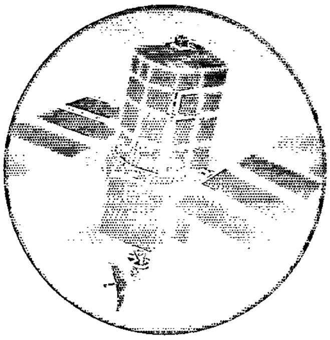
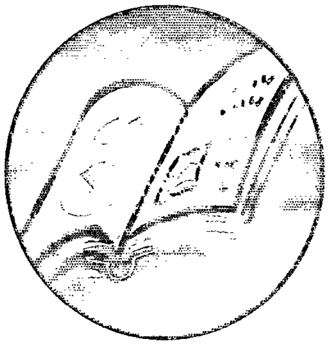
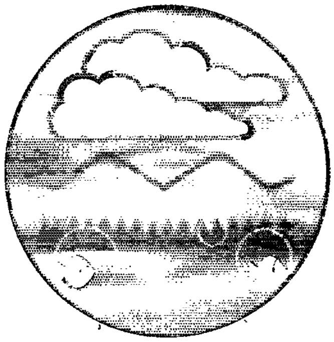
The Implications of Future Shoreline Management on Protected Habitats in England and Wales

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The Implications of Future Shoreline Management on Protected Habitats in England and Wales

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Statement of use
This report presents the findings of research carried out to predict , in broad terms, the possible coastal habitat losses and gains to European Sites, associated with future shoreline management proposals and natural processes. The information within this document is for use by Environment Agency and English Nature staff and others involved in the management of European Sites in England and Wales.

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ACKNOWLEDGEMENTS

We would like to thank the numerous staff from the Environment Agency, English Nature, the Countryside Council for Wales, DETR, Welsh Office, RSPB, local Coastal Defence Groups and conservation groups who attended workshops and provided practical insight into the probable future coastal defence policies and resultant habitat changes in their areas. The study has benefited from their detailed knowledge and we hope that the report has managed to convey the spirit of their advice. Special thanks are also due to John Adams (Environment Agency), Tim Collins (English Nature) and Rod Jones (Countryside Council for Wales) who organised and chaired the various workshops, and to Catherine Michael and Vicki Hendrick at Newcastle whose help throughout the project was invaluable.

EXECUTIVE SUMMARY

Future coastal defence policies and "natural" processes will have an impact on habitats within Special Areas of Conservation (SAC), Special Protection Areas (SPA) and Ramsar sites. An overview of the potential nature and extent of these changes (losses or gains) is needed to inform policy decisions on the legal and funding aspects of coastal defence options and possible habitat replacement, within the context of the Habitats Directive.

This research has involved establishing the likely areal changes to habitats within European sites (all possible, potential, candidate or designated SAC/SPAs) and Ramsar sites and providing a broad estimate of the costs of replacing any overall net loss of habitat. An assumption was made that habitats will change in response to landform change. Hence, an assessment of the potential coastal landform changes over the next 50 years has been used to give an indication of the nature and scale of potential habitat change. Predictions of coastal landform change were based on an extrapolation of what has happened in the past, but modified by an assessment of the potential implications of relative sea-level rise.

Loss/gain accounts have been developed for individual coastal cells in England and Wales, based on a single "best-guess" coastal defence scenario for the next 50 years (i.e. do nothing, hold the line, advance the line or managed retreat) identified from a review of available Shoreline Management Plans (SMPs) and through a series of regional workshops. These workshops were attended by experienced local staff from the Environment Agency, English Nature/Countryside Council for Wales, Department of the Environment, Transport and the Regions (DETR), the Welsh Office, RSPB, local Coastal Defence Groups and conservation organisations.

The results give a broad indication of the nature and scale of potential habitat losses and gains. The combined results of "natural" and "managed" changes are likely to produce a significant adjustment of landforms and a variety of habitat losses and gains.

If the "best-guess" coastal defence policies are implemented and if the predicted coastal changes occur, the following important habitat changes are possible:

i. there could be a net loss of freshwater and brackish habitat of around 4000 ha, primarily wet grassland (c3200 ha) but also including significant areas of coastal lagoon (c500 ha) and reed bed (c200 ha);

ii. there could be a net gain of intertidal (saltmarsh and mudflat/sandflat) habitats of around 2221 ha, with the gains associated with managed retreat (c12500ha) balancing the expected losses due to coastal squeeze and erosion on the unprotected coast;

iii. it is estimated that around 120 ha of sand dunes could be lost over the next 50 years, primarily in Northumberland, the South-west, Cardigan Bay and on the Sefton coast. Although this represents around only 1% of the sand dune resource within European Sites in England and Wales, it may involve the loss of a significant proportion of the important foredune dune communities in some areas;

iv. there could be a loss of around 130 ha of shingle bank habitats representing around 4% of the resource within European Sites in England and Wales;

v. relatively minor losses of cliff top habitats are predicted to occur, in the order of less than 2 ha/year, nationally.

The likely costs of freshwater and brackish habitat replacement, on a hectare-for-hectare basis, is estimated to be in the order of £50-60M, at current prices (1998), including site purchase, set-up and on-going management costs. If the site purchase and set-up costs are phased over a 10 year period, the Net Present Value (NPV) of potential replacement costs is estimated to be in the order of £30M.

Some habitats, however, are likely to be irreplaceable (e.g. sand dunes and shingle banks) whereas others may need no more than a simple change of management practice to re-create particular habitats (e.g. arable or pasture to grazing marsh). The report has also drawn attention to the possible need to select and develop replacement sites which are significantly larger than those which were lost, in order to ensure the correct ecological functioning of the habitat.

A number of important coastal defence-related issues have been identified which may constrain the successful implementation of the Habitats Directive. In summary, these are:

- the conflict between maintaining the favourable conservation status of the saltmarsh resource through managed retreat, and the resulting losses, in some areas, of freshwater habitats;

- saltmarsh re-creation associated with managed retreat may not necessarily lead to the production of habitats that would be integral to a site of international importance;

- the flood defence objective of achieving sustainable estuary forms may result in the need for additional managed retreat over-and-above that which was estimated by this study. This would place further pressure on freshwater habitats behind defence lines;

- if managed retreat is not implemented on the scale predicted by the workshops, there will be a significant net loss of intertidal habitat;

- the future management of sand dune and shingle bank systems needs to find an appropriate balance between the need for habitat diversity and flood defence;

- long-term coastal squeeze is inevitable in front of most existing defences and will place pressure on bird populations, especially those which feed on mudflats and sandflats.

A number of specific recommendations have been made:

1. Individual habitat loss/gain accounts should be compiled for each individual European Site, for each of the alternative coastal defence strategies, and organised on a regional basis;

2. A GIS and data management programme should be established to allow the predictions to be modified as and when SMP decisions are finalised or revised;

3. Links should be established with the monitoring programmes currently being developed as part of SMPs, with the aim of compiling records of landform change and habitat loss/gain on, for example, a 10 year basis;

4. Effort should be directed towards developing suitable and robust geomorphological and ecological tools for predicting change. Probabilistic methods, for example, may be an appropriate approach to address the uncertainties inherent in predicting coastal and habitat change;.

5. In light of the difficulties in predicting long-term changes to sand dunes, it is recommended that a detailed review of the status of dune systems should be undertaken. This review should consider the potential for future change within the context of the sediment budgets and long-term dune behaviour;

6. Experience of habitat replacement should be consolidated and critically reviewed in terms of the effectiveness of the scheme and the broader environmental impacts. The lessons learnt should be widely disseminated;

7. Field experiments should be undertaken in a range of coastal environments to establish the feasibility of and techniques for habitat replacement in different parts of England and Wales, with appropriate post project monitoring;

8. Management of dynamic coastlines will result in changes to habitats and associated species. There is, therefore, a need to identify mechanisms for resolving the potential conflicts between coastal defence and conservation objectives for intertidal and freshwater designated sites;

9. Following completion of all SMPs covering the coast of England and Wales a further review should be carried out to determine their effectiveness in addressing the need to maintain the favourable conservation status of the European Sites. It may prove necessary to develop guidance to inform coastal authorities about how the maintenance of the Natura 2000 network should be treated within the SMP process.

Keywords

Habitats Directive, net losses and gains, shoreline management plans, coastal cells, prediction, coastal defence policies, managed retreat, coastal squeeze, erosion, replacement costs

1 INTRODUCTION

1.1 Background

The EC Habitats and Species Directive (the "Habitats Directive"; Council Directive 92/43/EEC) requires member states to designate areas of importance for particular habitats and species as Special Areas of Conservation (SACs). Together with Special Protection Areas (SPAs) designated under the Conservation of Birds Directive (the "Birds Directive"; Council Directive 79/409/EEC), these areas will form a Europe-wide series of sites known as "Natura 2000". In Great Britain the Habitats Directive is implemented through the Conservation (Natural Habitats &c) Regulations 1994 (SI 2716), which employs the term "European Site" to encompass SACs and SPAs. As a signatory to the 1971 Ramsar Convention, the UK Government is also obliged to protect wetlands of international importance (the so-called "Ramsar sites").

The Habitats Directive sets out measures intended to maintain at, or restore to, a "favourable conservation status" those habitats and species designated as SAC/SPA. The conservation status of a habitat is considered to be favourable when:

- its natural range and areas it covers within that range are stable or increasing; and
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future; and
- the conservation status of its typical species is favourable.

Member states are required to take appropriate steps to avoid the deterioration of natural habitats and the habitats of species, as well as the significant disturbance of species, in SAC/SPA sites. If a plan or project is approved that could adversely affect a designated site, the Member States have a duty to ensure compensatory measures are taken to preserve the overall coherence of the "Natura 2000" network.

The coast is a dynamic environment where the nature and distribution of habitats have varied over time, either "naturally" or as a consequence of human activity. For example, many sand dune systems have experienced significant periods of accretion or erosion over the last 1000 years or so, particularly between 15th and 17th centuries, around the time of the so-called "Little Ice Age". There have been considerable changes to the distribution of saltmarshes and mudflats within many estuaries, notably as a result of land reclamation, channel training works and the introduction of *Spartina anglica*. It follows that the current distribution of habitats is not static, rather an artefact of the ongoing coastline responses to "natural" processes and human activity.

Coastal defences can have significant impacts on habitats, both directly (e.g. where defences are extended onto intertidal areas) and indirectly (e.g. through promoting accelerated erosion of the intertidal area in front of the defences i.e. "coastal squeeze"). In other circumstances, coastal defences may protect the interest of a site and too low a standard of protection may lead to the loss of that interest. Shoreline Management Plans (SMPs) provide a framework for sustainable coastal defence policies for a length of coast, but potentially include policies which, if implemented, could adversely affect some SAC/SPA sites. Indeed, each of the four generic policy options could have an impact on a site, for example:

i. **do nothing**; i.e. carry out no defence works except for safety measures. This could lead to continued erosion or flooding of a designated site;

ii. **hold the line**; holding the defence line in its present position, could result in further coastal squeeze in front of the defences whilst protecting freshwater and brackish habitats inland;

iii. **advance the line**; moving the defences seaward could result in the loss or degradation of intertidal habitats;

iv. **retreat the line**; i.e. moving the existing defence line landward (the so-called "managed retreat" option). This could result in the loss or degradation of freshwater habitats behind the current defences, and the re-creation of intertidal habitats.

SMPs have been prepared, or are in preparation, by coastal authorities in England and Wales (e.g. the Environment Agency, local authorities) for all coastal cells (a practical sub-division of the coast into units for management which, in general, reflect broad patterns of coarse sediment transport; (Figure 1.1). Many of these plans have acknowledged the relevance and importance of the Habitats Directive, but few SMPs have given detailed consideration to the options for future sustainable management within a context which recognises the needs of wildlife and the impact that the Directive will have on future coastal management decisions. It has not been possible for coastal authorities to assess the impact (positive or negative) that future policies will have on the "favourable conservation status" of SAC/SPA sites.

To this end, the Environment Agency (EA), English Nature (EN) and the Countryside Council for Wales (CCW) require a quantitative overview of the potential impact of future coastal defence works and "natural" coastal processes on habitats within SAC/SPA and Ramsar sites. This information is needed to provide an assessment of the likely change in coastal habitats in order to inform policy decisions on the legal and funding aspects of defence options and possible habitat replacement.

1.2 Objectives

The objectives of the study were:

i. to undertake an assessment of the potential impact of future shoreline management proposals and coastal processes on the sustainable management of SPA/SAC/Ramsar habitats in England and Wales;

ii. to assess the requirements, and estimate costs, for replacement for the habitat losses for England and Wales, predicted by the study;

iii. to assess the constraints on the successful implementation of the Habitats Directive imposed by the adoption of sustainable coastal defence options, as they impact on European coastal habitats in England and Wales.

1.3 Methodology

The research was undertaken between November 1997 and March 1998, and has been directed towards establishing the likely areal changes to habitats within European Sites (all possible, potential, candidate or designated SAC/SPA sites and Ramsar sites) and providing a broad

Table 1.1 Shoreline Management Plans available to this study.

Sub cell	Sub-cell boundaries	SMP	Received
1a	St Abbs Head to the River Tyne	St Abbs Head to the River Tyne SMP	✓
1b	The Tyne to Seaham Harbour	The Tyne to Seaham Harbour SMP	
1c	Seaham Harbour to Saltburn	Seaham Harbour to Saltburn SMP	
1d	Saltburn to Flamborough Head	Saltburn to Flamborough Head SMP	✓
2a	Flamborough Head to Sunk Island	Humber Estuary Coastal Authorities Group SMP	✓
	Humber Estuary	Humber Estuary ESMP	
2b	Immingham to Donna Nook	Humber Estuary Coastal Authorities Group SMP	✓
2c	Donna Nook to Gibralter Point	Lincolnshire SMP	✓
2d	Gibralter Point to Snettisham	The Wash SMP	✓
3a	Snettisham to Sheringham	North Norfolk SMP	✓
3b	Sheringham to Lowestoft	Sheringham to Lowestoft SMP	✓
3c	Lowestoft to Harwich	SMP for Lowestoft to Harwich	✓
3d	Harwich to Canvey Island	Essex SMP	✓
	Thames		
4a	Isle of Grain to North Foreland	North Kent Coast - Isle of Grain to Dover	✓
4b	North Foreland to Dover Harbour	Harbour SMP Sub-cells 4a & 4b	
4c	Dover Harbour to Beachy Head	Beachy Head to South Foreland SMP	✓
4d	Beachy Head to Selsey Bill	Selsey Bill to Beachy Head SMP	✓
5a	Selsey Bill to Hamble	East Solent SMP	✓
5b	Portsmouth Harbour to Southampton	West Solent SMP	
5c	Hamble to Hurst Spit	West Solent SMP	
5d	Isle of Wight (North Coast)	Isle of Wight SMP Sub-cells 5d & 5e	✓
5e	Isle of Wight (South Coast)		
5f	Hurst Spit to Durlston Head	Poole & Christchurch Bays Stage 1 SMP	✓
5g	Durlston Head to Portland Bill	Durlston Head to Portland Bill SMP	
6a	Portland Bill to Dawlish Warren	Lyme Bay and South Devon Phase 1 SMP	✓
6b	Dawlish Warren to Start Point	Lyme Bay and South Devon Phase 1 SMP	✓
6c	Start Point to Rame Head	Lyme Bay and South Devon Phase 1 SMP	✓
6d	Rame Head to Lizard Point	Rame Head to Lizard Point SMP	
6e	Lizard to Lands End	Lizard to Lands End SMP	
	Isles of Scilly		
7a	Lands End to Trevose Head	Lands End to Trevose Head SMP	
7b	Trevose Head to Hartland Point	Trevose Head to Hartland Point SMP	
7c	Hartland Point to Morte Point	Hartland Point to Morte Point SMP	
7d	Morte Point to Sand Bay	Morte Point to Sand Bay SMP	
7e	Sand Bay to Sharpness	Sand Bay to Sharpness SMP	
	Severn		
8a	Wellhouse to Lavernock Point	Wellhouse to Lavernock Point SMP	
8b	Lavernock Point to Worms Head	Lavernock Point to Worms Head SMP	
8c	Worms Head to St Govan's Head	Worms Head to St Govan's Head Stage 1 SMP	✓
8d	St Govan's Head to St David's Head	St Govan's Head to St David's Head SMP	
9a	St David's Head to Afon Glaslyn	St David's Head to Afon Glaslyn SMP	
9b	Afon Glaslyn to Bardsey Sound	Afon Glaslyn to Bardsey Sound SMP	
10a	Bardsey Sound to Menai Strait	Bardsey Sound to Menai Strait SMP	
10b	Isle of Anglesey	Isle of Anglesey SMP	
10c	Fort Belan to Great Orme	Fort Belan to Great Orme SMP	
11a	Great Orme to River Mersey	Great Orme to River Mersey SMP	
11b	River Mersey to Fleetwood	Formby Point to Fleetwood Stage 1 SMP	✓
11c	Fleetwood to Walney Island	Fleetwood to Walney Island Stage 1 SMP	✓
11d	Walney Island to St Bees Head	St Bee's Head to Earnse Point SMP	✓
11e	St Bees Head to Solway Firth	St Bees Head to Solway Firth SMP	

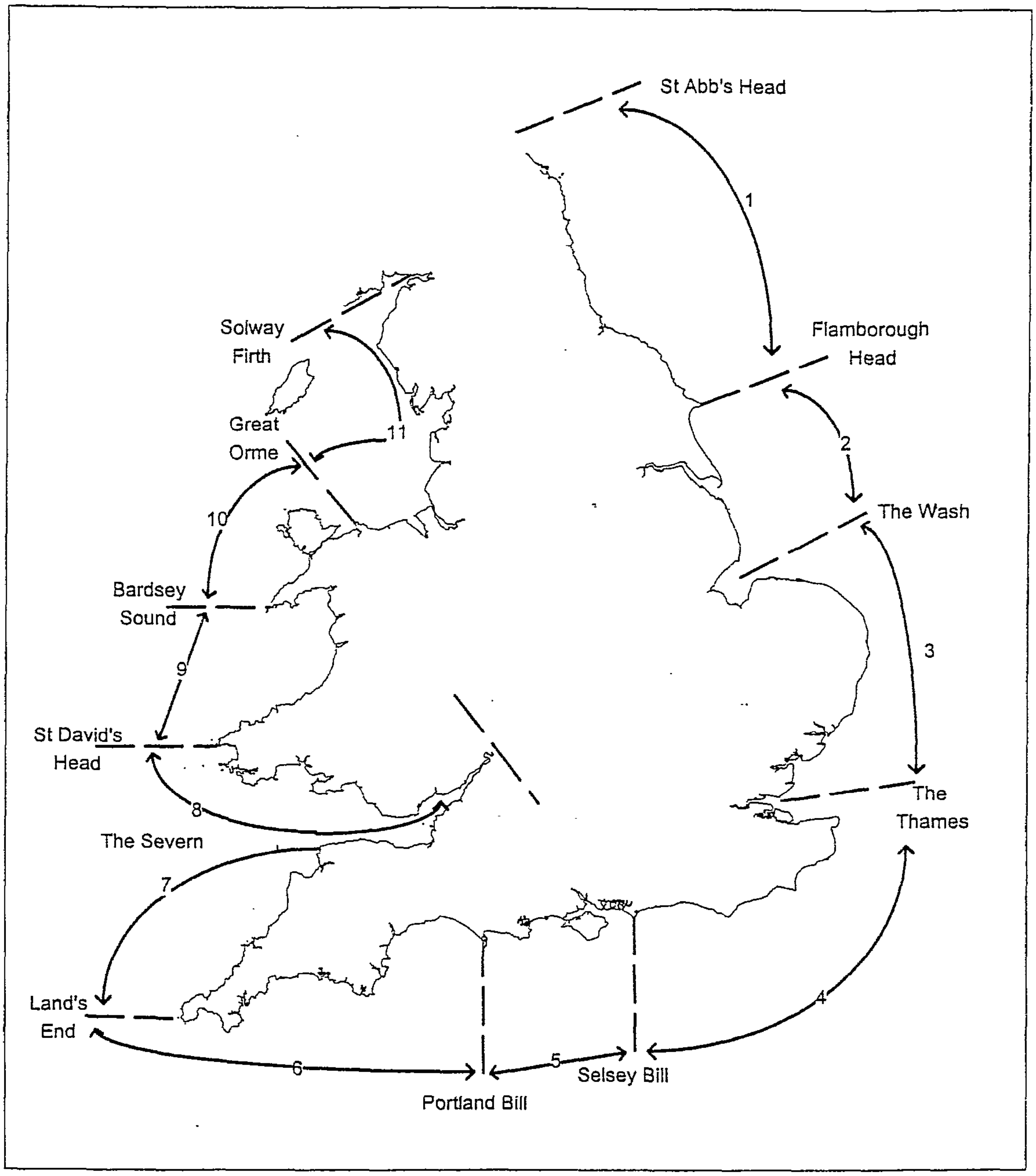

Figure 1.1: Coastline of England and Wales showing boundaries of major coastal cells.

estimate of the costs of replacing any overall net loss of habitat, at a national level. The research has involved the following tasks:

i. **Identification of Coastal Defence Scenario**; for each European Site, or part of a site, a single, "best-guess", coastal defence scenario for the next 50 years was identified (i.e. do nothing, hold the line, advance the line or managed retreat) from a review of available SMPs (Table 1.1) and through a series of regional workshops (Table 1.2).

   The broad criteria used to identify the defence scenario for each site were: cost-benefit, technical feasibility and environmental acceptability. The resulting scenarios reflected a consensus view from the workshop attendees; where there were disagreements about the likely scenario, the *status quo* was selected.

ii. **Prediction of Coastal Landform Change**; a fundamental assumption was made that habitats will change in response to landform change. Hence, an assessment of the potential coastal landform changes over the next 50 years will give a reliable indication of the nature and scale of potential habitat change. To this end, a prediction was made of the likely change to coastal landforms within each European Site, over the next 50 years. The predictions were based on an extrapolation of what has happened in the past, but modified by an assessment of the potential implications of relative sea-level rise on the rate of coastal change. Further details can be found in Chapter 2.

iii. **Prediction of Habitat Change**; Simple habitat loss/gain models were developed to illustrate the variety of potential coastal defence scenarios involving change to European Sites (Figures 1.2-1.4). Of particular significance are those scenarios which could involve a gain of intertidal habitat at the expense of freshwater (hinterland) habitat. These models formed the basis for discussion at the workshops and guided the subsequent assessment of loss/gain at each site.

   Where the future coastal defence scenario was considered by the workshops to be managed retreat, specific effort was made to ensure that the potential habitat losses and gains were defined by the local English Nature/Countryside Council for Wales officers present.

   A simple classification of habitats was adopted: intertidal (non-vegetated), saltmarsh, shingle banks, sand dunes, cliff top, soft cliff and hard cliff (cliff face habitats), wet grassland (including grazing marsh), coastal lagoon and reed bed.

iv. **Assessment of Replacement Costs**; an indication of the likely long-term costs of habitat replacement to counterbalance any overall net loss of habitat was guided by discussions with Environment Agency, English Nature/Countryside Council for Wales and RSPB officers with experience in habitat re-creation. Costs of land purchase were supplied by English Nature.

v. **Review of Constraints to the Implementation of the Habitats Directive**; a series of meetings with officers from Environment Agency, English Nature/Countryside Council for Wales and RSPB were held to identify key issues that might constrain the successful implementation of the Directive. The workshops also provided an opportunity for broader discussion of these issues.

Table 1.2 The Regional Workshops

A series of regional workshops were arranged by the Environment Agency, together with English Nature/Countryside Council for Wales, to discuss current and future SMP proposals and potential habitat changes with local coastal managers. Workshops were held in the North East (3.2.98), Anglian (16.2.98), Southern (18.2.98), South West (23.2.98), Wales (25.2.98) and North West (26.2.98) regions and were attended by experienced local staff from the Environment Agency, English Nature/Countryside Council for Wales, DETR, Welsh Office, RSPB, local Coastal Defence Groups and conservation organisations. A separate meeting was held with Environment Agency Midlands Region to discuss coastal defence issues along the lower Severn.

The aims of the workshops were to:

1. determine the distribution and character of SAC/SPA sites and Ramsar sites in the region;

2. identify and quantify threats to individual sites from natural coastal processes and SMP proposals;

3. identify opportunities for habitat replacement or restoration within the region.

In particular, the workshops were directed towards establishing:

1. those SAC/SPA sites and Ramsar sites, or parts of sites, **currently protected** by coastal defences but where there is a realistic possibility that the **defences may not be maintained** over the long-term (i.e.. the next 50 years). The workshops identified:

- what habitats could be lost and gained in this situation;
- where, in general terms, the new defence line might be;
- where the lost habitats could be replaced, if at all.

2. those SAC/SPA sites and Ramsar sites, or parts of sites, which are experiencing, or are likely to experience, "**coastal squeeze**". This might include those sites where the "roll-on" or landward migration of the habitats is constrained by sea defences, land use (e.g. golf courses) or topography (e.g. high ground). The workshops identified:

- what habitats could be lost and gained in this situation;
- where the lost habitats could be replaced, if at all.

1.4 Sea-level Rise and Global Warming

Tide-gauge records suggest that there has been an increase in mean sea-level around the UK of between 0-4mm/year over the last 100 years or so (Woodworth 1987; Table 1.3). Quite distinct differences in the trend have emerged in northern and southern areas, reflecting differential isostatic conditions (Figure 1.5). The Intergovernmental Panel on Climate Changes has identified the extent to which rising sea-levels are in evidence around the world, and the extent to which further rises may be expected as a result of global warming (Houghton et al 1990). The Second World Climate Conference (Jager and Ferguson, 1991) reached similar conclusions, which in the case of the UK suggest that there could be arise of between 50 and 70cm over the next 100 years. Bray et al (1997) suggest that the combination of historical trends of sea-level rise and an acceleration in sea-level rise caused by global warming could result in rates of around 6-9mm/year in the SCOPAC area on the south coast of England (Figure 1.5). This combined rate would be more rapid than any recorded for this region over the past 5000-6000 years.

As yet, British tidal gauge records show no clear evidence of an acceleration in the rate of sea-level rise (Woodworth, 1990; Woodworth et al, 1991; Shennan and Woodworth 1992). However, even if there is no acceleration, mean sea-level is predicted to rise by as much as 10cm over the next 20 years on parts of the south coast (Bray et al, 1992). Allowances given by MAFF (November 1991; see also DoE Circular 30/92) for the design or adaption of coastal defences with an effective life beyond 2030 range from 6mm per year (south east and southern England) to 4mm per year (north west and north east England) and 5mm per year (the remainder of England and Wales).

A wide variety of studies have indicated the potential for changes in the nature and rate of physical processes in different physical environments (e.g. Doornkamp 1990; Parry et al., 1991, Shennan 1993). There appears to be general agreement that extreme climatic events, such as storm surges, are likely to be more frequent over the next century; this could lead to a significant increase in the magnitude of impact on coastal systems. Rising sea-level has the potential to affect most coastal systems (Figure 1.6), with the natural response of the coastline being one of landward migration. However, attempts to define the likely changes in magnitude, frequency and impact of future events are constrained by a number of problems:

- the changes are likely to be extremely varied in character, reflecting the varying sensitivities of different coastal systems;
- events are frequently the consequence of the interaction between a range of factors of which climate change is merely one set of controls;
- many problems are a reflection of local conditions which are very difficult to predict at a general level.

Sea-level rise is not new. Patterns of coastal change or stability over the last 100 years have developed in response to a trend of slowly rising sea-level. It is assumed, therefore, that, in the future, much of the coast will continue to adjust to its effects in a similar manner i.e. the historical record provides a broad indication of the nature and scale of coastal change over the next 50 years. Here, it is possible to recognise two contrasting types of system, which probably represent end-points on a continuum of responses:

Table 1.3 Mean sea-level trends around the UK coast (after Woodworth 1987, Carter 1989; Bray et al 1994)

Region	Cell	Location	Historical Sea-level Rise mm/year	Period	Predicted Sea-level Rise mm/year *	Ratio of Predicted to Historical SLR
North East	1	North Shields	2.57	1916-1982	4	1.56
Humber	2	Immingham	1.7	1961-1982	5	2.94
East Anglia	3	Lowestoft	-0.3		5	5.00
		Harwich	1.7		5	2.94
		Southend	3.11	1934-1966	6	1.93
Thames	4	Sheerness	2.27	1916-1982	6	2.64
South East		Dover	2.3	1961-1987	6	2.61
		Newhaven	4.1		6	1.46
South Central	5	Portsmouth	5	1962-1982	6	1.20
		Southampton	1	1951-1966	6	6.00
South West	6	Devonport	-0.3		5	5.00
		Newlyn	1.75	1916-1984	5	2.86
	7	Avonmouth	0.66	1925-1980	5	7.58
Wales	8	Pembroke	-3.2		5	5.00
	10	Holyhead	3.1	1938-1988	5	1.61
North West	11	Liverpool	2.03	1959-1981	4	1.97
		Isle of Man	0.26	1938-1977	4	15.38
		Belfast	-0.25	1918-1963	4	4.00

Note: * Predictions based on MAFF's advised allowance for sea-level rise.

- "natural" systems which are resilient and able to adjust to the effects of global warming and sea-level rise. At a broad scale (e.g. a whole estuary) it is assumed that there would be no net change to the coastal system, although individual elements may be continuously adjusting, as manifest through accretion or erosion. These adjustments will be dynamic and be reflected in the maintenance of a steady state balance between processes and characteristic forms;

- "man-modified" systems which have been progressively changing in response to sea-level rise and other factors (e.g. previous coastal engineering works). Much of the coastline is developed and protected by coastal defences. These defences have prevented and will continue to prevent the landward migration of coastal landforms, leading to coastal squeeze. The long-term prognosis for these systems is one of progressive erosion of features such as beaches, saltmarshes and mudflats.

For the purposes of this study, it has been assumed that sea-level rise will simply lead to an adjustment in the contemporary patterns of erosion and accretion in an area (Figure 1.7). The adopted strategy for predicting change is, therefore, one of extrapolation from the historical records, with an allowance for sea-level rise, following the broad principles of the Bruun Rule (Bruun 1988).

In many areas erosion is likely to increase, possibly at a rate proportional to the ratio of the future sea-level rise to past sea-level rise. In this context, it is worth noting that Bray and Hooke (1997) have predicted that soft cliff erosion on the south coast of England could increase by 20-130% over the next 50 years, releasing considerable volumes of additional beach and mudflat/saltmarsh building material. Sand dune accretion may continue at current rates or even accelerate if there is sufficient sediment supply; alternatively, the deeper water in the nearshore zone will probably restrict the potential for a long-term lateral accretion of saltmarshes. These principles are expanded in Chapter 2, where they form the basis for predictions of coastal change.

1.5 Limitations

The aim of the research has been to produce a national overview of the potential changes that might occur to European Sites on the coast, over the next 50 years. The work has not involved a detailed appraisal of specific changes in particular areas. The limitations to the results should be self evident; predictions are seldom verifiable and may be wrong. As the accuracy of the predictions depends on the extent to which potentially complex coastal change (notably in response to sea-level rise) is understood, it is important to be realistic about what can be achieved.

Further limitations arise as a result of the uncertainty about whether current shoreline management proposals will be implemented over the long-term. For example, there have been a number of recent proposals to realign the existing coastal defences on the Anglian coast (e.g. Environment Agency et al 1996; Suffolk Coastal District Council et al 1996); it is by no means certain that these proposals will be undertaken. In other circumstances, it may not prove technically feasible or economically viable to maintain a "hold the line" policy over the long-term. Indeed, hydrodynamic studies may indicate that managed retreat or hold the line policies could cause damage elsewhere within the coastal cell.

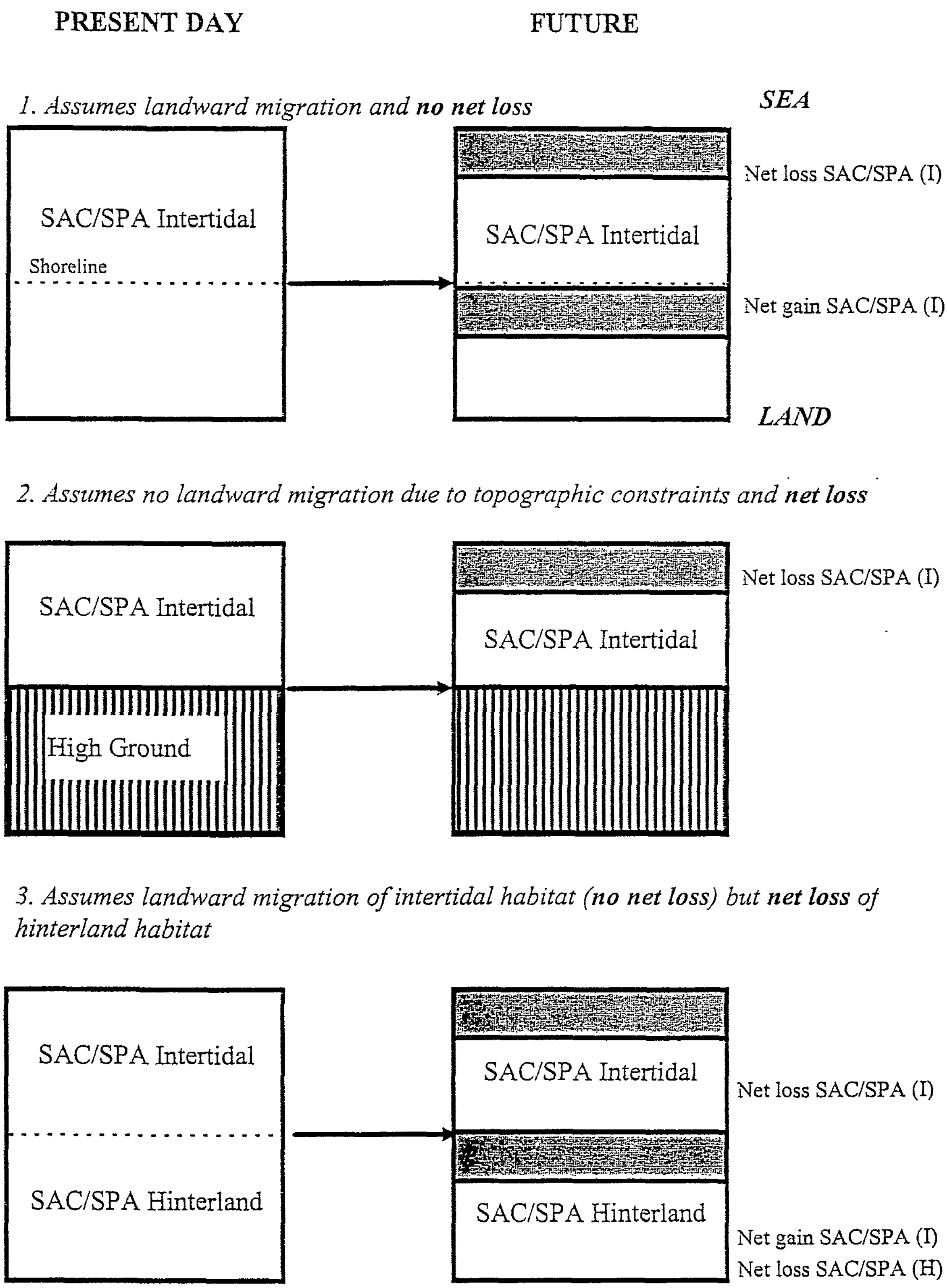

Figure 1.2: A simple habitat loss/gain model for the undefended coast.

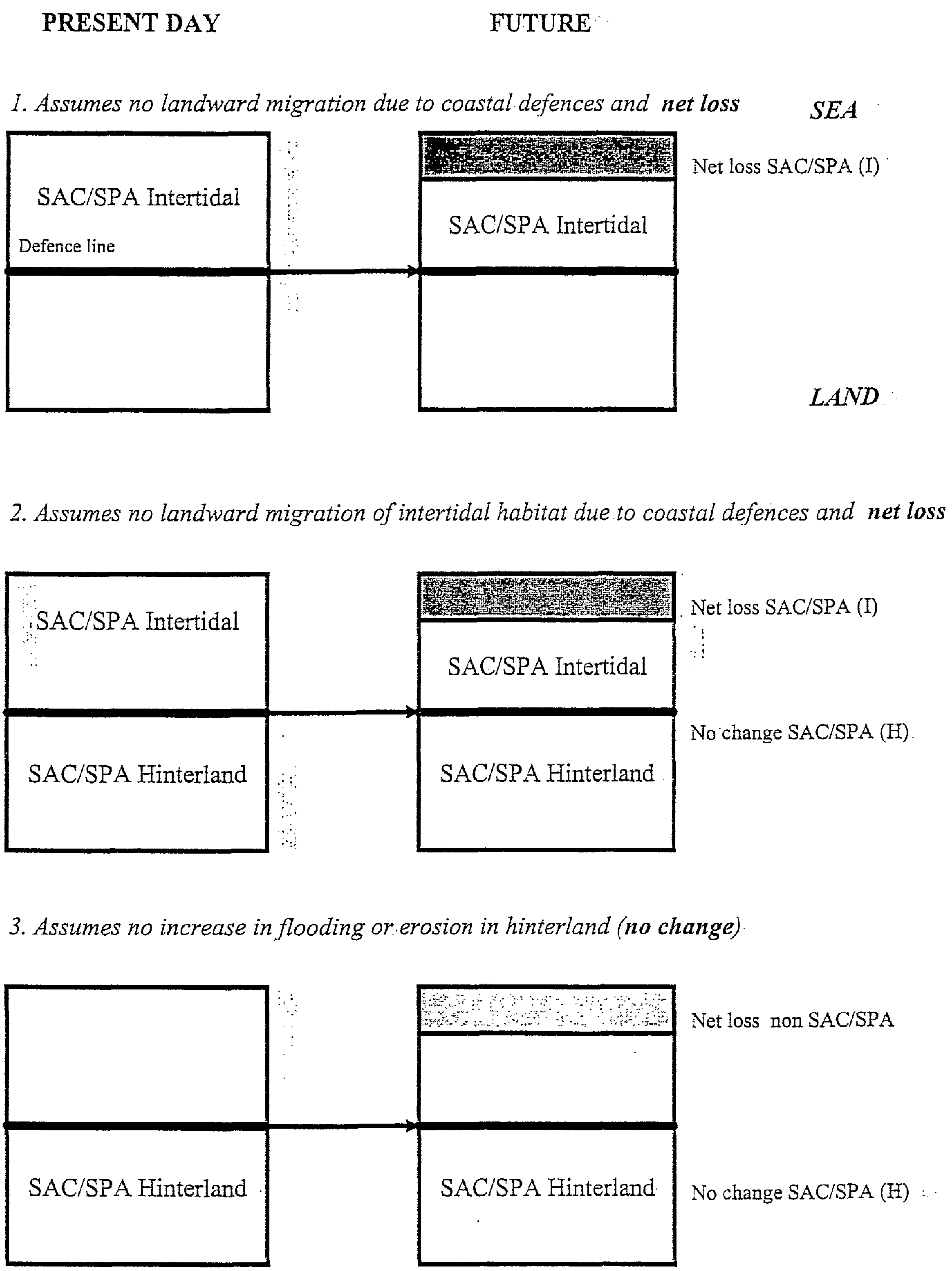

Figure 1.3: A simple habitat change model for the defended coast: hold the line.

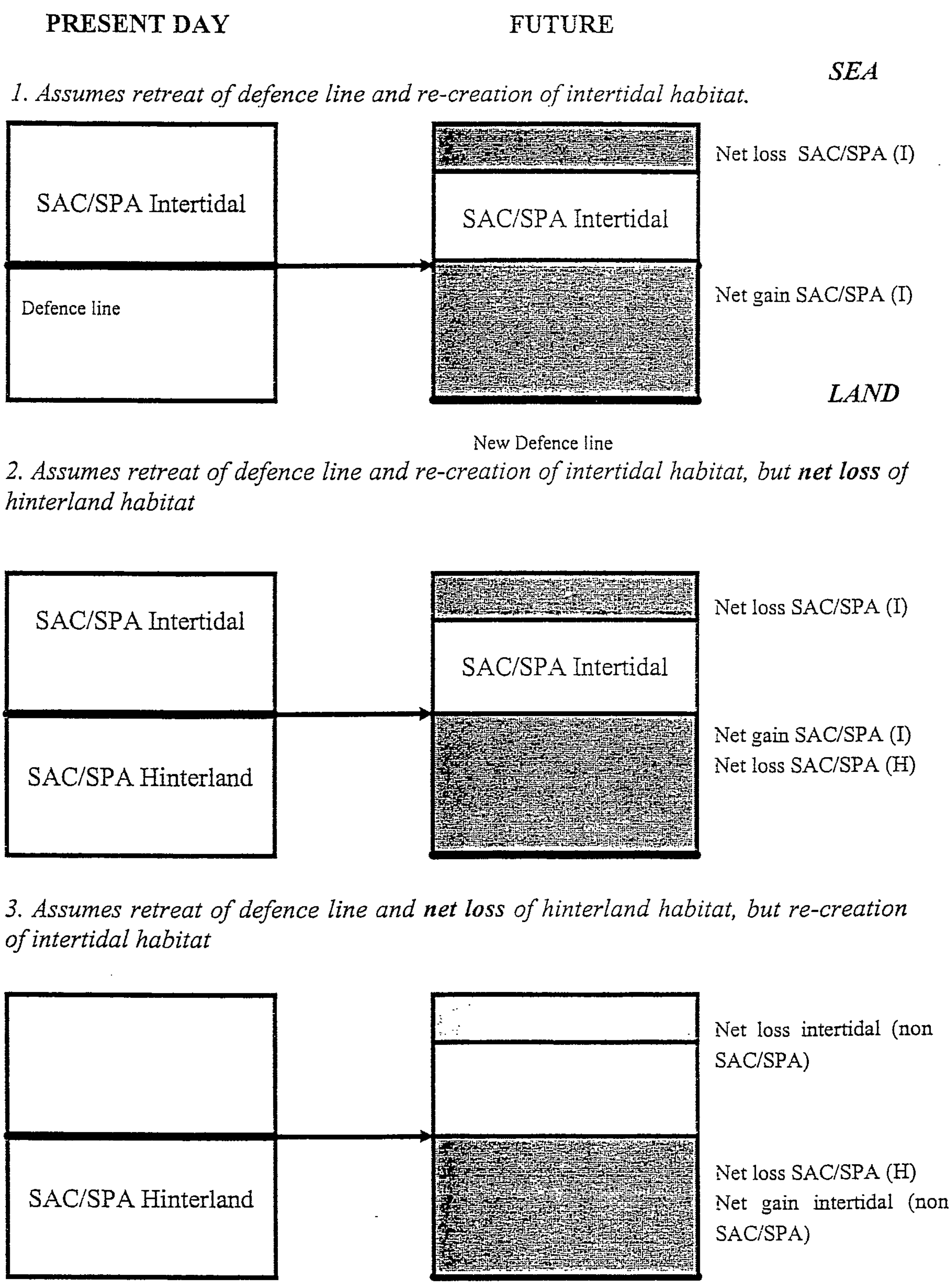

Figure 1.4: A simple habitat loss/gain model for the defended coast: managed retreat.

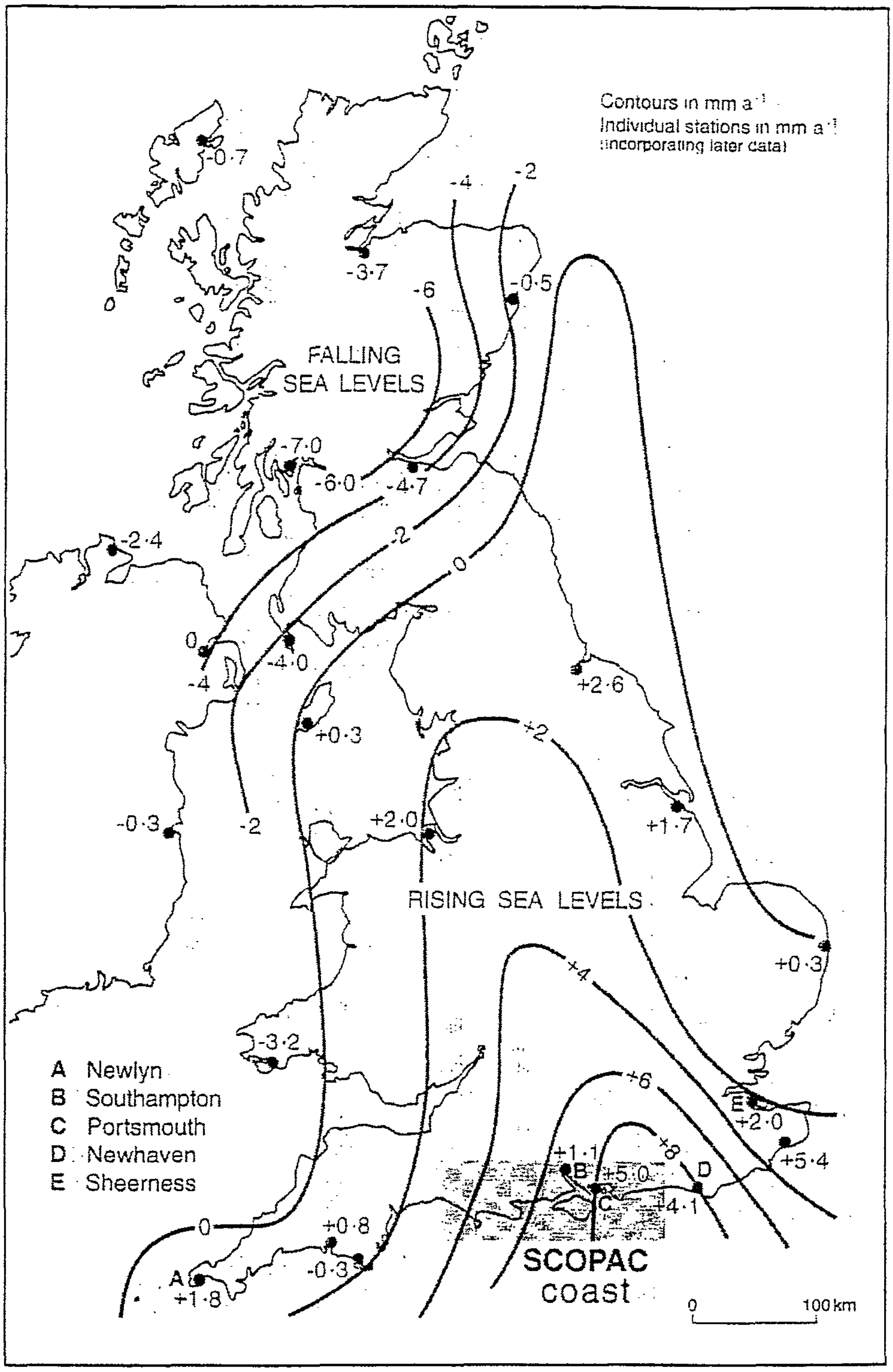

Figure 1.5: Recent sea-level trends (after Dugdale 1990; Carter 1989; Emery and Aubrey 1985).

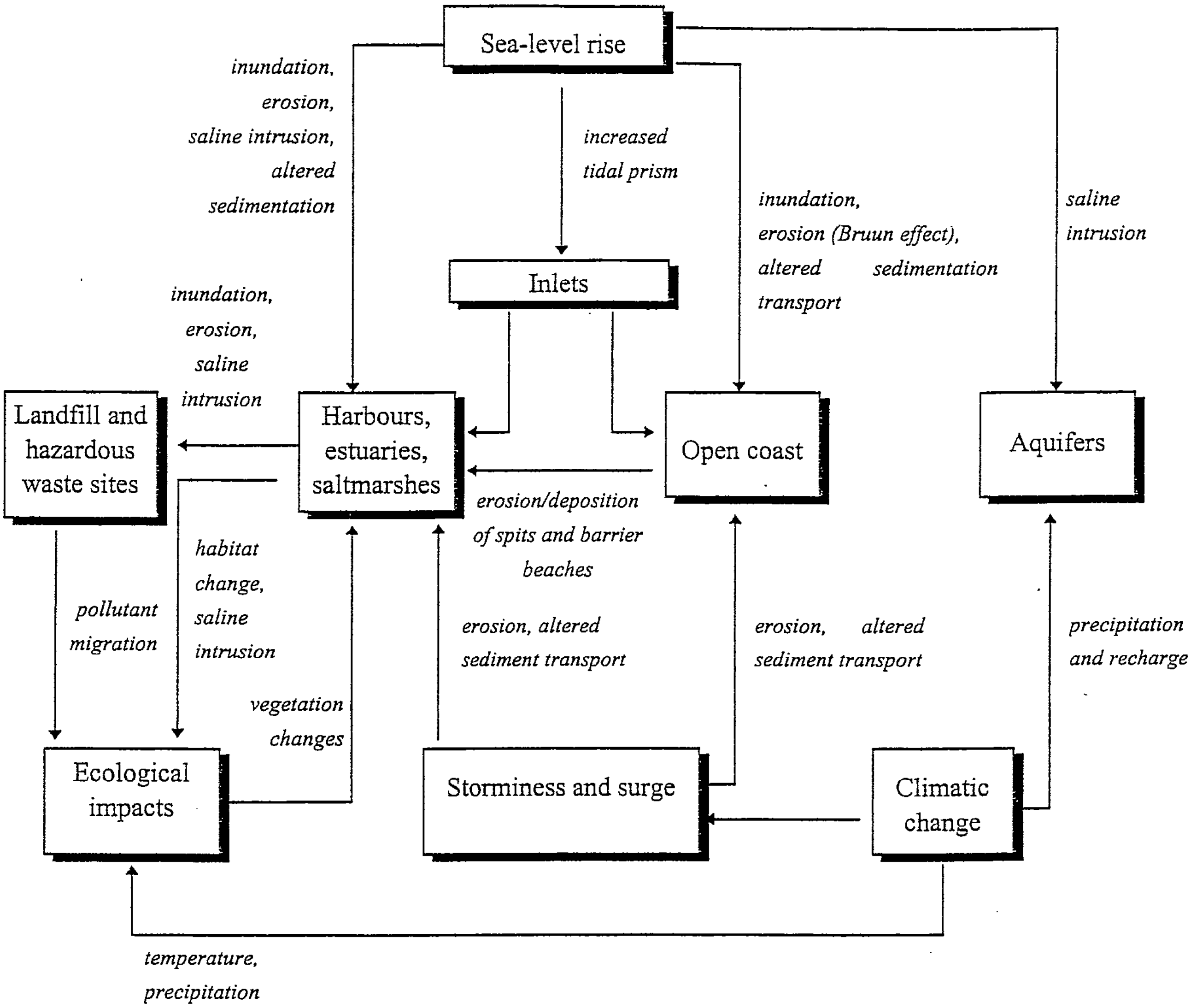

Figure 1.6 An overview of potential impact of sea-level rise on coastal systems (after Bray et al 1997).

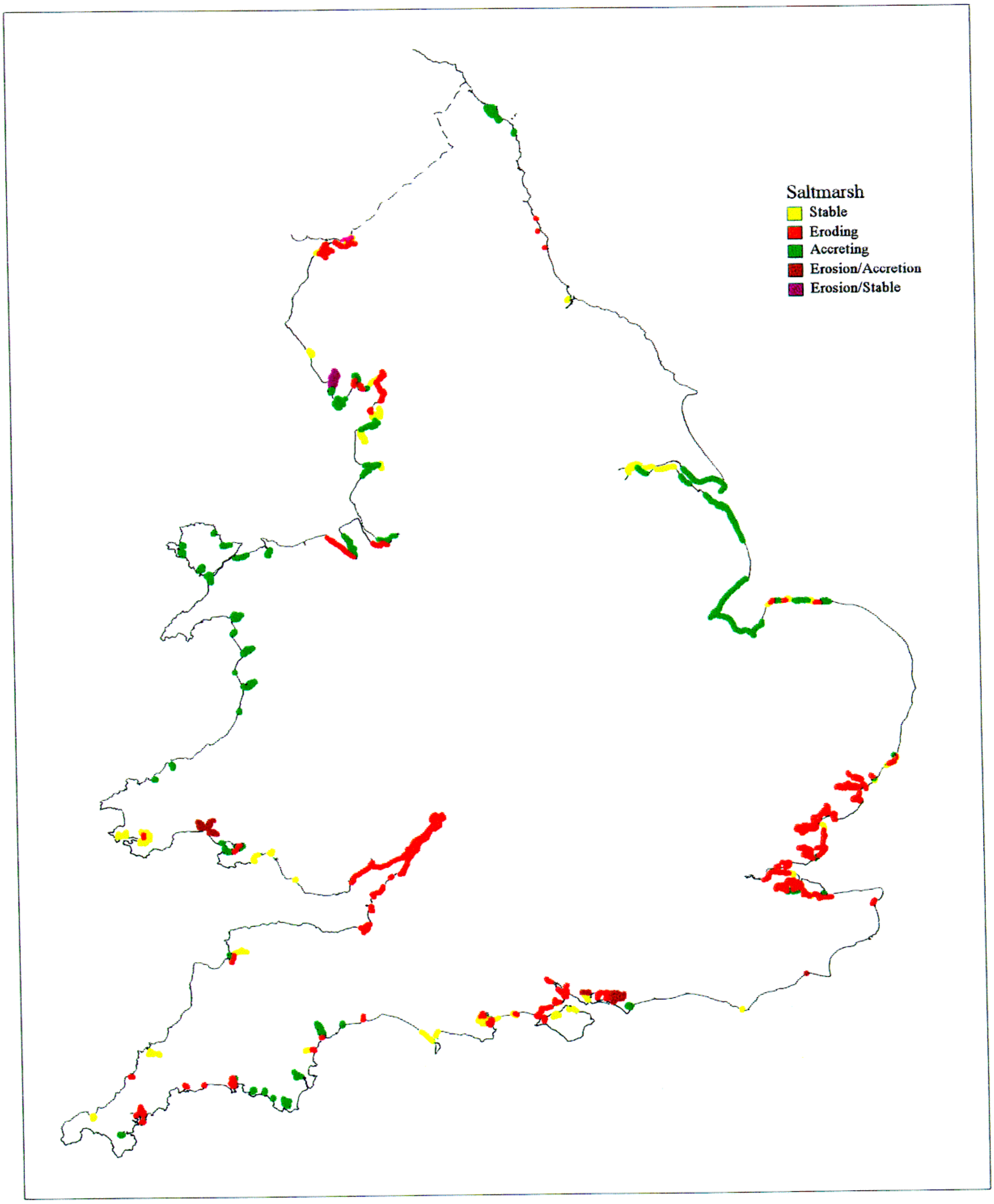

Figure 1.7a Eroding and accreting saltmarshes in England and Wales (after Pye and French 1993b).

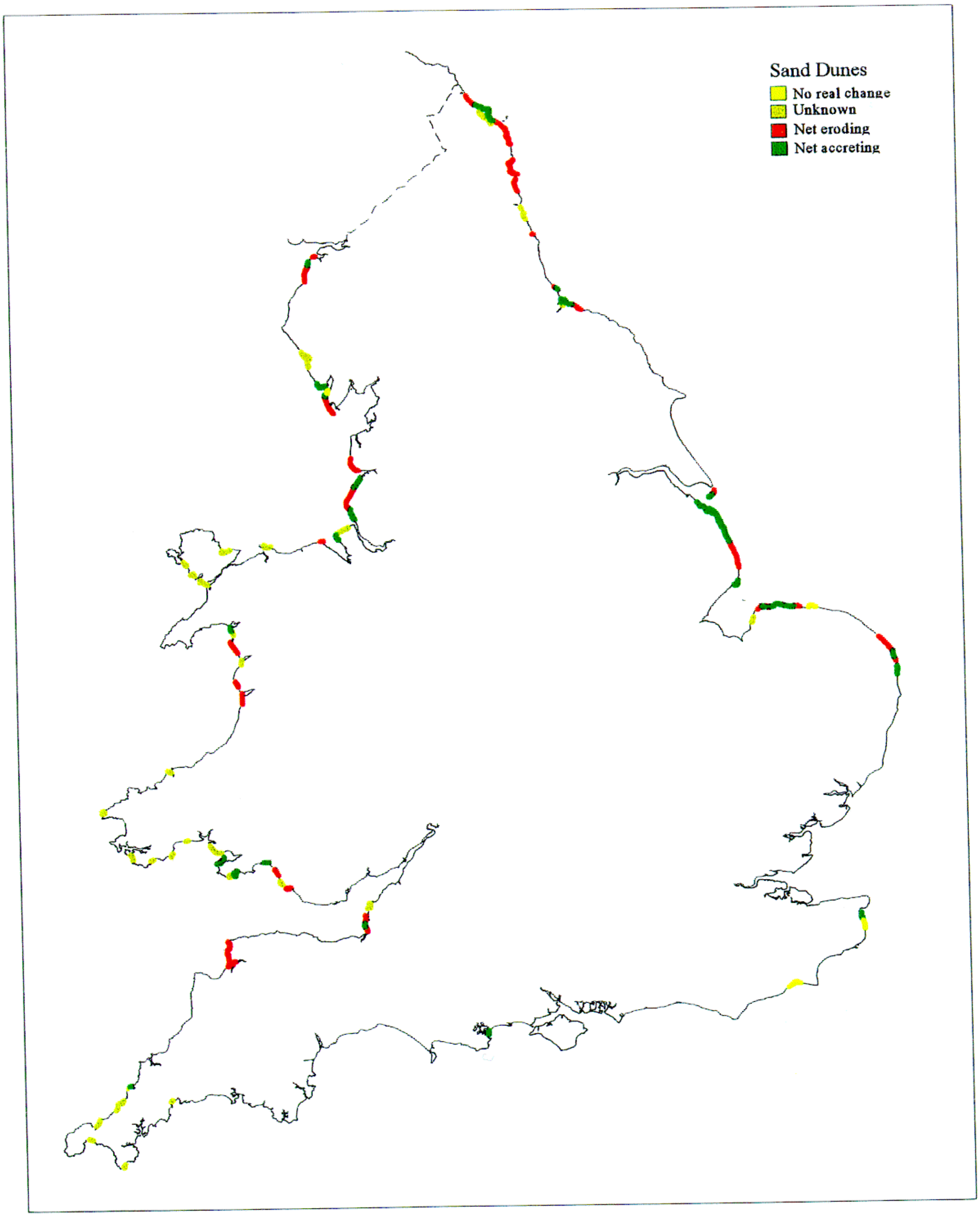

Figure 1.7b Eroding and accreting sand dune systems in England and Wales (after Rendel Geotechnics 1995).

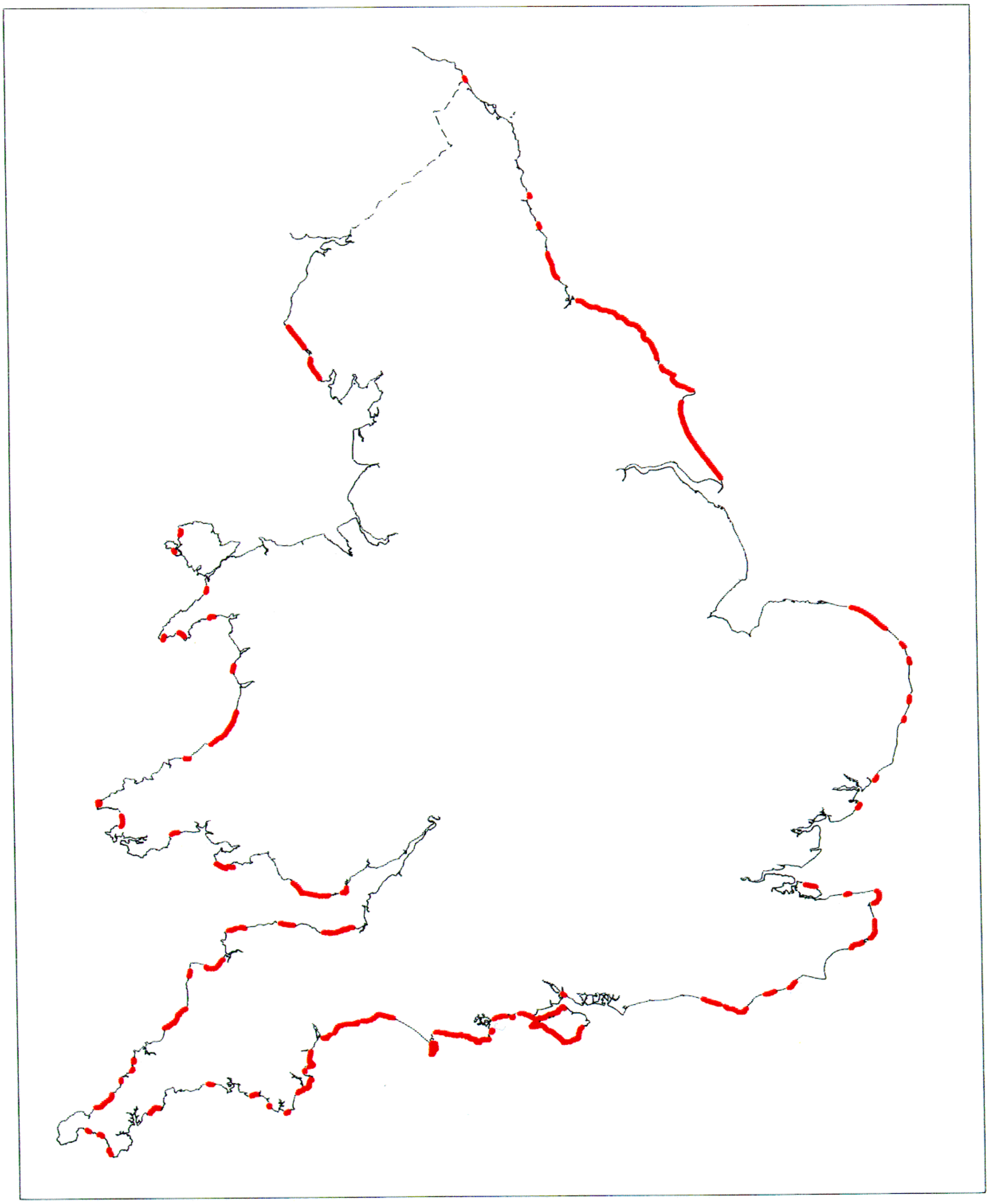

Figure 1.7c Coastal cliff erosion in England and Wales: cliffs affected by significant landslide activity or cliff recession (after Rendel Geotechnics 1995).

2 PREDICTIONS OF HABITAT CHANGE

2.1 Introduction

Coastal habitats face pressures from the anticipated effects of climate change and relative sea-level rise, which are likely to result in an intensification or acceleration of existing patterns of erosion and accretion. Potential also exists for conflict between the future changes in habitat that could result from shoreline management and the obligations to maintain the favourable conservation status of designated sites; of particular concern, in some areas, is the impact of managed retreat on the freshwater habitats behind the current defence line (e.g. RSPB 1997). In order to quantify the impact of these trends on the areal extent of habitats within designated European Sites, it is necessary to develop a picture of how the coast will look in these areas in 50 years time. This is not a straightforward task and a number of important questions have to be addressed for each site:

- what will be the coastal defence strategy for a particular site, or part of a site, in 50 years time?
- which elements of the site will be vulnerable to coastal change?
- what will be the long-term erosion or accretion rate of a particular element of a site?
- what will be the resultant areal changes to habitats within the site?

2.2 Method of Analysis

A "best-guess" coastal defence strategy was identified from SMPs (where available; see Table 1.1) and through the workshop discussions with local staff from the Environment Agency (flood defence and conservation officers), English Nature/Countryside Council for Wales, RSPB, local authority representatives from coastal defence groups and other conservation bodies. The workshops adopted a presumption in favour of maintaining the current strategy unless this strategy was unlikely to be sustainable over the next 50 years on economic, technical and environmental grounds. Alternative strategies were also tested, in general terms, against these criteria before they were either adopted as the "best-guess" scenario for a particular site, or rejected.

Figure 2.1 provides a simple framework used to identify the vulnerable landform elements on different lengths of coast. This model recognises that different coastal defence strategies present different potential problems or opportunities for habitats within designated sites. In broad terms, estimates of landform change were compiled for each site, or part of site, as follows:

i. **"do nothing"**; on the unprotected coastline, potential change was assessed from a combination of records of past change (see Table 1.3) and a geomorphological appreciation of how particular landforms in different areas may respond to the effects of sea-level rise.

ii. **"hold the line"**; it was assumed that the current defences or proposed improvements will ensure that there will be no habitat loss or change behind the defence line. However, it should be appreciated that there is potential for loss/degradation of coastal freshwater habitats behind seawalls and embankments if more frequent overtopping or saline groundwater intrusion occurs as a result of sea-level rise.

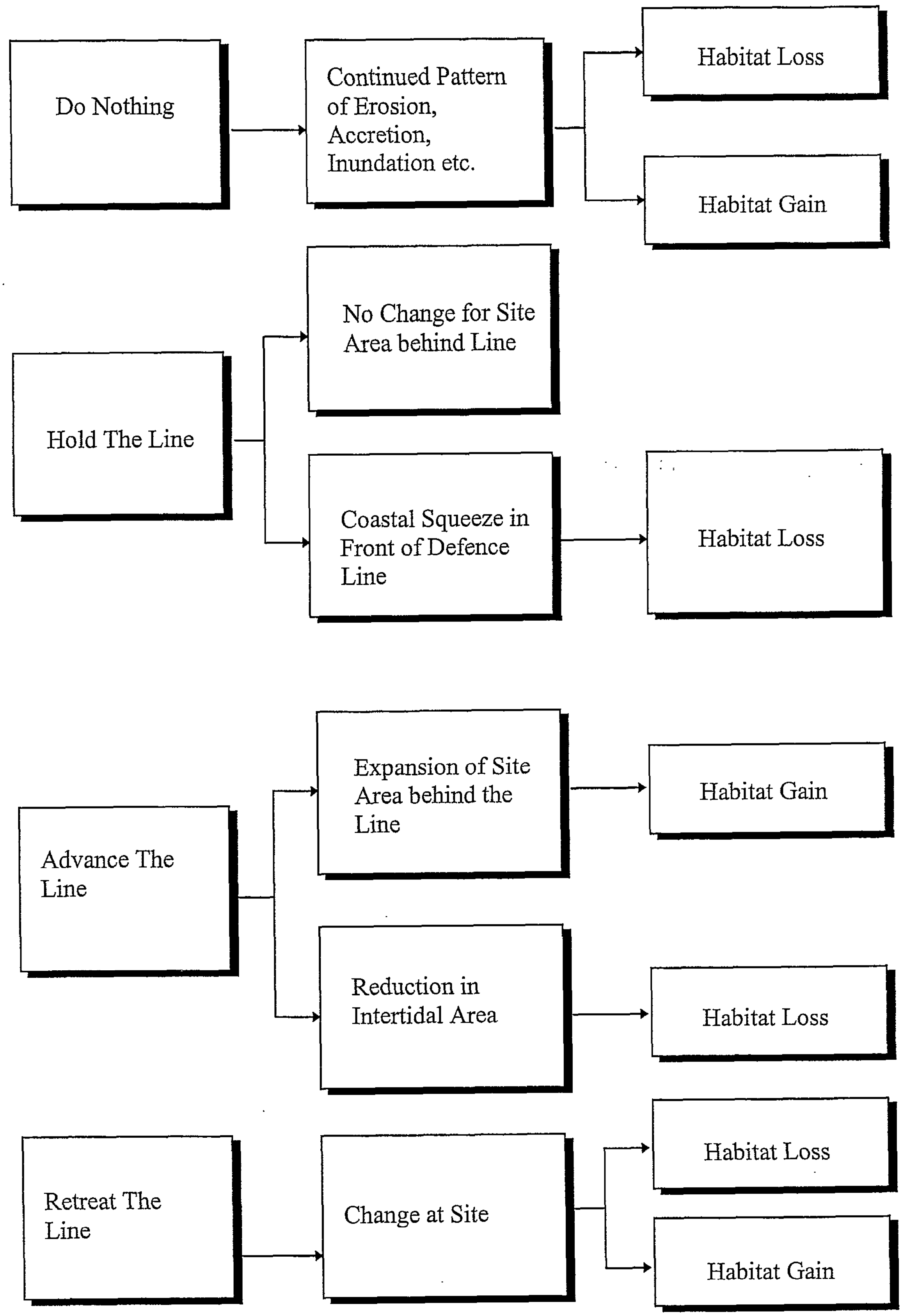

Figure 2.1 A framework for evaluating potential change, based on coastal defence strategy.

Table 2.1 Key sources of coastal change information.

1. **Mudflats/sandflats:**
- JNCC Inventory of UK Estuaries (JNCC 1997)
- Targets for Habitat Re-creation (Pye and French 1993a)

2. **Saltmarshes:**
- Erosion and Accretion Processes on British Saltmarshes (Pye and French 1993b)
- The Saltmarsh Survey of Great Britain (Burd 1989)
- Erosion and Vegetation Change on the Saltmarshes of Essex and North Kent (Burd 1992)
- Review of Erosion, Deposition and Flooding in Great Britain (Rendel Geotechnics 1994)

3. **Shingle Banks:**
- The Shingle Survey of Great Britain (Randall et al 1990; Sneddon and Randall 1991)
- Targets for Habitat Re-creation (Pye and French 1993a)

4. **Sand Dunes:**
- National Inventory of Sand Dunes (Radley 1992; Dargie 1995)
- Macro Review of the Coastline of England and Wales (HR Wallingford 1986)
- Review of Erosion, Deposition and Flooding in Great Britain (Rendel Geotechnics 1994)

5. **Coastal Cliffs:**
- The Investigation and Management of Soft Rock Cliffs in England and Wales (Rendel Geotechnics 1998)
- Review of Erosion, Deposition and Flooding in Great Britain (Rendel Geotechnics 1994)

The potential intertidal habitat loss in front of existing defences was assessed from a combination of historical and current trends, taking into account the potential effects of sea-level rise.

iii. "**advance the line**"; workshops discussions identified those sites where this might prove to be a viable option. The landform gain (e.g. saltmarsh) and loss (e.g. mudflat) was determined from a broad assessment of the site characteristics.

iv. "**retreat the line**"; potential managed retreat sites were identified through discussions with local officers at the workshops. A judgement was made about the possible future defence line and the likely landform changes that would arise.

Potential managed retreat sites were sub-divided into:

- sites within SAC/SPA sites and Ramsar sites involving retreat onto **non-designated** land;
- sites within SAC/SPA sites and Ramsar sites involving retreat onto **designated** land;
- sites outside SAC/SPA sites and Ramsar sites involving retreat onto **non-designated** land i.e. areas with potential for habitat re-creation.

It was recognised that short-term erosion and accretion rates have been highly variable, particularly for saltmarshes (e.g. Pethick 1992), sand dunes (e.g. Pye 1990) and soft rock cliffs (e.g. Rendel Geotechnics 1998). Pethick (1996) has noted that simple observations of temporal variability of coastal landforms is insufficient to allow assessment of long-term deterioration; instead, temporal changes must be assessed in conjunction with its expected behaviour. For example, *ad hoc* observations of foredune erosion need not be taken as an indication of long-term erosion of the system. The sensitivity of sand dune systems to slight random changes in environmental conditions means that such short-term change is expected and may continue for several years before a period of accretion ensues. In this context, the vulnerability index (Pethick 1995) provides an indication of the sensitivity of a landform to slight changes in its environment.

For example, the National Inventory of Sand Dunes (Radley 1992; Dargie 1995), carried out between 1987 and 1991, identified that many dune systems showed evidence of net erosion damage to the frontal dunes. The survey period was characterised by a number of severe storms (e.g. January 1989 and February 1990), which caused serious and extensive erosion to many dunes. However, as Pye and French (1993a) note, detailed studies of the behaviour of dune coasts over a number of years have shown that the evidence of a severe storm may be slowly eradicated over a number of years. The rate of foredune recovery is related to the sediment budget; if the budget is positive and more sand is accreted to the beach/foredune system in the interval between storms than is removed by these extreme events, then the shoreline will show net accretion over a period of years. The reverse is true if the sediment budget is negative and erosion during storms will not be fully compensated by accretion during the intervening period.

As the sand dune example has intimated, over the long-term there is a tendency for the natural variability in erosion and accretion rates to smooth themselves out, and a relatively uniform net erosion or accretion rate will emerge. For many coastal landforms, a 50 year time period is likely to be sufficient for a relatively uniform long-term rate to be relevant and provide a reasonable basis for prediction.

The potential long-term landform changes were assessed as follows:

i. **Mudflats and Sandflats**; the potential losses due to sea-level rise were related to the long-term inundation of the seaward part of the intertidal area i.e. as sea-level rises the intertidal area narrows (assuming the intertidal area cannot simply "roll-back" landwards because of fixed coastal assets and that accretion does not increase and keep pace with sea-level rise). The intertidal losses were estimated as:

   $$\text{Intertidal Loss} = \frac{\text{Cumulative Sea-level Rise}}{\text{Tidal Range}} \times \text{Intertidal Area}$$

   Intertidal area and tidal range data were compiled from the Inventory of UK Estuaries (JNCC 1997); sea-level rise predictions are as in Table 1.3

ii. **Saltmarshes**; saltmarshes occupy a limited tidal range and are not only vulnerable to inundation, but also to erosion if the wave climate alters and becomes more aggressive (Pethick 1992). Studies around the world have shown that vertical accretion of saltmarshes is able to keep pace with rates of sea-level rise of up to 10mm/year, provided that an adequate sediment supply is maintained (Pye and French 1993b; Reed 1990, 1993). Lateral accretion may also continue, especially in sheltered sites. However, sea-level rise is expected to intensify the problems experienced on eroding coasts, such as the Essex Estuaries (Burd 1992), with the main mechanisms including recession of the marsh edge and internal dissection by widening and headward extension of creeks. In places, marshes are continuing to accrete vertically whilst suffering lateral retreat of the marsh edge (Pye and French 1993b).

    The past 100 years or so has also witnessed the rapid expansion and subsequent "die-back" of *Spartina anglica*, especially in southern England, promoting significant increases and, more recently, decreases in marsh area. Sea-level rise, sediment shortage, pollution and genetic variation that might affect niche occupation have all been suggested as possible causes of this pattern (Gray 1992). As *Spartina* has died-back there has been widespread saltmarsh erosion and the formation of mudflats at a lower level.

    Historical records of saltmarsh lateral erosion and lateral accretion were compiled from the MAFF-commissioned review of Erosion and Accretion Processes on British Saltmarshes (Pye and French 1993b), SMPs and other studies of saltmarsh change (e.g. Burd 1992). It was assumed that sea-level rise would lead to an acceleration of the current recorded patterns of saltmarsh erosion and a gradual decline (and possible cessation) of accretion. The following equations were used to estimate the long-term changes:

    $$\text{Future Erosion Rate} = \text{Historical Erosion Rate} \times \frac{\text{Future Rate of Sea-Level Rise}}{\text{Past Rate of Sea-Level Rise}}$$

    $$\text{Future Accretion Rate} = \text{Historical Accretion Rate} \times \frac{\text{Past Rate of Sea-Level Rise}}{\text{Future Rate of Sea-Level Rise}}$$

    Where no historical records were available, it was assumed that the contemporary trend of erosion or accretion identified by Pye and French (1993; Figure 6) would continue, at a representative rate for that particular area.

iii. **Shingle Banks**; Shingle ridges generally respond to rising sea-level by an overtopping, breaching and "roll-over" mechanism (Carter 1988; Orford et al 1995), provided the backshore is low enough to allow the process to occur. If there is sufficiently large shingle supply, overtopping may be prevented and the face of the beach may accrete despite the rise in sea-level.

Long-term erosion rates for Orfordness and Dungeness were obtained from the relevant SMPs. However, in most cases it was assumed that shingle banks were either free to migrate on land in response to sea-level rise (e.g. Chesil Beach), or that they would continue to be protected by coastal defences (e.g. Hurst Spit); in both cases there would be no net erosion or accretion.

iv. **Sand Dunes**; the effects of sea-level rise on sand dune systems is likely to vary around the coast, and through time. Whilst an acceleration in the erosion of front dunes might be expected, under certain circumstances the more frequent severe storms, that are anticipated to accompany sea-level rise, may actually lead to an increase in dune area (Pye and French 1993a). For example, storms may lead to the formation of new ridges of sand and shingle which subsequently act as nuclei for dune growth. In other circumstances, a succession of storms may cause major "blow-outs" and trigger landward migration of the dune system.

Most dune systems are, at present, stabilised by vegetation and are unable to migrate inland. Even where dune migration might be possible, the potential for "roll-back" is constrained by coastal assets such as golf courses.

There have been no systematic surveys of sand dune erosion and accretion, although observations on the recent status were recorded in the National Inventory of Sand Dunes (Radley 1992; Dargie 1995). Long-term records are available for the Sefton coast (e.g. Pye and Smith 1988) and the Lincolnshire coast (e.g. Anglian Water 1988). Because of the uncertainties about future dune behaviour highlighted above, these historical rates have been extrapolated over the next 50 years.

It should be stressed that there are considerable difficulties in predicting long-term changes to sand dunes, because of the lack of information about the historical and current status of many dune systems, especially the sediment budgets and long-term behaviour. Where no historical records are available, it was assumed that the contemporary trend of erosion or accretion identified by various sources (e.g. SMPs) would continue, at a representative rate for that particular area. For most systems it was assumed that the dune frontage is likely to experience net erosion over the next 50 years, at long-term rates of between 0.5 - 2m per year. As most dune systems are, at present, stabilised by vegetation or constrained at the rear by fixed assets, it was assumed that they will be unable to migrate inland.

iv. **Cliffs**; long-term cliff recession rates around the coast of England and Wales have been compiled as part of the MAFF-commissioned research "Prediction of Cliff Recession Rates and Erosion Control Techniques" (Rendel Geotechnics 1998). These data were adjusted slightly to take account of the potential effects of sea-level rise and extrapolated over the next 50 years to predict the future cliffline changes in the European Sites.

v. **Coastal Lowlands**; since Roman times land reclamation has resulted in the transformation of extensive areas of saltmarsh into what is now arable land, grazing marsh and reed beds. Most of these areas are protected by coastal defences, ranging from "hard" structures to managed shingle ridges. These sites are, however, particularly vulnerable to a combination of inundation and accelerated erosion. Many such areas have been identified in the workshops as possible sites for managed retreat, primarily because of the technical difficulties and high costs of maintaining and improving the existing defence line. It is assumed that managed retreat will result in the inundation or erosion of these lowland areas, with the subsequent creation of intertidal saltmarsh and mudflat systems.

A number of important assumptions were made in relating the predictions of landform change to habitat change. These are:

- habitat loss or gain equates directly to landform erosion or accretion;
- where managed retreat may involve retreat onto designated land there will be a balance between the freshwater habitat loss and the intertidal habitat gain i.e. a freshwater habitat of international quality will be replaced by an intertidal habitat of international quality within the next 50 years;
- where managed retreat may involve retreat onto non-designated land an intertidal habitat of international quality will be created within the next 50 years;
- the intertidal habitat gain associated with managed retreat has been arbitrarily sub-divided into intertidal non-vegetated (50%) and saltmarsh (50%), reflecting experience from existing managed retreat sites. In reality, the proportion of saltmarsh/mudflat that will be created will vary from site to site;
- it is assumed that there is a net balance between saltmarsh and mudflat/sandflat habitat changes as a result of "squeeze" and erosion on the open coast (i.e. the do nothing and hold the line strategies). In such circumstances, saltmarsh erosion or accretion result in mudflat/sandflat gain or loss, respectively;
- the intertidal mudflat/sandflat losses associated with the retreat of LWM have been assigned to the "do nothing" scenario, where they are combined with the losses arising from saltmarsh accretion on the unprotected coast;
- on eroding cliffs there will be no long-term net loss of cliff face habitats i.e. the cliff profile may retreat, but over time the area of vegetated sea cliff or bird habitat will remain constant. However, there will be a net loss of cliff top habitat (e.g. cliff top heathland, chalk grassland etc.) equivalent to the cumulative recession over 50 years.

2.3 Results: Habitat Gains and Losses

Table A.1 to A.12 (Appendix A) present estimated loss/gain accounts for SAC/SPA and Ramsar sites within individual coastal cells in England and Wales, in relation to different generic coastal defence strategy types. These accounts assume that the "best-guess" coastal defence strategies are implemented and that the coastal change predictions come to fruition.

An estimated habitat balance for the whole of England and Wales is presented in Table 2.2a. This reveals:

i. there could be a net loss of freshwater and brackish habitat of around 4000 ha, primarily wet grassland (c3200 ha) but also including significant areas of coastal lagoon (c500 ha) and reed bed (c200 ha);

ii. there could be a net gain of intertidal (saltmarsh and mudflat/sandflat) habitats of around 2221 ha, with the gains associated with managed retreat (c12500ha) balancing the expected losses due to coastal squeeze and erosion on the unprotected coast. The overall balance of intertidal loss/gain is sensitive to the assumed proportions of saltmarsh/mudflat creation, as indicated in Table A.13 (Appendix A);

iii. it is estimated that around 120 ha of sand dunes could be lost over the next 50 years, primarily in Northumberland (Cell 1), the South-west (Cell 7), Cardigan Bay (Cell 9)and on the Sefton coast (Cell 11). Although this represents around only 1% of the sand dune resource within European Sites in England and Wales, it may involve the loss of a significant proportion of the important foredune dune communities in some areas;

iv. there could be a loss of around 130 ha of shingle bank habitats representing around 4% of the resource within European Sites in England and Wales;

v. relatively minor losses of cliff top habitats are predicted to occur, in the order of less than 2 ha/year, nationally.

There are significant regional differences in the patterns of habitat loss/gain (Table 2.2b). The largest changes are likely to occur on the coastline between The Wash and Portland Bill (Cells 3-5), and on the North-west coast (Cell 11). Overall net losses of habitat (in the range of around 100-1000 ha) can be anticipated in most coastal cells, with the exceptions of Cell 3 (The Wash to the Thames), Cell 7 (Land's End to the Severn) and Cell 8 (The Severn to St David's Head). The problem of retreat onto designated freshwater habitats appears to be largely confined to the coast between The Wash and Poole Harbour. In this context, it is worth noting that there are few areas of designated land behind defences in the South-west, Wales and North, where the European Site boundaries frequently only extend inland to around HWM (with the exception of sand dunes).

Table 2.2a Estimated Habitat Loss/Gain Account for SAC/SPA and Ramsar sites in England and Wales.

Habitat	Estimated Loss (ha)	Estimated Gain (ha)	Balance (ha)
Mudflat/sandflat	11459	12991	1532
Saltmarsh	6996	7685	689
Shingle Bank	238	110	-128
Sand Dune	504	381	-123
Cliff Top	133	0	-133
Soft Cliff	0	0	0
Hard Cliff	0	0	0
Wet Grassland	3214	0	-3214
Reed Bed	172	0	-172
Coastal Lagoon	530	30	-500
Total	23246	21197	-2048

Note: Predictions are based on a single "best-guess" coastal defence scenario for the next 50 years, identified from a review of available SMPs and through a series of regional workshops.

Table 2.2b Estimated Overall Habitat Changes to SAC/SPA and Ramsar sites, by Coastal Cell in England and Wales.

Cell	Estimated Loss (ha)	Estimated Gain (ha)	Balance (ha)
1	339	76	-263
2	1713	1223	-490
3	9408	9666	259
4	2746	2209	-537
5	2690	2313	-377
6	268	61	-207
7	759	768	9
8	679	1458	780
9	711	573	-139
10	199	15	-184
11	3736	2836	-900

3 REPLACEMENT REQUIREMENTS

3.1 Introduction

The Habitats Directive requires that, if approved plans or projects affect the integrity of a designated European Site, compensatory measures need to be undertaken to ensure that the overall coherence of the Natura 2000 network is protected. In this context, the integrity of a site has been defined in PPG 9 Nature Conservation as "the coherence of its ecological structure and function across its whole area, that enables it to sustain the habitat, complex of habitats and/or the levels of population of species for which it was classified" (DoE 1994). For the purposes of this report it has been assumed that SMP proposals (i.e. do nothing, hold the line, advance the line or retreat the line) could potentially affect all SAC/SPA sites and Ramsar sites and that the resulting losses (described in Chapter 2) will need to be replaced on a like-for-like basis. In this context, a number of issues are worth highlighting:

- some habitats are likely to be irreplaceable (e.g. sand dunes, shingle banks);
- some sites may need no more than a simple change of management practice (e.g. arable or pasture to grazing marsh);

A number of basic principles can be identified which could guide the selection of sites for habitat replacement. These are:

1. The chosen site should replace as far as possible the designated habitats and species of the area of loss. For example, compensation for loss of areas of SPAs should consider the habitat requirements of species of birds for which the areas was designated.

   The area of the chosen site should be sufficiently large to ensure replacement of the lost habitat is achieved. The difficulties of precise definition of habitat boundaries and the necessity to provide for peripheral areas which allow the correct functioning of the habitat, will, in many cases, mean that an area must be selected which is significantly larger than that which has been lost.

   The location of the site should be as close to the area of loss as is possible in order that independent environmental conditions are replicated (climate, tides, sediments, water chemistry etc.). The basic criterion should be to locate as close as possible to the lost area, preferably within, or adjacent to, the same SAC/SPA sites and Ramsar site, but failing this and in decreasing order of suitability, the same Natural Area, Regional Sea or within the Natura 2000 site framework.

2. Any modification of the chosen site, in order to achieve replication of the lost habitat, should not have adverse impacts on the geomorphological or ecological functioning of the area in which it is located and should avoid impacts on the existing interest of designated sites.

3. The chosen site should usually be self sustaining, that is it should function both as a natural component of the wider area in which it is located and should possess an internal structure necessary to ensure sustainability.

4. The development of the necessary replacement habitats on the chosen site, either by artificial or natural means, should be as rapid as possible or in advance of the predicted losses.

There are a variety of ways in which the habitat replacement issue could be addressed in the future; from an ad-hoc, site-by-site basis to a strategic approach organised at a regional or national level. The latter approach has been adopted for the purposes of this exercise. Figure 3.1 provides a framework for habitat re-creation, with a cascading sequence of studies leading to site works and management.

An indication of the likely costs involved has been established as follows:

i. **land purchase**; general prices of agricultural land in the coastal zone have been provided by English Nature regional offices, indicating that an average figure of around £6500/ha is broadly applicable.

ii. **site development, construction and management costs**; a general indication of the costs was obtained through discussion with Environment Agency staff (e.g. the saltmarsh re-creation scheme at Orplands, Essex; Dixon and Weight 1995) and the RSPB (e.g. the Lakenheath reed bed re-creation scheme).

With regard to the potential availability of land for sustainable habitat re-creation in the coastal zone, it is expected that the extensive areas of land below 5m will provide many potentially suitable sites for further consideration (Figure 3.2). Other sites might be found within river floodplains or former sand and gravel workings.

3.2 Estimated Replacement Costs: Freshwater and Brackish Habitats

It is widely recognised that sand dune and shingle bank habitats are largely irreplaceable. Table 3.1, therefore, presents a breakdown of the estimated costs for the replacement, on a hectare-for-hectare basis, of the 4000 ha of freshwater and brackish habitats that have been predicted to be lost as a result of shoreline management proposals and coastal processes. These costings are based on a "typical" replacement site of 100 ha. It is estimated that the likely costs of habitat replacement will be in the order of £50-60M, at current prices, spread over the next 50 years. However, if it is assumed that the site purchase and set-up costs will be phased over a 10 year period, the Net Present Value (NPV; the annual costs discounted at 6% per year) of potential replacement costs is estimated to be in the order of £30M (see Table A.14; Appendix A). This is the equivalent of around £3M per year over a 10 year period for site purchase and set-up costs, with additional site management costs of around £0.5M per year over 50 years.

Table 3.1 Estimated Costs of Freshwater Habitat Replacement in England and Wales.

Item	Unit Cost	Number Required	Total
Regional Strategic Study	£100K/region	6	£600K
Site Survey	£10K/site	40	£400K
Site Design	£10K/site	40	£400K
Land Purchase	£6500/ha	4000	£26M
Construction	£100K/site	40	£4M
Site Management	£10K/year/site	40 sites/50 years	£20M
Post Project Monitoring	£2.5K/year/site	40 sites/50 years	£5M
		Total	£56.4M

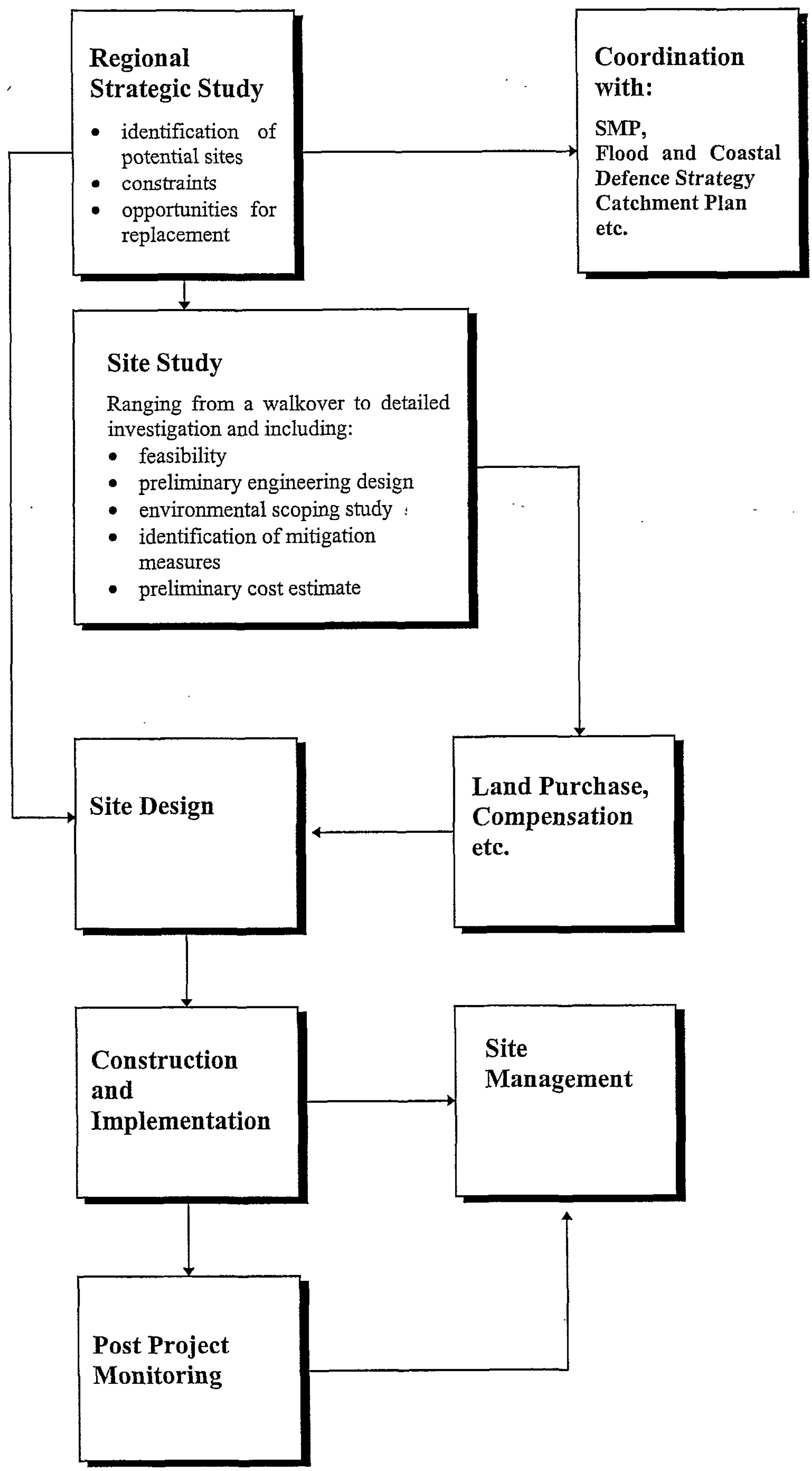

Figure 3.1 A simple framework for habitat re-creation.

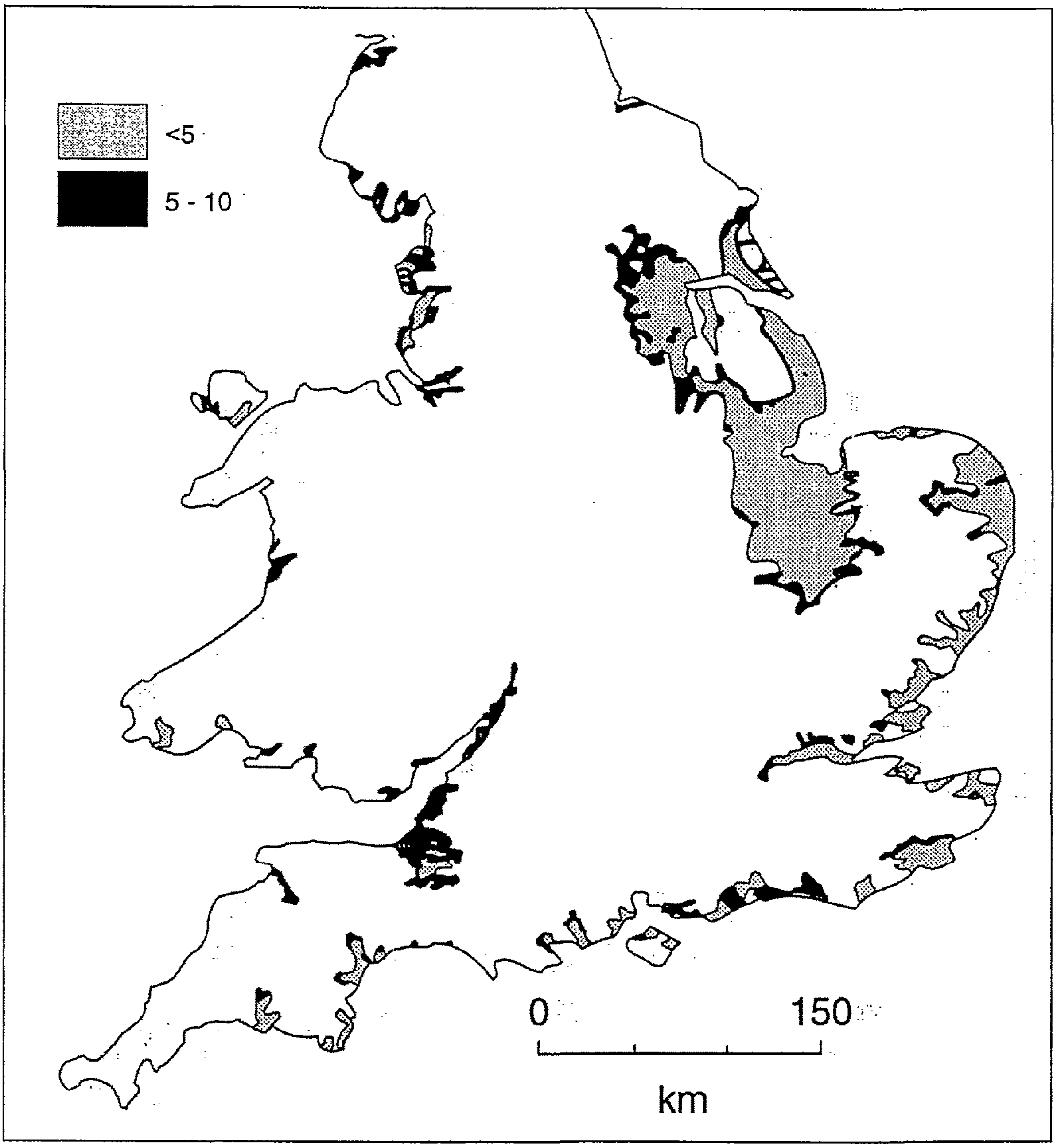

Figure 3.2. Potential habitat replacement sites: Land below 5m AOD in England and Wales.

4 THE HABITATS DIRECTIVE: CONSTRAINTS ON IMPLEMENTATION IMPOSED BY COASTAL DEFENCE OPTIONS

The Habitats Directive requires coastal authorities to have regard to the requirements of the directive in exercising their functions, imposing a general duty to maintain the "favourable conservation status" of designated sites. This duty could extend to a need to provide replacement habitats to compensate for the habitat losses associated with the implementation of SMP policies. In this context, SMP policies can have a range of impacts on European Site habitats, from simply not interfering with the "natural" patterns of erosion and accretion of habitats on the unprotected coast (i.e. "do nothing") to promoting coastal squeeze where "hold the line" is the preferred policy, or the planned loss of freshwater habitats where "managed retreat" is undertaken in areas of wet grassland, reed bed or lagoon interests and the subsequent re-creation of intertidal habitats. Whether the losses associated with all SMP policies (i.e. those involving no direct intervention as well as specific coastal defence schemes) need to be compensated for is not clear. However, it is apparent that sustainable coastal defence does present a number of important issues that might constrain the successful implementation of the Directive. These include:

1. There is a potential conflict between maintaining the favourable conservation status of intertidal areas and avoiding the degradation and loss of freshwater areas (e.g. Huggett 1997; Huggett and Sharpe, 1996). From a habitats perspective, future SMP proposals on some parts of the coast present a stark choice between:

   - the protection of freshwater sites and accelerated coastal squeeze of intertidal habitats and downdrift erosion of sand dunes or shingle banks; or

   - the realignment of the existing defence line and "replacement" of the freshwater habitat by intertidal and brackish habitats.

   The preferred option is not a straightforward choice between two internationally important habitats. Intertidal areas, especially saltmarshes, play an important role in managing flood risk by allowing the main defences to be of a lower specification than if a fronting saltmarsh was absent, through their ability to dissipate wave energy (e.g. Spencer and Moeller 1995). Thus, saltmarshes have a financial value for flood defence, with cost savings arising from the lower seawall or embankment specifications (e.g. Environment Agency 1996). Managed retreat could also deliver significant reductions in coastal defence expenditure on some coasts. By contrast, whilst defences could be provided to protect freshwater habitats, the schemes may cost a disproportionate amount compared with both the flood defence and conservation benefits gained. In addition, it can be argued that, in some areas, such defences are unlikely to be sustainable in the long-term.

2. It follows that freshwater habitats are likely to be the loser in the setting of strategic coastal defence policies in some SMPs, especially in parts of Anglian and Southern regions. It should also be noted that there is potential for loss/degradation of coastal freshwater habitats behind seawalls and embankments if more frequent overtopping or saline groundwater intrusion occurs as a result of sea-level rise. To ensure that the plans are sustainable as a whole and are consistent with the Habitats Directive, there is a need to address these potential freshwater habitat losses within the plan framework.

3. There is an assumption that saltmarsh/mudflat re-creation as part of managed retreat flood defence schemes will be able to deliver habitats of international quality or integral to a site of international importance. In recent years there has been some progress towards understanding how to create saltmarshes (e.g. NRA 1995), but it is too early to judge whether the resulting habitats will be of international importance and merit inclusion within the Natura 2000 network of European Sites.

4. It is clear that managed retreat will create pressure on freshwater habitats behind the existing defence line. An indication of the possible scale of this pressure has been compiled as part of this research, through workshop discussions with local staff from the Environment Agency, English Nature/Countryside Council for Wales, RSPB and others. However, it is not clear whether the predicted extent of managed retreat is compatible with the strategy of the Environment Agency and English Nature of achieving sustainable estuary forms (EA/EN 1997). In some circumstances the requirement for managed retreat to achieve a sustainable defence infrastructure for a whole estuary may have been underestimated by this study; this could result in additional pressures on freshwater habitats behind the current defence line.

5. Maintaining the favourable conservation status of the saltmarsh resource is heavily dependent upon managed retreat. However, implementation of this coastal defence strategy could lead to serious conflicts of interest because, at present, there is no mechanism for adequately compensating the affected landowners. Managed retreat may also cause unacceptable impacts on the hydrodynamics of an estuary, resulting in flood defence or environmental problems elsewhere in the coastal cell. If managed retreat does not become a widespread reality there will be a net loss of saltmarsh/mudflat habitats, to the benefit of freshwater habitats that would otherwise have been lost.

6. Some SMP proposals will result in the continued loss of what may be regarded as largely irreplaceable habitats. For example, some sand dune systems may be lost or significantly reduced in area unless they are allowed to migrate landwards. However, in many areas the dunes are an integral part of the flood defences. Allowing the systems to develop major blow-outs and re-mobilise will lead to an increase in flood risk to the hinterland. Once again, the choices are difficult:

   - mobile dune systems that are capable of responding to sea-level rise by landward migration, with a diverse range of habitats, including embryo dunes; or

   - static "fossilised" dune systems that provide flood defence, but will gradually become more vulnerable to erosion of the frontal dune habitats.

   The situation is compounded by the problem that, in the long-term, the flood protection provided by dunes will inevitably decline as the effects of sea-level rise and global warming become apparent. The response to this problem will probably determine the long-term fate of many dune systems, e.g.:

   - build hard defences, for example at HWM, that cut the dunes off from the foreshore or sediment supply. This will lead to a gradual decline in the diversity of habitats, especially the loss of pioneer embryo dunes interests. Indeed, it can be argued that the complete loss of this one habitat unit, however limited in extent, may be more significant than the loss of larger areas of more abundant dune habitat;

- undertake large-scale beach recharge to stimulate the creation of new ridges of sand which provide the focus for dune growth. This could maintain or enhance the diversity of habitats within dune systems, but cost and availability of suitable sediments are significant constraints to the widespread adoption of this approach;

- accept a higher level of flood risk and remove the obstacles to landward dune migration (e.g. fixed assets behind the dunes such as golf courses, plantations etc.). This may lead to the development of long-term sustainable dunes, but will lead to a change in land use potential behind the system.

  Shingle ridges present similar problems related to "quality"; roll-over instead of artificially maintained high crest levels will lead to sustainable shingle banks but enhanced flood risk.

7. The sand dune and shingle ridge examples described above highlight an inherent conflict between the different "demands" placed on some coastal landforms by flood defence and conservation interests. The former favour stable forms which provide a fairly constant and reliable standard of protection, but tend to be associated with low diversity; the latter favour unstable forms characterised by high diversity, but with largely unpredictable and highly variable standards of protection. This conflict will be heightened by the effects of sea-level rise and the need to maintain the favourable conservation status of dune or shingle bank habitats.

8. Long-term squeeze is an inevitable consequence of the "hold the line" strategy on many coasts, and will result in the progressive decline in intertidal habitat area. Saltmarsh re-creation (e.g. as part of managed retreat) will partly address this loss, but often at the expense of intertidal mudflats and sandflats. This, for example, may lead to loss of wader feeding grounds and increased bird densities on the remaining mudflat/sandflat areas, which in turn increases competition for food and adds further pressure on bird populations.

There are no simple solutions to these issues. The SMP process can be adapted to provide a mechanism to seek sustainable coastal defence policy options which address habitat losses within the plan area and, thereby, contribute to broader targets for habitat re-creation. However, it can be argued that there is need for a legal and administrative framework to deliver integrated coastal defence and habitat replacement at a strategic, as well as local level. This might help ensure that appropriate weight is given to the national or regional needs to recreate or maintain particular habitats when scheme options to protect individual sites are considered.

5 CONCLUSIONS AND RECOMMENDATIONS

This Study has identified the possible landform and habitat changes in European Sites, over the next 50 years, associated with "best-guess" future coastal defence policies and taking into account the potential effects of one (of many) predicted sea-level rise scenarios. The combined results of "natural" and "managed" changes are likely to produce a significant adjustment of landforms and a variety of habitat losses and gains. If, and it must be a big "if", the coastal defence policies are implemented and the predicted coastal changes occur, the following important habitat changes are possible:

i. there could be a net loss of freshwater and brackish habitat of around 4000 ha, primarily wet grassland (c3200 ha) but also including significant areas of coastal lagoon (c500 ha) and reed bed (c200 ha);

ii. there could be a net gain of intertidal (saltmarsh and mudflat/sandflat) habitats of around 2221 ha, with the gains associated with managed retreat (c12500ha) balancing the expected losses due to coastal squeeze and erosion on the unprotected coast;

iii. it is estimated that around 120 ha of sand dunes could be lost over the next 50 years, primarily in Northumberland, the South-west, Cardigan Bay and on the Sefton coast. Although this represents around only 1% of the sand dune resource within European Sites in England and Wales, it may involve the loss of a significant proportion of the important foredune dune communities in some areas;

iv. there could be a loss of around 130 ha of shingle bank habitats representing around 4% of the resource within European Sites in England and Wales;

v. relatively minor losses of cliff top habitats are predicted to occur, in the order of less than 2 ha/year, nationally.

From the analysis it is clear that the future impacts of the implementation of the "best-guess" coastal defence policies are likely to be at least as important as the coastal changes that could occur due to natural processes such as sea-level rise. In some areas the future defence policy will be the most important factor in determining habitat change or survival.

The likely costs of freshwater and brackish habitat replacement, on a hectare-for-hectare basis, is estimated to be in the order of £50-60M, at current prices (1998), including site purchase, set-up and on-going management costs. If the site purchase and set-up costs are phased over a 10 year period, the Net Present Value (NPV) of potential replacement costs is estimated to be in the order of £30M.

Some habitats, however, are likely to be irreplaceable (e.g. sand dunes and shingle banks) whereas others may need no more than a simple change of management practice to re-create particular habitats (e.g. arable or pasture to grazing marsh). The report has also drawn attention to the possible need to select and develop replacement sites which are significantly larger than those which were lost, in order to ensure the correct ecological functioning of the habitat.

A number of important coastal defence-related issues have been identified which may constrain the successful implementation of the Habitats Directive. In summary, these are:

- the conflict between maintaining the favourable conservation status of the saltmarsh resource through managed retreat, and the resulting losses, in some areas, of freshwater habitats;

- saltmarsh re-creation associated with managed retreat may not necessarily lead to the production of habitats that would be integral to a site of international importance;

- the flood defence objective of achieving sustainable estuary forms may result in the need for additional managed retreat over-and-above that which was estimated by this study. This would place further pressure on freshwater habitats behind defence lines;

- if managed retreat is not implemented on the scale predicted by the workshops, there will be a significant net loss of intertidal habitat;

- the future management of sand dune and shingle bank systems needs to find an appropriate balance between the need for habitat diversity and flood defence;

- long-term coastal squeeze is inevitable in front of most existing defences and will place pressure on bird populations, especially those which feed on mudflats and sandflats.

A number of specific recommendations have been made:

1. Individual habitat loss/gain accounts should be compiled for each individual European Site, for each of the alternative coastal defence strategies, and organised on a regional basis;

2. A GIS and data management programme should be established to allow the predictions to be modified as and when SMP decisions are finalised or revised;

3. Links should be established with the monitoring programmes currently being developed as part of SMPs, with the aim of compiling records of landform change and habitat loss/gain on, for example, a 10 year basis;

4. Effort should be directed towards developing suitable and robust geomorphological and ecological tools for predicting change. Probabilistic methods, for example, may be an appropriate approach to address the uncertainties inherent in predicting coastal and habitat change;

5. In light of the difficulties in predicting long-term changes to sand dunes, it is recommended that a detailed review of the status of dune systems should be undertaken. This review should consider the potential for future change within the context of the sediment budgets and long-term dune behaviour;

6. Experience of habitat replacement should be consolidated and critically reviewed in terms of the effectiveness of the scheme and the broader environmental impacts. The lessons learnt should be widely disseminated;

7. Field experiments should be undertaken in a range of coastal environments to establish the feasibility of and techniques for habitat replacement in different parts of England and Wales, with appropriate post project monitoring;

8. Management of dynamic coastlines will result in changes to habitats and associated species. There is, therefore, a need to identify mechanisms for resolving the potential conflicts between coastal defence and conservation objectives for intertidal and freshwater designated sites;

9. Following completion of all SMPs covering the coast of England and Wales a further review should be carried out to determine their effectiveness in addressing the need to maintain the favourable conservation status of the European Sites. It may prove necessary to develop guidance to inform coastal authorities about how the maintenance of the Natura 2000 network should be treated within the SMP process.

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APPENDIX A: LOSS/GAIN ACCOUNTS FOR COASTAL CELLS

Note: Predictions of change to European Sites are based on a single "best-guess" coastal defence scenario for the next 50 years, identified from a review of available Shoreline Management Plans and through a series of regional workshops.

Table A.1 Habitat loss and gains (in hectares): England and Wales

Habitat	Do Nothing		Hold the Line		Advance the Line		Managed Retreat		Total		Balance
	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	(ha)
Intertidal	9792	245	1517	6651	50	0	100	6095	11459	12991	1532
Saltmarsh	245	23	6651	1517	0	50	100	6095	6996	7685	689
Shingle Bank	19	0	119	20	0	0	100	90	238	110	-128
Sand Dune	204	269	301	113	0	0	0	0	504	381	-123
Cliff Top	133	0	0	0	0	0	0	0	133	0	-133
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	3214	0	3214	0	-3214
Coastal Lagoon	0	0	0	0	0	0	530	30	530	30	-500
Reed Bed	0	0	0	0	0	0	172	0	172	0	-172
Total	**10393**	**537**	**8588**	**8301**	**50**	**50**	**4216**	**12310**	**23246**	**21197**	**-2048**

Table A.2 Habitat loss and gains (in hectares): Cell 1 St Abb's Head to Flamborough Head

Habitat	Do Nothing		Hold the Line		Advance the Line		Managed Retreat		Total		Balance
	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	(ha)
Intertidal	215	0	34	0	0	0	0	4	249	4	-246
Saltmarsh	0	0	0	34	0	0	0	4	0	38	38
Shingle Bank	0	0	0	0	0	0	0	0	0	0	0
Sand Dune	45	35	38	0	0	0	0	0	83	35	-48
Cliff Top	0	0	0	0	0	0	0	0	0	0	0
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	0	0	0	0	0
Coastal Lagoon	0	0	0	0	0	0	7	0	7	0	-7
Reed Bed	0	0	0	0	0	0	0	0	0	0	0
Total	**260**	**35**	**72**	**34**	**0**	**0**	**7**	**7**	**339**	**76**	**-263**

Table A.3 Habitat loss and gains (in hectares): Cell 2 Flamborough Head to The Wash (Snettisham)

Habitat	Do Nothing Loss (ha)	Do Nothing Gain (ha)	Hold the Line Loss (ha)	Hold the Line Gain (ha)	Advance the Line Loss (ha)	Advance the Line Gain (ha)	Managed Retreat Loss (ha)	Managed Retreat Gain (ha)	Total Loss (ha)	Total Gain (ha)	Balance (ha)
Intertidal	1645	0	68	0	0	0	0	490	1713	490	-1223
Saltmarsh	0	0	0	68	0	0	0	490	0	558	558
Shingle Bank	0	0	0	0	0	0	0	0	0	0	0
Sand Dune	0	175	0	0	0	0	0	0	0	175	175
Cliff Top	0	0	0	0	0	0	0	0	0	0	0
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	0	0	0	0	0
Coastal Lagoon	0	0	0	0	0	0	0	0	0	0	0
Reed Bed	0	0	0	0	0	0	0	0	0	0	0
Total	**1645**	**175**	**68**	**68**	**0**	**0**	**0**	**980**	**1713**	**1223**	**-490**

Table A.4 Habitat loss and gains (in hectares): Cell 3 The Wash (Snettisham) to The Thames (Canvey Island)

Habitat	Do Nothing Loss (ha)	Do Nothing Gain (ha)	Hold the Line Loss (ha)	Hold the Line Gain (ha)	Advance the Line Loss (ha)	Advance the Line Gain (ha)	Managed Retreat Loss (ha)	Managed Retreat Gain (ha)	Total Loss (ha)	Total Gain (ha)	Balance (ha)
Intertidal	2387	0	107	4238	0	0	100	2661	2594	6899	4305
Saltmarsh	0	0	4238	107	0	0	100	2661	4338	2768	-1571
Shingle Bank	19	0	25	0	0	0	0	0	44	0	-44
Sand Dune	0	0	120	0	0	0	0	0	120	0	-120
Cliff Top	26	0	0	0	0	0	0	0	26	0	-26
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	1834	0	1834	0	-1834
Coastal Lagoon	0	0	0	0	0	0	335	0	335	0	-335
Reed Bed	0	0	0	0	0	0	117	0	117	0	-117
Total	**2432**	**0**	**4490**	**4345**	**0**	**0**	**2486**	**5321**	**9408**	**9666**	**259**

Table A.5 Habitat loss and gains (in hectares): Cell 4 The Thames to Selsey Bill

Habitat	Do Nothing Loss (ha)	Do Nothing Gain (ha)	Hold the Line Loss (ha)	Hold the Line Gain (ha)	Advance the Line Loss (ha)	Advance the Line Gain (ha)	Managed Retreat Loss (ha)	Managed Retreat Gain (ha)	Total Loss (ha)	Total Gain (ha)	Balance (ha)
Intertidal	613	0	2	1081	0	0	0	553	615	1634	1019
Saltmarsh	0	0	1081	2	0	0	0	553	1081	555	-526
Shingle Bank	0	0	94	20	0	0	100	0	194	20	-174
Sand Dune	0	0	18	0	0	0	0	0	18	0	-18
Cliff Top	0	0	0	0	0	0	0	0	0	0	0
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	768	0	768	0	-768
Coastal Lagoon	0	0	0	0	0	0	33	0	33	0	-33
Reed Bed	0	0	0	0	0	0	37	0	37	0	-37
Total	**613**	**0**	**1195**	**1103**	**0**	**0**	**938**	**1106**	**2746**	**2209**	**-537**

Table A.6 Habitat loss and gains (in hectares): Cell 5 Selsey Bill to Portland Bill

Habitat	Do Nothing Loss (ha)	Do Nothing Gain (ha)	Hold the Line Loss (ha)	Hold the Line Gain (ha)	Advance the Line Loss (ha)	Advance the Line Gain (ha)	Managed Retreat Loss (ha)	Managed Retreat Gain (ha)	Total Loss (ha)	Total Gain (ha)	Balance (ha)
Intertidal	1024	0	0	964	0	0	0	605	1024	1569	545
Saltmarsh	0	0	964	0	0	0	0	605	964	605	-360
Shingle Bank	0	0	0	0	0	0	0	90	0	90	90
Sand Dune	0	20	0	0	0	0	0	0	0	20	20
Cliff Top	87	0	0	0	0	0	0	0	87	0	-87
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	442	0	442	0	-442
Coastal Lagoon	0	0	0	0	0	0	155	30	155	30	-125
Reed Bed	0	0	0	0	0	0	18	0	18	0	-18
Total	**1111**	**20**	**964**	**964**	**0**	**0**	**615**	**1329**	**2690**	**2313**	**-377**

Table A.7 Habitat loss and gains (in hectares): Cell 6 Portland Bill to Land's End

	Do Nothing		Hold the Line		Advance the Line		Managed Retreat		Total		Balance
Habitat	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	(ha)
Intertidal	251	0	0	0	0	0	0	31	251	31	-221
Saltmarsh	0	0	0	0	0	0	0	31	0	31	31
Shingle Bank	0	0	0	0	0	0	0	0	0	0	0
Sand Dune	0	0	0	0	0	0	0	0	0	0	0
Cliff Top	17	0	0	0	0	0	0	0	17	0	-17
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	0	0	0	0	0
Coastal Lagoon	0	0	0	0	0	0	0	0	0	0	0
Reed Bed	0	0	0	0	0	0	0	0	0	0	0
Total	**268**	**0**	**0**	**0**	**0**	**0**	**0**	**61**	**268**	**61**	**-207**

Table A.8 Habitat loss and gains (in hectares): Cell 7 Land's End to The Severn (Sharpness)

	Do Nothing		Hold the Line		Advance the Line		Managed Retreat		Total		Balance
Habitat	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	(ha)
Intertidal	476	200	0	38	0	0	0	265	476	503	27
Saltmarsh	200	0	38	0	0	0	0	265	238	265	27
Shingle Bank	0	0	0	0	0	0	0	0	0	0	0
Sand Dune	45	0	0	0	0	0	0	0	45	0	-45
Cliff Top	0	0	0	0	0	0	0	0	0	0	0
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	0	0	0	0	0
Coastal Lagoon	0	0	0	0	0	0	0	0	0	0	0
Reed Bed	0	0	0	0	0	0	0	0	0	0	0
Total	**721**	**200**	**38**	**38**	**0**	**0**	**0**	**530**	**759**	**768**	**9**

Table A.9 Habitat loss and gains (in hectares): Cell 8 The Severn (Sharpness) to St David's Head

Habitat	Do Nothing Loss (ha)	Do Nothing Gain (ha)	Hold the Line Loss (ha)	Hold the Line Gain (ha)	Advance the Line Loss (ha)	Advance the Line Gain (ha)	Managed Retreat Loss (ha)	Managed Retreat Gain (ha)	Total Loss (ha)	Total Gain (ha)	Balance (ha)
Intertidal	485	0	0	125	50	0	0	628	535	753	218
Saltmarsh	0	8	125	0	0	50	0	628	125	686	561
Shingle Bank	0	0	0	0	0	0	0	0	0	0	0
Sand Dune	18	20	0	0	0	0	0	0	18	20	3
Cliff Top	1	0	0	0	0	0	0	0	1	0	-1
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	0	0	0	0	0
Coastal Lagoon	0	0	0	0	0	0	0	0	0	0	0
Reed Bed	0	0	0	0	0	0	0	0	0	0	0
Total	**504**	**28**	**125**	**125**	**50**	**50**	**0**	**1255**	**679**	**1458**	**780**

Table A.10 Habitat loss and gains (in hectares): Cell 9 St David's Head to Bardsey Sound

Habitat	Do Nothing Loss (ha)	Do Nothing Gain (ha)	Hold the Line Loss (ha)	Hold the Line Gain (ha)	Advance the Line Loss (ha)	Advance the Line Gain (ha)	Managed Retreat Loss (ha)	Managed Retreat Gain (ha)	Total Loss (ha)	Total Gain (ha)	Balance (ha)
Intertidal	256	0	400	0	0	0	0	80	656	80	-576
Saltmarsh	0	0	0	400	0	0	0	80	0	480	480
Shingle Bank	0	0	0	0	0	0	0	0	0	0	0
Sand Dune	50	13	3	0	0	0	0	0	53	13	-41
Cliff Top	2	0	0	0	0	0	0	0	2	0	-2
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	0	0	0	0	0
Coastal Lagoon	0	0	0	0	0	0	0	0	0	0	0
Reed Bed	0	0	0	0	0	0	0	0	0	0	0
Total	**308**	**13**	**403**	**400**	**0**	**0**	**0**	**160**	**711**	**573**	**-139**

Table A.11 Habitat loss and gains (in hectares): Cell 10 Bardsey Sound to Great Orme

Habitat	Do Nothing		Hold the Line		Advance the Line		Managed Retreat		Total		Balance
	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	(ha)
Intertidal	171	0	0	0	0	0	0	0	171	0	-171
Saltmarsh	0	15	0	0	0	0	0	0	0	15	15
Shingle Bank	0	0	0	0	0	0	0	0	0	0	0
Sand Dune	28	0	0	0	0	0	0	0	28	0	-28
Cliff Top	0	0	0	0	0	0	0	0	0	0	0
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	0	0	0	0	0
Coastal Lagoon	0	0	0	0	0	0	0	0	0	0	0
Reed Bed	0	0	0	0	0	0	0	0	0	0	0
Total	**198.5**	**15**	**0**	**0**	**0**	**0**	**0**	**0**	**199**	**15**	**-184**

Table A.12 Habitat loss and gains (in hectares): Cell 11 Great Orme to Solway Firth

Habitat	Do Nothing		Hold the Line		Advance the Line		Managed Retreat		Total		Balance
	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	Loss (ha)	Gain (ha)	(ha)
Intertidal	2269	45	906	205	0	0	0	781	3175	1031	-2145
Saltmarsh	45	0	205	906	0	0	0	781	250	1687	1437
Shingle Bank	0	0	0	0	0	0	0	0	0	0	0
Sand Dune	19	6	123	113	0	0	0	0	141	119	-22
Cliff Top	0	0	0	0	0	0	0	0	0	0	0
Soft Cliff	0	0	0	0	0	0	0	0	0	0	0
Hard Cliff	0	0	0	0	0	0	0	0	0	0	0
Wet Grassland	0	0	0	0	0	0	170	0	170	0	-170
Coastal Lagoon	0	0	0	0	0	0	0	0	0	0	0
Reed Bed	0	0	0	0	0	0	0	0	0	0	0
Total	**2333**	**51**	**1234**	**1224**	**0**	**0**	**170**	**1561**	**3736**	**2836**	**-900**

Table A.13 Managed retreat: estimated saltmarsh and mudflat loss/gain (ha) under different habitat creation scenarios.

Cell	Intertidal Gain (ha)	Habitat	Scenario 1 Gain (ha)	Scenario 2 Gain (ha)	Scenario 3 Gain (ha)
1	8	Mudflat	2	4	6
		Saltmarsh	6	4	2
2	980	Mudflat	245	490	735
		Saltmarsh	735	490	245
3	5322	Mudflat	1330.5	2661	3991.5
		Saltmarsh	3991.5	2661	1330.5
4	1106	Mudflat	276.5	553	829.5
		Saltmarsh	829.5	553	276.5
5	1210	Mudflat	302.5	605	907.5
		Saltmarsh	907.5	605	302.5
6	62	Mudflat	15.5	31	46.5
		Saltmarsh	46.5	31	15.5
7	530	Mudflat	132.5	265	397.5
		Saltmarsh	397.5	265	132.5
8	1314	Mudflat	328.5	657	985.5
		Saltmarsh	985.5	657	328.5
9	160	Mudflat	40	80	120
		Saltmarsh	120	80	40
10	0	Mudflat	0	0	0
		Saltmarsh	0	0	0
11	1562	Mudflat	390.5	781	1171.5
		Saltmarsh	1171.5	781	390.5

Balance	Mudflat	3063.5	6127	9190.5
	Saltmarsh	9190.5	6127	3063.5

Total	12254	12254	12254

Scenario 1 Mudflat (25%), Saltmarsh (75%)
Scenario 2 Mudflat (50%), Saltmarsh (50%)
Scenario 3 Mudflat (75%), Saltmarsh (25%)

Impact on overall loss/gain account for England and Wales

Habitat	Scenario 1	Scenario 2	Scenario 3
Mudflat	-1449.5	1614	4677.5
Saltmarsh	3784.5	721	-2342.5
Total	2335	2335	2335

Table A.14a Estimated costs of freshwater/brackish habitat replacement: Phased programme of expenditure.

Year	Discount Factor	Sites	Cost £M	NPV £M
1	1	4	3.08	3.08
2	0.94	4	3.08	2.90
3	0.88	4	3.08	2.71
4	0.83	4	3.08	2.56
5	0.78	4	3.08	2.40
6	0.73	4	3.08	2.25
7	0.69	4	3.08	2.13
8	0.65	4	3.08	2.00
9	0.61	4	3.08	1.88
10	0.57	4	3.08	1.76
			Total	£23.65M

Table A.14b Estimated costs of freshwater/brackish habitat replacement: Site Management and Monitoring

Year	Discount Factor	Sites	Cost £M	NPV £M
1	1	0	0	0
2	0.94	4	0.05	0.05
3	0.88	8	0.1	0.09
4	0.83	12	0.15	0.12
5	0.78	16	0.2	0.16
6	0.73	20	0.25	0.18
7	0.69	24	0.3	0.21
8	0.65	28	0.35	0.23
9	0.61	32	0.4	0.24
10	0.57	36	0.45	0.26
11	0.54	40	0.5	0.27
12	0.51	40	0.5	0.26
13	0.48	40	0.5	0.24
14	0.45	40	0.5	0.23
15	0.42	40	0.5	0.21
16	0.4	40	0.5	0.20
17	0.37	40	0.5	0.19
18	0.35	40	0.5	0.18
19	0.33	40	0.5	0.17
20	0.31	40	0.5	0.16
21	0.29	40	0.5	0.15
22	0.27	40	0.5	0.14
23	0.26	40	0.5	0.13
24	0.24	40	0.5	0.12
25	0.23	40	0.5	0.12
26	0.21	40	0.5	0.11
27	0.2	40	0.5	0.10
28	0.19	40	0.5	0.10
29	0.18	40	0.5	0.09
30	0.17	40	0.5	0.09

31	0.16	40	0.5	0.08
32	0.15	40	0.5	0.08
33	0.14	40	0.5	0.07
34	0.13	40	0.5	0.07
35	0.12	40	0.5	0.06
36	0.11	40	0.5	0.06
37	0.11	40	0.5	0.06
38	0.1	40	0.5	0.05
39	0.1	40	0.5	0.05
40	0.09	40	0.5	0.05
41	0.08	40	0.5	0.04
42	0.08	40	0.5	0.04
43	0.07	40	0.5	0.04
44	0.07	40	0.5	0.04
45	0.07	40	0.5	0.04
46	0.06	40	0.5	0.03
47	0.06	40	0.5	0.03
48	0.05	40	0.5	0.03
49	0.05	40	0.5	0.03
50	0.05	40	0.5	0.03
			Total	*£5.66M*

Note: NPV = Cost x discount factor