No. 13

Targets for coastal habitat re-creation

K Pye & P W French

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TARGETS FOR COASTAL HABITAT RECREATION

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EXECUTIVE SUMMARY

Background to the report

English Nature has committed itself to trying to halt and reverse the loss of coastal habitats and natural features resulting from coastal squeeze and from the disruption of sedimentary systems. As part of thisl strategy, the overall goal has been set to maintain coastal habitats and features equivalent to their distribution and total area in 1992 (English Nature, 1992).

In order to achieve this goal it is first necessary to define the distribution and extent of the current resource, to estimate recent rates of loss or gain and to project these forward, taking into account the possible effects of changes in environmental conditions (sea level, wind / wave climate, sediment supply) and future human impact on the coastal zone. This information can then be used to set targets for habitat recreation at local, regional and national scales.

Objectives

The objectives of this report were:

(1) to summarise existing information about the extent and variability of the following major habitats and natural features in England, including presentation of data for each administrative county and major process cell: *sand dunes, saltmarshes, intertidal sand and mudflats, shingle structures, saline lagoons, unprotected soft cliffs, maritime cliff grassland, coastal heath*

(2) to collate existing information on current and recent rates of of loss or gain for each of these major habitat divisions

(3) to use the information from 1 and 2 to estimate current average rates of net loss or gain for each of the major habitat divisions

(4) to review in very broad terms the likely trends in future coastal land use and natural environmental change, including sea level rise, and to use this information, in combination with estimates of rates of recent coastal change, to predict possible future rates of net gain or loss over the next 20 years

(5) to convert those estimates which predict future losses into target figures for the recreation of habitat natural features that would allow the policy objective of no net loss to be met

Methodology and report structure

In view of the short time period available for completion of this project, heavy reliance has been placed on information contained in existing datbases, reports and published papers. Since comprehensive data do not exist for all habitat types, in some instances it has been necessary to make a best estimate of extent and rates of change based on scattered data relating only to specific areas.

For ease of treatment, each habitat type is considered separately in the report following an initial summary of sea level trends and changes in attitudes to coastal zone management and planning which may have a bearing on estimates of future habitat loss. For each type of habitat or natural feature, sub-sections of the report consider the working definition of the habitat, the nature and reliability of the data sources used, the present extent, the nature of threats to the habitat, recent rates of habitat loss (or gain), projected future rates of loss, and targets for habitat recreation. The final section of the report summarises the major conclusions and makes a number of recommendations concerning the requirements for an improvement in data quality and further research to assess the suitability of different habitat recreation and conservation options within particular regions.

Resource Extent

Reasonably good information is available concerning the location and extent of sand dunes and salt marshes, both of which have been the subject of detailed national inventories. Information for intertidal flats, shingle features, saline lagoons and unprotected soft cliffs is less complete and less reliable, but generally adequate for the purpose of this report. The extent of maritime cliff grassland and coastal heath is not well defined, however, and consequently it has not proved possible to obtain anything more than very broad figures. On this basis, the best available estimates of the present national extent of each habitat are as follows

	area (ha)
sand dunes	11897
saltmarsh	32462
intertidal flats	233361
shingle	12376
saline lagoons	1215
unprotected soft cliffs	256 (km)
maritime cliff grassland	1895
coastal heath	462

Recent habitat loss

Available information about recent habitat loss is fragmentary and of highly variable quality. Systematic surveys which provide quantitative estimates of loss of a particular habitat type are very few in number and generally refer only to localized areas. However, the most detailed information is available for saltmarshes and intertidal flats, which are the habitats which have apparently suffered the most severe losses in recent decades. Estuaries in southeast England have suffered between 10 and 44% loss of saltmarsh area since 1973, mainly due to erosion (Burd, 1992), and there have been additional significant erosion losses on the south coast and in the Severn estuary / Bristol Channel. Loss of other habitats has been on a smaller scale and has mainly been related to human activities such as residential development, waste tipping and aggregate extraction.

Projected habitat loss

Continued, and possibly accelerated, sea level rise in the next 20 years is, in general terms, is likely to exacerbate the widespread erosion problem on the English coast. The total amount of relative sea level rise during this period is forecast to be at least 40-100 mm, varying with location, and may be as large as 80-200 mm if the predicted effects of greenhouse warming become reality. The response of coastal features to sea level rise of this magnitude will vary depending on other local conditions, particularly exposure to wave action, availability of sediment and littoral drift rates. In general terms, however, continued or accelerated erosion may be expected at the updrift end of coastal sediment cells while stability or accretion is likely at the downdrift end of such cells. Saltmarshes and intertidal flats in southeast and southern England are likely to suffer a further major reduction in area as the low water mark moves landward and there is further offshore movement of intertidal sediment. By comparison, the effects on sand dunes, shingle structures, lagoons and cliffs is likely to be less significant.

Changing attitudes to coastal zone management and planning, involving greater appreciation of the conservation and recreation value of the coastal zone, combined with a trend towards more widespread adoption of 'soft' coastal engineering methods, suggest that rates of loss of coastal habitat and natural features due to human activities may decline in the next 20 years. However, much of the natural coast has already been lost or severely damaged, and there is a danger that there will be increasing pressure to 'manage' a significant proportion of the remainder, albeit using 'soft' engineering methods.

Targets for habitat recreation

Based on an assessment of all the currently available information, it is suggested that the following minimum targets for coastal habitat recreation should be set to replace likely losses in the next 20 years:

	area (ha)
sand dunes	240
saltmarsh	2750
intertidal flats	10,000
shingle	200
saline lagoons	120
unprotected soft cliff	10 km
maritime cliff grassland	150
coastal heath	50

Attainment of these targets will require adoption of a variety of approaches suited to local circumstances. The options include 'managed retreat', involving set back or removal of sea defences, 'managed advance' in areas where natural accretion trends can be encouraged or erosion reversed (e.g. by construction of artificial rock groynes and breakwaters), and 'managed stability', using techniques such as foreshore recharge and sediment recycling.

Key recommendations

Better data relating to the extent and nature of several of the habitat types considered in this report are urgently required. Meaningful assessment of the impact of future changes, and of the success or otherwise of the habitat recreation policy, requires adequate baseline information. Further detailed studies of particular habitats and/ or natural features should therefore be commissioned.

The successful creation of new areas of habitat such as saline lagoons, maritmecliff grassland and coastal heath requires an understanding of the ecological requirements of key species which inhabit them. Similarly, the basic geomorphological and sedimentological processes which govern the response of coastall features to both natural and engineered changes in the environment must be fully understood. There is an urgent need for further research which addresses these issues in the context of different coastal management options.

ACKNOWLEDGEMENTS

We are grateful to Dr. Nick Davidson and Eva Leck of the J.N.C.C. for provision of information from the *Estuaries Review* database, to Teresa Bennett for access to information in the *Coastwatch* database, and to Dr. Geoffrey Radley for access to the *Sand Dune Inventory* database. Additional unpublished information was provided by the following organizations: Kent County Council; Humberside Councty Council; Sefton Metropolitan Borough Council; Hampshire County Council, Norfolk County Council, Purbeck District Council, Christchurch Borough Council, and Rendel Geotechnics.

SECTION 1 INTRODUCTION

1.1 Report rationale

English Nature has committed itself to trying to halt and reverse the loss of coastal habitats and natural features resulting from 'coastal squeeze' and from the disruption of sedimentary systems.

Coastal squeeze results from a combination of:

1. Development or intensive agricultural use of land up to the edge of an eroding cliff, out into the intertidal zone of a low-lying coast or onto coastal dunes or shingle features.

2. Landward movement of the high and/or low water marks due to erosion, rising sea level or a combination of these factors.

Loss of coastal habitats to development and land claim has been recognized as a major problem for some years. English Nature is continuing to seek ways of minimising such losses. However, in recent years another cause of coastal habitat loss has been identified.

Many current forms of flood defence and coast protection use static structures which fix the landward edge of the coastal zone. These structures prevent the shoreline and its associated coastal habitats moving landward on eroding shorelines. In these circumstances such works become an important contributory factor to coastal squeeze.

Flood defence and coast protection works may also disrupt sedimentary systems by interfering with longshore drift or by removing sources of sediment. They can thus have an impact on sections of coastline at some distance from the works themselves. Protection works may also lead to the stabilization and degradation of cliff exposures which are important Geological Sites of Special Scientific Interest, thereby reducing their value as a teaching and research resource.

English Nature is trying to influence the design of flood defence and coast protection works so that in future these side effects can be largely eliminated. The objective is to ensure that new or replacement sea defences do not further exacerbate coastal squeeze and help to reverse it wherever possible. The overall goal has been set to maintain coastal habitats and natural features at a level equivalent to their distribution and total area in 1992 (English Nature, 1992).

In order to achieve this goal it is first necessary to define the distribution and extent of the current resource, to estimate recent rates of loss or gain and to project these forward, taking into account the possible effects of changes in environmental conditions and future human impact on the coastal zone. This information can then be used to set targets for habitat recreation at local, regional and national scales.

1.2 Project objectives

The initial objectives of this study were defined as follows:

1. To summarise existing information concerning the extent and variability of each of the major types of coastal habitat and natural features listed below, including presentation of data for England as a whole, for each adminstrative county, and for each major process cell (as defined in the *Macro Review of the Coastline of England and Wales*; Hydraulics Research Ltd., 1986 *et seq.*, Figure 1.1):

   sand dunes
   salt marshes
   intertidal sand and mudflats
   shingle structures
   saline lagoons

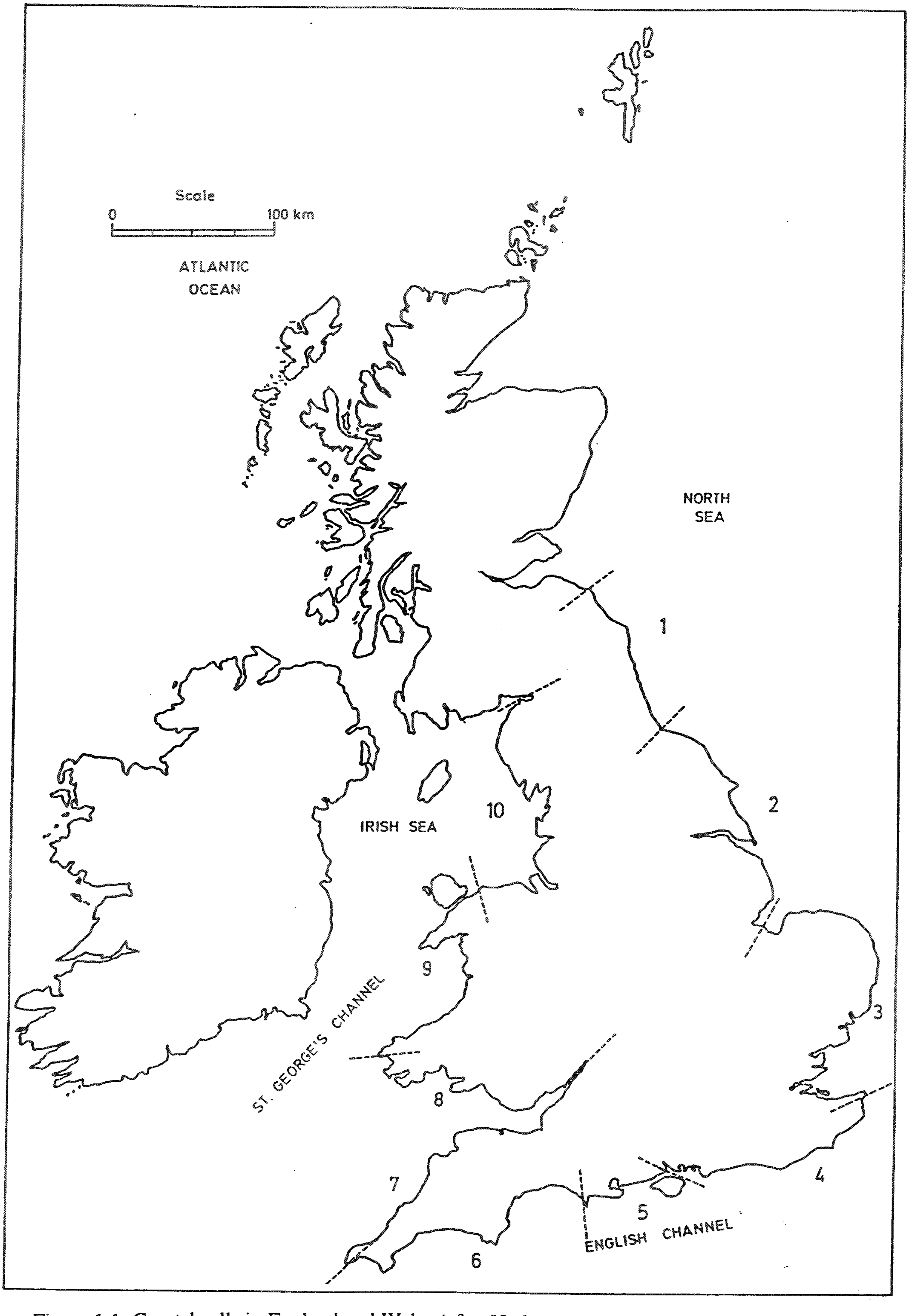

Figure 1.1. Coastal cells in England and Wales (after Hydraulics Research Ltd., 1986 *et seq.*)

unprotected soft cliffs
maritime cliff grassland
coastal heath

2. To collate existing information on current and recent rates of loss or gain for each of the major habitat divisions listed above.

3. To use the information from 1 and 2 to estimate current average rates of net loss or gain for each of the major habitat divisions in each adminstrative county and major process cell.

4. To review in very broad terms the available information on likely trends in land use and predicted rates of relative sea level rise, and to use this information, together with estimates of rates of recent coastal change, to predict possible future rates of net loss or gain for each of the major adminstrative counties and process cells over the next 20 years.

5. To convert those estimates which predict future losses into target figures for the recreation of habitats or the freeing up of natural features that would allow the policy objective of no net loss to be met.

1.3 Report structure

For ease of treatment, each habitat type is considered separately in the report following an initial summary of sea level trends and changes in attitudes to coastal zone management and planning which have a bearing on the estimates of future habitat loss. For each habitat type, separate sub-sections of the report consider the working definition of the habitat in question, the nature and reliability of the data sources used, the estimated habitat extent, the nature of threats to the habitat, recent rates of habitat loss (or gain), projected future rates of habitat loss and targets for habitat recreation, including the alternative response options available.

It was not intended that this study should identify or assess the suitability of particular sites for habitat recreation or evaluate particular management options in individual locations. However, Section 11 of the report includes a number of general comments and recommendations concerning the requirements for an improvement in the data quality relating to habitat extent and rate of change.

1.4 Methodology and data sources

In view of the short time period available for completion of this project, it was clear from the outset that heavy reliance would be placed on existing information in the form of available databases, published papers and reports. It was also recognized that comprehensive data do not exist for all habitat types. Consequently it has been necessary in some instances to make a best estimate of trends based on data relating to specific areas obtained from publications, reports, maps and direct communication with relevant organizations.

The most comprehensive source of data is provided by the *Coastwatch* database, now administered by the J.N.C.C. Although the results of this survey are not yet published, access to relevant information was granted for the purposes of this review. Data were collected for the *Coastwatch* project during the late 1980's by groups of volunteer field workers who were issued with written guidelines by N.C.C. headquarters staff. The entire coastline was divided into blocks of four 1 km grid squares and mapped at a scale of 1:10,000 (or 6" to 1 mile). Maps were returned to headquarters in Peterborough for processing and entry into the database. Some inconsistencies may have arisen due to the use of multiple personnel, some of whom had limited experience in recognition of vegetation community and landform types. Inaccuracies may also have arisen in some areas through the use of base maps which took no account of recent coastal changes, and by uncertainties surrounding the landward and seaward cutoff points of the survey. The *Coastwatch* mapping returns recorded no information about soft cliffs, protected or unprotected. However, *Coastwatch* is the only source which provides information about the majority of habitats for the entire open coast and most of the estuarine shoreline length of England.

Other sources of information with wide geographical coverage which were used in this study include the *Macro Review of the Coastline of England and Wales* (Hydraulics Research Ltd., 1986 *et seq.*), the *Saltmarsh Survey of Great Britain* (Burd, 1989), the *Invenory of English Sand Dunes and Their Vegetation* (Radley, 1992), the *Shingle Survey of Great Britain* (Sneddon & Randall, 1991), the *Directory of Saline Lagoons* (Smith & Laffoley, 1992), the *Estuaries Review* database (Davidson *et al.*, 1991), the *Coast Protection Survey 1980* (Herlihy, 1982), and the *Saltmarsh Datbase* currently being prepared for MAFF by Cambridge Environmental Research Consultants Ltd (Pye & French, in prep.). A detailed update of the *Estuaries Review* to August 1992 was provided by J.N.C.C. Although a number of these surveys are not comprehensive in their geographical coverage, the information contained in them shows a high degree of internal consistency due to the fact that the work was carried out by a relatively small number of dedicated personnel.

Difficulties arise in combining information from a number of sources since coastal features and habitats have often been defined in different ways, or the data grouped into different administrative units. This problem is illustrated, for example, by varying estimates of the length of the English coast. The *Coast Protection Survey 1980* (Herlihy, 1982) indicates a total length in England of 2918 km, whereas the figure for total coastline length cited by the *Coastwatch* survey is 10677 km. No separate data for the Isle of Wight are given in the *Coastwatch* survey, while the Herlihy report gives zero returns for Cheshire, Greater London, Cambridgeshire and Nottingham, counties which contain tidal rivers and estuarine shorelines but no open coast (Table 1.1). In compiling this report every attempt has been made to take account of such variations in reporting practice, but the inherent limitations of the data used should be clearly recognized.

Table 1.1: Estimated coastal length along the English coast (Km).

County	Coastwatch Database	Herlihy (1982)
Cumbria	624.75	264.0
Lancashire	474.11	94.0
Merseyside	141.46	56.0
Cheshire	136.85	0.0
Gloucestershire	150.96	29.0
Avon	121.87	63.5
Somerset	165.26	76.0
Devon	790.65	333.0
Cornwall	1082.18	473.0
Dorset	391.46	205.0
Hampshire	581.61	95.5
Isle of Wight	-.-	117.0
Sussex	435.83	163.0
Kent	827.38	169.0
Greater London	173.96	0.0
Essex	1119.59	125.0
Suffolk	467.99	80.0
Norfolk	956.52	122.0
Cambridgeshire	93.58	0.0
Lincolnshire	616.15	56.0
Nottinghamshire	64.52	0.0
Humberside	484.43	109.5
Yorkshire	220.35	71.0
Cleveland	176.21	40.5
Durham	24.94	17.0
Tyne & Wear	146.92	30.0
Northumberland	237.28	129.0
Total	**10676.81**	**2918.0**

SECTION 2 - BACKGROUND ISSUES

2.1. The basis for prediction of future habitat change

Assessment of likely future changes to coastal habitats in the next 20 years or longer requires consideration of possible changes in the major environmental forcing factors, namely sea level and wind / wave climate, and in attitudes to coastal zone management and planning. Considerable uncertainty surrounds both issues, and a full discussion is beyond the scope of this report. However, the principal aspects are summarized below.

2.2 Sea level rise

A large body of geological evidence indicates that global sea level rose rapidly at a rate averaging 12 - 14 m /yr during the late Pleistocene and early Holocene, and since 6000 yr B.P. the average rate of rise has been about 1 mm /yr (Emery & Aubrey, 1991). However, regional variations have been large, reflecting a combination of isostatic, hydro-isostatic and tectonic adjustments. In Britain, quite distinct differences in sea level trend have been experienced by the northern and southern parts of the country, largely reflecting a differential isostatic response to ice unloading (Lambreck, 1991).

Tide-gauge records suggest an increase in global mean sea level of between 0 and 2.4 mm/yr in the past 100 - 200 years, although there is still debate about whether this reflects net land movements or an actual change in ocean surface level. Evidence from UK stations shows a relative rise of 1 - 2 mm at most locations in the southeast and south of England, with no net change or a slight fall in the north and Scotland (Table 2.1; Woodworth, 1987).

Predictions made by the Intergovernmental Panel on Climate Change (IPCC) suggest that, as a result of 'greenhouse' warming, mean global air temperature may rise by 1.0 to 1.5^{o}C by the year 2030 (Houghton *et al.*, 1990), although there will be marked regional differences, not only in the magnitude of temperature change, but also in the nature of changes in precipitation, cloud cover and frequencies of extreme events.

As a consequence of global warming, mean sea level has been forecast to rise by between 9 cm and 29 cm, with a best estimate of 18 cm, between 1985 and 2030 (Warrick & Oerlemans, 1990). This implies an acceleration in the rate of rise to between two and seven times the average rate for the last century. Such a rise would not only raise the probability of tidal flooding in low lying areas, but may be expected to lead to an increase in the rate of shoreline erosion as greater water depths allow storm waves to move closer inshore (Whittle, 1990; Mansard, 1990). Some model predictions also suggest a greater frequency, and possibly intensity, of storms over mid-latitudes, thereby increasing the frequency and / or magnitide of storm surges in coastal areas. As a result of these changes, it has been suggested that the 1 in 1000 year flood height in 1990 might be reduced to the 1 in 30 year flood height by 2030. More frequent erosion would lead to a landward shift in the position of mean high water mark, with a concomitant seaward movement of sediment as the nearshore profile becomes modified in an attempt to achieve a new equilibrium with the new wave energy conditions (cf. Bruun, 1962, 1988 ; Dubois, 1992).

British and northwest European tide gauge records as yet show no clear evidence of an acceleration in the rate of sea level rise due to global warming (Woodworth, 1990; Woodworth *et al.*, 1991). However, MAFF have considered it prudent to issue guidelines which recommend an allowance for sea level rise of 6 mm/yr in the design of new sea defences in southeast England, with slightly smaller allowances elsewhere.

Recent work has suggest that initial projections have over-estimated the rate of possible sea level rise due to global warming, and values in the lower range of estimates now seem more likely to be correct (Meier, 1990; Wigley & Raper, 1992). However, even if there is no acceleration in the next 20 years

Table 2.1: Linear mean sea level trends relative to land for selected ports, based on tide guage measurements.

		Direct Analysis		With Atmospheric Correction		Estimated Vertical Land Movement (see text)
	Data Span	Trend	SD	Trend	SD	
Newlyn	1916 - 1982	1.72	0.16	1.78	0.11	-0.3
Devonport	1962 - 1982	0.8	2.5			
Portsmouth	1962 - 1982	5.0	0.5			-3.5
Sheerness/ Southend	1916 - 1982	2.27	0.21	1.94	0.23	-0.4
Lowestoft	1956 - 1982	0.3	0.7			+1.2
Immingham	1961 - 1982	1.7	1.1			
North Shields	1916 - 1982	2.57	0.22	2.61	0.24	-1.1
Douglas (IOM)	1938 - 1977	0.26	0.67			+1.2
Aberdeen	1916 - 1982	0.52	0.21	0.86	0.19	+0.6
Lerwick	1958 - 1982	-2.0	0.7			+3.5

Note: All values in mm/year
Source: Based on Woodworth, 1987

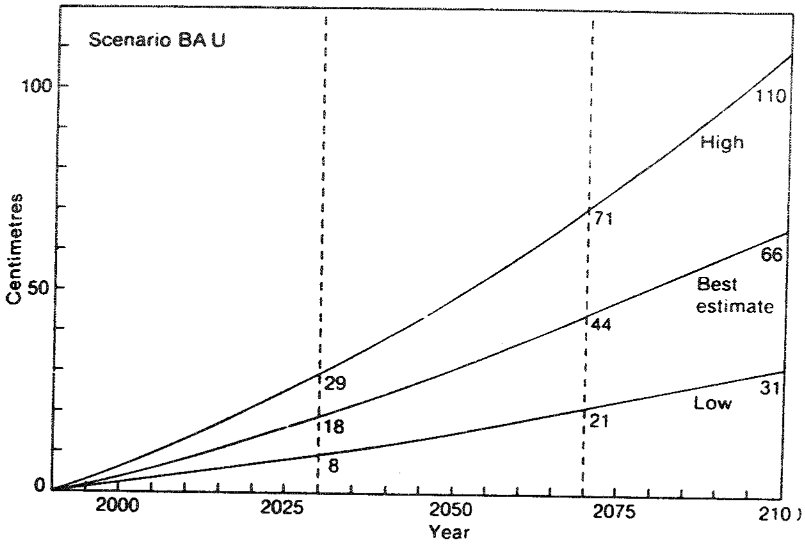

Figure 2.1. Projected rise in global mean sea level, 1990-2100, based on Business-as-Usual Policy Scenario (after Warrick & Oerlemans, 1990)

mean sea level is forecast to rise by 4 - 6 cm in the Outer Thames estuary, 2 - 4 cm in southwest England, the northwest and on the east coast, and perhaps by as much as 10 cm on parts of the south coast (Bray *et al.*, 1992). Changes of this magnitude will certainly maintain, and possibly enhance the present erosion trend which is affecting large parts of the coast (Herlihy, 1982; Anglian Water 1988a; Bray *et al.*, 1991), lead to a significant increase in flooding risk (Whittle, 1990), and result in a wide range of ecological changes (Boorman *et al.*, 1989; Burd & Doody, 1990).

2.3 Changes in wind / wave climate

The effect of global warming on the frequency and magnitude of storms in the northeast Atlantic is by no means certain (see Warrick & Barrow, 1991). Since mean wind strengths and intensity of frontogenesis are in general terms related to the magnitude of latitudinal temperature gradients, it can be argued that a general warming in mid and high latitudes should lead to a decrease in mean wind speeds and storm intensity. A simple northerly shift in the mean track position of westerly depressions during winter would also result in generally less stormy conditions across the British Isles. Geological evidence relating to earlier periods of the Holocene strongly suggests that warmer intervals in the British Isles were less stormy than the present, whereas colder periods (such as the Little Ice Age) were considerably more stormy (e.g. Lamb, 1982, 1991).

There is some evidence that the northeast Atlantic and North Sea have become rougher in recent years (Carter & Draper, 1988; Bacon & Carter, 1991; Hoozemans & Wiersma, 1992), but as yet there is no evidence that this is anything more than short-term natural variation which is unrelated to global warming.

2.4 Attitudes to coastal zone management and planning

The past two decades have seen major changes in attitude towards the British coast. Prior to the late 1960's, relatively little of the coast received statutory protection, leading to widespread development and exploitation (Rothwell & Housden, 1990; Davidson *et al.*, 1991). The past two decades have seen both an increase in statutory protection and a tightening of planning regulations in coastal areas (Gubbay, 1986, 1988). There are encouraging signs that this trend will continue, with some further tightening of local planning controls and a trend towards integrated coastal zone management which takes more account of the underlying physical processes (see, for example, Hampshire County Council, 1991; House of Commons Environment Committee, 1992; Department of the Environment 1992a,b; Institution of Civil Engineers, 1992). Traditional views of coast protection and flood defence are also being re-examined in the light of changing demands for agricultural products and the increasing recognition of 'non-economic' values (National Audit Office, 1992; Powell, 1992).The U.K. currently has no national coastal defence policy of the kind formalized in the Netherlands (Rijkswaterstaat, 1990), but the development of such a policy in the future cannot be ruled out (e.g. Whittle, 1992; Rendel Geotechnics, 1992). In such a climate of changing attitudes and evolving statutory powers, forecasts of future habitat losses due to human activities are necessarily subject to considerable uncertanty. For the purposes of this report, a largely 'business as usual' scenario has been assumed, but indications are given where possible future changes in policy might have a significant impact on the nature of future habitat changes.

SECTION 3 - SAND DUNES

3.1 Habitat definition

For the purpose of this study, coastal sand dunes are taken to include all areas of coastal windblown sand, whether forming true dunes, undulating 'links' or sand sheets with minimal dune topography. Composite features composed of blown sand and shingle are included where the former is dominant. Near-coastal deposits of Late-Glacial age aeolian coversand, such as the Shirdley Hill Sand of Merseyside and West Lancashire, are not included.

3.2 Data sources and reliability

A list of sand dune sites and their areal extent was obtained from the draft report of English Nature's *National Inventory of English Sand Dunes and Their Vegetation* (Radley, 1992). This was compiled by field mapping of vegetation community types onto aerial photograph overlays and O.S. base maps at a scale of 1:10,000 or 1:10560. The area covered by each community was then determined using an ARC-INFO GIS system. The accuracy of the total dune area cited is in part governed by the accuracy of the seaward and landward limits of the dune areas shown on the O.S. maps (or as subsequently modifed based on air photograph interpretation and field survey). However, significant errors are likely only in the few areas of very rapid recent change.

A second, independent, source of areal extent information by county was provided by the *Coastwatch* database. The following mapping categories used in the survey have been combined to produce an aggregate figure for 'sand dunes' cited in this report: *sand dunes, terrestrial sand, terrestrial sand / shingle and terrestrial sand / boulders.*

Although some non-aeolian sand may be included in this aggregate figure, the *Coastwatch* database in fact provides a lower estimate of the total extent of sand dune habitat than the*Sand Dune Inventory*. This can be attributed mainly to the fact that in some instances the *Coastwatch* survey did not include full information where blown sand extends some considerable distance inland.

Qualitative information about erosion/ accretion status of the frontal dunes was obtained from the *National Sand Dune Inventory* and from the *Macro Review of the Coastline of England and Wales* (Hydraulics Research Ltd.1986 *et seq.*). Quantitative data relating to rates of dune loss are only available for a small number of specific areas where direct measurements have been made over the past few decades (e.g. Smith, 1982; Pye & Smith, 1988).

Information about loss of dune resource due to human activities in the vicinity of estuaries was obtained from the *Estuaries Review* database. However, dunes on more open parts of the coast are generally excluded, and have not been the subject of any other systematic investigation. Information relating to specific open coast dune areas has been obtained from published papers and reports (e.g. Smith, 1982; Doody, 1992a,b), and by direct contact with the Planning and Engineer and Surveyor's Departments of a number of County and District Councils.

3.3 Resource extent

3.3.1 National area

11897 ha (Radley, 1992)

3.3.2 Regional distribution and habitat importance

Dunes represent a particularly diverse habitat, occurring in a wide range of geomorphological situations. A number of different morphological types coastal aeolian sand accumulation can be identified (Pye, in prep.), including: (1) barrier island dunes (2) tombolo barrier dunes; (3) barrier spit dunes; (4) cliff-foot dunes; (5) climbing dunes; (6) cliff-top dunes; (7) ness dunes; (8) bayhead dunes;

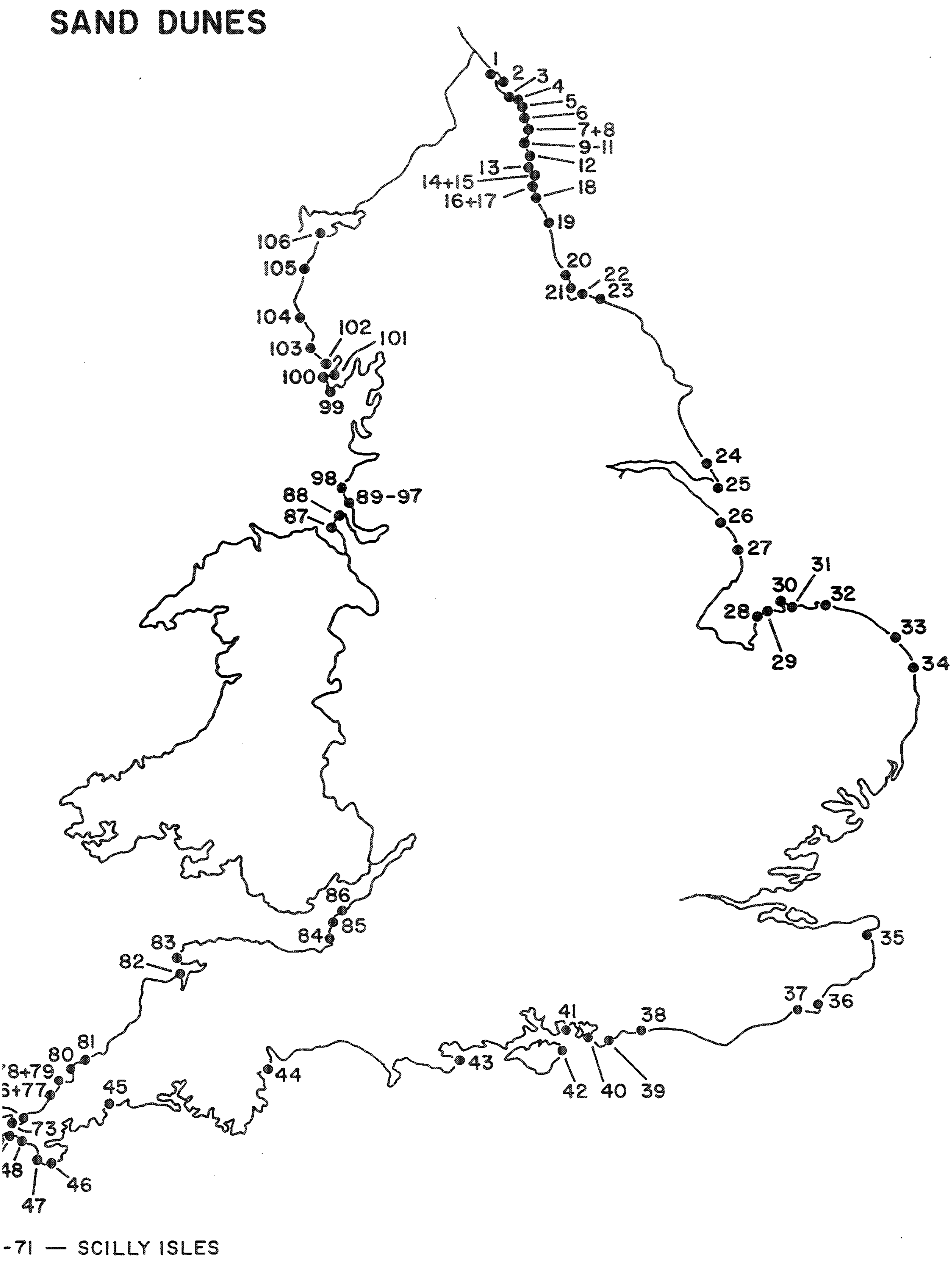

Figure 3.1.Major coastal sand dune localities in England.

Table 3.1: Location of sand dunes in England.

Site	Site Name	Grid Reference	Area (Ha)	Status	County	Cell
001	Cheswick Sands	NU 06 45 - NU 03 47	160.0	SSSI	Northumberland	1
002	Lindisfarne	NU 09 43 - NU 13 43	207.0	NNR, SSSI, R, A, (S) HC, NT	Northumberland	1
003	Ross Links - Budle Bay	NU 13 40 - NU 16 36	348.0	NNR, SSSI, (R), (S)	Northumberland	1
004	Bamburgh - Seahouses	NU 21 32 - NU 17 35	92.0	SSSI	Northumberland	1
005	Annstead Rocks	NU 22 30 - NU 22 31	16.0		Northumberland	1
006	Beadnell Bay	NU 23 26 - NU 23 28	62.0		Northumberland	1
007	Embleton Bay	NU 24 22 - NU 24 23	61.0		Northumberland	1
008	Houdiemont & Sugar Sands	NU 26 16 - NU 26 15	9.0		Northumberland	1
009	Alnmouth Town	NU 25 11 - NU 24 10	5.0	SSSI, A, HC	Northumberland	1
010	Alnmouth Dunes	NU 24 10 - NU 25 08	35.0	SSSI, A, HC, NT	Northumberland	1
011	Warkworth Dunes	NU 25 07 - NU 26 05	76.0	SSSI, HC	Northumberland	1
012	Amble	NU 27 04 - NU 28 03	25.0	HC	Northumberland	1
013	Druridge Bay	NZ 29 93 - NU 28 02	135.0		Northumberland	1
014	Lynemouth	NZ 30 91	19.0		Northumberland	1
015	Lyne Sands	NZ 30 90 - NZ 31 89	69.0		Northumberland	1
016	North Seaton	NZ 29 85 - NZ 30 85	3.0		Northumberland	1
017	Cambois	NZ 30 85 - NZ 30 83	16.0		Northumberland	1
018	Seaton Sluice	NZ 32 79 - NZ 33 77	37.0		Northumberland	1
019	South Shields	NZ 37 67	-.-		Tyne & Wear	1
020	North Sands	NZ 51 34 - NZ 48 37	35.0		Cleveland	1
021	Seaton Dunes & North Gare	NZ 52 30 - NZ 53 26	77.0	SSSI, (R), (S)	Cleveland	1
022	South Gare	NZ 55 27 - NZ 59 25	217.0	SSSI, (R), (S)	Cleveland	2
023	Redcar & Marske	NZ 61 24 - NZ 63 23	-.-		Cleveland	2
024	Holderness	TA 40 19 - TA 41 16	52.0	SSSI	Humberside	2
025	Spurn	TA 41 12 - TA 39 10	64.0	SSSI, (R)	Humberside	2
026	Mablethorpe - Cleethorpes	TF 50 86 - TA 31 08	884.0	NNR, SSSI, (R), (S), CNT, NT	Humberside/Lincs.	2
027	Sutton-on-Sea - Gibraltar Point	TF 56 57 - TF 57 62	376.0	NNR, SSSI, (R), (S) CNT, NT	Lincolnshire	2
028	Holme	TF 72 45 - TF 68 43	134.0	SSSI, R, S	Norfolk	3
029	Thornham - Brancaster	TF 73 45 - TF 79 45	108.0	SSSI, R, A, S, HC, B RS, NT	Norfolk	3
030	Scolt Head	TF 78 46 - TF 84 46	80.0	NNR, SSSI, R, A, S, HC NT, B	Norfolk	3
031	Holkham Bay	TF 85 45 - TF 91 45	266.0	NNR, SSSI, R, A, S, HC, B	Norfolk	3
032	Blakeney - Cley	TG 03 45 - TG 04 44	109.0	SSSI, R, A, S, HC, NT, B	Norfolk	3
033	Winterton - Horsey	TG 45 25 - TG 50 18	302.0	NNR	Norfolk	3
034	Caistor - Yarmouth	TG 52 11 - TG 53 09	137.0		Norfolk	3
035	Sandwich Bay	TR 34 62 - TR 35 62	481.0	RS, NT	Kent	4
036	Romney Warren	TR 08 20 - TR 08 24	77.0		Kent	4
037	Camber Sands	TQ 95 18 - TQ 96 18	101.0	SSSI, (R), (S)	Sussex	4
038	Climping Beach	SU 99 00 - TQ 02 01	16.0	SSSI	Sussex	4
039	Pagham Beach	SZ 87 95 - SZ 88 96	2.0	SSSI, R, S, LNR	Sussex	4
040	East Head	SZ 76 99 - SZ 79 98	21.0	SSSI, R, A, S, LNR, NT	Sussex	5
041	Hayling Island	SU 72 02	93.0	R	Hampshire	5
042	The Duver, St. Helens	SZ 63 89 - SZ 63 88	13.0	SSSI, A, NT	Isle of Wight	5
043	Studland	SZ 03 83 - SZ 03 86	204.0	SSSI, R, S, HC	Dorset	5
044	Dawlish Warren	SX 98 79 - SX 99 80	46.0	SSSI, (R), S, LNR	Devon	6
045	Par Sands	SX 08 53	9.0		Cornwall	6
046	Kennack	SW 73 16	12.0		Cornwall	6
047	Church & Poldu	SW 66 20 - SW 66 19	46.0		Cornwall	6
048	Praa Sands	SW 57 28 - SW 58 27	-.-		Cornwall	6
049	Marazion	SW 51 30	4.0		Cornwall	6
050	Pelistry Bay	SV 92 11	10.0		Scilly Isles	6
051	Bar Point	SV 91 13 - SV 91 12	12.0		Scilly Isles	6
052	Porth Hellick Pool	SV 92 10	12.0		Scilly Isles	6
053	Wingletang Down	SV 88 07	7.0		Scilly Isles	6
054	Porth Conger	SV 88 08	5.0		Scilly Isles	6
055	Burnt Island	SV 87 08	11.0		Scilly Isles	6
056	Samson	SV 88 12	35.0		Scilly Isles	6

Continued.....

Site	Site Name	Grid Reference	Area (Ha)	Status	County	Cell
057	Rushy Bay Dunes	-	22.0		Scilly Isles	6
058	Appletree Banks	SV 89 13	47.0		Scilly Isles	6
059	Old Grimsby	SV 89 15	9.0		Scilly Isles	6
060	Great Bay Dunes	-	15.0		Scilly Isles	6
061	Higher Town Dunes	SV 93 15	6.0		Scilly Isles	6
062	Lower Town Dunes	SV 91 15	10.0		Scilly Isles	6
063	Pentle Bay	SV 90 14	23.0		Scilly Isles	6
064	Porth Loo	SV 90 11	6.0		Scilly Isles	6
065	Popplestone Banks	-	-.-		Scilly Isles	6
066	East Coast	-	11.0		Scilly Isles	6
067	Grimble Porth	SV 88 15	16.0		Scily Isles	6
068	Eastern Isles	SV 93 14 / 94 14 / 93 13 94 13	-.-		Scilly Isles	6
069	Norwethel	SV 89 16	-.-		Scilly Isles	6
070	St. Helens	SV 89 16 - SV 90 16	-.-		Scilly Isles	6
071	Tean	SV 90 16	-.-		Scilly Isles	6
072	Sennan Cove	SW 35 26	-.-		Cornwall	7
073	St. Ives Bay	SW 58 42 - SW 52 39	304.0	SSSI, A, CNT	Cornwall	7
074	Godrevy	SW 80 20	76.0		Cornwall	7
075	Porth Trowan	SW 69 48 - SW 68 47	-.-		Cornwall	7
076	Penhale	SW 76 58 - SW 75 54	542.0	SSSI	Cornwall	7
077	Holywell Bay	SW 76 59	70.0	SSSI	Cornwall	7
078	Crantock	SW 77 60 - SW 78 61	20.0	NT	Cornwall	7
079	Fistral Bay	SW 79 62 - SW 79 01	41.0		Cornwall	7
080	Constantine Bay	SW 85 74	76.0		Cornwall	7
081	Rock Dunes	SW 92 75	96.0	SSSI, S, HC	Cornwall	7
082	Braunton Burrows	SS 44 37 - SS 46 32	1084.0	NNR, SSSI, A, (S), B	Devon	7
083	Woolacombe	SS 45 43 - SS 44 40	46.0		Devon	7
084	Berrow Dunes	ST 29 58 - ST 29 50	177.0	SSSI, R, (S)	Somerset	7
085	Weston Dunes	ST 31 58 - ST 31 59	5.0	SSSI	Avon	7
086	Sand Bay	ST 32 63 - ST 33 65	22.0	SSSI	Avon	7
087	Hoylake	SJ 20 88 - SJ 20 86	74.0	(NNR), SSSI, R, S	Merseyside	10
088	Wirral Coast	SJ 28 93 - SJ 24 91	83.0	SSSI	Merseyside	10
089	Seaforth - Hightown	SJ 30 98 - SD 29 02	155.0	SSSI, (R), (A), (S), CNT	Merseyside	10
090	Formby Point	SD 26 06	178.0	SSSI, (R), (S)	Merseyside	10
091	Formby Golf Course	SD 27 08	303.0	SSSI, (R), (S)	Merseyside	10
092	Cabin Hill	-	237.0	NNR, SSSI, NT	Merseyside	10
093	Ainsdale LNR	SD 27 09 - SD 29 12	111.0	SSSI, LNR	Merseyside	10
094	Ainsdale NNR	"	343.0	NNR, SSSI	Merseyside	10
095	Birkdale Hills	SD 30 13 - SD 31 15	418.0	SSSI, LNR	Merseyside	10
096	Southport	SD 31 16 - SD 34 19	78.0	SSSI	Merseyside	10
097	Lytham St. Anes	SD 35 26 - SD 32 27	-.-		Lancashire	10
098	Fylde Coast	SD 31 28 - SD 30 31	57.0	(SSSI)	Lancashire	10
099	South Walney	SD 18 73 - SD 16 70	81.0	SSSI	Cumbria	10
100	North Walney	SD 16 71 - SD 17 73	142.0	SSSI, (R), (S)	Cumbria	10
101	Sandscale Haws	SD 19 75 - SD 18 74	199.0	SSSI, (R), (S), NT	Cumbria	10
102	Haverigg	SD 13 79 - SD 16 78	130.0	SSSI, (R), (S)	Cumbria	10
103	Eskmeals	SD 07 91 - SD 04 99	227.0	SSSI, (R), LNR, CNT	Cumbria	10
104	Seascale - Drigg	SD 04 99 - NY 03 01	345.0	SSSI, LNR	Cumbria	10
105	Silloth - Hightown	NY 03 37 - NY 10 53	322.0	SSSI, A	Cumbria	10
106	Grune	NY 12 56 - NY 14 56	55.0	SSSI, A	Cumbria	10

KEY

1. Status: Concerns the conservation status of each site. Blank areas indicate that no designations are known to apply to those particular sites. Where the code letters are within brackets, this indicates that the designation in question is proposed for that site.

Codes Used:

NNR -	National Nature Reserve	LNR -	Local Nature Reserve
SSSI -	Site of Special Scientific Interest	B -	Biosphere Reserve
R -	Ramsar Site	RS -	R.S.P.B. Reserve
A -	Area of Outstanding Natural Beauty	NT -	National Trust
S -	Special Protection Area	CNT -	County Naturalist Trust Reserve
HC -	Heritage Coast	C -	Coastal Protection Area

2. Cell: Refers to the process cell designated in the Macro Review of the Coastline of England & Wales (Hydraulics Research, see References). Cells 8 and 9 occur along the Welsh coast and as such, are not considered in this report.

{SOURCE: Radley (1992), with additional data from other sources.}

Table 3.2: Estimated area of sand dunes along the English coast (ha).

County	Coastwatch Database	Radley (1992)
Cumbria	978.76	1501.0
Lancashire	105.26	57.0
Merseyside	903.62	2113.0
Cheshire	0.00	0.0
Gloucestershire	0.00	0.0
Avon	4.50	27.0
Somerset	77.20	177.0
Devon	978.58	1176.0
Cornwall	853.26	1334.0
Scilly Isles	-.-	288.0
Dorset	67.90	204.0
Hampshire	24.74	93.0
Isle of Wight	-.-	13.0
Sussex	68.46	139.0
Kent	402.26	593.0
Greater London	0.00	0.0
Essex	17.88	0.0
Suffolk	99.20	0.0
Norfolk	999.72	1136.0
Cambridgeshire	0.00	0.0
Lincolnshire	1342.46	1235.0
Nottinghamshire	0.00	0.0
Humberside	76.42	141.0
Yorkshire	2.88	0.0
Cleveland	245.15	329.0
Durham	14.20	0.0
Tyne & Wear	23.46	0.0
Northumberland	955.71	1375.0
Total	**8241.62**	**11897.0**

Process Cell	Dune Area (ha.) (Radley 1992)
1	1487.0
2	1593.0
3	1136.0
4	698.0
5	310.0
6	481.0
7	2521.0
10	3671.0
Total	**11897.0**

and (9) fringing dunes. Some of the larger and older dune complexes are composite, being composed of more than one morphological element or having evolved from one type to another .

In England, dunes occur in four main areas, with scattered occurrences elsewhere (Figure 3.1):

1. The northeast coast between Lindisfarne and Redcar. Most of the dunes here consist of relatively narrow fringing and bay-head complexes, with some barrier spit developments. The foredunes are often backed by rolling 'links' topography which has traditionally been heavily grazed.

2. The east coast between north Lincolnshire and northeast Norfolk. Many of these dunes here have developed on prograding barrier spits and islands, although examples of fringing dunes and ness dunes are also represented.

3. The coast of southwest England, including the Isles of Scilly and north coast of Cornwall, Devon and Somerset. Examples of bay-head, cliff-foot, climbing, cliff-top and barrier spit dunes are well represented.

4. The coast of northwest England between the Wirral and north Cumbria. This area contains the largest single area of blown sand in the the United Kingdom, located between Liverpool and Southport (Pye, 1990), the main body of which originated as a barrier island which has subsequently been modified (Pye & Neal, 1993). Fringing dunes, cliff-foot dunes and barrier spit dunes are well-represented elsewhere on this coast.

A list of dune sites and information about areal extent and conservation status is presented in Table 3.1. Summaries of resource extent by county and by major process cell are given in Table 3.2 .

Merseyside has the largest area of windblown sand, followed by Cumbria, Northumberland, Cornwall and Norfolk. Dunes are generally poorly developed along the coasts of southeastern and southern England.

In several areas dunes play an important sea defence function, although there have been fewer attempts to manage dunes in the U.K. for this purpose than in some other countries, for example The Netherlands. Examples where dunes are important in this context include the Sefton coast and the coast of northeast Norfolk between Sea Palling and Horsey (although the latter section has been reinforced by hard defences).

3.3.3. Vegetation communities

There are six major community structures whose distribution and abundance partly reflects the pattern of variation in dune accumulation type (Malloch, 1985, 1989; Radley, 1992):

1. Strandline communities (SD2 & SD3) - The SD2 (*Honkenya peploides / Cakile maritima*) community has a nation-wide distribution but with major areal development in Norfolk, Cumbria, and the Scilly Isles. In contrast, SD3 (*Matricaria maritima / Galium aparine*) is found only in Merseyside and Northumberland.

2. Mobile dune communities (SD4, SD5 & SD6) - The SD4 (*Elymus farctus* ssp. *borealis atlanticus*) foredune community is restricted mainly to the east coast, as is SD5 (*Leymus arenarius*), which is found only as far south as the Wash. Much more widespread is the SD6 *(Ammophila arenaria)* community, which dominates most mobile dune belts. Within SD6, 7 sub-communities are recognized in the National Vegetation Classification (NVC). SD6A (*Elymus farctus*) achieves national coverage with the exception of the Isles of Scilly; SD6b (*E. farctus / Leymus arenarius*) is predominantly restricted to north east England, but with a major outlier at Berrow Dunes in Somerset. Similarly, SD6c (*L. arenarius* sub-community) is restricted to the north. SD6d ('typical' *Ammophila arenaria* sub-community) occurs only on the west coast. SD6e (*Festuca rubra* sub-community) is widely distributed, SD6f (*Poa pratensis*) has a predominantly northern and eastern distribution, and

SD6g (*Carex arenaria*) is rare with widely scattered occurrences.

3. Semi-fixed dune communities (SD7) dominated by *A. arenaria* sub-communities. SD7a (*A. arenaria / Festuca rubra* 'typical' sub-community) is mainly restricted to Northumberland and Norfolk, but with small areas in the south and west. SD7b (*Hypnum cupressiform*) has a wide range but is absent on the south coast. SD7c (*Ononis repens*) and SD7d (*Tortula ruralis*) both occur nation-wide, although SD7c is more abundant on the west coast. In contrast, SD7e (*Elymus pycanthus*) is largely restricted to the east coast.

4. Fixed dune grassland communities, dominated by *Festuca rubra* (SD8), *Ammophila arenaria / Arrhenatherum* (SD9) and *Carex arenaria / Festuca ovina / Agrostis capillaria* (SD12) communities. SD8 contains six sub-communities: SD8a ('typical') is the most widespread with SD8b (*Lazula campestris*) being restricted to the north and west. SD8c (*Tortula ruralis*) is predominantly western with isolated east coast appearances to the north of the Wash. Both SD8d (*Bellis perennis / Ranunculus acris*) and SD8e (*Prunella vulgaris*) are restricted to the north and west. SD9a ('typical') is widespread except in the south and southwest, whilst SD9b (*Geranium sanguineum*) is exclusively found in the northeast. SD12a (*Anthoxanthum* sub-community) occurs nationwide while SD12b (*Holcus lanatus*) is restricted to the north and east.

5. Fixed dune sand sedge dominated communities, dominated by *Carex arenaria* (SD10) and *C. arenaria / Cornicularia aculeata* (SD11). The SD10a (*Festuca rubra*) sub-community is widespread, but SD10b (*F. ovina*) is largely restricted to Norfolk and Kent. SD11a (*A. arenaria* sub-community) has a nationwide distribution, but with a high concentration in Norfolk. The SD11b (F. ovina) sub-community is confined to East Anglia.

6. Dune slack communites dominated by *Salix repens* (SD13, SD14, SD15 & SD16) and *Potentilla anserina / Carex nigra* (SD17). The SD13a sub-community (*Poa annua / Hydrocotyle vulgaris*) is nationally rare while SD13b (*Holcus lanatus / Festuca rubra*) is restricted to Northumberland and Merseyside. The four sub-communites of SD14 (*S. repens / Campylium stellatum*) have 75% of their national extent at Braunton Burrows, while those of SD15 (*S. repens / Calliergan cuspidatum*) are restricted to the west coast and a small area in Northumberland. All three SD16 sub-communities have a national distribution, while the four SD17 sub-communities show a high northerly concentration with an outlier of SD17d in Cornwall.

3.4 Threats to sand dune habitats

Natural threats to the extent of coastal sand dunes are associated principally with coastal erosion. Threats due to human activity range in severity from change in land use (e.g. from dune grassland or heath to cultivated land or golf course) to complete obliteration through sand mining or urban development. Although many usages of dune areas, such as military firing ranges and recreation developments, result in damage to the habitat, they do not generally lead to a total loss, and some or all of the damage may be recoverable.

Conversion of dune areas to grazing land may cause partial or total loss of particular vegetation communities and their replacement by others, but many British dune areas have been grazed for centuries (Boorman, 1989) and for the purpose of this review such a change is not considered as habitat 'loss'.

Afforestation has previously been considered as a means of loss of dune habitat , although its effects are reversible. Only two dune areas in England contain significant conifer plantations, Sefton (269 ha, representing 22% of the total area), and Holkham (90 ha, representing 10% of the area reported by Doody, 1989a). In both areas most of the trees were planted around the turn of the century. Since 1989 part of the coniferous woodland within the Ainsdale NNR has been removed to increase the area of 'yellow dune' within the Reserve.

Development of golf courses has also been considered to be a cause of loss of dune habitat (Doody, 1989a,b, 1992), although their existence has sometimes served to protect dune areas from more damaging developments. The same is true of military training areas.

Construction of coastal protection works may lead to a partial or total isolation of a dune area from the beach which acts as its source of sediment, but in such circumstances the existing dunes are usually only partially lost through levelling, excavation for use as fill, or burial by roads and car parks (e.g. on the north coast of the Wirral). If sand supply to the beach is abundant, new dunes may form rapidly to seaward or on top of the hard defence, as has occurred on the Sea Palling to Horsey coastline in northeast Norfolk.

3.5. Recent habitat loss

3.5.1 Erosion loss

No systematic national or regional surveys of dune habitat loss have been carried out, but it was observed during fieldwork for the *National Inventory of English Sand Dunes*, carried out between 1987 and 1991, that 67 out of a total of 121 sites surveyed showed evidence of recent net erosion damage to the frontal dunes, compared with a total of 21 sites which showed evidence of net progradation. The remaining sites were either in approximate equilibrium or are 'relict', being cut off from the sea by coastal defences or by younger coastal deposits (Radley, 1992). Almost all of the sites in Northumberland were observed to show evidence of recent foredune erosion. By contrast, accretion or stability appeared to be dominant in south Humberside and north Lincolnshire, south Lincolnshire and Norfolk. A majority of sites in southwest England showed evidence of recent erosion, but in northwest England a complex pattern was observed, with areas of both net erosion and net accretion occurring in close proximity.

The observed pattern of widespread erosion may reflect an observed increase in mean wave heighy around the British Isles (Bacon & Draper, 1991). However, it would be unwise to base estimates of longer-term change on the results of a 'snap-shot' survey. The period 1989-1991 saw the occurrence of a number of exceptionally severe storms, most notably in January 1989 and February 1990, which caused severe and extensive damage to soft coastal features. Detailed studies of the dynamic behaviour of dune coasts over a number of years have shown that it may take several years for the evidence of a severe storm to be eradicated (Pye, 1990; 1991; Pye & Neal, in prep.). The rate of foredune recovery isdirectly dependent on the littoral sediment budget within any given length of coast. If the budget is positive, and more sand is accreted to the beach / foredune system in the interval between major storms than is removed by each such storm, then the shoreline will display net seaward progradation over a period of years. If, on the other hand, the sediment budget is negative, coastal retreat during storms will not be compensated by progradation during the intervening periods and the shoreline will show a net landward displacement.

A number of local authorities, private landowners and reserve wardens have made measurerments of coastal erosion / accretion in recent decades, but there are few continuous and reliable long-term data sets. One of the best documented cases relates to the Sefton coast in northwest England (Smith, 1982; Pye & Smith, 1988). Several lines of evidence show that dunes prograded seawards along the entire coast between Southport and Altcar during the second half of the 19th century, in part encouraged by the planting of rows of faggots on the upper foreshore. This practice ended around the turn of the century, when erosion began at Formby Point. Since then erosion of the dune frontage has spread northwards towards Ainsdale, and is currently most severe on the north side of Formby Point where the frontal dunes are being eroded at an average rate of approximately 3 m/yr. The change to erosion is related to bathymetric changes offshore from Formby Point which were in part caused by the construction of training walls in the Mersey approaches (Pye & Neal, in prep). Since 1900 the high water mark at Formby Point has moved landwards by more than 500 m, and more than 80 ha of dunes have been lost. However, this has been compensated by progradation of new dunes to the north and south of the eroding shore section.

A broadly similar situation exists on the east coast between the Humber and the Wash. The remaining unprotected frontal dunes between Mablethorpe and Skegness have suffered slight net retreat during the last 30 years (average rate 0.5 m/yr), but to the north of Mablethorpe near Donna Nook and to the south of Skegness at Gibraltar Point new dune-capped spits and bars have prograded seawards and alongshore (average rate 4 - 8 m/yr; Anglian Water, 1988a).

In north Norfolk, a spatially more variable pattern exists, with seaward progradation or longshore-extension of dune-capped bars and spits having taken place near Holme next-the Sea, Thornham, between Burnham Harbour and Wells, and at Blakeney Point, while the dune frontage has been eroding between Titchwell and Brancaster, at the eastern end of Scolt Head Island and at Stiffkey. Maximum retreat rate on eroding sections is 2 m/yr, but 0.5 - 1.0 m /yr is more typical (Anglian Water, 1988a). At many of the eroding sites, the frontal dune has not disappeared, but has retreated landwards.

Little information is available about average rates of dune erosion / accretion over the last 20 years in southwest England, although published accounts and map evidence suggest a pattern of net stability. Some frontal dune recession has occurred, e.g. at Woolacombe, Croyde and Braunton, but in some of the more high energy embayments blown sand has continued to extend inland. Overall, the total loss of dune area due to erosion in the southwest is unlikely to exceed 10 ha.

Similarly, little quantitative information is available about rates of frontal dune erosion in northeast England, but evidence available from maps and air photographs suggests the total loss in the last 20 years is relatively small (<20 ha; Pye, in prep).

Nationally, the total net loss of dune area due to erosion is estimated to be less than 1% (120 ha) during the last 20 years.

3.5.2. Loss due to human activities

No quantitative data relating to areas or rates of loss are available either on a national or regional basis, but there is ample qualitative evidence that such losses have been significant since the Second World War. The major mechanisms of loss have been residential and recreational development, sand mining, waste dumping and golf course construction.

The most serious losses occurred prior to the mid 1970's, but even in the last 20 years a number of significant areas have been lost. Major housing developments encroached on dune land at Formby, Ainsdale, Birkdale, Hightown and Crosby on the Sefton coast during the 1960's and 1970's, although it is now the Local Planning Department's policy to resist further proposals for such development (Houston & Jones, 1987; Cox, 1990).

Since the late 1960's, increasing areas of dune land have been purchased or become subject to management agreements by conservation bodies such as the National Trust, Nature Conservancy, Royal Society for the Protection of Birds and local Naturalists Trusts. Many local authorities have also designated dune areas as Country Parks or Local Nature Reserves. Added protection has been provided by the designation of some areas with Heritage Coast areas, Ramsar sites, and Special Protection Areas. Consequently the rate of loss of dune habitat due to human activities, like that of many of the other coastal habitats considered in this report, has steadily declined in the last 20 years. Most affected in the very recent past, and likely to be so in the future, are dune areas which have no formal conservation status and which are relatively accessible from urban areas.

3.6 Projected habitat loss

3.6.1 Erosion loss

The effect of accelerated sea level rise is likely to vary greatly between different sections of coastline. The balance of the sediment budget often varies significantly in a longshore direction within individual coastal cells, particularly where the coastal orientation is oblique to the approach direction of the dominant waves. Under such conditions, littoral drift is a significant process and sediment budgets are typically negative at the updrift end of the coastal cells. At the downdrift end of the cell the sediment budget may be positive. Foredunes may therefore prograde seawards or grow vertically at one end of a coastal embayment while eroding at the other (May, 1985). By redistribution of sediment from the updrift to the downdrift end of the cell the coastline orientation may be changed to one which is in closer equilibrium with the incident-wave and current processes.

An increase in the frequency or magnitude of major storms, if it occurred, would be expected to lead to an acceleration in the rate of frontal dune erosion. The areas most at risk would be exposed sections of coastline, particularly on the west coast of England, which receive the full impact of storms from the southwest, west and northwest. However, under certain circumstances, severe storms may actually lead to an increase in the areal extent of dunes. Two cases may be cited: (1) storms may form new ridges of sand and shingle which subsequently act as nuclei for dune growth; many of the spit dune complexes in England, including Gibraltar Point, have developed in this way; (2) a succession of storms may initiate the development of major blowouts and transgressive sand sheets which migrate inland, burying non-dune topography. Much of the inland blown sand at Formby and elsewhere originated in this way during stormy periods of the Middle Ages (Pye & Neal, 1993).

Seaward progradation of beach and foredune ridges is the exception, rather than the rule, on the moderate to high energy coastline of England at the present day, occuring only when there is a markedly positive beach sediment budget. Such circumstances may be found naturally in areas of wave divergence, or can be triggered by a change in offshore bathymetry and wave refraction patterns, either natural or induced by dredging, training wall construction and land claim. Although such circumstances will continue to occur locally, most coastal dune frontage is likely toexperience some degree of erosion in the next 20 years. The average rate of shoreline recession will vary, but is likely to be in the range 0.5 - 2 m/yr in most situations, giving a total linear retreat of 10 - 40 m over the period. Recession during a single storm can amount to 10-20 m (Pye, 1991), but much of this may be quickly regained.

Not all of the sand eroded from the frontal dunes will be lost offshore or alongshore; on windy coasts, especially, shoreline recesssion is likely to be accompanied by the build-up of a high foredune which retreats landward, or by the development of multiple blowouts and transgressive sand sheets (see Pye, (1990) and Psuty (1989) for a discussion of factors which control dune morphological response to erosion).

Given the substantial inland extent of many of England' s major dune complexes, it is unlikely that more than 2% of the present area will be lost through erosion in the next 20 years. These losses are likely to occur mainly in areas with limited supplies of sand and a steep nearshore profile (e.g. many embayments in Northumberland, Cornwall, and north Devon).

Changes in groundwater levels associated with sea level rise and climate change, and the direct effects of changes in temperature and rainfall, will have a more wide-ranging influence on the ecology of coastal dune systems (van der Meulen 1990; Carter 1991). However, they are unlikely to have a significant effect on their total areal extent.

3.6.2 Human activities

At present, dune areas under statutory protection form a comparatively small proportion of the total area of habitat. The National Trust manages 17 sites, and 10 NNR's contain significant areas of dune habitat. Local Nature Reserves account for a further 6 sites and there are 31 others managed by various other conservation bodies (Radley, 1992). In addition, 12 dune areas fall within Ramsar sites (a further 16 fall with proposed areas), and 12 are within designated SPA's (a further 15 lie in proposed areas). These sites are, therefore, likely to less vulnerable to future anthropogenic habitat loss than sites with no statutory designation. However, increasing recreational pressure on designated reserve areas may result in damage and some further loss to car park construction, visitor facilities etc.

The *Estuaries Review* database 1992 update records a number of planning proposals involving dune habitat loss (Table 3.3). The large proposal in Merseyside relates to a golf course development which has very recently been switched to a location outside the dune area (Sefton Planning Department, pers. comm.).

Table 3.3: Proposals involvling dune habitat loss, recorded in the Estuaries Review Database (updated to 1992).

County	Area (ha)	
Cumbria	6.0	
Merseyside	140.0	
Lincolnshire	3.0	
Cleveland	25.0	
Total	174.0	(2.1% of the national resource)

3.7 Targets for habitat recreation

By comparison with some of the other habitats considered in this report, sand dunes remain relatively abundant and are judged not to be at serious risk of major loss. The total net loss in the next 20 years is unlikely to exceed 240 ha, or 2% o the existing resource. New dunes are actively forming in some areas, for example at Ainsdale and Holkham, and are likely to continue to do so even if there is a slight acceleration in sea level rise. Left to adjust naturally, many dune systems will respond to coastal erosion by moving landwards. Where possible, dunes should be allowed to retreat unhindered (subject to the requirements of maintaining an adequate sea defence). If such a policy cannot be adopted, for example where dunes are backed by residential property, dune stabilization measures may be necessary, perhaps involving shoreline maintenance by beach feeding in preference to the construction of hard defences. Where there is a natural accretion trend, or general stability, foredune growth should be encouraged and steps taken to prevent loss of the newly formed habitat areas (e.g. by sand mining or intensive recreational development).

4 SALT MARSH

4.1 Habitat definition

Coastal saltmarshes are environments high in the intertidal zone which are covered by halophytic vegetation. The lower limit of pioneer marsh vegetation corresponds approximately with the level of mean high water of neap tides, while the potential upper limit is slightly above the level of mean high water spring tides. In many areas algal-covered mud or sand-flats occur to seaward of the saltmarsh zone, while the landward margin is formed by a transition zone to brackish and freshwater communities, or by an artificial embankment.

4.2 Data sources and reliability

A listing of saltmarsh sites and areas was obtained from *The Saltmarsh Survey of Great Britain* (Burd, 1989). A second source of data was provided by the *Coastwatch* database. The original *Coastwatch* mapping categories of *salt marsh* and *salt marsh / pasture* have been combined to produce a single figure for 'salt marsh' which is cited in this report. In the case of the *Saltmarsh Survey*, marsh areas were drawn on sketch maps, based on reconnaissance field walking, often without close reference to an O.S. base map or aerial photographs. The information from sketch maps was then transferred by hand to base maps at a scale of 1:25,000 or 1:50,000. Areas covered by individual vegetation communities were calculated by manual techniques using dot grids. Data for a few areas (principally Roach / Foulness) were not included owing to difficulties in obtaining access and adequate air photograph coverage. The estimates of aerial extent therefore cannot be regarded as entirely accurate but probably give a representative picture of relative regional differences.

The total national figure for saltmarsh area given by Burd is approximately 15% higher than that indicated by the *Coastwatch* database. A possible explanation for this is that the latter survey did not extend sufficiently far seaward in areas with a very wide intertidal zone.

Data on changes in saltmarsh extent were obtained from a variety of published and unpublished sources which are referenced in the *Saltmarsh* database being compiled by CERC Ltd. under contract to MAFF Flood Defence Divsion (Pye & French, in prep.). However, the only detailed study of areal extent changes on a regional scale so far published is the survey of *Erosion and Vegetation Change on the Saltmarshes of Essex and north Kent between 1973 and 1988* (Burd, 1992). This was based on a comparison of the results of the 1973 Maplin survey (Boorman & Ranwell, 1977) with 1:10,560 colour (for Suffolk and Kent) and 1:5,000 black and white (for Essex) air photographs taken in 1985 and 1988 respectively. The position of the marsh edge and community boundaries were mapped directly onto O.S. base maps, being validated by ground observations in a majority of cases. Differences in marsh extent between the times of the two surveys were determined using an Intergraph GIS system. However, the mapping of the saltmarsh edge in the 1973 survey was rather generalized, and some apparent differences between the two surveys may be an artifact of the mapping techniques used (Burd, 1992, p.75). The apparent rates of loss probably slightly overestimate the actual loss, since internal details within marsh areas were not fully represented in the earlier survey. However, the general patterns of loss identified are considered to be valid.

4.3 Resource extent

4.3.1 National Area:

32462 ha (Burd, 1989)

4.3.2 Regional distribution and habitat importance

The distribution of major saltmarshes in England is shown in Figure 4.1 and a listing of sites given in Table 4.1. In terms of area, the most extensive active marshes occur in southeast England (Essex, north Kent and the southern part of Suffolk), northwest England (Cumbria, Lancashire, Merseyside and Cheshire), eastern England (Lincolnshire and north Norfolk), and southern England (Hampshire, Dorset and West Sussex (Table 4.2). The Outer Thames estuary alone contains 19% of the total national resource.

Active saltmarshes play an important role both as natural habitats and as coastal defences (see papers in Allen & Pye, 1992; Hydraulics Resarch Ltd. 1987, 1988; Toft & Townend, 1991). In ecological terms, marshes are particularly important as roosting areas and nesting sites for birds, including a number of species of international importance. In sea defence terms, saltmarshes which are located in front of earth embankments act as a natural buffer which absorbs the impact of wave energy, thereby reducing the probability of overtopping and breaching (Brampton, 1992). During storms, erosion of the saltmarsh edge serves to resupply the fronting mudflat with sediment, thereby reducing the rate of lowering of the intertidal profile and encouraging the establishment of a new equilibrium with the indicent waves (Pethick, 1992a, 1992b).

4.3.3 Vegetation communities

Although many species of marsh vegetation occur throughout the country, there are important differences in overall character between marshes on the western, eastern and southern coasts (Ranwell, 1972; Adam, 1978, 1990). Many of the more sandy west coast estuarine marshes are dominated by a *Puccinellia* sward which has traditionally been heavily grazed, although there has also been a rapid spread of *Spartina* in some areas during the present century. Many of the east coast marshes are typically more muddy and are dominated by *Salicornia - Aster - Halimione* communities. In general, the influence of grazing has been less pronounced than on the west coast. *Spartina* has also colonized some east coast marsh areas in the past 100 years, but it remains less dominant than on the south coast where such marshes are very widespread (see papers in Doody, 1985; Gray & Benham, 1990). Areal extent data for the different marsh communities in the former NCC regions are given in Burd (1989).

4.4 Threats to saltmarsh habitats

The principal natural threat to saltmarshes is erosion, which may be induced by a number of factors including the migration of estuarine channels, changes in coastal nearshore profile, a reduction in sediment supply, an increase in sea level, or an increase in storm wave activity.

Erosion may also follow damage to the vegetation, caused by disease or environmental stress. Changes in temperature, rainfall and soil chemistry conditions are likely to be most significant where particular species exist close to the limits of their range, either latitudinal or with respect to the tidal frame.

The main anthropogenic threats (excluding erosion induced by dredging, navigation etc.) are land claim for agriculture or industrial development, spoil dumping and waste tipping, sediment extraction (e.g. for brick-making), pollution and tidal barrage construction. Serious damage may also occur to parts of a marsh where recreational pressure is heavy, for example along pathways and around marinas, and where material is taken from the marsh surface to facilitate improvements to sea defences. Turf cutting and grazing of unenclosed marshes often reduces the species diversity of marshes but rarely results in major damage or total loss of the habitat (Doody, 1992a).

4.5 Recent habitat loss

4.5.1 Erosion loss

A review of the accretion / erosion status of saltmarshes around the coast of England has indicated that the majority of marshes in the northwest have experienced stability or lateral accretion in the past two decades, although there are localized areas of erosion (Pye & French, in prep.). There has been rapid expansion of saltmarsh in parts of the Dee estuary, Ribble estuary, Solway Firth, Morecambe

SALT MARSHES

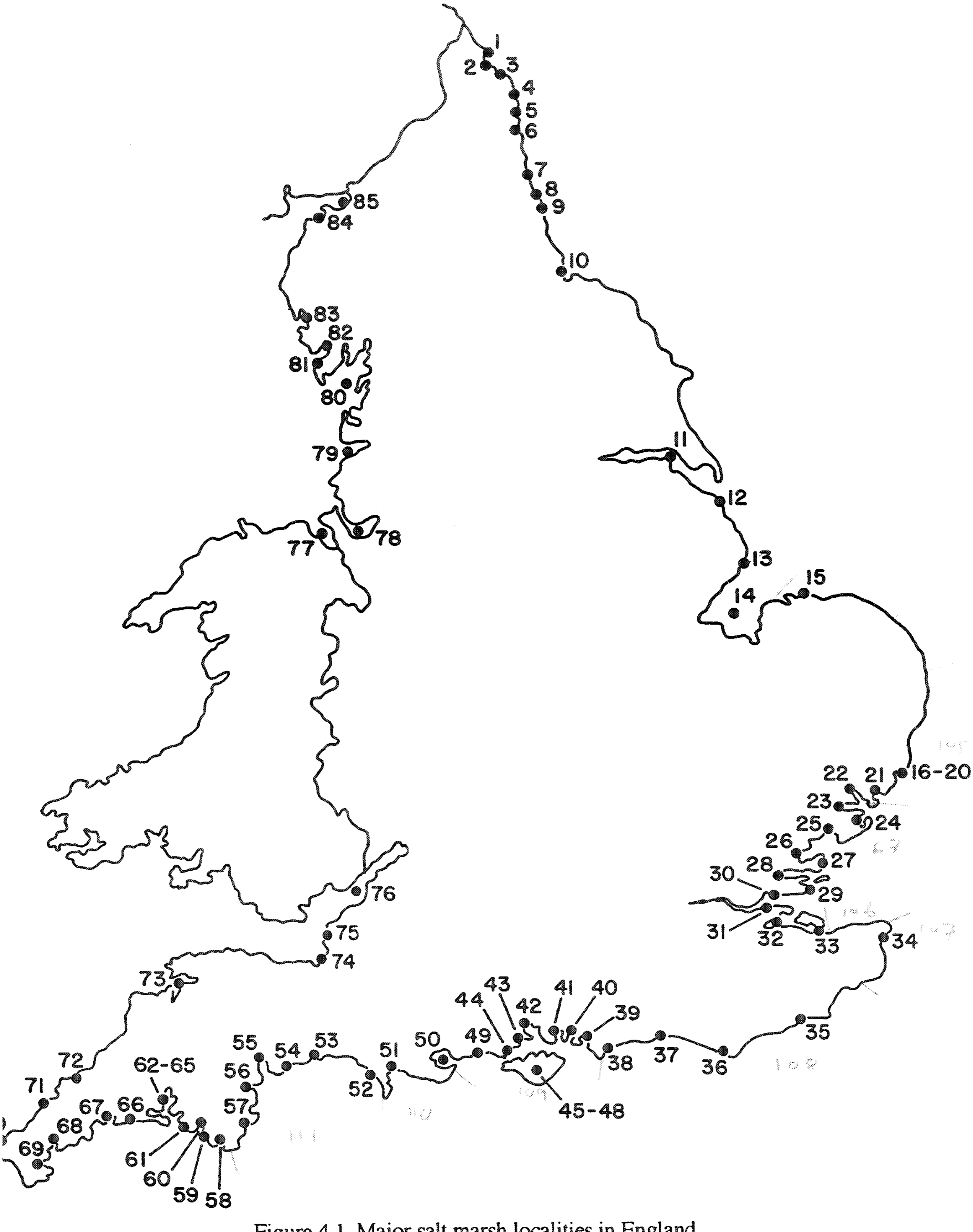

Figure 4.1. Major salt marsh localities in England.

Table 4.1: Location of salt marshes in England

Site	Site Name	Grid Reference	Area (Ha)	Status	County	Cell
01	Holy Island	NU 107 433	33.00	NNR, SSSI, R, A, S, HC, NT	Northumberland	1
02	Lindisfarne	NU 087 412	175.71	NNR, SSSI, R, A, S, HC	Northumberland	1
03	Budle Bay	NU 144 352	9.00	NNR, SSSI, R, A, HC	Northumberland	1
04	Long Nanny	NU 227 269	9.00	SSSI, A, HC	Nothumberland	1
05	Alnmouth	NU 243 102	23.78	SSSI, A, HC	Northumberland	1
06	Warkworth	NU 258 057	14.54	SSSI, A, HC	Northumberland	1
07	Seaton Sluice	NZ 334 763	3.90		Northumberland	1
08	Willington Gut	NZ 313 668	3.36	SSSI	Tyne & Wear	1
09	Castletown Marshes	NZ 360 576	5.55	SSSI	Tyne & Wear	1
10	Cowpen Marsh	NZ 500 259	34.16	SSSI, (R), (S), LNR, CNT	Cleveland	1
11	Humber Estuary	TA 17 22	647.86	SSSI, (R), (S), (HC), LNR CNT, RS	Humberside	2
12	North Lincolnshire Coast	TA 420 001	771.35	SSSI, (R), (S)	Lincolnshire	2
13	Gibraltar Point	TF 566 590	66.64	SSSI, LNR	Lincolnshire	3
14	The Wash	TF 360 360	4133.00	NNR, SSSI, CNT, B, RS	Lincolnshire/Norfolk	3
15	North Norfolk Coast	TF 88 45	2126.65	NNR, SSSI, R, A, S, HC RS, B, CNT	Norfolk	3
16	Alde River	TM 420 570	162.80	SSSI, A, HC, CNT	Suffolk	3
17	Orfordness	TM 452 490	116.54	NNR, SSSI, R, A, (S), HC	Suffolk	3
18	Havergate Island	TM 415 475	29.20	NNR, SSSI, R, A, CNT (S), HC, RS	Suffolk	3
19	River Ore	TM 390 459	129.67	SSSI, A, HC	Suffolk	3
20	Butley River	TM 397 490	123.68	SSSI, A, HC	Suffolk	3
21	River Deben	TM 300 418	461.30	A, HC	Suffolk	3
22	River Orwell	TM 220 385	118.79	SSSI, (R), A, (S), CNT	Suffolk	3
23	River Stour	TM 180 330	296.57	SSSI, (R), A, (S), RS, CNT	Suffolk/Essex	3
24	Hamford Water	TM 230 255	863.27	NNR, SSSI, (R), (S), CNT	Essex	3
25	River Colne & Mersea Island	TM 075 155	670.56	NNR, SSSI, (R), (S) CNT, LNR	Essex	3
26	River Blackwater	TL 940 070	1102.85	NNR, SSSI, (R), (S) RS, LNR, CNT	Essex	3
27	Dengie	TM 035 040	404.84	NNR, SSSI, (R), (S), CNT	Essex	3
28	River Crouch	TQ 900 965	468.28	SSSI, (R), (S), LNR, CNT	Essex	3
29	River Roach & Foulness	TQ 966 905	590.52	SSSI, (R), (S)	Essex	3
30	Canvey Island	TQ 770 855	376.91	NNR, SSSI, (R), (S), LNR, CNT	Essex	3
31	South Thames	TQ 795 789	77.67	SSSI, (R), (S), (LNR)	Kent	4
32	River Medway	TQ 850 710	754.46	NNR, SSSI, RS, LNR	Kent	4
33	River Swale	TQ 960 665	413.82	NNR, SSSI, R, S, RS, LNR, CNT	Kent	4
34	Sandwich Bay	TR 345 625	99.28	NNR, SSSI, NT, LNR, RS, CNT	Kent	4
35	Rye Harbour	TQ 934 195	54.43	SSSI, (R), (S), LNR	Sussex	4
36	River Cuckmere	TV 516 990	9.66	SSSI, A, HC, LNR	Sussex	4
37	River Adur	TQ 206 059	8.66	SSSI, A, RS	Sussex	4
38	Pagham Harbour	SZ 870 970	33.30	SSSI, (R), LNR, CNT	Sussex	4
39	Chichester Harbour	SU 760 000	1076.92	SSSI, A, S, (LNR)	Sussex/Hampshire	5
40	Langstone Harbour	SU 700 030	100.28	SSSI, R, S , CNT, LNR, RS	Hampshire	5
41	Portsmouth Harbour	SU 620 035	181.15	SSSI	Hampshire	5
42	Southampton Water	SU 460 065	354.99	SSSI, (R), (S), CNT, LNR	Hampshire	5
43	Western Solent	SZ 335 938	505.90	SSSI, A, (S), CNT, LNR	Hampshire	5
44	Beaulieu River	SZ 416 998	1151.20	NNR, SSSI, A	Hampshire	5
45	King's Quay	SZ 537 938	13.80	SSSI	Isle of Wight	5
46	River Yar	SZ 352 885	66.41	SSSI, A	Isle of Wight	5
47	Newtown Harbour	SZ 420 910	120.26	SSSI, A, (S), HC, NT, LNR	Isle of Wight	5
48	River Medina	SZ 508 923	13.34	SSSI	Isle of Wight	5

Continued....

Site	Site Name	Grid Reference	Area (Ha)	Status	County	Cell
49	Christchurch Harbour	SZ 175 910	49.80	SSSI, LNR	Dorset	5
50	Poole Harbour	SZ 000 880	696.93	NNR, SSSI, (R), A, (S) CNT, HC	Dorset	5
51	Lodmoor	SY 687 813	31.56	SSSI, RS, CNT	Dorset	5
52	The Fleet	SY 620 612	51.45	SSSI, R, A, S, HC	Dorset	6
53	River Axe	SY 254 910	34.25	C	Devon	6
54	River Otter	SY 075 825	19.25	SSSI, A, RS, CNT, C	Devon	6
55	River Exe	SX 980 840	66.52	SSSI, (R), (S), RS, LNR NT, CNT, C	Devon	6
56	Teign Estuary	SX 905 725	13.00	C	Devon	6
57	Dart Estuary	SX 860 558	25.00	A, HC, NT, C	Devon	6
58	Kingsbridge Estuary	SX 746 408	4.50	SSSI, A, HC, (LNR) NT, C	Devon	6
59	River Avon	SX 678 462	25.52	A, NT, C	Devon	6
60	Erme Estuary	SX 622 490	20.75	SSSI, A, HC, C	Devon	6
61	River Yealm	SX 545 498	2.46	SSSI, A, HC, NT, C	Devon	6
62	River Tamar	SX 430 650	135.76	(SSSI), NT, CNT	Devon/Cornwall	6
63	River Tavy	SX 460 625	34.73		Devon	6
64	Lynher Estuary	SX 400 560	175.26	SSSI,	Cornwall	6
65	St. John's Lake	SX 427 540	13.60	SSSI	Cornwall	6
66	East & West Looe Rivers	SX 252 538	5.99		Cornwall	6
67	River Fowey	SX 115 567	2.78	A	Cornwall	6
68	Fal Estuary	SW 850 405	93.45	SSSI, NT, CNT	Cornwall	6
69	Helford River	SW 720 258	4.50	A	Cornwall	6
70	Hayle Estuary	SW 555 375	19.00	SSSI, A, CNT	Cornwall	7
71	The Gannel	SW 809 607	20.25	(SSSI), NT, CNT	Cornwall	7
72	River Camel	SW 945 739	49.47	(SSSI), A, HC	Cornwall	7
73	Taw & Torridge Estuary	SS 470 310	239.00	NNR, SSSI, A, (S), B, RS, NT	Devon	7
74	Bridgwater Bay	ST 281 485	487.04	NNR, SSSI, R, (S)	Somerset	7
75	River Parrett	ST 305 585	11.70	SSSI	Somerset/Avon	7
76	Severn Estuary	ST 580 930	562.94	SSSI, (R), (S), RS, CNT	Avon/Gloucestershire	7
77	Dee Estuary	SJ 220 800	2107.99	(NNR), SSSI, R, S, RS	Cheshire/Merseyside	10
78	Mersey Estuary	SD 460 780	848.39	SSSI, (R), (S), CNT	Cheshire/Merseyside	10
79	Ribble Estuary	SD 408 254	2184.00	NNR, SSSI, S	Merseyside/Lancashire	10
80	Morecambe Bay	SD 350 690	3314.15	SSSI, (R), (S), CNT	Lancashire/Cumbria	10
81	North Walney	SD 176 722	48.75	SSSI, CNT	Cumbria	10
82	Duddon Estuary	SD 200 800	488.22	SSSI, (R), (S)	Cumbria	10
83	Ravenglass	SD 084 962	158.00	SSSI, (R)	Cumbria	10
84	Moricambe Bay	NY 185 554	1190.16	SSSI, (R), (S), LNR, RS	Cumbria	10
85	Solway Firth	NY 280 610	1088.73	SSSI, (R), (S), CNT	Cumbria	10

KEY

1. Status: Concerns the conservation status of each site. Blank areas indicate that no designations are known to apply to those particular sites. Where the code letters are within brackets, this indicates that the designation in question is proposed for that site.

Codes Used:

NNR -	National Nature Reserve	LNR -	Local Nature Reserve
SSSI -	Site of Special Scientific Interest	B -	Biosphere Reserve
R -	Ramsar Site	RS -	R.S.P.B. Reserve
A -	Area of Outstanding Natural Beauty	NT -	National Trust
S -	Special Protection Area	CNT -	County Naturalist Trust Reserve
HC -	Heritage Coast	C -	Coastal Protection Area

2. Cell: Refers to the process cell designated in the Macro Review of the Coastline of England & Wales (Hydraulics Research, see References). Cells 8 and 9 occur along the Welsh coast and as such, are not considered in this report.

{SOURCE: Burd (1989) with additional detail from other sources.}

Table 4.2: Estimated area of salt marsh along the English coast (ha).

County	Coastwatch Database	Burd(1989)
Cumbria	4971.53	4161.12
Lancashire	2937.15	4038.89
Merseyside	728.48	492.79
Cheshire	1743.84	1864.41
Gloucestershire	73.22	248.89
Avon	242.51	313.85
Somerset	173.50	498.74
Devon	321.99	549.73
Cornwall	202.14	455.32
Dorset	592.42	829.75
Hampshire	1619.24	2660.48
Isle of Wight	-.-	213.81
Sussex	534.58	816.01
Kent	1408.87	1345.23
Greater London	24.90	0.00
Essex	3537.47	4636.96
Suffolk	863.63	1278.82
Norfolk	2637.04	2874.85
Cambridgeshire	1.56	0.00
Lincolnshire	4420.92	4222.79
Nottinghamshire	0.00	0.00
Humberside	532.43	647.86
Yorkshire	0.00	0.00
Cleveland	16.46	34.16
Durham	0.00	0.00
Tyne & Wear	1.52	8.91
Northumberland	322.04	268.96
Total	**27907.44**	**32462.33**

Process Cell	Marsh Area (ha.) (Burd 1989)
1	312.03
2	1419.21
3	12242.07
4	1451.28
5	4362.54
6	728.79
7	1389.20
10	10557.21
Total	**32462.33**

Bay and some of the smaller estuaries. Erosion has generally been confined to areas where there have been recent shifts in channel position. Saltmarshes on the east coast between Northumberland and north Norfolk have also shown predominant stability with lateral accretion in some areas, including parts of the outer Humber estuary, the Wash, and at several points between Hunstanton and Blakeney in north Norfolk (Pye, 1992a). By contrast, a high proportion of marshes in Suffolk, Essex and north Kent, and on the south coast in West Sussex, Hampshire and east Dorset, have suffered net erosion in the last 20 years (e.g. Gray & Pearson, 1984). Lateral accretion (e.g. at Shellness, Isle of Sheppey), has been the exception, rather than the rule in these areas. In the southwest, most of the small estuarine marshes in Cornwall and Devon have remained stable, but active marshes along the shores of the Bristol Channel and Severn estuary have suffered widespread erosion of the marsh edge.

Erosion of the saltmarshes takes a number of different forms, including (1) landward retreat of the marsh edge, either as a coherent cliff, or as a seaward-dipping ramp which is frequently dissected by linear channels to form a series of shore-normal mud-mounds; (2) internal dissection of the marsh by widening, deepening and headward extension of the tidal creeks; and (3) large-scale death and subsequent removal of vegetation, with subsequent scouring and lowering of parts of the marsh surface. Two or more forms of erosion frequently occur together. In many places, however, marshes are continuing to accrete vertically while suffering lateral retreat of the seaward edge and / or internal dissection.

Although there is abundant qualitative evidence of the recent changes affecting saltmarshes, and there is significant quantitative information about rates of vertical accretion/ erosion and marsh edge advance / retreat (e.g. Harmsworth & Long, 1986; Hill, 1987; Stoddart *et al.*, 1991), information about changes in marsh area is scarce. The only detailed regional study so far completed is Burd's (1992) investigation of changes in Suffolk, Essex and north Kent between 1973 and 1988. This study showed that 20% of the total marsh area was lost to erosion during the period, with as much as 44% being lost in the Stour estuary (Table 4.3). Erosion has particularly affected the pioneer and lower marsh communities which are particularly vulnerable to wave action.

4.5.2 Loss due to human activities

Burd's (1992) study of marshes in southeast England showed that, although small by comparison with erosion, losses due to land claim were still significant (2% of the 1973 area; Table 4.3). Only a few small agricultural land claims were made in the southeast during this period, but in other regions such land claims were more extensive during the 1970's, notably in the Wash (858 ha between 1970 and 1980, Pye, 1992b) and the Ribble estuary (Doody, 1992b).

Landclaims for marina construction, housing and industrial development have been made all around the coast and are continuing (Table 4.4). Significant losses have occurred in Portsmouth harbour and the Solent, largely in association with dock developments and construction of the M27 and M275 motorways. The Orwell estuary has lost about 14.5 ha of marsh to the Felixtowe dock extension and Langstone Harbour has lost about 80 ha since 1962 to tipping and building (Davidson *et al.*, 1991).

The major area of ongoing loss in Kent (Table 4.4) relates to large areas of degraded marsh in the lower Medway estuary which are licensed for the tipping of domestic refuse. The value quoted for Avon excludes marsh loss caused during construction of the second Severn crossing, work on which started in 1992.

4.6 Projected habitat loss

4.6.1 Erosion loss

If recent erosion trends continue, as seems likely given the projected rates of sea level rise and diminishing sources of fine-grained sediment as a result of coastal protection works, further loss of up to 1500 ha of saltmarsh may be expected in the Outer Thames estuary during the next 20 years. To

Table 4.3: Loss of saltmarsh in south-east England (based on data in Burd 1992). (N.B. The Roach/Foulness complex was not included in the survey)

Site	Period	Original area (ha)	Loss to land claim (ha)	Loss to land claim (%)	Erosion loss (ha)	Erosion loss (%)	Annual Erosion loss (ha)	Annual Erosion loss (%)
Dengie Peninsula	1973 - 88	474	-	-	47	10	3.1	0.7
Colne	1973 - 88	792	5	0.7	93	12	7.8	0.8
Swale	1973 - 85	377	3	0.9	58	15	4.8	1.3
Hamford Water	1973 - 88	876	1	0.1	169	19	11.3	1.3
Thames (Kent)	1973 - 85	78	3	4.0	14	18	0.9	1.5
Blackwater	1973 - 88	880	-	-	200	23	13.3	1.5
Thames (Essex)	1973 - 88	366	22	6.0	83	23	5.5	1.5
Medway	1973 - 85	844	18	2.1	180	21	15.0	1.8
Crouch	1973 - 88	467	22	4.7	124	27	8.3	1.8
Orwell	1973 - 85	100	8	8.0	32	32	2.7	2.7
Stour	1973 - 85	264	13	0.4	116	44	9.7	3.7
Total	**1973 - 88**	**5518**	**95**	**1.7**	**1116**	**20**	**74.4**	**1.4**

Table 4.4: Sites of ongoing marsh loss, recorded in the Estuaries Review Database (updated to 1992).

County	Area (ha)
Cumbria	21.0
Avon	29.5
Sussex	0.3
Kent	390.0
Essex	60.5
Suffolk	16.5
Norfolk	27.0
Lincolnshire	22.0
Total	566.8 (2.0% of the national resource)

this may be added an estimated further loss of 550 ha on the south coast and 50 ha on the English side of the Severn estuary. The main mechanisms of erosion are likely to be further recession of the marsh edge, with widening and headward extension of creeks in some areas. Accretion on the intervening surfaces of mature marshes is likely to be able to keep pace with an upward movement of sea level in the range 2-6 mm/yr. However, vertical accretion may not keep up with sea level rise on some of the lower marshes where wave action at high water is more pronounced. In other parts of the country, it is likely that local losses due to erosion will be compensated, or exceeded, by accretion at nearby more sheltered sites.

4.6.2 Human activities

Although losses of saltmarsh due to landclaim in southeast England have been comparatively small in relation to erosion losses, and a significant proportion of the remaining marsh is now owned or managed by conservation bodies such as the RSPB, National Trust, English Nature and Local Wildlife Trusts, there are grounds for believing that pressures for further land claim will continue in the next 20 years. The recent falls in value of agricultural land make it unlikely that there will be any large-scale agricultural land claims, but proposals for development in the east London corridor, around the Medway ports, and along the line of the Channel Tunnel rail link may involve further loss of both enclosed and active marsh. Proposals for construction of new marinas, and extensions to existing ones, are also numerous, although individually they affect relatively small areas. The recent DOE decison not to approve the proposed 'Lionhope' development on grazing marsh and active intertidal areas of the Swale may yet be overturned on appeal by the developers.

As a working estimate, it is suggested that a further 2% (650ha) of the remaining saltmarsh area in England may be lost to development and other land claim over the next 20 years, if recent trends continue. The bulk of this loss will be in areas close to, or accessible from, coastal conurbations, particularly around the Medway ports, southeast Essex, Portsmouth, and Southampton. This estimate is based on the assumption that no major tidal power schemes will be constructed during the period. The results of feasibility studies completed to date suggest that if a trial scheme is undertaken, it is likely to be in northwest England (e.g. the Wyre or Morecambe Bay).

4.7 Targets for habitat recreation

The total loss of saltmarsh habitat in the next 20 years, from both natural and human causes, is projected to be about 2750 ha, of which about 1800 ha (65%) is likely to be in the southeast and 650 ha (23%) in the south. Projected losses of this magnitude suggest that there is a strong case for direct action both to recreate saltmarsh habitat and to limit its rate of loss due to erosion and to human activities.

In principle there are two main ways in which new saltmarsh could be created:

1. Extension of the saltmarsh seawards using a combination of methods, including (a) construction of offshore breakwaters and polders, (b) raising of foreshore levels by sediment nourishment, using dredge spoil or other suitable material, to a point where vegetation can naturally gain a foothold, and (c) artificial transplanting of pioneer marsh vegetation ('the managed advance' option). A number of these techniques are currently being employed on a trial basis, notably in Essex (Holder & Burd, 1990; Toft & Townend, 1991; NRA, 1992) and their feasibility in other areas has been demonstrated (e.g. Posford Duvivier, 1992).

(2) Extension of the saltmarsh in a landward direction, by allowing areas of enclosed marshland to be once again flooded by the sea (the 'managed retreat' option).

An evaluation of the case for managed retreat has recently been undertaken by Posford Duvivier (1991) and Brooke (1992). In general terms, such a policy appears to offer the possibility of cost savings on maintenance of sea defences while at the same time turning surplus agricultural land into habitats of high conservation valu, notably saltmarsh and mudflats (Leafe, 1992). It does not suffer from the drawback associated with the managed advance option, namely that a seaward expansion of saltmarsh would exacerbate the 'squeeze' on intertidal mudflats and sandflats in the face of rising sea level.

The successful implementation of a manged retreat policy will require careful consideration of the evidence provided by examples of natural 'set back' which have occurred following storm breaching of sea defences during the last centruy, and refinement of the necessary soft engineering and environmental management methods. Studies of examples of natural 'set back' are currently in hand, and regular monitoring of a small-scale experimental 'set back' in the Blackwater estuary is currently being undertaken (Hull University, 1991, 1992). Larger-scale field trials are under discussion.

In areas where successive landclaims down the centuries have moved the shoreline seawards over large distances, the older sea embankments have often been removed and there is no remaining line of secondary sea defence to which to retreat. Building of a new wall might be as expensive, if not more so, than maintaining and improving the existing one, and it would generally be impractical to allow tidal flooding on a scale of thousands or tens of thousands of hectares. For these reasons, the managed retreat option seems is unlikely to be appropriate in such environments. Elsewhere, however, where a relatively narrow but laterally extensive strip of enclosed marsh is backed by naturally rising land, there is considerable scope for managed retreat at minimal cost. A number of the Essex estuaries, including the Crouch and Roach, offer realistic possibilities in this respect. However, a full regional evaluation, taking into account all relevant local factors of geomorphological setting, process environment, ecological requirements and existing landuse practice, is required before specific sites can be identified.

In some situations where managed retreat may be proposed, it will be necessary to raise the land level to allow colonization by saltmarsh plants. This could be achieved naturally over a period of years by allowing tidal waters to enter the enclosed area through a series of sluices, and by carefully controlling the rate of ebb drainage. Alternatively it could be achieved more quickly by importing sediment (e.g. dredge spoil) from an external source

Although managed retreat appears to offer a promising course of action in the short to medium term, a third management option should also be considered with a view to the longer term, namely the possibility of modifying the hydraulic behaviour of selected estuaries or their constituent parts by carefully designed hydraulic engineering measures. The techniques used to date to limit marsh erosion within British estuaries have been mainly small-scale, principally involving the erection of groyne systems along eroding marsh frontages and damming of small marsh creeks to regulate erosive ebb discharge. These measures have met with only very limited success, since they cannot begin to tackle the underlying problem which is associated with tidal hydraulics coupled to sea level rise (Pye & French, in prep.). The possibility that the problem might be more successfully tackled on a larger scale by engineered adjustments to the hydraulic geometry and flow regime of particular estuaries warrants urgent research attention.

In summary, the problem of present and future saltmarsh loss may best be addressed by a three-pronged approach. First, developments which are likely to lead to further loss or major damage to existing saltmarshes should be vigorously opposed. Second, detailed local studies should be undertaken to identify suitable sites and techniques for managed retreat, with a view to the recreation of at least 2500 ha of active saltmarsh in the next 20 years. Third, research should be taken to explore whether it is possible to develop a longer term solution by soft hydraulic engineering at an estuary-wide scale.