata were ranked lowest (having little maritime vegetation).

Historical aspects

8.2.11 Most periods of history are represented by archaeological features in the coastal mask. Prehistoric periods are mainly represented by 'find' sites (ie where objects have been found), together with hut circles and Bronze Age barrows. The Roman period is dominated by find sites, with a scattering of other types including settlements. Representation of the Early Medieval and the Medieval periods is sparse but includes some evidence of settlements. The Post Medieval period is represented by nearly all types of feature but, especially, settlements forming villages and small towns, and industrial and transport sites.

Designation

8.2.12 It was recognised that, without time-series data, it was difficult to assess the effect of designation. It was not known, for example, whether correlations between 'good' areas of coastal vegetation and some form of designation were because the designation had been effective, or whether the designation was made because of the quality of the habitats. The approach adopted in this study was to stratify the field sample according to designation status.

8.2.13 Results related to designation are included in Section 7.3, but clearly different types of designation may have different purposes. Within the coastal mask, SSSIs cover the largest area in the estuarine and soft coast areas where AONBs are also important. In the hard coast areas, AONBs cover the largest area and Heritage Coasts are important. Nearly all (81%) of the Green Belt areas are in the estuarine areas and most (66%) of the National Parks are in the hard coastal areas.

Objective 4: To develop models to predict the effect of environmental and management changes on the distribution and quality of the landscape types and their constituent habitats

8.2.14 Unlike other landscapes studied in this project, it was found that selecting potential environmental impacts by modelling was inappropriate for the coastal landscape. This is because the specialist coastal vegetation types (eg saltmarsh) are known to be relatively insensitive to acidification and nitrogen loading (the two pollutants that were considered) within the project.

8.2.15 The study has made use of the C-S-R classification of functional types and the TRISTAR2 model, which takes a given specification of an initial steady-state vegetation, adopts some altered environmental and/or management scenario, and predicts the composition of the new steady-state vegetation in terms of its component functional types. Most of the 'core' coastal vegetation was composed of competitor, ruderal and competitor/ruderal species. The remaining vegetation plot types were representative of all other combinations of functional types.

8.2.16 The TRISTAR2 model calculated the predicted change in abundance of the functional types, under each of six specimen change scenarios, and an index of vulnerability was produced. The coastal mask includes a heterogeneous grouping of saltmarshes, maritime, grassland and scrub types of habitat. The differences between habitat groupings are marked, with woody classes among the most vulnerable, and saltmarsh and other maritime types the least vulnerable. Grassland types occupy an intermediate position. Vulnerability of different habitat types differs only slightly according to scenario.

Objective 5: To make recommendations on ways in which policy instruments may be refined to further protect, enhance or re-establish habitats which characterise the landscape type

8.2.17 The results from the field survey and the outputs from the vegetation change models have been considered in the light of current policy measures.

8.2.18 The coasts comprise a valuable landscape, dominated by vegetation which is determined partly by natural, physical processes and also by agricultural management practices. The survey results indicate that, of the core vegetation within the coastal landscape, about 29 490 ha (55%) is saltmarsh and other maritime vegetation. Most of the rest is unmanaged grassland.

8.2.19 An expert group meeting within this study took as the starting point the MAFF strategy and the English Nature and Countryside Commission initiatives for coastal areas in agreeing the following broad hierarchy of objectives for the coastal landscape:

- to enable natural physical processes to continue along the whole length of the coast through managed retreat (or advance) of the coastal belt;
- to protect and enhance existing systems of near-natural habitats, particularly sand dune and saltmarsh systems;
- to restore some near-natural habitats such as sand dunes which have been damaged by recreational or development pressures and re-create habitats such as saltmarshes where opportunities arise.

8.2.20 Nature conservation designation and a number of well-established schemes now cover large proportions of the eligible land area. However, if further work indicates that the above objectives are justifiable, then opportunities do exist for re-creating grazing meadows and saltmarshes on arable and pastoral land as part of the managed retreat process. For hard coasts there have been fewer initiatives to re-create habitats, but in some areas cliffs are being left to retreat naturally in the hope that valued under-cliff habitats will re-establish themselves.

8.2.21 To ensure that the benefits of these measures are retained in the long term, and transferred to other areas, it is also essential that effective management approaches continue to be identified and publicised.

Objective 6: To develop a methodology for measuring change in these habitats which is sufficiently robust and precise to assess the effectiveness of policies, at a national (England) scale

8.2.22 In designing the field survey, measurement of future change was a major consideration. Methods were developed from the Countryside Survey 1990 approach (which has as a major objective the establishment of a high-quality baseline, against which future change can be measured). The potential and chosen approaches for measuring change are reported separately from these landscape reports (Bunce in prep).

8.3 Advantages and disadvantages of the research approach

8.3.1 The basic approach used to address the objectives given above is shown in para 1.4.2. The advantages and disadvantages of the approach are considered under a range of headings.

Use of available, spatial data to define the coastal mask

8.3.2 At the start of the study there was no national map of coastal habitats. To study areas with potential to become 'better' coastal habitats, a broad definition of the coastal zone was necessary (in which to study change).

Use of a 1 km square as a sampling unit

8.3.3 To be compatible with Countryside Survey 1990, the sampling unit chosen was a 1 km square. This is said to represent a good balance between an area which contains enough information for it to be classified as a particular land type and one which is not too large to be field-surveyed. The 1 km squares were capable of including land which was not 'coastal' in character, leading to some inefficiency and wasted effort. The approach did allow the calculation of national estimates but, for reasons of matching sample number to scale, these estimates are not highly accurate (see calculation of statistical errors in Chapter 4).

The choice of strata

8.3.4 Part of the sampling strategy was to stratify the field sample so that differences in vegetation change between different land types, and between designated and non-designated areas, could be identified. The relatively small number of samples meant that only six strata were appropriate and, further, all designation types had to be aggregated to allow any comparisons to be made at all: no results are available in relation to any one designation type. The choice of 'estuarine, 'soft' and 'hard' coastal strata was logical and proved revealing, but more samples in a wider range of land types would have given clear indications as to where threats were greatest and most change was likely to occur.

Modelling vegetation change

8.3.5 Although not as conceptual in approach as had originally been specified, the UCPE approach to modelling was shown to be valuable in terms of identifying vulnerability to likely threats under a range of scenarios. However, the links between suggested scenarios and policy implementation were not spelled out and might form the focus of further work.

8.4 Future research needs

8.4.1 Research of the type undertaken in this ambitious project cannot answer every question and inevitably leads to more questions. Some of the areas for future research are listed below.

Monitoring

8.4.2 As stated above, the present project has laid a baseline against which further survey results may be measured and compared. It will be important to monitor the land cover changes and the quadrats which have already been recorded and to link these monitoring results with information on take-up from agri-environment schemes, and others. Links should be made explicitly with other environmental monitoring schemes, including any future Countryside Surveys and the Environmentally Sensitive Area monitoring. Only in this way can change be objectively determined and links with policy instruments properly understood.

Interpretation of modelling results

8.4.3 There is scope for further analysis of the modelling results, especially in identifying both the spatial and vegetational characteristics of areas likely to undergo change.

Integration of data

8.4.4 As stated above, opportunities to link the results of this study with work elsewhere should be sought so that links between change, habitat management/creation and policy may be better understood.

Landscape ecology

8.4.5 The spatial characteristics of habitats in the coastal areas are interesting in terms of fragmentation and connectedness. If habitat creation (and management) is to lead to maximum saltmarsh quality, for example, then the spatial characteristics of potential areas need to be known. The landscape ecology of the coasts has not been well studied and needs further investigation, especially in relation to areas of potentially improved habitat as defined within this project.

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Appendix 1 Tables to accompany Chapter 4 – Ecological characteristics of the lowland heath mask

This Appendix includes Tables that add detail to Chapter 4 and information on the use of quality criteria for site evaluation (Box A1.1).

Box A2.1 The use of quality criteria for site evaluation

The development of the concept of evaluation for sites originated in the post-war years when the Nature Conservancy was set up with the objective of identifying a series of National Nature Reserves. The impetus originally came from the work of Tansley (1939) on British vegetation and was encapsulated in Cmnd 7122. Whilst it was implicit that the sites should form a representative series of the 'best' examples of habitats in Britain, explicit criteria were not defined and other factors such as diversity and variety of species often determined the status of individual sites. In some regions, series were set up explicitly, eg the woodland series of sites set up by R E Hughes (unpublished) on the basis of a combination of geological and climate criteria in north Wales. The necessity to rationalise the number of sites throughout Britain led to the *Nature conservation review,* carried out in the early 1970s but eventually described by Ratcliffe (1977). That document set out the quality criteria that had been used in the selection process but these were largely *post hoc* as the large number of contributors largely worked independently.

In the early 1980s there was much discussion of the necessity for objective criteria, eg the conference at University College London (Rose 1981). Bunce (1981) laid out the necessity of prerequisites of classification to ensure that differences of quality were not inherently due to basic differences between the ecological character of sites. For example, limestone vegetation is usually species-rich whereas acid vegetation is species-poor. More recently, Usher (1991) has also pointed out that the diversification of inherently simple ecological systems represents degradation.

Usher (1986) summarised the work up to that date on evaluation and drew heavily on the work by Margules and Usher (1981). He discussed in detail the criteria laid down by Ratcliffe and showed how they had been used by various studies in different ways. He also showed how the relative weighting attached to the importance of the criteria varied widely between individuals. In this respect, conservation evaluation had paralleled that in the analogous field of landscape evaluation. Liddle (1977) laid out comparable principles and Robinson *et al.* (1976) demonstrated how objective criteria could be used for landscape assessment. The next stage for both topics was that objective criteria were virtually ignored because of the over-riding necessity for speed in the evaluation process. In landscape evaluation a decision on objective criteria could take one or even two orders of magnitude longer than on-the-spot examination, yet the outcome would, to a policy advisor, be identical.

In the case of nature conservation evaluation, the criteria had been laid down but the pressure for site safeguard meant that the majority of sites were evaluated intuitively. Within the voluntary movement this is epitomised by the recent requirement to justify the status of many sites long after they had been identified as of conservation significance.

Although there is negligible recent literature on evaluation techniques in Britain, there has been a continuing programme abroad, especially in Australia. A major meeting on systematic and conservation evaluation was held in South Africa in 1992, where most of the British speakers emphasised the need for speed in the evaluation process because of threats rather than the development of objective criteria. Crowe (1993) summarised these criteria and identified particularly the work by Margules (1989), Pressey and Nicholls (1989), Rebolo and Siegfried (1990) and Williams, Vane-Wright and Humphries (1993) in that 'together their papers embodied principles, criteria and analytical methods necessary for scientific evaluation'. They agreed that the limit of analysis should be the site and that accurate species and abundance data for the sites under consideration should be obtained. Whilst this is never completely possible, surrogate measures could be used which allow the prediction of presence or absence of individual species.

This strategy had been followed in the threatened habitats project, with measures of vegetation being used as the taxon for evaluation, partly because of the ease of consistent recording and partly because of its ready correlation with other groups. Crowe (1993) concluded that ecologists did not appreciate the severity of the conservation crisis and that short cuts were essential to identify species in crisis. Whilst this conclusion may be true on a world scale, the necessity in the present project is to develop objective measures which can determine explicitly the effects of designation in statistical terms. In this respect the methodology employed in the current project represents a combination of the criteria laid down by Margules (1989) and Pressey and Nicholls (1989), together with the vegetation survey principles of Austin and Heyligers (1989). It has also been decided as a matter of principle to rank the various scores separately and not to add them together to achieve a final 'score' – statistical considerations preclude such additions as the scale of the various measures is not known. Further, as Pielou (1991) has emphasised, and Crowe (1993) has subsequently reinforced, simple measures are more readily understood.

Table A1.1 Coastal landscapes – estimates of land cover types, based on descriptions of land cover at 16 grid points, in each survey square

	Percentage area					
	Estuarine		Hard coast		Soft coast	
Land cover categories	Designated	Non-designated	Designated	Non-designated	Designated	Non-designated
Bare shore	3.6	1.8	4.3	3.0	6.3	3.4
Saltmarsh	14.0	2.4	0.0	0.0	17.7	0.0
Maritime vegetation	3.6	2.4	3.0	2.3	6.3	1.4
Waterside/marsh	1.4	2.9	0.0	0.0	2.5	1.4
Unmanaged grass	2.3	4.7	3.5	1.5	7.6	2.1
Neutral/improved grassland	20.4	28.2	23.8	31.6	17.7	17.2
Calcareous grassland	0.0	0.0	8.2	0.0	0.0	0.0
Crops	23.5	45.3	19.9	25.6	10.1	25.5
Scrub	1.4	0.6	8.2	6.0	1.3	0.7
Woodland	1.8	0.0	3.0	2.3	2.5	0.0
Recreation	6.3	2.9	6.1	1.5	10.1	11.0
Roads/tracks	5.0	2.4	2.2	4.5	3.8	9.7
Buildings/curtilage	15.8	6.5	16.9	21.1	13.9	27.6
Other	0.9	0.0	0.9	0.8	0.0	0.0
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

	Percentage area					
	Combined			Combined		
Land cover categories	Designated	Non-designated	Estuarine	Hard coast	Soft coast	All
Bare shore	4.4	2.4	3.0	4.1	5.3	3.6
Saltmarsh	10.9	1.4	10.2	0.0	11.4	5.0
Maritime vegetation	4.0	2.1	3.2	2.9	4.6	3.0
Waterside/marsh	1.2	2.1	1.9	0.0	2.1	1.2
Unmanaged grass	3.7	3.5	3.1	3.1	5.6	3.3
Neutral/improved grassland	20.8	26.9	23.0	25.3	17.5	23.4
Calcareous grassland	2.3	0.0	0.0	6.6	0.0	1.9
Crops	19.8	37.1	30.7	21.0	15.6	25.9
Scrub	3.2	1.4	1.1	7.8	1.1	3.4
Woodland	2.3	0.3	1.2	2.9	1.6	1.6
Recreation	7.0	4.9	5.2	5.2	10.5	6.0
Roads/tracks	4.0	4.6	4.1	2.6	5.9	4.4
Buildings/curtilage	15.7	14.2	12.8	17.7	18.8	16.8
Other	0.7	0.1	0.6	0.8	0.0	0.5
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

Table A1.2 Coastal: proportion of boundary types by strata based on nearest field boundary (within 100 m) of each grid point

	Estuarine		Hard		Soft		Total					
Boundaries	Des	Non-des	Des	Non-des	Des	Non-des	Des	Non-des	Estu-arine	Hard	Soft	Total
% of points without boundary	62	55	51	49	72	63	63	56	59	50	66	55
% of points with boundary	38	45	49	51	28	37	44	44	41	50	34	45
% of points with a boundary:												
Bank	5		12	19		1	8	7	3	15	1	10
Fence	48	50	38	38	53	50	44	46	49	38	51	42
Fence/bank	2	1	3	3	3	8	2	4	1	3	7	3
Hedge	19	21	5	8	29	8	13	13	20	6	15	11
Hedge/bank	5	1	4	6		3	4	3	3	5	2	4
Hedge/fence	9	19	8	13	12	3	9	12	13	10	6	11
Hedge/fence/bank	8	2	4	1		1	5	2	5	3	1	3
Hedge/wall		1	1	1			+	1	0	1		1
Hedge/wall/fence			1				+			+		+
Wall	4	4	15	10	3	15	9	9	4	13	11	10
Wall/bank				1				+		+		+
Wall/fence			8			10	4	3		5	7	4
Wall/fence/bank			1				+			+		+
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*

Table A1.3 Classification of quadrats from the coastal landscape (using TWINSPAN). Numbers in plain type give the numbers of quadrats at each division. Bold letters in square brackets correspond to the plot class. Numbers in italics indicate maximum score for left hand-side of division

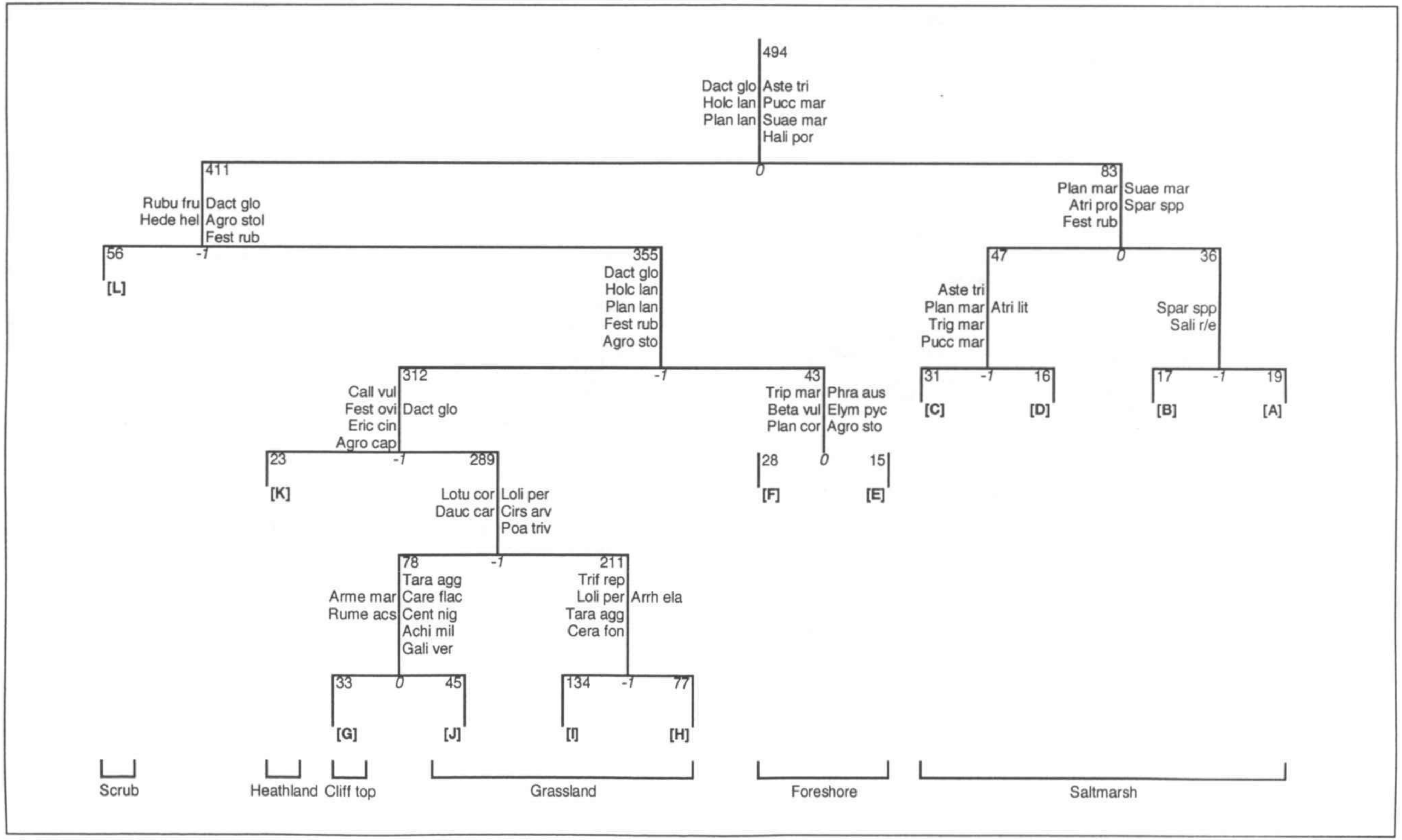


Table A1.4 Coastal landscapes – TWINSPAN plot class description

Plot class	Total no. of plots	Description	Coast: hard, soft estuarine	Predominant counties	Predominant land uses	Preferential species	Constant species	Dominant species	% bare ground/ rock
PCA	19	Lower saltmarsh	Estuarine Soft	Essex Suffolk Sussex	Saltmarsh	*Suae mar* *Hali por*	*Suae mar* *Hali por*	*Hali por* *Pucc mar*	12
PCB	17	*Spartina* saltmarsh	Estuarine	Lincoln Hampshire	Saltmarsh	*Suae mar* *Spar* spp.	*Suae mar* *Spar* spp.	*Pucc mar* *Spar* spp.	13
PCC	31	Mature saltmarsh	Estuarine Soft	Humberside Norfolk Lancashire	Saltmarsh Inundation grass	*Aste tri* *Plan mar*	*Aste tri* *Plan mar*	*Pucc mar* *Aste trip*	15
PCD	16	Immature saltmarsh	Estuarine Soft	Sussex Norfolk	Saltmarsh Strandline	*Elym pyc*	*Elym pyc* *Hali por*	*Elym pyc* *Hail por*	14
PCE	15	Maritime with fresh-water influence	Estuarine Soft	Norfolk Humberside	Aquatic macrophytes Saltmarsh	*Phra aus*	*Phra aus* *Elym pyc*	*Phra aus* *Elym pyc*	15
PCF	28	Foreshore	Soft Hard	Norfolk Humberside	Strandline Foredune	*Trip mar*	*Trip mar* *Elym rep*	*Elym rep* *Trip mar*	24
PCG	33	Cliff-top	Hard	Cornwall Devon	Maritime grassland	*Fest rub* *Dauc car* *Hypo rad*	*Fest rub* *Dauc car*	*Fest rub* *Dact glo*	11
PCH	77	Tall/overgrown grassland	Hard Estuarine Soft	Humberside Kent Isle of Wight	Maritime grass Agricultural grass	*Arrh elat* *Agro sto*	*Agro sto* *Dact glo* *Arrh ela*	*Agro sto* *Arrh ela* *Elym rep*	4
PCI	134	Neutral semi-improved grassland	Hard Soft Estuarine	Cornwall Devon Norfolk	Agricultural grass Maritime grass	*Loli per* *Dact glo* *Holc lan*	*Loli per* *Dact glo* *Agro stol*	*Loli per* *Agro sto* *Fest rub*	5
PCJ	45	Neutral/calcareous meadows	Hard Soft	Isle of Wight Devon	Maritime grass Calcareous grass	*Plan lan* *Lotu cor* *Fest rub*	*Plan lan* *Fest rub* *Lotu cor*	*Fest rub* *Plan lan* *Agro sto*	5
PCK	23	Heathland	Hard Estuarine Soft	Cumbria Dorset	Maritime heath/grass	*Call vul*	*Call vul* *Agro cap* *Hypn cup*	*Call vul* *Eric cin* *Fest rub*	0
PCL	56	Scrub	Hard Estuarine Soft	Cornwall Devon Isle of Wight	Scrub	*Rubu fru* *Hede hel* *Sile dio*	*Rubu fru* *Hed hel* *Urti dio*	*Hede hel* *Pter aqu* *Rubu fru*	3

Appendix 2 Technical Appendix to Chapter 5 – Historical characteristics of the coastal mask

This Appendix includes:
- details of the work programme associated with characterising the coastal mask (A2.1)
- commentary on available data (A2.2)
- Tables which provide further, detailed results from work on historical aspects of the coastal mask (A2.3), not given in Chapter 5.

A2.1 Detailed work programme

A2.1.1 At the outset, a work programme was set out in a project design but this was later modified to reflect the nature of the data gathered. The resulting methodology is summarised below.

1. Review of literature and consultations with ITE
2. Survey of historic features
   - 2.1 Collation of existing data from ITE
     List of km squares for the coastal landscape in paper and digital form
     List of aerial photographs (APs) available at ITE
     Map overlay for each square
   - 2.2 Collation of data from County Sites and Monuments Records (SMRs) and National Archaeological Record (NAR)
     Mailing to SMRs and NAR, requesting map overlay and data printout for each square
     Data collation and map interpretation
     Computer entry of collated SMR, NAR and ITE data
     Collation of additional data on management regimes from English Heritage (EH) Register of Scheduled Monuments (RSM)
     Computer entry of EH RSM data
   - 2.3 AP work
     Examination of subsample of squares defined by AP availability at ITE
     Computer entry of AP data
   - 2.4 Data analysis
     Correlation of site type/period/form, the Royal Commission on the Historical Monuments of England (RCHME) classes and designations within the coastal landscape
     Quantification of management history data
3. Assessment of the effectiveness of current designations in protecting historic features within the coastal landscape type
4. Predictive models of the effect of environmental and policy changes – effect on historic features, including an assessment of the impact of archaeological management plans
5. Recommendations for refinement to policy instruments – to enhance protection of historic features. Based on results of 3 and 4, formulation of proposals to minimise threats to archaeology.

A2.1.2 Physical examination of the sample squares was carried out by ITE field surveyors during the course of the ecological fieldwork between 1990 and 1993. The major part of the work was contained in stage 2, essentially a data-gathering process involving consultation with archaeological curators, together with limited AP analysis and map interpretation. This work was carried out between July 1993 and April 1994. As expected and as described below, the available data were found to be inadequate to carry out items 3–5.

A2.2 Assessment of archaeological data

Data sources

A2.2.1 The extended national archaeological database in England is composed of several distinct databases (see RCHME 1993). SMRs provide regionally co-ordinated summaries of recorded archaeological sites. The core of these records is a computerised index. The NMR is maintained by RCHME as a permanent, publicly accessible source of information in three main parts: the National Archaeological Record (NAR), the National Buildings Record (NBR), and the National Library of Air Photographs (NLAP). Together these three sections are responsible for creating a national database of information about sites and buildings of historic and architectural interest. Historically, the NAR developed in parallel with county SMRs, and it is this subset of the NMR which has been consulted.

A2.2.2 In theory, data exchange between SMRs and the NAR should enable consultation with this single central database to provide a full indication of the recorded archaeological content of each square. In practice, such exchange is in its early days and is far from standard such that, in general, the SMRs hold a great deal of information not yet indexed by the NAR. In addition, the NAR holds additional datasets not on the county SMRs. Hence, both databases were consulted. In addition, the RSM is maintained by English Heritage as a management tool for Scheduled Ancient Monuments and holds additional data on the condition of these monuments.

A2.2.3 Information on listed buildings is not yet in computerised form for the whole country. Some SMRs have computerised the lists at least in part. In 1994, the RCHME commenced central computerisation of these lists on to the NBR. Hence, for this project, the incidence of listed buildings on the project database will not reflect reality, rather the policy of individual SMRs over whether to include or exclude entries from the lists of historic buildings and, if included, to what extent this listing has been implemented.

Database structure

A2.2.4 Data compiled from the above sources were used to create a database of archaeological sites identified for the ITE sample squares. The structure of this database is outlined in Table A2.1. The information collated divides into three main groups:

- identifiers and location;
- archaeological classification; and
- management information.

A2.2.5 Identifiers and location information is routinely given in archaeological databases and was readily collated.

A2.2.6 Archaeological classification is represented by standard RCHME classes, together with archaeological 'site types'. The specification of 'site types' is supposedly standardised. In practice, there is considerable variation between SMRs. A rationalisation process was therefore undertaken to check site type against the RCHME thesaurus and modify accordingly. However, as the data were compiled, it became apparent that the variety of site type entries was too great to be of use in the analysis process, and a further stage of simplification was carried out. For example, a wide variety of prehistoric flint implements have been found whose specific identification is of no relevance to this project. The variety of entries covering these artefacts were therefore replaced by the single entry 'flint'.

A2.2.7 The form entry is important as it provides the first indication of the condition of a monument. Very broadly, any archaeological site slowly decays from its original 'intact' state. Rates of decay vary considerably and some form of equilibrium may be achieved at any point. Once again, SMR entries are far from standard and it was necessary to impose an appropriate rationalisation as shown in Table A2.3 (based on Trueman & Williams 1993, 13). The interpretation of SMR/NMR entries which was necessary to enter this item during the course of the project made it apparent that some simplification of this system was required if any analysis of this entry were to be made. To this end the 'form group' field was added. This is structured to reflect decay from standing structures through to totally removed sites. (Note that 'features' are intended to be sites whose original form was an earthwork and which survives largely unaltered, a category which is very difficult to apply with many sites, and is probably best considered as part of 'earthworks'.)

A2.2.8 Management information was derived directly from SMR and NMR entries. A separate database of sample squares was supplied by ITE. This included designation data and in the analysis process was related to the archaeological database.

Nature and quality of archaeological data

A2.2.9 Archaeological data were compiled for 630 archaeological sites in 61 sample squares drawn from 18 counties. A breakdown by county (Table A2.5) shows considerable variation in the mean density of identified monuments. This variation is as likely to reflect the difference in details in individual SMRs as much as any real variation in the archaeological resource.

A2.2.10 One factor which is clear in the biases of the compiled data is the effect of the extent and type of site identification work undertaken by individual SMRs. For example, the importance of sites from the period of England's industrial revolution has only recently been accepted by SMRs and the NMR (following the RCHME's decision in 1990 to move the NAR entry cut-off date from 1714 to 1945). In the process of SMR/NMR enhancement that is underway, some counties are well ahead (eg Cornwall), whilst others are not (eg Shropshire).

A2.2.11 A further clear factor is the presence of particularly well-known and thoroughly investigated sites. For example, the high Suffolk figure of 115 sites is boosted by 40 entries for the kilometre square containing Sutton Hoo. This variation in the data between counties precludes any attempt to examine genuine regional variations of the archaeological resource.

A2.2.12 New sites (165) identified through ITE fieldwork, AP work and map analysis constitute 26.2% of the total number, representing an increase of 35.5% on the SMR/NMR entries (465). Reflecting the dependence on recent edition OS maps, the majority of these new sites almost certainly originated in the Post Medieval and Modern periods (although technically in most cases they are, and have been entered on the database as, 'unknown'). The number of sites is low compared to other landscape types, with site types including farms and field systems, quarries, mines and lime kilns.

A2.2.13 It is also apparent from the compiled data that the mean density of monuments at 10.3 sites per km^2 is notably higher than the national figure of 1.2 per km^2 quoted for the Monuments at Risk

Survey (MARS) project (Darvill, Fulton & Bell 1993, 11). However, this latter figure is based on NMR data and, as Table A2.7 makes clear, NMR figures for site numbers are consistently low in the lowland heath landscape when compared to SMR entries (by a factor of between 1.5 and 3).

A2.2.14 Although this project is only dealing with a specific landscape type, these data suggest that the national mean density of monuments on existing registers is considerably higher than previously supposed. However, the number and range of new sites identified strongly suggest that the data held by SMRs and the NMR fall well short of the total archaeological resource. Establishing a figure for this shortfall is not possible with the data presented here because of the severe limitations on the identification process used. Further work to establish the specific nature and size of SMR/NMR shortfalls for different periods would require an appropriate programme of combined mapwork, AP analysis and fieldwork.

A2.3 Tables which provide further, detailed results from work on historical aspects of the coastal mask (A2.3), not given in Chapter 5

Table A2.1 Archaeological data structure

	Field	Type	Notes
Identifiers and location	ITE no	char	As ITE
	Km grid ref	char	In one field, eg SD7534
	Qtr sht	char	In one field, eg SD73SW
	County	char	Abbreviated name
	Source	char	SMR/NMR/RSM/ITE/AP
	SMR no	char	As SMR
	Map id	char	As SMR
	NMR no	char	As NMR
	NG code	char	Eg SD
	NG east	num	Eg 7521
	NG north	num	Eg 3412
Archaeological classification	Site type	char	As SMR if confirmed by RCHME thesaurus. Enter separate records for different periods on same site
	Period	char	General period only, codify as Box 2
	Form	char	Codify as Box 3
	Formgroup	char	Codify as Box 3
	RCHME class	char	As RCHME thesaurus
Management information	Status	char	As SMR/NMR
	SAM	char	As SMR/NMR
	Land status	char	As SMR/NMR
	Area status	char	As SMR/NMR
	Condition	memo	Free text

Table A2.2 RCHME codes for period

Code	Period	Dates
PR	Prehistoric	PA–IA
PA	Palaeolithic	To 8000 BC
ME	Mesolithic	8000 – 3800 BC
NE	Neolithic	3600 – 2500 BC
BA	Bronze Age	2500 – 700 BC
IA	Iron Age	700 BC – 43 AD
RO	Roman	43 – 410 AD
EM	Early Medieval	410 – 1066 AD
MD	Medieval	1066 – 1540 AD
PM	Post Medieval	1540 – 1901 AD
MO	Modern	1901 – present
UN	Unknown	

Table A2.3 Form entry

Type	Term	Form code	Form group
Intact	Roofed building	ROOF	STRUCTURE
	Structure	STRU	
	Machinery	MACH	
	Linear feature	LIN	FEATURE
	Other feature	FEA	
	Underground feature	UFEA	UNDER-GROUND
Ruinous	Roofed ruin	RRUIN	RUIN
	Ruined building	RUIN	
	Ruined structure	RSTRU	
	Foundations	FOUN	
	Earthworks	EARTH	EARTHWORK
Buried remains	Crop mark	CROP	CROP/SOIL
	Soil mark	SOIL	
	Aerial photograph	AP	AP
	Geophysical survey	GEO	Not used
	Finds spot	FIND	FIND
Unlocated remains	Documentary	DOC	DOC/ORAL
	Oral	ORAL	
Non-extant	Excavated	EXC	EXC/REM
	Removed	REM	

Table A2.4 Data source totals for coastal landscape

County	All sites SMR/NMR	All sites New	Heath SMR/NMR	Heath New
Beds	13	7		
Berks	16	22		
Bucks	14	17		
Cambs	4	4		
Cleveland	2	4	2	4
Cornwall	213	36	166	24
Cumbria	53	32	7	8
Derbyshire	5	8		
Devon	141	29	56	3
Dorset	44	46		
Durham	6	7	4	7
Essex	9	12	9	10
E Sussex	12	18	9	12
Gloucester	50	15	16	8
Hants	51	46	3	3
Herts	2			
Humberside	28	14	28	14
Isle of Wight	58	27	54	23
Kent	36	16	4	6
Lancs	18	15	13	9
Lincoln	3	2		
Norfolk	110	47	49	15
Northants	14			
Northumberland	16	19		4
Nottingham	2	5		
N Yorks	65	40		
Oxford	9	2		
Salop	3	16		
Somerset	16	5		
Staffs	20	16		
Suffolk	135	21	20	10
Surrey	14	32		
Tyne & Wear	8	1	8	1
Warwick	4	5		
Wiltshire	29	6		
W Midlands		4		
Worcester	1	1		
W Sussex	28	8	17	4
York Dales	77	11		
Totals	*1329*	*616*	*465*	*165*
	1945		*630*	

Table A2.5 Total number of sites and average per square km, by county for full dataset

County	No. of km squares	SMR/NMR sites	Enhanced site totals	SMR/NMR sites km^{-2}	Enhanced sites km^{-2}
Bedfordshire	2	13	20	6.5	10.0
Berkshire	5	16	38	3.2	7.6
Buckinghamshire	4	14	31	3.5	7.8
Cambridgeshire	1	4	8	4.0	8.0
Cleveland	2	2	6	1.0	3.0
Cornwall	13	213	249	16.4	19.2
Cumbria	23	53	85	2.3	3.7
Derbyshire	2	5	13	2.5	6.5
Devon	17	141	170	8.3	10.0
Dorset	12	44	90	3.7	7.5
Durham	4	6	13	1.5	3.3
Essex	7	9	21	1.3	3.0
East Sussex	3	12	30	4.0	10.0
Gloucestershire	6	50	65	8.3	10.8
Hampshire	17	51	97	3.0	5.7
Hertfordshire	1	2	2	2.0	2.0
Humberside	7	28	42	4.0	6.0
Isle of Wight	5	58	85	11.6	17.0
Kent	6	36	52	6.0	8.7
Lancashire	4	18	33	4.5	8.3
Lincolnshire	2	3	5	1.5	2.5
Norfolk	15	110	157	7.3	10.5
Northamptonshire	1	14	14	14	14.0
Northumberland	11	16	35	1.5	3.2
Nottinghamshire	4	2	7	0.5	1.8
North Yorkshire	10	65	105	6.5	10.5
Oxfordshire	2	9	11	4.5	5.5
Shropshire	4	3	19	0.8	4.8
Somerset	3	16	21	5.3	7.0
Staffordshire	6	20	36	3.3	6.0
Suffolk	8	135	156	16.9	19.5
Surrey	5	14	46	2.8	9.2
Tyne & Wear	1	8	9	8.0	9.0
Warwickshire	1	4	9	4.0	9.0
Wiltshire	2	29	35	14.5	17.5
West Midlands	1	0	4	0	4.0
Worcestershire	1	1	2	1.0	2.0
West Sussex	3	28	36	9.3	12.0
Yorkshire Dales	6	77	88	12.8	14.7
Totals	*224*	*1329*	*1945*	*5.9*	*8.7*

Table A2.6 Data source by period

Period	SMR/NMR sites	New sites
A–PR	111	
B–PA	10	
C–ME	32	7
D–NE	36	
E–BA	109	5
F–IA	63	
G–RO	107	3
H–EM	32	
I–MD	151	3
J–PM	384	94
K–MO	18	6
UN	276	498
Totals	*1329*	*616*

Table A2.7 Number of sites and number of sites per square

Data source	Lowland heath 89 squares Sites	km^{-2}
SMR only	436	7.1
NMR only	130	2.1
SMR/NMR	465	7.6
New survey	165	2.7
Combined sources	630	10.3

Table A2.8 Quantity of features – site types by period for coastal landscape (showing site types occurring more than once in the dataset)

RCHME class	Site type	Period	No
Agriculture and subsistence	Agricultural building	J–PM	15
	Clearance cairn	A–PR	2
	Farm	J–PM	4
		UN	20
	Field system	A–PR	4
		I–MD	7
		J–PM	3
		UN	6
	Nursery garden	UN	2
	Wood bank	UN	2
Civil	Coastguard station	J–PM	2
		UN	2
	Post Office	J–PM	6
	School	UN	20
	Signal station	J–PM	2
Commemorative	War memorial	K–MO	2
Commercial	Inn	J–PM	2
		UN	2
Defence	Battery	J–PM	3
		K–MO	3
	Beacon	J–PM	2
	Castle	F–IA	3
	Firing range	UN	3
	Martello tower	J–PM	3
	Moat	I–MD	2
	Pillbox	K–MO	8
	Town defences	I–MD	3
		J–PM	2
Domestic	Deserted village	I–MD	2
	House	A–PR	3
		J–PM	21
	Hut	A–PR	10
		F–IA	3
	Midden	F–IA	2
	Round	F–IA	4
	Settlement	H–EM	3
		I–MD	4
	Village	I–MD	2
Garden and parks	Pavilion	UN	2

Appendix 3 Technical appendix to Chapter 6 – Predicting changes in coastal vegetation

This Appendix includes:
- details of the TRISTAR model
- figures showing the effects of different change scenarios on vegetation within the coastal mask.

A3.1 Introduction

A3.1.1 The UCPE contribution to the threatened habitats project involves taking vegetational survey data, provided for the selected habitats by ITE, and processing these data in three distinct phases by means of the TRISTAR2 model. After the final phase, the outputs of the modelling are examined and interpreted by UCPE. Each phase in this process will now be described separately, with illustrations given at intervals to provide a worked example.

A3.2 Phase I – allocation of functional types

A3.2.1 The initial steady-state vegetation is specified by ITE in the form of a list of abundances of species in each of many survey samples or records. An example of such data appears in Figure A. The record labelled A1-A is the first in the series and contains 12 species, bristle bent *(Agrostis curtisii)* to gorse *(Ulex europaeus)* inclusive. Each vegetation record arrives at UCPE bearing a classification according to both of two sets of criteria:
- the designated status, if any, of the site from which the record was taken, and
- the plant community type into which the vegetation of the quadrat falls.

The basis for these two classifications is the ITE TWINSPAN analysis which is described elsewhere in this Report.

A3.2.2 For each vegetation record, one of 19 functional types is then allocated to each of the component species using information from UCPE databases. The system used, the C-S-R classification of functional types (Grime 1974, 1979; Grime Hodgson & Hunt 1988), has been explained in moderate detail by Hunt *et al.* (1991). Briefly, it recognises two external groups of factors, both of which are antagonistic to plant growth. The first group is called *stress* and consists of factors which place prior restrictions on plant production, such as shortages of light, water, carbon dioxide, mineral nutrients, or chronically non-optimal temperatures. The second group, called *disturbance*, causes the partial or total destruction of plant biomass after it has been formed, and includes management factors such as grazing, trampling, mowing and ploughing, and also phenomena such as wind damage, frosting, droughting, soil erosion, acutely non-optimal temperatures and fire.

A3.2.3 When the four permutations of high and low stress against high and low disturbance are examined (Figure B), a different primary strategy type emerges in association with each of the three viable contingencies: *competitors* in the case of minimum stress and minimum disturbance, *stress-tolerators* in the case of maximum stress and minimum disturbance, and *ruderals* in the case of minimum stress and maximum disturbance. The initials of these three 'primary' strategists give the C-S-R model its name. The fourth contingency, that of maximum stress and maximum disturbance, does not support plant life at all. The triangular diagram (Figure B) which emerges from this view of plant life gives the TRISTAR system its name.

A3.2.4 Intermediate types of C-S-R strategy can be identified, each exploiting a different combination of intensity of external stress and disturbance. The positions of any of a wide variety of species (or, by aggregating its component species, of any vegetation type) can thus be displayed on a hexagonal diagram (Figure C) which represents the central zone of the original triangle (Figure B) turned clockwise through 45°. The positions on this diagram can each be identified by means of a C, S, and R co-ordinate on a scale of 1–5 (Figure D), thus facilitating the quantitative treatment of any position within C-S-R space. This can be done for individual species, for individual samples, or for groups of samples. All play a part in the modelling conducted within the threatened habitats project. Plant strategy theory in this form is thus applicable to vegetation systems other than those from which it was derived, and does not rely upon the estimation of specific plant parameters.

A3.2.5 The TRISTAR2 conflates the weighted abundances of up to a maximum of 19 individual functional types which may be present within each sample. This process created weighted abundances for each of seven broader groups of functional types (those shown in bold type in Figure C). These seven groups represent the three extreme corners of the C-S-R triangle ordination, its centre, and its principal intermediate positions. The seven groups are each converted into a two-part numerical code (seen, for example, in the second and third columns of Figure E). The two-part code provides a computational mechanism for representing both 'pure' and intermediate functional types.

A3.2.6 Once converted, the classifications according to functional type provide the basis for all further work on the vegetation sample by TRISTAR2. The first page of the presentation for each habitat (or subhabitat, if appropriate) consists of a divided percentage bar diagram illustrating the functional composition of all the plot classes present in the initial vegetation. Ecological notes on the habitat as a whole appear at this point.

A3.3 Phase II – effects of change scenarios on the abundance of functional types

A3.3.1 The TRISTAR2 model is next provided with various climate change or management scenarios. These have various implications for vegetation because they represent possible changes in environmental stress and disturbance. Initially, eight specimen scenarios were suggested by the project team (Figure F). Although these were all of direct interest to the project, it was felt that sufficient information on habitat sensitivity and resilience could be obtained by applying a smaller number of scenarios (Figure G). These involve only certain of the possible combinations of the two variable factors, environmental disturbance and eutrophication (the latter being defined as a *relaxation* of stress).

A3.3.2 For each factor and functional type within the six specimen scenarios, TRISTAR2 applies an appropriate numerical multiplier according to our understanding of the effects of the factor. The essence of the approach is that seven functional types are each driven by this weighting in different directions and with different gradients, according to information from UCPE's extensive survey and screening databases.

A3.3.3 However, even the six simple scenarios adopted do not always have a simple environmental interpretation. Their value lies in there being a representative group of theoretical changes against which the robustness of different habitats, of different categories of designation, or of different functional types or plant community may be tested. The main difficulty here is that a single scenario condition, such as 'increased eutrophication', may have a multiplicity of meanings. For example, it may literally mean reduced stress, in the sense of a reduced presence of toxic compounds or of a movement away from chronically non-optimal temperatures, or it may mean an enrichment of the environment in the sense of an increased availability of mineral nutrients or an enhancement of CO_2 level. The term 'decreased eutrophication' may have the opposite meaning to these, and similar arguments apply to 'decreased' or 'increased' levels of disturbance factors such as grazing, trampling, mowing, ploughing, wind damage, frosting, droughting, soil erosion, acutely non-optimal temperatures and fire.

A3.3.4 For these reasons the scenarios listed in Figure G cannot be identified explicitly in terms of *all* the environmental or management changes which they may present. The total number of permutations of scenarios runs into tens of thousands, and even one of the scenario lines in the Table may have very many variants, according to which definitions of disturbance and eutrophication are adopted.

A3.3.5 Nonetheless, each scenario prompts TRISTAR2 to predict a new abundance for each functional type under the new stable state. New percentage abundances for each functional type and designation stratum are calculated for all scenarios.

A3.3.6 For each of six scenarios a Table is computed (but not presented) which groups the predictions for each functional type in each plot classes presenting the habitat (PCA, PCB, etc). TRISTAR2 calculates the predicted change in percentage abundance of each of the seven functional types C, C-R, CSR, R, S, SC and SR relative to the initial composition of each plot class in the habitat. When charted, this analysis form the top left-hand element in the display of predictions for each scenario (pages 79–85).

A3.4 Phase III – computation of an 'index of vulnerability'

A3.4.1 Next, an index of vulnerability is computed for each plot class. This is done in three substages.

i. Examine the original data to find the number of quadrats deviating appreciably from the typical

The mean and standard deviation (SD) of each functional type within each plot class is calculated (the type-mean and type-SD). The mean across all seven type-SDs within each plot class is also derived (the class-type-SD). Each individual quadrat is then examined and the percentage abundance of each of its functional types is compared with the type-mean from the appropriate plot class; the result is expressed as a deviation from the type-mean. The mean of all such deviations for the quadrat is then compared with the class-type-

SD to find which quadrats have mean deviations greater than one unit of SD. Such quadrats are classified as outliers and their number is noted; the remaining quadrats, those within one class-type-SD (the great majority), are classified as typical.

ii. **Examine the TRISTAR2 predictions to find the new number of quadrats deviating appreciably from the original composition**

In the model prediction the abundances of CSR types within each of the quadrats have often changed. The new abundances are compared with the original class- and type-means and SDs (as in substage (i)). The new counts of typical or outlying quadrats are obtained. Some plot classes may contain more outliers under the new scenario, but others may be more resistant to predicted change, or may even contain fewer outliers (ie be made more typical) in certain instances.

iii. **Find the 'index of vulnerability' for each plot class**

This is simply the proportional change (on a scale of −1.0 to +1.0) in the number of quadrats identified as 'outliers', in each plot class, found by comparing substages (i) and (ii).

A3.4.2 The index of vulnerability is displayed as a bar diagram for each plot class in the habitat (the top right-hand section of the presentation in pages79–85). A value of 0.0 in this diagram indicates that no increase or decrease in number of outliers has taken place as a result of the imposition of the scenario in question. If some change has taken place, this is classified as 'decreased' (ie having fewer outlying quadrats, indicating a composition even more typically uniform than before), or 'increased' to a 'low', 'moderate' or 'high' degree (indicating an appropriate amount of departure from typicality) according to the thresholds shown on each diagram. These particular thresholds have no absolute validity in themselves and are provided only as comparative tools. The indices of vulnerability are summarised across all plot classes in a small Table below the diagram. Ecological notes on the effects of the particular scenario within the current habitat conclude the presentation of each scenario.

A3.4.3 Finally, page 86 summarises the mean index of vulnerability across all scenarios for each plot class within the current habitat. Further ecological notes are added at this point. Comparisons between different habitats (or subhabitats) will ultimately be made possible by means of such material.

Figure A. Sample of raw data as received from ITE

Quadrat identifier	Species	Cover (Inner nest)	Cover (Outer nest)
A1–A	*Agrostis curtisii*	5	0
A1–A	*Calluna vulgaris*	10	0
A1–A	*Campylopus* sp.	1	0
A1–A	*Carex pilulifera*	1	0
A1–A	*Erica cinerea*	15	0
A1–A	*Erica tetralix*	10	0
A1–A	*Hypogymnia physodes*	1	0
A1–A	*Leucobryum glaucum*	1	0
A1–A	*Molinia caerulea*	40	0
A1–A	*Potentilla erecta*	1	0
A1–A	*Pteridium aquilinum*	10	0
A1–A	*Ulex europaeus*	1	0
A1–B	*Calluna vulgaris*	95	0
A1–B	*Cladonia impexa*	1	0
A1–B	*Cladonia* sp.	1	0
A1–B	*Erica cinerea*	5	0
A1–B	*Molinia caerulea*	1	0
A1–C	*Agrostis canina canina*	1	0
A1–C	*Agrostis curtisii*	20	0
A1–C	*Molinia caerulea*	35	0
A1–C	*Polygala serpyllifolia*	1	0
A1–C	*Pteridium aquilinum*	90	0
A1–C	*Rubus fruticosus*	1	0
A1–C	*Teucrium scorodonia*	1	0
A1–C	*Ulex europaeus*	1	0
A1–D	*Calluna vulgaris*	95	0
A1–D	*Dicranum scoparium*	1	0
A1–D	*Erica cinerea*	1	0
A1–D	*Hypnum cupressiforme*	1	0
A1–E	*Agrostis curtisii*	1	0
A1–E	*Calluna vulgaris*	5	0
A1–E	*Cephalozia* sp.	1	0
A1–E	*Drosera intermedia*	1	0
A1–E	*Drosera rotundifolia*	5	0
A1–E	*Erica tetralix*	15	0
A1–E	*Eriophorum angustifolium*	1	0
A1–E	*Gymnocolea inflata*	1	0
A1–E	*Juncus bulbosus*	1	0

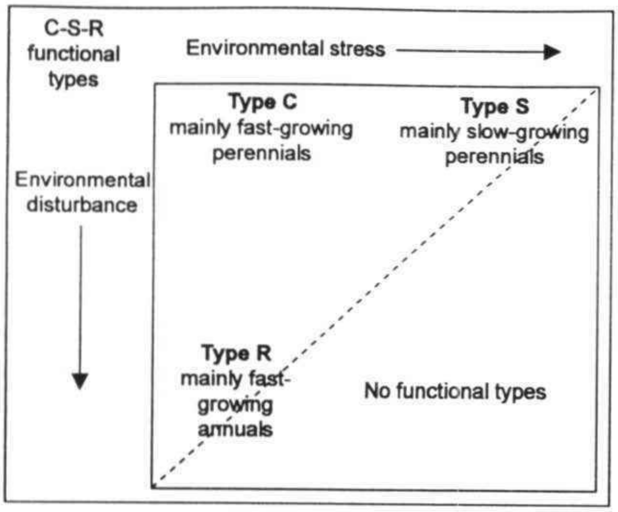


Figure B. The relationship between stress and disturbance factors and the C-S-R types

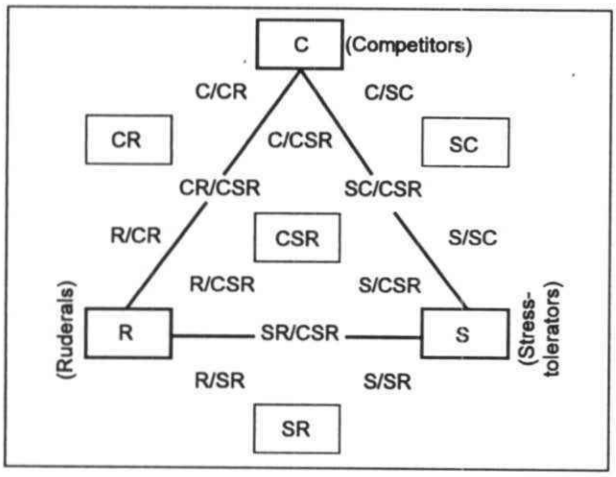


Figure C. The C-S-R triangle ordination showing the three principal functional types and intermediate positions

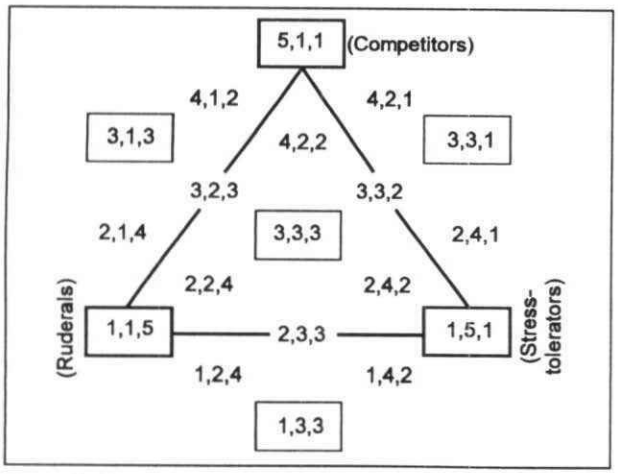


Figure D. C-S-R co-ordinates of functional types

Figure E. Reclassification of species according to functional types

Quadrat identifier	Species	C-S-R classification Part 1	Part 2	Cover
A1–A	*Agrostis curtisii*	5	5	5
A1–A	*Calluna vulgaris*	6	6	10
A1–A	*Campylopus* sp.	7	7	1
A1–A	*Carex pilulifera*	5	5	1
A1–A	*Erica cinerea*	5	6	15
A1–A	*Erica tetralix*	5	6	10
A1–A	*Hypogymnia physodes*	0	0	1
A1–A	*Leucobryum glaucum*	5	5	1
A1–A	*Molinia caerulea*	6	6	40
A1–A	*Potentilla erecta*	3	5	1
A1–A	*Pteridium aquilinum*	1	1	10
A1–A	*Ulex europaeus*	6	6	1
A1–B	*Calluna vulgaris*	6	6	95
A1–B	*Cladonia impexa*	5	5	1
A1–B	*Cladonia* sp.	5	5	1
A1–B	*Erica cinerea*	5	6	5
A1–B	*Molinia caerulea*	6	6	1
A1–C	*Agrostis canina canina*	3	3	1
A1–C	*Agrostis curtisii*	5	5	20
A1–C	*Molinia caerulea*	6	6	35
A1–C	*Polygala serpyllifolia*	5	5	1
A1–C	*Pteridium aquilinum*	1	1	90
A1–C	*Rubus fruticosus*	6	6	1
A1–C	*Teucrium scorodonia*	3	4	1
A1–C	*Ulex europaeus*	6	6	1
A1–D	*Calluna vulgaris*	6	6	95
A1–D	*Dicranum scoparium*	5	5	1
A1–D	*Erica cinerea*	5	6	1
A1–D	*Hypnum cupressiforme*	5	7	1
A1–E	*Agrostis curtisii*	5	5	1
A1–E	*Calluna vulgaris*	6	6	5
A1–E	*Cephalozia* sp.	7	7	1
A1–E	*Drosera intermedia*	5	7	1
A1–E	*Drosera rotundifolia*	3	6	5
A1–E	*Erica tetralix*	5	6	15
A1–E	*Eriophorum angustifolium*	5	6	1
A1–E	*Gymnocolea inflata*	7	7	1
A1–E	*Juncus bulbosus*	3	7	1

Figure F. Eight specimen scenarios

1 An 80% reduction in sulphur emissions

2 A 40% reduction in nitrogen emissions

3 A 10% increase in nitrogen emissions

4 A 3°C increase in temperature, together with
- 10% extra precipitation
- 10% less precipitation

5 Reduction of grazing to 50% (where relevant)

6 Removal of land from arable (where relevant)

7 Removal of land from forest (where relevant)

Figure G. Six simplified scenarios used by UCPE.

UCPE scenario	Disturbance factor	Eutrophication factor	Example
1	Decreased	The same	Less grazing, trampling, cutting or burning, etc, but resource levels unaltered
2	Decreased	Increased	Less grazing, trampling, cutting or burning, but more resources such as light, water or nutrients
3	The same	Decreased	No change in grazing, trampling, cutting or burning, etc, but fewer resources such as light, water or nutrients
4	The same	Increased	No change in grazing, trampling, cutting or burning, etc, but more resources such as light, water or nutrients
5	Increased	Decreased	More grazing, trampling, cutting or burning, etc, and fewer resources such as light, water or nutrients
6	Increased	Increased	More grazing, trampling, cutting or burning, etc, and more resources such as light, water or nutrients

Baseline [the intial state]

General notes on this habitat

The coastal landscape plot classes will, for the purposes of this interpretation, be divided into three groupings that relate to habitat type:

- **scrub** (plot class L)
- **grassland habitats** (plot classes G–K)
- **saltmarsh and other maritime habitats** (plot classes A–F)

Grassland is further subdivided by functional type into **base-rich** (plot classes G–J; relatively productive) and **acidic** (PCK; unproductive heathland, with high representation of type S and SC), and saltmarsh (PCA–PCD) is separated from other maritime habitats (PCE–PCF).

1. **Scrub** (plot class L) Analysis of data from the various scenarios is difficult because separated analyses have not been carried out on the shrub and herb layers. The two layers will not necessarily respond in the same way to the same scenario. A further problem relates to another characteristic group of woodland species not adequately separated by type alone, namely vernal herbs. These spring flowers are classified as type SR. They have more or less completed their annual growth cycle before the tree canopy is fully expanded and are particularly important to the public perception of woodland. Some of Britain's best-loved flowers are woodland vernals (eg bluebell (*Hyacinthoides non-scripta*) and wild daffodil (*Narcissus pseudonarcissus*)). However, this grouping appears poorly represented in scrub.

2. **Grassland habitats** (plot classes G–J) The ecological theory is not yet available for TRISTAR to separate species from maritime habitats, and the **base-rich** elements of this grouping are rather heterogeneous. Tall/overgrown grassland and neutral/semi-improved grassland (plot classes H–I) are the more eutrophic habitats and neutral/calcareous meadows and the semi-maritime habitat cliff-top (PCG, PCJ) the most unproductive, with type S well represented. An early stage in reclaiming the land for intensive agriculture would have been the application of lime. Thus, the **acidic** vegetation (heathland, plot class K) is almost by definition 'unimproved'. It has most of type S and will be the least productive. Many species of type C, CR and SC indicate low or no management inputs, ie dereliction. Plot class H (tall/overgrown grassland) is an example of abandoned grassland with very high values of C, CR and SC. The presence of ruderal types is difficult to interpret for grassland habitats. Most ruderals are entirely dependent upon the production of seed for regeneration, and flowering shoots tend to be removed by grazing animals. Thus, the presence of ruderals in grassland may paradoxically be most characteristic of derelict conditions. For example, there are more annuals in meadows, which have an unmanaged phase before the hay cut, than in pasture, which is grazed throughout the growing season. However, there are exceptions. A few species, particularly thistles (*Carduus* and *Cirsium*), are protected against most herbivores and the low-growing annual meadow-grass (*Poa annua*) is characteristic of over-grazed conditions. Also, ruderals may originate as a

consequence of previous land use practices. If land was formerly under arable cultivation, weeds will appear in short-term leys for many years, even if they are unable to set seed. Their stock will be replenished from the soil seed bank.

3. **Saltmarsh and other maritime habitats** (plot classes A–F) Saltmarshes (plot classes A–D) appear eutrophic with a predominance of types R and CR. This is particularly true for the lower marsh (PCA–PCB) which is more disturbed by tidal movements. These two classes also lack type C. Of the other maritime habitats (PCE–PCF), maritime with freshwater influence (PCE) is a productive, somewhat disturbed habitat with a predominance of types C and CR. Foreshore (PCF) is even more disturbed with more type R and less type C.

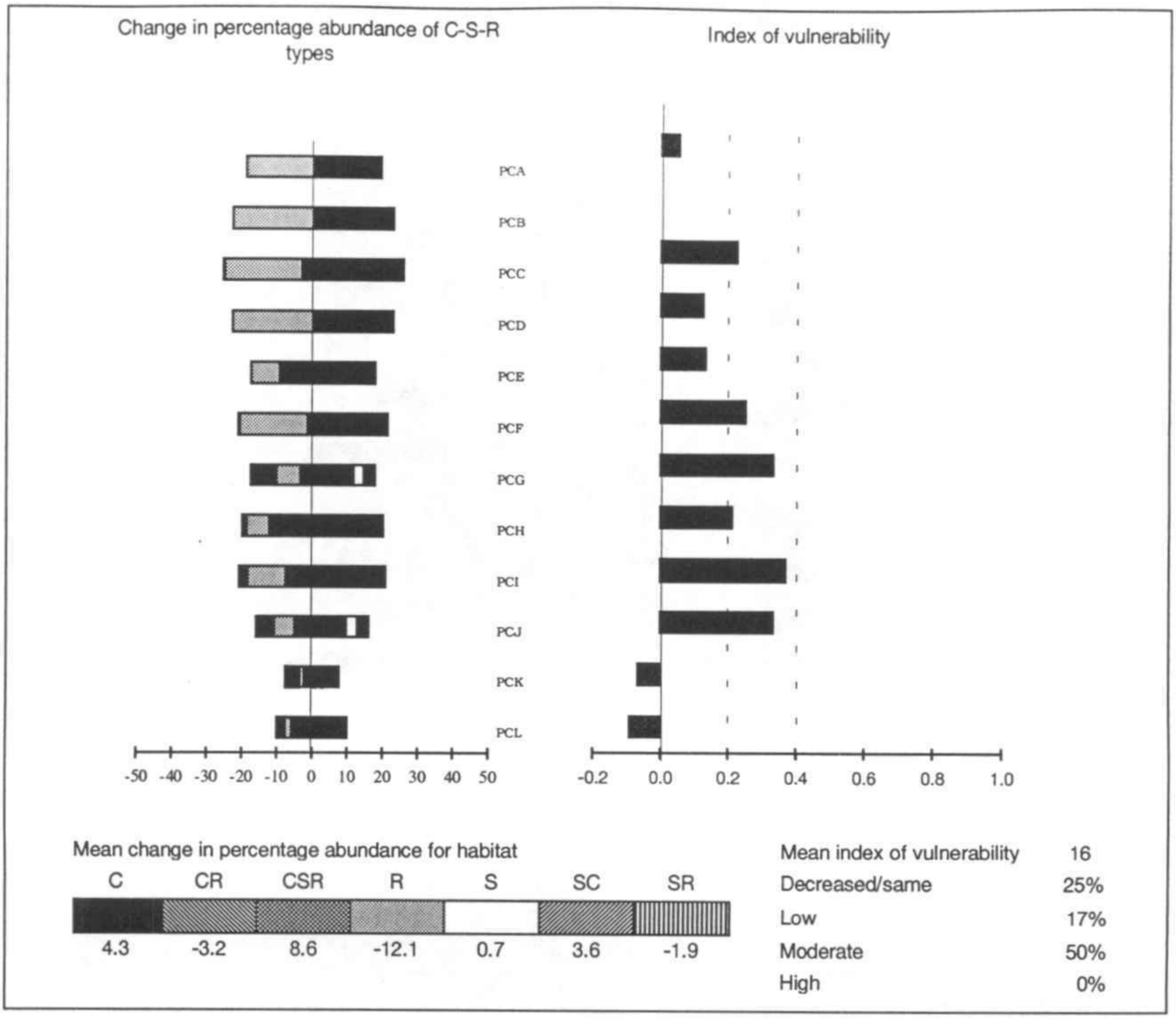
Key species

Cord-grass (*Spartina anglica*), common saltmarsh-grass (*Puccinellia maritima*), sea-purslane (*Atriplex portulacoides*), cord-grass (*Spartina anglica*) and red fescue (*Festuca rubra*).

Important invaders

- **Derelict conditions**
  Birch (*Betula pendula, B. pubescens*)
  and other trees and shrubs
  Bracken (*Pteridium aquilinum*)
  Mat-grass (*Nardus stricta*), tor-grass (*Brachypodium pinnatum*) and other coarse grasses
- **Derelict eutrophicated conditions**
  Gorse (*Ulex europaeus*) – especially in areas which become burnt
  Bramble (*Rubus fruticosus*)
  Stinging nettle (*Urtica dioica*)
  Rosebay willowherb (*Chamaerion angustifolium*) and other tall herbs
  False oat (*Arrhenatherum elatius*) and other coarse grasses
  In wet areas
    soft rush (*Juncus effusus*)
    tufted hair-grass (*Deschampsia cespitosa*)
    common reed (*Phragmites australis*)
  In saltmarshes
    cord-grass (*Spartina anglica*)
    sea couch (*Elytrigia atherica*)

Scenario 1 – [Disturbance decreased; eutrophication the same]

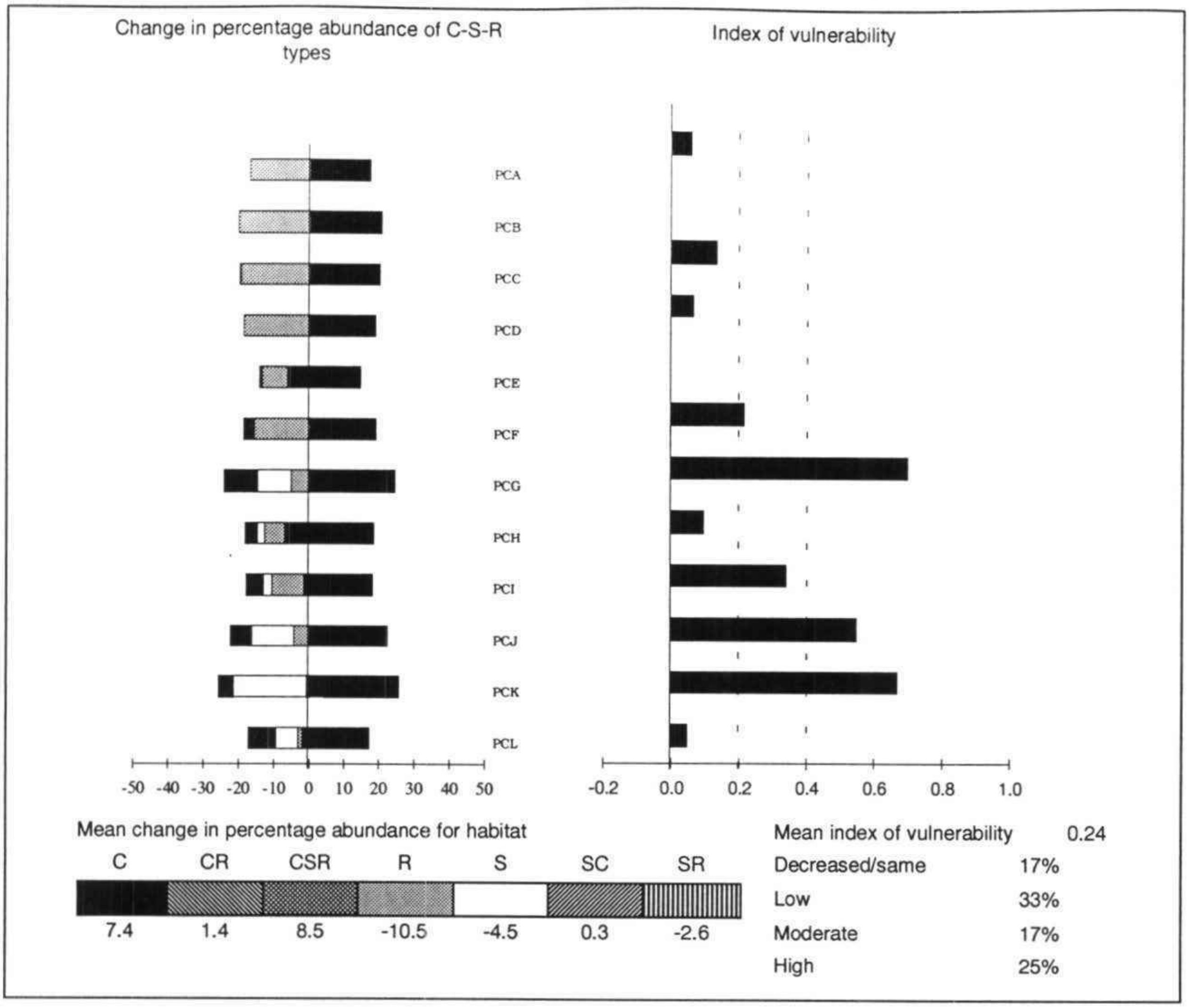


Possible causes of this scenario

- **Scrub** – *decreased disturbance* – no tree thinning [in heathy areas a reduced incidence of fires]
- **Grassland habitats** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires
- **Saltmarsh and other maritime habitats** – *decreased disturbance* – reduced effect of tidal activity, either naturally following increased sedimentation or fewer storms, or as a consequence of human activity (normally these would also reduce nutrient inputs into system), colonisation by a species tolerant of disturbance (cord-grass (*Spartina anglica*)), less recreational pressure

In **scrub** (plot class L), a small change is predicted with an increase in types C and SC, particularly at the expense of type CR. However, floristic and strategic composition is strongly influenced by the dominants of the system, ie trees and shrubs. Most are of type SC and will change little. However, slightly increased shade and greater litter production are likely, which would tend to suppress further the herb layer and could even encourage species of type S and woodland vernals of type SR. In **base-rich grassland habitats and other maritime habitats** (plot classes E–J), increases in types C, CSR and SC are predicted. In the more eutrophic classes (E–F and H–I), these increases are primarily at the expense of types R and CR, but in the less productive classes (G and J) losses of SR and gains of type S are also predicted. In the even less productive **acidic vegetation** (plot class K), where growth rates are slower, smaller changes are expected, with type SC increasing most. Paradoxically, reduced disturbance from land use activities could in unproductive heathland eventually result in episodes of increased disturbance. An increase in above-ground biomass is predicted and, in the event of fire, a greater quantity of combustible material would be present. **Saltmarsh** (plot classes A–D) is eutrophic and a similar but slightly greater change to that for productive grassland might have been predicted, namely an increase in types C, CSR and SC. However, for lower shore marshes (plot classes A–B), types CR and CSR are predicted to expand at the expense of type R. This result is probably only true in the very short term. Some increase in type C might also have been expected, making the vegetation more similar to that in less disturbed habitats higher up the shore (plot classes C–D). The values for index of vulnerability vary with plot class. They are consistently high in base-rich grassland habitats (plot classes G–J) and negative for woody vegetation (plot classes K–L). Thus, short-term impacts on the strategic composition of the vegetation are potentially high for some plot classes and slight for others.

Scenario 2 – [Disturbance decreased; eutrophication increased]

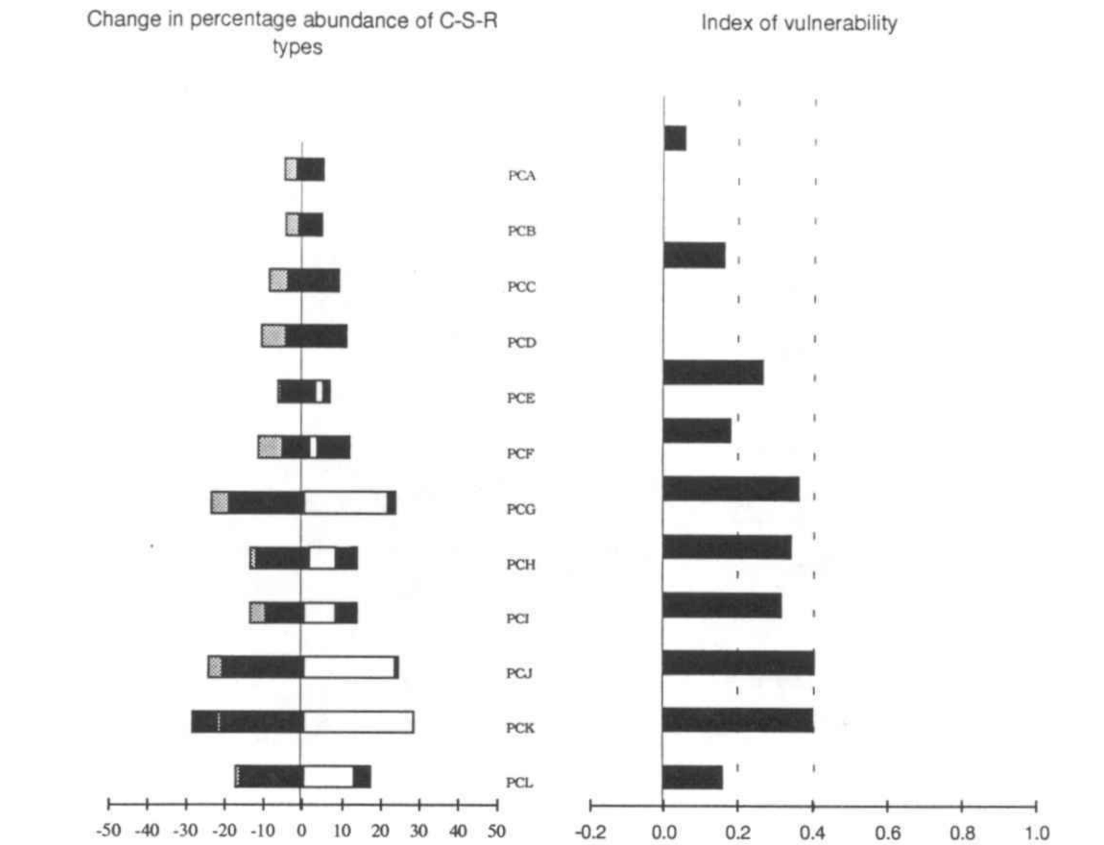


Possible causes of this scenario

- **Scrub** – *decreased disturbance* – no tree thinning [in heathy areas a reduced incidence of fires]; *increased eutrophication* – fertilizer runoff or atmospheric deposition
- **Grassland habitats** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires; *increased eutrophication* – fertilizer runoff or atmospheric deposition
- **Saltmarsh and other maritime habitats** – *decreased disturbance* – reduced effect of tidal activity either naturally following increased sedimentation or fewer storms or as a consequence of human activity (normally these would also reduce nutrient inputs into system), colonisation by a species tolerant of disturbance (cord-grass (*Spartina anglica*)), less recreational pressure; *increased eutrophication* – fertilizer runoff or atmospheric deposition

Increased eutrophication in combination with decreased disturbance will have an even greater and more rapid impact on the distribution of functional types than that exhibited in the previous scenario (disturbance decreased; eutrophication same). Taller, faster-growing vegetation should be produced and overall losses of types S, SR and R and an increased representation by type C, CSR and CR are predicted. The reality for **scrub** (PCL) may be somewhat different to that predicted by TRISTAR. Floristic and strategic composition is strongly influenced by the dominants of the system, ie trees and shrubs. Most are of type SC, and therefore the predicted losses within type SC and gains of type C may not happen. Increased shade and litter production are likely, which would tend to suppress further the herb layer. In reality, types SR (vernals) and S seem most likely to increase in the longer term, provided that there are no barriers to their initial establishment. In **base-rich grassland habitats** and **other maritime habitats** (classes E–J), the prediction of losses of types S and ruderals and an increased representation by types C and CSR accords better with expectations. In the less productive **acidic vegetation** (PCK), change will be slower and major losses will primarily involve type S. **Saltmarsh** (classes A–D) is eutrophic and a similar but slightly greater change to that for productive grassland might have been predicted, namely an increase in types C and CSR. However, for lower shore marshes (classes A–B), types CR and CSR are predicted to expand at the expense of type R. This result is probably only true in the very short term. Some increase in type C might also have been expected making the vegetation more similar to that in less disturbed habitats higher up the shore (classes C–D). Even if natural processes (erosion and sedimentation) restrict the impact of this type, sites should be more strongly vegetated. Eutrophication should encourage rapid recovery following disturbance. The values for index of vulnerability vary. It appears that low-growing, less productive plot classes (G and I–K) have a high vulnerability and, in productive plot classes (eg A–E), the strategic composition of the vegetation will be slight.

Scenario 3 – [Disturbance same; eutrophication decreased]



Mean change in percentage abundance for habitat

C	CR	CSR	R	S	SC	SR
-1.7	-4.8	-1.9	-3.3	8.8	1.9	0.9

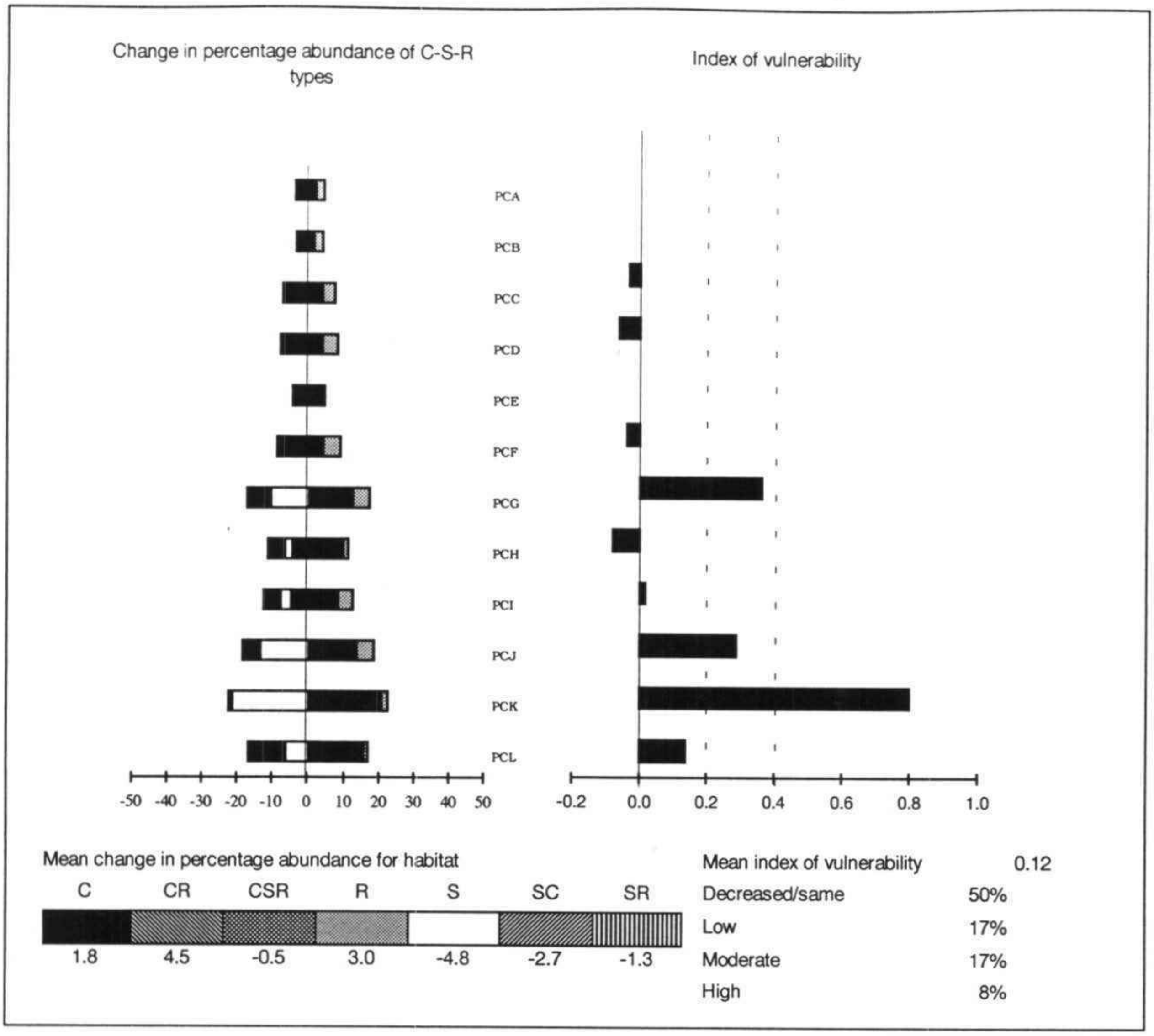
Mean index of vulnerability	0.22
Decreased/same	17%
Low	25%
Moderate	33%
High	8%

Possible causes of this scenario

- **Scrub** – *decreased eutrophication* – potentially a natural consequence of scrub ageing, the soil becomes progressively depleted of nutrients as the scrub biomass increases
- **Grassland habitats** – *decreased eutrophication* – decreased usage of or pollution from fertilizers
- **Saltmarsh and other maritime habitats** – *decreased eutrophication* – decreased usage of or pollution from fertilizers, decreased inundation by nutrient-bearing waters (but this is normally associated with disturbance and deposition of silt, sand or stones)

Increases in types S, SR and SC and decreasing C, CR and R are predicted. In less productive habitats [the more unproductive classes of **base-rich** and **acidic grassland habitats** and **scrub** (PCG, PCJ–PCL)], CSR will decrease while in more eutrophic ones [**saltmarsh and other maritime habitats** (plot classes A–F) and the more productive classes of **base-rich grassland habitats** (PCH–PCI)], CSR increases instead of more extremely slow-growing functional types (eg S). However, in any event, type S, which grows very slowly, will take a considerable period to establish and results may be less marked than predicted. Many species of type S do not form a persistent bank of seeds in the soil or exhibit long-distance dispersal. Thus, sites in plot classes where type S is initially poorly represented (eg plot classes H–I) may fail to be colonised by type S. In practice, the decreased eutrophication scenario is likely to occur rather rarely in **saltmarsh** habitats. Impacts on **scrub** (plot class L) are difficult to predict. The predictions given are probably incorrect because the canopy and herb layer were not separated prior to the analysis. If growth of the shrub canopy is reduced, an increase in the biomass of the ground flora is possible. Because the nutrient demands of small fast-growing herbs may well be less than those of large slow-growing trees, increasing types could even include type C. Values for index of vulnerability vary. Grassland and heath plot classes (G–K) appear to have moderate vulnerability and in productive plot classes (eg A–E) the strategic composition of the vegetation will be slight.

Scenario 4 – [Disturbance the same; eutrophication increased]

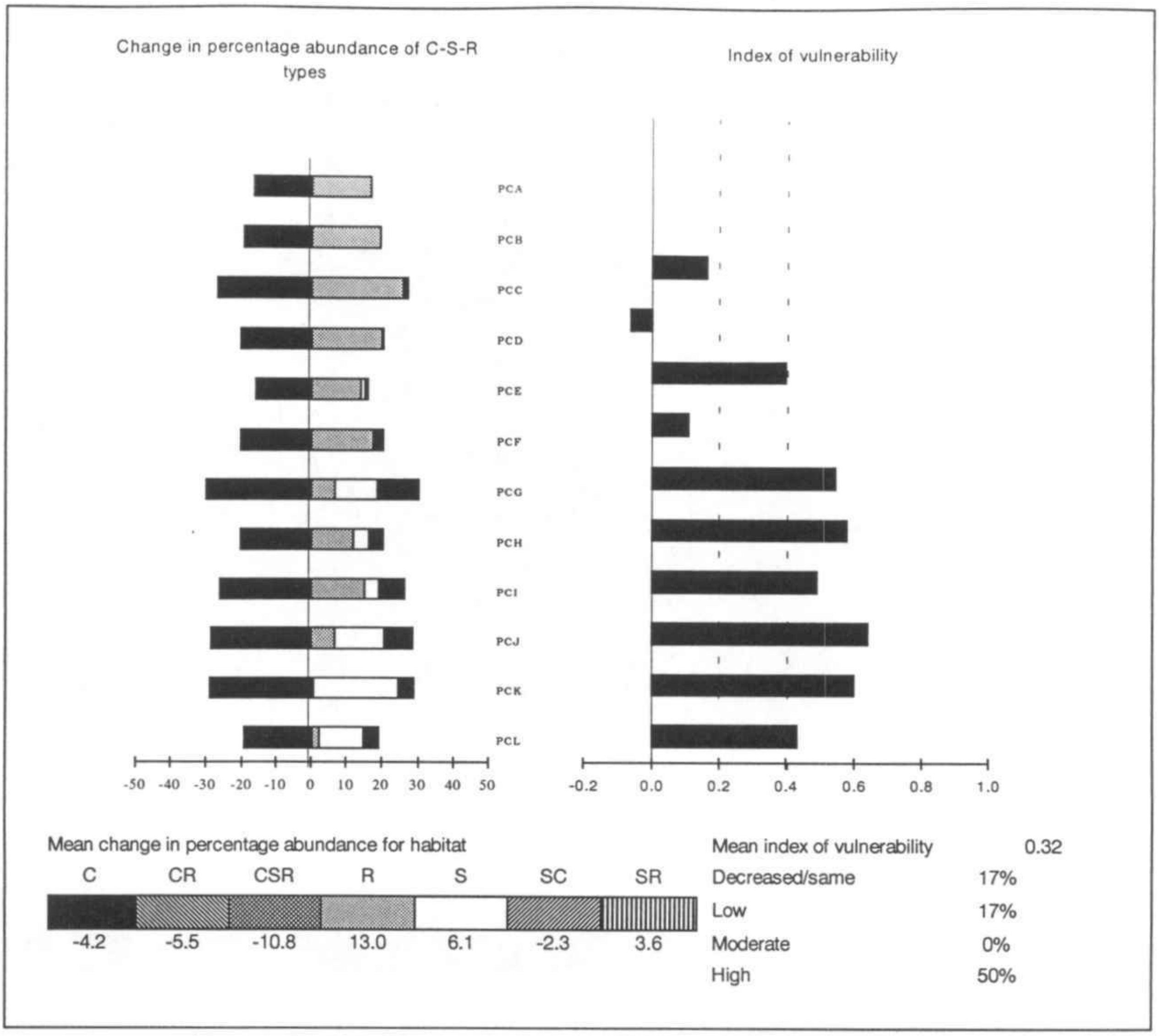


Possible causes of this scenario

- **Scrub** – *increased eutrophication* – fertilizer runoff or atmospheric deposition mainly from agricultural sources, fertilizer applications as a part of silvicultural practice
- **Grassland habitats** – *increased eutrophication* – fertilizer runoff or atmospheric deposition
- **Saltmarsh and other maritime habitats** – *increased eutrophication* – increased flooding (in absence of appreciable disturbance), fertilizer runoff or atmospheric deposition

Increased eutrophication is one of the most important scenarios to consider with respect to changing land use. Within more productive classes of **base-rich grassland** (plot classes H–I), where many species are fast-growing, rapid changes are predicted with a decrease in S, CSR, SR and SC types and an increase in C, R and CR. In less productive classes of **base-rich grassland** (plot classes G and J) and **acidic vegetation** (plot class K), growth rates are slower and the predicted shift is mainly from class S and SC to CSR, CR and R. **Saltmarsh and other maritime habitats** (plot classes A–F) are eutrophic and some increase in types C might have been expected as in **base-rich grassland** (plot classes H–I). The predicted increase in only type R or in types R and CR may be incorrect. Also, in the **scrub** grouping (plot class L), the initial predicted invasion by herbs of types C, CR and R will perhaps only occur at the scrub margin. Increased eutrophication may increase tree growth and shade. This would reduce the cover of ground flora species of all functional types, except perhaps vernals (type SR) and type S. The most vulnerable habitats appear to be unproductive 'grassland' habitats, particularly **acidic vegetation** (plot class K). For **saltmarsh and other maritime habitats** (plot classes A–F), largely negative values for index of vulnerability suggest that short-term impacts on the strategic composition of the vegetation will be small. However, the extent to which competitive species can colonise may have been underestimated.

Scenario 5 – [Disturbance increased; eutrophication decreased]



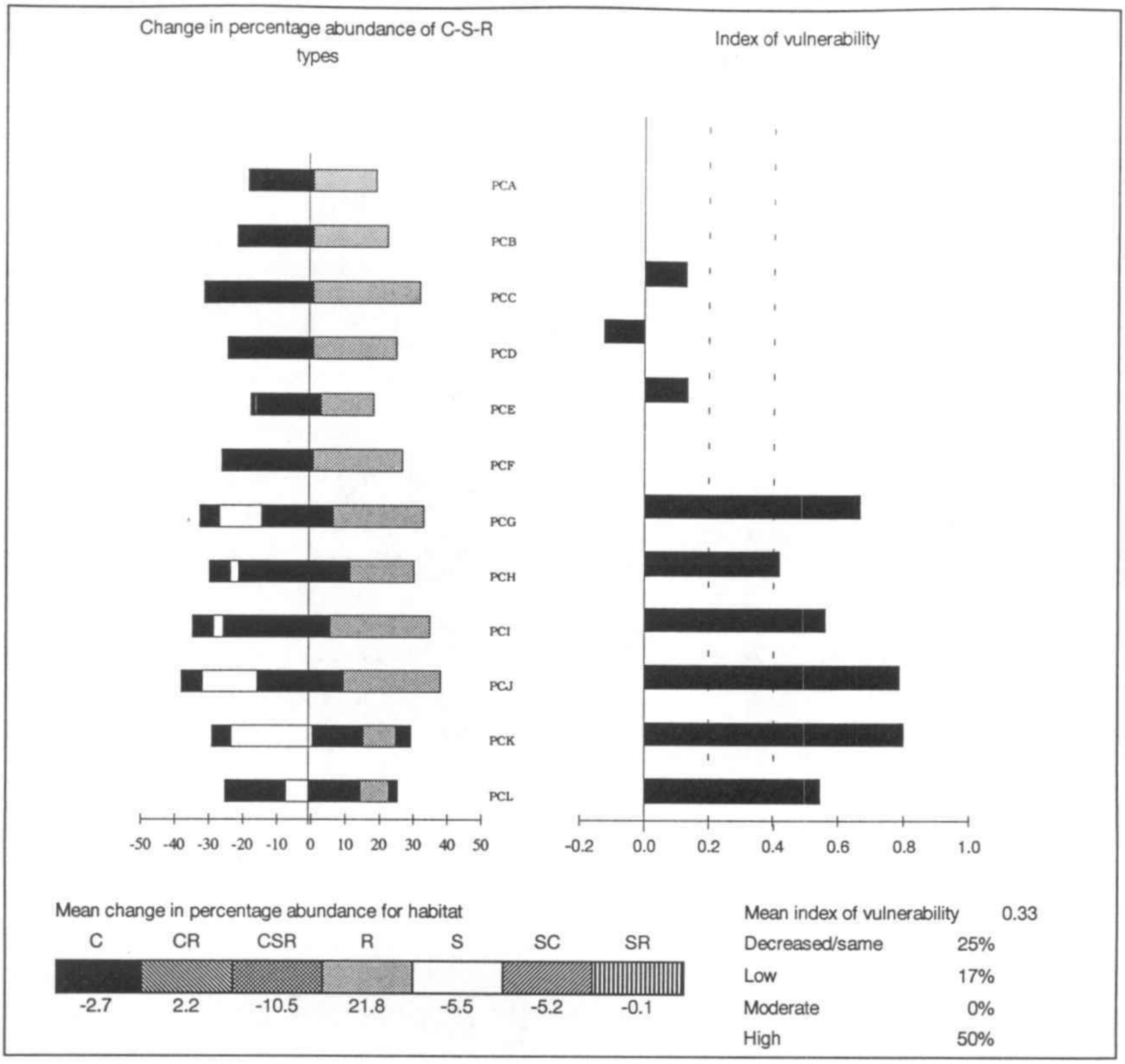
Possible causes of this scenario

- **Scrub –** *increased disturbance* – tree thinning, incidence of fire (discouraged during forestry practice); *decreased eutrophication* – potentially a natural consequence of scrub ageing, the soil becomes progressively depleted of nutrients as the scrub biomass increases
- **Grassland habitats –** *increased disturbance* – increased grazing or cutting, reduced incidence of fires, increased recreational pressure; *decreased eutrophication* – less fertilizer runoff or atmospheric deposition
- **Saltmarsh and other maritime habitats –** *increased disturbance* – increased effect of tidal activity either naturally following increased sedimentation or more storms (normally these would also increase nutrient inputs into the system) or as a consequence of human activity, more recreational pressure; *decreased eutrophication* – decreased usage of or pollution from fertilizers, decreased inundation by nutrient-bearing waters (but this is normally associated with disturbance and deposition of silt, sand or stones)

Increased disturbance coupled with decreased eutrophication will have a major impact on the composition with respect to functional types. Impacts of increased disturbance will be rapid in eutrophic **base-rich grassland habitats** (plot classes H–I). Damage to perennial species should allow the spread of short-lived ruderal species if disturbance is intermittent (eg through ploughing). However, if disturbance is of regular occurrence (eg through grazing), these types will be less favoured because seed production will be impaired. Under these circumstances, perennial species of type CR and type CSR might be favoured. TRISTAR does not distinguish these effects of low-level disturbance over long periods from more severe but punctuated episodes of disturbance. This is a potential problem as a decrease in both type CR and CSR is predicted in this particular example. For **saltmarsh and other maritime habitats** (plot classes A–F), a similar problem exists. Type CSR, C and CR are expected to decline and annuals of type R are predicted to increase. In less productive classes of **base-rich grassland** (plot classes G and J) and **acidic vegetation** (plot class K), opportunities for species with short life cycles are more restricted. Type SR, particularly low-growing bryophytes, would be expected to be the main beneficiary of disturbance and such a change is predicted here. The main impact of decreased eutrophication should be an increase in type S. However, this type grows very slowly and many species of type S are poor colonists. Thus, changes will also be correspondingly slow and predictions for an increase in eutrophic plot classes H and I may not materialise. It is only in less productive classes of **base-rich grassland** (plot classes G and J) and **acidic vegetation** (PCK) that major increases in type S are likely. The changes affecting the **scrub** grouping (plot class L) are difficult to predict. Increased disturbance coupled with decreased eutrophication will reduce the density of the tree canopy. The extent to which the lower strata can respond to the decreased shading will depend on the severity of the nutrient stress imposed and on whether disturbance directly affects all strata. Less severe scenarios may encourage the expansion of all functional types in the ground layer rather than ruderals and type S as suggested here. The values for index of vulnerability show a wide range of susceptibilities. Most **saltmarsh and other maritime habitats** (plot classes A–F) show little increase in vulnerability, but high vulnerability is shown by all **grassland** and **scrub**.

NB This scenario assumes only modest changes in disturbance and eutrophication. Under conditions both of high stress (which permits only slow growth) and of high disturbance (where recovery necessitates rapid growth), no plant species can survive. This combination of high stress and high disturbance is characteristic of many areas of 'open country' suffering problems of recreational damage (eg the Pennine Way).

Scenario 6 – [Disturbance increased; eutrophication increased]



Possible causes of this scenario

- **Scrub** – *increased disturbance* – tree thinning, reduced incidence of fires (a normal component of forestry practice); *increased eutrophication* – fertilizer runoff or atmospheric deposition mainly from agricultural sources, fertilizer applications as a part of silvicultural practice
- **Grassland habitats** – *increased disturbance* – increased incidence of fires, more grazing, more recreational pressure; *increased eutrophication* – fertilizer runoff or atmospheric deposition
- **Saltmarsh and other maritime habitats** – *increased disturbance* – increased effect of tidal activity either naturally following increased sedimentation or more storms (normally these would also increase nutrient inputs into system) or as a consequence of human activity, more recreational pressure; *increased eutrophication* – increased flooding (in absence of appreciable disturbance), fertilizer runoff or atmospheric deposition

The combination of increased eutrophication and increased disturbance, which is a very common impact upon the British landscape, will have major impacts on the composition with respect to functional types. Almost universally an increase in types R and CR is predicted at the expense of all other types. The two exceptions are **acidic vegetation** (plot class K) and **scrub** (plot class L), where type SR and, for plot class K, also CSR are predicted to increase. Of these predictions that for **scrub** (plot class L) is the most contentious. A combination of increased eutrophication and increased disturbance may result in periods with a relatively open canopy immediately following disturbance but with rapid recovery because of eutrophication. Under these circumstances, fast-growing species of type C, CR and R might temporarily be encouraged, particularly if these species had good dispersal in space (numerous, wind-dispersed seeds or spores) and/or in time (a persistent seed bank in the soil). Half of the classes (**grassland** and **scrub**; plot classes G–L) have high values for index of vulnerability, while the remainder (**saltmarsh and other maritime habitats** (plot classes A–F) have low values.

Index of vulnerability

'Coastal habitats' form a heterogeneous grouping of saltmarsh and other maritime habitats, heath, grassland and scrub. Moreover, the individual classes differ in their representation of functional types. The plot classes with a predominance of ruderal types from eutrophic habitats (CR and R) are saltmarsh and other maritime habitats (plot classes A–F), although class E also has the highest representation of type C. Grasslands (plot classes G–K) predictably have most CSR; grazing is both a disturbance event (the removal of biomass) and induces stress (removal of nutrients). Furthermore, the least productive variants (plot classes G, J and K) have the highest proportion of types S and SR. Scrub, as befits a habitat dominated by woody species, has a high representation of type SC.

The most extreme scenarios appear to be 'increased disturbance and eutrophication' and 'increased disturbance and decreased eutrophication', with six plot classes showing high vulnerability. The impact to the various scenarios can be summarised as follows.

Low – moderate impacts
('Disturbance – same; Eutrophication – increased'< 'Disturbance – decreased; Eutrophication – same< 'Disturbance – same; Eutrophication – decreased' <'Disturbance – decreased; Eutrophication – increased')

High impacts
('Disturbance – increased; Eutrophication – decreased'<'Disturbance – increased; Eutrophication – increased')

The differences between habitat groupings are also relatively great and average vulnerability can be ordered as follows:

Low – moderate impacts
(Saltmarsh (classes A–D)< other maritime habitats (E–F)< scrub(L)< eutrophic base-rich grassland (H–I))

High impacts
(Less productive base-rich grassland (G, J)< heathland (K))